# A Sociocultural Approach to Conceptual Change Learning in First Year Pharmacy Students

Volume 2
Appendices

A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy in the Faculty of Education and Social Work at The University of Sydney

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# APPENDIX A PRIOR CONCEPTUAL CHANGE RESEARCH ON ACIDS AND BASES

Misconceptions identified, and teaching interventions adopted, in reported research into conceptions of acids and bases

| Reference | Cohort | Method | Specific conceptions identified | Teaching strategies | Results, conclusions & hypotheses | Critique of methodology |
|---|---|---|---|---|---|---|
| Cros et al (1986, 1988) | First and second year university students, France | Interview and questionnaire | 1. Some confusion in definitions of acids and bases.<br>2. Limited range of examples for acids, and difficulty in identifying bases.<br>3. Misunderstandings relating to the process of neutralisation.<br>4. Only liquids with pH values close to neutral are safe to drink. | | | Focused on identification of impeding conceptions.<br>Focused on descriptive aspects, not application or use of the concepts.<br>Many questions very ambiguous and open to differential interpretation between questioner and questionee.<br>Concluded that aim of teaching is to modify students' "tenacious" initial ideas – no acknowledgment that students hold different ideas based on different contexts, especially school and everyday life.<br>Questions asked in a manner so as to dissociate them from any meaningful context. |
| Hand and Treagust (1988, 1991) | Year 10, 15-16 yo, Far North Qld | Semi-structured interview | 1. An acid is something which eats material away; an acid can burn you.<br>2. Testing of an acid can only be done by trying to eat something away.<br>3. To neutralise is to break down an acid or to change from an acid.<br>4. A base is something which makes up an acid.<br>5. A strong acid can eat material away faster than a weak acid. | Conceptual conflict, using practical activities, small group and whole class discussions | Partial conceptual change observed, but authors conclude there was "insufficient conflict to cause a change to the students' belief systems." New "misconceptions" appeared subsequent to teaching. Explained partly by conceptual congruency (Pines and West, 1986; v1) | From students' perspective, most researcher-identified "misconceptions" are true in context although not scientifically precise.<br>No discrimination between definition and observation<br>Very teacher focused, not learner focused – emphasis on learner being able to use same concept as teacher.<br>Focus on conceptual conflict strategy which may not have actually produced conflict because students may not have engaged with the material since it was not personally meaningful.<br>Statistical analysis in second study was flawed and therefore unreliable. |
| Vidyapati and Seetharamappa (1995) | Higher secondary students, India | Interviews and questionnaire | 1. Difficulties in definitions of Arrhenius, Bronsted-Lowry and Lewis acids and bases.<br>2. Some difficulties in giving examples of acids and bases.<br>3. Some misunderstanding of neutralisation.<br>4. Antacids are acids because they do not react with acids. | None | Cooperative learning, activities such as experiments, and connections to daily life should replace chalk-and-talk methods. | Similar questions used to Cros et al, and at least one was quite ambiguous.<br>Very superficial treatment of area and sweeping conclusions about how changes should be effected, through a change to a constructivist approach and cooperative learning without specifying how this might be achieved. |

| Reference | Cohort | Method | Specific conceptions identified | Teaching strategies | Results, conclusions & hypotheses | Critique of methodology |
|---|---|---|---|---|---|---|
| Toplis (1998) | Year 8 students, England | Interviews and class observations, focussing on meaning of terms and examples | 1. Sometimes students confused both the definitions and examples of acid and alkali.<br>2. Acids may be alkaline or neutral.<br>3. Alkalis are weaker than acids and are sour. | Not specified | Students' initial conceptions had been formed from a range of experiences including media, family and friends, previous schools, household labels.<br>Students were more familiar with examples of acids than of alkalis.<br>It was suggested that teaching was the "overloading pupils with too many ideas and words that are beyond their everyday experience." | Summarises relevant previous work.<br>Uses "alternative frameworks" as explanation for teaching "failures" – recognises children's construction of beliefs to explain their world, and that children and teachers may interpret the same activity from completely different perspectives.<br>Asking students where they obtained ideas from was appropriate.<br>Practical work seemed only to address laboratory applications not everyday ones.<br>Failed to distinguish between bases and alkalis – this is critical since some substances are basic but not alkaline.<br>Did not indicate how the practical activity was expected to modify student conceptions.<br>Noted that perhaps overloading students with too many new concepts and words. |
| Nakhleh and Krajcik (1993) | Year 11 students, east coast USA | Semi-structured observation of titration | When acids and bases are mixed, either a physical mixture is formed, or the reaction occurs by an acid and base sticking together to form one particle. | Practical exercises in titration using different levels of technology. Researchers constructed concept maps from pre and post practical interviews | Students using microcomputer based learning showed increase in both appropriate and inappropriate concept linkages after practical. However this was a poor study and little confidence can be placed in results and conclusions. | Poor study in terms of both qualitative and quantitative methodology – groups were not initially equivalent, some students were outside the selection criteria, data on equivalence was not stated, analysed thinking by counting statements with no account of length or complexity, claimed treatment differences without statistical analysis (no sd data), impossible to be confident in the conclusions drawn.<br>Implications drawn from the study simply highlight the shortcomings of the study.<br>Conclusions very tenuous, poorly supported by data<br>Little relevance since only deals with titrations – focuses on the effect of technology (computer, pH meter, indicator) |
| Ross and Munby (1991) | Grade 12 students, Canada | Concept maps drawn by the authors from student interviews, following MCQ | 1. Difficulties with neutralisation, the concept of pH, definition and description of acids and bases.<br>2. From everyday experience, acids are more memorable than bases.<br>3. Lack of understanding that pH is a measure of basicity. | | | Use of concept maps is good, but not drawn by students so cannot be sure that student conceptions match concept map.<br>Also, compared with a model concept map drawn by experts, so not approaching conceptions from student perspective – researchers looked for missing conceptions and misconceptions as deviations from the ideal – no room for students to express themselves. Although claiming to elicit students' views, actually highlighting how closely the student ideas matched the prescribed curriculum.<br>A comment is made that there was discrepancy between understanding revealed from MCQ and interviews suggesting the MCQ perhaps did not necessarily tap into student understanding from their perspective |

| Reference | Cohort | Method | Specific conceptions identified | Teaching strategies | Results, conclusions & hypotheses | Critique of methodology |
|---|---|---|---|---|---|---|
| Botton (1995) | Year 9 students, England | Concept maps | 1. Confusion between strong and concentrated.<br>2. Misunderstandings related to neutralisation.<br>3. Difficulties with the notion of indicators. | Collaborative concept mapping, as an "opportunity to undergo meaningful discursive practices" | Relatively low degree of linkages between concepts. Students showed evidence of conceptual understanding although there was no guarantee that they attained "understanding compatible with accepted scientific norms". Students were able to "talk science" with feedback but without summative assessment. | Has an understanding of learning by participation in community through "conversation in the context of authentic activity". Also that school community has a counter culture to the communities outside schools.<br>Concept maps were drawn by collaborative peer groups using a set of fixed labels.<br>Used as dynamic formative assessment – useful for detecting confusion and dealing with it in constructive way, though it was emphasised that there was no perfect concept map.<br>Focused on what students learned rather than on measuring their performance against teacher's expectations.<br>Resulted in attitude change in classroom and increased confidence among students. |
| Schmidt (1991) | Upper high school students, Germany | Test including both MCQ and short answer questions | 1. Neutralisation results in a solution without hydrogen or hydroxyl ions.<br>2. Neutralisation always results in a neutral solution. | | | Describes history of the development of understanding about what happens when acids and bases are mixed, showing the original term – neutralisation – is no longer appropriate and is indeed misleading.<br>Questions used were considerably less ambiguous than those used in previously described studies – focused on ions rather than pH. Results interpretable in terms of confusion at ionic level. Limited in scope to neutralisation but done appropriately.<br>Demonstrated it is likely the confusion is at least in part due to drift in meaning of scientific term.<br>Included relevant comments about implications for teaching. |
| Banerjee (1991) | Undergrads & secondary science teachers, India | Diagnostic test | 1. There are no hydrogen ions in distilled water or solutions of NaOH.<br>2. pH is determined only by the concentration of an acid and not by its strength.<br>In addition, general conceptual diversity in the relationship between rate and extent of equilibrium.<br>Teachers performed worse than undergraduates. | | | Very superficial investigation of acid-base concepts – 4 questions requiring yes/no answers (2 qns) or <=> choice (2 qns). For one question, an incorrect response is labelled as correct in one place (Table 4) but the reverse is implied in the text underneath. Also, this question tests specific knowledge which contradicts intuitive understanding of acid-base theory so is not a good question. Little scope for individual response or "talking science" though probably valid as far as it goes. |

| Reference | Cohort | Method | Specific conceptions identified | Teaching strategies | Results, conclusions & hypotheses | Critique of methodology |
|---|---|---|---|---|---|---|
| Zoller (1996) | First year university students, Haifa, Israel | Higher order cognitive skills (HOCS) oriented examinations | 1. Substances classified as acid or base through method of writing chemical formula (intentionally obscure).<br>2. pH can only range between 1 and 14.<br>3. Confusion about the meaning of particular values of equilibrium constant. | HOCS oriented examinations | Conceptual questions can allow diagnosis of misconceptions which are masked by solely algorithmic questions. Such diagnosis can then suggest appropriate teaching strategies. However, it is suggested that there needs to be "different specifically designed teaching strategies for each required conceptual remediation." | Guided by a constructivist framework, but very cognitive approach though more rigorous than most other studies.<br>Regards misconceptions as problems to be overcome through use of higher order cognitive skills.<br>Sees assessment as critical part of learning process.<br>Categorised problems as misconceptions (MC), misunderstandings (MU) and no conceptions (NC) – though these terms are not defined or explained.<br>Essential finding is that asking students to explain their answers, rather then T/F or MCQ, provides insights into their thinking,.<br>Author claims superiority therefore of conceptual questions over algorithmic, even in MCQ, however the example presented is ambiguous (equation is incorrect in question) and the results conflict between table and text. In addition, a correct answer in a MCQ can be achieved by guessing and the small numbers reported are not convincing. |
| Nakhleh at al (1996) | First year university students, Indiana | Group problem solving sessions, and "conceptual" exams | Confusion between the concepts of concentration and strength. | Group problem solving sessions relating to "conceptual questions" rather than algorithmic | When students were given sufficient exposure and practice, exam performance was not impaired. Students appeared to be "more interested, more alert and more active". | Aim to narrow gap between algorithmic and conceptual understanding (also identified by Zoller).<br>Based on generative learning model which includes experiences of the world together with beliefs and theories about the world.<br>Cognitive underpinning – representations and linkages are the focus.<br>Collaborative problem solving provided more in depth discussion of issues than a lecture format.<br>Some conclusions about the effectiveness of the interventions in improving student performance in exams were to say the least speculative. |
| Banerjee and Power (1991) | Science teacher education students, India, all with three years tertiary chemistry study | | | Modules on chemical equilibrium, including acid-base – including an outline of probable misconceptions and assumed prior knowledge of students | Confusion between rate and extent of reactions, and use of equilibrium constants in predictions thereof.<br>Misconceptions reduced but significant conceptual difficulties still existed at the end of the modules (~30%). Given students at the end had completed four years of chemistry, and were science teacher students, far from ideal.<br>Concluded misconceptions difficult to change. | |

| Reference | Cohort | Method | Specific conceptions identified | Teaching strategies | Results, conclusions & hypotheses | Critique of methodology |
|---|---|---|---|---|---|---|
| Read et al (2004, 2007) | First year university students, University of Sydney | Analysis of written examination answers | | | Two questions relating to buffers were answered with significantly different competence suggesting that students did not understand the concepts but could apply arithmetic rules. | Study limited to analysis of examination papers and narrow topic focus. |
| Roche, 2007 | Second year pharmacy students, Omaha, USA | Analysis of written examination answers | | Teaching sequence supported by comprehensive handout | Students were able to score highly on examination, and evidence of reasonable retention for 6 months | No indication of prior understanding, evidence of change limited to examination performance. |

# APPENDIX B TABULATED RESULTS FROM POPULATION STUDY

## Table 4.1

| | Initial survey | Final survey |
|---|---|---|
| **Population (number)** | 190 | 193[#] |
| **Responses (number)** | 182 | 150* |
| **Response rate (percent)** | 95.8 | 77.7 |

Table 4.1: Details of cohort and response rates: initial and final surveys

[#] 155 were also part of the cohort for the initial survey. * 120 were identifiable as having completed the initial survey, 4 may have completed the initial survey, 24 were identifiable as not having completed the initial survey, and 2 student identification numbers were invalid. Consequently, between 120 and 126 students may have completed both surveys, which equates to a response rate of 63.2-66.3 percent with respect to the initial survey. However, as there were only 155 possible respondents to both surveys, the effective response rate to the final survey was 77.4-81.3 percent.

## Table 4.2

| Age distribution | % |
|---|---|
| 17-19 | 73.6 |
| 20-24 | 20.3 |
| 25-29 | 2.7 |
| 30-39 | 1.6 |
| 40 and older | 1.6 |

| Gender distribution | % |
|---|---|
| Male | 26.9 |
| Female | 73.1 |

| Origin | % |
|---|---|
| Australian citizen | 86.8 |
| Permanent resident | 1.6 |
| International | 11.0 |
| New Zealand citizen | 0.5 |
| Local | 89.0 |
| International | 11.0 |

| Language background | % |
|---|---|
| Primary language English | 54.9 |
| Primary language not English | 45.1 |
| English spoken at home | 28.6 |
| Language other than English spoken at home | 71.4 |

| Educational background | % |
|---|---|
| First year at uni | 68.7 |
| Not first year at uni | 31.3 |
| Years of prior university study | % |
| 0 | 68.7 |
| 1 | 13.2 |
| 2 | 1.6 |
| 3 | 5.5 |
| 4 | 8.8 |
| 5 | 1.1 |
| 8 | 0.5 |
| 10 | 0.5 |

| Primary languages other than English | n |
|---|---|
| Cantonese | 20 |
| Arabic | 15 |
| Mandarin | 13 |
| Vietnamese | 11 |
| Chinese | 7 |
| Hindi | 4 |
| Korean | 3 |
| Persian | 2 |
| Cambodian | 1 |
| Greek | 1 |
| Polish | 1 |
| Portuguese | 1 |
| Telugo | 1 |

Table 4.2: Demographic characteristics of the cohort

## Table 4.3

| | | Agree | | | Disagree | |
|---|---|---|---|---|---|---|
| | | I | F | | I | F |
| **Enjoyment and interest** | | | | | | |
| 1 | Chemistry is one of my favourite subjects. | 45 | 43 | | 22 | 27 |
| 4 | I enjoy studying chemistry. | 52 | 47 | | 15 | 17 |
| 7 | I do not enjoy doing chemistry problems. | 27 | 33 | | 30 | 33 |
| 2 | I find chemistry to be of little interest. | 20 | 15 | | 61 | 58 |
| 12 | I want to learn more about chemistry. | 64 | 55 | | 8 | 9 |
| **Confidence** | | | | | | |
| 3 | I feel confident in my understanding of chemistry. | 37 | 46 | | 35 | 23 |
| 8 | I am uncertain about how well I have grasped chemistry in my previous study. | 45 | 36 | | 35 | 32 |
| 11 | I find chemistry difficult. | 43 | 41 | | 21 | 25 |
| **Relevance** | | | | | | |
| 5 | What I have learned in chemistry is not relevant to my everyday activities. | 23 | 14 | | 49 | 60 |
| 9 | I can easily see how the things I have learned in chemistry are useful to me in other contexts. | 60 | 71 | | 9 | 5 |
| 6 | Understanding chemistry is important for studying pharmacy. | 91 | 93 | | 4 | 1 |
| 10 | A pharmacist does not need to know much about chemistry. | 4 | 2 | | 90 | 89 |

Table 4.3 Attitudes towards chemistry in initial and final surveys

Data were collected using a five-point Likert scale ranging from 'strongly agree' to 'strongly disagree'. All values are expressed as percentages of the total response. The value in the 'Agree' column is the sum of 'agree' and 'strongly agree'; likewise the value in the "Disagree' column is the sum of 'disagree' and 'strongly disagree'. I refers to the initial survey, F refers to the final survey. The item numbers indicate the order in which the items were presented, however they have been grouped for convenience into categories of enjoyment/interest, confidence and relevance.

**Table 4.4**

| | | Correct | | Unsure | |
|---|---|---|---|---|---|
| | | I | F | I | F |
| 1 | Acids have pKa values of less than 7. | 28 | 51 | 24 | 9 |
| 2 | An acid will react with an alkali to form a salt and water. | 92 | 88 | 4 | 6 |
| 3 | A neutral solution has a pH of 7. | 98 | 94 | 1 | 2 |
| 4 | Rainwater has a pH of 7. | 81 | 70 | 10 | 16 |
| 5 | The addition of 25mL of 0.1M sodium hydroxide solution to 25mL of 0.1M acetic acid solution will produce a neutral solution. | 73 | 63 | 11 | 12 |
| 6 | Bases have pKa values greater than 7. | 28 | 44 | 25 | 17 |

| | | Choice | |
|---|---|---|---|
| | | I | F |
| 7 | In a sample of distilled water | | |
| | A: there are no $H_3O^+$ ions or $OH^-$ ions present | 11 | 14 |
| | B: the concentration of $H_3O^+$ ions is higher than the concentration of $OH^-$ ions | 2 | 2 |
| | C: the concentration of $H_3O^+$ ions is lower than the concentration of $OH^-$ ions | 1 | 1 |
| | D: **there are approximately equal concentrations of $H_3O^+$ ions and $OH^-$ ions** | **86** | **83** |
| 8 | For a given weak acid, HA, the numerical value of $K_a$ | | |
| | A: will change with the pH | 18 | 33 |
| | B: **will change with the temperature** | **43** | **41** |
| | C: cannot be less than $10^{-7}$ | 12 | 14 |
| | D: cannot be greater than $10^{-7}$ | 27 | 13 |
| 9 | Which of the following solutions has the lowest pH? | | |
| | A: 0.08 mol/L sulphuric acid | 15 | 19 |
| | B: 0.08 mol/L hydrochloric acid | 25 | 22 |
| | C: 0.20 mol/L acetic acid (ethanoic) | 23 | 17 |
| | D: **0.20 mol/L nitric acid** | **37** | **43** |
| 10 | Two acid-base titrations are carried out, both with the same solution of strong base in the burette. In titration A, the conical flask contains 25mL of a 0.020 mol/L solution of a weak monoprotic acid. In titration B, the conical flask contains 25mL of a 0.020 mol/L solution of a strong acid. Which of the following statements is true? | | |
| | A: The volume of base required to reach the equivalence point will depend on the particular acid used. | 23 | 22 |
| | B: The weak acid will require less base than the strong acid to reach the equivalence point. | 44 | 37 |
| | C: The weak acid will require more base than the strong acid to reach the equivalence point. | 9 | 16 |
| | D: **The weak acid will require approximately the same amount of base as the strong acid to reach the equivalence point.** | **23** | **25** |

Table 4.4 Responses to closed questions about conceptual understanding

For items 6-10, the response in bold is the correct alternative.

## Table 4.5a

For Tables 4.5a, 4.5b and 4.5c, the data are tabulated as percentages of students giving a particular response. Column totals exceed 100% because most students provided more than one response to the item. To reduce the burden on individual students, each was asked to respond either about acids or bases, but not both. Figures in bold are those where substantial change was observed between the initial and final surveys.

| Classification | | initial | | final | |
|---|---|---|---|---|---|
| | | Acid | Base | Acid | Base |
| No response | | 1.1 | 1.1 | 2.0 | 3.0 |
| Structural or functional characteristic | proton donor or acceptor (Bronsted-Lowry) | 39.6 | 38.5 | **93.9** | **94.9** |
| | appropriate salt forms | | | **2.0** | |
| | reference to conjugates | | | **12.2** | **4.0** |
| | reference to pKa | | | **2.0** | |
| | structural features | | | **3.0** | **3.0** |
| Physical or reaction characteristics | physical properties | 56.0 | 42.9 | **42.9** | **31.3** |
| | specific value of pH | 51.6 | 62.6 | 55.1 | **37.4** |
| | production of $H^+$ or $OH^-$ in water (Arrhenius) | 27.5 | 27.5 | 2.0 | 23.2 |
| | inorganic chemical reactions | 20.9 | 33.0 | **12.2** | **14.1** |
| Errors or confusion | inappropriate characteristic | 4.4 | 6.6 | 4.0 | 4.0 |
| Number of students | | 91 | 91 | 49 | 99 |

Table 4.5a Student responses to the task 'List the major characteristics of acids/bases.'

## Table 4.5b

| Classification | | initial | | final | |
|---|---|---|---|---|---|
| | | Acid | Base | Acid | Base |
| No response | | 18.7 | 18.7 | 8.2 | 16.2 |
| Appropriate representation or reference | Correct equation | 14.3 | 8.8 | 16.3 | 7.1 |
| | Reference to strength – no apparent confusion | 27.5 | 18.7 | **53.1** | **40.4** |
| | Reference to dissociation – no apparent confusion | 25.3 | 11.0 | 28.6 | 11.1 |
| | Appropriate reference to ionisation state | | | **4.1** | **1.0** |
| | Appropriate reference to conjugate | | | | **6.1** |
| Errors or confusion | inappropriate or confused reference | 20.9 | 24.2 | 18.4 | **8.1** |
| | Incorrect equation | 8.8 | 6.6 | | 10.1 |
| | Reference to strength – incomplete or confused | 13.2 | 9.9 | **4.1** | 7.1 |
| | Reference to dissociation – incomplete or confused | 11.0 | 25.3 | 10.2 | **15.2** |
| | Inappropriate reference to pH | 5.5 | 3.3 | | |
| | Irrelevant aspect | | 3.3 | | 1.0 |
| Number of students | | 91 | 91 | 49 | 99 |

Table 4.5b Student responses to the questions 'What is meant by the pKa of an acid/base?' and 'What information does it provide about the acid/base?'

**Table 4.5c**

| Classification | | initial | | final |
|---|---|---|---|---|
| | | Acid | Base | Acid |
| No response | | 5.5 | 5.5 | 3.4 |
| Inorganic or high school chemistry | Strong acid/base dissociates completely, weak acid base dissociates partially | 48.4 | 48.4 | 45.9 |
| | Strong acid/base produces higher/lower pH | 13.2 | 7.7 | 6.1 |
| Broader chemistry/ pharmacy definition | Strong acid/base dissociates to greater extent than weak | 22.0 | 24.2 | **34.5** |
| | Strength indicated by pKa | 2.2 | 2.2 | **4.7** |
| Errors or confusion | Inappropriate response | 12.1 | 11.0 | 8.8 |
| | Answer incomplete | 6.6 | 6.6 | 4.7 |
| Number of students | | 91 | 91 | 148 |

Table 4.5c Student responses to the question 'What is the difference between a strong acid/base and a weak acid/base of the same concentration?'

To reduce the burden on individual students, each was asked to respond either about acids or bases, in the initial survey; in the final survey all students were asked about acids.

**Table 4.6a**

| **Age distribution** | **Population** | **Sample** |
|---|---|---|
| 17-19 | 74 | 100 |
| 20-24 | 20 | 0 |
| 25-29 | 3 | 0 |
| 30-39 | 2 | 0 |
| 40+ | 2 | 0 |
| **Gender distribution** | | |
| Male | 27 | 18 |
| Female | 73 | 82 |
| **Place of origin** | | |
| Australian citizens, permanent residents, NZ citizens | 89 | 100 |
| International students | 11 | 0 |
| **Language background** | | |
| Native English speakers | 55 | 55 |
| Consider English as not primary language | 45 | 45 |
| Speak another language at home | 71 | 64 |
| **Educational experience** | | |
| 1st year at University | 69 | 91 |
| Prior experience of tertiary chemistry | 23 | 9 |
| More than 100 hours of tertiary chemistry | 15 | 0 |

Table 4.6a Population and sample characteristics – background

All values are expressed as percentages of the total.

## Table 4.6b

| Item | Agree | | Disagree | |
|---|---|---|---|---|
| | Population | Sample | Population | Sample |
| 1 | 45 | 41 | 22 | 23 |
| 2 | 20 | 27 | 61 | 55 |
| 3 | 37 | 32 | 35 | 41 |
| 4 | 52 | 41 | 15 | 23 |
| 5 | 23 | 18 | 49 | 55 |
| 6 | 91 | 95 | 4 | 5 |
| 7 | 27 | 45 | 30 | 23 |
| 8 | 45 | 50 | 35 | 36 |
| 9 | 60 | 68 | 9 | 18 |
| 10 | 4 | 0 | 90 | 100 |
| 11 | 43 | 50 | 21 | 14 |
| 12 | 64 | 59 | 8 | 5 |

Table 4.6b Population and sample – attitudes to chemistry (initial survey)

Data were collected using a five-point Likert scale ranging from 'strongly agree' to 'strongly disagree'. All values are expressed as percentages of the total response. The value in the 'Agree' column is the sum of 'agree' and 'strongly agree'; likewise the value in the "Disagree' column is the sum of 'disagree' and 'strongly disagree'. Table 4.3 details the items by number.

# APPENDIX C TIMELINE FOR STUDY

The table below sets out the time line for the 36 weeks covered by the research study. It should be noted that the examination (**ex**) was held in week 15, and the table indicates whether an interview was held before or after the examination in that week

| | Week of the study | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | ex | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| | **13th August – 21st September** | | | | | | | | **8th October – 2nd November** | | | | **5th November – 30th November** | | | | **3rd December – 5th April** | | | | | | | | | | | | | | | | | | | **1st April – 19th April** | | |
| | **Initial interviews** | | | | | | | | **Teaching period** | | | | **Second interviews** | | | | **Break – summer vacation and start of second academic year** | | | | | | | | | | | | | | | | | | | **Third interviews** | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | ex | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| **TC** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Jan | x | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | x | |
| Geo | | x | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | x | |
| Lar | x | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | x | |
| Luc | | x | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | x | | |
| Emm | | | | | | x | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | x | | |
| **PC** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ver | | | | | x | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | | | x | |
| Den | | x | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | | x |
| Isa | | x | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | x | |
| Jas | | | | | x | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | | x | |
| Kel | | x | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | x | |
| Ali | | x | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | x | |

## Legend

| | |
|---|---|
| **TC** | **Transient change group** |
| Jan | Janine |
| Geo | Geoffrey |
| Lar | Larry |
| Luc | Lucy |
| Emm | Emma |

| | |
|---|---|
| **PC** | **Persistent change group** |
| Ver | Veronica |
| Den | Denise |
| Isa | Isabelle |
| Jas | Jasmine |
| Kel | Kellie |
| Ali | Alicia |

# APPENDIX D SEMI-STRUCTURED INTERVIEW QUESTIONS

Chapter 5 includes a summary of the general tenor of questioning in the interviews, and more details about the questions themselves can be found below.

## Interview 1

Only chemistry content was covered in interview 1. The general structure of the questions was as follows:

- What makes something an acid? What makes something a base? What are the characteristics or defining features of acids and bases? Do all acids and bases have these features?
- In what different situations would you expect acids and/or bases to be found or to be important?
- Do the words acid and base always mean the same thing to you? If no, can you give me some examples of different places where they mean different things?
- What makes acids different from each other? What makes bases different from each other? What do you understand by the terms strong and weak? What does it mean for an acid or base to be strong or weak?
- What does pH mean? What does it measure? What does it refer to? Can it refer to basicity?
- What can you tell me about a solution that has a low pH? Tell me everything you can.
- What do you know about a solution which is neutral? Again, tell me everything you can.
- What does the $pK_a$ refer to? Does it refer to acids or bases or both? How do you use it, or what information does it give you?
- Can you give me an example of some acids and bases? How would you represent these on paper? Do you know more than one way of representing them? What ways do you know? How do they relate to each other?
- What happens when an acid is mixed with a base? Is this neutralisation? What does neutralisation mean? What does neutralisation involve? Does it always result in a neutral solution?
- What are buffers? What do they do – what is their purpose?
- What happens when an acid is added to a buffer solution? What about a base? Can you show me using specific examples of acids, bases and buffers?
- What comes to mind when I mention equilibrium in chemistry?
- How do you write down an equilibrium?
- What is an equilibrium constant and how do you calculate it?
- What would the equilibrium look like for an acid in water? What about a base?
- What would happen to the equilibrium if you added more of one of the species in the reaction? Would it make a difference if you added more reactant or more product?

## Interview 2

Similar content questions were asked to those of interview 1, together with the addition of the following:

- How do you think your understanding of acids and bases has changed during the semester? Has it changed? Do you think differently about acids and bases now? In what ways?
- Are there differences in how you think about acids and bases in Chemistry and Pharmacy? If yes, what are some of these differences? (Strong and weak, physical characteristics, do you think acids turn litmus paper red and bases blue?)
- When we talk about drugs as acids and bases, what do you look for to work out whether a drug is an acid or a base or neither? Let's look at a few drug structures – can you tell me what they are, acids, bases or something else? Can you tell me what you are looking for when you are classifying them?
- We spent quite a lot of time talking about pH and pKa. What do these terms mean to you? How does this relate to what you've learned in Chemistry?
- Can you describe how dissociation equilibria work? Can you draw for me the dissociation for ibuprofen and amoxycillin?

In addition, the following general questioning was included in the second interview:

- Thinking back to the last three weeks of semester, how were you feeling about university, your exams, other people, the world – anything at all?
- Are there any things going on in your life at the moment or recently that might have affected your learning?
- How are/were you feeling about the exams? The IPS exam in particular? How are/were you studying for it? Is this how you prefer to study for exams? Why? (If after the exam: How do you feel now?)
- Tell me a little about how your group went during the semester. What was good about working with your group members? What wasn't so good? Would you say that you were friends with any of them before this semester? Has that changed? How? Do you work with them in any other classes? Do you see any of them outside class?
- In terms of your own learning, did being in that group help? Why or why not? Were there certain people who were particularly helpful or hindrances? What did you think about the sorts of activities you did? Which ones were the most useful to you (memory strategies, trying to explain things, calculations, identifying structures, equations, etc)? Why? What would you say you got out of being in that group?

## Third interview

Similar content questions were asked to those of interview 2, together with the addition of the following:

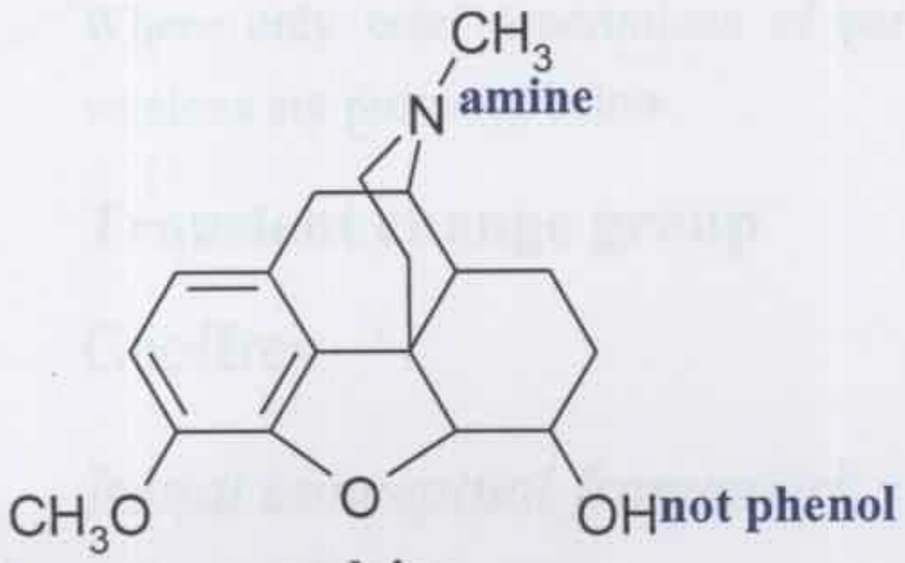
- What would you say are the most important things you learned last semester about acids and bases?
- Why do you think it is important in Pharmacy to know about the acidic and basic properties of drugs?
- Why did you decide to take part in this study? Would you do it again? Do you think it was beneficial for your learning, harmful or had no effect? What were the best things about it and what were the least good things about it?

## Final questions and feedback form

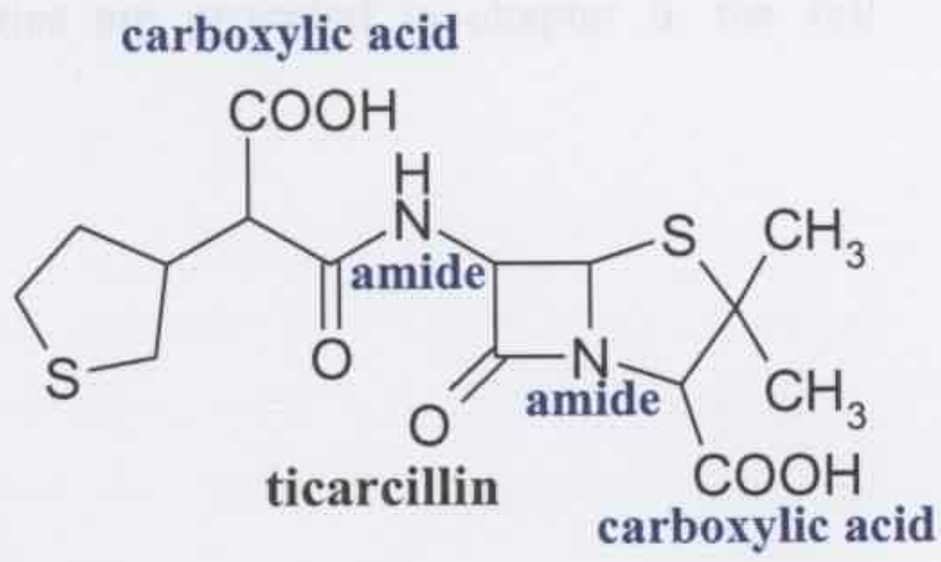
The following questions formed part of the third interview and were also included on a written feedback form which could be returned anonymously if the participant so chose.

- What was the reason or reasons that you agreed to take part in the study when you were invited?
- Did you have any fears or reservations about taking part? If so, were they a problem for you at any stage in the study?
- Do you think you got anything positive out of being in the study? If yes, what was it?
- Do you think you suffered anything negative out of being in the study? If yes, what was it?
- Would you be interested in participating in something like this again if you were asked?
- Do you have any other comments about the study?

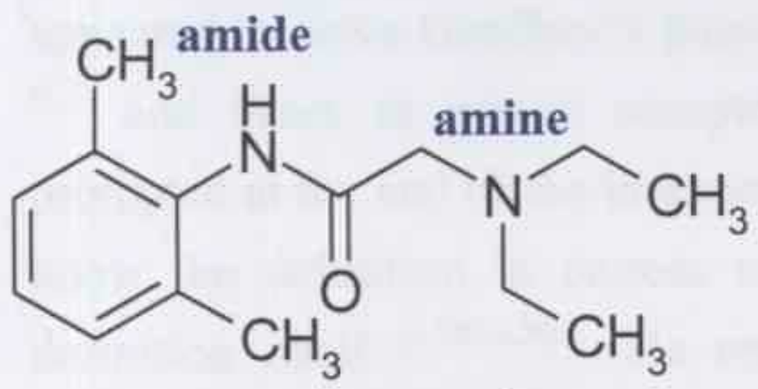
# APPENDIX E STRUCTURES OF MOLECULES



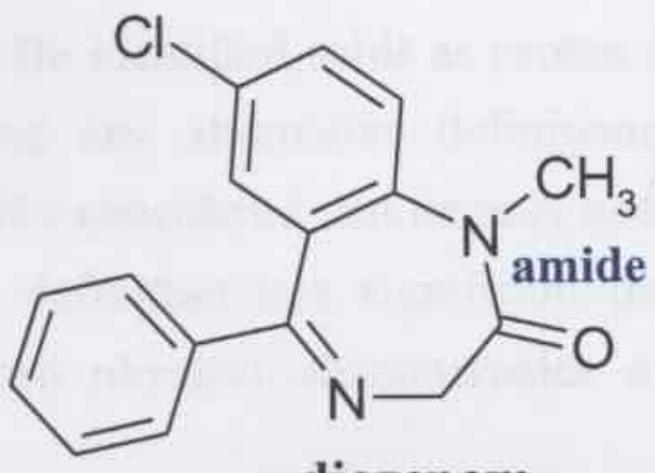

codeine



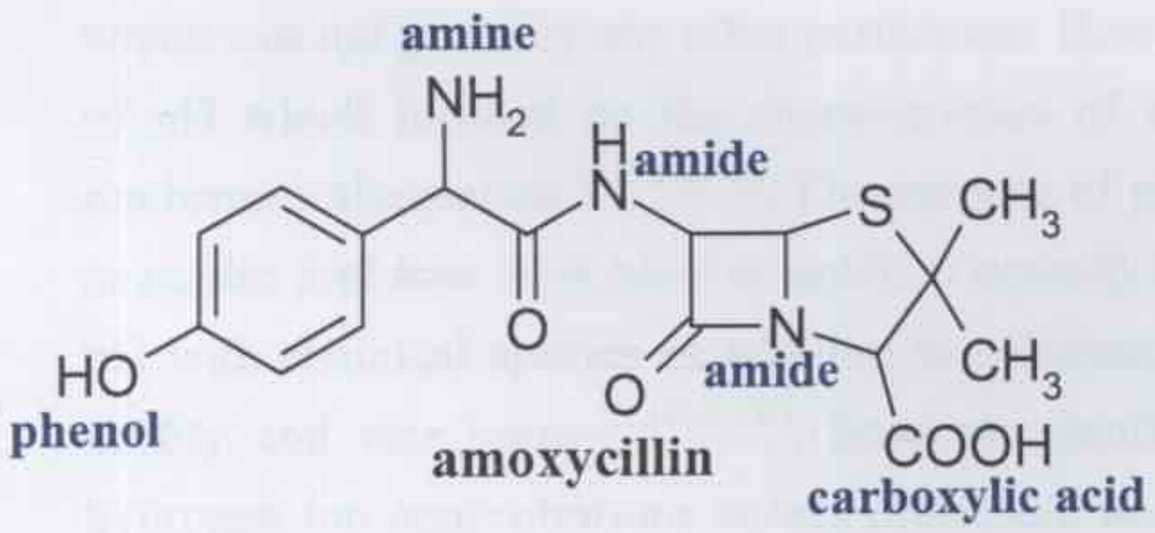

ticarcillin



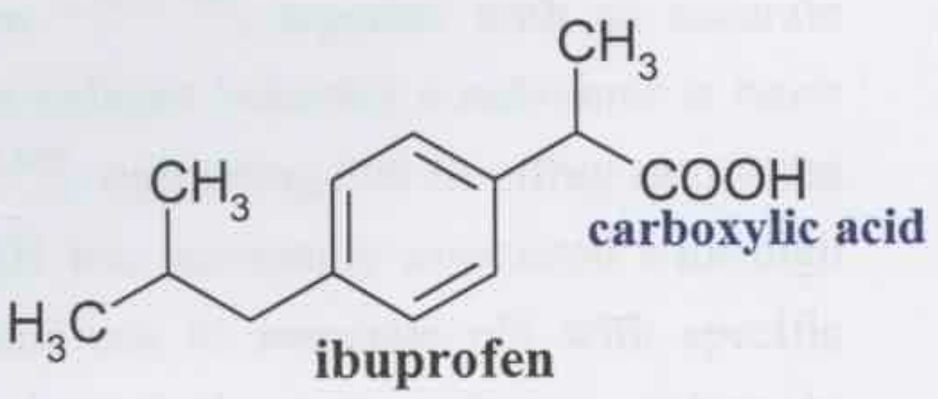

lignocaine




diazepam

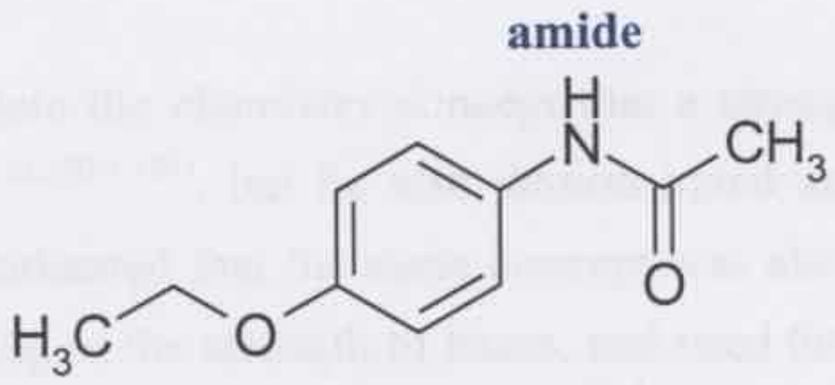



amoxycillin




ibuprofen


cephradine




phenacetin

# APPENDIX F PARTICIPANT TRAJECTORIES (CHAPTER 6)

Where only brief descriptions of participants' trajectories are provided in chapter 6, the full versions are provided below.

## Transient change group

### Geoffrey

#### *Initial conceptual framework*

On commencing the study, Geoffrey demonstrated a narrow but solid understanding of the nature of acids and bases as he had learned it in secondary school chemistry. This narrow approach appeared to serve Geoffrey's purposes in a practical manner. He identified acids as proton donors (1.2) and bases as proton acceptors (1.14) without mentioning any alternative definitions until prompted at the end of the interview (1.5491.572), and pragmatically considered that he only needed to know the definition in current use, with the name of the definition less significant than the definition itself (1.560-1.562). He readily identified the standard physical characteristics of, and associated pH with, both acids and bases (1.4-1.16, 1.178-1.186).

Geoffrey described pH as '*potential hydrogen*' (1.158), an appropriate but rarely used description which was not given by any other participant. However he also articulated an appropriate definition of pH which focused on the characteristics of a solution (1.162-1.164), together with an accurate mathematical equation (1.172-1.174). The purpose of pH was to indicate '*whether a substance is basic or acidic, and how, how basic or acidic it actually is*' (1.178-1.180), suggesting that Geoffrey associated pH with chemical species in addition to solutions. Low pH was accurately associated with high acidity and vice versa (1.182-1.186), however Geoffrey tended not to associate pH with specific hydrogen ion concentrations unless prompted, and required a calculator to work out a relatively simple calculation. Geoffrey therefore demonstrated a generally descriptive conception of pH, with the mathematical expression in the background. As with much of his other knowledge about acids and bases, the descriptive and mathematical conceptions of pH appeared disconnected from each other, with the result that his overall concept of pH was somewhat fragmented.

In relation to strength, Geoffrey was easily able to articulate the chemistry concept that a strong acid dissociated completely whereas weak acids did not (1.150-1.154), but he also demonstrated an understanding of relative strength (1.104-1.106). Although he indicated that the same concept was also true for bases (1.108), he struggled to explain his understanding of the strength of bases, and used the Arrhenius rather than Bronsted-Lowry framework (1.122, 1.130-1.132).

# *Geoffrey's trajectory*

## Changes to existing understanding

### *Interview 2*

By the end of the teaching semester, Geoffrey was still confident in defining acids as proton donors, but his terminology had become significantly more precise than in his first interview (2.496-2.502), reflecting good command of pharmacy conventions. He could not remember any other characteristics of acids and bases, but with prompting was able to identify the appropriate formation of salts (2.508-2.512), and the relationship between pH and ionisation states (2.536-2.538). The precision of his definition and the need for prompting in order to recall other characteristics may have resulted from the proximity of the interview to the examination (four hours after finishing), since he seemed to perform best when presented with a specific question for which there was an explicit answer in his lecture notes, rather than a general conceptual question. When asked, he could articulate taste and corrosiveness as characteristics of acids and bases which applied to chemistry and not to pharmacy, but he appeared simply not to have considered these characteristics in the context of pharmacy rather than developed contextual discrimination in the sense of consciously recognising that they did not belong in pharmacy. Indeed the questions in the interview appeared to stimulate his thinking about these issues for the first time (2.555-2.564).

Geoffrey did not perceive any significant confusion in the use of the terms acid and base in chemistry and pharmacy, and explained this as a result of the way his mind worked: '*when I'm in chemistry, I'm in chemistry, when I'm in pharmacy, I'm in pharmacy*' (2.424). However he did concede the potential for confusion: '*like I'd be talking to Lucy and then I'd say what's such and such and she'd explain it to me and then she goes "Oh hold on a second that's in chemistry." Yeah so I suppose that does exemplify a bit of confusion*' (2.430-2.434).

With regard to strength, Geoffrey was able, without prompting, to articulate concisely the differences between the meaning of strong and weak in chemistry and pharmacy (2.456-2.458, 2.464-2.466). He associated strong acids with pKa of less than 7 and weak acids with pKa of greater than 7, displaying no concern or problems with the latter (2.467-2.468). His lack of difficulty with acidic pKa values greater than 7 appeared to stem from his understanding that '*Ka is merely just like an equilibrium constant and the pKa is just negative log 10 of that*' (2.470-2.472). Geoffrey therefore appeared to have developed his concept of strength in the context of pharmacy to include mathematical relationships, and he was confident and accurate in his explanation and application of the mathematics.

In summary therefore, Geoffrey demonstrated evidence of an understanding that acids and bases were different in chemistry and pharmacy, and was able to articulate a very specific definition of the pharmacy convention, but his understanding appeared to be somewhat superficial and fragmented. He could answer direct questions which related to either chemistry or pharmacy, but

struggled to articulate both connections and differences between them in a more integrated or holistic manner. He demonstrated some evidence of contextual discrimination in meaning, particularly in relation to strength, but this was more appropriately described as compartmentalisation because he focused on learning specific details which fitted exclusively into one or other of the chemistry and pharmacy compartments.

***Interview 3***

Five months later, Geoffrey had returned to his original simple definitions of proton donor (3.300) and acceptor (3.334), displaying little evidence of the precise definition articulated in his second interview. When probed for additional characteristics, he specified the '*physical characteristics*' (3.304) of taste (3.306, 3.312, 3.370) and pH (3.338-3.342), with no mention of salts or the relationships between pH and ionisation state. These descriptions strongly indicated that Geoffrey had reverted almost completely to his chemistry understandings, as these were characteristics which had been presented as belonging to solutions of acids and bases as found in chemistry rather than acidic/basic drugs in pharmacy. Geoffrey himself admitted that he had '*stuck with those since year, year 8 chemistry*'[1] (3.310), since '*what you learn first, I suppose, is what sticks*' (3.368). In contrast to his comments during the second interview, he did not distinguish between the chemistry and pharmacy domains, and he did not appear aware that there were differences which he had previously been able to articulate. Some development of concepts was identified on deep probing, as Geoffrey indicated that the terms acid and acidic drug did not necessarily mean exactly the same to him (3.362-3.364), but he could only highlight the issue of strength as a point of difference.

His explanation of the reason for perceiving a difference lay in the context of learning: '*the reason why I distinguish acidic drugs with (pause) ah, other acids is because I learned about certain acids in chemistry and certain acids in pharmacy... they're different, because I learned them in, I learned about them in different (pause) different places, different situations, like different, for different reasons*' (3.400-3.408). This explanation is consistent with many of Geoffrey's responses in his second interview which strongly suggested compartmentalisation of understanding. Geoffrey could not articulate specific differences, but perceived some form of global difference because they were learned in different situations and for different reasons.

While strength was the primary characteristic identified by Geoffrey as different between chemistry and pharmacy, his descriptions were considerably less precise than in his earlier interview. Geoffrey appeared to classify all acidic drugs as weak acids (3.384-3.388) but needed prompting to confirm that he meant weak in chemistry rather than pharmacy terms (3.396-3.398). He was able, with assistance, to associate pKa with strength of acids and bases in pharmacy, but he was very confused about the specific relationships and about the definition of pKa in general, in stark contrast to his responses in the second interview. He could no longer provide the appropriate mathematical

[1] Year 8 is the second of six years of secondary school in Australia. Students are typically 13 to 14 years old at this time.

relationship between Ka and pKa [3.422-3.451], which he had previously articulated with ease and confidence.

Even after the mathematical relationship was re-established by the interviewer, Geoffrey still struggled to associate low and high values with strong and weak, suggesting that his numerical reasoning in relation to the connection between extent of dissociation and pKa was rather tenuous. He was clearly hesitant and lacking confidence in his answers, and his first thought that high pKa meant a strong acid [3.456-3.458] appeared not to be based on reasoning but on guessing. He needed hints from the interviewer in order to direct his thinking, and continued to confuse the mathematical operations of raising to a power and taking logarithms [3.464]. Eventually he was guided to the point where he could link stronger acid with lower pKa [3.464-3.466], the correct connection which he had been able to carry out with ease during the second interview.

In relation to bases, Geoffrey was able to write the dissociation equilibrium accurately [3.502-3.504], but then attempted to use a completely different mathematical equation, the Henderson-Hasselbach equation, to derive the strength relationships. This approach was inappropriate for the purpose, and his attempt was characterised by much confusion and little success. It appeared that he had conflated the concept of strength with the Henderson-Hasselbach equation, perhaps because both were closely associated with pKa. He attempted to write out the Henderson-Hasselbach equation but it was not clear to the interviewer what he was trying to demonstrate by it, and his approach was quite confused, an impression which was supported by an inability to differentiate between the equations for acids and bases. As the interviewer attempted to probe, Geoffrey introduced the concept of Kb, the base dissociation constant. This train of thought provided significant insight into the difficulties experienced by Geoffrey with base strength since he clearly associated bases with Kb to a greater extent than with Ka. Kb was firmly established in his chemistry conceptual understanding, and the semester of using Ka with bases had not changed his underlying conceptual foundations, despite specific instruction that Kb did not feature in the pharmacy conventions at all [3.554-3.559].

Geoffrey's lack of confidence continued to be evident, together with his struggle to direct his thinking in productive directions. He remained unable to connect weakness of a base with the extent of dissociation, presumably because of the confounding concept of Kb, and required the direct negation of his ideas by the interviewer [3.560-3.572].

This last exchange strongly supported other episodes in the third interview which indicated that Geoffrey had essentially reverted to chemistry conventions at the expense of pharmacy concepts. When he did attempt to articulate pharmacy conventions, Geoffrey relied on three strategies, namely memory, logic and instinct. Previously he had indicated that his preference was for logical reasoning rather than memorisation [3.472-3.476], and he believed that he could derive all he needed from the dissociation equilibria [3.480-3.484]. This appeared to be a productive strategy, but he also claimed to use '*educated guesses*' [3.496], and the overall success of his strategies was clearly

contingent on memory of appropriate use of the equations rather than simply memory of their form. In this situation, his logic was undermined because he was attempting to use an equation which was not suitable for solving the problem at hand, and the only approach which would have been fruitful was the one he chose not to adopt, going with instinct, which provided the correct answer (3.538-3.544).

In summary, Geoffrey appeared to have learned to distinguish between contexts during the teaching semester, but this learning did not persist into the following academic year. His third interview was characterised by hesitancy in response, and long periods where he attempted to work through his thinking. Often he was unable to move in appropriate directions without specific prompting from the interviewer, and the result was extended passages of dialogue involving unproductive starts, multiple pauses and much confusion. His responses confirmed the impression given in the second interview that his conceptual understanding was compartmentalised and fragmented. His explanations of the nature of acids and bases had reverted to his pre-pharmacy concepts, and he appeared to have forgotten the pharmacy conventions almost completely. Similarly, Geoffrey reverted to his pre-pharmacy concepts of strength, mixed with a confused notion of pKa. He experienced particular difficulty with the strength of bases because he had not appropriated the idea that Kb was used in chemistry but not in pharmacy. Some vestiges of an appreciation of differences between chemistry and pharmacy remained, but they were not expressed spontaneously or voluntarily, and Geoffrey struggled to articulate his thoughts. The significance of his original understanding of acids and bases was clearly evident, and its dominance was such that the new material appeared to make minimal impact and consequently had not been appropriated to any significant extent. His pragmatic approach was less successful at the time of the third interview than it had been in earlier stages of the study, in that his three strategies of memory, logic and instinct often failed to provide him with adequate direction in solving problems. Little fundamental conceptual change was apparent.

## Concepts new to pharmacy

### *Interview 2*

Four hours after his examination, Geoffrey was able to identify the majority of relevant functional groups on the nine test molecules, and also on four additional molecules which he analysed voluntarily (dopamine, ephedrine, oxazepam and amitryptyline). He was most confident in identifying carboxylic acid groups (2.680-2.688), but was also easily able to describe the salient features of phenols and to distinguish them from aliphatic alcohols (2.674-2.680). In general he was comfortable with identifying amines, and was particularly thorough in distinguishing between amine and amide groups to eliminate the latter as non-basic (2.640-2.646). He was a little confused about other non-basic nitrogens, and attempted to apply sp hybridisation to a nitrogen in diazepam, and he needed prompting to re-focus appropriately on the hybridisation state of the carbon (2.762-2.782), with which he was familiar (2.828). Geoffrey was able to classify molecules with both acidic and basic functional groups accurately, and to give a rational explanation for describing them as neither acid nor base (2.724-2.732).

Geoffrey believed that he had had a very good understanding of the process for identification of acidic and basic functional groups and would be able to remember it for an extended period (2.878) because he had a complete understanding of the ideas rather than having learned them by rote (2.880), and he knew what he was looking for and why (2.882). He appeared to base this confidence on the fact that he could do the particular type of problem quite easily at the time of this interview, and that he had completed a number of related problems recently (2.870, 2.872, 2.912). Any errors were attributed to '*silly mistakes*' (2.914) and he claimed that he could essentially do these identifications in his head without too much thinking (2.920-2.926). The key appeared to be recognition of patterns (2.861-2.866). This belief was largely borne out by the evidence from his third interview.

Since Geoffrey was clearly familiar with the pharmacy material in this interview, he was only asked to draw the dissociation equilibrium task for amoxycillin. Interestingly, he preferred to explain orally rather than write his response (2.974), which was consistent with the manner in which he identified the functional groups on the test molecules. He assigned pKa values appropriately and carried out the dissociations in the correct order, with generally concise and accurate explanations (2.980-2.1006). He emphasised repeatedly that the molecule was always ionised (2.708, 2.730, 2.1018), a concept which was firmly associated with amoxycillin being neither an acid nor a base. However he struggled to reconcile this concept of permanent ionisation with his understanding of the relationships between pH and pKa. He was aware of the pharmacy convention that when pH and pKa differed by 2 or more units, the approximation of 100% ionisation or non-ionisation was made, and attempted to find a pH at which amoxycillin could be considered 100% unionised (2.1049-2.1058). However he seemed unaware that this attempt was incompatible with his previous statement that amoxycillin was always ionised. He was correct from a pharmacy perspective in stating that at pH 0.4 and lower, the molecule would be considered to be fully protonated (2.1054), but he appeared to associate the state of full ionisation with an unionised molecule (2.1058), which was only true for acidic structures and not amoxycillin. It is likely that this confusion was a consequence of not writing down the structures on paper as he carried out the task, as this meant that he did not have a visual depiction of the ionisation of each functional group at different pH values. A visual representation may perhaps have allowed him to recognise that the reason why the molecule was always ionised was that all possible structures had at least one site of ionisation.

### *Interview 3*

Five months later, Geoffrey remained able to identify the relevant functional groups and thus the nature of codeine, lignocaine, amoxycillin, ticarcillin, diazepam and ibuprofen, however he demonstrated greater uncertainty than he had during his second interview, and considerable probing and hinting was necessary for accurate classification of most of the molecules. In codeine (3.608-3.623), he identified the amine group as basic, but briefly identified the hydroxide group as phenol. Lignocaine (3.624-3.685) presented a significant challenge as he began by writing the structure incorrectly and without the necessary number of bonds for structural validity, which necessitated a long discussion of the order of the atoms in the molecule (3.643-3.669). However, once Geoffrey had successfully drawn the molecule, he had little difficulty in identifying the amine and amide. The

analysis of amoxycillin was completed easily (3.694-3.708), and Geoffrey continued to classify it as neither acidic nor basic, using the appropriate explanation based on pH and ionisation state which he had employed in the second interview (3.718-3.722). Ticarcillin (3.731-3.744) and ibuprofen (3.787-3.790) proved easy for Geoffrey, as they contained carboxylic acids which he found easy to identify, and groups which he could now identify by pattern recognition because he had identified them on molecules such as lignocaine and amoxycillin. Diazepam was problematic because it contained a nitrogen in a structural pattern with which he was not familiar, and he found it necessary to ask for assistance (3.746). Direction from the interviewer channelled him into the productive train of thought of considering hybridisation, but he remained uncertain of the specific requirement and required very specific guidance (3.753-3.770).

Geoffrey was asked to draw the dissociation equilibria for both ibuprofen (3.803-3.808) and amoxycillin (3.821-3.856), and in both cases he was successful with few errors and little hesitation. Somewhat surprisingly, he elected to draw the equilibria on paper, which he had avoided during the second interview, and this appeared to facilitate his solution of the problem significantly. Apart from a slight hesitation in assigning the pKa of 7.4 (3.844-3.852) and minor confusion about what constituted complete ionisation (3.856-3.860), he completed the task both orally and in written form generally in accord with pharmacy conventions.

## Emma

### *Initial conceptual framework*

At the beginning of the study Emma readily identified an acid as '*something that donates a proton*' (1.2) and a base as a proton acceptor (1.16). She associated a small number of characteristics with acids and bases, namely taste, feel and reactivity with litmus, but these characteristics were not uniformly associated with both (1.9-1.14). Emma named her definition of proton donation/acceptance as Bronsted-Lowry, but only in the survey, and did not mention corrosiveness as a characteristic of either acids or bases.

In her survey Emma identified low pH with acids, but in her interview she demonstrated a strongly negative attitude to the concept of pH, and when the topic was initially mentioned she immediately commented '*I hate pH*' (1.86). She articulated the purpose of pH (1.90), but was shaky about the mathematical relationship (1.96). In contrast, her survey response included the correct form of the equation, but she appeared unable to use it correctly in simple calculations.

Emma was comfortable in characterising a solution of pH 7 as neutral (1.122), and stating that equal concentrations of hydrogen and hydroxide ions were present at pH 7 (1.119-1.120). She indicated that a solution of pH 2 would be '*very acidic*' (1.102) and one of pH 12 would be '*alkaline*' (1.112), and was well aware that there would be traces of hydroxide ions present at pH 2 (1.106) and traces of

hydrogen ions at pH 12 (1.118). These responses indicated a reasonably sophisticated understanding of pH, despite her stated dislike of the concept.

Emma distinguished in her interview between strong and weak acids on the basis of dissociation (1.46-1.48), and was confident that bases could also be strong or weak, although she did not clearly describe how dissociation applied to bases. However her survey responses indicated a deeper understanding in that she differentiated more precisely between a strong acid as one which dissociated completely, and a weak acid which '*reach[ed] equilibrium with ions in solution*'.

## *Emma's trajectory*

### Changes to existing understanding

#### *Interview 2*

Two days after her exam Emma continued to use the definitions and characteristics of acids and bases that she had at the beginning of the study. Acids were proton donors (2.336) and tasted sour (2.338) while bases accepted protons (2.346) and were bitter and slippery (2.348). The retention of chemistry conventions strongly suggested that Emma had not developed significant contextual discrimination in relation to the characteristics of acids and bases.

Emma did distinguish between chemistry and pharmacy in the association of pH with acids and bases, noting that only pH was relevant in chemistry, whereas the relationship between pH and pKa was important in pharmacy (2.755-2.768). She was confident that the strength of an acid or base in pharmacy was indicated by its pKa (2.368), and she was able to state the relevant conventions correctly, although with some hesitancy (2.374-2.376). This hesitancy appeared to stem from a lack of understanding of the meaning of pKa, and a consequential need to memorise the relationships. Emma could define and use the term (2.372-2.376), but admitted that she did understand its meaning (2.376), and believed that others shared her ignorance (2.372).

Emma could relate the extent of dissociation to the strength of an acid (2.390), however she did not distinguish clearly between chemistry and pharmacy despite recognising that '*Nothing in, um, pharmacy is considered to dissociate completely, is it?*' (2.406), and struggled to connect all three notions of pKa, strength and dissociation. She recognised that strength was related individually to both pKa and dissociation, but did not connect pKa and dissociation until it was explained (2.395-2.397). This failure to link the three concepts was clearly a consequence of Emma's approach to her learning, and her lack of time to seek understanding (2.412). It could be speculated that Emma had learned isolated fragments of information because she had not experienced opportunities to see how the fragments related to each other, but the interviewer's explanation of how the concepts fitted together allowed her to develop a greater appreciation of their interconnectedness.

Emma had little difficulty with the use of the terms acid and base in chemistry and pharmacy. She recognised that the concepts were different in the two domains (2.294), but avoided confusion by adopting the pragmatic approach of keeping the two sets of concepts completely separate from each other (2.296-2.300). However she did not '*give it that much thought*' (2.402) why or how the two domains were linked, and why the concepts were different in each. She admitted that she was happy to have two "boxes", one each for chemistry and pharmacy (2.413-2.414), and to use each box selectively for examinations. In many respects this approach was strategic for Emma, since she had not had the opportunity to learn and practice the material during the semester in collaborative interactions with her peers and tutors in workshops. Her ability to "cram" (2.62) became a survival mechanism in the circumstances in which she found herself, and her approach was therefore understandable. Although it could be argued that she demonstrated contextual discrimination, it is likely that this was primarily for the purpose of attempting the examinations and did not signify fundamental conceptual change. Emma's own words tended to support this contention in that she claimed to be able to '*forget everything else you've learnt, just look at the, (pause) the one that you have to do now*' (2.298).

However, Emma was not entirely consistent in her separation of the domains, and was able to use the concepts of one to solve problems in the other, particularly those which dealt with the relationship between pH and pKa. Unlike Larry and Lucy, who used the table from their notes, Emma was able to work out the relationships from her prior knowledge of chemistry (2.322-2.326). The insight demonstrated by Emma in this anecdote is intriguing, since it suggests that she may have been able to develop a deeper understanding of the relationships between chemistry and pharmacy if she had not been unable to work for most of the semester. Her capacity for conceptual change had also been constrained by the lack of opportunity to experience appropriate modeling of pharmacy discourse in workshops, further limiting her opportunities to appropriate new concepts.

### *Interview 3*

Five months later, Emma continued to use the concepts of proton donation and acceptance, together with taste, as characteristics of acids and bases (3.132-3.142). She was also able to state the appropriate conventions about pH and pKa (3.176-3.192) and to explain the meaning of pKa (3.194-3.198). It is not clear, however, whether these examples illustrate conceptual change, or the outcome of Emma's excellent memory (2.880-2.884). Some evidence to support the primacy of memory was related by Emma in her admission of visualisation as a means of recall (3.159-3.166), however this was not conclusive. Her discrimination between pH and pKa in terms of their context, '*that pH is more a measure of the, (pause) maybe of the solution, does that make sense? And that pKa is more (pause) of the acid itself, the, the thing itself*' (3.188-3.192), suggested that she may have appropriated some of the dialogue from the second interview, thus enabling her to make connections which had not been apparent earlier. She had not previously articulated the relationship between pH, pKa, acids and acidic solutions in such explicit terms, and her conceptual understanding as expressed in the third interview appeared to be more developed than previously. This interpretation lends further weight

to the suggestion that exposure to appropriate discourse modeling during the semester may have facilitated conceptual change for Emma.

Emma continued to attribute differences in the meanings of strong and weak as the major discriminator between chemistry and pharmacy, but was less able to articulate her ideas than she had been in the second interview. Her primary reason for recognising the differences continued to be the emphasis given to the concept in lectures, rather than the development of her own understanding (3.208-3.210), although she was confident of the relationships between strength and magnitude of pKa (3.384-3.392). However, as in her second interview she did not specifically link the concepts of dissociation, strength and pKa, and in this case did not appear to have appropriated the explanation of those relationships which had been discussed earlier with her.

Emma also continued to express little confusion between the meaning of terms in the two domains of chemistry and pharmacy, and as was the case in the second interview, it was apparent that Emma had adopted this approach as a pragmatic solution to her shortage of study time (3.212-3.214). However it was clear that she also relied on external authority to define what was appropriate to believe.

In summary, Emma adopted strategic approaches to compensate for her illness and lack of study time during the semester. These approaches revolved around her strengths, primarily her very strong memory (2.880-2.896) and ability to cram (2.60-2.62), and reliance on external sources of authority rather than attempting to understand the fundamental principles. As a consequence, she strictly compartmentalised her learning (2.413-2.414), so that she held only one framework at a time in her mind, and discarded it when the examination was over. She used these approaches effectively, but this resulted in difficulty in externalising the comparisons and contrasts between the two contexts. Interestingly, her ideas about strength and pKa appeared to persist to a greater extent than others in her group.

## Concepts new to pharmacy

### *Interview 2*

At the end of the teaching semester, Emma remembered that the three functional groups she needed to identify were '*phenols, carboxylic acids or amines*' (2.430), and further indicated that of the three, amines caused her the greatest confusion (2.432). She displayed an imprecise understanding of the structural characteristics of amines: '*an amine um, is attached to different things*' (2.478-2.480), but could not explain the nature of the '*different things*'. She did recognise that $sp^3$ hybridised carbons were involved in the definition of an amine (2.454), but struggled to describe what she would look for in order to identify that the nitrogen was indeed attached to an $sp^3$ hybridised carbon. She knew that single bonds were important (2.459-2.460), and that '*if it has a double bond, then it's not an $sp^3$ carbon*' (2.488), but was not sure which bonds needed to be single in order to make the functional group an amine. With prompting, she could work through the fragments of her knowledge to come to an

appropriate conclusion, but it was clear that she had not completely appropriated the concepts [2.483-2.498][2].

On further probing, Emma admitted that she had developed an idiosyncratic approach to the identification of amines because of her lack of study time [2.524]. Her strategies included:

- always classifying $NH_2$ groups as amines [2.522]
- identifying amides and other non-basic nitrogens by sight [2.560]
- using an educated guess rather than drawing out the full structure to find $sp^3$ hybridised carbons, because she lacked confidence in her ability to draw the structures correctly [2.456, 2.464]

As a consequence of these approaches, she did not always identify the amines and amides correctly, however her success rate was clearly acceptable to Emma, and was sufficient for her to identify all of the structures in the examination correctly. In the interview, she only made one error with regard to amines, in that she misclassified one of the two nitrogens on lignocaine [2.440-2.448]. She made no errors with either carboxylic acids or phenols, she since had clearly learned their conventions. In particular she had no difficulty with phenols, identifying that the OH group needed to be attached to a benzene ring [2.513-2.516].

Emma could state that the presence of both acidic and basic functional groups in amoxycillin rendered it neither acidic nor basic [2.532-2.534], but did not demonstrate a conceptual understanding for her statement, and indicated that to her this was counter-intuitive [2.536-2.538]. Emma had not been present in class when the explanation had been discussed, and was therefore forced to rely on her individual reasoning, supplemented by what she had read. Her rationale that two acidic groups took priority over a single basic group was superficially logical, but did not take into account the critical characteristics of acids and bases. Since Emma could not recognise the crucial point that acids were unionised and bases ionised at pH values lower than their pKa, she was unable to identify the fundamental criterion for classification of amoxycillin. As a consequence, she was able to state the convention which she had memorised, but she had clearly not appropriated it in a way that was personally meaningful.

The interviewer took considerable time to explain the appropriate rationale to Emma, and she appeared to accept and understand the explanation. However, evidence from her third interview strongly suggested that Emma did not appropriate this explanation, and on the latter occasion she even failed to recall her 'rule'.

Emma was asked to draw the dissociation equilibria for both ibuprofen and amoxycillin. She was confident and accurate in drawing the dissociation of ibuprofen [2.620-2.622], and was able to explain, with a small amount of prompting, why she placed the pKa value on top of the equilibrium arrows

[2] This section of dialogue is an indication that she did not readily recognise that it was the bonds coming from the carbon which needed to be single. Since she used gestures to the written page of examples rather than verbalisations, the interviewer's responses outline what Emma was referring to and pointing at.

and how to use the pKa to select pH values where ibuprofen would be ionised or unionised (2.624-2.648). In relation to amoxycillin, she did not assign the pKa values accurately to the three functional groups, (2.660-2.662), giving the pKa of 7.4 to the phenol and 9.6 to the amine. When the interviewer explained her error, and the appropriate approach to use, Emma did not appear to recognise the information and it seemed that she was encountering it for the first time. Her conceptual framework did not include linking pKa ranges to particular functional groups, and she needed to ask the interviewer to repeat the specific details, suggesting that this was not something that she had considered necessary to memorise (2.669-2.678). Instead, she had devised her own idiosyncratic and only partially successful method of assigning pKas, apparently based on chemistry conventions, with low pKa values assigned to acids and high values to bases without acknowledgement that weak acids could also have high pKas.

Once she had corrected her pKa assignment, she proceeded to draw the equilibria almost correctly, and with minimal assistance. Initially she forgot to add the $H^+$ to the $NH_2$ group on the first structure, but she corrected herself when she reached the second dissociation step (2.698-2.700), and subsequently completed the task with only one minor error. She had no difficulty identifying that the drug was ionised at all pH values (2.650, 2.724), and could explain, albeit with hesitation, why the presence of both positive and negative charges did not make the molecule neutral (2.746-2.748).

In summary, during the process of studying for her examination, Emma had developed a number of strategies for identifying and classifying functional groups, some of which were consistent with pharmacy conventions, and others of which were idiosyncratic. In all cases, she was aware of her reasons for adopting the strategies, namely to give her the greatest opportunity of passing her examinations. She relied heavily on external authority, and was happy to suspend the beliefs and intuitions she had gained in studying chemistry in order to provide the answers which she believed were required in pharmacy. Evidence for some form of conceptual change was present, but it appeared fragile and constructed on rather shaky foundations.

### *Interview 3*

Five months later, Emma continued to struggle with the identification of amines and amides, although she did demonstrate a stronger appreciation of the need to locate single and double bonds as a means of discrimination. She continued to search for $sp^3$ carbons in order to identify amines (3.254, 3.264-3.266), and recognised that double bonds prevented the nitrogen from being an amine (3.266), but was unable to integrate her ideas sufficiently to be able to locate and identify the groups in lignocaine as amine and amide (3.263-3.272). She had demonstrated a similar difficulty with lignocaine in the second interview, but with assistance had been able to solve the problem. In the third interview, she was unable to repeat that solution. She was, however, still able to identify amide groups in amoxycillin and ticarcillin (3.284, 3.308-3.314).

One interesting change was apparent, however, in that Emma seemed to have modified her approach to the $NH_2$ group. In the second interview she stated that she always classified these groups as amines without really thinking about why they usually were, but in the third interview she commented about this group as it appeared in codeine as '*an amine coz it's attached to a C, s, (pause), is it $sp^3$ hybridised?*' (3.254). Although clearly hesitant and phrasing her answer as a question, Emma appeared to have made a connection which had not been evident at the earlier interview. The significance of this development is unclear and no follow-up was done.

Emma continued to demonstrate no difficulty in identifying carboxylic acid and phenol groups, and it was clear that she had retained an appropriate conceptual understanding of the rationale for their identification. However when confronted with a molecule containing both acidic and basic groups, she incorrectly classified it on the basis of the relative number of acidic and basic groups (3.288-3.292). This classification clearly reflected her intuitive rationale, since she had previously indicated that the only reason she had classified the molecule as neither acid nor base was because it was in her notes as a rule (2.536-2.538). Having now forgotten the rule, she reverted to her intuitive expectation, and despite a recapitulation of the explanation, Emma displayed no recognition of the conventional rationale for classifying such molecules (3.293-3.301). This was not altogether surprising since the situation in which the original explanation had been given was not conducive to internalisation of the conversation, and Emma had no subsequent opportunity to use the explanation either in conversation or in problem-solving.

When asked to repeat the task of drawing dissociation equilibria, Emma's memory of the error she made in the second interview was very clear, and she volunteered the incident as the only example of identifiable conflict in her thinking about the differences between chemistry and pharmacy (3.212-3.222). Her memory of the error was so clear that she was determined to avoid repeating the mistake, which she did (3.358-3.362), however she admitted that she still found the concept counter-intuitive (3.366-3.370) and only responded as she did through reverse logic. Emma's conceptual framework was still firmly grounded in the notion that acids had lower pKa values than bases, and although she had trained herself to remember the 'rule' that this concept did not apply in the context of pharmacy, she had not developed a personal understanding of the reason for this discrepancy (3.365-3.400). Her final comment in this dialogue that '*in the scheme of things, a weak acid should be below a strong base*' indicated that conceptual change had not occurred.

Nonetheless, Emma was able to draw dissociation equilibria with little assistance, and was successful in completing this task for both ibuprofen and amoxycillin (3.404-3.412). Interestingly she made the same error with respect to the protonation of the amine group of amoxycillin as she had in the second interview, and corrected herself at the identical place in her problem solution. She retained the ability to identify pH values where molecules would be ionised and unionised (3.341-3.354).

In summary, Emma had learned a range of new concepts about the nature of acidic and basic functional groups and their ionisation behaviour, and where these new ideas did not conflict with her previous understanding of chemistry, she was generally reasonably confident and accurate in solving simple problems. However, she remained unaware of the rationale for distinguishing the meaning of concepts between the domains of chemistry and pharmacy, and struggled to recognise why she made errors in pharmacy when using concepts which had always served her well in chemistry. As a strategy for dealing with these difficulties and because of her reduced learning and study opportunities, she devised rules which on the surface appeared to suffice for the purposes of examinations, but she did not remember most of the rules beyond the end of the teaching semester as they were frequently counter-intuitive.

## Persistent change group

### Denise

#### *Initial conceptual framework*

Denise's initial response was that an '*acid is a proton donor*' (1.2) and a '*base is a proton acceptor*' (1.4). She characterised acids as possessing low pH (1.30), and bases '*pH higher than 7*' (1.32). Both acids and bases were regarded as corrosive (1.38, 1.44), but Denise only associated taste with acids (1.164-1.166).

No other characteristics or properties of acids or bases were identified by Denise in her interview but evidence from her survey responses suggested a more comprehensive conceptual framework. She identified two theories, namely the Arrhenius and the Bronsted-Lowry, and although she indicated that she had forgotten the Arrhenius definition, she was able to state the Bronsted-Lowry definition concisely and accurately: '*Bronsted-Lowry says bases are proton acceptors as opposed to acids which are proton donors*'.

Denise was quite hesitant about pH, although she was able to indicate that it '*measures the acidity and basicity*' (1.110) and that the value was important (1.112-1.114). She knew that there was a mathematical relationship between pH and hydrogen ion concentration, but could not recall the details in her interview (1.118), although she wrote the equation on her survey form. Given the break in her study of chemistry, it is not surprising that Denise struggled to recall the very specific relationship, however she indicated a general appreciation of the origin of the pH parameter and was aware that low pH indicated a high concentration of hydrogen ions (1.125-1.128).

Denise's initial mention of strength was in the context of the corrosiveness of acids (1.44), however she was able to expand on this concept and explain her understanding of the chemistry perspective (1.54-1.58). Although she did not specifically link strong acids with complete dissociation, evidence from her second interview suggests the possibility of this understanding.

# *Denise's trajectory*

## Changes to existing understanding

### *Interview 2*

Denise continued to define acids as proton donors and bases as proton acceptors (2.404, 2.420-2.422), but she now also attributed specific salt formation (2.404, 2.422), the presence of specific functional groups (2.430-2.432, 2.436), and pKa (2.438-2.442) as identifying characteristics. Strong and weak acids and bases were associated with characteristic pKa values (2.469-2.472), however Denise also recognised that pKa alone was not a sufficient criterion for identifying an acid or a base (2.438-2.442). pH was no longer regarded as a characteristic of acids and bases (2.462-2.464), but rather as an influence on the behaviour in solution of acidic and basic drugs (2.450-2.460).

Denise did not refer specifically to the differences in her understanding of the concepts of acids and bases in the contexts of chemistry and pharmacy, however she made it clear that she did discriminate between the two sets of meanings through her comment that she had '*separated them from the chemistry terms*' (2.346).

Although her initial interview had not clarified whether Denise regarded strong acids in chemistry as those which dissociated completely, her second interview tended to support this conclusion as she commented that in pharmacy, '*the strength of acids and bases isn't just whether they dissociate or not, like completely*' (2.370), and in relation to chemistry '*when they're talking about the strengths don't they say like if (pause) it's strong then it completely ionises* (2.1074). However Denise now displayed an understanding of strength which corresponded with pharmacy conventions (2.376-2.378), and was comfortable with the concept of strength in relation to both acids and bases (2.378-2.382, 2.384-2.390). She had no difficulty with the concept that weak acids had high pKa values (2.469-2.472), and she indicated that she had clearly separated the notions of acid strength and pH (2.462-2.464). Her concise explanations suggested a confidence in her understanding, and the coherence of her externalisations suggested that she had appropriated the concepts effectively and usefully. She described her change in understanding as '*at the beginning it was like more simplistic, now it's a bit more, like I, have a better understanding like, of the actual meaning of strength*' (2.394-2.396).

### *Interview 3*

Five months later, Denise again described acids as '*proton donator*' (3.188) and bases as proton acceptor (3.194), but she continued to attribute pH values to both in that acids were perceived as having pHs '*below 7*' (3.190) and bases '*above 7*' (3.194) without appearing to discriminate between chemistry and pharmacy. Denise indicated that she thought differently about acids and bases in chemistry and pharmacy, but found it difficult to articulate the specific differences: '*I think of them differently but I don't really know how to explain it*' (3.216). Nevertheless, in support of her perceived

distinction between the contexts, she associated pharmacy acids and bases with pKa values (3.302-3.306, 3.417-3.424), and discriminated between acids and acidic molecules (3.234-3.238). She was able to apply her changed understanding about the role of pH in solving problems more effectively, in that she was readily able to select the appropriate form of a drug at specific pH values.

Strength continued to be perceived in terms of dissociation and the magnitude of the pKa value. Denise indicated that both acids and bases could be strong or weak, but her definition (3.206) suggested that she retained her chemistry conceptual framework in relation to dissociation. However she was also aware of the relationship between pKa, dissociation and strength as she indicated that '*Ka is the acid dissociation constant um, which is like the products over the reactants and then pKa is the minus, minus log of the Ka*' (3.240-3.244), that pKa denoted '*the extent of dissociation*' (3.246) and that pKa values denoted relative strength (3.306, 3.419). Bases were also perceived in terms of pKa (3.424). It appeared therefore that while aspects of her chemistry conceptual framework persisted, Denise was able to recognise that it was not the only possibility. From the interview, it was difficult to ascertain the extent to which she discriminated between contexts, however strong elements of pharmacy conventions were clearly apparent. It was also unclear whether she recognised that some discrepancy existed between her concepts of 'strong=complete dissociation' and 'strong=low pKa' for acids.

In summary, at the end of the teaching semester, Denise demonstrated evidence of conceptual change in relation to the nature and strength of acids and bases, in that she had appropriated the pharmacy conventions and displayed some contextual discrimination between chemistry and pharmacy. Much of this change persisted until the end of the study, although the context-based distinctions became less clear and she appeared to have blended concepts from both when considering pH, strength and dissociation.

## Concepts new to pharmacy

### *Interview 2*

Denise chose to identify the functional groups in all of the molecules made available to her in the interview, including those listed in Table 6.1 as well as dopamine, cefoxitin, ephedrine, oxazepam and amitryptyline (2.488-2.660). She believed that this would be good practice for her examination the following day (2.627), but it also appeared that she found the activity enjoyable and satisfying. She was confident in her identification of all of the functional groups and clearly articulated the criteria she used to make the identification. Amines were identified on the basis of the hybridisation of the adjacent carbons (2.488-2.490), and were clearly distinguished from amides (2.504). She was able to distinguish $sp^3$ and $sp^2$ carbons from each other without difficulty (2.516), and correctly indicated that the presence of an $sp^2$ carbon next to a nitrogen prevented the nitrogen from being an amine (2.592-2.594). Denise recognised that for an hydroxyl group to be a phenol it needed to be directly attached to a benzene ring (2.492, 2.649-2.650), and she found no difficulty in locating carboxylic acid groups.

Denise was confident in identifying carboxylic acid groups as strong acids (2.692-2.694) and phenols as weak acids (2.697-2.698).

Denise was able to recognise that the presence of acidic groups rendered a molecule acidic, and the presence of basic groups rendered a molecule basic but she was initially uncertain about the status of drugs which contained both acidic and basic groups and need to resort to guesswork in relation to amoxycillin (2.536-2.546). The interviewer explained that the presence of both acidic and basic groups meant that the molecule was neither acidic nor basic, and gave the rationale for that classification (2.547-2.561). Denise appeared to be satisfied with the explanation and used it subsequently when discussing dopamine (2.630-2.632). However, evidence from her third interview indicated that she did not incorporate this explanation into her conceptual framework.

Denise's confidence in identifying the groups on the assigned molecules was so high that the interviewer asked her if she had in fact memorised the structures themselves. Denise was adamant that she had not done so (2.581-2.584), but she admitted that she had learned to recognise different ways of representing an amide group: '*I remember that has caught me out a few times so I guess I've just learnt from that*' (2.670-2.672).

Since Denise was very confident about molecular structures, she was initially asked to draw the dissociation equilibria for amoxycillin, which she completed with confidence and ease. She drew the appropriate initial structure (2.708-2.712), and completed the task accurately with minimal articulation of her thinking. However she became confused about what she should do with the pKa values, and attempted to write expressions for the corresponding Ka terms. The interviewer tried to divert her, but ultimately needed to ask a direct question to guide her thinking into more productive directions: '*do you remember putting pKas on top of the arrows?*' (2.757). Once questioned, Denise remembered that placing the pKas on top of the arrows allowed her to identify which form predominated at a particular pH, but she continued to struggle with the problem involving multiple pKas. To assist her, the interviewer asked her to complete the equivalent task with ibuprofen, which had only one pKa, and with which she was more comfortable. For this exemplar she readily drew the equilibrium (2.845-2.850), identified the form which predominated at particular pHs, and was able to state pH values where the drug would be either completely ionised or completely unionised (2.851-2.863).

However she still did not appear to appreciate fully the significance of the visual representation, and tended to rely on the numerical relationships of the Henderson-Hasselbach equation. The fact that the Henderson-Hasselbach equation was not used in the context of multiple equilibria appeared to be the source of some confusion and resulted in her inability to recognise that increasing pH resulted in increasing loss of protons from amoxycillin. Instead she focused only on the loss of the proton from the carboxylic acid group, and suggested that the zwitterion form was present even when the pH was raised to 14. Finally she recognised that her reasoning was inconsistent with her understanding that amoxycillin was not an acid (2.799-2.830).

It was only when the interviewer explicitly indicated that the subsequent pKas were also significant that Denise began to query her conceptual framework. Her question: '*You mean it will go to that?*' (2.814) was a critical point in her development, allowing her to progress beyond her previous understanding of a dualism comprising only acid and base forms to a multi-form conceptual framework where structures differed because of the number of protons. Her third interview responses suggested that she had in fact made this progression, and that the incident in her second interview had provided the critical input for internalisation that was missing from her existing conceptual framework.

### *Interview 3*

Five months later, Denise struggled a little with identifying functional groups, and identified most, rather than all. She still found carboxylic acids the simplest to identify (3.282-3.284, 3.308-3.310, 3.328), and was confident about phenol groups (3.290-3.292), but her concept of amines now only included $NH_2$ groups. She quickly recognised that this group on amoxycillin was basic (3.292-3.294), but did not recognise that both codeine and lignocaine also contained amines, primarily because the relevant groups were tertiary nitrogens and thus had no hydrogens already attached to them (3.272, 3.278-3.280). In contrast, she was confident and accurate in identifying amide groups (3.274, 3.286-3.288, 3.312, 3.320), and also in identifying nitrogens which were neither amines nor amides (3.322-3.324). She was less forthcoming than in her second interview with the rationale for her identification of groups, particularly amines, where she did not refer to hybridisation at any stage.

Denise continued to recognise that the presence of acidic groups rendered a molecule acidic (3.316, 3.328-3.330), and the presence of a basic group rendered the molecule basic (3.439-3.440), and she also retained the flawed understanding demonstrated in the second interview of the significance of having both types of group on the same molecule (3.346-3.350).

Although this may in one sense be regarded as a failure of her learning, it nevertheless reinforces the need for practice of the concepts. Since Denise had no opportunities to use what she had been told in the second interview, the processes of transformative internalisation and externalisation were unable to occur effectively or in any meaningful way, and therefore conceptual change was hindered.

Denise remained confident about the relative strengths of carboxylic acids and phenols and about the relative values of pKa (3.298-3.302-3.306).

On this occasion Denise was asked to draw out the dissociation equilibria of both ibuprofen and amoxycillin. She continued to recognise that the process began with all functional groups protonated (3.380), and that the dissociation proceeded by loss of protons sequentially according to increasing pKa (3.382-3.386). However, in common with the other students and for the same reasons, (3.386-3.400), she reversed the assignment of the pKas of the phenol and amine groups in amoxycillin.

Once her error was corrected, she was able to draw the dissociation accurately in accordance with pharmacy conventions. Importantly, she appeared to have learned from her second interview the significance of placing the pKa values above the equilibrium arrows, as she was now able to state with some assurance which species would predominate at specific pH values. The persistence of this ability was not restricted to structures for which she had drawn equilibria in the second interview, but was also apparent in the context of the multiple dissociations of dopamine (3.452-3.456)[3]. Further, she retained the ability to identify from the dissociation equilibrium the pH values at which an acid was either completely ionised or completely unionised (3.339-3.342) and was able to state with more confidence than in her previous interview that amoxycillin was ionised at all pH values (3.405-3.408).

In summary, Denise learned new foundational material in accordance with pharmacy conventions, although some of the applications were appropriated less effectively than others. She remained able to articulate the majority of these concepts in her final interview, suggesting that persistent conceptual change had occurred. In addition, conceptual development appeared to have occurred between the second and third interviews in relation to dissociation equilibria. A number of ideas had been forgotten, however, and there was also evidence of the persistence of inappropriate conceptual understanding, particularly in relation to drugs with multiple functional groups.

## Isabelle

### *Initial conceptual framework*

In her interview, Isabelle identified an acid as a '*proton donor*' (1.2), '*sour*' (1.8), able to '*turn litmus, blue litmus, red*' (1.14), and able to form a salt with bases (1.16). Bases were described as '*proton acceptor*' (1.22) and '*slippery*' (1.24). Isabelle perceived both to be '*powerful*' (1.6, 1.26), which appeared to be associated with their ability to burn the skin (1.33-1.34). Acids were associated with '*H plus*' (1.4) but bases were not immediately associated with specific ions, and pH was a property of both acids and bases (1.131-.136).

Isabelle's survey responses extended her interview responses in that she provided both the Arrhenius and Bronsted-Lowry definitions for acids. The Arrhenius theory was described as '$H^+$ *found in solution*' and Bronsted-Lowry as '*proton donors*', both of which were consistent with chemistry conventions.

Isabelle provided the precise equation relating pH to hydrogen ion concentration and indicated that pH was a measure of '*whether it's an acid or a base*' (1.130), and '*how strong the acid or weak it is*' (1.128). She was confident and comfortable in using the equation to calculate concentrations of both

[3] She had encountered dopamine in the second interview but had only identified the functional groups without drawing the dissociation equilibria.

hydrogen and hydroxide ions at specific pH values (1.146-1.150), recognised the relationship between pH and pOH, and was able to use this relationship accurately in calculations (1.159-1.180).

With respect to strength, Isabelle indicated the two major discriminants between acids were pH (1.90) and dissociation (1.92-1.94), the latter determining both pH (1.96) and strength (1.98), and strength was defined in terms of the extent of dissociation (1.99-1.114). Isabelle tended to conflate the concepts of strength and concentration to some extent in that she identified pH as a measure of strength (1.127-128), in addition to its definition as the concentration of hydrogen ions (1.146).

## *Isabelle's trajectory*

### Changes to existing understanding

#### *Interview 2*

At the end of the teaching semester, Isabelle indicated that she now identified functional groups as the primary characteristic of both acids and bases (2.342-2.348, 2.363-2.369), with proton donation for acids (2.344) and proton acceptance for bases (2.372) also prominent in her conceptual framework.

However, she differentiated between acids and bases in pharmacy and in chemistry in a number of ways, describing it globally as '*one topic with two ideas*' (2.330). The concept of functional groups was unique to pharmacy (2.378), in contrast to chemistry (2.357-2.360). This differentiation represented a quite profound change in conceptualisation, and was true for Isabelle in the context of both acids and bases (2.373-2.374), particularly the latter (2.380-2.382). It appeared that the catalyst for her change in thinking was the recognition of differences between inorganic and organic acids and bases (2.308-2.312), and the move from classifying bases as inorganic species containing hydroxide ions to organic species which gained protons was a critical aspect of her conceptual change learning.

A second major difference between the two contexts was the roles of pKa and pH, particularly in relation to strength. Isabelle recognised that both parameters were relevant to both contexts, but differentially (2.318). pKa was no longer a purely numerical term, '*just for calculation purposes*' (2.430), but was now '*more of an indicator sort of thing*' (2.432) in that the numerical value was associated with strength (2.398, 2.436-2.438). The concept of pKa was new to her at university, and she had found it '*a bit difficult to understand*' (2.404) until she worked through the idea in IPS (2.406). Previously, high school and university chemistry had taught her to focus on pH (2.412-2.416), but she now regarded pKa rather than pH as central (2.318), and the significance of the number 7 was no longer in differentiating between acid and base, but between weak and strong. Interestingly Isabelle did not refer at all to the chemistry definition of strength that she had outlined in her first interview and survey. It is possible that she had dismissed this idea from her framework because it was no longer relevant to her.

Thirdly, Isabelle indicated that she discriminated between chemistry and pharmacy in terms of the potential danger and corrosiveness of acids and bases (2.456-2.462). Pharmacy acids and bases were considered not to be harmful, in contrast to their counterparts in chemistry.

### *Interview 3*

Five months later, Isabelle continued to regard proton donation (3.134) and acceptance (3.152) as central to her definitions of acids and bases, however she also named pKa (3.128, 3.150) as a second key idea, particularly in relation to strength.

Of the three major ways in which she perceived chemistry as different from pharmacy in her second interview, all three persisted to some extent as evidenced by her responses in the third interview. Isabelle did not specify functional groups in her definition of pharmacy acids and bases, but her identification of acidic and basic groups on examples of drug molecules made it clear that she retained this concept. Further, she continued to regard pH as more significant in chemistry and pKa in pharmacy (3.135-3.148). pKa was closely related to the strength and extent of dissociation, although Isabelle's ideas about dissociation included both chemistry (3.162-3.164) and pharmacy conventions (3.130-3.132, 3.150).

Finally, Isabelle continued to regard pharmacy and chemistry as different in purpose, and this continued to have an impact on her perceptions of the dangers afforded by acids and bases (3.177-3.180).

In summary, Isabelle began the study with a well developed conceptual framework in accordance with the conventions of chemistry. During the teaching semester, she developed appropriate pharmacy conventions, and was able to discriminate clearly and confidently between the two contexts. The strong persistence of both the pharmacy conventions and contextual discrimination beyond the end of the teaching period suggested that Isabelle had appropriated these notions successfully into her conceptual framework, with her externalisations providing evidence for transformative internalisation. The only area in which some contextual confusion was apparent was in regard to the relationship between strength and dissociation where elements of both chemistry and pharmacy conventions appeared to co-exist.

## Concepts new to pharmacy

### *Interview 2*

At the end of the teaching semester, Isabelle identified all of the relevant functional groups – carboxylic acids, phenols, amines and amides – on codeine, lignocaine, amoxycillin, ticarcillin, diazepam, ibuprofen and phenacetin – with confidence, and was able to explain her rationale for identifying phenols (2.506-2.510, 2.562), amines (2.566-2.570), and amides (2.548-2.550). Isabelle was a little

confused about the ring structure of codeine, but once it was explained to her she had no difficulty in identifying the nitrogen as basic (2.516-2.540). She was not confused by the different ways of representing amides in molecules, but indicated that '*I looked for it*' (2.592). Isabelle was slightly confused by the second nitrogen in diazepam, which was a new molecule to her, but she recognised that it was neither an amine nor an amide, and reasoned that it was not an amine because the carbon was $sp^2$ hybridised (2.630-2.652).

Isabelle was confident that the presence of only acidic groups on a molecule rendered it acidic (2.621-2.622, 2.676), and that the presence of only basic groups on a molecule rendered it basic (2.541-2.542, 2.555-2.556). Further, she recognised that the presence of both types of group on the same molecule rendered it neither acidic nor basic (2.596), and was able to articulate her reasoning behind this statement (2.602-2.608).

Isabelle was asked to draw out the dissociation equilibria for both ibuprofen (2.696-2.708) and amoxycillin, and carried out both activities with confidence. She recognised that '*it's supposed to start with all the protons attached*' for both ibuprofen (2.696) and amoxycillin (2.800), and that the dissociations occurred in increasing pKa order (2.808-2.832). She correctly assigned all of the pKas to the relevant groups in amoxycillin using appropriate reasoning (2.786-2.798) as used in lectures and workshops, based on the readily identifiable pKa ranges for carboxylic acids and phenols, and the wider range of values for amines.

Isabelle was aware of the purpose and utility of drawing the dissociation equilibria in this way (2.712-2.722) and applied her reasoning to questions about both ibuprofen (2.723-2.742) and amoxycillin (2.839-2.848), however she needed significant prompting before she was able to recognise that amoxycillin was ionised at all pH values in aqueous solution (2.853-2.865).

Interestingly, despite her assertion that she could '*see*' the form that acids and bases would be in at different pH values, Isabelle also relied on a memorised table, which she wrote out both in her interview and on her examination paper (2.750-2.758). The table had the abbreviations '*in*' and '*un*' in the four cells, in a diagonal pattern as Isabelle had described. It is difficult to ascertain whether Isabelle chose to memorise this as her primary learning tool or as a form of safety net, since she did appear to understand the process of identifying forms by simply observing the dissociation equilibria: '*it was a thing when you showed us like if it's less it's here if it's more it's here*' (2.728). Her third interview responses provided some support for the latter.

### *Interview 3*

Five months later, Isabelle carried out the identification of functional groups and the consequent classification of drug molecules in an almost identical manner to that demonstrated in her second interview, with all relevant functional groups located and classified correctly on codeine, lignocaine, amoxycillin, ticarcillin, diazepam and ibuprofen. She was again confident in

differentiating between phenols and non-phenolic OH groups on the basis of attachment or non-attachment to a benzene ring (3.200-3.202), and she continued to recognise the difference between basic nitrogens in amines and the structural features which created an amide: in the latter case the nitrogen '*can't be attached to a carbon that's attached to an oxygen*' (3.214). She did not specifically refer to hybridisation as part of her conceptual framework for identifying amines, however she was not asked about this during the interview as she was experiencing no difficulties in identifying the appropriate groups. She continued to recognise that the presence of only acidic groups conferred acidic nature upon a molecule, and a similar situation occurred for a molecule containing only basic groups. Further, she correctly stated that amoxycillin, which contained both acidic and basic functional groups, was neither acidic nor basic (3.252-3.254).

Isabelle was specifically asked about the relative strength of particular functional groups, and indicated that carboxylic acid groups were strong (3.242-3.244) while phenol groups were weak acids (3.220-3.224).

Isabelle again drew the dissociation equilibria accurately for both ibuprofen and amoxycillin, apart from mis-assigning two pKa values for the latter. In common with all other students, Isabelle assigned the phenol group a lower pKa than the amine group (3.342-3.354); it is likely that her reasoning was similar to that of the other students, however she was not specifically asked to explain her rationale. Once the pKa assignment was corrected she was able to complete the dissociation equilibria according to pharmacy conventions and in an almost identical manner to that demonstrated in the second interview.

Isabelle indicated again that the advantage of drawing up the equilibria in the way that she had was that it allowed her to identify the form at any pH value (3.310-3.314). Interestingly she did not refer to the table she had used in the second interview and the exam. This supported the suggestion that the table was more of a safety net for Isabelle, rather than her primary means of identifying the state of ionisation, and Isabelle's confident externalisations strongly suggested that she had effectively internalised the pharmacy conventions and approaches to solving this type of problem.

She was able without prompting to indicate that amoxycillin was ionised at all pH values (3.368), which suggested that she had remembered this aspect from the previous interview. It was not possible to determine whether she had simply memorised the fact or was able to state it because she had internalised the explanation given to her on the earlier occasion, but it would be reasonable to infer that the latter possibility was the case.

In summary, Isabelle maintained a high level of proficiency in identifying acidic and basic functional groups through the teaching semester and for five months afterwards. She based her identification and classification on relevant pharmacy conventions and she was confident and concise in articulating her understanding in relation to these aspects of the topic. She also retained the ability to assign pKa values to functional groups (with one exception), to draw the dissociation

equilibria, and to use these equilibria to solve relevant problems. The evidence from her interviews, including her utterances and the diagrammatic representations she used, strongly supported the contention that she had effectively appropriated the pharmacy conventions, and the persistence of these conventions indicated the presence of conceptual change.

# Kellie

## *Initial conceptual framework*

Kellie's conceptual framework for acids and bases at the beginning of the study was quite rudimentary. Her initial response was that an acid was '*sour*' (1.2), and she added the concept of proton donor (1.12), but she tended to provide examples of acids more than their characteristics (1.4-1.10). Bases were identified as '*bitter*' (1.18), '*soapy*' (1.20) and proton acceptors (1.22), but Kellie did not spontaneously give examples of bases. When pressed further, she mentioned acid reactions (1.24-1.30), but she did not articulate any definitions although her framework appeared based on Bronsted-Lowry. Interestingly she did not mention acids and bases as having specific pH values.

Kellie defined pH as the '*power of hydrogen*' (1.96), and indicated that it was a scale of acidity and basicity (1.98-1.104). Kellie's understanding of pH appeared to be superficial, however, as she did not indicate the mathematical relationship between hydrogen ion concentration and pH, and struggled with the implications of the concept of pH. When asked to describe the composition of a solution of pH 2, she indicated, after prompting, that '*a pH of 2 means that it's acidic*' (1.110), and that '*it'd have hydrogen ions, probably, so it could donate to a base*' (1.108), however she could not identify any other ions which might be present in the solution, and was uncertain if there would be hydroxide ions present at that pH (1.113-1.116). Similarly at a pH of 12, she was unable to identify any constituents of the solution (1.117-120). Although she was aware that a solution of pH 7 was neutral (1.102), she did not believe that there were any hydrogen or hydroxide ions present in a solution of that pH; rather it was just '*pure water*' (1.128). It therefore appeared that Kellie did not perceive a significant relationship between hydrogen and hydroxide ions, or between hydroxide ions and pH. It is likely that this reflected a fragmented understanding of the concept, which would be in accord with a lack of appreciation of the underlying mathematical relationships.

Kellie identified strength in her first interview as a characteristic that differentiated between acids, and described strength as '*how much it dissociates into ions*' (1.65). Strong acids dissociated completely (1.68), whereas a weak acid '*only partially dissociates*' (1.70). She agreed that there were strong and weak bases as well as acids (1.79-1.82), and in her survey indicated that strong bases dissociated completely and weak bases dissociated only partially.

In summary, Kellie's initial conceptual framework appeared based on Bronsted-Lowry, but it was incomplete. Her understanding of pH was particularly weak, and pH, strength and dissociation were only tenuously linked.

# *Kellie's trajectory*

## Changes to existing understanding

### *Interview 2*

By the end of the teaching semester, Kellie's definition of both acids and bases was considerably more comprehensive than in her previous interview and closely reflected pharmacy conventions. An acid was '*something that donates a proton to become a charged species*' (2.354-2.356) and '*a base accepts protons to become a charged species*' (2.366). Kellie associated ionisation at different pH values as characteristic of acids and bases although she was initially confused about the relationship and needed prompting from the interviewer (2.358-2.364). Once corrected about the relationship for an acid, Kellie easily recalled the equivalent relationship for a base (2.368). Kellie did not associate acids and bases with specific pH values (2.383-2.384), but she had not actually articulated this connection in relation to chemistry acids and bases in her first interview. By this point in the semester, however, she was able to articulate considerably more confidently her conceptual understanding about pH (2.386-2.388) and regarded pKa as characteristic of acids and bases (2.391-2.394). When specifically asked, Kellie indicated that she associated corrosiveness with acids and bases in chemistry, but not in pharmacy (2.799-2.808).

Kellie associated strength and pKa in that a high pKa denoted a weak acid (2.401-2.402), and a weak acid '*doesn't easily donate a proton*' (2.407), however she was not particularly confident about the concept. Initially she indicated that a high pKa '*means it's more ionisable I think*' (2.398), and significant prompting was required before she could make the correct link. This concept was not followed up to any great extent in this interview.

Towards the end of the interview, the topic of strength was again raised in the context of perceived differences between chemistry and pharmacy. Kellie indicated that she did not regard strength differently in the two contexts, although surprisingly she recalled that there were acids which would be differentially categorised in the two disciplines (2.780), even if she was unable to bring to mind specific examples.73-2.792).

This interchange again revealed the fragmented nature of Kellie's conceptual framework. She was able to recall isolated pieces of information, but struggled to link them meaningfully in a coherent fashion. To some extent, her definition of a weak acid was relevant to both contexts, and the fact that she no longer recalled the chemistry convention possibly reduced the likelihood of confusion, however the intention was that students develop contextual discrimination, whereby they recognised the conventions appropriate to different contexts. Kellie demonstrated little evidence of the development of this capacity.

### *Interview 3*

Five months later, Kellie's definitions reflected primarily the pharmacy conventions, with brief reference to those of chemistry. Acids were proton donors (3.108-2.110) and '*sour*' (3.114)[4], and possessed pKa values rather than pH values (3.133-3.138, 3.187-3.190). Kellie did not perceive many differences between acids and bases in chemistry and pharmacy, '*except for the strength, I think that's different*' (3.198), and she did not differentiate between acids and acidic drugs (3.207-3.208).

Kellie continued to link pKa and strength as she had in the second interview, although she was initially confused about the numerical relationship (3.148), and required specific correction by the interviewer before she was able to articulate the appropriate convention (3.160-3.162). Kellie was aware that bases also had pKas, and was able to indicate the appropriate numerical relationships (3.172-3.174). Her ability to articulate this relationship without hesitation, albeit after being reminded of the corresponding relationship for acids, suggested that she had understood the reciprocal relationships between acids and bases in terms of strength. Further, Kellie was able to explain the meaning of strength in the pharmacy context, both for acids (3.178-3.182), and for bases (3.184-3.186).

Kellie's understanding of the differences between the chemistry and pharmacy concepts of strength had actually increased by the time of her third interview. She was now confident that the difference related to the extent of dissociation (3.198-3.202), suggesting that she had been able to link several fragments of her conceptual framework together, possibly as a result of the modeling provided by the interviewer in the second interview.

In summary, Kellie commenced the study with only a rudimentary framework for acids and bases, and she tended to provide only brief explanations for the phenomena she was asked to discuss. During the teaching semester she demonstrated conceptual development in relation to characteristics of acids and bases, and her utterances became longer and more complex as she described the aspects which she had learned. The key pharmacy conventions persisted beyond the teaching period, and she continued to focus on pKa and proton donation as characteristics of acids.

She exhibited little contextual discrimination both during and after the teaching period, apart from a recognition that only chemistry acids were corrosive, and needed prompting to elicit her thoughts, but it is probable that her relatively sparse initial chemistry understanding provided little contrast to the newly developed pharmacy concepts.

In relation to strength, Kellie began the study with a simple understanding of the chemistry conventions for strength, and learned the pharmacy conventions relating strength and dissociation to pKa, but her pharmacy conceptual framework was somewhat tenuous even at the time of her second interview. She also demonstrated poor contextual discrimination at this time and was unable to articulate the differences without assistance, primarily because she could not recall the chemistry

[4] The physical characteristic of sour was never specifically denied as a characteristic of acids in pharmacy.

definitions. However she retained the pharmacy notion of strength until the end of the study, and somewhat surprisingly was able to articulate the differences between the contexts in her final interview.

## Concepts new to pharmacy

### *Interview 2*

Apart from carboxylic acids, Kellie was somewhat tentative about her identification of acidic and basic groups. She confidently located all of the carboxylic acid groups in amoxycillin (2.548), ticarcillin (2.596-2.602) and ibuprofen (2.630), and agreed that this group was particularly easy to find (2.632). On the other hand, she struggled initially with both phenols and amines. She suggested that the OH group on codeine was a phenol (2.422-2.426), and substantial prompting and hinting was necessary before she was able to recognise that the ring to which it was attached was not a benzene ring (2.484-2.487). She subsequently identified the OH group on amoxycillin as a phenol (2.530-2.532). It appears likely that Kellie's difficulty was more with the recognition of the structure of benzene than with her ability to identify phenols as OH groups attached to benzene rings, suggesting that her background in organic chemistry was also weak or fragmented.

Similarly, she initially suggested that the nitrogen in codeine was part of an amide group (2.430-2.432). Further probing established that Kellie was aware of the conditions for a nitrogen to be an amine (2.444-2.453), however she had struggled to visualise the ring structure of the codeine molecule. She had decided that the ring containing the nitrogen was not aliphatic (2.432) because of its unusual shape (2.433), and the interviewer needed to explain carefully how the three dimensional molecular structure was represented in two dimensions on the paper (2.459-2.467). Only when Kellie was convinced that the nitrogen was attached to three $sp^3$ hybridised carbons was she able to recognise its basic amine nature. Subsequently, she had no difficulty identifying amines for the remaining structures (2.520-2.526, 2.534-2.540). Again, Kellie's initial difficulty appeared to be related to a weakness in the recognition of the structures of organic molecules from chemistry rather than a lack of understanding of the structural requirements of amines as learned in pharmacy.

Kellie was able to identify all of the amides on the basis of their proximity to a carbonyl group (2.544, 2.546, 2.598, 2.604, 2.608), but she tended to conflate the concept of an amide with any nitrogen which was not an amine. In relation to codeine, she suggested that an amide resulted from the bonding of a nitrogen to a non-aliphatic ring (2.430-2.432), and in relation to diazepam she made a similar assertion that (2.618). As indicated above she was aware that $sp^3$ hybridised carbons were necessary for amines, but she tended to regard all non-$sp^3$ hybridised carbons as resulting in amides. The interviewer corrected her on every occasion of error, but she had virtually no opportunity to practice verbalising this new understanding, and therefore the possibilities for transformative internalisation and externalisation were very limited. Evidence from her third interview suggested that little or no appropriation of this concept occurred.

Kellie was confident in designating as acids those molecules containing only acidic groups, and as bases those containing only basic groups. She was also very confident in stating that molecules containing both types of groups were neither acidic nor basic (2.476-2.478, 2.566-2.575) and her reasoning was sound: although her articulation was imprecise, she recognised that the ability both to donate and accept a proton rendered a molecule neither purely acidic nor purely basic (2.578). To reinforce her understanding, the interviewer explained further reasons for this classification, but again Kellie had no opportunity to articulate them herself during the remainder of the interview (2.585-2.589).

As Kellie was struggling somewhat, she was asked initially to draw the dissociation equilibrium for ibuprofen, before moving to the more complex amoxycillin. She completed the exercise for ibuprofen quickly and correctly, with the pKa written above the equilibrium arrows and the deprotonated form on the right hand side (2.639-2.646). She was able to explain the benefit of drawing the equilibrium in this way (2.648-2.654), and indicated pH values where the drug was essentially completely unionised (2.659-2.664), and essentially completely ionised (2.665-2.666).

When she attempted the multiple dissociation equilibria of amoxycillin, she recognised that '*you have to start with all the protons attached*' (2.686), and remove the protons in order of pKa values starting with the lowest (2.710-2.716). She correctly removed the first proton from the carboxylic acid group (2.720), but despite the fact that the pKa was labelled as that of the base, she attempted to remove the phenolic hydrogen at the pKa of 7.4 (2.726-2.737). When specifically asked, she indicated that she recalled phenols having pKa values in the range of 9 to 11 (2.732), hence this appeared to be another instance where Kellie failed to connect relevant fragments to form a coherent concept, and thus was unable to solve a problem without assistance. After correcting her pKa allocations, Kellie was able to draw the dissociation equilibria accurately.

Previously in the interview, Kellie had indicated that she had memorised the fact that amoxycillin was ionised at all pH values in solution (2.554-2.556), and the interviewer attempted to explore this concept further. It was not obvious that Kellie recognised the basis for this fact, and the interviewer needed to ask her to identify the form of amoxycillin at four specific pHs before Kellie was able to appreciate the basis for what she had memorised: '*I didn't understand why. I just memorised it...yeah I understand now*' (2.768-2.772). Her memory of this fact did not persist until the final interview, nor did her perceived new understanding.

### *Interview 3*

Five months later, Kellie again located and identified with ease all of the carboxylic acid groups on amoxycillin (3.286), ticarcillin (3.316-2.318) and ibuprofen (3.352), but she continued to struggle a little with phenols and amines. As she had in the second interview, she erroneously suggested that the OH group in codeine was a phenol (3.214-3.217), and was initially confused about the conditions for OH groups to be phenols. At one point she suggested that attachment to a benzene ring was necessary for a group to be an amine (3.256-3.260), but after prompting corrected herself (3.266). She subsequently

identified the phenol in amoxycillin with no difficulty (3.298). She continued to recognise that amines comprised a nitrogen attached to carbons which were $sp^3$ hybridised (3.269-3.272), and was able to identify both $sp^2$ and $sp^3$ hybridised carbons (3.276, 3.292, 3.296, 3.342). She located and identified all of the amide groups, which she recognised as consisting of a nitrogen attached to a carbonyl group (3.276-3.280), but she again conflated non-amine nitrogens with amides as she suggested that both nitrogens in diazepam were amides (3.330-3.332). She readily identified phenols as weak acids (3.216) and carboxylic acids as strong acids (3.286-3.288), and continued to recognise that a molecule with only acidic groups was acidic (3.326), a molecule with only basic groups was basic (3.284), and a molecule with both types of group was classified as neither acidic nor basic (3.314).

Kellie continued to experience no difficulty in drawing the dissociation equilibrium for ibuprofen, and she again explained why she placed the pKa value above the equilibrium arrows (3.358-3.360). She also remained confident about the pH values which were necessary for the drug to be completely unionised and ionised (3.361-3.372).

When given the three pKa values for amoxycillin, she correctly assigned the lowest pKa to the carboxylic acid, but in keeping, and with similar reasoning, with the other students assigned the other pKas in reverse (3.376-3.380). By this time Kellie had forgotten the pKa range for phenols (3.388), but when reminded that this range was approximately 9 to 11, she was willing to change the assignment of pKa for the phenol and amine (3.392). In drawing up the dissociation, she remembered that it was necessary to start '*with all the protons attached*' (3.394), and added the hydrogen to the amine group at the beginning (3.396). She further recognised where to start (3.410), however she initially attempted to remove the hydrogen from the amine group rather than the carboxylic acid (3.412) before correcting herself and removing it from the correct group (3.414-3.416). She completed the remaining dissociation equilibria rapidly and accurately (3.420-3.422), however she had forgotten the fact that she had memorised for the examination, namely that amoxycillin was ionised at all pHs in aqueous solution.

In summary, Kellie's understanding and consequent ability to identify acidic and basic functional groups persisted until the third interview with only minor change. Carboxylic acids were always easy to identify, and she was aware in both the second and third interviews that these were considered as strong acids in pharmacy. Kellie was deceived on both occasions by the ring structure in codeine into mistakenly identifying the OH group as a phenol, however she did recognise in both interviews that phenols required the OH group to be directly attached to a benzene ring. Her recognition of amines declined slightly from the second to the third interview as she initially confused their conditions with those of phenols, but she was able subsequently to identify them on the basis of carbon hybridisation. She continued to recognise amides and to classify them as non-basic (3.281-3.282), but she also continued to classify other non-basic nitrogens as amides. She appeared to have constructed a dichotomous conceptual framework, whereby she recognised amines as basic, and attached the convenient label of 'amide' to all non-basic nitrogens. This idiosyncratic framework appeared to persist together with the appropriate pharmacy

conventions she had learned in relation to other functional groups. It is likely that Kellie's difficulties with both phenols and amides stemmed from a weak background in organic chemistry, since her difficulties appeared to be related to aspects which were assumed chemistry knowledge rather than the structural features which were taught during the semester.

Similarly, her ability to draw dissociation equilibria persisted throughout the study for both simple and complex molecules. She recognised the fundamentals and the rationale, and stumbled only in her allocation of pKa values to the functional groups. Kellie differed a little from the others in her group in that in her second interview she failed to link a known pKa range for phenols with the data provided for amoxycillin, however she was in accord with them in her third interview in believing that basic groups always had higher pKas than acids.

# APPENDIX G EXCERPTS FROM INTERVIEW TRANSCRIPTS

## Part A Conceptual change outcomes (chapter 6)

Transient change group: Janine

*Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | They're proton donors **(1.4)** |
| names of theories | The three definitions, OK. The first one is um, the um, the old definition, the Arrhenius I think they used to call it. What did that, what was that one? It was ah, something that can dissociate into $H^+$ ions in water, so that was a pretty narrow definition, and then the, the next definition was the proton donor definition where it's, an acid is something that can donate a proton to another species, and then the Lewis definition was, a, acid was something that can accept a lone pair of electrons. Yep. And then, OK the bases the three definitions was, um, the base, the Arrhenius definition was that the base could dissociate into a hydroxide ions in solution, and then the um, second definition was that a base was a, something that could accept a proton, and then the third definition was the Lewis one and that was a base was something that could donate a lone pair of electrons to another species in a chemical reaction. **(1.8-1.22)** |
| taste and feel | I think it's um, the bases that are sour, they had those, the, the tastes down, and they're, and it could've been the acids that are um, I can't remember now, I think that. No no no the acids must be sour coz lemons are sour and the bases are like soapy to the touch. **(1.26-1.28)** |
| corrosiveness | I think acids and bases are both corrosive **(1.30)** |
| other characteristics | acids are, I think, yep, they turn litmus red whereas bases turn litmus blue **(1.2)** |
| Chemistry acids characterised primarily by pH | something with a high pH is basic, which is above 7. Something with a low pH is acidic, that's below 7 **(1.89-1.91)** |
| strength described on the basis of complete and partial dissociation | dilute versus concentrated is just um, sort of how many moles in solution it has, so the more moles in solution, the more concentrated. But strong versus weak is its ability to dissociate completely into ions' **(1.75-1.77)**<br>a strong acid can dissociate completely into $H_3O^+$ ions but um, a weak acid can only dissociate partially, and the less it can dissociate the more weak it is **(1.77-1.79)** |
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | pH is a measure of the hydrogen ion concentration of the solution…and it's the negative logarithm of the hydrogen ion concentration **(1.89-1.91)** |
| use of mathematical relationship to solve numerical problems | *Carried out correctly on all occasions* |

Transient change – Janine

## *Changes to existing understanding*

### Interview 2

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | Oh, OK. In chemistry um, an acid is like a proton donor, that's the definition, and in pharmacy an acid is a proton donor **(2.366-2.368)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | the characteristics were that acid donates um, a proton to form a charged anion, it's ionised at higher pHs, it's more soluble at higher pHs, it forms salts with cations and um, it can be titrated with OH minus, and it, it is not corrosive and it does not turn litmus red **(2.376-2.380)**<br>I don't know, I guess I think it's all true for chemistry except maybe the salt thing, I didn't, yeah I don't know if that applies so much, we never really thought about it that much, coz you do, you don't do, you do inorganic acids and bases more than organic **(2.382)** |
| differences between tightness of definitions | I guess chemistry is a little more um, broad in that you can say things are characteristics of acids and bases, that may not be really characteristic, like it's a characteristics of a solution of a particular pH but you just go yeah, that's all right, like that'll do. The definitions aren't as set in stone like, well we, you could say, um, actually we did say in the HSC, you'd say like acid oh, yeah, turns litmus red, no probs **(2.382-2.384)** |
| pharmacy acids characterised by pKa rather than pH (secondary concept that pH refers to solutions) | *Implied but not specifically stated* |
| strength in pharmacy characterised by values of pKa<br>strength characterised significantly differently in pharmacy and chemistry | In chemistry a strong acid or a strong base, strong base is something that dissociates completely in solution, whereas in pharmacy it's practically no drugs dissociate completely in solution, so you define a strong acid and a strong base based on the size of the pKa value **(3.398-3.400)** |
| acids and bases in pharmacy both have pKa<br>in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | a strong acid has a pK, a low pKa, like usually below 7 and a strong base has a high pKa usually above 7 **(3.400)**<br>A weak acid um, has (pause) I guess it, yeah, it has a um, pKa usually above 7, yeah, like a phenol **(2.402-2.404)** |

Transient change – Janine

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | Interviewer: So how would you define um, an acid, what, what makes something an acid?<br>Janine: Proton donor. **(3.79-3.80)**<br><br>Interviewer: OK, what about um, bases?<br>Janine: Bases are proton acceptors **(3.99-100)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | Um (pause) OK. (pause) You, you can titrate it with an OH, with OH minus. (pause) No, that's about it…Oh, I just remembered one, um, its salts with cations **(3.85-3.90)**<br><br>in chemistry yeah, I just, (pause) no, I don't, yeah, I don't think, I'm kind, kinda trying to remember which is right and which is wrong any more, but no coz I just remember like, with the acidic solutions there was all sorts of characteristics, yeah, and not necessarily of the acid itself. Um (pause) yeah, no, just proton donors, (laughs) I'll stick with that one **(3.90-3.94)**<br><br>Bases are proton acceptors, and um, you can titrate them with $H^+$ and they form salts with, um (pause) now I've forgotten, anions. They form salts with anions, and um, yeah they can exist, I guess they can exist um, in an ionised or an unionised state depending on the pH of the solution that they're put in. Um, they have a characteristic pKa, um, yeah that's about it **(3.100-3.108)** |
| difference between acids and acidic solutions | Yeah, yeah, the acidic solutions had the whole thing with the um, litmus testing and they turn litmus red or, acidic solutions tend to be corrosive but that relates to the pH of the solution, it's not necessarily a characteristic of the acid coz the acid is the compound itself **(3.96-3.98)** |
| pharmacy acids characterised by pKa rather than pH | *Implied but not specifically stated* |
| strength in pharmacy characterised by values of pKa<br>acids and bases in pharmacy both have pKa<br>pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | Janine: Um, a, a low pKa indicates it's acidic which is less than 7, and a pKa which is greater than 7 would indicate that's its basic.<br>Interviewer: OK. So that's a, that's an absolute is it? pKa greater than 7 must be basic?<br>Janine: No, I think it was a strong acid, it was less, pKa less than 7 indicated it was um, a strong acid, pKa greater than 7 was a strong base, but, um (pause) **(3.112-3.116)**<br><br>Janine: Actually no, hold on, I'm just thinking, hold on, coz the phenol was 9 to 11 wasn't it? So that's, and that's an acid, that's like a weak acid. Yeah, so they could all, I think they all varied heaps, I'm just trying to remember what the ranges were now. Yeah so it must have been the low (pause) low pKa. (pause) I can't remember now. (pause) I can't remember, I'll have to write it down probably and think about it.<br>Interviewer: You can write it down if you want to, but, OK, you said that phenol's 9 to 11, so what does that, what are phenols in terms of strong and weak?<br>Janine: Phenols are acids and they're weak, they're weak acids. And then we had like, but then you had like the carboxylic acid, which is like the COOH group and that was um (pause) but they were like 2 to 5 or something I think, yeah. |

Transient change – Janine

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|---|---|
| | Interviewer: So are they strong or weak?<br>Janine: And they were strong acids, yeah, so that was right yeah. Less than 7 was definitely a strong acid. I think. (laughs)<br>Interviewer: OK, so less than 7 is a strong acid and greater than 7 can be a weak acid?<br>Janine: Yeah, can be a weak acid. It's because they're so varied.<br>Interviewer: OK, and can you have a, a pKa of less than 7 for a base?<br>Janine: (pause) Hmm, I, I think so yeah.<br>Interviewer: What would that make it, strong or weak?<br>Janine: That would make it weak, coz greater than 7 makes it strong **(3.118-3.136)** |
| strength characterised significantly differently in pharmacy and chemistry | Interviewer: OK. And what do you mean by strength, I mean what's, what's something that you call strong?<br>Janine: Um, a strong um, acid or a base completely dissociates in solution whereas the weaker ones only partially dissociate, but that's more like chem, from chemistry. Coz in the pharmacy, in the pharmacy um, terms hardly any of the drugs completely dissociate.<br>Interviewer: OK, so if we had carboxylic acid which you said is a strong acid, how would that be different then from a phenol? In terms of, coz you said one's strong but you've also said that it doesn't dissociate completely so how would you differentiate between a carboxylic acid and a phenol, in terms of dissociation?<br>Janine: Yeah. I guess maybe if you had the same concentration of the carboxylic acid, and the same concentration of the phenol, the carboxylic acid, acid would produce a more acidic solution with a higher concentration of $H^+$.<br>Interviewer: OK. So it would dissociate more?<br>Janine: Yeah, exactly **(3.139-3.152)** |



## *Concepts new to pharmacy*

| **Characteristic** | **Transcript excerpt – interview 2** | **Transcript excerpt – interview 3** |
|---|---|---|
| carboxylic acids | *Experienced no difficulty but did not verbalise* | *Experienced no difficulty but did not verbalise* |
| phenols | This one is a phenol group, which is an OH directly attached to a benzene ring, it's an acidic group **(2.438-2.440)** | *Experienced no difficulty but did not verbalise* |
| aliphatic amines | Janine: OK, this one is a base because it's got just um, one amine group and it's an amine group because it's attached only to carbon atoms that are $sp^3$ hybridised.<br>Interviewer: OK, how do you identify an $sp^3$ hybridised carbon?<br>Janine: Single bonds only. They've all got single bonds don't they? OK<br>Interviewer: OK, so you would call that, you would call codeine what?<br>Janine: That's an amine, it's got an amine group sorry, so that is a base **(2.416-2.422)** | Interviewer: OK, so codeine.<br>Janine: Oh this is hard, isn't it?<br>Interviewer: And you if you can talk through what you're looking for.<br>Janine: Hmm. (pause) Yeah I vaguely remember. Um, (pause) that was like, an amine, I think, yeah. That's amine, so it was a base.<br>Interviewer: So, are you remembering this, rather than working it out?<br>Janine: Yes, pretty much. Well, yeah, coz I pretty much just memorised it **(3.157-3.164)** |



Transient change – Janine

| | | |
|---|---|---|
| amides | lignocaine, um (pause) that, that's an amide, so it's non basic because it's attached to C double bond O **(2.426-2.428)**<br><br>This one, yeah? Um, OK this one is attached to a carbonyl group so it's an amide, and this one is also attached to a carbonyl group so, an amide so they're non-basic…But that, that is one way I guess that expanded as well my understanding of acids and bases, because we did just do organic chem so we are just learning about amides and all that stuff, and we didn't really learn that, like we learnt what an amine was and that it was basic, but we didn't really learn that to be an amine it's only attached to a carbon atom, or hydrogen atom but the carbon has to be $sp^3$, like we didn't learn it in that much depth **(2.476-2.482)** | (pause) Oh OK, um, nup, that's an amide (pause) that would be, no, that's not right, coz that's not $sp^3$ or something **(3.198)** |
| multiple functional groups | Janine: (pause) and that's it, this was on our exam, and because you've got acid and basic functional groups in the same molecule it's neither acid or base.<br>Interviewer: OK. Can you expand a bit on your understanding of why, why we say it, that it's neither?<br>Janine: Um, (pause) I don't think I have much of an understanding on that because I remember not even writing it down in the lecture and only finding out at a workshop when Larry reminded me **(2.450-2.452)** | Interviewer: Amoxycillin?<br>Janine: Um (pause)…This one is acidic, coz it's phenol. Um. (long pause) That one's amine, so it's basic. That one's acidic. Um, that's carboxylic, (pause) so that's acidic.<br>Interviewer OK. So what does that make the drug overall?<br>Janine: That's neither acid or base, coz it's got all those groups in it **(3.173-3.186)** |
| dissociation of ibuprofen | *Not required* | Janine: OK, so, you start with all the um, H's attached, and then you just draw in a little equilibrium and take it off, so it's just R CO O minus, and then a little four point four goes up the top like that.<br>Interviewer: OK. Why do we put the four point four on top of the arrows?<br>Janine: Um, well that helps us keep track of which functional group's dissociating as well. Because some of them have more than one pKa relating to more than one functional group **(3.236-3.246)** |

Transient change – Janine

| | | |
|---|---|---|
| dissociation of amoxycillin<br>allocation of pKa values<br>addition of proton to amine<br>correct order of dissociation | Janine: Yeah. (pause) Um, OK, well with the aci, acidic pKas, the lowest one is going to be with a strong acid so that's two point four, and then this one is nine point six and then the base is seven point four so what you do is, you start with all your protons attached so that's already attached, that's already attached, but this has to be converted to $NH_3^+$ so that's the molecule you'll start with, and then you lose hydrogens, in order of increasing pKa values. So the first one, like I'd write, I'd do the little equilibrium signs and the two point four above it, and then do you want me to write it all out, or?<br>Interviewer: You can write R for the<br>Janine: Yeah, OK, so I'll write $RCOO^-$, that would be like the first loss<br>Interviewer: Uhuh. But you still need to have the other functional groups attached.<br>Janine: Oh OK, so what, how would you write that, like with an R?<br>Interviewer: Yes, just with three, three things coming off it.<br>Janine: Oh. Fair enough. OH, and then $NH_3^+$, And then<br>Interviewer: We're not very fussy in pharmacy.<br>Janine: Oh, that's nice, I wouldn't do that in the exam though, I'd be too paranoid. So um, then the second highest is seven point four so the base would lose its proton next, and it would turn to $NH_2$, R, $CO_2^-$, OH, and then the final loss will be above a pKa value of nine point six, when a, when the pH is above nine point six sorry, then the phenol group will lose its um, hydrogen and turn into $O^-$ **(2.566-2.594)** | Janine: They, they start with all the um, H pluses attached, so this one would be $NH_3^+$, ah, this is OH, and that's right. Then, then you, um, they lose $H^+$ in order of increasing pKas so two point four would lose it first. Oh, OK, you have to assign them, don't you? OK (laughs)<br>Interviewer: That's a good start.<br>Janine: That'd be the two point four.<br>Interviewer: Carboxylic acid?<br>Janine: Yeah. Um, (pause) the phenol's nine point six, coz it's between 9 and 11, so that means the amine must have been seven point four. So the two point four goes first, so, that's all right if I just do it with the R?<br>Interviewer: Yep, yeah.<br>Janine: So it's R and then $CO_2^-$ and then the second step would be the loss of (pause) the $H^+$ from the amine group. So it would be (pause) $RNH_2$ and then, like 2 minus, and then the last step would be the loss of the H from the phenol group. So it's going to like, (pause) O minus, and then yeah, $NH_2$, R, yeah so it's gonna have, two negative charges at that, at that point **(3.256-3.280)** |
| prediction of form at specified pH | OK, well when the pH is below two point four it's going to be right down the bottom when they're all protonated, so they're all in the um, acidic form. And then when you get above two point four it's going to go to the next form, above seven point four it'll go to that form and above nine point six it'll go to that form. And if the pH is 2 units say, um below two point four, then it will be completely, like it'll be effectively 100% in that form or say it would be 2 units above that it'll be, it'd have to be 100% in this form **(2.598-2.604)** | Interviewer: at what pH would you say that molecule [ibuprofen] would be completely ionised?<br>Janine: Two units above the pKa or more. So that would be six point four or more.<br>Interviewer: OK, and completely un-ionised?<br>Janine: It would have to be two units below pKa, so we're talking two point four or below **(3.248-3.252)**<br><br>Janine: above pH of four point four it's [amoxycillin] always going to be ionised, completely.<br>Interviewer: What about below four point four?<br>Janine: Below four point four, like between two point four and four point four it's going to be um, a little bit ionised, but not completely, and then |

Transient change – Janine

| | | |
|---|---|---|
| | | um, when it's (pause) in this stage, which is like it's two units below two point four, um, at, at pH of, so that would be at pH of point four or below, it's not going to be ionised. Oh yeah, it is going to be ionised, sorry. I missed that one. So it's ionised at all pHs **(3.282-03.284)** |
| strategies – Janine's preference for relying on memory | now I'm going to have trouble remembering whether this one was basic or not. (pause) In chemistry it's different that's why **(2.514)** | See above – aliphatic amines: **(3.157-3.164)**<br><br>I'm just trying to remember what the ranges were now. Yeah so it must have been the low (pause) low pKa. (pause) I can't remember now. (pause) I can't remember **(3.120)**<br><br>I'm just, can't really remember with, how to add and subtract H from this one **(3.350)**<br><br>To tell you the truth, I just, I didn't even remember how to do partitioning, like I remembered how to do it that way, like theoretically, but I couldn't remember how to go about it, like, writing it out **(3.398)** |

## *Additional issues – interview 2*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| quaternary ammonium salts | Janine: Um, that's ionised at all pHs and it's non-basic and it's um, just got, it's got four atta, it's got four, sorry this is hard to say, four bonds instead of three, like a nitrogen in an amine group would have three things attached to it, the quaternary ammonium salt's got four things to it and it's got a positive charge. I don't know why I'm confused.<br>Interviewer: Uhuh. So its lone pair is actually used up?<br>Janine: Yes, OK.<br>Interviewer: So it can't, it can't attach a proton because it doesn't have a spare lone pair.<br>Janine: Yeah, that would be good, I wouldn't have thought of that as much **(2.546-2.550)** | Janine could state the distinguishing features of each but could not explain the reason for quaternary ammonium salts being non-basic, and this explanation was required to be provided by the interviewer. Janine was happy to accept the explanation, which she had apparently not previously considered. |





Transient change – Janine

## *Additional issues – interview 3*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| identification of ephedrine | So you think that third one's a phenol? You think ephedrine's a phenol.<br>Oh, no, whoops. It's an amine, um **(3.341-3.342)** | Janine initially identified the OH group as a phenol and missed the amine group, but on prompting, recognised her error. |
| ionisation of amine group in ephedrine | Janine: it's got an amine grouping, and I'm just, can't really remember with, how to add and subtract H from this one. This is about the $NH_2$ thing. Um, so,<br>Interviewer: OK, well $NH_2$ becomes $NH_3$, what would NH become?<br>Janine: Yeah, NH would become N then.<br>Interviewer: No, you're adding one.<br>Janine: Oh, $NH_2$ then?<br>Interviewer: Yep.<br>Janine: $NH_2^+$?<br>Interviewer: Yep **(3.350-3.357)** | Janine was familiar with how to create an ionised form of a primary amine ($RNH_2$) because it was familiar from many examples, whereas when the form changed only slightly to a secondary amine ($R_2NH$), she struggled to provide the correct response. |

## Transient change group: Geoffrey

### *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | An acid's a proton donor **(1.2)**<br><br>A base is the opposite, OK, of course. Um, it accepts protons **(1.14)** |
| names of theories | Interviewer: Have you ever heard of any other definitions of acids, other than proton donors?<br>Geoffrey: Yes, but I can't remember them. (laughs) (pause) I do remember, I do remember hearing, um (pause) like, ah, familiar names and stuff, like Bronsted Lowry.<br>Interviewer: Yeah, which one's the Bronsted Lowry, is that?<br>Geoffrey: I, I've forgotten.<br>Interviewer: That's fine. (laughs)<br>Geoffrey: But I do, I do remember hearing um, like more than one definition. But the one, the one, um with proton acceptor and donor seems to be the one that I've remembered …I'm sort of just, like I, (pause) I'm under the impression that like I, if I, all I need to do is remember one, because the other ones really aren't used as much any more.<br>Interviewer: That's right, there was the Arrhenius one, which was the really old one, which said acids um, produced $H^+$ ions and bases produced $OH^-$ ions. And then there's Lewis acids and bases, have you heard about them?<br>Geoffrey: Yeah.<br>Interviewer: Which are about um, oo I don't even remember that, about electrons, rather than protons, so. Yeah but the proton donor one, which is Bronsted Lowry, is, is kind of what everybody uses now, I think.<br>Geoffrey: Yeah, OK. I remember the Arrhenius one, after you'd said that, but I don't remember the, the Lewis one. I do remember hearing it, though<br>**(1.549-1.572)** |
| taste and feel<br>corrosiveness<br>other characteristics | Geoffrey: OK, um, it turns litmus red. Um, it has a sour taste. Um, when I think acid, I usually think corrosive. OK, um, and that's about all.<br>Interviewer: OK. What about a base?<br>Geoffrey: A base is the opposite, OK, of course. Um, it accepts protons, it turns litmus blue, has a bitter taste **(1.4-1.16)** |
| Chemistry acids characterised primarily by pH | pH, I think, just gives an indication of um, whether a substance is basic or acidic and how, how basic or acidic it actually is. So, the lower the pH, means the more acidic, or vice versa **(1.178-1.186)** |

| | |
|---|---|
| strength described on the basis of complete and partial dissociation | Yeah. Well, a strong acid usually fully dissociates. Yeah. So, you've got um, hydrochloric acid, nitric acid, sulphuric acid, they fully dissociate. OK, and um, weak ones, weak acids don't **(1.150-1.154)**<br><br>Geoffrey: So, the more, the more it dissociates, the um, stronger the acid is, and vice versa, and the same with bases as well.<br>Interviewer: OK. How does it work for bases? Coz they're proton acceptors, as you said, so how does that strength thing work?<br>Geoffrey: OK, so, if it was an OH ion, (pause) and well, OK and you place that in water, I suppose, it's the more um (pause) it, it goes, it reacts with water. (pause) Hang on, let me get this right. (laughs) (pause)<br>Interviewer: We're thinking in terms of strength here, so a strong base.<br>Geoffrey: Yeah. (pause) OK, if you, if you had sodium hydroxide, I'll use that example again, and you mix that in water, the stronger the base, would that be more sodium and hydroxide ions you get?<br>Interviewer: You can tell me.<br>Geoffrey: That's what I think it is, yeah **(1.104-1.124)**<br><br>Interviewer: So if you had a weak base, what, what would happen if you put that in water?<br>Geoffrey: It wouldn't, it wouldn't you wouldn't get as many free ions. OK, and um, you'd get a lot of molecules, more molecules than you would ions, yeah **(1.129-1.132)** |
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | that just accounts for the amount of hydrogen ions present in, in solution **(1.162-1.164)**<br><br>pH equals the negative log 10 of the concentration of hydrogen ions **(1.172-1.174)** |
| use of mathematical relationship to solve numerical problems | *Carried out inconsistently* |



## *Changes to existing understanding*

### Interview 2

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | an acidic drug is a drug which will donate a proton and then become ionised whereas a base would be anything that accepts a proton to become ionised **(2.496-2.502)** |
| pharmacy characterised by functional groups | *Not specifically described* |



Transient change – Geoffrey

| | |
|---|---|
| chemistry but not pharmacy characterised by physical characteristics | Interviewer: In terms of what chemistry thinks of as acids, are there other characteristics that, when you're in the chemistry context you would think, that's true of an acid or that's true of a base?<br>Geoffrey: The taste, but then you know I wouldn't be exactly tasting acids and bases, like acids are supposed to be sour and bases are supposed to be bitter. Acids are supposed to be, yeah.<br>Interviewer: Would that be true in a pharmacy context do you think?<br>Geoffrey: (longish pause) Well, I'm not sure actually because when I take drugs, I don't actually suck on the tablets or anything. (Interviewer laughs)<br>Interviewer: No, it's better not to.<br>Geoffrey: Yeah. But um, (pause) I don't know actually **(2.555-2.564)**<br><br>with chemistry it's anything that has like a, anything that's classed as a strong acid if you spill it on your skin then you start worrying, oh no, whereas in pharmacy if you spill a strong acid on your skin I don't think that would be as worrying **(2.568-2.570)** |
| other characteristics | anything which is, forms a salt with a cation OK, is acidic and vice versa, anything that forms a salt with an anion is basic **(2.508-2.512)**<br><br>an acid will um, ionise more at a high pH and a base will ionise more at a lower pH **(2.536-2.538)** |
| pharmacy acids characterised by pKa rather than pH | *Implied but not specifically stated* |
| strength in pharmacy characterised by values of pKa<br>strength characterised significantly differently in pharmacy and chemistry<br>in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | in chemistry um, a, a strong acid might be something which dissociates completely whereas in pharmacy a strong acid is something which has pKa of less than 7 **(2.456-2.458)**<br><br>Geoffrey: A weak acid is something which dissociates partially, you know like.<br>Interviewer: In chemistry?<br>Geoffrey: In chemistry, yeah whereas in pharmacy it's anything with a pKa of greater than 7 **(2.464-2.466)**<br><br>Interviewer: Um, did pKa enter much into chemistry?<br>Geoffrey: (pause) Well in, no not, not as much, nowhere near as much and we tended to use pKb as well, I think **(2.551-2.552)** |
| acids and bases in pharmacy both have pKa | *Not specifically addressed* |

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | What makes something an acid? (pause) Donates a proton **(3.300)**<br><br>Interviewer: what makes something a base?<br>Geoffrey: Oh they accept protons **(3.333-3.334)** |
| pharmacy characterised by functional groups | *Not described* |
| indiscriminate characterisation by physical characteristics | [acid] tastes sour, all that sort of stuff **(3.312)**<br><br>they [bases] have a bitter taste **(3.334)**<br><br>I've always been under the impression you know, acids taste sour, bases taste bitter **(3.370)**<br><br>I associate acids with pHs less than 7, and vice versa. Yeah bases have a pH above 7 **(3.338-3.342)** |
| difference between acids and acidic drugs | Well they, they mean the same thing in the fact that they behave the same way, as in that they donate protons. But, no, they don't mean the same thing to me **(3.362-3.364)**<br><br>Geoffrey: Like when I look at acidic drugs, they're quite weak. Type of stuff, they don't dissociate very much at all, in relation to say, hydrochloric acid or something like that. So that's what the major difference is. The weak, the, the strength of the acid.<br>Interviewer: All right. So acidic drugs you would classify them all as weak acids?<br>Geoffrey: Yeah. They are all weak acids, aren't they?<br>Interviewer: In chemistry terms, they're all weak acids.<br>Geoffrey: Yeah that's what I mean, in chemistry terms **(3.384-3.398)** |
| calculation of pKa | Geoffrey: (pause) pKa relates to the dissociation constant. 10 to the negative Ka, and Ka's the dissociation constant. … (pause) OK, say, Ka for acids, is equal to the H+, A- (pause) … So, 10 to the negative Ka (pause) is pKa, right? So, if, if that was, say, high (pause) if that was<br>Interviewer: Actually no it's the other way round.<br>Geoffrey: What?<br>Interviewer: pKa is log, negative log of<br>Geoffrey: Oh yeah yeah sorry, yeah. Log (longish pause) are you sure?<br>Interviewer: Yep. 100 percent.<br>Geoffrey: (laughs) Yeah, you ought to. Negative log 10 to the Ka?<br>Interviewer: Yeah.<br>Geoffrey: You sure? Oh.<br>Interviewer: For the Ka, yeah **(3.422-3.451)** |

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|---|---|
| acids and bases in pharmacy both have pKa – confounding effect of Kb | Geoffrey: See I've still, I remember we, in um high school we learned Kb as opposed to Ka.<br>Interviewer: Yeah, and I said forget everything you've ever learned about Kb, so.<br>Geoffrey: Whereas Kb would be the same as Ka.<br>Interviewer: That's right, Kb, Kb for a base is the same as Ka for an acid, but Kb requires you to have hydroxide ions in it.<br>Geoffrey: Yeah.<br>Interviewer: And we don't want to have hydroxide ions, we just want to work on hydrogen ions **(3.554-3.559)** |
| pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7<br><br>strength characterised by extent of dissociation | Geoffrey: So, (pause) if, if the pKa was high, then that would suggest that the acid is (pause) is strong. (pause) Is that right?<br>Interviewer: Tell me how you reason that.<br>Geoffrey: Well, (pause) if it's, if that's, (pause) if the acid is strong, then the numerator's going to be higher than the denominator.<br>Interviewer: Yep. So that means Ka will be high.<br>Geoffrey: Ka will be high. (pause) 10 to the Ka. Sorry negative, negative log 10 of that. Oh, actually sorry, that's going to be lower. So, the lower it is, the stronger the acid's going to be **(3.456-3.466)**<br><br>Geoffrey: (pause) OK, so there's going to be a low amount of that, isn't there?<br>Interviewer: OK, so we're talking, tell me if we're, are you working on a strong base or a weak base here?<br>Geoffrey: I'm working on (pause) a weak base, OK? So a weak base would have a low concentration of H+, (pause) no, yeah, it would wouldn't it?<br>Interviewer: What does a weak base mean in terms of its dissociation?<br>Geoffrey: Weak base.<br>Interviewer: In terms of the dissociation equilibria you've written there, for a weak base<br>Geoffrey: A weak base has more of that than that.<br>Interviewer: No.<br>Geoffrey: Is it the other way round?<br>Interviewer: The other way round.<br>Geoffrey: Oh, damn, OK. (laughs) A weak base has more unionised than ionised **(3.560-3.572)** |
| strength characterised differently in pharm/chem | *Not described* |
| Geoffrey's strategies – logical reasoning, guessing, instinct | But I wouldn't have just tried to remember the fact, OK high Ka means such, low Ka equals that. I would have tried to reason, yeah from first principles. Like I find that's the best way to do it, coz it's a lot better, coz then, that way, you can just you know, learn one thing and everything else you can just branch off that, as opposed to learning all the branches, do you see what I mean? **(3.472-3.476)**<br><br>I've always like, made educated guesses **(3.496)**<br><br>Geoffrey: Yeah I'm just trying to you know, try and get around it logically coz I couldn't actually remember. Like, I, I, I would've, if I was to go with instinct, even though I usually don't, I would have gone, as I was discussing before, I would've gone that, the rule would've been different for acids and bases, because bases are the opposite of acids, that's the way I look at them. So I would have said a higher, higher Ka, (pause) pKa value would equal (pause) a stronger base.<br>Interviewer: Yes. It does **(3.538-3.545)** |

Transient change – Geoffrey

*Concepts new to pharmacy*

| Characteristic | Transcript excerpt – interview 2 | Transcript excerpt – interview 3 |
|---|---|---|
| carboxylic acids | Geoffrey: that's also acidic, the COOH. Whenever I see COOH I automatically assume it's acidic.<br>Interviewer: So is that the easiest one to work out?<br>Geoffrey: Yes. Yeah, coz there's no, like you don't have to look for like, you don't have to look around it and see if there is anything which might um, cancel it out, you see what I mean **(2.680-2.688)** | Acidic. There's an acidic C double OH group there **(3.732)**<br>Interviewer: Ibuprofen?<br>Geoffrey: That's acidic. You can tell straight away, that's an easy one. Just based on the COOH group there. Yeah.<br>Interviewer: So do you find C double bond, the carboxylic acid groups easiest to identify?<br>Geoffrey: Yep **(3.787-3.792)** |
| phenols | Geoffrey: Well an OH, a phenol is acidic whereas an OH is not.<br>Interviewer: OK, but how do you know it's a phenol?<br>Geoffrey: Because it's attached to a benzene ring, yeah, directly attached to a benzene ring **(2.674-2.680)** | Geoffrey: That, the phenol's not acidic, is it? That's not even, is a phenol acidic?<br>Interviewer: A phenol is, is that a phenol?<br>Geoffrey: (longish pause) No.<br>Interviewer: Why is it not a phenol?<br>Geoffrey: Oh coz there's no benzene ring **(3.616-3.620)** |
| aliphatic amines | Geoffrey: I think codeine's a base because the nitrogen is attached to the carbon, carbon, another carbon, OK and like, and there's no, there's no double oxygen, like a doubly, sorry, an oxygen attached to a carbon which is directly (pause) attached to a nitrogen…OK, so (long pause) all right anyth, anything with that, which is a carbon bonded to a nitrogen, the carbon being…adjacent to the nitrogen with um, a doubly bonded oxygen to it, that's not basic.<br>Interviewer: OK. Why isn't it or what is it?<br>Geoffrey: Well it's, it's an amide and amides aren't considered basic whereas an amine, I think that's what you call it, an amine…I'm looking for an amine group not an amide group. And um, if in amine group is present then (pause) that means it's basic **(2.630-2.662)** | Geoffrey: OK. (pause) Codeine's basic.<br>Interviewer: Uhuh. Why?<br>Geoffrey: Because of the N, that group there.<br>Interviewer: The nitrogen there yep.<br>Geoffrey: Yeah, it is basic, isn't it? **(3.610-3.614)** |
| amides | and this nitrogen here (pause) that would be, no it wouldn't be (pause) because (pause) coz this adjacent carbon is sp, $sp^2$ hybridised and it has to be $sp^3$, both have to be $sp^3$ **(2.828)** | Geoffrey: All right. I've identified (pause) the basic group there.<br>Interviewer: OK, so you've got an amine.<br>Geoffrey: An amine. And I've got an acidic group here.<br>Interviewer: What sort of acidic group is that?<br>Geoffrey: C double OH. And then there's one over here as well, which is a phenol. And um (pause) the other two nitrogens are part of an amide group, because of the (pause) the um, double bond oxygen on the adjacent carbon.<br>Interviewer: So, you've said that makes it overall<br>Geoffrey: Neither acidic or basic **(3.694-3.708)** |

Transient change – Geoffrey

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| multiple functional groups | pH is greater than pKa then it's ionised and vice versa if pH is less than pKa it's unionised OK and the opposite occurs with bases. Whereas with amoxycillin for example it's always ionised so in, in that sense I wouldn't consider it a acid or a base **(2.724-2.732)** | |
| other nitrogens | Geoffrey: the N which is doubly bound coz I think it's um (pause) only sp hybridised.<br>Interviewer: OK. Is it basic?...<br>Geoffrey: I don't know what it is, tell you the truth. (pause) I don't think, um<br>Interviewer: The N with the double bond on it, you don't think that's acidic or basic?<br>Geoffrey: Well I, (pause) because I thought um, it had to be, had to be (pause) sp, $sp^2$ hybridised, whereas for that, it's, that's sp hybridised isn't it?<br>Interviewer: Well nitrogens I don't think have hybridisation so much as carbons…what we were looking for was the hybridisation of carbons anyway, so it's the carbon next to it, its state of hybridisation.<br>Geoffrey: This one here, oh that one, that's, that's $sp^2$ and it's supposed to be $sp^3$ so than that's, like it wouldn't be, it's neither acidic or basic **(2.762-2.780)** | Geoffrey: (pause) Diazepam. (long pause) See what does this double bond here, what implication does that double bond here have? I know this, this nitrogen here bound to the methyl group, that's an amide. Whereas this nitrogen, here.<br>Interviewer: Not so sure?<br>Geoffrey: (pause) No<br>Interviewer: OK, so that, I talked about the hybridisation state of that carbon. Do you remember what that was all about?<br>Geoffrey: (pause) The hybridisation state. It's got to be sp, it's got to be $sp^3$? $sp^2$?<br>Interviewer: Yeah, it's got to be $sp^3$.<br>Geoffrey: $sp^3$ yeah.<br>Interviewer: And if a, if a nitrogen's attached to any carbons that aren't $sp^3$, then that makes the nitrogen not basic.<br>Geoffrey: (pause) Well it's $sp^2$, isn't it?<br>Interviewer: Yeah, the on, the C double bond O is $sp^2$. What about that one there, with the double bond coming from the nitrogen? What hybridisation state would that be?<br>Geoffrey: (pause) It's $sp^2$, is it?<br>Interviewer: It's $sp^2$, yeah.<br>Geoffrey: Yeah, so, it's not<br>Interviewer: So it's not basic.<br>Geoffrey: So it's neither **(3.746-3.770)** |
| dissociation of ibuprofen | *Not required* | Interviewer: OK with ibuprofen, it's got a pKa of four point four. Can you use that to draw up a dissociation equilibrium for ibuprofen?<br>Geoffrey: (pause) Yeah. (pause) OK, so, well, (pause) what was the pKa?<br>Interviewer: four point four.<br>Geoffrey: And that goes into ah, C double O minus. Yep. That's (pause) that's at a pH four point four **(3.803-3.808)** |

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| dissociation of amoxycillin<br><br>allocation of pKa values<br><br>addition of proton to amine<br><br>correct order of dissociation | Geoffrey: All right at um, pK, pH less than two point four then all the, OK the um, H is still present on the phenol, it's still present on the C double O and also still present, it's $NH_3^+$ in terms of the um, amine. At um, less than, less than seven point four<br>Interviewer: Yeah, so two point four to seven point four?<br>Geoffrey: Yeah two point four to seven point four, then um (pause) the C, the C, (pause) the H has left the C double OH, OK but everything else still has the proton on it. Um (longish pause) Sorry I think I've stuffed up.<br>Interviewer: No, no you're right. It was two point four to seven point four and seven point four to nine point six.<br>Geoffrey: Yeah at less than nine point six, between seven point four and nine point six, the C double O has already lost its hydrogen and the um (pause) the phenol has also, no it's the um the NH, the hydrogen attached to the $NH_2$ that's gone, then at um, greater than nine point six they've all lost their hydrogens **(2.980-2.1006)** | Geoffrey: Yeah, I put the $H^+$, $H^+$ onto the $NH_2$ so that it becomes an $NH_3^+$, and that's a pH (pause) less, two less than two point four, (pause) and then at two greater than two point four, so around four point four or say 5. Then the $H^+$, (pause) the hydrogen, has been um (pause) removed from the C double OH, (pause) so do you want me to draw that as well?<br>Interviewer: Yes please.<br>Geoffrey: OK. Well, C double O minus, (pause)…Yeah, OK, um, (long pause) that, greater than seven point four so 9.4. (pause) It's going to be O minus.<br>Interviewer: So the seven point four belongs to the phenol?<br>Geoffrey: Yeah it belongs, no, (pause) it doesn't, does it?<br>Interviewer: No it doesn't.<br>Geoffrey: No.<br>Interviewer: Why not?<br>Geoffrey: Because it's such a weak acid. So the weak, yeah it's, belongs to the base. (pause) It's the $NH_2$, so the base is going to become $NH_2$ as opposed to $NH_3$, (pause) phenol's still going to be there. And then, at greater than nine point six, (pause) it's going to be completely ionised **(3.826-3.856)** |

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| prediction of form at specified pH | it's always ionised no matter what, no matter what pH and so (pause) in that sense (pause) I wouldn't call it, I wouldn't call it an acid or a base **(2.708-2.712)**<br><br>Whereas with amoxycillin for example it's always ionised so in, in that sense I wouldn't consider it a acid or a base **(2.730-2.732)**<br><br>Interviewer: OK, um, so if, if it's below two point four then you say it's got all its protons attached.<br>Geoffrey: Yeah.<br>Interviewer: How far below two point four would it have to be for all of it to have all of its protons?<br>Geoffrey: Less than 2, less than 2<br>Interviewer: 2?<br>Geoffrey: 2, less than 2 units I suppose, like um, at two point four it would be at around point four or less… if you um, go back to the, I think it's the Henderson-Hasslebach equation then you'll find it'll be highly, like there will be a highly unionised, a highly ionised, no highly union, unionised **(2.1049-2.1058)** | when I think about when the drug's actually ionised, it's actually ionised all the time, so that's another reason why it's neither acidic nor basic **(3.718-3.722)**<br><br>Interviewer: OK, why do you put it there? Like what, what's the point of putting the four point four on top of the arrows?<br>Geoffrey: Well to indicate, that indicates that if the pH is (pause) less than four point four, then the drug is (pause) unionised, whereas if pH is greater than four point four, it becomes ionised.<br>OK.<br>So that would, yeah.<br>Interviewer: OK. How far above four point four would it have to be before you considered it completely ionised?<br>Geoffrey: About 2, a pH of 2?<br>Interviewer: A pH of 2 or 2 above?<br>Geoffrey: 2 above, yeah.<br>Interviewer: Yeah, OK. And is it the same in the other direction?<br>Geoffrey: Yeah **(3.809-3.818)** |
| self-evaluation of learning | Interviewer: You're very quick at doing that. Do you, are you doing that visually, do you think. Like I mean are you just seeing those things and not having to think about them, or are you thinking quickly?<br>Geoffrey: I just, I don't know, I just look at it and I just (pause) see and I think yeah. Well, coz I, coz I know what to look for, I, I've, I've had enough, I think I've had enough experience with these just to say, like just to look at it and think yeah, I've noticed, (pause) yeah to notice the similarities and the differences **(2.861-2.866)**<br><br>Geoffrey: No well yeah. In my head like I'll do, go from there to there, there to there or from there to there but I don't have a<br>Interviewer: But you're pretty comfortable with it now?<br>Geoffrey: Yeah, well actually I, that's what I did initially but now I can sort of just look at it and say "That's, yeah that's that" so I don't really have to go to that step anymore **(2.920-2.926)** | |

## Transient change group: Larry

### *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | They're proton, (pause) no, proton, they lose protons in a reaction **(1.4)**<br><br>Bases are much the same, they're proton acceptors, though **(1.8)** |
| names of theories | *Not given* |
| taste and feel | Interviewer: No? OK, so, nothing about taste, or touch, or<br>Larry: Oh. I don't know whether you're meant to touch acids or not.<br>Interviewer: Well what do you think would happen if you did touch an acid?<br>Larry: Well you'd get an acid burn, the same would happen if you got a base. Don't you get a burn from base as well?<br>Interviewer: OK, so that's a physical characteristic, they burn. |
| corrosiveness | Larry: They burn. Um, as for touch, um, feel, no, what else did you say?<br>Interviewer: Taste?<br>Larry: Taste. Taste. Bases are meant to be, no acidic things are meant to be, no acidic things are meant to have I suppose an acidic taste. And a base thing, I don't think I've ever tasted a basic thing. I don't really remember, but I remember from vinegar, and lemon juice and things like that, have a bitter taste **(1.39-1.48)** |
| other characteristics | pH is the other one. Record of pH and proton acceptors/proton donators **(1.14-1.16)**<br><br>Interviewer: Litmus paper?<br>Larry: Litmus paper. Litmus paper, depends which colour it is, was it blue or red?<br>Interviewer: OK, well what, what do acids do?<br>Larry: Do they, do acids bleach it? Or do they not bleach it? Or they change the colour. I think in red litmus paper, acid turns it blue, or purple. Or is that bases? I can't remember which one's which, but I remember there's a differentiation between the colours of red and blue **(1.51-1.56)** |
| Chemistry acids characterised primarily by pH | Larry: It's a way of measuring whether it's acid or base.<br>Interviewer: OK. Well, how does that work then, how does it work as a measure?<br>Larry: It's based on a scale of 1 to 14, or, not 1 to 14, well it's based at 14, type of thing and 7 being neutral, 14 being the most basic and 1 being the most acidic, and then we use it, various chemical equations, like the negative log of the concentration of the hydrogen ions in the solution calculates your pH of acids, and your, the negative log of your concentration of OH minus or the hydroxide ions in the solution measures how basic it is, and then you've got other different equations for working out different things.<br>Interviewer: OK. OK. So, if we had a pH of 1, is that acidic or basic?<br>Larry: Acidic. |

Transient change – Larry

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|---|---|
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | Interviewer: Very acidic, or only a little bit acidic?<br>Larry: Very acidic…<br>Interviewer: Um, are there any hydroxide ions at pH 1?<br>Larry: Depends on what's in the solution. I don't know. Depends what solution it is, doesn't it?<br>Interviewer: OK, so it's a solution of hydrochloric acid, point 1 molar hydrochloric acid.<br>Larry: (pause) Um, I'm not sure, don't think so. But there could be because, oh, no, I'll say no.<br>Interviewer: OK. All right.<br>Larry: There could be. (laughs) **(1.90-1.118)** |
| use of mathematical relationship to solve numerical problems | *Carried out correctly* |
| conflation of strength and concentration | Interviewer: OK, what makes um, one acid different from another acid?<br>Larry: The pH **(1.81-1.82)**<br><br>And then with your pH, the larger the pH, the more acidic it is. But then of course you can get, like hydrochloric acid comes in a whole different range of pH, so I suppose that's not a good way of differentiating between it **(1.88)** |
| Larry's prior experience and approaches to learning | I really had trouble with um, acids and bases and working out pH. Always had trouble with it coz we didn't do it much for the VCE, I don't think. And so, always had trouble and everyone was so far ahead **(1.448)**<br><br>she [college Chemistry tutor] was great. And she was just so happy and helpful and everything and understood everything, explained it really basically …she just sat me down and we just did heaps and heaps and heaps of them. It was just so much better. So much easier **(1.448)**<br><br>Larry: I don't know all like the definitions, because you're basically taught in the exams that you just plug in the numbers …You're never really asked to give definitions…<br>Interviewer: OK. Do you think that um, knowing what the definitions are might help you in using equations?<br>Larry: No. They haven't so far (laughs)<br>Interviewer: OK, so how do you pick an equation to use?<br>Larry: You just, you, by that time, you've had that many past exams, that you look at the question and you're goin', "right, that's what that's asking".<br>Interviewer: OK, so you're actually saying that you don't need to understand the question, just recognise it?<br>Larry: Yes.<br>Interviewer: OK. Has that worked so far at university?<br>Larry: Yes…Yeah, it has! Coz they give, in chemistry was one of the good ones, they gave you like five past exam papers and, and the, this year's one was based on the last ones. But I didn't know that, but I'll tell my freshers next year in college, that don't worry about studying for it, just study the past exam papers **(1.402-1.418)**<br><br>it's better when you got the stuvac and you're just sitting at home, and you can just go through past paper, past paper, past paper, so you get a general drift of, and then you can time yourself and work it all out, it's all relative, it all fits. That's what I did for the VCE, anyway **(1.430)** |

Transient change – Larry

## Interview 2

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | for an acid, it will lose, no, it will gain. Acids are acceptors?... Acid dissociation. (pause) That's the pharmacy one, is it different for chemistry, I can't remember. No I think it's the same for chemistry and pharmacy, the acid dissociation, so it's um, ah, it loses **(2.224-2.226)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | Interviewer: do you think of acids in any way as dangerous?<br>Larry: In chemistry, yes you do, you're told they're very dangerous. In Pharmacy you wouldn't say so, because you know that carboxylic acid is a weak acid, anyway.<br>Interviewer: OK, so you've kind of got it in the back of your mind that it really should be a weak acid?<br>Larry: Well, it should be. It is. But I can understand why, coz as you said in Pharmacy you're not dealing with strong acids very much when you're concerned with drugs, so you've got to be concerned about the ones that are weaker.<br>Interviewer: OK, so are you saying that your understanding in Chemistry is that strong acids are dangerous and weak acids are not?<br>Larry: Well no, not as dangerous, no, depending on the concentration of it.<br>Interviewer: OK, so what's dangerous about, about acids in Chemistry?<br>Larry: Oh well like, acid, acid burns, if it spills on you, it'll damage your clothes, or whatever.<br>Interviewer: Uhuh. And so do you think even something like ibuprofen, which is carboxylic acid, would that burn you if you spilt it on you, do you think?<br>Larry: No, I don't think so **(2.597-2.610)** |
| pharmacy acids characterised by pKa rather than pH | *Implied but not specifically stated* |
| strength characterised significantly differently in pharmacy and chemistry | Interviewer: OK, so acid<br>Larry: Dissociates completely to lose a proton.<br>Interviewer: Completely?<br>Larry: Well that, that's for a strong acid.<br>Interviewer: In chemistry or pharmacy?<br>Larry: In chemistry, for a strong acid.<br>Interviewer: So a strong acid in chemistry dissociates completely, losing a proton. OK?<br>Larry: Losing a proton. And in pharmacy, a strong acid is indicated by a low pKa. And it doesn't necessarily dissociate completely, but it is a proton, it does lose a proton in the process.<br>Interviewer: OK. So how do chemistry and pharmacy differ then in what they call weak acids? |

Transient change – Larry

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|---|---|
| | Larry: In weak acids? Well, in chemistry, a weak acid will not dissociate completely, so it won't lose all its protons, and in pharmacy, a weak acid is one with a high pKa **(2.229-2.246)** |
| strength in pharmacy characterised by values of pKa<br>acids and bases in pharmacy both have pKa<br>in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | Larry: the pKa's a predictor of whether it's a strong acid or a weak acid. And whether it's, and the pH is more to do with just testing it, rather than um, predicting whether it's strong or weak, it's just testing it, I think?<br>Interviewer: OK, we'll, we'll come back to that idea, but OK. So, what, what pKa do you associate with a strong acid?<br>Larry: A low pKa.<br>Interviewer: What do you mean by low?<br>Larry: Less than 7.<br>Interviewer: OK. And a strong, a weak acid rather?<br>Larry: Greater than 7.<br>Interviewer: OK, what about a strong base?<br>Larry: Greater than 7.<br>Interviewer: And weak base?<br>Larry: Less than 7 **(2.186-2.198)** |
| Larry's strategies | Interviewer: And weak base?<br>Larry: Less than 7.<br>Interviewer: OK, you've done well. Was that memorised, or?<br>Larry: Memorised. Yeah, it was pretty, it was memorised. There's, there was a fair bit of memorising **(2.197-2.202)**<br>Larry: The table you gave us. pH is greater than pKa, so an acid is ionised yep (pause). So there's more, H, more, A minus present. That's the little table, I memorised that table, it's the best table.<br>Interviewer: It's quite clear that you did, coz you still brought it up in the same place.<br>Larry: Yeah, well that's how I've memorised it, the pH. (laughs) I visualised, I can visualise it. This is the base one, and, yeah…<br>Interviewer: Do you do that, do you do that a lot?<br>Larry: No. Depends, depends on how much the bulk of information, if it's something bulky like that was, and it was a table that was so important, that had so much information **(2.280-2.296)** |

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | Larry: An acid? Well, let me see now this is where I've probably forgotten the definition, your definition. But it used to be something that dissociates, or loses a hydrogen ion. No, is it lose, or is it gain? Oh<br>Interviewer: If you want to write anything down, if that kind of helps, you can do that.<br>Larry: It loses. It does.<br>Interviewer: Loses the hydrogen ion.<br>Larry: Loses the hydrogen ion.<br>Interviewer: And what makes something an acid, a base.<br>Larry: It gains a proton, yeah **(3.148-3.154)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | *Physical characteristics not mentioned* |
| difference between acids and acidic drugs | (pause) Well, as you said, drugs tend to be not as acidic, they're more, you don't, you don't, yeah (pause) There is a difference between, like most acidic drugs don't be, tend to be as strong as normal acids, like your hydrogen chloride or whatever is a stronger, much stronger acid, whereas your um, acidic drugs are not as strong **(3.166-3.168)** |
| chemistry and pharmacy acids characterised by pH | Interviewer: do you think of acids as having a pH?<br>Larry: Yes. In the, between, generally, 1 and 7, or 0 and 7.<br>Interviewer: OK, and is that in all contexts?<br>Larry: What do you mean?<br>Interviewer: Well, so, all acids have pHs between 1 and 7.<br>Larry: Um, yeah **(3.159-3.164)** |
| strength in pharmacy characterised by values of pKa | *Not described* |
| acids and bases in pharmacy both have pKa | |
| pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | |

Transient change – Larry

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|---|---|
| strength characterised significantly differently in pharmacy and chemistry | Interviewer: is there a difference in your mind between acids in chemistry and acids in pharmacy?<br>Larry: (pause) Well, yeah. In chemistry, they're meant, acids are meant to dissociate completely, when they're strong. Whereas in pharmacy, you, it never tends, oh you, you only assume they dissociate completely when something, something, something. There's 100 percent, well you assume there's 100 percent dissociation in some cases. In some weird prac somewhere **(3.175-3.182)** |
| Larry's visual recall | Larry: It was a graphy thing. It's just, it's like, that. One's for an acid, and one's for a base.<br>Interviewer: What might be on the axes?<br>Larry: (pause) (Both laugh) There's S one, there's S eleven and there's something or other, and it goes up here and there's little points, and then here you assume that there's<br>Interviewer: OK. What might S stand for?<br>Larry: (long pause) No.<br>Interviewer: Is this kind of a photographic memory thing that you see, you remember it on the page? OK.<br>Larry: Yeah, I remember it on the page, but I can't remember what it means **(3.186-3.196)** |





Transient change – Larry

*Concepts new to pharmacy*

| Characteristic | Transcript excerpt – interview 2 | Transcript excerpt – interview 3 |
|---|---|---|
| carboxylic acids | carboxylic acid group, um C double O H **(2.362)** | *Experienced no difficulty but did not verbalise* |
| phenols | that's a phenol group, so that's an acid. Because the OH is directly attached to the benzene ring **(2.356-2.358)** | the OH group attached to the, directly to a benzene ring, which is a phenol group **(3.214)**<br>a phenol group, and therefore it's basic **(3.214-3.216)**<br>Ah, see, there you go. Assume the OH group, OH groups are basic, normally **(3.256)** |
| aliphatic amines | the amine group, so you look like that, and if it's all bonded to C, um, to carbons that are $sp^3$ hybridised, or hydrogen atoms, so you can say that that's a base **(2.342)** | one of these things, now they've gotta be attached to, directly to a (pause) one of those carbons that has four things off them **(3.218)**<br>Larry: That is a thingy group, amine, did you call it?<br>Interviewer: So what does that make lignocaine?<br>Larry: That makes it a acidic drug.<br>Interviewer: Nope.<br>Larry: It's a basic drug?<br>Interviewer: Amines are basic **(3.248-3.253)** |
| amides | this end here in the chain can't be an, er, amine group, because it's attached to an $sp^2$ hybridised, coz that, C has got a double bonded O **(2.362)** | Interviewer: OK, well looking at the other nitrogens in that molecule, which you haven't identified as being amines, why didn't you?<br>Larry: Because this nitrogen is attached to a carbon that has a double bonded O **(3.231-3.232)** |
| multiple functional groups | Larry: it's got two acids and a base. So it's got a combination of the two, so therefore, it's neither. **(2.382)** | Larry: this one's neither…<br>Interviewer: Why is it neither?<br>Larry: Ah, I remember this, coz I didn't actually know it last time. Then you explained it to me, and it actually clicked. But now I've forgotten it. It's something to do with, because (pause) they all, at, at every like pH or pKa or something like that, they all, at some point are ionised, and so therefore are never really all basic or all acidic, because of differing, I think, I think it's pH. They are all, like, um, ionised or something **(3.268-3.274)** |





Transient change – Larry

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|---|---|---|
| dissociation of ibuprofen | Um, you put the little thingies, and you go four point four then you do the, the dissociation so it's C double bond, with the minus bonded to the R group **(2.440-2.444)** | Interviewer: If I told you the pKa of ibuprofen is four point four, can you draw me up the acid base dissociation for that?...<br>Larry: OK. (pause) Yeah, OK. (pause) Was it four point four?<br>Interviewer: four point four, yeah.<br>Larry: R group. CH (pause) COO minus **(3.291-3.298)** |
| dissociation of amoxycillin<br>allocation of pKa values<br>addition of proton to amine<br>correct order of dissociation | OK. So we start with, firstly, with all the um, protons attached. Then we've got our OH, R, $NH_3$ plus...and C double O H. Then you...then you go for the lowest pKa, and you take one proton off when you move up one step, so then you take the one off the acid, coz that's the pKa associated with that, with that acid. Then you have your OH, R, C double O minus, and $NH_3$ plus group...and then you would go up to the next pKa, and take, and that's the one associated with the base, here, the nitrogen, so you take um, a proton off of that. And you end up with the $NH_2$. And then you would do your final dissociation at nine point six which is associated with the phenol group. So you take a proton off of that. And you end up with that structure **(2.504-2.532)** | [amoxycillin] Larry: I can do that. I can try, anyway. (pause) OK, so if the, for an acid and a base, that'll be acid and a base down here, (pause) base, and the pH is greater than the pKa, that would be the pH is less than the pKa, and for an acid, this was ionised, unionised, unionised, (pause) ...So, at a, so it's gotta have, at a p of two point four, so the pH is, no this is the tricky bit now. I've gotta work out what exactly I'm doing. The acid, we'll concentrate, these ones are the acids, this one and this one. Just wondering if the (pause) Is that right? Yeah. (pause) pH is greater than pKa, (pause) Oh, you gotta associate, which, which one is which?<br>Interviewer: Well, you should tell me that, first.<br>Larry: OK, two point four is the carboxylic acid, nine point six is, oh, no, no, no, no. (pause) I think nine point six is the OH group, and the seven point four is here.<br>Interviewer: That would be correct.<br>Larry: There you go. I'm doing well for myself.<br>Interviewer: You are.<br>Larry: OK. So, for this one, (laughs) it's (pause) an acid, and if the pH is (pause) less than the pKa, that one is ionised, at greater, pH is greater than the pKa. (pause while writing) Yeah, OK. So seven point four, and that's the base, so if the pH is less, is greater than pKa, it is unionised. So the pH is greater than the pKa, so we got (longish pause)...OK, so if that one's an acid, and the pH is greater than the pKa, it's ionised. So, this one has to be, um 1. And the OH, OH, OH, and somehow we link all these ones up (laughs) **(3.330-3.348)** |

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| prediction of form at specified pH | [ibuprofen] Interviewer: why does that, writing it that way, what does that, what information does that give you?<br>Larry: That gives you that the fact, that if the pK, if the p, if, if this was put into a solution with a um, with a pH greater than the pKa, then it'd be, (pause) well this is an acid, pH is greater than pKa, it, this'd be ionised, so it'd be in this form. So if it was anything greater than four point four and if it was less, then it'd be unionised and it'd be in this form.<br>Interviewer: Uhuh. At what point could you say it was completely in the ionised form?<br>Larry: When it was, when it's above, um, the pH is above six point four, ie, two units above the pKa.<br>Interviewer: OK. And what about completely un-ionised?<br>Larry: Um, two point four, it'd occur around two point four coz it's more than two units, well it's two units or more below the pKa **(2.445-2.454)**<br><br>[amoxycillin] Larry: Well, I know amoxycillin's ionised at any pH. Well, almost any, I think just about everything you could throw at it, it pretty much. It'll always be ionised.<br>Interviewer: OK. Why can we say that?<br>Larry: …it's the fact that the base and the acid groups, I mean one will dissociate at a higher pH, and the other one will, will not, and then at a low pH, the one will ionise and one will, will not **(2.534-2.544)**<br>Interviewer: what form is this drug mostly in at say, pH 5?<br>Larry: At pH of 5. Um (pause) well I'll have to go through for each one, almost. 2.5 (pause) unionised, have to be in this one (circling on paper).<br>Interviewer: OK. So, the second one, the one with the plus and the minus. What logic did you use there? It's correct, so whatever logic you used worked.<br>Larry: Yeah, I just, I. Because you, you're looking at the um, the pKas here, of two point four and seven point four, of which this is in between, so therefore if you put it in a solution of 5, then it'd have to be around in that one, between those two **(2.565-2.576)** | [ibuprofen] Interviewer: at what pH would you say the drug is completely in the ionised form?<br>…OK, at the pH, OK, so it's the pH (long pause) That's for an acidic drug. (pause) It's in the ionised form. So, it'd be at a Larry: pH greater than four point four.<br>Interviewer: Certainly greater than four point four, but how much greater than four point four would it need to be, before you can say it was 100 percent in the ionised form?<br>Larry: Six point six.<br>Interviewer: So, two point two units above.<br>Larry: Oh, no, six point four **(3.301-3.310)** |

Transient change – Larry

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|---|---|---|
| strategies – Larry's preference for relying on memory | Larry: it's got two acids and a base. So it's got a combination of the two, so therefore, it's neither.<br>Interviewer: Is that something you just memorised, or is that something that, I mean what, what makes you say that?<br>Larry: Because there was four steps. If it's got only acids present, therefore it's an acid, if it's only got bases present, therefore it's a base, if it's got both, then it's neither, and if it's got neither an acid or a base, it's neither. It was four steps you gave us.<br>Interviewer: Yes. That's another table that you visualised, is it?<br>Larry: It's on one of the handouts I go one two three four **(2.382-2.390)**<br>Larry: you just learn to recognise structures, just basically through looking at it.<br>Interviewer: OK, so the fact that you've done lots of examples of this, is that how come you find it easier now?<br>Larry: Yes. That's the only reason why I find it easy, otherwise I'd probably struggle a little bit…I've learnt to, and plus I know all of these structures basically off by heart now **(2.404-2.412)** | *Larry did not articulate any new strategies in his final interview, but clearly maintained use of those already outlined.* |



## *Additional issues – interview 3*

| Characteristic | Transcript or diagram excerpt | Comment |
|---|---|---|
| imprecise and idiosyncratic terminology | you only assume they dissociate completely when something, something, something **(3.178)**<br>The carbon, the carbon has to be a type of that, that carbon has to be special type of carbon, for it to be an amine **(3.228)**<br>it's not one of those ones with thingies **(3.234-3.236)**<br>that is a thingy group, amine did you call it? **(3.248)** | Larry did not focus on definitions at any stage, having stated in his first interview that he did not need them for passing examinations. His language was consistent with a disregard of definitions and tended was often imprecise. |

# Transient change group: Lucy

## *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | [acid] it's a proton donor **(1.6)**<br>[base] proton acceptor **(1.8)** |
| names of theories | *Not given* |
| taste and feel | I remember bases are slippery um, and they're more alkaline, all that sort of thing, yeah like detergents and stuff **(1.22-1.26)** |
| corrosiveness | other acids are really strong and you can't, can't touch them or anything like that coz it burns **(1.46)** |
| other characteristics | Interviewer: Litmus?<br>Lucy: Oh yeah, it, no, but I can't remember which one it does **(1.17-1.18)** |
| Chemistry acids characterised primarily by pH | *Implied but not specifically stated* |
| strength NOT described on the basis of complete and partial dissociation – conflation of strength and concentration | Um, the strength is like whether it's like one molar or two molar or whatever I think, and the concentration is how much, like whether it's dilute or concentrated, whether it's like, dissociate, how much it dissociates **(1.54)**<br>OK, well a pH of 1 means it's like concentrated, um or a stronger one **(1.80)**<br>well like sometimes, sometimes acids, I mean it depends on what their, how strong they are but like things like you know vinegar and citric acid and stuff like that you can, you can sort of eat it and stuff but other acids are really strong and you can't, can't touch them or anything like that coz it burns **(1.46)** |
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | The negative log to base 10 of the hydrogen concentration, hydrogen ion concentration **(1.70)**<br>So, um, OK, well a pH of 1 means it's like concentrated, um or a stronger one, a stronger acid or, um, and a pH of 7 means it's more neutral. So, and then the other direction is the bases so pH 14 would be, yeah, a stronger one **(1.80-1.82)** |
| purpose of pH | to measure the concentration, I think it is, of an acid or base **(1.72-1.74)** |
| use of mathematical relationship to solve numerical problems | *Carried out inconsistently* |

**Interview 2**

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] In pharmacy it's still a proton donor **(2.146)**<br><br>[base] Proton acceptor or a H acceptor **(2.164)**<br><br>I'm just trying to think back to all my IPS stuff. (Brief pause) Well I think it's, I know it's still got the hydrogen on it, I think that's still a part of it now. Um. Yeah, whereas in chemistry they've got, like other things can be acids as well I think it's still the hydrogen part of it **(2.148-1.152)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | Interviewer: do you think about um, acids in either or both areas as being like dangerous in any way?<br>Lucy: Um, well probably in pharmacy I don't. Like they're, they're I guess they're considered weak acids in chemistry but I guess if you take them the wrong way or if you take too much of them or whatever then they can probably be harmful. But um, yeah, the strong acids in chemistry, and I guess it depends what concentration you have them as well. Yeah, they're, they can be dangerous as well.<br>Interviewer: What about bases, do you think of them as dangerous?<br>Lucy: Yeah, oh yeah, same thing **(2.437-2.442)** |
| other characteristics, particularly differences | Interviewer: does the idea of the salt form have any part of your? No?<br>Lucy: No, not really. Yeah I remember doing, like I remember doing that, but that, like it wasn't really major **(2.153-2.156)**<br><br>Interviewer: What about, um, when, when drugs are ionised or unionised, does that, is that part of how you think of an acid?<br>Lucy: Um, yeah, yeah, sort of (hesitantly) but that was just sort of extra stuff that I've learnt, like now so I still haven't got that sort of, you know, in my head **(2.159-2.160)**<br><br>there was the same sort of things in there like you know, the pH and whatever, that was all the sort of the same thing. But yeah, just a few things were a bit different and I think once I'd studied it, you know, really really well for the exams I think that's when I sort of understood the differences **(2.100)** |
| differences between acids and bases in pharmacy and chemistry | I just, I assume pharmacy's just um, like just with the drugs and you know, where it dissolves and how it gets to different parts of your body whatever. Chemistry is just chemistry, it's reactions and whatever **(2.434)** |
| pharmacy acids characterised by pKa rather than pH | *Implied but not specifically stated* |

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|---|---|
| strength characterised significantly differently in pharmacy and chemistry | there's the strong acid in chemistry isn't the strong, the strong acid in pharmacy isn't the strong acid in chemistry and that's, yeah that was just a bit weird. And the pKas and all that sort of thing, that was yeah, just a bit different **(2.108)**<br><br>I found it really confusing because we've had you know, chemistry drilled into us since year 10 and then we go to this pharmacy thing and it's just all different, and you just go "Oh, OK." …Yeah, I found it confusing sometimes **(2.98)**<br><br>Lucy: like a strong acid, the ones that dissociate but I guess they, um, like I guess the other ones do as well, but I know I just know the names of them. So there's like, you know, hydrochloric acid and sulphuric acid and I know that they're the strong ones whereas the other one that<br>Interviewer: Acetic acid.<br>Lucy: Yeah, um, and carboxylic acid. Those ones, they're sort of the stronger ones whatever in pharmacy.<br>Interviewer: They're the strong ones in pharmacy but<br>Lucy: Yeah, but they're weak in, in chemistry.<br>Interviewer: OK, so, um if you, do you just think about the names of them in chemistry and you know these ones are strong and these ones are weak?<br>Lucy: Yeah.<br>Interviewer: OK. So the extent of dissociation is not how you think about it?<br>Lucy: No that's not how I think about it, but like that's, yeah I know that's what it is. But I think of in terms of what they are, the names of them **(2.116-2.132)** |
| strength in pharmacy characterised by values of pKa | well I know this [COOH] is a stronger one so it's going to have a lower, a lower pKa than that one [phenol] **(2.342)**<br><br>well, um, strong acid is below 7 for the pKa and a weak acid is above 7 **(2.348)**<br><br>strong bases have, theirs is higher than 7 and weak bases is less than 7 **(2.350)** |
| acids and bases in pharmacy both have pKa | |
| in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | |
| conflation of pH and pKa | well pKa is similar to pH isn't it, so if you've got a low pKa it's like that's going to mean its going to have a low pH anyway, isn't it? **(2.356)** |
| Lucy's strategies | when I was by myself I usually would just um, go over things, like write notes pretty much or summarise things. Um, just read over it and try and remember things, understand it **(2.12)**<br><br>I just went "OK I'm just going to learn this for the exam". Um, I didn't, yeah I don't really know lots about the differences **(2.112)** |

Transient change – Lucy

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] It's still a proton donor **(3.104)**<br>[base] it's the same thing, just a proton , proton acceptor **(3.120)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | *Not described* |
| difference between chemistry and pharmacy acids | the different ones that we use, in um, like that we used in chemistry and then different ones from pharmacy **(3.114)** |
| difference between acids and acidic drugs | I guess it's got different properties, that, like an acid, I don't know, I just associate acid with something sitting in the jar. It's just like a liquid and then an acidic drug is something that it's made from an acid but it's, like completely different **(3.148-3.150)** |
| pharmacy acids characterised by **pH** rather than pKa | Interviewer: Um, do you think of acids and bases as having characteristic pHs?<br>Lucy: Yeah. Yeah, um, acids are smaller pHs and bases are higher pHs **(3.123-3.124)** |
| strength in pharmacy characterised by values of extent of dissociation | a strong acid is something that dissociates more easily than a weak one **(3.128)**<br>Interviewer: And what about a strong versus weak base?<br>Lucy: Yeah, it's the same thing whether it dissociates more readily.<br>Interviewer: but you say bases accept protons so that's not really a dissociation.<br>Lucy: Oh. Well I don't know **(3.129-3.134)** |
| acids and bases in pharmacy both have pKa | pKa. Um, OK, well Ka is what, (pause) it's, oh I can't remember, I know it's got something to do with Ka **(3.162)** |
| pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | Lucy: Yeah, pH and Ka but I just can't remember the relationship between them. That's terrible it's only been, it hasn't been very long.<br>Interviewer: OK, um, does it have anything, do you associate pKa with strength of acids and bases?<br>Lucy: Yeah, but I can't remember which one it is, whether it's high or low, or, yeah **(3.168-3.170)** |
| strength characterised significantly differently in pharmacy/chemistry | Well, the ones that we used in chemistry were a lot stronger, and I think it was just for different, coz we were doing different experiments like titrations and whatever, and, and I think, yeah, but in pharmacy because like with drugs they're a lot of, more associated with the weaker acids **(3.142-3.144)** |

Transient change – Lucy

| Characteristic | Transcript excerpt – interview 2 | Transcript excerpt – interview 3 |
|---|---|---|
| carboxylic acids | Yeah, this one [carboxylic acid] and the phenol you can see, like you can see they're just there so it's, you don't have to actually think about it you can just kind of say "OK that's acidic" **(2.284)** | Interviewer: What about ibuprofen?<br>Lucy: That's carboxylic acid **(3.301-3.304)** |
| phenols | Um, that one's a phenol there. Because it's got the OH joined to there, benzene ring, aromatic ring **(2.212-2.214)**<br><br>That's just an OH group. If it was joined to that or if it, yeah if it was joined to an aromatic ring, then it would be an, um, alcohol, it would be a phenol **(2.200)** | Oh that's a phenol, that's right. So that's, and that's acidic **(3.238-3.240)**<br><br>Lucy: Um, I have a feeling that might be an acidic one but I wouldn't, I don't know.<br>Interviewer: The OH group?<br>Lucy: Yeah, the OH but I don't, I don't think it is.' **(3.194-196)** |
| aliphatic amines | Interviewer: Do you think anything special about, like does it have to be special carbons or just any carbons?<br>Lucy: They're $sp^3$.<br>Interviewer: OK. How do you identify them as $sp^3$?<br>Lucy: Um, They've got three, they've got only two, is it two or four, they've got four um, bonds around them **(3.193-3.196)** | I don't know, it's got to be connected in some, in a certain way. I just can't remember. It can't have a double bonded oxygen **(3.186)**<br><br>Lucy: Um, (pause) I don't know if that's. Um, I'm not sure but that one could be, but I don't know coz of the double bond…No, because it's not attached to another carbon with a double bond.<br>Interviewer: Well it is really isn't it?<br>Lucy: Is it?<br>Interviewer: Yeah, if you look at the carbon that it's attached to, that carbon has a double bond coming off it going back to the nitrogen.<br>Lucy: Oh, it is, oh OK, so it is then.<br>Interviewer: So it still, it still counts, it's got a double bond.<br>Lucy: Yeah, oh OK.<br>Interviewer: So although it's not an amide it's not an amine either.<br>Lucy: Oh OK **(3.280-3.296)** |
| amides | that's an amide because it's joined to the C double bond O **(2.222)**<br><br>Interviewer: What's it joined to on the other side?<br>Lucy: Oh no it's joined to an O as well so it's not.<br>Interviewer: Is it the nitrogen joined to the O is it?<br>Lucy: Yes, this one here, Oh it's joined to the O, so I don't, I guess it doesn't really matter. I don't know about that one actually. That's joined to that one.<br>Interviewer: So how would you draw out that particular um, sequence of atoms?<br>Lucy: Well it's got C, this one's CH, that's $CNH_2$, N or it could go like (pause) no that would have to be there wouldn't it?<br>Interviewer: Otherwise you wouldn't have bonds coming from carbon.<br>Lucy: Have another, yeah, it has to be that, so it's an amide, so it's not a base, not a base **(2.225-2.236)** | Lucy: That's, (pause) now is that a basic one? Yes. That's basic as well.<br>Interviewer: OK, so that a nitrogen on the left hand end?<br>Lucy: Yep, that one there. And that one I think is as well.<br>Interviewer: OK, so you've got two basic nitrogens in that molecule?<br>Lucy: Yep.<br>Interviewer: OK. If we were to look at the one on the left hand side, what's next to it?<br>Lucy: Carbons, oh no, a hydrogen.<br>Interviewer: So does that, the way that I've written it there, NHCO, is that like, in your mind a straight chain of those things attached to each other? |

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| | | Lucy: No, well that, that's up here somewhere, like that.<br>Interviewer: Yep, so the hydrogen's not?<br>Lucy: Yeah.<br>Interviewer: What about the carbon oxygen? Does that go carbon, oxygen, carbon?<br>Lucy: No, the oxygen's up here.<br>Interviewer: Yep. So it's a double bond?<br>Lucy: Yeah, I think.<br>Interviewer: Yeah, it is.<br>Lucy: Oh yeah, so it is a double bond so it's not basic, it's an amide. Is it an amide?<br>Interviewer: Yep, that's correct. But that's still got that one there so that's still basic.<br>Lucy: The one on the right hand side is still basic, yeah.<br>Interviewer: Yeah. Oh OK yeah it's just the way that it's there. In a way specifically designed to trap **(3.202-3.235)** |
| multiple functional groups | Interviewer: How, what would you call amoxycillin then? Would you call it an acid or a base or something else?<br>Lucy: Um, it's one of those um, is that one of those amino acids or something like that?<br>Interviewer: It's like an amino acid, yeah.<br>Lucy: Yeah, um, I don't know. You would call it both or neither or something I think, I don't know **(2.255-2.258)** | Interviewer: what does that make the overall drug?<br>Lucy: (pause) Um, well that's one of those ones where it's three and it can change depending on the pH, is that right?<br>Interviewer: It is, yes.<br>Lucy: Um, I don't know what it would make it though. It depends on yeah, it depends on what pH it is **(3.257-3.260)** |
| dissociation of ibuprofen | *Carried out without significant verbalisation* | Lucy: It starts with that, and then, so what is it, 4 point?<br>Interviewer: four point four.<br>Lucy: I think I know how to do this. (pause while writing) Something like that? **(3.312-3.316)** |
| dissociation of amoxycillin | Lucy: OK, (writing) so you've got that, and you start with all of them on that, do you want me to like draw the whole thing?<br>Interviewer: Yeah, you can if you want to or you can just put the R.<br>Lucy: Yeah, I'll just put the, put the R and $CNH_3^+$, um and then, ah (thinking and writing). Make it COOH. So that's the first step, that's with everything on it. And then you go two point four, and then that just go R. Um. (pause). Next one is seven point four, (longish pause). Oops, not that. | *Carried out without significant verbalisation* |
| allocation of pKa values | | *Phenol and amine switched* |

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|---|---|---|
| addition of proton to amine | $NH_2$.<br>Interviewer: A single bond rather than, yeah.<br>Lucy: Yeah<br>Interviewer: OK, so, so um, you've done there, you've started with all the protons attached and then you take them off one by one **(2.380-2.389)** | Interviewer: One of the things that we said when we're doing these dissociation equilibrium is we always start with a particular form of the drug.<br>Lucy: Mm<br>Interviewer: Do you remember what that might have been? No? All protons have to be attached to start with.<br>Lucy: Oh, so that one's on there **(3.391-3.396)** |
| correct order of dissociation | | *Order correct* |
| prediction of form at specified pH | Interviewer: How does that help you to understand what happens to the drug under different conditions?<br>Lucy: Well, it just shows which, which, which form of it's going to be at different pKas, what, yeah, what it's going to look like.<br>Interviewer: At different pKas?<br>Lucy: Yeah.<br>Interviewer: What do you mean by that?<br>Lucy: Well, if it's going to be, if it's going to be bigger than nine point six it's going to be all of here, all this version.<br>Interviewer: Do you mean the pH bigger than nine point six or the pKa?<br>Lucy: Um, I don't know. It must be the pH because then you use your little table again which I drew before.<br>Interviewer: If you can find it, yeah, OK. OK, yeah. So the pKas are constant, you can't kind of change them. All right, so um, what would be the form that you would expect to be present at say pH 5?<br>Lucy: pH 5, um (thinking and looking through notes) So pH (pause) mm. Well at this pKa, pH 5 is bigger so this one's going to be unionised, (pause) no that's ionised I mean. At the second one, um, the p, what was it again? 5?<br>Interviewer: 5 yeah.<br>Lucy: pH equals 5, so the pH is less than the pKa so it's going to be unionised.<br>Interviewer: So that's the OH is unionised, the COOH is ionised, is that what you're saying?<br>Lucy: I think that means this one, that means this one and the next one is still, that's still smaller, right so that's unionised. Um. So which one's the most, which, what were you asking again?<br>Interviewer: What form would you expect to see at pH 5. | Interviewer: what pH, just looking at that equilibrium, what pH would be one where you could say that it was completely ionised?<br>Lucy: Completely ionised, that's that, we, um (longish pause) So,<br>Interviewer: Does it have anything to do with the pKa?<br>Lucy: Ah, I don't know. Yeah. No I can't remember.<br>Interviewer: Can't remember? OK.<br>Lucy: Nuh **(3.321-3.328)**<br><br>Interviewer: Remember one of the things that we did, well you may not remember and I'll tell you. One of the reasons we put the pKa on the arrows was to say, well if we had a pH on the left hand side, so if it was less than four point four, then the drug would be mostly in the form on the left hand side. And if we had a pH that was higher than four point four that is so that it was over on the right hand side, then the form of the drug at that pH would be mostly in the right hand side form. So in this case it would be ionised.<br>Lucy: Oh, OK. That's pKa?<br>Interviewer: That's pKa, yes.<br>Lucy: But you're saying when it's at a certain pH then it's one of these?<br>Interviewer: Yeah.<br>Lucy: Oh, OK.<br>Interviewer: So, at say pH 7, because 7 is on that side of four point four,<br>Lucy: It would be that<br>Interviewer: then it would be that form that predominates. That ring any bells, or not really?<br>Lucy: Yeah. Not the, well yeah it does ring some bells but just not the relationship between pKa and pH. Like, yeah. Can't remember **(3.329-3.346)** |

Transient change – Lucy

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| | Lucy: At pH 5. Um, I don't know. I don't know. (Pause) pH 5, I'm guessing maybe that one.<br>Interviewer: OK, it is, it is, but why would you guess that? Like, kind of what's<br>Lucy: Because the other two are unionised, that's the only one that's ionised **(3.389-3.418)**<br><br>Interviewer: The other way of looking at it is just to say well we've got these pKas here and what you were doing in your table is right, but another way of looking at it visually is to compare pH being greater than pKa or less than pKa. We can say a pH of 5 is greater than two point four,<br>Lucy: Oh, but it's less than seven point four<br>Interviewer: less than seven point four<br>Lucy: So it's the middle one<br>Interviewer: so it's the one with the, with the, in the middle.<br>Lucy: Oh, OK. Yep **(2.419-2.424)**<br><br>Interviewer: Yep, OK. Um, OK. With um, with the amoxycillin that you've drawn out here, would you, can you tell me a pH where it would be completely, or where it would be unionised?<br>Lucy: A pH?<br>Interviewer: Yeah, where amoxycillin would be unionised.<br>Lucy: Unionised, well that's just going to be, um, unionised, the pH has to be smaller than the pKa so, yep, so smaller than that, smaller than that and smaller than that. (tapping the page can be heard)<br>Interviewer: Uhuh. So at say pH, what 1?<br>Lucy: Yeah.<br>Interviewer: It would be complet, it would be unionised?<br>Lucy: Yep.<br>Interviewer: Any of those structures that you've drawn, are any of them unionised?<br>Lucy: Um, (pause) No they're all ionised. Oh so it's not, that's right it's not unionised, that's right, it's always, that one's always yeah<br>Interviewer: Always ionised?<br>Lucy: Always ionised **(2.463-2.476)** | |

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| strategies – preference for relying on the table and Larry | Well when pH, we learnt this little table, pH is less, less than the pKa, so for an acid, it's going to be unionised, unionised, and when the pKa, no when the pH is bigger than the pKa, it's going to be ionised **(2.308-2.312)**<br><br>I remember doing a question like that with Larry but he um, I think he just sort of did it and I didn't really, I didn't really sort of pick it up. Like he, he went through it but I didn't actually go over it afterwards. I think I just sort of thought oh, I'll remember it, but I didn't **(2.428-2.430)**<br><br>Lucy: At pH 5. Um, I don't know. I don't know. (Pause) pH 5, I'm guessing maybe that one **(2.414)** | |

## *Additional issues – interview 1*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| Non-scientific language about acids and bases | giving away **(1.162)**; takes one away from **(1.164)**<br><br>it'd move in that direction just to eat some of it up **(1.258)** | referring to donating and accepting protons<br><br>describing how equilibria re-form after a disturbance |
| Lucy's attitudes and beliefs about chemistry | Lucy: like it was a hard topic and you need to sort of keep, um, keep studying with it to remember stuff. Like that's, that the sort, all those sort of things I can probably usually answer if I keep, you have to keep sort of, like it's not something you sort of remember in your head forever, which is, yeah.<br>Interviewer: And why do you think that might be?<br>Lucy: Like, oh, I don't know, probably coz I don't really like it' **(1.300-1.302)** | Lucy's negative attitude towards chemistry is likely to have influenced her beliefs about her capabilities. Further, she specifically indicated that she need to **remember**, without reference to understanding the material. |





Transient change – Lucy

*Additional issues – interview 2*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| indifference towards content | I don't know, yeah, I don't know. I think it's just everything, like the whole, yeah the whole thing's been yeah there's no things that are more important than the others I don't think **(2.568)** | When asked what was the most important aspect she had learned during the semester, Lucy's ambivalence strongly suggested a lack of personal relevance and engagement with the topic. |
| relationship between chemistry and pharmacy | we've just had the whole lot of chemistry things so you sort of know how that works and then it's just a whole new different thing **(2.98)**<br>there was the same sort of things in there like you know, the pH and whatever, that was all the sort of the same thing, But yeah, just a few things were a bit different and I think once I'd studied it, you know, really really well for the exams I think that's when I sort of understood the differences **(2.100)** | Lucy perceived that there were commonalities and differences between chemistry and pharmacy, but struggled to articulate specific examples. |

# Transient change group: Emma

## *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | [acid] something that donates a proton **(1.2)**<br><br>[base] they accept protons **(1.16)** |
| names of theories | *Bronsted-Lowry, but named in survey only* |
| taste and feel | Interviewer: do acids have any other characteristics, any like physical or any other chemical characteristics?<br>Emma: Sour. Um, (pause) that'd be about as far as I'd go actually.<br>Interviewer: OK. Fair enough. What about bases?<br>Emma: Bases are bitter, and they're slimy **(1.9-1.14)** |
| corrosiveness | *Not described* |
| other characteristics | |
| Chemistry acids characterised primarily by pH | Interviewer: do you know what pH is for, what does it measure?<br>Emma: (pause) um, (pause) I imagine (pause) the acidity or alkaline of the solution **(1.89-1.90)** |
| strength described on the basis of complete and partial dissociation | strong completely dissociates in water. And weak doesn't **(1.46-1.48)** |
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | I don't know, pH (pause) equals the negative log of Ka or something like that **(1.96)** |
| use of mathematical relationship to solve numerical problems | *Carried out inconsistently* |

## Interview 2

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained without contextual discrimination | [acid] it donates a (slight pause) proton **(2.336)**<br>Bases accept protons **(2.346)** |
| pharmacy characterised by functional groups | *Not described* |
| physical characteristics – no apparent contextual discrimination | [acid] And um, taste-wise, it's (pause) sour **(2.338)**<br>[base] they're bitter. (pause) And slippery **(2.348)** |
| strength characterised significantly differently in pharmacy and chemistry | [strong acid] it dissociates, almost completely **(2.390)**<br>Nothing in, um, pharmacy is considered to dissociate completely, is it? **(2.406)** |
| pharmacy acids characterised by pKa rather than pH | Interviewer: what about um, pKas? How do they sort of mesh into um, your idea about acids and bases?<br>Emma: Um, I remember that that's the way that Pharmacy tends to classify acids. Um I mean I know what a, (pause) I don't tend to know exactly what pKa means. I have asked people, and they don't think, I don't think they know, either. I just know that pKa you know is equal to minus you know, um log of the Ka, yay! Um, and that you can use it to compare against pH, to find out you know, if things are ionised or whatever. But other than that, I don't think a lot of us know what it, I mean we know that high pKa you know, indicates a (pause) is it a strong (pause) base? Don't want to get this wrong. (laughs) And the other way round. Um, so we know how to use it. I don't think we actually know what (pause) it really means by itself **(2.367-2.376)** |
| strength in pharmacy characterised by values of pKa | |
| acids and bases in pharmacy both have pKa | |

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|---|---|
| pH and pKa in chemistry and pharmacy | Interviewer: do you think of acids as having pHs?<br>Emma: Acids as having pHs?<br>Interviewer: Yeah. Like if I said<br>Emma: (pause) I tend to think more of pKa. Um, yeah, I suppose so, I suppose I associate low pHs with acids, and high pHs with bases.<br>Interviewer: OK. Is that both in Chemistry and Pharmacy, in both those boxes?<br>Emma: (pause) Hmm, no. With Pharmacy, I tend to do (pause) associate, I (pause) I tend to just use it as that um, pKa is lower than pHs. That, that idea, I don't really think about pH by itself.<br>Interviewer: OK. In Pharmacy?<br>Emma: In Pharmacy.<br>Interviewer: In Chemistry, do you think pKa and pH, or pH?<br>Emma: I'm thinking pH, but I'm probably wrong. (laughs) **(2.755-2.768)** |
| in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | *Not specifically described* |
| Emma's strategies, particularly to deal with the consequences of her illness, using her perceived strengths | I just (pause) took it as yeah, OK, that's what they think **(2.412)**<br><br>you know what? I didn't put them together, did I? Coz that's the message we got at the end. So, I did the chemistry, and then went "IPS". And so, I mean there were differences in it. I think you just, you just learn lots. I don't know, I have this ability to just say "OK, well let's forget everything else you've learnt, just look at the, (pause) the one that you have to do now." So I just read your notes, and if you've said that something was a weak acid, then I said it was a weak acid **(2.296-2.300)**<br><br>Interviewer: you were happy to sort of say "Here's a box for Chemistry, here's a box for Pharmacy"?<br>Emma: Yeah, very much so **(2.413-2.414)**<br><br>I've always been a crammer. I just, I crammed the HSC, I cram all the time **(2.62)**<br><br>with the whole stuff where the pH is greater than the pKa, and whether it was ionised or not. Because (pause) with the Chemistry knowledge, I could just work it out, I didn't have to, like Larry recited the table, and so did Lucy, they, they could see the table and they went "Oh, yeah it's ionised, coz you know that ionised is in that corner, you know." Um, I ended up working it out, because I knew the chemistry of it **(2.322-2.326)**<br><br>I usually have an incredible memory. I think that most people get shocked with how much, how good it is…Like I, I can remember word for word conversations, and I'm terrible, with, (pause) if I have a fight with someone, I will never forget it, ever. I can remember exactly the quote that they said to me from kindergarten **(2.880-2.882)** |

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] It's a (pause) proton donor **(3.132)**<br>[base] it's a proton (pause) acceptor **(3.140)** |
| pharmacy characterised by functional groups | *Not described* |
| physical characteristics – no apparent contextual discrimination | [acid] sour taste **(3.134)**<br>[base] and it's bitter **(3.142)** |
| pharmacy acids characterised by pKa rather than pH | Interviewer: do acids have um, characteristic pHs?<br>Emma: (pause) Yes.<br>Interviewer: All acids?<br>Emma: (pause) Oh, hang on. (pause) No this is where I get confused. OK, here you go, they have characteristic pKa values, but they don't have characteristic pH values **(3.173-3.178)** |
| strength characterised significantly differently in pharmacy and chemistry | Now, I remember how many times you told us in lectures that there was a big difference. Um, isn't it just more the fact that pharmac, pharmaceutical products don't tend to dissociate completely, therefore they're mainly weak acids, weak bases **(3.208-3.210)** |
| strength in pharmacy characterised by values of pKa | if you've got a low pKa, you get a strong acid. Right. (pause) So, I suppose that this should be high, coz it's (pause) a weak acid. And (pause) low is a strong acid, and low is a weak base. But this is a strong base, so it has to be high **(3.384-3.392)** |
| acids and bases in pharmacy both have pKa | |
| pH and pKa in chemistry and pharmacy | Interviewer: What's the difference between pH and pKa?<br>Emma: Ohhh, I was trying to think of this just before I came. I'm thinking "She's going to ask me this and I have absolutely no idea."<br>Interviewer: OK, well tell me, tell me what you associate with pH?<br>Emma: (pause) pH, like I know what it is.<br>Interviewer: Yeah, well tell me.<br>Emma: Um, negative log 10 of the hydrogen ion concentration. Um (pause) so, I (pause) imagine that pH is more a measure of the, (pause) maybe of the solution, does that make sense? |

| | |
|---|---|
| difference between acids and acidic solutions | Interviewer: Yep, yep.<br>Emma: and that pKa is more (pause) of the acid itself, the the thing itself.<br>Interviewer: OK. Do you know what pKa refers to?<br>Emma: The negative log of the Ka concentration.<br>Interviewer: Ka concentration? Is Ka a concentration?<br>Emma: K, no, just Ka.<br>Interviewer: And what is Ka?<br>Emma: Ka's the acid dissociation constant, is it? **(3.181-3.198)** |
| pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | *Not specifically described* |
| Strategies and approaches | Interviewer: How did you, how did you bring that to the surface? Were you visualising it?<br>Emma: Yes.<br>Interviewer: So you could see something on the page?<br>Emma: Yes.<br>Interviewer: OK. Lots of people do that, I do that. It's an excellent way of remembering, I think.<br>Emma: Yeah. It's good for cramming. Like you turn over the pages in the exam, you're like "Oh God, I saw that, I saw that, where? Go back, go back, go back. There!" (laughs) **(3.159-3.166)**<br><br>I didn't experience that much trouble, but that's coz I really didn't have that many time to get my mind around the whole thing, it was just like, well look, if that's what Erica says, that's what you learn, that's what you write down. You don't have time to, you know, really take it in and start thinking, hang on, this does conflict **(3.212-3.214)** |





Transient change – Emma

| Characteristic | Transcript excerpt – interview 2 | Transcript excerpt – interview 3 |
|---|---|---|
| carboxylic acids | *Experienced no difficulty but did not verbalise* | *Experienced no difficulty but did not verbalise* |
| phenols | Interviewer: why is it a phenol?<br>Emma: Because it's got the benzene ring and the OH at the end **(2.513-2.516)** | *Experienced no difficulty but did not verbalise* |
| aliphatic amines | Amines is where I usually have a problem, because I usually don't know which ones they are **(2.432)**<br>I think that I was told that an ami, an amine um, is attached to different things **(2.478-2.480)**<br>I know that an amine is attached to (pause) a C, an, ah C that's sp, is it 3 hybridised? **(2.454)**<br>Interviewer: what $sp^3$ hybridised is, what would you look for?<br>Emma: Um, just single bonds **(2.459-2.460)**<br>if it has a double bond, then it's not an $sp^3$ carbon **(2.488)**<br>Interviewer: whereabouts are you looking for $sp^3$ carbons?<br>Emma: Um (pause) we'd be looking to see if this (pause) has single bonds, if it has a double bond, then it's not an $sp^3$ carbon.<br>Interviewer: That's right. OK, so you've identified that it's a nitrogen, you've identified it's attached to two carbons and, and a hydrogen, so what you then actually need to do is to say, OK, what are the carbons<br>Emma: What are the carbons attached to?<br>Interviewer: Yeah.<br>Emma: Which is, this is a double bond zero, right?<br>Interviewer: Yes.<br>Emma: Which probably means that it's not an $sp^3$ hybridised carbon. (laughs) And um, this one's attached to a benzene, which has got double bonds. So, you know what, I don't think it is any more. (laughs) Probably an amide **(2.483-2.498)** | that's an amine coz it's attached to a C, s, (pause) is it $sp^3$ hybridised? **(3.254)**<br>Interviewer: And lignocaine.<br>Emma: (longish pause) OK. (pause) That's not $sp^3$, is it, coz it's H to C. (pause) Er, so it's just (longish pause)<br>Interviewer: What are you looking for when you're looking for $sp^3$ carbons?<br>Emma: OK. I'm looking for the branches. So I'm looking (pause) oh, I can't remember. All right, hang on. I'm trying to think. (longish pause) Nup, that doesn't work, that one's not, because it's a double bond, isn't it, to the O?<br>Interviewer: Is it?<br>Emma: I don't know.<br>Interviewer: What does that group actually, that $NHCOCH_2$, if you were to draw it kind of, instead of just in a line, with all the bonds in, what would it look like?<br>Emma: The C double bond O $CH_2$, like that, and that's carboxylic is it? No, yes, no, because that needs a three. (pause) Ah, I don't know, I don't know. I wouldn't know **(3.263-3.272)**<br>Emma: and (longish pause) no, that's not an amine (pause) I don't think. No.<br>Interviewer: Why is it not an amine?<br>Emma: I don't know! That's what I'm getting confused about. Hang on, so it's attached to a carbon, carbon, carbon. (pause) No, it can't be, coz this carbon that it's attached to (pause). No, it's not.<br>Interviewer: OK, it's not, but the reason is because that carbon<br>Emma: Has got a double bond<br>Interviewer: has a double bond coming off it.<br>Emma: And this one, this carbon does have a double bond as well **(3.308-3.314)** |
| amides | | |

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|---|---|---|
| strategies – Emma's identification of amines and amides | Interviewer: And you're confident that's an amine?<br>Emma: Yes, because $NH_2$ usually is. (laughs) This is what happens if you leave it to the last minute, you work out your own little theories and they're usually wrong, but hey.<br>Interviewer: So essentially what you're saying is that you did an adaptive thing to say "The chances are that if I see an $NH_2$, it's going to be<br>Emma: An amine.<br>Interviewer: an amine, so I'm prepared to stick my neck out<br>Emma: Yes.<br>Interviewer: and say that"? OK **(2.521-2.529)**<br><br>I just usually know to look at that and go "No, that's not it." **(2.560)**<br><br>But you know, I never bothered to work out if it's $sp^3$ hybridised, coz it takes too long, so usually I just guess… I'd have to draw, draw this out, see I'm not very good at this **(2.456, 2.464)** | |
| multiple functional groups | That would mean it's (pause) neither, because it's got acid, acid and base, and (pause) that means neither **(2.532-2.534)**<br><br>In my mind, the explanation is I wrote it down on the paper that it said if there was different ones, it's neither. um, personally, I would think that this is probably, I mean I would expect looking at it that it'd be acid, because it's got two acids and one base. But I read that it said neither, so I'm going to say neither (laughs) **(2.536-2.538)** | Emma: So that means it's acid, weak acid, base. (pause) Probably acid.<br>Interviewer: And why do you say acid?<br>Emma: (pause) Because there's more acid? (laughs)<br>Interviewer: There's more acids than bases. OK.<br>Emma: I'm guessing. Yeah **(3.288-3.292)** |
| dissociation of ibuprofen | Um, I know I just put R and then COO, (pause) actually, I, I did work this out from um (pause) looking at the past tutes, when you did your answers, you just did that, so **(2.620-2.622)** | *Carried out with minimum verbalisation* |





Transient change – Emma

| | | |
|---|---|---|
| dissociation of amoxycillin | the lowest always goes to the acid, and the highest always goes to the base. And this one's a weak acid, so I put it in the middle **(2.660-2.662)**<br><br>Interviewer: carboxylic acids, pKa range of 2 to about 5 and a half. Phenols range of about 9 to 11, and bases could be anything.<br>Emma: Oh! (pause) Oops.<br>Interviewer: So what would that mean then, in terms of the ionisation, ah the pKas? Which one, would you revise anything there?<br>Emma: Say it again? (laughs)<br>Interviewer: Carboxylic acids 2 to 5.5, phenols 9 to 11, and bases can be anywhere, amines can be anywhere<br>Emma: Oh, yeah, I probably would. I'd probably put this [phenol] as the 9 **(6.669-6.678)** | Emma: Not really. I, I didn't experience that much trouble, but that's coz I really didn't have that many time to get my mind around the whole thing, it was just like, well look, if that's what Erica says, that's what you learn, that's what you write down. You don't have time to, you know, really take it in and start thinking, hang on, this does conflict. No, not really.<br>Interviewer: So, no, no conflict that you're aware of, OK.<br>Emma: Except for when I did the entire thing wrong. With the um, you know how you made me circle the functional groups, and I got it wrong, the first time round **(3.212-3.222)**<br><br>Now this is where I got it wrong. OK. Hang on, let's see if I can work this right. This has to be two point four, and before I think I would have said that this was nine point six, because it's a base, but I remember you said last time that it was wrong, so there we go **(3.358-3.362)**<br><br>Well, see, this is what I don't understand, because you'd think that that's a weak (pause) acid, therefore you'd think that it would have a lower pKa than the base. Which was my theory in the first place. But I remember being told that was wrong, so I just remember thinking "Cross out, doesn't work, but just (pause) think about it that way and then go back." **(3.366-3.370)**<br><br>Emma: my thing is that if it, the lower the pKa, the stronger yeah, an acid is. Yeah. I suppose that would make sense, then, wouldn't it? (pause) …Hang on a tick, (pause) if you've got a low pKa, you get a strong acid. Right. (pause) So, I suppose that this should be high, coz it's (pause) a weak acid. And (pause) low is a strong acid, and low is a weak base. But this is a strong base, so it has to be high. But it still doesn't explain to me why they're that way.<br>Interviewer: I think that the tricky, well the tricky bit is recognising that you can have an acid with a higher pKa than a base. Because that's kind of counter-intuitive from chemistry, coz you're always thinking in terms of chemistry, acids low, bases high, don't you?<br>Emma: Yep. But it's all, more the fact that um, yeah, this is a strong base, isn't it? And this is a strong acid. So you'd think that (pause) in the scheme of things, a weak acid should be below a strong base **(3.365-3.400)** |
| allocation of pKa values | | |

| | | |
|---|---|---|
| addition of proton to amine | and that goes R (pause) Oh oh, hang on, I've done something wrong. Wooshka I've done something wrong. OK we have to make this all (pause) like that, don't we? And then we make this, so this is 3 plus **(2.698-2.700)** | Emma: (long pause) I don't know if this is how you can represent it, but I'm not writing out that thing. (pause) OK, seven point four, so then you get (long pause) ohoh, hang on, wait a second, did something wrong. (pause) I was supposed to (pause) protonate this, wasn't I?<br>Interviewer: You were, but that's all right.<br>Emma: So three to the plus?<br>Interviewer: It's not too late, you've recognised it now.<br>Emma: And this goes to, (pause) and so in this case I go 3 H. And then (long pause) and then, the rest of them (pause) and this is nine point six **(3.404-3.412)** |
| correct order of dissociation | *Carried out with minimum verbalisation* | |
| prediction of form at specified pH | Emma: The pKa's four point four?<br>Interviewer: Yeah. Why do we write the pKa up on top of it, the arrows, apart from the fact that I said to?<br>Emma: (pause) I really don't know. I just know that that's what you do.<br>Interviewer: OK, if I said to you what form of the drug dominated at pH 6?<br>Emma: pH 6? Um, it would be there.<br>Interviewer: The one on the right hand side.<br>Emma: Yeah.<br>Interviewer: And why do you say that?<br>Emma: Because (pause) it would be, because um, it's over on this side, it's larger than four point four. Go to the right.<br>Interviewer: So that's why we put the pKa up there, so that visually, you can um, identify what form<br>Emma: Oh OK.<br>Interviewer: predominates at particular pHs. OK? At what pH would you say that the drug was completely ionised?<br>Emma: Um (pause) above four point four, probably way above four point four on the other end, so about 12?<br>Interviewer: It would be at 12, but what would be the lowest pH that you could say that it was completely ion, completely ionised?<br>Emma: Ooh, I wouldn't know.<br>Interviewer: You didn't get to that bit?<br>Emma: I don't think so, I think I completely lost that.<br>Interviewer: OK, 2 pH units above the pKa?<br>Emma: Oh, OK, yes, yes, I do get that yes.<br>Interviewer: Does that ring a vague bell? | Interviewer: at what pH would you say that that molecule [ibuprofen] would be completely ionised?<br>Emma: (pause) OK hang on, we established that it was an acid. Rightio. (pause) When pKa, when pKa's greater than pH, so (pause) when the pH (pause) is (pause) less than four point four, that doesn't work, does it? Yes it does. (pause) That means it's in, the acidic form. (pause) That's going to be it, yeah. When it's less than (pause) four point four.<br>Interviewer: It's in its acidic form. Is that the ionised form or the unionised form?<br>Emma: Oh, that's the unionised form. So, when you want it (pause) ionised, you need greater than that.<br>Interviewer: Uhuh. How much greater would make it completely ionised?<br>Emma: Um, two units away from (pause) where they're equal. Isn't it, no? Yes.<br>Interviewer: OK yeah. Where are they equal? What pH would they be equal?<br>Emma: four point four.<br>Interviewer: OK. So, at six point four and above?<br>Emma: six point four, yes.<br>Interviewer: OK, and what about completely unionised?<br>Emma: (pause) Below, two point four **(3.341-3.354)** |

Transient change – Emma

| | | |
|---|---|---|
| | Emma: Yes, it does. OK.<br>Interviewer: OK. And completely unionised?<br>Emma: Would be 2 below **(2.624-2.648)**<br><br>that's [amoxycillin] always ionised **(2.650)**<br><br>it pretty much covers all the range of pKas and at every stage, there's something that's been lost. Or, you know, in the ionised form **(2.724)**<br><br>Um, because they're (pause) far away, and um (pause) because they're not in close contact with each other? **(2.746-2.748)** | |

*Additional issues – interview 2*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| Emma's study resources | Which is my problem because um, I tend to, no matter how much or little time I have, I still do it pretty much in depth. So, when I'm learning stuff, I'd learn everything that could possibly be asked on that topic, and that way I can say "I've done that, and now I've got this to go." (laughs) I do that with everything. I learn so much in depth that you couldn't possibly be asked everything, but at least confidence-wise, I'm very comfortable in that area. So, um, I went to the orange book, and because I was lacking in a lot of notes, um, the first few ones, like section 1 and 2, and a bit of section 3 I had, but the rest of them, no, um it was just bits and pieces. Um, so I went to the orange book a lot, read it. Section 4 I didn't understand the orange book, um…That bit I didn't understand, um from reading it, I didn't. And the formulas just looked so complica, complicated, I just went "Oh my God." Um, I did a lot of work at night, by myself, um, I think because when there are people around me, especially, we've been doing this experiment ah, in college, ah, that Larry, Lucy and I will go and do group work. That's how we did Chemistry. And if it wasn't for that group work, there is no way I would have passed. Because Larry was really good at the um, amino acids, I think he did it in HSC. Um, so he could teach us that, and we taught him other things, like the, you know, um, organic chemistry drawing, which he didn't know how to do, so, it was absolutely brilliant. So I tried to do it for IPS, and it had an adverse affect on me. I just gave up. I just went, "Oh my God, they know so much. I don't know that, I don't know this, I don't know that." It stressed me out. So, it was at night, that when nobody was there, I could cry myself, and then go "OK, get on top of it, you can do it. Work tonight and then see how you, you go with it tomorrow" you know. So, I think, I don't know. I, I did read the orange book a lot **(2.126-2.150)** | Emma indicated that she adopted her usual study patterns of attempting to learn as much as possible about each topic, using all of the resources available, however in the case of IPS she was hindered by incomplete lecture notes. Where she had some understanding of the basics, she could use the orange book, or course reader, and could seek assistance from her peers to supplement her notes, but where she had no understanding of the fundamentals (section 4) she could not work though the orange book and was intimidated by the amount that her peers apparently knew. She was willing to ask questions occasionally, but not to the extent that she felt she needed, and did not always receive a sympathetic response to her difficulties. |

Transient change – Emma

| | | |
|---|---|---|
| | Larry ended up helping me with the chemic, the chemical balance thing, he sat down for five minutes and helped me, and I yeah, I wouldn't have been able to do it without him, because I didn't understand it. Um, and Geoffrey helped me with one question that I couldn't do **(2.152-2.154)**<br><br>I tend to not ask [Janine for assistance], rather than ask, um, but when I do ask, she's usually good, if you have one or two questions. If you have any more than that, then you're pushing it **(2.192-2.194)**<br><br>Geoffrey was great. He's been wonderful, he's been there, I mean he doesn't do much work, or he doesn't seem to do much work. I think he probably does it consistently throughout the term, I don't see how he would know it, unless he did. Um, but during the exams, he definitely took it, you know, relaxed, and. He was usually the person, if you really did have a stressful period, you'd run to him, and say "God, tell me that it's not that bad." and he'd sit there and go "No, it's easy, don't worry about it, you'll be fine", you know **(2.210-2.216)** | |

# Persistent change group: Veronica

## *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | something about hydrogen accepting and donating hydrogens **(1.150)**<br>I think with the strong acids they would more readily donate their hydrogen, their proton. Um, yeah and the, the weaker ones would not do so as readily **(1.152-1.154)** |
| names of theories | *Not given* |
| taste and feel | [acid] Ah, sour, like, um, yeah something, a liquid that's acidic **(1.2-1.4)**<br>A base. I think of something powdery **(1.24)** |
| corrosiveness | [acid] OK, it would be um, corrosive, um, (pause) it would dissolve things, in that, I don't know. I think about like um, metals, like, it makes gases **(1.12-1.18)**<br>bases would also be corrosive I think **(1.46)** |
| other characteristics | [base] something that can neutralise an acid **(1.26)** |
| Chemistry acids characterised primarily by pH<br>strength described on the basis of pH rather than complete and partial dissociation | Veronica: Um, (pause) it has a low pH which, um, yeah, that would make it stronger. Yeah<br>Interviewer: And a weak acid?<br>Veronica: And a weak acid would have um, a higher pH<br>Interviewer: OK. Does that sort of strong/weak um, distinction also apply to bases?<br>Veronica: Yes.<br>Interviewer: OK. So what would, what do you, what's characteristic of a, say a strong base?<br>Veronica: Ah, well, bases would also be corrosive I think and ah, a very strong base would have um, a high pH whereas a, a weaker base would have a lower pH **(1.34-50)** |
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | Interviewer: That comes as a numerical scale doesn't it?<br>Veronica: OK, yeah.<br>Interviewer: Do you know what the numbers might relate to?<br>Veronica: Um. (pause)<br>Interviewer: In general terms if, if, if not in specific. Like what does, what's pH a measure of for example?<br>Veronica: Oh, no, I don't know. (laughs)<br>Interviewer: Don't know? OK. Does it, does it ring a bell to say it's a measure of the hydrogen ion concentration?<br>Veronica: Oh, yeah. Oh, yeah, the concentration of them, yeah.<br>Interviewer: Of hydrogen ions, OK. So, would a low, what does it, what sort of, if we had a low pH, would that mean a high concentration of hydrogen ions or a low concentration of hydrogen ions?<br>Veronica: High. |

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| | Interviewer: High concentration, OK. If we had um, so if we had a high pH what would that mean about the hydrogen ion concentration?<br>Veronica: It would be very low **(1.159-1.171)**<br><br>because um, all those numbers they, they kind of, like we use them with ten to the minus whatever so ten to the minus 1, that would be pH of 1 and that would be a large number as compared to ten to the minus 14, which is a smaller number **(1.172-1.180)**<br><br>Interviewer: Can pH ever refer to hydroxide ions?<br>Veronica: Um, pH, no. Um, usually I would think of that as pOH.<br>Interviewer: OK, and what's pOH then?<br>Veronica: Um, well, considering your definition, then it would be um, the concentration of hydroxide ions **(1.181-186)** |
| use of mathematical relationship to solve numerical problems | *Carried out inconsistently* |





Persistent change – Veronica

*Changes to existing understanding*

**Interview 2**

| Characteristic | Transcript excerpt |
|---|---|
| holistic description of acids and bases in chemistry and pharmacy | acids in chemistry um, are either strong or weak um, depending on how easily they can um donate a proton, and that's the same in pharmacy except there's this kind of continuum where you talk about one being stronger than the other. Um (pause) um, and in pharmacy we talk about acids, um drugs being acids when we mean like they have acidic functional groups, um, whereas in, in chemistry when we talk about an acid, it's an actual thing, the thing, the whole thing is an acid, yeah. Um, oh yes, and just going to the other point, in chemistry I don't really associate acids with having salts, whereas in pharmacy, we do **(2.696-2.708)** |
| ability to gain and lose protons retained for both contexts | Interviewer: having a carboxylic acid group or a phenol group or an amine group, how is that related to being an acid or a base, like what's so special about them?<br>Veronica: Um (pause) what do you mean by that? It changes the behaviour of the drug, um, how it dissociates.<br>Interviewer: OK, So how, how does carboxylic acid dissociate?<br>Veronica: Ah, (pause) well you just take off the protons…and um bases gain protons to become charged **(2.305-2.316)** |
| pharmacy characterised by functional groups | when you talked about acids you talked about like the acid functional groups on the drugs, on the acidic drugs and basic drugs **(2.254-2.256)**<br><br>I thought about a drug and it having like acidic functional groups and another drug so therefore you called it an acid but then another drug that had basic functional groups and that was a base, basic drug, yeah **(2.260-2.264)**<br>Interviewer: given that we're talking in a pharmacy context, what makes um, something an acid? What do you think of as being characteristic of an acid?<br>Veronica: Um, (pause) I think of like, functional groups like um carboxylic acid functional groups and phenol. Um (pause)<br>Interviewer: What about bases then?<br>Veronica: Bases, um, having amine functional groups **(2.295-2.304)** |
| difference between acids and acidic drugs | I thought about drugs as like entities, and then like in chemistry an acid is an acid, it's, it's not a drug **(2.268)** |
| chemistry but not pharmacy characterised by physical characteristics | Interviewer: Would you say Pharmacy, well in Chemistry or Pharmacy, do you associate acids with an idea of being corrosive?<br>Veronica: Yeah<br>Interviewer: In both or just in one?<br>Veronica: Well, in Chemistry but not in Pharmacy<br>Interviewer: OK. Why not, why don't you think of them as being corrosive in Pharmacy?<br>Veronica: Um, because (pause), um, well, drugs shouldn't be corrosive (both laugh) **(2.711-2.716)** |
| pharmacy acids characterised by pKa rather than pH | Interviewer: in terms of pH, do you think of acids as having a pH?<br>Veronica: Yes.<br>…<br>Interviewer: is that just in chemistry or is that in pharmacy as well?<br>Veronica: Ah, well in chemistry yes, um, in pharmacy, um, not as much **(2.363-2.374)** |

Persistent change – Veronica

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|---|---|
| strength in pharmacy characterised by values of pKa | well this is a strong acid so it has a low pKa and this is a weaker, not as strong acid…higher pKa, yeah **(2.582-2.586)** |
| strength characterised significantly differently in pharmacy and chemistry | Veronica: the concept of strength and um, how in pharmacy we talk about strength in um, relative um, values, like um, this is stronger than that, yeah.<br>Interviewer: And in chemistry?<br>Veronica: And in chemistry it's um, well this is a strong acid and this is a weak acid **(2.274-2.282)** |
| acids and bases in pharmacy both have pKa | Veronica: I guess we talk about it a lot so I have kind of a better understanding of it. Um, oh yeah, just the fact that we use pKa for both acids and bases.<br>Interviewer: OK, that's different is it?<br>Veronica: Yes. I used to think about pKb as well. Yeah.<br>Interviewer: OK. Um, does, is it confusing to have pKa for a base?<br>Veronica: Um, no, not now **(1.336-344)** |
| in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | *Not addressed by the interviewer or mentioned by Veronica* |





Persistent change – Veronica

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | I'd say that an acid would act by um, donating its protons **(3.200)**<br><br>bases, well um, they would accept protons **(3.204)** |
| pharmacy characterised by functional groups | well a drug is acidic because it has an acidic functional group on it **(3.194)**<br><br>Veronica: They have like similar meanings but there is a shade to the meanings within chemistry and pharmacy.<br>Interviewer: OK. Can you expand on that a bit more for me?<br>Veronica: Yeah. Um, ah, (pause) um, OK. In, I think in pharmacy we call things ah, acidic if they have like acidic functional groups, and um, then that leads to like strong and weak and so sometimes when we talk about strong acids in pharmacy they're not strong acids in chemistry **(3.222-3.230)** |
| chemistry but not pharmacy characterised by physical characteristics | *Not described* |
| difference between acids and acidic drugs | Acidic drugs have, um, acidic functional groups on them but there's like other parts to the drug as well. Whereas acids are just acids itself **(3.290-3.294)**<br><br>Interviewer: was there a particular thing that helped you make the distinction between chemistry and pharmacy or was it pretty easy?<br>Veronica: (pause) I don't think there was anything in particular **(3.297-3.298)** |
| pharmacy acids characterised by pKa rather than pH<br><br>strength in pharmacy characterised by values of pKa | Interviewer: So how is that described in chemistry and pharmacy, in terms of strength.<br>Veronica: Ah, how is it described? Um, in chemistry we don't, we kind of talk about things in pH whereas I found that in pharmacy we talk more about pKa **(3.235-3.238)** |
| acids and bases in pharmacy both have pKa | *Implied but not specifically stated* |





Persistent change – Veronica

| | |
|---|---|
| pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | Veronica: Um, pKa is kind of, we talk about it when we talk about the acid dissociating um, and, um, yeah (laugh). Ah, yeah, with pH, um there's a delineation at number 7, at pH of 7 and that makes things either acidic or basic. Um, acidic is below 7 and basic is above. Um, but with pKas it's a bit strange to me because, um acids can have pKas of ah, above 7.<br>...<br>Interviewer: So how can an acid have a pKa of greater than 7? What does that mean about the acid?<br>Veronica: Um, it means that it doesn't readily donate its proton, it's like how easily it donates the protons.<br>Interviewer: OK. So if it doesn't ah, easily donate its proton and it's got a pKa greater than 7, how would we describe that?<br>Veronica: Um, we would describe it as, um, a weak acid.<br>Interviewer: A weak acid. OK. So what would a strong acid be?<br>Veronica: A strong acid, an example of one?<br>Interviewer: No, the, in terms of pKa and what it does?<br>Veronica: A lower pKa.<br>Interviewer: So, less than<br>Veronica: less, um, like, less than 7 **(3.242-3.266)** |
| strength characterised significantly differently in pharmacy and chemistry | Interviewer: Coz you said you tend to talk more about pH rather than pKa. So in pharmacy we define a strong acid is a pKa less than 7, how does chemistry define a strong acid?<br>Veronica: Ah, (pause) it, um, how do we do it? (laughs) Um, yeah it's also how easily it donates a proton but, um (pause) I don't know.<br>Interviewer: OK. That's good because I'd rather you remembered the pharmacy definition and not the chemistry one. (laughs)<br>Veronica: Yeah.<br>Interviewer: Do you remember talking about complete dissociation versus partial dissociation?<br>Veronica: Oh, yep.<br>Interviewer: Does that ring a bell?<br>Veronica: Uh huh.<br>Interviewer: OK, so is that how they make the distinction?<br>Veronica: Oh, yes, it is, isn't it. Oh, so that's the difference, if it's complete or partial compared to how easily. Oh.<br>Interviewer: Yeah. So chemistry kind of has a, it's kind black and white. If it's complete then it's strong, if it's not complete then it's weak.<br>Veronica: Oh, OK<br>Interviewer: But pharmacy is kind of a range thing. It's comparative rather than the two extremes.<br>Veronica: Oh, yeah. I remember thinking that one time but I forgot it **(3.271-3.288)** |



Persistent change – Veronica

*Concepts new to pharmacy*

| Characteristic | Transcript excerpt – interview 2 | Transcript excerpt – interview 3 |
|---|---|---|
| carboxylic acids | | |
| phenols | this is not a phenol because this is not a benzene ring **(2.502)**<br>this is a phenol so that's like, acidic **(2.514)** | |
| aliphatic amines | yeah, well I just look at this and then I see the N, and then um, to be, to be a basic N it has to be attached to a carbon which is $sp^3$ hybridised which is like a tetrahedral shape, and um, I can, and that usually occurs when there's no double bonds, so since there's no double bonds there, then I'm thinking that it should be a base **(2.492-2.498)**<br>Veronica: Ah, wait (pause), oh well maybe it is<br>Interviewer: What else apart from $sp^3$ hybridised carbons um, is the nitrogen allowed to be attached to?<br>Veronica: It can be attached to other atoms, like hydrogens<br>Interviewer: Actually hydrogen is about the only other thing that it can be attached to.<br>Veronica: So this should be a base **(2.520-2.526)** | OK that would be amine **(3.312)**<br>Because it's got ah (pause) carbons coming from it and there's three bonds coming from it um, whereas amides are different because it's joined to a carbon which has, which is then joined to an oxygen **(3.322-3.326)**<br>Oh, something about hybridisation, $sp^3$ hybridised, has to, something about the nitrogen has to be um, connected to a, a carbon which is $sp^3$ hybridised. OK, so OK. This one, um, no that wouldn't be $sp^3$ hybridised, no **(3.412-3.416)** |
| amides and non-basic nitrogens | ah I just look at all the Ns first and I say well no this one can't be basic because it's attached to a carbon which is like in a benzene ring **(2.508)** | |





Persistent change – Veronica

| | | |
|---|---|---|
| multiple functional groups | Interviewer: you've got one base, and two acids. Why do you think it's neither? Why, why not call it an acid coz it's got two acids? Veronica: Um, well at this point you can't, I can't, um, quantify, like um, the ratios of how much acid is there and how much base is there, so yeah, I just call it neither. **(2.553-2.554)**<br><br>Interviewer: So that's one of the other reasons why we call it neither, is it doesn't form salt like, salt forms like an acid or a base. But, I mean it is, it is attractive to think 'Well, yeah that would make sense' because that one's got the strongest functional group, so that would be able to form a salt, but it kind of doesn't work that way because, we'll look at it in a minute, but it doesn't, we'll come back to it. The other reason why we don't call it an acid or a base is tied up with it, and it's, it doesn't behave in terms of ionisation um, where we've looked at pKa and pH, it doesn't have um the characteristics that um, acids and bases do. So, characteristic of acids is that at pHs below their pKa they're unionised. Um, and with bases, at pHs above their pKa they're unionised. Molecules like amoxycillin don't behave like that and so we don't call them acids and bases **(2.561)**<br><br>Interviewer: Coz you can't draw a um, a structure that doesn't have a charge on it. Coz at really low pHs, so you know, down all the way down to one or, or zero, it's gonna have the charge there, and it doesn't lose that um plus off the nitrogen until after it's lost the um H off the carboxylic acid group. So, you've always got that charge somewhere on the molecule. And that's kind of what I meant before, it's another reason why we don't call something like this an acid or a base, coz it's never unionised at any pH, it's always completely ionised, and so it, you can't say well it behaves like an acid because an acid, there are pHs where it's unionised.<br>Veronica: Oh, yeah<br>Interviewer: And the same with bases, there are pHs where the base is actually unionised. So that's kind of one of the reasons, that's the other big reason why we say well it's not an acid, it's not a base. It's something odd. Do you remember what we called that sort of form?<br>Veronica: Ah<br>Interviewer: With a plus and a minus?<br>Veronica: Ah, a zwitterion<br>Interviewer: A zwitterion, yeah. So it's not saying that it's neutral, but it's saying that it's not, it's not clearly an acid or clearly a base **(2.677-2.687)** | I don't think you can say it's either basic or acidic…because, ah, has more than one, and you can't really assume that they would cancel each other out or they would be stronger than the other or something like that **(3.378-3.384)** |

Persistent change – Veronica

<table>
<tr><td>dissociation of ibuprofen</td><td>Not required</td><td>Carried out with minimum verbalisation</td></tr>
<tr><td>dissociation of amoxycillin</td><td rowspan="3">Carried out without significant verbalisation<br><br>Yep, OK, so I have to add on a proton here (2.626-2.628)</td><td rowspan="2">Carried out without significant verbalisation</td></tr>
<tr><td>allocation of pKa values</td></tr>
<tr><td>addition of proton to amine</td><td><u>Veronica</u>: Oh (pause while writing) um, we have to start it off with everything attached.<br><u>Interviewer</u>: Yeah, so that makes it $NH_3^+$, yep (3.514-3.517)</td></tr>
<tr><td>correct order of dissociation</td><td><u>Veronica</u>: Um, then what's first, two point four I'd say that would be that one coming off there<br><u>Interviewer</u>: The carboxylic acid yep<br>…<br><u>Interviewer</u>: OK, seven point four next (watching Veronica write)<br><u>Veronica</u>: Ah, that would be ah, the phenol, (long pause while writing) nine point six (3.518-3.528)</td></tr>
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Persistent change – Veronica

| | | |
|---|---|---|
| prediction of form at specified pH | Interviewer: can you tell me um, what form the drug would be in say at pH 5?<br>Veronica: 5, um, it should be in this form because, yeah, yeah, it should be there **(2.653-656)**<br><br>Interviewer: OK. Is there any pH, can you work out from that then, a pH where um, amoxycillin would be completely unionised?<br>Veronica: Unionised, so that means in this form?<br>Interviewer: Well, it means without any charge on it.<br>Veronica: Ah, without any charge. Oh, coz that has a charge, mm<br>Interviewer: Uhuh, so the first one's got a plus on it (tape ends) Can you find one?<br>Veronica: Um, not really sure how you would do that<br>Interviewer: Well, you've seen the first one's got a plus on it, what's the second one got on it?<br>Veronica: It's got a plus and a minus.<br>Interviewer: And the third one?<br>Veronica: A minus. Is that?<br>Interviewer: And the fourth one?<br>Veronica: Ah, two minuses.<br>Interviewer: OK, so what does that suggest to you about the possibility of finding an unionised form?<br>Veronica: Um, oh, it should be ionised at, it should be ionised to some extent at any pHs that you've chosen. laughs)<br>Interviewer: Well, it's more than just to some extent – it's completely ionised<br>Veronica: It's like, oh, completely ionised at all pH **(2.659-676)**<br><br>Interviewer: at what point we would say that that acid is completely unionised, at what pH it would be completely unionised?<br>Veronica: Completely unionised, so, um it should be like, this way um, two pK, no two units below the pKa.<br>Interviewer: OK, so that would be pH of?<br>Veronica: Oh, 3 and under<br>Interviewer: Yep, and where would it be completely ionised?<br>Veronica: Um, 7 and yeah, over **(2.725-2.738)** | well with um more low pKa, that would um, mean that, it more readily goes to this side. And higher ones would mean that it more, more likely go that way **(3.458-3.462)**<br><br>Interviewer: what pH would you need for that drug for it to be completely in its COO minus form?<br>Veronica: Um, I think it would have to be a pH above this pKa<br>Interviewer: How far above? For it to be completely, or effectively completely in that form?<br>Veronica: (pause) Two? **(3.467-3.476)**<br><br>Interviewer: what state of ionisation is it [amoxycillin] in at different pHs?<br>Veronica: What state of ionisation?<br>Interviewer: Mm<br>Veronica: (pause) No<br>Interviewer: No? OK, is it ever unionised?<br>Veronica: Oh, no, no it isn't.<br>Interviewer: No, OK, so it's ionised at all pHs **(3.577-3.563)** |



Persistent change – Veronica

| | | |
|---|---|---|
| interchange of pKa for phenol and amine in amoxycillin | | well I, I know that's like a weaker acid, but it's not, ah, but I know that this is a base so it would have to be, the pKa for the acid would be lower than the one for the base yeah, um that's what I thought **(3.534-3.538)** |





Persistent change – Veronica

# Persistent change group: Denise

## *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | acid is a proton donor. Yeah, um. (pause) That's all I can remember…base is a proton acceptor **(1.2-1.4)** |
| names of theories | *Mentioned only in written survey* |
| taste and feel | Denise: people have to like, they think like acids as being like a sour tasting.<br>Interviewer: Uhuh. OK. Yeah, that's fine. Do they think of bases as having a particular taste?<br>Denise: Not really, not that I know of **(1.164-1.166)** |
| corrosiveness | And then basic things can be caustic I think, something like that **(1.38)**<br>if they're really strong acids they can burn as well **(1.44)** |
| Chemistry acids characterised primarily by pH | Acid has a higher pH, I mean lower pH, yep um, and yeah which is opposite to a base which would have like pH higher than 7 **(1.30-1.32)** |
| strength described on the basis of complete and partial dissociation | Denise: There's like weak and strong acids and weak and strong bases as well, they have different properties.<br>Interviewer: All right, well can you tell me, expand a little bit on the weak acid, what makes a weak acid different from a strong acid?<br>Denise: Um, they don't dissociate completely.<br>Interviewer: Which ones?<br>Denise: The weak acids **(1.54-1.58)** |
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | things with low pH would be acidic, and at the high scale like up to 14, 7 to 14 it's basic and in the middle 7 is neutral **(1.112-1.114)**<br>There's like pH equals $H^+$ (pause) um, to the, wait, 10 to the (pause) there's somewhat relationship. $H^+$ equals ten to the pH or something like that **(1.118)**<br>Interviewer: if we had a solution of pH 2, what would that tell you about the, what's in that solution?<br>Denise: Um, there's quite a high concentration of $H^+$ ions **(1.125-1.128)** |
| use of mathematical relationship to solve numerical problems | *Not carried out* |

## Interview 2

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] Well it donates a proton **(2.404)**<br>Bases are just the opposite of those three things. Like they can, they (pause) um not donate but accept protons **(2.420-2.422)** |
| pharmacy characterised by functional groups | You'd look for acidic groups, which are like, COOH and phenol **(2.430-2.432)**<br>$NH_2$, like the amine **(2.436)** |
| chemistry but not pharmacy characterised by physical characteristics | I kind of think of acids in pharmacy as pretty harmless…we're studying them so we can make them useful, like to dissolve and things. But I don't really think of it, yeah, as corrosive **(2.1022-2.1026)** |
| other characteristics, particularly differences | [acid] it forms salts with (pause) cations, which are like positive ions **(2.404)**<br>[base] they form salts with anions, which are negative ions **(2.422)** |
| pharmacy acids characterised by pKa rather than pH | for strong acids because they lose it very easily…so it has a really low pKa' **(2.378-2.382)**<br>strong bases it likes to hold onto the proton really, like a lot, so it has a high pKa because it's really hard to remove that proton **(2.384-2.390)**<br>Interviewer: Uh huh. OK, so, something that makes the drug acidic is the functional group rather than something else about it?<br>Denise: Um (pause) yeah, and also look at the pKa, if it's given. But then you can't always tell because like a weak, a weak acid might have the same range of pKa as a strong base. I mean, yeah, strong<br>Interviewer: Yeah, yeah, that's quite true, yeah.<br>Denise: So you can't rely on the pKa **(2.437-2.442)**<br>Denise: I think like, at different pH like the drugs may be in different forms so that's important that way. So whether they're acidic or basic will make a difference like to the reactions that they undergo.<br>Interviewer: What do you mean by different forms?<br>Denise: Um, like basic or acidic forms, like ionic or un-ionised, yeah, and because you said like being, the solubility is really important so pH will affect solubility **(2.450-2.460)**<br>before I used to think that if it has a low pH then it must be an acid but now I just think of it in terms of pKa **(2.462-2.464)** |
| strength in pharmacy characterised by values of pKa | |
| acids and bases in pharmacy both have pKa | |
| strength characterised significantly differently in pharmacy/chemistry | pKa means like how easily they lose or hold onto…a proton **(2.376-2.378)**<br>if we're talking about the strength then in chemistry it has a different definition to pharmacy…how to measure the strength **(2.1000-2.1006)** |

Persistent change – Denise

| | |
|---|---|
| in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | Interviewer: do you have any difficulty with the pKa of a weak acid?<br>Denise: No, because it's high.<br>Interviewer: Yep, OK, high meaning in what sort of numbers?<br>Denise: Above 7 **(2.469-2.472)** |

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] it can be like a proton donator **(3.188)**<br>[base] proton donator, I mean acceptor **(3.194)** |
| pharmacy characterised by functional groups | *Implied but not specifically stated* |
| chemistry but not pharmacy characterised by physical characteristics | *Not described* |
| difference between acids and acidic drugs | the acidic molecule would have like just, oh actually an acidic group on it, but then it may have other groups as well, so that isn't an acid. An acid would just have the acidic group and you just, solely acid **(3.234-3.238)** |
| pharmacy acids characterised by pKa rather than pH<br>strength in pharmacy characterised by values of pKa<br>acids and bases in pharmacy both have pKa | I remember that now. Like if it's a strong acid, then it has a low pKa **(3.306)**<br>Interviewer: how is that then related in your mind to pKa?<br>Denise: The pKa of the carboxylic acid would be lower.<br>Interviewer: Uh huh and the weak one has a high pKa?<br>Denise: Yeah<br>Interviewer: OK. Do you think that's also true for bases? That they might, is it possible for them to have both high um or low pKas?<br>Denise: Yep.<br>Interviewer: How would that work?<br>Denise: Um, (pause) I guess it'd be the reverse like for a strong base, they would have a high pKa **(3.417-3.424)** |
| pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | *Not specifically described* |

Persistent change – Denise

| | |
|---|---|
| strength characterised significantly differently in pharmacy and chemistry | weak ones like dissociate poorly in like a solution, aqueous solution. And then the strong ones dissociate completely **(3.206)** |

## *Concepts new to pharmacy*

| Characteristic | Transcript excerpt – interview 2 | Transcript excerpt – interview 3 |
|---|---|---|
| carboxylic acids | COO is like a, like COOH is really a strong acid **(2.692-2.694)** | Denise: There's an acidic group.<br>Interviewer: Yep, what's that called?<br>Denise: Um, carboxylic acid, isn't it? **(3.282-3.284)** |
| phenols | I thought this was a phenol but it's not coz it doesn't have a benzene ring **(2.492)**<br>Interviewer: What's wrong with the hydroxyl group?<br>Denise: It's not directly attached to the O, I mean the benzene ring **(2.649-2.650)**<br>Interviewer: OK, so the phenol would be the nine point six?<br>Denise: Yeah, coz it's a weak acid **(2.697-2.698)** | I think this is the phenol here, it's an acidic group that can lose a H **(3.290-3.292)** |
| aliphatic amines | with codeine, that's an amine because it's connected to the C which is $sp^3$ hybridised and yep, and then Hs **(2.488-2.490)** | if it had a H attached to it, it could be, it could dissociate, but I can't see any **(3.272)**<br>Denise: (pause, talking under breath) I don't think that's anything either, in lignocaine.<br>Interviewer: Again because it doesn't have any hydrogens?<br>Denise: Yeah, attached to the N, yeah **(3.278-3.280)**<br>I think this one can gain a H plus, to become a $NH_3^+$, that's a basic group **(3.292-3.294)** |
| amides | it's N attached to a C which is double bonded to O **(2.504)**<br>I don't think this has any, like it's not acid or basic because it doesn't have either of the groups in it, because this is a, well this is not amide but it's attached to a $sp^2$ carbon so it doesn't make it a amine **(2.592-2.594)** | |





Persistent change – Denise

| | | |
|---|---|---|
| multiple functional groups | Denise: so that you've got two acid groups and one [basic], so it would have three pKas and overall would probably be more acidic.<br>Interviewer: Why do you say more acidic?<br>Denise: I'm just guessing, because it's got two acidic groups and one basic. But I don't like,<br>Interviewer: don't know, not sure?<br>Denise: Yeah, you can't tell can you? **(2.536-2.546)**<br><br>Interviewer:, it's not a competition between the acids and the bases… trying to make the point when I was talking about these is I said if it's got both acid and basic groups it's neither acidic nor basic.<br>Denise: Even if it's got two of one and one of the other?<br>Interviewer: Yeah.<br>Denise: OK.<br>Interviewer: Because you can't call it an acid because it can accept a proton, to the basic group. You can't call it a base because it can donate its two protons. So it's not a pure acid, it's not a pure base because it's got characteristics of the other so one of the things that we said is that if it's got both then we call it neither coz it doesn't behave like an acid and it doesn't behave like a base **(2.547-2.561)**<br><br>That's got two phenol groups and one amine so it's neither **(2.630-2.632)** | Denise: I think that would make it acidic, yeah.<br>Interviewer: Coz it's got more acidic groups?<br>Denise: I think so, but I'm not sure whether you can say that. Because oh, (pause) because they might be, oh well this one's a pretty strong acidic group<br>Interviewer: It is, yeah.<br>Denise: but if you had like two weak acidic groups, it may not be the case then. Yeah, it would be acidic, I think **(3.346-3.350)** |
| dissociation of ibuprofen | Interviewer: But what we might do is look at another one which is just an acidic drug, say um ibuprofen. How would you draw up the equilibrium for that and then we'll come back to the amoxycillin.<br>Denise: All right well it's already attached so that would be the first thing and it only has one pKa.<br>Interviewer: Which is four point two. Four point four but that's all right<br>Denise: So it would have O minus like that **(2.845-2.850)** | |
| dissociation of amoxycillin | *Completed with minimal verbalisation* | *Completed with minimal verbalisation* |
| allocation of pKa values | *Incorrectly done* | I, yeah, I think the carboxylic acid has a, is strongest, then followed by that, and followed by that (pointing). And that would be the order of the pKas as well I think **(3.298-3.302)** |
| addition of proton to amine | So start off with all the protonated, so all the Hs attached **(2.708-2.712)** | you go, well start with all the protons attached **(3.380)** |

Persistent change – Denise

| | | |
|---|---|---|
| correct order of dissociation | *Completed with minimal verbalisation* | and then at two point four it would go to, like OH, NH, C double O minus. That would lose it first. Seven point four goes to O minus, (pause while writing) and then finally the N at nine point six **(3.382-3.386)** |
| prediction of form at specified pH | Interviewer: OK, so what happens then at different pHs in that um, equilibrium?<br>Denise: OK, it depends on which side it's on, like<br>Interviewer: OK, so at a pH, say 3.<br>Denise: 3? It would tend to sit on this side.<br>Interviewer: OK, on the left hand side.<br>Denise: Yep.<br>Interviewer: Yep. Um, at what point would you say it was completely in that form on the left hand side?<br>Denise: If it's two units less than that. So anything less than two point two.<br>Interviewer: Uh huh. So at what point, what pH would it be that it's completely ionised?<br>Denise: Completely ionised is up here so it would be six point two.<br>Interviewer: OK. So what we've got then, is rather than trying to remember um, an acid with a pH below the pKa or above the pKa you can actually draw it out like that **(2.851-2.863)**<br>Interviewer: what happens, what happens if we say got up to pH of 11, 12, 13, 14?<br>Denise: It would keep on going to that side and then coz it's so high all of it, this is an, oh, it's a neither. Coz I'm trying to think like if it's an acidic drug and it goes so high that it doesn't work<br>Interviewer: Not when it's neither and what you've actually brought up there is one of the reasons why you can't call it an acid. Because you're right, it does keep going in the left hand, right hand direction, but what's further in the right hand direction than this one here with the plus and the minus on it?<br>Denise: Oh, pardon?<br>Interviewer: If it keeps going right it's not going to stop with that one is it?<br>Denise: (pause) You mean it will go to that? [third form]<br>Interviewer: Yeah.<br>Denise: Oh really<br>…<br>Interviewer: So, so it doesn't just stay. Once it's lost its first proton it doesn't just stay at that no matter how high the pH goes. If you push the pH | Interviewer: is there anything um, significant or interesting about amoxycillin based on how you've drawn it, drawn up that dissociation equilibrium?<br>Denise: (pause) Um, that it can exist in three, like four different forms.<br>Interviewer: Uh huh. Anything kind of, any pattern that you see to the forms?<br>Denise: (pause) Oh they're all um, ionised **(3.405-3.408)**<br>So that would be $NH_3^+$ here (pause) and that would be eight point eight and ten point six would be there. O minus, O minus, yeah. So in water, which is the pH is 7, it would tend towards (pause) that side **(3.452-3.454)** |

Persistent change – Denise

| | | |
|---|---|---|
| | up even further, it will pull the hydrogen off the amino group and then if you bring the pH up even further it pulls it off the phenol group as well.<br>Denise: OK **(2.799-2.830)** | |
| interchange of pKa for phenol and amine in amoxycillin | | Denise: Seven point four goes to O minus, (pause while writing) and then finally the N at nine point six.<br>Interviewer: OK, so you've said the pKa of two point four belongs to the carboxylic acid<br>Denise: Uh huh<br>Interviewer: seven point four belongs to the phenol,<br>Denise: Uh huh<br>Interviewer: and nine point six to the amine. OK. If I said phenols characteristically have pKas between nine and eleven,<br>Denise: Oh, OK<br>Interviewer: would that change anything<br>Denise: Yep<br>Interviewer: that you've said? What, did, so you saw the amine group and you thought well that must have the highest pKa because it's a base?<br>Denise: Yeah **(3.386-3.400)** |



## *Additional issues – interview 2*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| Denise's perceptions | after in the lecture you defined like the definitions that you wanted us to know for chem like pharmacy then I kind of, I think I got used to those terms and then kind of separated them from the chemistry terms. I knew that you like were emphasising that they were different **(2.340-2.348)**<br>I think, like before I just knew the basic, like definitions of acids and bases from chemistry and then from here, like you told us those things about acids and bases **(2.366-2.368)**<br>and then I also learnt that the strength of acids and bases isn't just whether they dissociate or not, like completely **(2.370)** | Denise indicated that she had not experienced significant confusion between the two contexts. |

## Persistent change group: Isabelle

### *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | [acid] proton donor **(1.2)**<br>[base] proton acceptor **(1.22)** |
| names of theories | *Articulated only in written survey* |
| taste and feel | [acid] I think they're supposed to be sour **(1.8)**<br>[base] they're supposed to be slippery **(1.24)** |
| corrosiveness | Interviewer: if you got them on your skin, would they burn you?<br>Isabelle: Um, if they were strong **(1.33-1.34)** |
| other characteristics | [acid] to turn litmus, blue litmus, red **(1.14)**<br>[acid] when it comes in contact with a base, to form a salt in water **(1.16)** |
| Chemistry acids characterised primarily by pH | Interviewer: what makes um, one acid different from another acid?<br>Isabelle: Its pH.<br>Interviewer: Uh huh<br>Isabelle: Um, the dissociation of um, the ions. Which is like how, which determines the pH and, and um, if it's strong or weak **(1.89-98)**<br>Interviewer: OK, so what would tell you something was an acid?<br>Isabelle: pH, um, of less than 7.<br>Interviewer: And a base?<br>Isabelle: Of more than 7.<br>Interviewer: OK, what's so important about 7?<br>Isabelle: 7 is neutral **(1.131-1.136)** |
| strength described on the basis of complete and partial dissociation | Interviewer: what makes something a strong acid?<br>Isabelle: Um, when it dissociates completely into its constituent ions.<br>…<br>Interviewer: And so what would a weak acid be then?<br>Isabelle: Um, incomplete dissociation.<br>Interviewer: OK, great. Does that, is that true also for bases?<br>Isabelle: Yes<br>Interviewer: Are there strong and weak bases?<br>Isabelle: Yes.<br>Interviewer: So what would, what would be characteristic for the strong base?<br>Isabelle: Um, the same. So, um, complete dissociation into its ions **(1.99-1.114)** |

| | |
|---|---|
| | Um, what does that tell you about a solution, to know its pH, then?<br>Um (pause) how strong or weak it is **(1.127-1.128)** |
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | Isabelle: Oh, OK, um. Hydrogen ion concentration equals pH to the, no, no, no equals, (laughs) (pause) ten to the minus pH.<br>Interviewer: OK, so at pH 2, that would be, yeah, that's right.<br>Isabelle: Yeah, coz ten to the minus two.<br>Interviewer: And what units would that be in?<br>Isabelle: That would be in mm, moles (laughs) per litre? **(1.146-1.150)**<br><br>Interviewer: No, OK. What about a pH of say, 13? What can you tell me about pH 13?<br>Isabelle: Um, pH 13, has a hydrogen ion concentration of ten to the minus 13.<br>Interviewer: OK. What else would you find in a solution of pH 13?<br>Isabelle: (pause) Mm<br>Interviewer: What would you find a lot of?<br>Isabelle: Ah, a lot of (pause)<br>Interviewer: What would be the most, most, probably the most common ion, for example?<br>Isabelle: Oh, OH minus.<br>Interviewer: OK. Do you know what the OH minus concentration would be at pH 13?<br>Isabelle: Yeah. You have to swap them round, don't you?<br>Interviewer: Yeah<br>Isabelle: So, um, pH plus pOH is 14. And then that's thirteen, so, pOH is 1 or something<br>Interviewer: Yep. So what would be the hydroxide ion concentration? (pause while Isabelle writes) Ten to the minus 1.<br>Isabelle: ten to the minus 1 **(1.159-1.180)** |
| use of mathematical relationship to solve numerical problems | *Carried out accurately* |



## *Changes to existing understanding*

### Interview 2

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] the loss of a proton **(2.344)**<br><br>[base] um it gains protons, yeah **(2.372)**<br><br>[base] there's a lot of the OH minus thing in chemistry, and in pharmacy it's more trying to find a, um the proton, has it moved or whatever **(2.380-2.382)** |

Persistent change – Isabelle

| | |
|---|---|
| pharmacy characterised by functional groups | Um, (pause) functional groups, yeah. Um, (pause) functional groups, the loss of a proton, and that's the same thinking. But mainly the functional groups, noticing the functional groups **(2.342-2.348)**<br><br>Interviewer: what do you think about a base?<br>Isabelle: Same thing, the NH um attached to um, a carbon and you have to be careful it's not an amide<br>Interviewer: Uh huh. (Isabelle laughs) Yep.<br>Isabelle: Um, yeah, just that.<br>Interviewer: OK, so again it's the functional group thing? **(2.363-2.369)**<br><br>well, you change from the inorganic acids and bases to being the drug, organic yeah, acids and bases and it's more carbon chemistry **(2.308-2.312)** |
| chemistry but not pharmacy characterised by physical characteristics | Isabelle: I think you're afraid that it's really bad like that the, the compounds are really toxic and stuff in chemistry whereas it's more, well it's not as strong perhaps<br>Interviewer: Not as dangerous?<br>Isabelle: Yeah, in pharmacy.<br>Interviewer: So you don't have a kind of fear of acids in pharmacy but you would in chemistry?<br>Isabelle: Yeah **(2.456-2.462)** |
| other characteristics, particularly differences | Interviewer: OK. Now you say in pharmacy, what would you look for in chemistry?<br>Isabelle: Um, just the, (pause) the compound yeah, all together coz usually it's not so big **(2.357-2.360)**<br><br>Interviewer: So, again thinking about that analogy that you had with acids, so you've got the idea of amines in, in pharmacy, what about bases in chemistry?<br>Isabelle: Oh, the same small molecule thing **(2.373-2.374)**<br><br>it's just a molecule with a functional group in pharmacy **(2.378)** |
| pharmacy acids characterised by pKa rather than pH | there's more emphasis on pH in the chemistry and more on the pKa in pharmacy **(2.318)**<br><br>[in chemistry] pH um below 7 was an acid, pH above 7 was a base yeah, and um uh red to blue was a base and blue to red was an acid **(2.412-2.416)** |
| acids and bases in pharmacy both have pKa | |

| | |
|---|---|
| strength in pharmacy characterised by values of pKa | |
| strength characterised significantly differently in pharmacy and chemistry | like for a weak um base it can be under pKa 7 **(2.398)** |
| in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | strong acids have a pKa of usually below 7 um, and weak ones above pKa of 7 **(2.436-2.438)** |

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] it's a proton donator **(3.134)**<br>[base] it's a proton acceptor **(3.152)** |
| pharmacy characterised by functional groups | *Implied but not specifically stated* |
| chemistry but not pharmacy characterised by physical characteristics<br>difference between acids and acidic drugs | Interviewer: In a laboratory, yeah, OK. Um, is there kind of a difference in your thinking between the word acid and to call something an acid versus an acidic drug, or does that not, that distinction not really matter?<br>Isabelle: Um (pause) it is a little bit of a distinction in that you think, oh acid it's, it's dangerous and then when you say acidic drug and you think oh, well it does this and that, it's not so dangerous **(3.177-3.180)** |
| pharmacy acids characterised by pKa rather than pH (secondary concept that pH refers to solutions) | Interviewer: Do you think of acids as having pHs, or just pKas?<br>Isabelle: Um, pHs as well but pKas as being more applied in pharmacy rather than pH.<br>Interviewer: OK, so pH is kind of more related to chemistry is it?<br>Isabelle: Yeah<br>Interviewer: So acids in chemistry have pHs? Or not?<br>Isabelle: they have both but I think in pharmacy it's more important to have a pKa.<br>Interviewer: OK, and in chemistry the emphasis is more on pH?<br>Isabelle: Yes, sure **(3.135-3.148)** |
| strength in pharmacy characterised by values of pKa<br>acids and bases in pharmacy both have pKa<br>pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | Um, (pause) strong acids ah, have a pKa of less than 7 and weak above 7 **(3.130-3.132)**<br>[base] pKa of more than 7 makes it strong, less than 7 makes it weak **(3.150)** |
| strength characterised significantly differently in pharmacy/chemistry | Isabelle: Umm, it does it completely or almost completely as opposed to weak acids that don't do it completely or hardly any.<br>Interviewer: Hardly any in fact, some of them, yeah, OK. And is that also true about bases. Does that strong weak thing?<br>Isabelle: Yes **(3.162-3.168)** |

Persistent change – Isabelle

## *Concepts new to pharmacy*

| Characteristic | Transcript excerpt – interview 2 | Transcript excerpt – interview 3 |
|---|---|---|
| carboxylic acids | *Identified without verbalisation* | Isabelle: A carboxyl group.<br>Interviewer: Yep, carboxylic acid yeah that's good, that's OK. Is that a strong or a weak acid?<br>Isabelle: Ah, strong **(3.242-3.244)** |
| phenols | um, not that one, not the OH because it's not connected to a benzene ring, it's not a phenol **(2.506-2.510)**<br>an OH directly attached to the benzene ring **(2.562)** | Isabelle: No, that's not a phenol coz it's not directly attached and that's not, yeah<br>Interviewer: OK, so it's not a phenol coz it's not a benzene ring that it's attached to.<br>Isabelle: Yeah **(3.200-3.202)**<br>Isabelle: That is a phenol and that's acidic<br>Interviewer: Yep. Strong or weak?<br>Isabelle: Ah, weak **(3.220-3.224)** |
| aliphatic amines | basic functional group…connected to a $sp^3$ hybridised C' **(2.566-2.570)** | *Identified without verbalisation* |
| amides | [a nitrogen] connected to a C with a double O, double bond O **(2.548-2.550)** | *Identified without verbalisation* |
| other nitrogen containing groups | Isabelle: that is not (pause) a, has to be connected to a (pause) a C that's $sp^3$ hybridised. I, I wouldn't say that's, that's one. I don't think I've seen this.<br>…<br>Interviewer: you were going down the right track I think because you were talking about the carbon that was next door to the nitrogen. So what, what hybridisation does that carbon have?<br>Isabelle: Um (laughs), $sp^2$.<br>Interviewer: OK, so it's a $sp^2$ carbon. So what does that mean about whether or not that nitrogen can be an amine?<br>Isabelle: According to the definition it's not allowed to be **(2.630-2.652)** | *Identified without verbalisation* |
| multiple functional groups | you're not allowed to call it an acid or a basic drug **(2.596)**<br>because it can do both things. So you can't call it just an acidic drug coz it has one more acidic thing to it than, yeah, it's yeah coz it can do both things **(2.602-2.608)** | *Implied but not specifically stated* |

| | | |
|---|---|---|
| dissociation of ibuprofen | it's supposed to start with all the protons attached, like you have to, yeah and you'd have the little double arrow thing, and you'd have the pKa, also of four point four, and then you'd draw the whole thing if you wanted to, but yeah, and you'd do that and you'd have double O minus **(2.696-2.708)** | *Carried out without verbalisation* |
| dissociation of amoxycillin<br>allocation of pKa values | the phenol which has a pKa range of 9 to 11, so you'd go, oh, that one. And then the, carbo, ah the I don't know what you call the group, the C double O H um, pKa range of I think 2 to 5.5 or something. So you'd look, oh OK, that's that one, and then the base, that's that one **(2.786-2.798)** | and that's the strongest one so that's the C double O H that loses that. (pause) That one and then, I'm going to run out of room, and then the next one which is the phenol, is going to lose that. (pause) And (laughs)…then the next one that's the amine, that's R, R $NH_2$ **(3.342-3.354)** |
| addition of proton to amine | you start with everything attached **(2.800)** | |
| correct order of dissociation | Isabelle: Yeah, and then you start of with the first, oops I'm too close, that one, the two point four and then…and then the $NH_3$ and then another R (laughs) coz I felt like it, and the C double OH minus<br>Interviewer: That will be fine with me, all right.<br>Isabelle: OK, and then um I'd have another one, and I'd put in the next one that's seven point four, and I'd have the OH and the R and NH, oh that's a plus thing here, $NH_2$, and like that, and then I'd have another arrow thing, and then the nine point six and then I'd have O, minus, um $NH_2$ um, (pause) like that **(2.808-2.832)** | |
| prediction of form at specified pH | you can see the whole acidic thing and the yeah like the conjugate base and it helps… you can, (pause) yeah I think see which one it's going to be, like which form it's going to be in, with the equilibrium thing like that **(2.712-2.722)**<br>Interviewer: OK so can you give me an example of how um you would be able to tell um with a particular pH? So if you had a pH of 3, what form would it be in?<br>Isabelle: Um, it would be in this form.<br>Interviewer: On the left hand side.<br>Isabelle: Yeah.<br>Interviewer: And why do you know that?<br>Isabelle: Um, I think it was a thing when you showed us like if it's less it's here if it's more it's here.<br>Interviewer: OK, so it's just where the numbers fall in respect of each other?<br>Isabelle: Yeah.<br>Interviewer: OK. If I wanted the drug to be completely in the unionised | Isabelle: Oh, well if you have, if they say what form will it be in at six pH of six, you can go, oh it'll be that one.<br>Interviewer: OK coz it's on that side<br>Isabelle: That side of it, yes **(3.310-3.314)** |

| | | |
|---|---|---|
| | form on the left hand side, what pH would, would we need to have?<br>Isabelle: Ah, 2 units less or more than two, so ah, two point four.<br>Interviewer: OK, and what about if we wanted it completely ionised?<br>Isabelle: Um, two units um, plus or more, so six point four **(2.723-2.742)**<br><br>Interviewer: So we've got a pH 5, what form would you expect it to be in?<br>Isabelle: Um, this one.<br>Interviewer: The second one<br>Isabelle: Uh huh<br>Interviewer: yeah, OK. And why is that?<br>Isabelle: Um it's more (laughs), it's less, I don't know, it's yeah.<br>Interviewer: Yeah, coz it's in between two point four and seven point four.<br>Isabelle: Yeah<br>Interviewer: So it's less than the pKa of seven point four, and more than the pKa of two point four<br>Isabelle: Yeah **(2.839-2.848)** | |
| Isabelle's strategies | I had acidic there and basic drug here and pH less than pKa here and pH more than pKa and then I did a diagonal thing, like that, really (laughs) really simple but I could remember it better **(2.750-2.758)** | |



## *Additional issues – interview 2*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| Side benefits of IPS | I didn't come into contact with pKa until first semester um chemistry and it was a bit difficult to understand it but it got better with this semester pharmacy **(2.402-2.406)**<br><br>Oh, it took me a long time to work out that, um hybridisation, um, yeah, in chemistry and like I think you sparked the thing with the whole, its single bond you had single bonds everywhere around it, but then my understanding got better in chemistry **(2.572-2.584)** | Isabelle's increasing confidence with pharmacy concepts provided benefits for her chemistry understanding also, in the areas of pKa and hybridisation. |

## Persistent change group: Jasmine

### *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | *Not described* |
| names of theories | *None mentioned, but Arrhenius implied* |
| taste and feel | *Not described* |
| corrosiveness | Jasmine: Well before I did science it would be something that would burn your skin.<br>…<br>Interviewer: OK, so you don't think it means it burns your skin any more?<br>Jasmine: Yeah, I, I will still be really wary when I'm you know, doing prac and everything **(1.4-1.14)**<br><br>and base, I think base also burns you as well if it's really, really strong **(1.34)** |
| other characteristics | if you put it [acid] in water, the H plus, oh it will form $H_3O$ plus **(1.10)**<br><br>then if you chuck that [base] in water you would get OH minus ions **(1.30-1.32)** |
| Chemistry acids characterised primarily by pH | [acid] would be something below the pH of 7 **(1.8)**<br>[base] will be pH of more than 7 **(1.28)** |
| strength described on the basis of complete and partial dissociation | if it's strong or weak it depends on how, the degree of conversion **(1.40)**<br><br>So if, if um just say water itself, it is both acid and base so it's both weak acid and weak base I think. So yeah it undergoes that conversion thing but it's so little that it won't burn you, if that makes sense. But if it's like sulphuric acid then that, that conversion thing happens a lot **(1.44-1.50)**<br><br>Interviewer: All right, so when you're talking about conversion, would it help if you wrote something down to tell me what you mean by conversion?<br>Jasmine: Like just that simple equation like HCl plus water gives you the $H_3O$ plus. Yeah, and then the Cl minus **(1.53-1.58)**<br><br>Interviewer: OK, and a strong acid goes, so you've got a completely, a goes to completion arrow there so does that mean<br>Jasmine: Yeah most of them will be that and if it's weak, a little bit, there's a little arrow going back, kind of thing **(1.67-1.70)**<br><br>NaOH (pause) in water is strong so it will go all the way **(1.250)** |
| conflation of strength and concentration | I would say that's a strong acid but somehow I'm confused as well now that you've asked me, maybe it's something to do with, with the molarity of that as well **(1.60-1.62)** |
| mathematical relationship between pH and $H^+/OH^-$ ion | So, that's one of the formulas that we've learnt. The p is like negative log 10, I think and then you go like that and the concentration of H plus ions and that's the same as the $H_3O^+$ ions, and somehow, I don't know where, but you get con, you get little numbers underneath and you can just put that in, into the equation and then you can work out the pH from there **(1.98-1.108)** |

| | |
|---|---|
| concentration | Jasmine: So as in if you know the pH is 2 you can work out the, the concentration of H plus then.<br>Interviewer: OK, can you do that for me?<br>Jasmine: OK. So 2 equals negative log 10 and then you want that. Oh my gosh....OK, hold on let me think about that. (pause) Isn't that just easy, like 10 to the negative 2? **(1.132-1.148)** |
| use of mathematical relationship to solve numerical problems | *Carried out inconsistently* |

## *Changes to existing understanding*

### Interview 2

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | So HA's, HA becomes H plus and A minus **(2.470)**<br>No, the base itself is B **(2.518)**<br>[acid] When it's got the H (pause) somewhere and it can, it can um, donate it **(1.532)**<br>[base] When it accepts a H plus **(1.534-1.536)** |
| pharmacy characterised by functional groups | *Not specifically described* |
| chemistry but not pharmacy characterised by physical characteristics | *Not described* |
| pharmacy acids characterised by pKa rather than pH | in primary school then you learn about acids and bases that's [pH] one thing that always goes with it **(2.538-2.540)** |
| strength in pharmacy characterised by values of pKa | [acid] The lower that pKa value is, the more stronger it is **(2.480)** |





Persistent change – Jasmine

| | |
|---|---|
| pKa in pharmacy associated with dissociation | in an acid this side is the ionised form so if the pKa is low then the probability of getting the, the drug in the ionised form is higher **(2.490-2.492)**<br>the base is just the other way around **(2.502)** |
| acids and bases in pharmacy both have pKa | in pharmacy we always, somehow we always get all the protonated form on one side, maybe that helps with putting the K, pKa on the arrow that's why **(2.522-2.524)** |
| strength characterised significantly differently in pharmacy and chemistry | *Implied but not specifically stated* |
| in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | Usually the COOH is a carboxylic acid is strong, stronger than the, the phenol. We learnt that's a weak acid **(2.806-2.810)**<br>the phenol ones I think are high, above 7 but the COOH ones are below 7, maybe like 1 or 2 or 3 or something like that **(2.812-2.816)** |



## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] a proton donor… It will become CH plus and Cl minus **(3.227, 3.233)**<br>[base] Bases is kind of opposite to that… and it accepts protons **(3.247, 3.255)** |
| pharmacy characterised by functional groups | *Not specifically described* |
| chemistry but not pharmacy characterised by physical characteristics | *Not described* |

| | |
|---|---|
| pharmacy acids characterised by pKa rather than pH | pH below seven. Yep, that'll be something acidic, if you test it with the paper **(3.243-3.245)**<br>[base] if you put it in solution, it'll dissociate to OH… and it'll be pH above 7, so 8 to 14 **(3.249,3.253)** |
| strength in pharmacy characterised by values of pKa | Interviewer: with those two um, acidic groups, what's, what's the difference between them?<br>Jasmine: Um, the strength of the acid.<br>Interviewer: OK. What would you say about the strength of those two groups, then?<br>Jasmine: Normally that is strong, well the COOH is stronger than the phenol. It has a lower pKa, I think.<br>Interviewer: The carboxylic acid?<br>Jasmine: Yes **(3.416-3.423)**<br><br>Interviewer: OK, so, strong acids, low pKa.<br>Jasmine: Yes.<br>Interviewer: All right. Do pKas also apply to bases?<br>Jasmine: Yes.<br>Interviewer: And how does the strong and weak match up with pKas?<br>Jasmine: Um, I think they also have the pKb as well, don't they?<br>Interviewer: They do, yes.<br>Jasmine: Yes, and that works exactly the same as pKa for acids. But if you're talking about pKas for bases, then there's a twist, but I don't remember what it was. Um (pause) would it be the less, the less of the value of the pKa would be more basic, for bases?<br>Interviewer: No, the other way round.<br>Jasmine: The other way round. But isn't the, OK, the less pKa for an acid, is the stronger the acid **(3.424-3.437)** |
| acids and bases in pharmacy both have pKa | |
| pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | Interviewer: what about weak acids, what sort of pKas do phenols have as weak acids, do you remember?<br>Jasmine: Oh, they can go up to ten, I think! **(3.552-3.553)** |
| strength characterised significantly differently in pharmacy and chemistry | Interviewer: if we had two different acids, what would make them different from each other?<br>Jasmine: The strength, which is the concentration, um, yeah I think the dissociation, how much it dissociates. So as I said before, the stronger that is, they are, then they will dissociate easier **(3.290-3.295)**<br><br>Interviewer: OK. So a strong acid is one that dissociates more than a weak acid?<br>Jasmine: Yep.<br>Interviewer: Or a strong acid dissociates completely?<br>Jasmine: A strongER acid would dissociate more, but a strong acid would go completely' **(3.296-3.299)**<br><br>Interviewer: do bases also have strengths? |

Persistent change – Jasmine

| | |
|---|---|
| | Jasmine: Yes.<br>Interviewer: How does that work?<br>Jasmine: Um, it's like the same thing. If it's stronger, then - I think I'm repeating myself.<br>Interviewer: That's all right.<br>Jasmine: Yeah? If it's stronger, then it will dissociate to the OH and whatever ion, if it's the strong one, then it will go completely, dissociate completely. If it's weaker, then not as much **(3.300-3.311)** |

*Concepts new to pharmacy*

| **Characteristic** | **Transcript excerpt – interview 2** | **Transcript excerpt – interview 3** |
|---|---|---|
| carboxylic acids | *Identified without verbalisation* | *Identified without verbalisation* |
| phenols | next to a benzene ring, it's a OH there and there is no C in the middle **(2.640-2.644)**<br><br>that is not even a phenol…because the ring isn't there **(2.580-2.584)** | That is not a phenol, coz the, it's not a benzene ring **(3.349-3.351)** |
| aliphatic amines | Jasmine: hold on there is an N there, (pause) oh OK, (laughs) that could be basic actually.<br>Interviewer: OK, what, what do you need to know about the nitrogen to say whether it's basic or not?<br>Jasmine: If it's not an amide, amide is like an N next to a C double O, that it's not basic, but that is not next to a C double O, and sometimes you can get a ring, like that pyridine or something with the N there and that is not basic either, not anything. So that's got nothing on it so maybe that's basic **(2.590-2.604)**<br><br>C double bond O so that one is amide, don't worry about **(2.612)**<br><br>Interviewer: there's kind of a deeper reason for why they're not amines and it's because, do you remember about hybridisation of orbitals?<br>Jasmine: Yes vaguely. | *Identified without verbalisation* |





Persistent change – Jasmine

| | | |
|---|---|---|
| amides | Interviewer: Yeah. OK, do you know the difference between $sp^3$ and $sp^2$ hybridised carbon?<br>Jasmine: $sp^3$, oh my goodness, is something like, $sp^3$, OK it's joined to three different things, $sp^3$, four different things.<br>Interviewer: Yes, so it's a carbon not a nitrogen.<br>Jasmine: Oh, whoops. Yeah, and then if, if, what's the other one?<br>Interviewer: $sp^2$.<br>Jasmine: Then one of them is the lone pair and it's the pi electron.<br>Interviewer: Yes. It's not the lone pair so much as the double bond.<br>Jasmine: Oh, OK.<br>Interviewer: So $sp^3$ has single bonds coming from it<br>Jasmine: Uh huh, yeah<br>Interviewer: and $sp^2$ has a double bond **(2.717-2.737)** | *Identified without verbalisation* |
| multiple functional groups | is it because it's ionised all the time? **(2.670)** | you can't say it's acidic or basic, it depends on the pKa or the strength of those acid components **(3.411)** |
| dissociation of ibuprofen | *Not required* | *Carried out with minimum verbalisation* |
| dissociation of amoxycillin | *Carried out with minimal verbalisation* | The first one will have all the Hs…everything attached **(3.595-3.599)**<br>Interviewer: With bases, what does the protonated form look like?<br>Jasmine: (pause) Oh, $NH_3$! OK, so I would say these are all $NH_3$s, and this is too.<br>Interviewer: Yep, OK, so is that just $NH_3$, or does it have<br>Jasmine: Plus **(3.610-3.613)** |
| allocation of pKa values | | |
| addition of proton to amine | anything that's below all the pKas will have all the protons attached to it **(2.842-2.844)** | |
| correct order of dissociation | *Carried out with minimal verbalisation* | two point four, that H from the COOH will go, but everything is still intact. And after seven point four, OK, that's gone, seven point four, the NH, one of the H's is gone. Oh, gosh, this doesn't sound right. And after nine point six, I think everything, all the H's are gone **(3.601-3.607)**<br>That looks really strange, that NH minus, I've never seen that before **(3.609)** |
| prediction of form at specified pH | because it's, it's in order, if you tell me oh it's at 5, then I know it's between two point four and seven point four then I just say oh that's the zwitterion…there and then that one is the form that is there, mostly **(2.900-2.908)** | So anything on the left is smaller than pKa of four point four. Anything bigger will be on your right. So, if in the future, or in another question, if they ask you anything about being over four point four, then you can just look at the right and say "oh, it's the ionic form." **(3.531-3.533)** |

Persistent change – Jasmine

| | | |
|---|---|---|
| interchange of pKa for phenol and amine in amoxycillin | | Interviewer: Let's go back to amoxycillin. I'll give you its pKas, so you can assign the three pKas to the groups. And what I'd also like for you to have a go at is drawing up the dissociation equilibria for amoxycillin as well.<br>Jasmine: Yep, um OK, I will say the lowest one for the COOH. So that's two point four.<br>Interviewer: Yep. And is that because it's the strongest one?<br>Jasmine: Yes. Seven point four for the phenol, and the basic will be nine point six.<br>Interviewer: OK now why do you think the basic has nine point six?<br>Jasmine: Um, coz it's got the highest pKa. So it's the least acidic and the more basic.<br>...<br>Jasmine: relatively, the highest you gave me was nine point six. I would, I would think it's that.<br>Interviewer: Because it's, because it's a high number you think it's associated with a base?<br>Jasmine: Yes **(3.542-3.559)** |



## *Additional issues – interview 2*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| Jasmine's self-evaluation | throughout the year maybe it's a bit confusing when we're learning new concepts from you and then we've heard of those concepts in chemistry but they're different **(2.398-2.400)**<br>all the acids and bases as well, yes they, they were covered in chemistry but I think, coz you made it pretty clear what, what you know, the definitions are in pharmacy so I don't think it's a bit confusing **(2.406-2.410)**<br>the same template, but it's just in a different, like slightly off kind of thing. It's the same thing but it just doesn't match properly... the same thing but in a different context...it's probably like two pieces of overheads but they're kind of just a bit off centred **(2.416-2.426)**<br>it's definitely much easier when you know chemistry, doing pharmacy, and sometimes the logic behind this is the same as chemistry when you think about it **(2.434-2.436)**<br>Well, the thing is with chemistry we learn about acids and bases but you never thought that they, we will need to know anything about it, but with, with this, when um, when I read the notes it's all saying what happens if you swallow something that's acidic...it's more interesting I think **(2.446-2.452)**<br>Interviewer: in terms of strengths of acids, do you think differently in chemistry and pharmacy about the strengths of acids, or the same?<br>Jasmine: We did learn about the pKas in chemistry as well but mostly, I think it's pretty much the same actually, and we did this in chemistry this year, oh this semester as well so it's really similar in terms of that **(2.979-2.988)** | |

# Persistent change group: Kellie

## *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | an acid is like, a proton acceptor, oh, donator **(1.12)**<br>[base] and a proton acceptor **(1.22)** |
| names of theories | *Not described* |
| taste and feel | [acid] something that's sour **(1.2)**<br>[base] like it's bitter and um (pause) something like an alka, alkali. They're supposed to be soapy as well **(1.18-1.20)** |
| corrosiveness | *Not described* |
| other characteristics | Something like, um, something you use in a lab, you know, like, I think of hydrochloric acid. And like, the common ones like nitric acid and sulphuric acid, they come to mind. And um something with a H in front **(1.4-1.10)**<br>reacts with like, different things, so like it'll react with a base to, like in a neutralisation reaction, it'll form like, a salt and water and, yeah I know there are other reactions, but I can't think of them **(1.24-1.30)** |
| Chemistry acids characterised primarily by pH | *Not described* |
| strength described on the basis of complete and partial dissociation | Interviewer: anything that comes into your mind about strength.<br>Kellie: Just how much it dissociates into ions.<br>Interviewer: OK. So what would a strong acid be? Or do?<br>Kellie: Strong acid, um, dissociate completely.<br>Interviewer: Right. And what's the opposite then of a strong acid?<br>Kellie: It only partially dissociates, so it'll be a weak acid **(1.65-1.72)**<br>Interviewer: Is that true also for bases?<br>Kellie: Um, the strong and weak?<br>Interviewer: So, do you have strong and weak bases as well?<br>Kellie: Yeah, you have that as well **(1.79-1.82)** |
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | it's like a scale that um, it's to do with the, yeah, I think the acidity of things, of solutions, so it will, it'll say whether it's acidic or basic, and it's on like a scale from zero to 14. And 7 is like, neutral, and towards zero, then it's acidic, towards 14, then it's basic **(1.98-1.104)** |
| use of mathematical relationship to solve numerical problems | *Not carried out* |

## Interview 2

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] something that donates a proton to become a charged species **(2.354-2.356)**<br>a base accepts protons to become a charged species **(2.366)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | Interviewer: in Chemistry are you conscious of things like acids and bases being um dangerous?<br>Kellie: Yes.<br>Interviewer: In what way?<br>Kellie: Because like you know what, like yeah they'll burn your skin or whatever.<br>Interviewer: Do you think the same way about acids and bases in Pharmacy?<br>Kellie: Um, no, coz we haven't really worked with them in a practical sense.<br>Interviewer: Uh huh. So it's the prac sense that, that Chemistry warns you about these things, is it?<br>Kellie: Yes.<br>Interviewer: If you think, if you think about taking um, taking a drug which is an acid or a base, would you expect it to be, to burn your skin?<br>Kellie: No **(2.799-2.808)** |
| other characteristics, particularly differences | Kellie: it's more ionisable at a low pH, pKa sorry<br>Interviewer: More ionisable at a pH or pKa?<br>Kellie: pKa, I think. No, pH.<br>Interviewer: Uh huh. So, it ionises at high pH or low pH?<br>Kellie: Low.<br>Interviewer: You sure about that? (laughs)<br>Kellie: Oh, yeah, high. Should be high **(2.358-2.364)**<br>[base] more ionisable at a lower pH **(2.368)** |
| pharmacy acids characterised by pKa rather than pH (pH refers to solutions) | the pH refers to the solution which contains um the acid and, I think the acid and the base **(2.386-2.388)**<br>Interviewer: So what's, what's kind of the characteristic of an acid or a base if it's not the pH?<br>Kellie: It's the pKa, you look at the pKa **(2.391-2.394)** |
| acids and bases in pharmacy both have pKa values | |

Persistent change – Kellie

| | |
|---|---|
| strength characterised significantly differently in pharmacy and chemistry | Interviewer: you've talked about strong and weak, um, well strength in particular. Um, what do chemistry, what would chemistry call a weak acid?<br>Kellie: Um, (pause) something that doesn't um, readily donate a proton.<br>Interviewer: OK. So doesn't readily donate a proton. And what would you say in pharmacy? How would we define a weak acid?<br>Kellie: The same thing. (laughs)<br>Interviewer: The same thing. OK. Are there any acids in pharmacy that any, like, acids that in chemistry would be called weak, but in pharmacy would be called strong?<br>Kellie: Um (pause) yes, but I can't think of any. (laughs)<br>Interviewer: Can't think of any? OK. Thinking in terms, you mentioned strength in terms of pKa. Does that help? Not really.<br>Kellie: No<br>Interviewer: No, OK. If I said Chemistry usually defines a weak acid as something that doesn't dissociate completely in solution, does that ring a vague bell?<br>Kellie: Yes.<br>Interviewer: A vague bell. It's all right, you've done chemistry I understand that, that was last semester. (Kellie laughs) Um, and in Pharmacy we say um a weak acid is one that has a pKa above 7?<br>Kellie: (pause) Yes.<br>Interviewer: Yeah? Does that kind of vaguely ring a bell? Whereas in, in say in Chemistry, they would call something like ibuprofen a weak acid. Coz it's got, it's got a pKa of four point four, we'd call it a strong acid.<br>Kellie: Oh<br>Interviewer: So something with a carboxylic acid group, in um, in Chemistry they'd call it a weak acid because it doesn't dissociate completely, but in Pharmacy, we call it a strong acid coz it's, it, it donates its proton more easily than, say, a phenol does.<br>Kellie: Oh, OK **(2.773-2.792)** |
| strength in pharmacy characterised by values of pKa | |
| in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | *Not specifically described* |

Persistent change – Kellie

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | if it can donate protons then it's an acid **(3.108-3.110)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | [acid] physical characteristics like sour **(3.114)** |
| difference between acids and acidic drugs | Interviewer: is there a difference, do you think, between calling something an acid and calling it an acidic drug or does that mean the same thing to you as well?<br>Kellie: Um, (pause) I think, sounds the same to me **(3.207-3.208)** |
| pharmacy acids characterised by pKa rather than pH (pH refers to solutions) | Interviewer: Do you think of acids ah, as having a pH?<br>Kellie: No, they have a pKa. I think, I think pH is for solutions that contain acids or bases **(3.133-3.138)**<br>Interviewer: What do, what does pH have to do with?<br>Kellie: Ah, it has to do with the solution that contains acid or base. And it's a concentration of the ions **(3.187-3.190)** |
| acids and bases in pharmacy both have pKa | it's like, pKa if it's less than 7 then it's, I think it's a weak acid **(3.148)**<br>a pKa less than 7, that indicates it's a strong acid, and then if it's greater than 7, then it's a weak acid **(3.160-3.162)**<br>if pKa for a base is less than 7 then that would be a weak base and if it's greater than 7 it'll be a strong base **(3.172-3.174)** |
| pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | |
| strength characterised significantly differently in pharmacy and chemistry | a weak acid would mean that it doesn't easily accept, I mean, yeah donate… it will donate protons. So then if it's a strong acid then it will readily donate the proton **(3.178-3.182)**<br>a strong base would mean that it readily accepts a proton, and then a weak base would readily, I mean it wouldn't as readily accept a proton **(3.184-3.186)**<br>Kellie: Except for the strength, I think that's different.<br>Interviewer: OK, how is that different?<br>Kellie: Like a strong acid in Chemistry, you, ah it means that it dissociates completely. And in Pharmacy, like not all drugs wouldn't dissociate completely, so you just refer to the strength of that. |

Persistent change – Kellie

| | |
|---|---|
| | Interviewer: OK, so strong doesn't mean the same thing in both?<br>Kellie: Yeah **(3.198-3.204)** |

*Concepts new to pharmacy*

| Characteristic | Transcript excerpt – interview 2 | Transcript excerpt – interview 3 |
|---|---|---|
| carboxylic acids | *Identified without significant verbalisation* | *Identified without significant verbalisation* |
| phenols | OK, so then I look at this, I see a OH and so I recognise that as a phenol group, and then I know phenol is a weak acid **(2.422-2.426)**<br><br>Kellie: (pause) Oh, coz that isn't benzene.<br>Interviewer: That's right.<br>Kellie: Oh, it has to have a circle in it.<br>Interviewer: Yeah **(2.484-2.487)**<br><br>that is phenol coz it's attached to the benzene ring and it's directly attached to it **(2.530-2.532)** | Kellie: Oh, I've forgotten a lot of this. Um, OH, I think that's phenol, and (pause) is that a weak acid?<br>Interviewer: Phenols are weak acids, yes **(3.214-3.217)** |
| aliphatic amines | Kellie: it has to, has to be joined to an $sp^3$ hybridised carbon<br>…<br>Interviewer: Uh huh. OK. (Kellie laughs) And what does $sp^3$ carbons, how do you recognise an $sp^3$ carbon?<br>Kellie: If there's a C double bond O, then that's not $sp^3$.<br>Interviewer: Right. So $sp^3$, what sort of bonds do they have?<br>Kellie: There's one, oh what, they're just single bonds **(2.444-2.453)**<br><br>And this N, it's attached to…it's attached to the um carbon so, and that's a single bond, so that makes it $sp^3$ carbon bond. So then, that can be an amine **(2.520-2.526)** | Kellie: well, it's not directly attached to that<br>Interviewer: To the benzene ring, no.<br>Kellie: to the benzene ring. So<br>Interviewer: Is that necessary for amines?<br>Kellie: Yes **(3.256-3.260)**<br><br>I must have been thinking of phenol, it has to be directly attached. So it doesn't have to be for amines? **(3.266)**<br><br>Interviewer: Were there any conditions about amines that you can remember, that made a, a nitrogen into an amine, that you had to look for?<br>Kellie: Ah, to the carbon, coz um it has to be $sp^3$ like, hybridised **(3.269-3.272)** |
| amides | Kellie: There's aren't any basic, or, oh there's this N, but I think that's an amide, is that right?<br>Interviewer: OK, why do you think it's an amide?<br>Kellie: Because um, (pause) I don't remember this, but I think that's not a aliphatic ring.<br>Interviewer: OK. What makes you think it's not aliphatic?<br>Kellie: Because that like<br>Interviewer: Because it's a funny shape?<br>Kellie: Yeah **(2.430-2.436)** | Kellie: That is, that's $sp^2$.<br>Interviewer: Why is it $sp^2$?<br>Kellie: Coz of the like double bond to the O, so that will be amide **(3.276-3.280)**<br><br>Interviewer: is an amide basic?<br>Kellie: Um, no? **(3.281-3.282)** |

Persistent change – Kellie

| | | |
|---|---|---|
| other non-basic nitrogens | that carbon is double bonded to the N. So that's amide **(2.618)** | Kellie: and (pause) ah, is this another amide?<br>Interviewer: Well, It's not an amide, because it doesn't have a C double bond O next to it, but it's certainly different from the other things that you've seen. What was, go on.<br>Kellie: It's not amine **(3.330-3.332)** |
| multiple functional groups | that's a basic group and that's an acidic group so then the whole structure will be neither **(2.476-2.478)**<br><br>Kellie: [amoxycillin] these two are acidic and that's basic, so overall, um you don't know, right? Coz it's I thought it was like, if you have basic and acidic, then it's neither.<br>Interviewer: Uh huh, that's correct.<br>Kellie: So does that make the whole thing neither?<br>Interviewer: It makes the whole thing neither, yeah **(2.566-2.575)**<br><br>when you draw it up, the um, (pause) when it dissociates, then you, it's got both plus and minus **(2.578)** | So then, you've got basic, acidic, weak acid here, so it's neither **(3.314)** |
| dissociation of ibuprofen | Interviewer: with ibuprofen, for example, how would you draw up that dissociation?<br>Kellie: Um, OK, you'd draw that and then you draw this equilibrium sign and then you would write the pKa here.<br>Interviewer: Yep, which is four point four.<br>Kellie: And then you just draw the same, but um with the, donating the proton. (pause) So then yeah, the proton's gone **(2.639-2.646)** | *Carried out with minimum verbalisation* |
| dissociation of amoxycillin<br>addition of proton to amine | you have to start with all the protons attached **(2.686)** | Kellie: OK ah, and then you, you draw this with all the protons attached…(pause) that'll be $NH_3$<br>Interviewer: Yep. Just $NH_3$?<br>Kellie: plus **(3.394-3.398)** |
| correct order of dissociation | So then um, you draw the, you write the lowest pKa there, and then um the next step is when it loses a proton, so, (pause) um, I think, oh, the next one will be seven point four **(2.710-2.716)** | Kellie: All right, then you start with the lowest pKa and that's two point four. And then that would dissociate and will become (pause) NH2.<br>Interviewer: OK, um, you said that that loses<br>Kellie: Oh, wait, wait, it doesn't lose that first, all right.<br>Interviewer: No.<br>Kellie: It'll lose um this one.<br>Interviewer: The carboxylic acid,<br>Kellie: Yeah<br>Interviewer: not off the nitrogen, yeah, OK. Yep.<br>Kellie: Then, then it will lose the one off the phenol. Oh, no, this one |

Persistent change – Kellie

| | | |
|---|---|---|
| | | because it's seven point four.<br>Interviewer: Yeah, so it comes off the nitrogen next. (pause while writing) Yep<br>Kellie: And then it will lose the one off the phenol **(3.410-3.422)** |
| prediction of form at specified pH | when you wanna, when you look at a pH that is like, greater than or less than, you compare it to the pKa you see how much further away it is from that, and so you see which um form is, which form is most present **(2.648-2.654)**<br>Interviewer: is there a point which you can say it's pretty much all in that un-ionised form?<br>Kellie: Um, yes. When the pH is like, two or more, less than that.<br>Interviewer: OK, so it would be at pH what?<br>Kellie: Two point four or less **(2.659-2.664)**<br>Interviewer: And what about when it's completely ionised?<br>Kellie: Then that'll be six point four or more **(2.665-2.666)** | because that indicates the pKa and (pause) um so like if, um, when you're looking at this in a certain pH system, like yeah, some, like in some system with a certain pH, then you can see which way it goes **(3.358-3.360)**<br>Interviewer: what ah, pH would be necessary for you to say that it was completely in the ionised form?<br>Kellie: It would have to be two units more than that, two or more units away from four point four.<br>Interviewer: From four point four. In the, in what direction?<br>Kellie: In this direction.<br>Interviewer: Above it?<br>Kellie: Yeah.<br>Interviewer: OK. And what about if it was all in the COOH. What pH would you need to have for that?<br>Kellie: It would have to be two or less than four point four. So, two point four or less **(3.361-3.372)** |
| interchange of pKa for phenol and amine in amoxycillin | Kellie: And then um (pause) then, the next pKa is seven point four<br>Interviewer: Yep, that's right<br>Kellie: and that refers to the OH group, the phenol.<br>Interviewer: You reckon? I've said it's a base pKa.<br>Kellie: That's a base.<br>Interviewer: Well, what do you know about pKas of phenols? What normal range do they have?<br>Kellie: Um, nine to eleven.<br>Interviewer: Uh huh, so seven point four doesn't really sound like it's within that range, does it?<br>Kellie: So then that would have a pKa<br>Yeah<br>of seven point four.<br>Interviewer: Yeah, so it's just the $NH_3$ group, yeah **(2.726-2.737)** | Seven point four with (pause) the weak acid and then nine point six with the base…because the base is more basic **(3.376-3.380)** |

Persistent change – Kellie

*Additional issues – interview 2*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| Kellie's perceptions | before, at the beginning, it was like, something I really didn't like, you know, I didn't, coz I didn't understand, or I'd forget concepts and stuff like that **(2.334-2.336)**<br><br>I understand it a lot more…it was good doing this course coz um, you know I understood the concepts better **(2.334-2.338)**<br><br>in pharmacy, like because it refers to drugs so then it makes more sense when you learn it **(2.344-2.346)**<br><br>in chemistry it's kind of like, oh, you can't really um, visualise it **(2.348)** | Kellie indicated that she found learning in IPS helped her understanding of chemistry concepts, and also that the applications in pharmacy were more relevant |
| lack of confusion between chemistry and pharmacy | well in chemistry, when you say 'strong acid' or a 'strong base', that means that it dissociates completely in solution. But in pharmacy it's um, that's not possible. No drugs really dissociate completely so then they're based on the strength of the acid, and the pKa, I think. Yeah so, um once you understand that, then it doesn't, that's all you have to do, you just understand the concept and then it doesn't really you know, affect you **(2.292-2.304)**<br><br>Kellie: It's like Pharmacy is more like the reality of it. Like, you know it doesn't really dissociate, nothing really dissociates completely so<br>Interviewer: OK, and what, and Chemistry,<br>Kellie: And Chemistry (laughs)<br>Interviewer: what, more theoretical, or?<br>Kellie: Yeah **(2.308-2.314)** | Kellie experienced no difficulty in distinguishing the meaning of strength between Chemistry and Pharmacy |
| Kellie's learning strategies | Kellie: the other things, like, it was more memory work for me.<br>Interviewer: Right. OK. So there were some things that you understood and some things that you kind of had to basically memorise.<br>Kellie: Yeah, memorise **(2.898-2.900)** | When Kellie struggled with concepts, she resorted to memorisation. |

# Persistent change group: Alicia

## *Initial conceptual framework*

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons | *Not described* |
| names of theories | *Not described* |
| taste and feel | [acid] it smells, or something? **(1.16)** |
| corrosiveness | [acid] if you get it on yourself, it might yeah, burn your skin or something I guess **(1.14)**<br><br>Interviewer: What if you got a base on your skin, what would that do?<br>Alicia: Oh, I don't think about that **(1.33-1.34)** |
| other characteristics | [acid] I just think about um, yeah, hydrogen ions floating around in solution **(1.4)**<br><br>[acid] they neutralise a base **(1.8)**<br><br>[base] OH group **(1.26)** |
| Chemistry acids characterised primarily by pH | [acid] pH is low **(1.10)**<br><br>[base] pH is high **(1.36)**<br><br>because the acid is stronger, pH is lower **(1.110)** |
| strength described on the basis of complete and partial dissociation | Alicia: some are more acidic as in pH is like, it's stronger to um. No, when I think of acid, I think of it's like burning, like if you get it on your skin, you'll burn your skin or something like that. Some acids aren't really burning too fast, and some are not that weak, I mean not that strong. So they'd be weaker. Um, so I guess the pH would be different.<br>Interviewer: OK. So the pH is different. So you're talking about strong acids<br>Alicia: Strong acids, yeah.<br>Interviewer: and weak acids. So what makes, so the fact that it burns more quickly, does that make something a strong acid?<br>Alicia: I think it is. Yeah **(1.58-1.64)** |
| mathematical relationship between pH and $H^+/OH^-$ ion concentration | pH would be (pause) um, it relates to the concentration of um, hydrogen ions in solution. And so if there is more hydrogen ion, the pH would be lower **(1.106-1.108)** |
| use of mathematical relationship to solve numerical problems | *Not carried out* |

## Interview 2

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | an acid is a drug that loses its um, protons in solution **(2.270-2.272)**<br>a base is one that gains a proton **(2.276)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | [acid] has an, in solution, it has a low pH **(2.294)**<br>a base in solution would have a high pH **(2.298)** |
| pharmacy acids characterised by pKa rather than pH | [pKa] measures the, whether the drug is an acid or base, like it's the property of the drug **(2.316)**<br>Interviewer: Can you tell just by looking at a pKa whether a drug's an acid or a base?<br>Alicia: (pause) Yes.<br>Interviewer: Always?<br>Alicia: (pause) Er. Oh no, coz. No, because um, some drugs could be, they have like um, (pause) functions, I mean, properties, like functional groups on them, which has like different pKas. So some have like acid pKas and some have bases **(2.319-2.334)** |
| strength in pharmacy characterised by values of pKa | Interviewer: what about strong acids?<br>Alicia: A strong acid would have um, a low pKa.<br>Interviewer: In chemistry or in pharmacy?<br>Alicia: In pharmacy.<br>Interviewer: OK, what about in chemistry?<br>Alicia: In chemistry, a strong acid would be one that loses, I mean, yeah, loses its H easily in solution.<br>Interviewer: OK. And is that different from pharmacy?<br>Alicia: Um, yes, because um, most drugs are um, there's not many drugs that are like, strong acids. So um it's better to compare them by the pKa than by pH, like how much they lose their protons **(2.615-2.628)** |
| strength characterised significantly differently in pharmacy and chemistry | Interviewer: a strong acid is one that, how, how well does a strong acid hold onto its proton?<br>Alicia: Very well. Oh, no, um it doesn't, um, it loses it easily.<br>Interviewer: Yeah, OK. So a strong acid loses its proton easily,<br>Alicia: Yep<br>Interviewer: and a weak acid doesn't.<br>Alicia: Yep **(2.529-2.534)** |

Persistent change – Alicia

| | |
|---|---|
| acids and bases in pharmacy both have pKa | a strong acid, its pKa would be below 7, and um a strong base, its pKa would be above 7. A weak acid, its um pKa would be mm, above 7 **(2.302-2.306)** |
| in pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | |

## Interview 3

| Characteristic | Transcript excerpt |
|---|---|
| ability to gain and lose protons retained for both contexts | [acid] loses (pause) its um proton in solution **(3.106-3.108)**<br><br>bases, they gain protons. Um, they accept protons in solution **(3.136-3.138)** |
| pharmacy characterised by functional groups | *Not described* |
| chemistry but not pharmacy characterised by physical characteristics | *Not described* |
| difference between acids and acidic drugs | Interviewer: do you have a different kind of meaning for acid versus, say, acidic drug? Are they different ideas, or are they pretty much the same?<br>Alicia: (pause) Pretty much the same **(3.167-3.168)** |
| pharmacy acids characterised by pKa rather than pH | Alicia: An acid, um, it has um a low pH in solution, yeah. And (pause) it um (pause) has a low pKa.<br>Interviewer: All acids have those things, low pH and low pKa?<br>Alicia: I think all acids have um low pKas, but not necessarily low pHs **(3.112-3.118)**<br><br>[base] they have high pHs, but not necessarily, but they have high pKas **(3.140-3.142)**<br><br>Alicia: in Chemistry I don't think of um, acids and bases with um, pKas. But in Pharmacy, yeah, I think of that.<br>Interviewer: Right. OK, that's good. So why don't they have pKas, do you think, in Chemistry?<br>Alicia: In Chemistry? I think, (pause) hmm, (long pause) um, (pause) maybe the, maybe it's not relevant **(3.158-3.164)** |
| strength in pharmacy characterised by values of pKa | Interviewer: what do those pKas tell you about the strength of the various acids, well, particularly the acids? So, you've said two point four belongs to the phenol?<br>Alicia: Yeah, so phenol would have um, it has the low pH, so it's a strong acid **(3.275-3.278)** |

Persistent change – Alicia

| | |
|---|---|
| acids and bases in pharmacy both have pKa | Alicia: A high pKa is a strong base.<br>Interviewer: Uh huh. And a low pKa?<br>Alicia: Would be um a low base.<br>Interviewer: A weak base.<br>Alicia: (laughs) I mean, yeah a weak base **(3.452-3.456)** |
| pharmacy strong acids/weak bases have pKa values less than 7; strong bases/weak acids have pKa values greater than 7 | *Not described* |
| strength characterised significantly differently in pharmacy and chemistry – pharmacy by differential acceptance and loss of protons | Alicia: If they were weak um, acids.<br>Interviewer: OK. So what do you mean by a weak acid?<br>Alicia: Uh, it's one that doesn't lose its protons easily in solution.<br>Interviewer: Uh huh, OK. And so the opposite of that would be strong.<br>Alicia: Strong<br>Interviewer: How would you?<br>Alicia: Strong one would yeah, strong one would lose easily in solution.<br>…<br>Interviewer: OK, so what sort of things would be associated, what would be a strong base? I mean, how would you?<br>Alicia: A strong base would um, (pause) would accept a proton more easily.<br>Interviewer: All right, and a weak base?<br>Alicia: Would not accept it easily **(3.124-3.148)** |



Persistent change – Alicia

## *Concepts new to pharmacy*

| Characteristic | Transcript excerpt – interview 2 | Transcript excerpt – interview 3 |
|---|---|---|
| carboxylic acids | *Identified with minimum verbalisation* | *Identified with minimum verbalisation* |
| phenols | this is a benzene, it has um, the circle **(2.350)**<br>Alicia: that's a benz, um gosh, a phenol.<br>Interviewer: a phenol (both laugh) Is that a benzene ring?<br>Alicia: Yeah **(2.424-2.426)** | Interviewer: what's wrong with the OH group, why isn't that a phenol?<br>Alicia: That's um, coz the ring is not um (pause) I don't know there's no circle in it (laughs) **(3.213-3.214)** |
| aliphatic amines | this nitrogen is attached to a C, which is $sp^3$…then it would be an amine because the carbons are $sp^3$ hybridised **(2.356, 2.396)**<br>Interviewer: So how do you know something's $sp^3$ hybridised, what do you look for to say whether it's<br>Alicia: Just the single bonds **(2.401-2.402)** | because there's a nitrogen, (pause) um (laughs), and it's not connected to a, a C which has a double bond…all its bonds have to be single **(3.184-3.186, 3.228)** |
| amides | let's see, this nitrogen is an ami-ine. Um, this one isn't, because it's attached to the C which is double bonded to the O **(2.428-2.432)** | *Identified with minimum verbalisation* |
| other non-basic nitrogens | Interviewer: What about diazepam?<br>Alicia: (pause) This is an amide. This, is an (pause) it's not um, an amine.<br>Interviewer: That's correct, it's not an amine. Why do you say it's not an amine?<br>Alicia: I think it's got a um, it's got a double bond there **(2.455-2.460)** | *Identified with minimum verbalisation* |
| multiple functional groups | coz it has properties of, it has both um, acids and bases… it can't be a base but, I mean it can't be an acid, but it also can't be a base because it also has acid properties **(2.490-2.502)** | It's something else, because they have um, both acids and bases **(3.196)** |
| dissociation of ibuprofen | *Carried out with minimal verbalisation* | *Carried out with minimal verbalisation* |
| dissociation of amoxycillin | *Carried out with minimum verbalisation* | *Carried out with minimum verbalisation* |
| allocation of pKa values | Alicia: OK, I start off with all the protons attached, so (pause) um, sorry …<br>Alicia: So (pause while drawing)<br>Interviewer: OK, yep<br>Alicia: and then (pause) it would lose, the um, woops, that would be the phenol at two point four, so (pause) oops, and then (pause) um, NH2 (long pause) | Alicia: and (pause) um (pause) the phenol with this<br>Interviewer: OK, so, you're saying the two point four belongs to the phenol.<br>Alicia: Yep.<br>Interviewer: OK<br>Alicia: And then, (pause) oh, wait a minute. No, I'll start again…Um, so (pause) |

Persistent change – Alicia

| | | |
|---|---|---|
| addition of proton to amine<br><br>correct order of dissociation | Interviewer: OK, so you've given the um the two point four pKa to the phenol.<br>Alicia: Yes.<br>Interviewer: Does that make it strong or weak as an acid?<br>Alicia: It's strong.<br>Interviewer: OK and do you normally think of phenols as being strong acids?<br>Alicia: No I do.<br>Interviewer: OK. So, stronger than carboxylic acids?<br>Alicia: (long pause) Yes. (pause) Yep.<br>Interviewer: Yes?<br>Alicia: Yep **(2.506-2.526)** | Interviewer: Yeah that's fine, you can do however you wanna do. Yep<br>Alicia: So the first one, two point four, and (very long pause)<br>Interviewer: OK, so the seven point four is the carboxylic acid group?<br>Alicia: Yeah. (long pause) Nine point six **(3.260-3.274)**<br><br>Alicia: Yeah, so phenol would have um, it has the low pH, so it's a strong acid.<br>Interviewer: OK. And carboxylic acids?<br>Alicia: It's um, (pause) it's not that strong, compared to phenols **(3.276-3.282)** |
| prediction of form at specified pH | Interviewer: What kind of help is it to write out the dissociation that way?<br>Alicia: Ah, to compare um, which form would be the, which would be the major form given a pH of the solution.<br>Interviewer: So how does that work?<br>Alicia: So if, just say you're given a pH of five, um, you would say it's, there<br>Interviewer: It's the second one.<br>Alicia: Yeah, the<br>Interviewer: Yeah, yeah, OK. So how do you, how do you decide that? Like I mean why, why can you say that so confidently and be correct about it? What's your thinking is what I'm trying to get at.<br>Alicia: Um, coz five is above two, so it's more towards this region<br>Interviewer: OK, so it's above two point four. But why isn't it, say, the fourth one?<br>Alicia: Isn't it this one?<br>Interviewer: Yeah. Like why is that not?<br>Alicia: Oh, because it's also below<br>Interviewer: Below seven point four.<br>Alicia: Yeah<br>Interviewer: So it's in between the<br>Alicia: Yeah<br>Interviewer: two pKas **(2.537-2.561)** | Interviewer: why do you put the four point four on top of the arrow?<br>Alicia: (pause) Because I just do. (laughs)<br>Interviewer: You just do. OK, what does it help you?<br>Alicia: Oh, it helps to see um when the pH, no pH, but at what, what um, form the drug will be in at certain pHs.<br>Interviewer: OK, so can you explain that a little bit more?<br>Alicia: So, say if the pH is 8, then the um, the majority of the drug would be in that form.<br>Interviewer: In the ionised form?<br>Alicia: yeah<br>Interviewer: OK. And what would be a pH in which it was completely in the un-ionised form?<br>Alicia: It would be less than four point four.<br>Interviewer: OK, what about<br>Alicia: Two less.<br>Interviewer: completely? Two less<br>Alicia: Two less **(3.239-3.256)** |

Persistent change – Alicia

| | | |
|---|---|---|
| | Interviewer: What's true about it [ibuprofen] at say, pH two?<br>Alicia: pH two, it would be un-ionised **(2.573-2.574)**<br><br>Interviewer: At what pH would you expect it to be completely in the un-ionised form?<br>Alicia: Um, two units below the pKa.<br>Interviewer: Uh huh, and what's true then about it being completely ionised? What pH would it be completely ionised?<br>Alicia: Oh, um, two or?<br>Interviewer: No, completely ionised.<br>Alicia: Oh, ionised, sorry. Um, two units above, so, so, like, six point four **(2.675-2.684)** | |

## *Additional issues – interview 2*

| Characteristic | Transcript excerpt | Comment |
|---|---|---|
| Alicia's perceptions | how you explained it in the lectures, it was more clear. I don't, yeah, like I understood it better than in chemistry…I think you made it, um, you showed, you pointed out the difference pretty clearly **(2.248-2.258)**<br>In Chemistry, it's, I think it's more confusing. I still don't fully fully understand it but in, for like what I need to know for Pharmacy, I think I get it, understand it better **(2.590)**<br>Alicia: Some what I learnt from High School, and like from uni. It's like um, like when they teach it again, like they maybe assume you know something, and they just go on and you get confused or you don't fully understand it.<br>Interviewer: Did what they teach you in chemistry, was that, did that contradict what you'd learnt at school?<br>Alicia: Um, it didn't contradict, but it was (pause) I don't know, I think they taught it further assuming you know like some basics or something which you might not have learnt or you might have forgotten **(2.600-2.608)** | Alicia attributed much of her problem to inadequate preparation in secondary school. |





Persistent change – Alicia

## Part B: Relational space (chapter 7)

### Group functioning – transient change group: Janine

I don't think my group did very well in working together. I think it was, it depends on dynamics really, because I've worked with groups before that I've liked working with **(2.98)**

I think it's better, less in groups, in partners or three at max. Once you hit five that's, that can be an issue **(2.100-2.102)**

you had issues like Emma getting very sick and not turning up, and then when she did turn up she'd need everyone's help and everyone would get aggravated at her **(2.102-2.106)**

And then Larry resents totally anyone helping him, and yet at the same time if he doesn't get something he'll be angry at you if you don't explain it to him **(2.106)**

Lucy's good but often she just doesn't want to work, she just wants to sit there and bludge and then, that slows the rest of the group down if you're trying to work together **(2.108)**

if someone really, really wants to work and get it done that's fine if they're working with someone who really wants to get it done, but then if there are other people who are a bit slower then it can drag you behind **(2.112)**

I knew I'd have this problem like, I'd learnt from first semester that they, you know you learn everyone's working styles and I just knew that they're not as dedicated or like they're not as set on doing their work and stuff as I am **(2.116)**

I'm not the most patient person in the world, so I think that makes it hard with your friends **(2.128)**

Yeah, yeah, they're my best friends. Oh, the pharmacy group is really close in college **(2.132)**

Interviewer: Yeah. Yeah, so, so, um, I'm getting the sense that you would like to kind of keep the friendship quite different from the work, in that sense.
Janine: Um, not necessarily, I've worked with my friends before, like in high school and stuff it's just, I think they have to be on the same level in terms of dedication and in terms of um, where you're at, like, like they, that, my particular group of friends don't necessarily study as much as I do and that's the problem, coz then I'll know stuff that they won't know and I'll be too quick, and then I'll be rushing them and things like that, and get aggravated at them, that doesn't work. It's better when I was like, like I had a best friend in high school who would I often work with because we'd both usually be up to the same things. That's what I think is important **(2.139-2.146)**

I think Larry and Lucy, like they got really frustrated when they could see that I'd know things that they didn't have any idea about. Because then that makes them even more worried, makes them think that they should be up to that, when maybe I've done a bit more work than even I needed to do **(2.154-2.158)**

I work more efficiently on my own coz I'm, I just go real quick and try and learn what I want to learn instead of like trying to help other people or explain it to other people…But I can explain things, I, I, I usually do explain things, like I have no trouble explaining things **(2.210-2.216)**

I get more frustrated when they didn't want to do anything. That's, then I don't want to explain it to them if they don't want to do anything anyway. So they're just trying to get out of it, there's no point **(2.216-2.218)**

Geoffrey: the college itself has a library. But um, it's, it's harder to study coz you get distracted a lot easier. Yeah. But um, whereas at home, it's not as convenient, but it's a lot easier to concentrate. Coz you know, (pause) yeah you don't get sidetracked very easily.
Interviewer: Not as many people around to socialise with.
Geoffrey: Yeah, and that, (laughs) yeah **(1.594-1.600)**

I studied a little bit with Larry, Lucy and um, (pause) mainly Larry and Lucy as well, and I found um, if something, like well we'd study like all in a group and then when one person had a problem another one of us would try and explain it to them and that was really helpful as well…I found that the reason why we worked better outside was mainly because (pause) Janine wasn't there **(2.68-2.80)**

she [Janine] (pause) she causes a lot of stress amongst us **(2.84)**

she likes to work through her things first before helping anyone else. Like she likes to get her stuff done and she's very, she's very narky …like you would've noticed on the videos, and that mainly, it's mainly (pause) like Janine is working by herself when everyone else is working as a group. Because Janine likes to work by herself, she doesn't like group work I don't think **(2.88-2.98)**

when she goes to the tutes she knows what she's doing whereas many of us don't know what we're doing, we have to work it out at the tutes, like we have, we learn when we're at the tutes **(2.100-2.104)**

she'll fly through her work whereas we need to look through it and then think about it and then say, OK, looking back at the lecture notes, this is what happens **(2.106)**

she'll like turn up to the tutes pretty much prepared…I think she works, I think it's because she works beforehand **(2.106-2.108)**

I wouldn't say she's um, (pause) like smart in the sense that she understands every, like concepts just come to her really easily, but it's coz she's very um, conscientious and she's very um, studious person, so that's why she does so well in what she does **(2.110-2.112)**

it was very laid back and you could do it at your own pace…and um, everything was there, whether or not you wanted to learn from it, was up to you. So if you didn't benefit from those, like if you didn't work in those tutes then it was your fault, and yeah, but I felt everything was there and it was a good environment to work **(2.120-2.128)**

I learnt, I think I learnt more during the tutes, the workshops than in lectures **(2.130)**

Geoffrey: working in a group like outside of workshops, when we were studying, it was when one person didn't know something the other person could explain it to them. And that would not only help the person who didn't understand but also helped the person explaining it. Coz if they didn't get it, then they could look it up themselves and then, because by doing that, you also pick up a lot of what you don't know. Whereas if you're just working by yourself, you can only do everything that you do know, like you only look at all the stuff and say "yeah I can do all this" but then when someone throws a question at you, you think, "Oh hang on I haven't had a look at that yet."
Interviewer: Haven't considered that, yeah.
Geoffrey: Yeah, so that's why it's good working as a group I think **(2.144-2.156)**

sometimes it's, it's better if you work by yourself though like, well like, sometimes it can be, like it does slow you, like sometimes it might slow you down a bit **(2.162)**

I think what um, Janine sees the group work as, like sometimes she might see it as slowing her down a bit, because she knows what she's doing and she, and she sees us more

as, rather than helping us I think she sees us more as an interruption to her, to her work and her train of thought **(2.162-2.164)**

most of the time, and um, Lucy, Lucy most of the time, she'd [Emma] ask us, like if she needed help she would ask either me or Larry more than she'd ask Janine coz I think she kind, she was aware of the fact that Janine doesn't like to be disturbed. And then um, I think she also got the impression that when she asked for help from Janine, (pause) she would feel inferior, like Janine would make her feel a bit, would make her feel stupid **(2.170-2.172)**

We're pretty much a group of friends except, um, not so much with Janine of lately… our friendship, as in everyone else in our group with Janine, apart from Emma I think, has sort of deteriorated a bit **(2.196-2.228)**

I think the best thing to say to someone like Emma is just "Get some rest, I mean, don't stress, I mean do what you can, and if you can't do it then, (pause) then maybe you'll get some special consideration or maybe you'll be able to learn from these mistakes and work a little bit harder next time. And, if you yeah, if you work a little bit harder then maybe you'll be able to get, maybe you might be able to get through this stuff, you never know." **(2.226)**

like she's [Janine] been like that all along, it's just taken us this long to (pause) sort of realise it and then think, like, I mean there's no use in trying that hard anymore, you know what I mean, like trying that hard and trying to you know (pause) stay friends because it's really hard…hard to relate to her and you know, (pause) be on the same wavelength as her **(2.228-2.234)**

Like some people do work hard, some people work very hard right, but then when it comes to, like they, they don't, (pause) it doesn't affect their character though. Whereas it will get, affects her [Janine] char, her character **(2.236-2.238)**

and he's [Larry] quite studious, so that influences me. Whereas, if he was like, lazy then (pause) I'd probably, you know, follow suit **(3.112)**

he's [Larry] fairly competitive, I think. (pause) So I keep him going, he keeps me going, which is good **(3.118)**



## Group functioning – transient change group: Larry

Larry: having Tuesday to study for it [IPS] was really good, too. Coz we just had one big study session, Emma, Lucy, myself and Geoffrey all were over at Women's library and we just went through everything and everything and everything.
Interviewer: And that was good, was it?
Larry: It was the only way to go **(2.12-2.16)**

Larry: The only way to go is group work, coz, if you don't understand something, getting someone else to explain it, or explaining it to someone else confirms, consolidates it in your mind, whether that's the right way to do it or the wrong way to do it.
Interviewer: Yeah, OK. And, did you find that, um, it was OK, like, people weren't trying to run their own agendas? Like were you, I mean if like, if you were kind of worried about your own exam, that, was that an issue?
Larry: Well, it was a little bit when you knew something and someone else didn't know it, so you had to explain it to them so you had to take time out of your doing your study to do that. But I mean you don't really mind that, coz as I said, it just consolidates in your mind what you, what you know, and then, if you get the right answer, then you really do know it. Otherwise, if you can't explain it, then you don't really know it, so you should go back and study it anyway. And you should work through it anyway, so it wasn't really a problem **(2.22-2.24)**

[in workshops] we had Janine there, who's not exactly helpful **(2.36)**

when you try to get help from Janine, or, you know, you try to do anything with Janine, she just somehow just makes you feel almost stupid that you don't know, how can you not know this? Therefore, you know, this is how you do it and nernerner, and she can be really just plain annoying for that group work **(2.36)**

she [Janine] comes in there, she knows what to do, she does it… she's learned it all beforehand **(2.36-2.40)**

I think she [Janine] studies four to five hours a day, every day, and she studies the material before she goes in to the lectures and does all the proper things you're meant to do for uni , but the rest of us don't, we're in there trying to learn it together **(2.40)**

when the rest of us are trying to do it at our pace, she works at a much quicker pace… we work well as a group together but when you throw Janine into the equation when she's rushing through it, she's trying to get it out of the way and she just won't let us work at the pace that we want to work at **(2.36-2.42)**

if you work away from her [Janine] and then when she's done it, and you ask her a question, she feels like well, why should I have to answer it if you don't know the work **(2.44)**

it's all part of working as a group. It's just that group work is trying to help each other, and that's why we had such a, um good study sessions together over at Women's, with just the four of us, without Janine, because we could all, we were basically the same level, working at the same pace. We just helped each other **(2.44)**

I mean we were all just a little bit agitated, and sick of everything **(2.48)**

And I knew exams were approaching, and I was stressed because I couldn't do it, and then I was stressed because I couldn't, I just, I dunno, I was just basically stressed and agitated **(2.54)**

I think Janine left early that week [final workshop]. She left I think, early, and the video camera was off, so it was just us four, a little bit more relaxed, just trying to do it at our own pace **(2.64)**

Perhaps the pressure you put on yourself. Yeah, I think so. Partly, and then unless you take time out to relax a little and like, do our normal little just chit chats and whatever, and relax a little, I think you get, it's easy to get agitated, especially with me, you know, and around exam time…I'm one to be avoided in college **(2.78-2.80)**

we were all like, studying you know, the day before, and putting slaving in, and she's already done it all, and she [Janine] comes back to college wandering in, "I just can't be bothered studying more, I'm so over the whole process. Um, I've studied enough. There really isn't anything more that I can learn." And you know when Janine says that, it really is true, that there is nothing more that she can learn. It's just frustrating, coz you just go, "I have so much work to do, and I don't need to hear that you've got nothing to do at all." Ahh. I just hate that **(2.116)**

Which is all changing this year, in a big, dramatic way, everyone has just decided that our group doesn't work anymore. Everyone's gone in different directions…sometimes we all sit together, but most of the time the group has totally (pause) gone…Lucy and I still get along fine. More that she's more, just more relaxed. Geoffrey has decided he doesn't like Janine, and so won't sit anywhere near her, to, so to avoid Janine, sits across the other side of the room, um and Janine tends to follow Emma, and Emma gets more pissed off coz Janine is following her, and I don't know. Janine, she may be the problem with it all. I don't know. And it's, I have no problem with Janine, I think she's fine, and whatever, but they've all just type of gone our own separate ways…And I mean, yeah, Lucy, Emma and Janine I think are having difficulties together **(3.466-3.478)**

Definitely not a result of IPS, I think everyone just had personal issues, type of thing. Very much personal issues, I know Janine and Emma were having a fight at the time, and Emma and I were having difficulties… I think it comes from living in each other's pockets all the time. I mean Geoffrey and I this year, well. We used to be at opposite ends of the college. Now we're living right across the corridor from each other. And it can get very frustrating, I think he feels it more than I do, perhaps, and he just, I mean likes his own little thing, and I'm just like, OK, whatever… It just comes from yeah, being around each other constantly, we were, all the time. Mm. We all had the same type





Relational space – transient change group

of friends in college, we all lived, we all went and tried to help each other with pharmacy, we were all doing the same course, we were all sit, always sitting together, we just did too much together...And it just fell apart eventually **(3.470-3.486)**

Oh, I'm sure it'll get, it'll sort itself out in time, but I think people just need a bit of space now **(3.488)**

## Group functioning – transient change group: Lucy

I think I started probably studying a bit earlier and yeah, and then we started with that group work. Like it was just me and Larry pretty much to start with and then Emma sort of joined in, and Geoffrey, like we always got Geoffrey to help us if we needed help because he's the one who knows all the answers all the time **(2.8)**

we did practice questions as a group, practice questions, like all the calculations and whatever. That sort of thing usually as a group because like, I'd try, I'd do those myself but a lot, like there was quite a few of them that I couldn't do so it was better if that we had, you know, everyone there and just worked through them and just bounce ideas off each other and whatever **(2.12)**

I've never really been able to do like, the group study thing, um, usually just, I usually don't get anything done, I get distracted or something like that **(2.20)**

we, I think we were just both, like me and Larry pretty much just got really, we just got really scared and panicked and went "OK we're just going to sit down and do this", so I think yeah, that was sort of it, just the fact that we panicked a little bit **(2.22)**

I think what helped with the thing at college was that I'd read it over myself and I understood it whereas in the workshops I hadn't really...I think that was my problem with the IPS tutorials. I didn't really understand what we were doing so I'd just sort of sit there and go "Oh, all right, yeah" and write it down whatever, but like, yeah I didn't really understand it as much **(2.28)**

Janine I think sort of, coz she doesn't really like let you understand, like she just sort of thinks "why don't you know this, you know, you've got to do this" and whatever, so that, like that I didn't find very effective in helping me really...I sort of feel a bit intimidated and as though she's going to think I'm really stupid so um, I never really, like I don't, even at college I don't really ask her questions **(2.34-2.36)**

I thought it was a good thing, coz we're all friends and we all, yeah we all get along, and we all you know, we work well together really, so I think, yeah, it's turned out well **(2.40)**

## Group functioning – transient change group: Emma

Janine has got it together. I mean she's lacking in other things and personality-wise, I think, but you know, she really does have it. I, I am jealous of her in some ways, because she does, I don't think I'd want to be getting her marks, I don't think I'd sacrifice as much as she would to get them, but I do envy the fact that she's got it in control. I mean, she, she knows what she wants, she works for it, she's organised, she does, she says she does 4 to 5 hours study a night, I mean, if, that's good. And I just, I'd love to have that kind of discipline, and I, I don't, and I get very frustrated with me, and I think that's why I get so stressed **(2.66-2.74)**

we've been doing this experiment ah, in college, ah, that Larry, Lucy and I will go and do group work. That's how we did Chemistry. And if it wasn't for that group work, there is no way I would have passed **(2.144)**

Because Larry was really good at the um, amino acids, I think he did it HSC. Um, so he could teach us that, and we taught him other things, like the, you know, um, organic

chemistry drawing, which he didn't know how to do, so, it was absolutely brilliant **(2.146-2.148)**

I tried to do it for IPS and it had an adverse effect on me. I just gave up. I just went "Oh my God, they know so much! I don't know that, I don't know this, I don't know that." It stressed me out **(2.150)**

Larry ended up helping me with the chemic, the chemical balance thing, he sat down for five minutes and helped me, and I yeah, I wouldn't have been able to do it without him, because I didn't understand it. Um, and Geoffrey helped me with one question that I couldn't do **(2.152-2.154)**

Janine did her own work. Janine in fact did races to do her own work. Um, especially when she knew what we were doing...she did a lot of her stuff by herself **(2.170-2.172, 2.182)**

She [Janine] finished early and then I got rather pissed off actually, (laughs) coz she um, she finished and we'd all, you know, we all knew what we were, I didn't know what I was doing, but I picked it up from them ... she had to make a show of the fact that she'd finished, and she slammed down her books, and organised, and talked, and then went "I'm leaving", really loudly, and then left **(2.178-2.182)**

we all just ignored her [Janine], because at the mome, I obviously hadn't been around enough to get pissed off with her during the tutorials, but the feeling I got was that the others couldn't stand it, so they were all ignoring her **(2.182)**

Lucy usually didn't know in the, towards the beginning, she didn't know what she was doing, um but at the end, she, she'd obviously done a lot of work towards the end, and she did know what she was doing. Geoffrey tended to work by himself, but helped whenever he was requested, and never yelled and be very patient all the time. He's really good like that **(2.186)**



Sometimes I don't understand his [Geoffrey] explanations, so I'd sort of go "Yep, yep, yep" and think "God I'm going to have to ask Janine later." She is good at the explanations **(2.188)**

I usually felt that I was, you know, I, I came to her [Janine] and said "Look I don't understand this, please help" **(2.190)**

Larry just goes "OK, look I, I do, I've done theory, but I just don't understand how to do this question." And he used to feel that she would make him feel an absolute stupid person, that, you know, "Oh, Larry!" And she, I would see that in the tutorials, like she'd sit there and go "Larry, think about it, just think about it Larry!" And you could see the pressure rising, and Larry going, you know, and he's getting more and more anxious **(2.190-2.192)**

I tend not to ask, rather than ask, but when I do ask, she's usually good, if you have one or two questions. If you have any more than that, then you're pushing it **(2.192-2.194)**

Larry was really good towards the beginning of the term. Like, he'd help me with the calculus assignments, he'd stay up all night with me and do them **(2.200-2.202)**

Towards the exam period, I think we had a few clashes. Um, but that, that was all good, you know, it's just exam stress. **(2.202)**

Janine has definitely been alienated from our group...I mean, couldn't talk to her since the last holidays onwards, I haven't been talking to her **(2.204-2.208)**

There are some things I like about her [Janine]. I mean she, she can be really nice. She's just very difficult sometimes, I mean. Exam periods it definitely came to a boil **(2.208)**

Geoffrey was great. He's been wonderful, he's been there, I mean he doesn't do much work, or he doesn't seem to do much work. I think he probably does it consistently throughout the term, I don't see how he would know it, unless he did. Um, but during the exams, he definitely took it, you know, relaxed, and. He was usually the person, if

you really did have a stressful period, you'd run to him, and say "God, tell me that it's not that bad" and he'd sit there and go "No, it's easy, don't worry about it, you'll be fine", you know **(2.210-2.216)**

Lucy did a lot of work, and she's, she's a good worker. Like I did a lot of assignments with her…she's really laid back, but she'll do the work. She does it well **(2.218-2.222)**

we're [Emma and Lucy] very different people, um, I didn't have much to do with her at all, we mixed in different groups **(2.222)**

it's just that five friends for the entire year when you've got an entire roomful of people, that are, it's just very limiting. So, it's really fun. And sitting with different people, and, and them not taking it as seriously as my friends, it's just great **(3.26-3.28)**

## Group functioning – persistent change group: Veronica

the things that we did do, like we did it like in depth, like we'd like really figure it out together and um, we'd go back to the concepts, so I think that helped me a lot in understanding everything um, so I think it was a good group, yeah, it worked well with those people **(2.56-2.64)**

we just found out that we were in the same workshop and we said 'Oh yeah, let's just sit together' and on the day then I think Alicia, she was sitting with someone else and we told her to come to our group as well, because yeah, we hadn't really talked to her but we did know her **(2.76-2.80)**

Ah, well, with Isabelle, Jasmine and Kellie we're all doing another workshop together, so we know each other pretty well now um, but outside uni, then I go out with ah, Jasmine, Denise and Kellie so that's good **(2.92-2.98)**

it's easy to work with them because I feel comfortable with them, whereas if I was with some people that I wouldn't feel comfortable with, then um, it'd be harder to talk about the, the problems, yeah…I think it's just harder to discuss anything with people that you don't know that well **(2.106-2.112)**

I think it was useful to be like part of the study group, because that actually made us work more because we knew that we were being studied, so um, that made us like want to finish off the things **(2.128-2.132)**

we would have like, probably left early, like the other groups, (both laugh) but we tried to like stay there to the time to finish off um the thing that we had to hand in **(2.136-2.138)**

I think Alicia understood a lot of things but she wouldn't talk that much. Um, but, yeah, if we ever had a problem then we just ask someone else. Yeah. It was, I think every one contributed **(2.148-2.150)**



## Group functioning – persistent change group: Denise

I think I, like we all worked really well **(2.52)**

yeah they were really nice people and they were easy to work with. Yeah they were all really co-operative **(2.54-2.56)**

they were really easy to talk with, probably coz I knew most of them, and then like when we were discussing things it was just easier **(2.64-2.66)**

I have made friends with all of them **(2.76)**

I feel like when I talk things out in groups, like with all these other people it helps me understand it more because first of all like, I'm kind of repeating it like I'm saying it out so that's like re-iterating what's in my head and yeah it's just easier for me to learn that way as well **(2.118-2.126)**

I think they all had like really good qualities and they just all helped me out coz they had their own ideas **(2.130-2.134)**

Interviewer: And do you think that you were helpful for other people?
Denise: I hope so.
Interviewer: I mean being realistic, I mean obviously that's kind of a humble and modest answer
Denise: Yeah

Interviewer: but being realistic do you think that you had, that you contributed as well?
Denise: Umm, I think so. Yeah I think I did **(2.137-2.142)**

the tutes helped me more than like anything, yeah. I got more out of the tutes that like lectures or my own study **(2.164-2.170)**

[the workshops] made me work as well whereas like throughout the semester like I said I didn't do any work until the end because I knew I had to for the exams. But the tutes were like ongoing so they made me do it every week **(2.174)**

I think make more group work, (interviewer laughs) like make more tutes, maybe, (pause) actually two hours is quite enough. (pause) I don't know, I think two hours is a really good time for it, I probably wouldn't make any changes because like, if you made the tutes any longer then you'd kind of lose our concentration so I think it's, no it's fine **(2.180)**

I think group work only works, like it works best if like you have like a bit of an understanding, like a pretty good understanding as well. If you don't have any idea like just being in a group wouldn't really help you…I guess what I was going to say is, just like you know how I was saying the group work, worked really well for me, like it didn't work as well just, without me having to study like I had to know a bit first for it to work **(2.300-2.316)**

## Group functioning – persistent change group: Isabelle

Yeah, um, I thought they were all really smart and I felt a bit stupid. (laughs) Um, (pause) I'm not too much of a group work person but like I try to do stuff and then I feel guilty for copying their answers when, well not copying copying, but using their answers. Um, I try to understand things but I used their answers anyway and sometimes I'd just do work on, by myself and then told them what my answer was. But yeah, they were all really smart and I felt stupid. (laughs) **(2.118-2.128)**



Interviewer: Um, was it like, was it good to be with that group?
Isabelle: Yes **(2.129-2.130)**

they're friends now, they're my friends now **(2.134-2.136)**

even though I feel, felt less intelligent I, I still didn't feel bad when they um told me, hinted answers or whatever, so they were good to get along with and understanding **(2.140-2.144)**

just me not being up to scratch. (laughs) My mind **(2.154)**

Sometimes we, we did stuff besides work, like go shopping, not shopping, like for lunch or something **(2.166-2.168)**

Interviewer: it was a good experience overall?
Isabelle: Uh huh **(2.173-2.174)**

they did work and I really appreciate groups that want to, you know, get into it. I hate leaving things to the last minute and, and yeah they were good. Um, um, say when you have a group thing to do there's always you know, I'll write this bit, you write this bit and putting it together is usually difficult whereas this group was really good. We all contributed in some way and then put it all together and we had enough time and it was good **(2.176-2.186)**

Interviewer: in your group was there like any one person or a couple of people that you thought were particularly helpful in terms of helping you to learn or was it kind of even?
Isabelle: It was kind of even, yeah it was even, yeah **(2.233-2.236)**

## Group functioning – persistent change group: Jasmine

I think if I had to do the workshops by myself during that time of the year I wouldn't have gone through you know, many of them **(2.88)**

it's because it's towards the end of the day, we're, always, always exhausted…always half mentally dead **(2.88-2.90)**

you and Celina, Celina, were always there if we needed help, so that, that was good **(2.94-2.96)**

that time of the day you can't really concentrate **(2.96)**

sometimes when you find that you don't understand something, other people don't understand either then you know it's not really that you're stupid, maybe something just didn't go across and then you have the courage to ask then if the whole table don't understand **(2.106-2.114)**

they have alt, alternative ways of thinking about something and it made sense and it's easy that way and yes, it helps **(2.118-2.120)**

I think throughout the whole term maybe I've helped out once or twice so sometimes I do help out I think **(2.122)**

sometimes when I say something, they, they think that I don't understand the question or something **(2.124)**

Jasmine: Alicia, she, she's kind of quiet so, and also Isabelle I think, usually when we're having tutes it's just us four talking, Isabelle and Alicia they're a bit quiet so I don't want them to feel like we're being bossy though.
Interviewer: Do you think they did think that?
Jasmine: I don't think so, I think they, they work pretty well by themselves **(2.142-2.144)**

I think generally it's a good thing to work as a group **(2.146)**

I always say hello to her [Isabelle] and all that, and sometimes we sit together too **(2.162)**

they're good partners I think **(2.166)**

as long as the other people we get put in with actually do their work…I don't want to work with people who don't do anything **(2.168)**

you come in and suddenly it's IPS, because you have lunch before that with people that you don't do IPS. The very first few exercise would take ages to do and, and you just go on with the last page **(2.342-2.344)**

## Group functioning – persistent change group: Kellie

I think we worked well together um, coz you know, we all shared ideas and tried to work through the problems together…we'd just throw our ideas together about how to solve a problem. And um if there was something we didn't understand, maybe someone else could understand, they could explain it to us and that's how we learnt **(2.50-2.60)**

that's how we learnt, like, just everyone trying to help each other out **(2.60)**

I felt OK about it, coz it felt like, um we were all there to help each other and help each other learn so it was no problem if you didn't understand something, you would just speak up and then someone would try to explain it **(2.62-64)**

And then it helps them as well. Coz they try to, they learn from it as well coz they, by explaining it, yeah **(2.64-2.68)**

Kellie: Um, some people were quieter. But I don't know if that's a negative coz like, you know that's them and they don't want to speak up or something. But um that didn't really affect how we worked together so
Interviewer: Do you think they were listening, or do you think they were doing other things?
Kellie: I think they were listening. Or maybe it had to do with their personality as well, like they wouldn't speak up, or they were shy or something. Um, but it wouldn't be that they weren't paying attention. I think most of the time yeah, everyone was just, they were paying attention **(2.72-2.78)**

Yes, um. Jasmine, I see, like Jasmine and Veronica, they're in most of my classes and tutes, so we see a lot of each other, and um, Denise as well, I see her quite a bit **(2.94-2.100)**

it was good for learning. Coz um, if I just think oh, if I did all the workshops on my own, like I don't learn much, like coz I wouldn't know how to do it, really, so. So, some of the stuff, if I didn't know how to do it then I don't know, I'd just, it would take me longer to get around to it, but um, working with others is good like, just um helping each other learn **(2.118-2.120)**

Interviewer: Was there anybody in the group who you thought was particularly helpful? Like somebody whom you thought yeah, it really good to have them in the group coz they're really helpful for my learning.'?
Kellie: Um, (pause) I think Denise was good, and Jasmine and Veronica, probably **(2.121-2.122)**

the one about deriving the Henderson Hasselbach equation, I thought that was good, coz it was a problem in the um quiz. So then we actually got to do it again and understand how to get the right answer **(2.126-2.132)**

it was mainly, coz in general, everything was you know discussed **(2.148)**

just helping each other out, like um, as I said before, like if someone didn't understand something, someone else could help them understand it. They'd try to explain it to them **(2.154)**

it was good practice. Like um, it related to the concepts we learnt in lectures, so it was good to actually get practice doing the calculations **(2.162-2.168)**

# Group functioning – persistent change group: Alicia

I reckon each person had their own um, way of doing the questions, so we'll come up with the, even if we came up with the same answer, we were trying to figure out how come our methods were different, like the way we did it and stuff **(2.62)**

it was good that you had other ways like, of doing it. Like, open it up for you, like, you didn't know. Oh yeah, that's a better method or whatever…More brains **(2.68-2.72)**

If it was by myself, like, um, if you didn't know how to do it, you were like stuck and stuff, but if there's other people, you asked them, or you can help them, yeah **(2.74-2.76)**

Not good friends, like um, we just um, got introduced, like said 'hi' and kept walking past yeah, 'hi', 'bye'. But not all that close friends **(2.86)**

Alicia: We're still not like, well I don't hang out with them and stuff, but then, we're better, like I talk to them more now, not 'hi, bye'. It's 'hi, how was it?' (laughs)
Interviewer: So not close friends, but you know each other better.
Alicia: better, yeah **(2.90-2.98)**

Coz like, um (pause) coz the girls were nice, and stuff, but um, only, coz, because we were, I thought we were like, slow and stuff, so we couldn't move on, and we always like, we were never like, yeah we never finished I don't think any of our workshops, and we were always like half way, so we always did the easy parts, coz usually, yeah the first, first parts were easy questions, so then we left the harder questions out **(2.126)**

I think I understood like concepts like better coz we discussed it so many times **(2.170)**

I understood the basics really well. So when it was, it came to studying for exams, like because I knew the basics like pretty good, it was easier to just build on that for harder questions and stuff **(2.174-2.176)**

they [the other four students] studied all Stuvac together. I went home for Stuvac, coz I like, I study on my own, I'm just a bit different **(2.134)**

especially towards the end of semester, I mean you just knew, I think everyone was getting stressed for exams and when the material got harder **(2.170)**

At the beginning when the material was easy, it's like all right, you can just discuss it you're all fine, but when the material got harder and not everyone knew it, then you don't want, like they didn't want to come across as looking stupid, so they don't want to ask questions when maybe they would find it all right asking questions if the tape wasn't there **(2.172-2.176)**

I think it's more like if one person gets stressed about it they spread it to every one else. You know what I mean, like if, if everyone's excited about it, everyone's excited about it on a group level but if he's stressed about it, we can't be excited about it, like you have to just sort of go along **(2.188-2.194)**

So yeah, he [Larry] was stressed about it so I couldn't say, and like he asked me, like he, he was like "Um, she says that we can't, we don't have to have it if we don't want it, so do you want it?" Like what am I supposed to say to that you know? **(2.196)**

Interviewer: In terms of your learning um, was it helpful or hindrance or neutral being in a group like that do you think?
Janine: Oh, I think for me it's a hindrance but that's just because I work more efficiently on my own, coz I'm, I just go real quick and try and learn what I want to learn instead of like trying to help other people or explain it to other people **(2.209-212)**

Only, only, when all your friends start complaining and whingeing about it, and whingeing about it, but kids our age have a tendency to whinge about whatever we can **(3.418)**

all my group who was complaining about it, now they think it's the best thing, and they talk about it, and they like laugh about it and stuff **(3.426)**

no it was all fine, like I don't really care, it just, it was, yeah it didn't even bother me…like I said, it didn't bother me going through it…the cameras weren't that, weren't invasive or anything like that, and it didn't take up time or anything **(3.418-3.436)**

Interviewer: And it didn't have any effect on the way that you worked? Coz you would have done the, the work the same way?
Janine: I would have done the work, yeah, yeah, I think so.
Interviewer: Some people are saying "Oh well we worked, I worked a bit harder because I had the tape on me", but yeah, other people are saying that it didn't make any difference.
Janine: Oh may, well I think everyone else on the table did, yeah, no but I would've, I would've done the stuff anyway **(3.443-3.446)**

## Impact of recording equipment – transient change group: Geoffrey

the first five minutes during the first time we were filmed it was like "Oh, we're on camera" and then after a while it was like "Who cares, let's just go about your everyday work." But Larry, I think Larry got a bit um, (pause) annoyed with the camera sometimes **(2.242-2.246)**

No, not really. I suppose it was just, it was just, I'm not saying anything was bad but that was the worst thing. Yeah, so I could live with that, not really a problem **(3.1000-3.1002)**

## Impact of recording equipment – transient change group: Larry

The video was affecting how I learn. I just, I couldn't, I felt really claustrophobic, coz like, like the video camera was watching me and we were all trying to get it done so we could get it out of there and finished **(2.36)**

Perhaps the pressure you put on yourself. Yeah, I think so. Partly, and then unless you take time out to relax a little and like, do our normal little just chit chats and whatever, and relax a little, I think you get, it's easy to get agitated, especially with me, you know, and around exam time…I'm one to be avoided in college **(2.78-2.80)**

the videos I think a little bit in those tutorials got a little bit too much. And so perhaps hindered a little bit. But I mean I don't think that was really to do with the video, I think it was more to do with the group dynamics. So, I don't know, I don't think it hindered us at all **(3.432-3.436)**



## Impact of recording equipment – transient change group: Lucy

It did at the beginning but by the end of it, it didn't really. Like I think it, I think it affected other people but I didn't really, like I was just used to it…Larry just kept saying he didn't like it, he didn't want it there **(2.56-2.58)**

I guess it also, it probably also affected the way, the way that we talked to each other, and the way, well the way that just we spoke in general. So like, usually we have awful language, or terrible, you know, back at the college or whatever, but I don't think we said as much of that sort of thing. And um, yeah, I guess what we talked about as well, the things we talked about. I think we just focussed generally on our work and we didn't really talk about any other things **(2.58-2.64)**

Lucy: it just sort of picked up everything that you said and well, you know, how the, yeah, just the whole thing of how you, like how you worked and how you, you know worked things out and did things like that. That was, yeah, I was just sort of, I felt more, yeah I felt more conscious of how I was doing things
Interviewer: OK, so you felt a little bit what, embarrassed that someone else would be listening to it?
Lucy: Yeah, yeah **(3.478-3.480)**

# Impact of recording equipment – transient change group: Emma

Janine in fact did races to do her own work. Um, especially when she knew what we were doing. You know, um, and I think it was the last tutorial. Maybe it was the last tutorial. One of them right at the end, yeah. She um, she finished it, yeah, it was the last one. She finished early, and then I got rather pissed off actually, (laughs) coz she um, she finished, and we'd all, you know, we actually knew what we were, I didn't know what I was doing, but I picked it up from them, and I ended up working out how to do the Papp, Ptrue, and it wasn't too bad and I was doing it by myself, and um, she had to make a show of the fact that she'd finished, and she slammed down her books, and organised, and talked, and then went "I'm leaving", really loudly, and then left **(2.172-2.182)**

I forgot about it, to tell you the truth, I mean I didn't, I just completely forgot about it whenever I was there…it didn't bother me at all **(2.264-2.266)**

I think Larry got very concerned that he was (pause) being portrayed as stupid, and so he wasn't getting, he didn't like that at all. Whereas if the camera wasn't there, I think that he would have been much more laid back **(2.266)**

I think the, probably the group dynamic would have been much more laid back [in the absence of the recording equipment] because Janine was definitely there to show how much she knew, and how quick she could do it…I think that yeah, it probably did affect the group dynamics, (pause) but personally, even though I wasn't there very often, um, it didn't affect me **(2.268).**

everyone was trying to show out everybody else **(3.534)**

You did want to get finished, and we did sit there until the end, and we didn't decide "Oh well, screw it, we're not going to do the last question, let's just go." **(3.542)**

## Impact of recording equipment – persistent change group: Veronica

I didn't really notice anything different because we'd pretty much got used to the whole setup, um, well at times, I think some of us would say 'Oh, shush, like you know, don't say that' but I don't think it was very different or anything **(2.116-2.120)**

Veronica: it didn't really impinge on us very much, and
Interviewer: So it wasn't intrusive?
Veronica: yeah (3.726-3.730)

if say it was in like a practical setting, it would make me very nervous because I'm already very anxious in practicals **(3.734)**

since it was in a tutorial setting I thought it was OK **(3.738)**

## Impact of recording equipment – persistent change group: Denise

if anything it, it probably made us work more because we knew they were there so we'd like stray less like on to like other topics. Like non-relevant topics **(2.108-2.112)**

yeah, good because it made us like stick with the work **(2.114)**

Denise: coz normally maybe I wouldn't be discussing these kind of things. So yeah, it made me think more
Interviewer: Uh huh. Do you think you learnt more by doing it? Or
Denise: Um, yeah **(3.606-3.610)**

Denise: (laughs) Being videotaped.
Interviewer: Yeah. OK. But that, was that, did that put you off a lot?
Denise: Nup, not really (laughs)
Interviewer: Just every now and then you thought 'oh, whoops.'
Denise: Yeah **(3.614-3.618)**

## Impact of recording equipment – persistent change group: Isabelle

Interviewer: do you think that having the video camera and the cassette players there made any difference to how you worked in the tutorials?
Isabelle: Not me, not personally. No I, as I said I got used to it **(2.189-2.192)**

## Impact of recording equipment – persistent change group: Jasmine

Interviewer: Good. Um, do you think having the video camera and the cassette player there (Jasmine laughs), do you think that had an effect on how you worked as a group?
Jasmine: Not really, except for the hair. (laughs)
Interviewer: Yeah, I was very impressed the week that everybody came back with their, with their hair tied back. (both laugh) (2.173-2.175)

Jasmine: In the very first few weeks we were thinking, 'oh gosh', you know and we put our backs towards the camera but no, in the end it was just part of the room I suppose.
Interviewer: Mm. So did you kind of, were you always aware of it being there or did it kind of, you forget it was there sometimes?
Jasmine: Yeah, sometimes we'd forget it (2.178-2.180)

## Impact of recording equipment – persistent change group: Kellie

No, not really, coz um, I didn't really notice it most of the time. It was just every so often, it was like 'oh, you're covering the microphone' like. (both laugh) But you know, it didn't really affect um, how we were thinking and how we were speaking. It wasn't like, it wasn't really bothering us or anything, so it was OK **(2.112-2.116)**

## Impact of recording equipment – persistent change group: Alicia



I didn't change at all, like if it wasn't there, that's how, what I would do **(2.148)**

Interviewer: were you conscious of them being there, like did you think about them being there all the time?
Alicia: No, not all the time, no.
Interviewer: OK, so every now and then you kind of noticed,
Alicia: Yeah
Interviewer: and then forget about them again.
Alicia: Like if I, if I had my hair down, then 'oh, OK, I have to put it back up', yeah, but **(2.151-2.156)**

# APPENDIX H CRITICAL EPISODES FOR ANALYSIS OF THE CONTENT SPACE

This appendix contains brief outlines of the critical episodes relating to functional group identification and dissociation/ionisation which took place in workshops 1 and 2. The transcript excerpts are found in Appendix I, and the analysis is found in chapter 7 under the heading '*Concepts new to pharmacy*'.

## Transient change group

### Episode TC1.4 (16 min, 3 sec)

Within this episode, which involved the group completing the back page which was to be submitted, a number of distinct sub episodes occurred, involving different groupings of participants, although for the majority of the time Janine was interacting with Larry, Geoffrey was working independently and Lucy was engaging only intermittently with the material. Discussion was frequently disjointed, because participants were often working on different molecules, and Lucy's difficulties with the material tended to lead her into off-task activity into which she attempted to draw Geoffrey and Larry.

### Episode TC1.5 (3 min, 54 sec)

Work on the back page continued during this episode, with Janine working alone, Geoffrey attempting to engage in discussion with Larry, and Lucy looking lost. Halfway through the episode, Geoffrey left the table to seek confirmation from the tutor who followed him back to the table for a short discussion with him. For the remainder of the episode, Janine, Larry and Geoffrey worked individually and Lucy was either watching what they were doing or gazing at other tables.

### Episode TC1.6 (2 min, 55 sec)

This episode involved discussion which evolved into an argument about the nature of dopamine. Lucy and Geoffrey drew Larry into the discussion but Janine remained outside until her contribution sparked a heated exchange. The tutor was summoned to adjudicate but the group was interested only in the answer rather than a detailed conceptual discussion.

### Episode TC1.7 (2 min, 21 sec)

This short episode, occurring shortly before the group left, involved Janine asking to check Larry's version of the dissociation of amoxycillin which was to be handed in by the group. After a brief exchange with Larry, Janine perused his answer in silence for approximately 80 seconds before she began speaking to herself.

### Episodes TC2.2/2.3 (22 min, 14 sec)

These episodes occurred towards the middle of the second workshop, and covered an activity involving the process of acid and base dissociation. They began with a suggestion from Lucy that they all move onto the second question, but during the first part, only Janine appeared to be making good progress as the others engaged in off-task activity. For the remainder of the episode, Janine was considerably in advance of the other group members. The episode was characterised by long periods of individual and dyadic work, interspersed with occasional interactions of three or four participants, and a visit from the tutor at the request of Janine. The dyads changed frequently, with all pairs apart from Janine and Lucy forming at some point during the episode. There was no clear coordination of effort: the discourse reveals that individuals and dyads worked at different paces on the activity so that at any one time, several parts of the questions were under discussion. Janine, Larry and Geoffrey focused to a large part on the assigned activities, but Lucy was only intermittently engaged, and sought again to distract Larry and Geoffrey with off task activity and conversation.

## Persistent change group

### Episode PC1.5 (7 min, 34 sec)

This episode encompassed the first section of work on the identification of functional groups and classification of molecules as acidic, basic or neither. The normal pattern of work exhibited by the PC group was that each individual would attempt the problems independently, but when necessary, someone would offer an opinion or ask a question about the particular activity on which she was engaged. These comments could be addressed to an individual, or to the group as a whole, and a response was invariably made by one or more group members. Discussion ranged from dyadic to whole group, and the groupings within each conversation changed fluidly, although whole group interactions were common. The molecules under discussion in this episode included codeine and diazepam, and the focus was on the identification of phenol groups, with some progression to amines and amides. The episode concluded when the tutor was summoned to discuss an issue not related to the identification of functional groups.

### Episode PC1.6 (16 min, 37 sec)

This episode continued the activity begun in episode PC1.5, with similar interaction patterns observed as in that episode, together with two interactions with a tutor. Alicia appeared to be struggling somewhat in comparison to the other group members, as she spent more time reading and less time writing. This episode covered the molecules ibuprofen, lignocaine, phenacetin, chloroquine, dopamine, cefoxitin, ephedrine, ticarcillin, oxazepam and amitryptyline, and involved identification of carboxylic acids, amine and amides, as well as groups which were neither amine nor amide. Tutor assistance was sought in relation to the classification of molecules containing

both acidic and basic groups, and also in relation to the criteria for classifying nitrogen atoms as amines, amides or neither. The episode concluded with the completion of the identification and classification activity.

## Episode PC1.7 (7 min, 31 sec)

This episode followed closely after episode PC1.6 as the group moved to the activity involving drawing dissociation equilibria for three molecules. Both Jasmine and Kellie took turns leading the problem solving, but all the others engaged in the process, by listening, reading, writing and responding as Jasmine articulated what she was writing. When focusing on lignocaine, additional discussion ensued about the molecule itself, thus reinforcing the identification of amines and amides. The episode concluded with completion of the activity.

## Episode PC1.8 (2 min, 17 sec)

This episode occurred at the end of the workshop as Jasmine copied the group's answers (as decided in episode PC1.5) onto the sheet to be handed in for feedback. Although this was essentially revision of ideas developed during the workshop, further discussion ensued about a number of the molecules as Jasmine asked for explanations.

## Episode PC2.2 (20 min, 10 sec)

This episode occurred towards the middle of the second workshop, and covered an activity involving the process of acid and base dissociation. Similar patterns of activity were observed in this workshop as in the previous one, however Isabelle was also present on this occasion. The group perhaps took rather longer completing this activity then was generally envisaged, however through extended discussion and multiple interactions with a tutor, they were able to clarify a concept which had confused them, namely what constituted an ionised form of a molecule. By the end of the episode the concept had been thoroughly explored, and it appeared that the causes of the group members' confusion had been dealt with.

# APPENDIX I EXCERPTS FROM WORKSHOP TRANSCRIPTS

Appendix I consists of two parts, each containing excerpts from the workshop transcripts to which reference is made on several occasions and in several sections of chapter 7. Part A is devoted to the TC group and part B to the PC group. Within each part, the structure is chronological, but divided into episodes for ease of reference. Each episode is named as the group (TC or PC), the workshop in which it occurred (1 or 2) and a sequence number beginning at 1.

All speaking turns have been included, apart from those which related to off-task discussion. On occasion, parallel conversations occurred, but where relevant, the participants have been indicated in the analysis. Inaudible speech is denoted by '????'.

## Part A: Transient change group

### Workshop 1

#### *Episode TC1.1*

| | | |
|---|---|---|
| 49 | Lucy | ln $K_1$ on $K_2$, equals (reading from lecture notes) |
| 50 | Geoffrey | What does it equal? |
| 51 | Lucy | Um |
| 52 | Geoffrey | Negative delta H? |
| 53 | Lucy | Negative delta H on R brackets 1 on $T_1$ minus 1 on $T_2$ (continues reading from lecture notes) |
| 54 | Lucy | Is that enough? |
| 55 | Larry | Yeah, you got $T_1$ |
| 56 | Lucy | Well I'm stuck |
| 57 | Larry | You got $T_2$, you got your R, you got your delta H and you wanna find the um, solubility at fifty degrees, so your K2 |
| 58 | Geoffrey | So everything you need to know there Lu |
| 59 | Lucy | OK. May as well copy it out |

#### *Episode TC1.2*

| | | |
|---|---|---|
| 689 | Janine | What's the major difference? Um, |
| 690 | Larry | One dissociates completely and one doesn't dissociate completely. |
| 691 | Lucy | Der. |
| 692 | Geoffrey | What are you talking about? |
| 693 | Lucy | One |
| 694 | Janine | That's between acid and a strong base, that's not what she's |
| 695 | Geoffrey | Yeah, that's enough to find the correct answer |
| 696 | Lucy | Are you talking about acids and bases? |
| 697 | Janine | Well in Chemistry acid is anything that donates a proton |
| 698 | Lucy | Yeah |
| 699 | Janine | And a base is anything that accepts a proton |
| 700 | Lucy | OK, let's write that |
| 701 | Larry | But it's the same in Pharmacy |
| 702 | Janine | No it's not |
| 703 | Geoffrey | It is too |
| 704 | Lucy | Is it? |
| 705 | Janine | Who says it's true? I think I'll check it up. |
| 706 | Geoffrey | I said it's true |

| | | |
|---|---|---|
| 714 | Janine | um, the acidic drugs lose the proton to form charged anions and the basic drug gains protons to form charged cations. |
| 715 | Lucy | OK let's write that down, let's write that down Janine. Where is it? Do I have it? No. OK |

## *Episode TC1.3*

| | | |
|---|---|---|
| 737 | Lucy | Thank you, I thank you (silly voice) Discuss with the others in your group strategies you might find helpful in remembering |
| 738 | Geoffrey | You tell 'em. What are those? |
| 739 | Lucy | Acid. Janine said they're |
| 741 | Geoffrey | Acid is something that burns you when you touch it. |
| 742 | Lucy | Yeah |
| 743 | Geoffrey | But so's a base. |
| 744 | Lucy | Base is slippery, and |
| 745 | Geoffrey | Taste, tastes bitter. |
| 746 | Lucy | Tastes bitter. I thought acids are bitter. |
| 747 | Geoffrey | They're sour. |
| 748 | Lucy | Oh. Acids are sour and bases are bitter. |
| 749 | Geoffrey | (laughs) You beginner |
| 750 | Lucy | Good, I'm gonna keep these in mind for when we have to do that thing again |

## *Episode TC1.4*

| | | |
|---|---|---|
| 756 | Janine | Well, that's a phenol group, hold on. So what's the? OK |
| 757 | Larry | Phenol? |
| 758 | Janine | There's only two acids and a base that we have to know anyway. |
| 759 | Lucy | Can I do it on mine? |
| 760 | Larry | Yeah |
| 761 | Janine | The acid is the phenol and the base is that, um, amine group, right? |
| 762 | Lucy | Yep |
| 763 | Janine | Which has to be $sp^3$, right? |
| 764 | Larry | Yep |
| 765 | Lucy | Yep |
| 766 | Janine | And the um |
| 767 | Larry | Car box ylic acid |
| 768 | Janine | phenol, oh, and the carboxylic acid |
| 769 | Lucy | carboxylic acid yeah? Is that the strong one? |
| 770 | Janine | Oh, all right. I'll just go have a look. Um, |
| 771 | Larry | The first one, the OH |
| 772 | Janine | Is this? Is this? Hold on, what's that with this one? |
| 773 | Larry | Yeah that's what I didn't understand with that one. |
| 774 | Janine | It's connected to another carbon so it's got three bonds, so I'd say it's a base. So we'll circle it and we'll go base. This is an acid |
| 775 | Geoffrey | Oh. It's connected to that carbon there |
| 776 | Janine | and that's nothing. OK what else have we got |
| 777 | Geoffrey | But it's next to an O. |
| 778 | Janine | This one's, one two, three, this one's a base |
| 780 | Janine | Yep? |
| 782 | Larry | The carbon's not an $sp^3$ hybridised carbon |
| 784 | Janine | Is it only supposed to be connected to a carbon which is $sp^3$ hybridised? I'll check that |
| 785 | Larry | Yeah |
| 788 | Larry | N is attached to only H or $sp^3$ hybridised carbons |
| 789 | Janine | Really? Oh. |
| 790 | Larry | Yes. |
| 791 | Janine | Forgot about that one. Where is it? |
| 792 | Janine | Which one's that? |
| 793 | Larry | hundred and sixteen says |
| 794 | Geoffrey | This one's basic |
| 795 | Lucy | Can I do that one too? |
| 796 | Larry | So I think there's none of them |

| | | |
|---|---|---|
| 797 | Janine | Yeah. This isn't it. OK |
| 798 | Lucy | This one? Are you sure that's the right one? |
| 799 | Janine | So there's none. |
| 800 | Lucy | What's that, the base? |
| 801 | Janine | None |
| 802 | Lucy | Babe, you have to do it in pink pen. |
| 803 | Larry | No. |
| 804 | Janine | We have to give reasons. |
| 805 | Lucy | Whereabouts? On the back? |
| 806 | Janine | For this one, it's acid |
| 807 | Lucy | Strong acid? |
| 808 | Larry | Was it |
| 809 | Janine | And that's it, isn't it? Oh, does it ask for strong and weak? |
| 810 | Lucy | Coz isn't um, |
| 811 | Janine | It doesn't ask for strong and weak. |
| 812 | Lucy | a carboxylic acid strong? |
| 813 | Janine | It's strong, yeah. It's strong, that's right |
| 814 | Geoffrey | Is Valium neither? |
| 815 | Larry | These are neither |
| 816 | Janine | The nitrogen |
| 817 | Geoffrey | Oh are we doing the last one are we? Excellent. The last question? |
| 818 | Larry | There you are |
| 820 | Janine | Why is that neither? You got an acid and a base. |
| 821 | Larry | So. Remember she said if you've got an acid and a base, it's neither. |
| 822 | Janine | No she didn't! |
| 823 | Lucy | Yeah |
| 824 | Geoffrey | No she didn't. |
| 825 | Janine | No she didn't! |
| 826 | Geoffrey | Here it says a pH somewhere ??? |
| 827 | Lucy | Yes she did. |
| 828 | Janine | No she didn't. I don't know where you came up with that one. |
| 829 | Geoffrey | You made it up, Larry. |
| 830 | Larry | I did not make it up. |
| 831 | Lucy | NO, I, I, I remember that! |
| 832 | Larry | Here. Neither acid or base as contains both acidic and basic functional groups. |
| 833 | Janine | Where? |
| 834 | Larry | You got acidic functional groups only, it's acid |
| 835 | Geoffrey | If something contains, if there's something that contains both acidic and basic groups, it's neither? |
| 836 | Tutor | Yep |
| 837 | Geoffrey | Why? |
| 838 | Lucy | Hey! |
| 840 | Geoffrey | Why? Oh, Ok, yeah, I'll get you to explain it to me now |
| 840a | Tutor | Well, |
| 842 | Tutor | It's neither because |
| 844 | Tutor | it doesn't behave like an acid, so it doesn't have acid solubilities, doesn't have base solubilities, it's kind of hybrid. |
| 845 | Geoffrey | OK |
| 846 | Tutor | So you can't say, at pH below its pKa, then it's unionised, you can't say that, coz it's got basic properties as well. So it's got both, properties of both, so it makes it neither, in its pure form. Make sense? |
| 847 | Geoffrey | Yep. |
| 848 | Lucy | Yep. That's neither and that one's neither? |
| 855 | Larry | What's it attached to a C with a double bond? |
| 856 | Geoffrey | Which one are you talking about? Where, what is it? Which one? What's it called? |
| 857 | Larry | Phenacetin |
| 858 | Geoffrey | It's neither. |
| 859 | Janine | Ibuprofen you put as an acid right? |
| 860 | Larry | Yep. |
| 861 | Janine | And then this one is |
| 862 | Larry | Base |

| | | |
|---|---|---|
| 863 | Janine | Is it? |
| 864 | Geoffrey | Yeah. |
| 865 | Janine | Yeah it is. |
| 866 | Geoffrey | No no wrong one, you circled the wrong one. |
| 867 | Lucy | Are you sure? |
| 868 | Geoffrey | You circled the wrong N. |
| 869 | Larry | That one. To the next two Cs. |
| 870 | Geoffrey | Ooh, look at them Cs |
| 873 | Janine | This one's neither is it? |
| 874 | Larry | What? |
| 875 | Janine | Phenacetin's neither. Yeah |
| 876 | Larry | And that one they're all basic. It's a very strong base. |
| 877 | Janine | That's not basic, it's a benzene ring. Meaning one of them would be double, bonded. |
| 878 | Lucy | Ohh. Which one's that? |
| 879 | Larry | I think it's that one. |
| 880 | Janine | It's base |
| 881 | Larry | O H. But |
| 882 | Janine | That's not either, for the same reason |
| 882a | Larry | Damn! |
| 883 | Geoffrey | It's not acidic? |
| 884 | Lucy | Oh well |
| 885 | Janine | So it's still a base. |
| 899 | Larry | OK, if the O H is attached to a benzene ring, is that OK? |
| 901 | Janine | I don't think so. I'll just go look it up. |
| 910 | Larry | No that's the wrong one |
| 911 | Janine | No, because it's benzoic acid then |
| 912 | Larry | It's phenol |
| 913 | Janine | It's not a phenol, it's benzoic acid isn't it? |
| 914 | Lucy | Phenol |
| 915 | Larry | No, it's a weak acid, it's phenol |
| 916 | Janine | Oh, sorry. Oh phenols are O H attached to a benzene ring. Oh, I'm forgetting everything now. So if it's not attached to a benzene ring then it's not an acid. ??? |
| 917 | Geoffrey | ???? |
| 920 | Janine | That's right. Coz it's got to be attached to a benzene ring, not any ring. |
| 928 | Janine | Forgot what a phenol was. |
| 931 | Janine | OK |
| 932 | Larry | I reckon I could be wrong all the time |
| 933 | Janine | So this one is an acid, and this one is an acid, yeah? |
| 936 | Janine | Yeah, there's two acids |
| 939 | Janine | What if you have more acid than base functional groups? Probably it's neither |
| 942 | Larry | Is it neether or nyther? |
| 943 | Janine | Nyther or neether, it's the same thing. You can either change from long to short |
| 978 | Janine | Yeah, it's neither |
| 979 | Geoffrey | Yeah it's neither. OK, can I finish doing my work now? |
| 980 | Lucy | No. No work for Geoffrey. OW! |
| 981 | Larry | Err That one is |
| 981a | Geoffrey | laughs |
| 982 | Lucy | Hey |
| 983 | Geoffrey | Ooh, it's not that easy |
| 984 | Larry | Are the carbons in a benzene ring sp3 hybridised? No? |
| 985 | Janine | Sorry? |
| 986 | Larry | Are the carbons in the … |
| 987 | Janine | No, they're not, because of the double bond. It's sp2 hybridised. Anyway, it's the double bond |

## *Episode TC1.5*

| | | |
|---|---|---|
| 988 | Geoffrey | You start from the lowest pH don't you? When you're doing dissociation equilibria? |
| 989 | Lucy | I can't remember |
| 990 | Geoffrey | You shove all the protons on first, that's the way |
| 991 | Larry | Yeah, you do. It doesn't matter, you can't draw that, you can only draw the, Start the |

| | | |
|---|---|---|
| | | process with all protons attached, start with depol, the deprotonation of the functional groups from lowest to highest pKa |
| 992 | Geoffrey | It's neither? Hey, is dopamine neither? |
| 993 | Larry | Huh? |
| 994 | Geoffrey | Is dopamine neither? |
| 995 | Larry | Neither what? |
| 996 | Geoffrey | So you got neither? |
| 997 | Larry | We're certain. |
| 998 | Janine | We've got |
| 999 | Geoffrey | Yeah, the other page, yeah |
| 1000 | Larry | Neither |
| 1001 | Geoffrey | Janine? |
| 1002 | Janine | Neither |
| 1003 | Geoffrey | No, it's not |
| 1004 | Lucy | But that couldn't be that |
| 1005 | Geoffrey | It is so |
| 1006 | Larry | Why? |
| 1007 | Geoffrey | It's neither, you're right |
| 1008 | Lucy | Why is it neither? |
| 1009 | Geoffrey | No, it is! |
| 1010 | Lucy | But there're acids |
| 1011 | Geoffrey | That group's an aldehyde |
| 1012 | Lucy | Whatever that is |
| 1013 | Geoffrey | It's an aldehyde, it's an aldehyde that makes it acid |
| 1014 | Janine | Not in pharmacy |
| 1015 | Geoffrey | Damn pharmacists! |
| 1016 | Lucy | That's a neither is it? And is that coz it's got those two and then it's got that NH? Which ones do I circle? |
| 1016a | Janine | Do you start from the lowest pH and work up? |
| 1016b | Lucy | Don't circle them!! |
| 1017 | Larry | Do all of them the same way, yep |
| 1018 | Lucy | Nooo! |
| 1019 | Janine | OK, so let's do this one now |
| 1020 | Geoffrey | OK, so what's this $NH_2$ doing floating around here? |
| 1021 | Lucy | Where? |
| 1022 | Lucy | I don't know. It's a little bit random isn't it? |
| 1023 | Janine | There should be a line to it maybe I reckon. Or shouldn't it be? |
| 1024 | Larry | How do you do the? |
| 1025 | Janine | Is that an $NH_2$ just floating there or is it attached to the thing? This is an acid up here right? So this is your acid at two point four.? That's the acid at nine point six. |
| 1026 | Larry | Yeah |
| 1027 | Janine | But wouldn't that be the basic nitrogen then? Oh no it's not, it can't be so there's gotta be a line down to there, this is gotta be the basic nitrogen |
| 1028 | Larry | Yeah |
| 1029 | Janine | That's seven point four. |
| 1030 | Larry | Yeah |
| 1031 | Janine | So let's just attach them all on this diagram and make it easier for us |
| 1033 | Janine | We'll make this an $NH_3^+$, and then we'll go, one step, it's two point, no, yeah, it's two point four, OK? And we'll lose the H from there |
| 1034 | Geoffrey | That's, basic, it is basic, it's definitely basic |
| 1035 | Lucy | Ahahaha |
| 1036 | Tutor | Amides, are, um, OK that's an amide |
| 1037 | Geoffrey | yeah |
| 1038 | Tutor | Nitrogen next to a carbonyl |
| 1039 | Geoffrey | Yes, so is that? |
| 1040 | Tutor | Yeah, that's an amide, and that's an amide, and that's an amide |
| 1041 | Janine | ???? |
| 1042 | Geoffrey | OK |
| 1043 | Tutor | But that's just attached to the two hydrogens, and an $sp^3$ hybridised carbon attached to it, so that makes it aliphatic. |
| 1044 | Geoffrey | All right. Is this all you want us to do, just to circle it, right? That's it, basic? |

| | | |
|---|---|---|
| 1045 | Tutor | Acidic, basic or neither |
| 1046 | Geoffrey | OK. |
| 1047 | Tutor | And then hand in one from the group. |
| 1048 | Larry | (mumbles) we're about finished |
| 1049 | Lucy | So that one's basic, as well? |
| 1050 | Larry | Get the general drift? |
| 1051 | Janine | Oh, no! |
| 1052 | Lucy | This one here. |
| 1053 | Janine | Oh, no, that's right. |
| 1054 | Lucy | Chloroquine? |
| 1055 | Geoffrey | Yep. |
| 1056 | Janine | Do you need help? |
| 1057 | Larry | No, I don't need help. I need to be able to, draw these bloody diagrams |
| 1058 | Janine | That's why I put it down here, you won't fit it there, you'll have to move it. |
| 1059 | Larry | Just E T C |
| 1061 | Larry | Did she just mark your one? |
| 1062 | Janine | Which one? Yeah, seven point five, four, which is the base, $NH_3$. |
| 1063 | Larry | Yeah, we did. |
| 1064 | Janine | Yeah. |
| 1065 | Larry | Damn. |

## *Episode TC1.6*

| | | |
|---|---|---|
| 1087 | Janine | Can I check it? |
| 1088 | Geoffrey | Yep |
| 1089 | Lucy | Can I write, oh and this one, did you change that one, the basic one? |
| 1090 | Janine | You should put the pKas on top. |
| 1091 | Geoffrey | Change dopamine to basic? |
| 1092 | Lucy | Yeah, change dopamine to basic |
| 1093 | Larry | I put them over here |
| 1094 | Janine | No you put them on top, here. |
| 1095 | Larry | Oh, OK |
| 1097 | Larry | Oh, yeah |
| 1098 | Geoffrey | Yes, Larry? No? |
| 1101 | Geoffrey | Yes, yes, yeah, I did change dopamine to basic, did you? |
| 1102 | Lucy | Yeah, I changed dopamine to basic as well. |
| 1103 | Janine | What? |
| 1104 | Geoffrey | Coz dopamine is basic. |
| 1105 | Lucy | He said to change dopamine to basic. Where's dopamine gone, the other side. |
| 1106 | Lucy | Because that NH, that N is an |
| 1107 | Geoffrey | Amide |
| 1108 | Lucy | Is an amide, an amine, not an amide |
| 1109 | Geoffrey | An amine, sorry. No it is amide |
| 1110 | Lucy | That's an amide |
| 1111 | Geoffrey | That's an aldehyde |
| 1112 | Lucy | NO! |
| 1113 | Geoffrey | Yes it is. |
| 1114 | Larry | Why? Could you explain to me the reason instead of bickering over what the hell it is? |
| 1115 | Geoffrey | Could we just chuck an extra H there, there's no double Os, |
| 1116 | Lucy | There's no |
| 1117 | Geoffrey | it isn't necessary for it to be $sp^3$ hybridised C, it can be an H |
| 1118 | Janine | Yeah, we've got that, we've got a base and two acids which made it neither. |
| 1119 | Geoffrey | Oh, but these don't, you don't count these as acidic |
| 1120 | Janine | Why not? |
| 1121 | Geoffrey | Coz they're just phenols. Phenols you don't, you don't assume |
| 1122 | Larry | Phenols are acidic. |
| 1123 | Janine | A weak acid |
| 1124 | Lucy | I thought it was basic. That's what she said, well I don't know, that's what she said. |
| 1125 | Janine | Can we get her back? |
| 1126 | Larry | Yes, I think we should. |

## *Episode TC1.7*

| | | |
|---|---|---|
| 1128 | Janine | You've got $NH_2$ there, shouldn't it be $NH_3^+$? And then shouldn't it be, I don't know, now I've confused myself, hold on. Where does it go? |
| 1132 | Janine | Oh, yeah, that way, oh-oh, I've done it wrong. Oh-oh. OK, hold on. |
| 1135 | Janine | Two point four, so this is your seven point four |
| 1136 | Janine | And this is your nine point six, |
| 1139 | Janine | And you go from, that says $CH_2$ now. I knew I needed to check yours. $NH_3$. |
| 1141 | Janine | And it, that's right, and you should lose the seven point four, which is |
| 1143 | Janine | second to go. So that's $NH_2$ and then the O H |
| 1145 | Janine | All right, that's OK. |

## *Episode TC1.8*

| | | |
|---|---|---|
| 1149 | Lucy | I think I do. Can we just ask again, to be absolutely certain that dopamine is basic |
| 1150 | Larry | But if it's got the two phenol groups on it, so it has an acid and a base so it's neither. |
| 1151 | Tutor | Um, I hate to agree with Larry, but he is correct. |
| 1151a | Lucy | Ahhh! |
| 1152 | Larry | (Cheers) |
| 1153 | Janine | Yay! |
| 1154 | Tutor | Oh, OK |
| 1155 | Larry | So we were right! |
| 1156 | Tutor | So it was, it was Janine and Larry against you two was it? |
| 1157 | Janine | Oh, it wasn't a real fight |
| 1158 | Geoffrey | It wasn't a fight |
| 1159 | Janine | We weren't fighting, we worked them out |
| 1160 | Geoffrey | It was just like a disagreement |
| 1161 | Janine | No it was never gonna be a real fight, coz we didn't know what we were doing enough |
| 1162 | Lucy | Yeah |
| 1163 | Janine | After we study, then everyone will start really getting on each other's nerves. |
| 1164 | Janine | Arr, arr, arr |
| 1165 | Geoffrey | Oh, I see |
| 1166 | Lucy | But that's the principle, if it has both acidic and basic groups |

# Workshop 2

## *Episode TC2.1*

| | | |
|---|---|---|
| 679 | Geoffrey | I said these four. Malic, sodium carbonate, sodium bicarbonate and citric acid. |
| 680 | Larry | Sodium carbonate is acidic. |
| 681 | Geoffrey | It's basic. |
| 682 | Larry | But aren't you trying to maintain a low pH? |
| 683 | Janine | No, it's sort of, I don't know. |
| 684 | Geoffrey | Yeah we are. I don't know. (laughs) |
| 685 | Janine | Sodium carbonate isn't basic is it? Oh yeah it is coz it can accept a proton. |
| 686 | Geoffrey | Yeah |
| 687 | Janine | In Chemistry but it's not basic in pharmacy |
| 688 | Geoffrey | Probably not. |
| 689 | Janine | Yeah. |
| 690 | Geoffrey | What? |
| 691 | Lucy | So, next question! |
| 692 | Larry | Whatever |

## *Episode TC2.2*

| | | |
|---|---|---|
| 695 | Lucy | I'm not in the mood Gaz, right? Try the next question. Exercise two. |
| 696 | Janine | Oh, I'm gonna have to look this one up. Can't remember that. |
| 697 | Lucy | Ionised! |
| 698 | Janine | Unionised, where? Um |
| 699 | Larry | mmmm |
| 700 | Janine | Ionised? |
| 701 | Geoffrey | Yeah it is largely ionised. No. Yes. |
| 702 | Larry | Exercise two |

## *Episode TC2.3*

| | | |
|---|---|---|
| 740 | Lucy | Amoxcillin |
| 741 | Janine | I'm having trouble assigning the pH values. |
| 742 | Geoffrey | Let's do this one now |
| 743 | Lucy | Let's do the first one naproxen. |
| 744 | Geoffrey | That's acidic |
| 745 | Janine | Hold on, phenol is attached to a benzene ring |
| 746 | Lucy | Wheeee! |
| 747 | Geoffrey | That's the nine point six |
| 748 | Janine | That's the nine point six. |
| 749 | Larry | That's a carboxylic acid, right? |
| 750 | Janine | But if seven point four is the base |
| 751 | Lucy | what? |
| 752 | Janine | and they're all sp, they're attached to carbon atoms which are sp |
| 753 | Lucy | So, |
| 754 | Larry | But then a low pH value |
| 755 | Lucy | How about that? |
| 756 | Janine | 3 hybridised |
| 757 | Larry | ???? |
| 758 | Janine | Oh no this one's not a, |
| 759 | Geoffrey | yeah |
| 760 | Janine | So up here, |
| 761 | Geoffrey | The line below it's not |
| 762 | Lucy | that one is not, hold on, at at four point two is it going to be ionised or |
| 763 | Geoffrey | Not |
| 764 | Janine | No? All right. That's all right |
| 765 | Larry | What's when it's at pH three point eight? |
| 766 | Geoffrey | pH seven |

| | | |
|---|---|---|
| 767 | Lucy | Sorry? Oh right |
| 768 | Janine | pH seven |
| 769 | Lucy | Oh is that, that pH is it? |
| 770 | Geoffrey | It'd be largely unionised |
| 771 | Larry | Yep, it's gonna be, it'd have a pH less than its |
| 772 | Lucy | the pH value |
| 773 | Janine | Hold on, well at that |
| 774 | Lucy | at pH seven |
| 775 | Janine | It's less than seven point four and greater than two point four |
| 776 | Larry | These are pKas. |
| 777 | Janine | it's gonna mean half of them ionised and half of them not, you know, the acids are gonna be |
| 778 | Lucy | Are you sure? |
| 779 | Larry | fairly sure |
| 780 | Geoffrey | Yeah |
| 781 | Janine | So, then, if seven's greater than two point four, so it's gonna be yes for the COOH group, |
| 782 | Geoffrey | I think it's more unionised |
| 783 | Janine | it's gonna be $OO^-$, and then seven point four, no seven is less than seven point four for the base |
| 784 | Larry | You were given the pK, where's your last week's thing, we handed mine in |
| 785 | Janine | so the base is gonna be ionised too |
| 786 | Larry | I don't have it any more |
| 787 | Lucy | I didn't do it though |
| 788 | Lucy | Do you want it though? I didn't do it |
| 789 | Larry | Didn't do it? |
| 790 | Janine | The base is gonna be ionised too |
| 791 | Larry | We did it as a group |
| 792 | Janine | And then |
| 793 | Lucy | We didn't do it on mine |
| 794 | Janine | when it's less than, the pH is less than the pKa for the phenol group so it's gonna be unionised |
| 795 | Lucy | That? |
| 796 | Larry | Yes |
| 797 | Janine | it gonna be OH so it's like half/half. |
| 798 | Lucy | We haven't done all of it. |
| 799 | Janine | Ticarcillin, um. This one is two point five |
| 800 | Geoffrey | I don't think it's half/half for that one. |
| 801 | Larry | with all those pKas |
| 802 | Janine | Not half/half, but two to the one. |
| 803 | Geoffrey | which means it's more, it's more um, unionised |
| 804 | Janine | I'm just writing down all the groups and what they are. |
| 805 | Janine | Again, I can't find which |
| 806 | Lucy | They're the pHs? |
| 807 | Janine | Oh I see. Never mind (laughs). Sorry |
| 808 | Janine | OK, so, um, pH three. |
| 809 | Lucy | What's the pH ???? |
| 810 | Larry | What does that mean? |
| 811 | Janine | pH is greater than two point five, |
| 812 | Larry | There. pH is |
| 813 | Janine | greater than pKa |
| 814 | Lucy | by two or more Larry, but it's not by more than three |
| 815 | Geoffrey | Yeah, where's the, um where's the answers? |
| 816 | Lucy | So then, it's both, that's right, it's both. |
| 817 | Geoffrey | Why, where's the answers to those questions last week? |
| 818 | Lucy | It's not in the ionised or unionised form, it's in the both. Because of its structure, didn't she say? |
| 819 | Geoffrey | Last week? |
| 820 | Lucy | which is acid and base. It was a mixture of ionised and unionised |
| 821 | Lucy | on, um, |
| 822 | Janine | Oh, I cannot remember the percentage ionised! |
| 823 | Larry | Oh here, Ph |

| | | |
|---|---|---|
| 824 | Janine | How would you do that? |
| 825 | Larry | less than pKa, for an acidic drug. Is this an acidic drug? |
| 826 | Lucy | Yes. |
| 827 | Larry | yes it is. Then, what are we trying to work out? |
| 828 | Lucy | Whether it's ionised |
| 829 | Larry | Not. |
| 830 | Lucy | So it's not. |
| 831 | Larry | Not ionised |
| 832 | Larry | That was painful. |
| 833 | Lucy | OK, let's try the second one. Lignocaine. Oh, hello. Sorry, just trying to get those. pH |
| 834 | Larry | pH is lower than pKa for, this is a basic drug |
| 835 | Lucy | pH, |
| 836 | Larry | base |
| 837 | Lucy | Is it greater than pKa? |
| 838 | Geoffrey | Yes |
| 839 | Lucy | That's a base |
| 840 | Larry | Base |
| 841 | Lucy | pH |
| 842 | Geoffrey | not. Are you getting not, oh, you're not doing this part. |
| 843 | Lucy | What? |
| 844 | Lucy | Oh, I should do, I should be doing it up here shouldn't I? |
| 845 | Lucy | OK, so what's the next one? |
| 846 | Larry | We've got two friggin', there's two values |
| 847 | Geoffrey | Do you know how to work out the percentage ionised? |
| 848 | Lucy | So do we need the two values? |
| 849 | Janine | Um, diagram one oh eight |
| 850 | Geoffrey | OK |
| 851 | Larry | See lovey. When you get to it. |
| 852 | Lucy | Wait, show us this one first? So, pK, pH is |
| 853 | Geoffrey | where are, where are you up to? |
| 854 | Lucy | Here. |
| 855 | Geoffrey | Is that yours? |
| 856 | Lucy | For this bit the ibuprofen would be a basic or a non-basic, or a, acidic? |
| 857 | Geoffrey | Don't you guys need something? |
| 858 | Lucy | What things? |
| 859 | Geoffrey | Those sheets. |
| 860 | Lucy | Yeah, saw 'em before. Underneath the book. Um. |
| 861 | Lucy | What does that mean again? Ionised? Mean it's? Yes. |
| 862 | Lucy | Ionised |
| 863 | Larry | Amoxycillin |
| 864 | Lucy | OK, amoxycillin, where is it? Well what is it, is it a base or is it a, um |
| 865 | Larry | It's neither. |
| 869 | Larry | Where's amoxycillin? |
| 870 | Lucy | Um, it's up the top, didn't you just find it? |
| 871 | Larry | No that wasn't it. |
| 872 | Lucy | Oh. Amoxycillin, that's it, there. |
| 873 | Larry | It's neither |
| 874 | Lucy | Well, well if the pH is two point, um. Well at pH seven, maybe it's probably, it's gonna be just in the middle, coz it's in the middle. pH seven. Let's ask her |
| 875 | Geoffrey | Which one are you talking about? |
| 876 | Lucy | Amoxy |
| 877 | Geoffrey | Amoxycillin |
| 878 | Lucy | Yeah |
| 879 | Geoffrey | I think it's um |
| 880 | Lucy | Why do you think |
| 881 | Geoffrey | mostly unionised |
| 882 | Lucy | Why do you think it's unionised? |
| 883 | Geoffrey | If it's at pH seven, that there is not ionised, that, that there is ionised, no that there's ionised but that one's not. See these two aren't, so it's more unionised. |
| 884 | Larry | Why? |
| 885 | Lucy | How do you know? |

| | | |
|---|---|---|
| 886 | Geoffrey | Well, because, if this is at pH less than nine point six, if that's at pH less than nine point six, then that will be ionised. So eight point'd be that. No, no, eight, no no sorry, that will, that won't be ionised. OK |
| 887 | Janine | I can never remember all that. I just write it down. |
| 888 | Geoffrey | The pH won't be ionised at less than nine point six. |
| 889 | Janine | Isn't there a table that we had? |
| 890 | Lucy | Mmm |
| 891 | Larry | It's just pharmacy |
| 892 | Geoffrey | Unless, unless it's |
| 893 | Janine | That |
| 894 | Geoffrey | unless it's |
| 895 | Janine | It talks about it. |
| 896 | Geoffrey | confused myself now |
| 897 | Janine | Oh no I just made that up. Anyway |
| 898 | Geoffrey | OK let's, |
| 899 | Lucy | so it's depending on these two |
| 900 | Geoffrey | let's just do this one for example OK? |
| 901 | Larry | that one ???? yes? |
| 902 | Janine | yeah |
| 903 | Geoffrey | If the pH is greater than two point four |
| 904 | Janine | less than, greater than |
| 905 | Larry | But how, how do you know |
| 906 | Geoffrey | OK, then it's in the ionised state |
| 907 | Larry | This one has got, amoxycillin, does that mean it's |
| 908 | Janine | well some of them are gonna be ionised |
| 909 | Geoffrey | less than two point four |
| 910 | Janine | and some are not |
| 911 | Geoffrey | it'd be in nonionised state. |
| 912 | Janine | depends which ones are greater than |
| 913 | Geoffrey | And so that there, |
| 914 | Janine | and which ones are less than, which ones are acid and which ones are base |
| 915 | Geoffrey | pH seven, that's greater than two point four |
| 916 | Larry | what if we, remember there was that rule that if there were more than two |
| 917 | Geoffrey | pH is greater than two – stop this! Sorry |
| 918 | Janine | units, then they're effectively a hundred percent ionised |
| 919 | Larry | Where was that? |
| 920 | Janine | Well that's what that table says, says, doesn't it? |
| 921 | Larry | This one? So we were right with two of them, Lucy. So it's more than two apart so it means that it's something else. Where was that? Where did you find that Lucy? |
| 922 | Lucy | What? |
| 923 | Larry | That if it's more than two units apart then it's either completely unionised or completely ionised. |
| 924 | Lucy | I just told you that, we didn't find it anywhere |
| 925 | Larry | Yeah we did! |
| 926 | Janine | I think if you work with that, wouldn't it work out the same? |
| 927 | Larry | Sorry? |
| 928 | Janine | If you worked with that, pH less than pKa, pH greater than pKa, wouldn't it work out the same, like? |
| 929 | Larry | You'd have to do it for each of the pKas. |
| 930 | Janine | Coz if you're not asking, oh, doesn't matter, I don't know, I don't understand that. |
| 952 | Geoffrey | I've forgotten what we were talking about now. |
| 953 | Lucy | Well you were talking about unionised |
| 954 | Geoffrey | Yeah, OK. At pH seven |
| 955 | Lucy | yeah |
| 956 | Geoffrey | that's greater than two point four |
| 957 | Lucy | yep |
| 958 | Geoffrey | so that means that one's in its ionised state. No, that one's in its unionised state |
| 959 | Lucy | yeah |
| 960 | Geoffrey | ionised state, sorry. This one's unionised, seven is less than nine point six. That one's unionised, |
| 961 | Lucy | right |

| | | |
|---|---|---|
| 962 | Geoffrey | then pH of seven is, less than seven point four |
| 963 | Lucy | So it's unionised as well |
| 964 | Geoffrey | unionised |
| 965 | Lucy | so it's unionised. Oh OK. |
| 966 | Janine | Did you say for |
| 967 | Lucy | can you write that down? |
| 968 | Janine | um, NH, so the $NH_2$ group's unionised? |
| 969 | Lucy | I think I knew that |
| 970 | Janine | if it's pH less than pKa for a base, shouldn't it be ionised? pH seven, pKa seven point four |
| 971 | Geoffrey | where is, where did you find, where is the pH, pKa values? |
| 972 | Lucy | in the table |
| 973 | Janine | here, diagram one oh seven. pH less than pKa for a basic drug, it's gonna be ionised. So, yes. |
| 974 | Lucy | Oh so it's ionised. |
| 975 | Geoffrey | But how do you know the pKa values for these? |
| 976 | Lucy | What? |
| 977 | Janine | It says it. It says base seven point four. |
| 978 | Geoffrey | That's, is that a pH or pKa? |
| 979 | Lucy | pKa |
| 980 | Janine | pKa |
| 981 | Geoffrey | Oh. Oh! |
| 982 | Lucy | So that's ionised |
| 983 | Janine | So wouldn't that be ionised? |
| 984 | Geoffrey | I'm confused. |
| 994 | Geoffrey | Do you have that table? |
| 995 | Lucy | I've got it somewhere Geoff. |
| 996 | Larry | What's wrong? |
| 997 | Geoffrey | Nuthin'. Nuthin'. |
| 998 | Lucy | So it's gonna be ionised. |
| 999 | Larry | Have you done amoxycillin Lucy? |
| 1000 | Lucy | Yep. That's what I said to him, but he didn't believe me. |
| 1001 | Larry | Who? |
| 1002 | Lucy | Geoff. |
| 1003 | Geoffrey | We don't |
| 1004 | Larry | That would be ionised |
| 1005 | Lucy | yeah |
| 1006 | Larry | Which bit of it's ionised though? |
| 1007 | Lucy | In general. Because two bits of it are un, are ionised and one bit is union, unionised. |
| 1008 | Larry | So you're saying that makes the whole thing ionised? The base is ionised |
| 1009 | Lucy | What? |
| 1010 | Larry | The base is unionised? |
| 1011 | Lucy | yeah. The base is ionised. |
| 1029 | Janine | pH three |
| 1032 | Lucy | So, Geoff. |
| 1033 | Geoffrey | So what? |
| 1034 | Lucy | So what's, so e, e's the bit we didn't do before. |
| 1035 | Geoffrey | Oh |
| 1036 | Lucy | One up and one down |
| 1037 | Geoffrey | mmm, these'd be ionised though |
| 1038 | Lucy | It's more ionised? |
| 1039 | Geoffrey | yeah |
| 1040 | Lucy | Why? |
| 1041 | Lucy | Why? |
| 1042 | Larry | Half and half isn't it? |
| 1043 | Lucy | That's what I thought. |
| 1044 | Geoffrey | What this one? |
| 1045 | Lucy | No e. E, e |
| 1046 | Geoffrey | Oh no, e. E. E's half. E's half and half. |
| 1047 | Lucy | So what do you write, half and half? |
| 1048 | Geoffrey | I wrote half and half. |

| | | |
|---|---|---|
| 1052 | Geoffrey | Just looking at these |
| 1053 | Janine | Um, sorry |
| 1055 | Lucy | Help! Geoff |
| 1056 | Janine | With number d, you've asked us to find out the percentage |
| 1057 | Tutor | yeah |
| 1058 | Janine | ionised at pH seven, and you've written here a hundred. |
| 1059 | Tutor | yep |
| 1060 | Janine | It's a hundred for COOH, coz like I understand that, but then do you not want us to work out the ionisation percentage of the base? |
| 1061 | Lucy | What about ticarcillin? |
| 1062 | Larry | It is ionised? |
| 1063 | Geoffrey | I don't know |
| 1064 | Lucy | I don't know why ???? |
| 1065 | Larry | It's ionised at the two sites |
| 1066 | Geoffrey | Oh I get it |
| 1067 | Tutor | Um, no, because, if the carboxylic acid group's a hundred percent ionised, then the molecule is ionised. |
| 1068 | Lucy | Do we have to do this all again? |
| 1069 | Janine | Oh, so if one thing is, is that all it takes? |
| 1070 | Tutor | Why? Because just one charge is enough |
| 1071 | Janine | Oh. |
| 1072 | Tutor | to make the whole molecule ionised. |
| 1073 | Janine | OK. |
| 1074 | Tutor | If you've got last week's answers |
| 1075 | Lucy | yep, here. I think they're last week's answers. |
| 1076 | Tutor | yeah. This is worth listening to. |
| 1077 | Lucy | OK |
| 1079 | Tutor | OK. With, this is amoxycillin, its ionisation, or the way that I drew it with my, um, bizarre, drawing formulas. The way that it works is, this is what happens to it as the pH increases from really, really low to really high. OK? |
| 1080 | Lucy | How does it work? |
| 1081 | Tutor | At really low pHs it's ionised through, um, the amino group, then as you go up pH a bit, it becomes ionised at the carboxylic acid group and stays ionised at the amino group. Then it loses its ionisation at the amino group, but it's still ionised at the carboxylic acid. And then even higher, it's ionised at the carboxylic acid and the phenol. |
| 1082 | Larry | But |
| 1083 | Tutor | So the relevant thing is that on each of these forms, there is a charge. So each of those forms is fully ionised. It doesn't matter that the ionisation type changes from being a plus to a plus and a minus, to a minus, to two minuses. Each one of those forms is ionised. So this molecule, |
| 1084 | Lucy | yeah |
| 1085 | Tutor | is ionised, fully ionised, at all pHs. There's no form that you can find once you put it into solution, there's no form it can take which doesn't have a charge somewhere on it. And that means that it |
| 1086 | Lucy | so that's what results |
| 1087 | Geoffrey | Oh |
| 1088 | Lucy | that's um, the answers to that one |
| 1089 | Tutor | That's, yeah that's the worked answer to ninety-three. It's just that I knew what was in there so that's why I went for it. |
| 1090 | Lucy | OK |
| 1091 | Tutor | OK? |
| 1092 | Lucy | That's good |
| 1093 | Tutor | And so, the majority of compounds that have both acidic and basic groups in them, |
| 1094 | Janine | Is that how you do it? |
| 1095 | Tutor | they behave like that. |
| 1096 | Janine | So that's what you do, if one and yeah. I just confused the definitions there. All right. |
| 1097 | Tutor | So that's one of the reasons why I say we don't call them acid or base. Because they've got both |
| 1098 | Janine | Ahhh |
| 1099 | Tutor | They don't actually behave like acids and bases, |
| 1100 | Janine | yeah |

| | | |
|---|---|---|
| 1101 | Tutor | the functional groups behave like acidic and basic functional groups, but the molecule, its state of ionisation, doesn't behave like an acid, or a base. OK? |
| 1102 | Janine | That's right. Thank you. |
| 1103 | Janine | (mumbles quietly) Uh! |
| 1104 | Lucy | How about the second one, Geoff? Can you show me how to do that? |
| 1105 | Geoffrey | It's not right. |
| 1106 | Lucy | Isn't that what she said, that it'd be ionised? |
| 1107 | Geoffrey | What's those numbers there? |
| 1108 | Lucy | Oh that's wrong, I meant this one here. Sorry |
| 1116 | Lucy | So. So that's a hundred. Two hundred, what are the others? How do you know? |
| 1117 | Janine | How come we don't get asked to calculate the percentage ionised for e? It's ionised isn't it? It is. It is. Should I put ionised? For e? |
| 1118 | Larry | Yep |
| 1119 | Geoffrey | Yeah. A little bit |
| 1120 | Geoffrey | No we said they were both |
| 1121 | Janine | It's ionised. |
| 1122 | Geoffrey | Why? |
| 1123 | Janine | She just said that if one group is in ionic form, the whole molecule is ionised. Doesn't matter if the other groups aren't ionised, it's all ionised. It's got charge on it. Damn, damn, ???? concentrated |
| 1124 | Geoffrey | OK that's ionised |

# Part B: Persistent change group

## Workshop 1

### *Episode PC1.1*

| | | |
|---|---|---|
| 360 | Kellie | I don't understand why we have to square it. Like, we found the solubility, right? And then you put in the equation of, uh. |
| 361 | Jasmine | You don't understand why it's like that? |
| 362 | Kellie | No |
| 363 | Jasmine | Because Ksp is, is. OK, do you understand up to there? |
| 364 | Kellie | No |
| 365 | Jasmine | Like, that's exactly the same as what we did before. But the difference is that one dissociates, but that one doesn't. So that one goes to solution and solvent. That's like solvent and the ions. |
| 366 | Kellie | Yeah |
| 367 | Jasmine | Yeah. And what we learnt in Chemistry is always the product over reactant. That's what they did there. And that's what they did there. But then here, somehow, the activities is one or something. So, you understand this bit, don't you? |
| 368 | Kellie | Mmm |
| 369 | Jasmine | For the other case. Do you? Do you get why they go to one? |
| 370 | Alicia | It's a little ???? |
| 371 | Jasmine | Do you get why they go to 1? |
| 372 | Kellie | No, I just use the equation. I don't look at that part (laughs). |
| 373 | Jasmine | Oh, OK. Yeah, that one hasn't got an equation, there, whoops, mike. Anyway, it'll turn out to be that aA is from the ion. The plus ion, cation. aB is from the anion, put it there. And then the activity for the solid and the solvent and the liquid, they're all 1. Don't ask me why. But there's explanations from before. |
| 374 | Kellie | Yeah |
| 375 | Jasmine | OK. So it turns out to be all you're looking at is just the ratio |
| 376 | Kellie | Oh, right |
| 377 | Jasmine | not the ratio, but the products. You times the ions. And that is the Ksp. And before, just the other case all cancels out. It's just the solution. So, in other words, that is the squared of that. |
| 378 | Kellie | But where do we put it in there? |
| 379 | Jasmine | Why don't we put it in there? |
| 380 | Kellie | No, why do we put it in there? |
| 381 | Jasmine | Because we're doing exactly the same thing, but the theory, it's just different. That this has, dissociates, it's dissociated depending on the, the ratio. Remember Veronica was saying that it's one to one or something? Cos with this, this is AgCl, if you dissociate that, it's like Ag plus, and then one Cl. |
| 382 | Kellie | Cl minus |
| 383 | Jasmine | That's why you square it. But if you get like $AgCl_2$, then you get like Cl to the 2 |
| 384 | Kellie | Yeah, squared |
| 385 | Jasmine | and then that, right? And that, what you do with that is you |
| 386 | Kellie | Yeah, I get that |
| 387 | Jasmine | you cube root that. That's the same as Chemistry yeah? |
| 388 | Kellie | But I don't, I just don't get why you have to put it in place of $S_1$. |
| 389 | Jasmine | Oh. Normally, yeah, you get that equals the solubility. Which is the S thingie there. But here, what you get out is the Ksp. |

## *Episode PC1.2*

| | | |
|---|---|---|
| 806 | Denise | I know why we got it wrong, coz |
| 807 | Jasmine | Why |
| 808 | Denise | Coz they switched it around |
| 809 | Jasmine | Yeah, you told me. You showed me how to do it. |
| 810 | Kellie | If it's a minus log, then it's just log, and then you switch the two numbers around, right? |
| 811 | Unknown | Why? |
| 812 | Jasmine | Ohhh. |
| 813 | Denise | It's like two different variable things. If they can, if they just, like, what's it, the ionised over the |
| 814 | Kellie | No, pH equals pKa or something like that. |
| 815 | Denise | Yeah. If like, the one that we were used to was something like ionised over un-ionised. |
| 816 | Jasmine | Yeah. |
| 817 | Denise | And then it was pH equals to pKa. But if they swap it around, if they go pKa equals to pH, then they can swapped the ionised and un-ionised. |
| 818 | Jasmine | That is mean. That is so mean. |
| 819 | Kellie | Ohhhhh, yeah. |
| 820 | Denise | And like, we're so used to that, seeing that one |
| 821 | Jasmine | Oh God. OK. |
| 822 | Jasmine | We think it's wrong but we don't look at it carefully. |
| 823 | Kellie | So it depends on which one, like if it's pH equals something, or if it's pKa |
| 824 | Jasmine | Mmm equals something |
| 825 | Kellie | then the ionised and un-ionised is different. |
| 826 | Denise | They can change both and they'll still be the same. |
| 827 | Kellie | How do you know, though? |
| 828 | Jasmine | Yeah, how do we know? Is it the |
| 829 | Denise | You just have to remember one of the formulas. |
| 830 | Jasmine | Oh, is it log law, the law, some law with the logs, is it? |
| 831 | Denise | Log laws. Yes, or something like that |
| 832 | Jasmine | Oh, that thing. Oh, OK |
| 833 | Kellie | So you |
| 834 | Jasmine | But mathematically you switch it around. |
| 835 | Denise | I didn't know it was that one |
| 836 | Jasmine | Cos it goes upside down. |
| 837 | Jasmine | I'll take it as a yes then. |
| 838 | Denise | Pardon? |
| 839 | Jasmine | Yeah, like mathematically, if you put Kpa on the other side, does that go upside down? |
| 840 | Veronica | So is lnKa, pKa? |
| 841 | Denise | Is that what you mean? |
| 842 | Jasmine | Yes, it does, it does! |
| 843 | Kellie | Why? Why? |
| 844 | Jasmine | Because. Because, if it's, say, well normally it's that, Kpa minus log P is it? Blah, blah, blah. And then if you put it the other way, that becomes a plus. |
| 845 | Denise | Yeah it gets taken to the other side. |
| 846 | Veronica | But then |
| 847 | Jasmine | And what happens? |
| 848 | Kellie | Huh? |
| 849 | Jasmine | Coz normally, if you have the minus if you take that up, but you can't do it ???? |
| 850 | Kellie | Huh? If it's a minus, then you swap it around then you can make it a plus. |
| 851 | Jasmine | Yeah. |
| 852 | Kellie | Swap these two numbers around. |
| 853 | Alicia | Oh, OK. |
| 854 | Jasmine | Well, there you go. You put it |
| 855 | Kellie | That's what I said! |
| 856 | Jasmine | Oh, yeah, you can't. You can't though. |
| 857 | Kellie | Whadya mean you can't? |
| 858 | Jasmine | So, you're saying that if I put that over there. So I go pH right, log. Do I swap or not? You don't do you? |
| 859 | Alicia | No. |
| 860 | Jasmine | You leave it. |

| | | |
|---|---|---|
| 861 | Alicia | Yep. |
| 862 | Jasmine | Then it's still the same! |
| 863 | Denise | But then there's a plus there. Change it to a minus. |
| 863.5 | Alicia | ???? |
| 864 | Jasmine | Ohh, I get ya. OK, cool. Thanks. |
| 865 | Alicia | And that's why you use that. |
| 866 | Kellie | Because it's like to the power of minus one. |
| 867 | Jasmine | She wants to trick us, yes. |
| 868 | Jasmine | Yeah, normally, when you have a negative in front of a log you have to take it to the back, remember? It's minus 1. |
| 869 | Denise | Oh, yeah, yeah, yeah. |
| 870 | Jasmine | It's minus 1. And the a becomes |
| 871 | Denise | a log |

## *Episode PC1.3*

| | | |
|---|---|---|
| 1017 | Kellie | Oh, here we go again. |
| 1018 | Jasmine | Acid and base. Here we go again. |
| 1019 | Jasmine | Oh, between. Oh, I know |
| 1020 | Jasmine | Oh, that's the very first one |
| 1021 | Kellie | Look there's a hand in though |
| 1022 | Jasmine | Well in Pharmacy, it is a proton acceptor and donor, is it? That's OK. That's the same as Chemistry. |
| 1023 | Alicia | Definition |
| 1032 | Kellie | Hey, maybe that's the Chemistry one, that's the Pharmacy one. |
| 1033 | Denise | Yeah |
| 1034 | Veronica | Right? |
| 1035 | Jasmine | Which one? |
| 1036 | Veronica | Where? |
| 1037 | Kellie | The Bronsted-Lowry. Oh no, it's the same thing. |
| 1038 | Jasmine | It's the same thing. |

## *Episode PC1.4*

| | | |
|---|---|---|
| 1039 | Denise | No! Oh yeah, the Chemistry one has a limit, like it says it dissociates fully. |
| 1040 | Kellie | Oh, yeah. |
| 1041 | Denise | Oh no that's the strength. That's looking at that strength. And then Pharmacy says how easily it dissociates. That's the difference in strength. |
| 1042 | Jasmine | Can you say that again? |
| 1043 | Denise | Yeah, one dissociates fully. |
| 1044 | Kellie | Oh, here it is, yeah. In Pharmacy, therefore, drugs which are acid and bases |
| 1045 | Jasmine | Where is it? Oh. |
| 1046 | Kellie | are classified as strong or weak on the basis of pKa. Is that what you said? |
| 1047 | Veronica | Yeah, but we're not talking about strength. We're talking about the definitions of acids and bases. |
| 1048 | Denise | Yeah I know, just the actual definition. |
| 1049 | Kellie | But that's what the difference is. |
| 1050 | Chorus | Ohhhh |
| 1051 | Jasmine | They don't really have a difference. |
| 1052 | Kellie | But there is a difference. |
| 1053 | Jasmine | But with acid and base. |
| 1054 | Denise | That's for Chemistry |
| 1055 | Jasmine | It's the same. |
| 1056 | Jasmine | Like there are differences in the way we talk about the strength, and the pKa. |
| 1057 | Denise | I think these are the Chemistry ones, just proton donor and proton acceptor. They're really basic, and then these are the Pharmacy ones. |
| 1058 | Kellie | Whoa |
| 1059 | Denise | They have all different properties. I think that's the difference. |
| 1060 | Veronica | OK |
| 1061 | Jasmine | Let's ask. OK, let's go, go on with exercise four first. |

## *Episode PC1.5*

| | | |
|---|---|---|
| 1073 | Jasmine | Oh that's good. I like these. |
| 1074 | Veronica | Circle the functional groups which you think are acidic and basic. |
| 1075 | Jasmine | Keep reading, because I'm not using my eyes. |
| 1076 | Denise | OK, does someone want to be the person to hand in? |
| 1077 | Jasmine | I can write if you want me to. |
| 1078 | Denise | OK. |
| 1079 | Veronica | All right, OK. |
| 1080 | Denise | So the OH, oh that's not acid. That's neutral. |
| 1081 | Kellie | Is it? |
| 1082 | Denise | OH? Hydroxide, oh that's basic. That's so basic and I didn't even (laughs) |
| 1083 | Kellie | Is OH basic? |
| 1084 | Denise | Mm. Hydroxide. |
| 1085 | Veronica | No. |
| 1086 | Denise | Yeah, NaOH. |
| 1087 | Jasmine | No, if it's, but is it a phenol group? It depends on that. |
| 1088 | Denise | Oh it says the functional groups. |
| 1089 | Veronica | Yeah, it is a phenol. |
| 1090 | Jasmine | Then it is acidic. |
| 1091 | Denise | Then it's basic |
| 1092 | Veronica | No, phenol, |
| 1093 | Jasmine | It's a weak acid. |
| 1094 | Veronica | it's attached to a benzene ring. That's an aliphatic ring. |
| 1095 | Jasmine | Oh yeah. |
| 1096 | Denise | That's basic. |
| 1097 | Kellie | Oh, it's not directly attached. |
| 1098 | Jasmine | No, but this is Pharmacy, this is not Chemistry. |
| 1099 | Kellie | Yes it is. |
| 1100 | Jasmine | Is it? |
| 1101 | Alicia | The phenol's the same for both. |
| 1102 | Jasmine | Did we learn about, like, just OH by itself? Didn't we just learn about phenols? |
| 1103 | Kellie | OH by itself is alcohol. |
| 1104 | Alicia | Yeah |
| 1105 | Kellie | So is it wrong? |
| 1106 | Jasmine | Then, what were you guys talking about? |
| 1107 | Veronica | I dunno, what are you talking about? |
| 1108 | Kellie | That's phenol, OK. |
| 1109 | Jasmine | What are you talking about? |
| 1110 | Kellie | And that's a weak acid. |
| 1111 | Veronica | It's not a phenol. |
| 1113 | Veronica | Yeah |
| 1114 | Veronica | See, a phenol, |
| 1115 | Kellie | Huh? |
| 1116 | Veronica | It is. |
| 1117 | Veronica | it's attached to a benzene ring directly. |
| 1120 | Veronica | That's an aliphatic ring. |
| 1121 | Kellie | How do you know? |
| 1124 | Veronica | Benzene has this thing. It means it has like |
| 1125 | Denise | Oh yeah it is, like, |
| 1127 | Kellie | I thought sometimes it didn't have it. |
| 1129 | Veronica | A phenol has a benzene ring in it. |
| 1131 | Denise | That's not benzene. That's just a normal. |
| 1132 | Veronica | That's a normal ring. |
| 1133 | Alicia | Yeah. |
| 1134 | Veronica | So we're saying it's not? |
| 1135 | Denise | Yeah |
| 1136 | Veronica | So it's nothing. |
| 1137 | Denise | But it's a O H, so it's basic |
| 1138 | Veronica | No. |

| | | |
|---|---|---|
| 1139 | Kellie | Are you talking |
| 1140 | Denise | Do you know what? |
| 1141 | Denise | It's just a functional group |
| 1142 | Veronica | No, it's neither acidic nor basic. |
| 1143 | Jasmine | Which one are you talking about? The first one? |
| 1144 | Veronica | Look at diagram one hundred and seventeen. It tells you that if it's an alcohol group like that, then it's neither. |
| 1145 | Denise | Yeah but doesn't it just say circle the functional groups? |
| 1146 | Denise | Which you think are. And then evaluate whether the whole drug |
| 1147 | Jasmine | Oh, yeah, |
| 1148 | Veronica | No. |
| 1149 | Denise | So we sort of identify it |
| 1150 | Jasmine | Yeah, you've gotta circle them out first, and talk about the components before you say the overall. |
| 1151 | Veronica | Oh, man |
| 1152 | Kellie | Really? I thought you just, you point out the acidic and basic. |
| 1153 | Jasmine | Hey, read beyond the first line. |
| 1154 | Jasmine | No, no, sorry. I only found it out like, |
| 1155 | Kellie | "As a group you should have decided whether the following drugs are acids", ohh. I only read the first line. |
| 1156 | Jasmine | I only heard what Veronica said, and I, I took her word for it. Good one. |
| 1157 | Veronica | What, what, what? |
| 1158 | Kellie | OK, so that's neither. Right? OH |
| 1159 | Denise | OH |
| 1160 | Jasmine | It's OH basic? Who told you that? |
| 1161 | Veronica | It's neither! |
| 1162 | Kellie | Neither! |
| 1163 | Denise | Oh, so it's only like, NaOH's that are basic. |
| 1164 | Jasmine | No, no, no. But I |
| 1165 | Denise | I just always thought H plus is acidic. |
| 1166 | Jasmine | Oh no, OH is basic as in like NaOH |
| 1167 | Veronica | We're trying to dispel the myths, all right? |
| 1168 | Denise | Yeah, yeah |
| 1169 | Jasmine | Yeah, I get what you mean, OK. Veronica, is that right? |
| 1170 | Jasmine | All right, no one's concentrating. Come on. Do some work. |
| 1171 | Veronica | What's that $CH_3O$ thing? |
| 1172 | Jasmine | So do we? |
| 1173 | Kellie | It's carboxylic acid. |
| 1174 | Jasmine | Methyl? |
| 1175 | Veronica | That's not carboxylic acid. |
| 1176 | Kellie | What is it then? |
| 1177 | Veronica | That's an, that's an aldehyde or something. |
| 1178 | Denise | OK |
| 1179 | Veronica | None of us know what we're talking about. |
| 1180 | Denise | So it's not, it's neither OK? |
| 1181 | Veronica | It's naf-all |
| 1182 | Kellie | I dunno, um |
| 1183 | Denise | Hang on, that's an amine |
| 1184 | Veronica | Methanal |
| 1185 | Jasmine | That is definitely amide. A part of the amide group. |
| 1186 | Veronica | Amides groups don't have any |
| 1187 | Jasmine | So it doesn't do anything. |
| 1188 | Chorus | Yeah. |
| 1189 | Denise | This one |
| 1190 | Jasmine | Then that one's neutral as well, is it? |
| 1191 | Denise | OK |
| 1192 | Veronica | Mmm. |
| 1193 | Jasmine | Oh, this is hard. |
| 1194 | Denise | Oh, that's |
| 1195 | Kellie | The whole thing's neutral. |
| 1196 | Jasmine | For the second one too? |

| | | |
|---|---|---|
| 1197 | Jasmine | OK. How about the third one? |
| 1198 | Veronica | OK, so codeine is neither. |
| 1199 | Alicia | Yep. |
| 1200 | Kellie | Yep |
| 1201 | Jasmine | What's your reasoning for that, though? |
| 1202 | Veronica | Because those groups, they're amides |
| 1203 | Alicia | They're all neither |
| 1204 | Veronica | and hydroxyl groups, um are not basic, nor are they acidic. So you have to say that the molecule as a whole is neither. |
| 1205 | Jasmine | Do you want me to write that down then? You sure? Or wait till later? |
| 1206 | Denise | So when there's an OH there, isn't that basic? |
| 1207 | Veronica | I don't think it is. |
| 1208 | Kellie | Why? |
| 1209 | Denise | I thought that whenever you have an OH attached to something, it makes it basic. |
| 1210 | Jasmine | But isn't alcohol acidic itself? In Chemistry, like we |
| 1211 | Denise | I think alcohol, yeah. |
| 1212 | Jasmine | Yeah (coughs) Excuse me |
| 1213 | Unknown | Ibuprofen |
| 1214 | Denise | That's acidic |
| 1215 | Jasmine | That's really similar to that. |
| 1216 | Alicia | Which one? |
| 1217 | Jasmine | This one. Well, well the chains |
| 1218 | Veronica | This one doesn't do anything, really. It's an alcohol thing. It doesn't have any acidic or basic properties. |
| 1219 | Jasmine | The third one? |
| 1220 | Kellie | I took |
| 1221 | Jasmine | Which one? The second or the third one? |
| 1222 | Veronica | Codeine. |
| 1223 | Jasmine | Codeine |
| 1224 | Veronica | Coz Denise's still thinking of the OH group |
| 1225 | Denise | Oh, no, I've changed it again |
| 1226 | Veronica | OK, OK, let's go to Diazepam, then. |
| 1227 | Jasmine | Do the third one. |
| 1228 | Veronica | How about the second one? We haven't done it. |
| 1229 | Jasmine | Oh, OK. |
| 1230 | Denise | It's neither. |
| 1231 | Veronica | Is it? |
| 1232 | Kellie | How come? |
| 1233 | Denise | Because there aren't any acidic or basic functional groups |
| 1234 | Kellie | How do you? What's that? |
| 1235 | Denise | That's amide, not amine. |
| 1236 | Kellie | Oh, amide |
| 1237 | Jasmine | Amide. Like when the N is part of the amide or something. Ohhh. |
| 1238 | Denise | Well it's not amine. |
| 1239 | Jasmine | I've written it down for amide. But it probably means that it's, um, the lone pair is engaged, so it's not really free, so it's not basic. (Coughs) Oh God |
| 1251 | Kellie | What's, what's an amide? |
| 1252 | Veronica | What's an amide? |
| 1253 | Denise | That's an amide. |
| 1254 | Jasmine | Look at um one twenty. Page, it was one twenty. |
| 1255 | Veronica | Yeah |
| 1256 | Jasmine | Yeah. Did you circle it and saying, oh something's part of an amide? |
| 1257 | Veronica | Yeah, it's not basic |
| 1258 | Jasmine | That one, yeah. Oh, no |
| 1259 | Kellie | This one? |
| 1260 | Jasmine | Yep, that's it. It's not basic. |
| 1261 | Denise | Because it's got, ah this is C actually |
| 1262 | Jasmine | Because it's part of the amide group or something. |
| 1263 | Denise | Wait, wait, wait, I can show you. This is amide group here |
| 1264 | Kellie | Mmm |
| 1265 | Denise | Not the $CH_3$, doesn't have, that doesn't have anything to do with it. |

## *Episode PC1.6*

| | | |
|---|---|---|
| 1314 | Jasmine | Right, OK. So we've gotta circle all the groups, and then, and then |
| 1315 | Kellie | Yeah |
| 1316 | Denise | So diazepam is neither. You don't have any other |
| 1317 | Kellie | Neither. Ibuprofen is acidic. |
| 1319 | Denise | Ibuprofen. Um, acidic? |
| 1321 | Veronica | Yep. |
| 1326 | Denise | And then lignocaine. |
| 1327 | Jasmine | Hey, are you guys certain about that? I'm gonna write it down. |
| 1328 | Denise | Lignocaine's neither. |
| 1329 | Veronica | We are certain. |
| 1330 | Alicia | Yeah |
| 1331 | Jasmine | OK. Hey I wanna do this too, don't leave me out. I wanna do it. |
| 1332 | Veronica | We're circling away. |
| 1333 | Veronica | Hmm. Lignocaine. |
| 1334 | Jasmine | Are you doing the old painkiller thing? |
| 1335 | Veronica | No, the one before the old painkiller. |
| 1336 | Jasmine | Yeah? OK. Um. So there's an amide, she said. |
| 1337 | Denise | And nothing else. |
| 1338 | Veronica | Yeah, that's an amide, because it has double bonds. |
| 1339 | Denise | Oh hang on, there's an N here which |
| 1340 | Jasmine | Yeah, what does the N do? It's probably a basic N. |
| 1341 | Veronica | Doesn't it only count if it's like. Oh, yeah, it is kind of directly attached. It's really long, huh? |
| 1342 | Jasmine | N |
| 1343 | Kellie | How is it directly attached? |
| 1344 | Jasmine | $CH_2$ |
| 1345 | Veronica | Because it's on that long chain thing. |
| 1346 | Jasmine | $CH_2$ $CH_3$ |
| 1347 | Veronica | So you have to work out whether that N is basic or not. |
| 1348 | Jasmine | Yeah, that is, it's basic, I think. Because if you draw it out – |
| 1349 | Veronica | It's still got one lone pair. |
| 1350 | Jasmine | It's got, yeah, one lone pair left. Is that right, though? That's Chemistry, it's not Pharmacy. |
| 1351 | Veronica | Ohhh |
| 1352 | Kellie | Yeah, so that's |
| 1353 | Alicia | Yeah |
| 1354 | Jasmine | Do you think it's basic? |
| 1355 | Denise | It's basic. |
| 1356 | Jasmine | Basic N do you just call it? |
| 1357 | Veronica | Mm. |
| 1358 | Denise | So does that make the whole molecule basic? |
| 1359 | Veronica | Is the next one neither? Phenacetin? |
| 1360 | Jasmine | Um |
| 1361 | Denise | It has, that N has |
| 1362 | Jasmine | That's got |
| 1363 | Denise | That's got a lone pair as well |
| 1364 | Jasmine | Has it? But it's a amide. |
| 1365 | Veronica | But it's joined to a carbon which has double bonds? |
| 1366 | Denise | The carbon, oh yeah |
| 1367 | Jasmine | It's amide, isn't it? It's the same as the bit before. |
| 1368 | Veronica | Hmm |
| 1369 | Jasmine | How about the O? That doesn't do anything does it? |
| 1370 | Jasmine | No, nup, nup. It's part of the chain, OK |
| 1371 | Denise | Hey can you draw this out for me, coz I can't see it. |
| 1372 | Alicia | Sorry |
| 1373 | Denise | Like that N there. |
| 1374 | Jasmine | That one? |
| 1375 | Denise | Yeah. How would you draw that out? That one, and the other one, yeah. |
| 1376 | Jasmine | OK, that's like the ring thingy |

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|---|---|---|
| 1377 | Denise | Single bond to the N |
| 1378 | Jasmine | then it's got an N, and then it's got an H. It's got a C, |
| 1379 | Denise | Yep |
| 1380 | Jasmine | and then O, |
| 1381 | Denise | Uhuh |
| 1382 | Jasmine | and then $CH_3$. |
| 1383 | Denise | So what about here? |
| 1384 | Jasmine | Here? Normally, yeah, normally N's got four bonds. So, there's one, two, three, so that, therefore there's a lone pair there. |
| 1385 | Denise | Yeah, so wouldn't that make it basic? |
| 1386 | Jasmine | Oh, but, but, but, because it's part of this, every time |
| 1387 | Denise | Oh it's next to |
| 1387a | Jasmine | when an N is next to a C double O |
| 1388 | Jasmine | that means it's amide. |
| 1389 | Denise | I thought you were talking about that time there. OK |
| 1390 | Jasmine | I don't know why, but. |
| 1391 | Jasmine | How about the next one, the chloro thingy? Oh, is that neither? |
| 1392 | Kellie | Yeah |
| 1393 | Jasmine | OK |
| 1394 | Veronica | Yeah it's basic, the next one, chloroquine. |
| 1395 | Jasmine | Why? |
| 1396 | Veronica | Coz, the N near the end, it's joined to two groups. And also a C, so it's got a lone pair. |
| 1397 | Jasmine | OK |
| 1398 | Jasmine | How about the one near the ring? At the top? |
| 1399 | Veronica | Nup. Because it's joined to double bonds. |
| 1400 | Kellie | To the C |
| 1401 | Veronica | The C has double bonds. |
| 1402 | Jasmine | This one. |
| 1403 | Veronica | Yeah from the, up here |
| 1404 | Jasmine | Is that double bond? |
| 1405 | Veronica | Yeah. Anything with a benzene ring like that. |
| 1406 | Jasmine | Ohhh, OK |
| 1407 | Denise | Hang on, which one? This one? Or this thing here? |
| 1408 | Kellie | Yeah, to that C. |
| 1409 | Denise | So it's got two occupied there, one down to this ring |
| 1410 | Kellie | Oh yeah |
| 1411 | Denise | Wouldn't it have another pair? |
| 1412 | Jasmine | Then one's joined to the H, one's joined to the C. |
| 1413 | Veronica | With that C? Sorry |
| 1414 | Kellie | The double bond to the N |
| 1415 | Jasmine | So there's one pair with the C, one pair with the H. |
| 1416 | Kellie | Would that be |
| 1417 | Jasmine | And then double bond with the ring. How did you know it's a double bond with the ring? |
| 1418 | Denise | So the N |
| 1419 | Veronica | Because benzene rings have double bonds that, that change a lot. You know how we were talking about resonance structures, like |
| 1420 | Denise | So is it like this? Does it look like this? |
| 1421 | Jasmine | Yeah. |
| 1422 | Kellie | Yeah. Oh, wait. |
| 1423 | Veronica | Sometimes they'll bond there, sometimes there. |
| 1424 | Jasmine | Yeah. |
| 1425 | Veronica | And if a C has a double bond on it, then it's not an amine, which would be basic. It'll be an amide group. |
| 1426 | Kellie | I think that's single, the. |
| 1427 | Denise | Yeah that's single that's only got three bonds, OK? Doesn't it have the capacity to form four? |
| 1428 | Veronica | Amide, so that doesn't give it any properties, acidic or basic. |
| 1429 | Denise | I think that's double there. |
| 1430 | Jasmine | But then the thing is,- |
| 1431 | Kellie | Which one will go to the N to the C there. Um, |
| 1432 | Jasmine | What's a double? |

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| 1433 | Veronica | I dunno |
| 1434 | Denise | To the other C, like not the ring one |
| 1435 | Kellie | Across |
| 1436 | Kellie | From here to here |
| 1437 | Jasmine | Oh, OK. |
| 1438 | Kellie | Is that normal? |
| 1439 | Jasmine | Two, three |
| 1440 | Denise | That's what I thought you meant by double before. |
| 1441 | Alicia | Do you understand? |
| 1442 | Jasmine | Not really. How come? |
| 1443 | Denise | OK, so if you have three, occupied, and it has the capacity for four, there'd be a lone pair. |
| 1444 | Jasmine | Yeah, yeah. |
| 1445 | Denise | So then they're both basic Ns. |
| 1446 | Kellie | Yeah, because this C is attached to that C and then C-to-C, so it must be double there. Isn't it? |
| 1447 | Denise | But then there's a H there. |
| 1448 | Jasmine | But there's a H. This H goes in the below. |
| 1449 | Kellie | Oh so there's nothing there? |
| 1450 | Jasmine | So there's sort of one there, one there, one there and then one to N. |
| 1451 | Denise | And the N to, that will be, so it's basic |
| 1452 | Jasmine | But one question to you, Veronica, |
| 1453 | Veronica | Yes. |
| 1454 | Jasmine | You know with that thingy, |
| 1455 | Veronica | Yes. |
| 1456 | Jasmine | You said you don't know where, where the electrons are, but the thing is, isn't it like just double and single bonds inside the carbon? So it's got nothing to do with this one? |
| 1457 | Veronica | No, yeah, this is not a double bond. |
| 1458 | Jasmine | Oh. |
| 1459 | Denise | Oh |
| 1460 | Jasmine | Oh, but when you got a carbon that |
| 1461 | Veronica | I'm talking about the carbon that have double bonds. |
| 1462 | Jasmine | The carbon with double bonds. Oh. OK. |
| 1463 | Veronica | When the carbon is involved with that has a double bond, |
| 1464 | Jasmine | That means they're amide |
| 1465 | Veronica | Amide. |
| 1466 | Jasmine | Oh |
| 1467 | Denise | Amide. |
| 1468 | Veronica | Yeah. |
| 1469 | Denise | OK |
| 1470 | Denise | So it's still basic, the molecule |
| 1471 | Alicia | Mmm, yeah. |
| 1472 | Denise | So that's got a phenol, one extra |
| 1473 | Veronica | So, the next one, it has two, two hydroxyls, those are phenols. And I think it's also basic. |
| 1474 | Denise | Can't be phenol I don't think coz doesn't phenol only have one hydroxyl coming off it? |
| 1475 | Veronica | Only one? |
| 1476 | Denise | Yeah. |
| 1477 | Veronica | I dunno. |
| 1478 | Alicia | Can it have two phenols there? |
| 1479 | Denise | Can it? |
| 1480 | Veronica | I think it can have two. |
| 1481 | Denise | Oh, OK. So it's phenol and that's weak acid. |
| 1482 | Veronica | Yep, weak acid. It'll have a basic one, as well. |
| 1483 | Denise | That's stronger, hey. |
| 1484 | Veronica | So, what are we going to say? |
| 1485 | Denise | More basic. |
| 1486 | Veronica | Does two |
| 1487 | Veronica | But does two weaks equal a strong? |
| 1488 | Kellie | No |
| 1489 | Denise | I don't know, I don't think it's worked out as two weaks, like if you have two phenols, like two rings, then it would be a bit stronger. It has to be basic. Shall we ask? |
| 1490 | Kellie | Yeah. Celina? |

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| 1491 | Tutor2 | Yeah |
| 1492 | Denise | For this one, we're just trying to work out what the overall, like would the molecule be basic, or acidic. |
| 1493 | Tutor2 | Yep. You got acidic and you got a base. |
| 1494 | Kellie | But they're two weak ones. |
| 1495 | Tutor2 | Yeah |
| 1496 | Kellie | Does the basic |
| 1497 | Tutor2 | Override the acidic? |
| 1498 | Kellie | Yeah |
| 1499 | Tutor2 | Don't know. So, it's neither. It's neither acidic nor basic. From what you know then. |
| 1500 | Kellie | OK, cool. |
| 1501 | Denise | OK |
| 1502 | Kellie | So it's still neither? |
| 1503 | Tutor2 | It's neither, even though you have, even though you have both, an acidic functional group and basic. |
| 1504 | Kellie | So whenever there is both, then it's neither. |
| 1505 | Tutor2 | Well, from what Erica's asked you, that's all you can say. |
| 1506 | Jasmine | That it cancels out? |
| 1507 | Kellie | They wipe each other out. |
| 1508 | Tutor2 | From what Erica's asking you, she's just asking if there's either acidic, basic or neither. And from that you don't know if one is stronger than the other. |
| 1508a | Kellie | ???? |
| 1509 | Tutor2 | Don't know. |
| 1510 | Kellie | So even if we don't know, does that mean it's neither, |
| 1511 | Tutor2 | It's neither |
| 1512 | Kellie | or we don't know, but there is, it is either acidic or basic? |
| 1513 | Tutor2 | Yes. Actually that's the second one. |
| 1514 | Jasmine | Oh, the second one. |
| 1515 | Veronica | Oh. |
| 1516 | Tutor2 | Yep? |
| 1517 | Veronica | Yep. |
| 1518 | Jasmine | Also, this one, I don't know how to word it properly. That's what you were saying, Veronica. |
| 1519 | Denise | The basic nitrogen? |
| 1520 | Kellie | Yeah. |
| 1521 | Jasmine | Well, Veronica said that this isn't basic at all, because although it's single bonded there, and single bonded to everything else, it's connected to a C that is double bonded. That's why it's not basic. So how can I word that nicely I said N bonded to a carbon that is |
| 1522 | Tutor2 | In a benzene ring. |
| 1523 | Jasmine | Oh, OK. |
| 1524 | Kellie | These things can have basic parts, you don't know if it's acidic or basic |
| 1526 | Veronica | It's just based on our present knowledge. |
| 1527 | Denise | No I don't think ???? |
| 1527a | Veronica | Yeah |
| 1528 | Tutor2 | Actually, the main thing that Erica wants you to know from this is this thing, if it's going to be basic or acidic, it's going to be really obvious structures. Rather than that one. That one's a bit too hard to explain. |
| 1529 | Jasmine | So, it is basic. |
| 1530 | Tutor2 | Yep. |
| 1531 | Jasmine | OK |
| 1532 | Tutor2 | OK? |
| 1533 | Jasmine | Yep. Thanks |
| 1534 | Veronica | Ohhh, dear |
| 1535 | Veronica | OK, last one, cefoxitin |
| 1537 | Denise | There's an amide. |
| 1538 | Tutor2 | Yeah, but there's some on the other side of the page. |
| 1539 | Veronica | Yeah, last one on this page. |
| 1540 | Veronica | There's a carboxylic acid. |
| 1541 | Veronica | But the other N's that you can see, right, I reckon, - |
| 1542 | Denise | They're all amides. |
| 1543 | Veronica | Yeah, amides. |

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| 1544 | Denise | All three of them are. |
| 1545 | Kellie | Yeah. |
| 1546 | Denise | So it's acidic |
| 1547 | Veronica | Coolies. |
| 1548 | Denise | I hate amides, they're tricky |
| 1549 | Jasmine | OK, I've just gotta get answers off you later. |
| 1550 | Denise | N H |
| 1551 | Jasmine | That's a basic N, the first one, yeah? |
| 1552 | Kellie | Yeah |
| 1553 | Denise | Yep. |
| 1554 | Veronica | Should overall be basic. |
| 1555 | Veronica | This one's another amide. |
| 1556 | Jasmine | I know. |
| 1557 | Kellie | Carboxylic acid. |
| 1558 | Jasmine | And that one too, huh? Oh, der. |
| 1559 | Veronica | How come? Is it double bond C double bond O. |
| 1560 | Jasmine | Yeah. Is it? |
| 1561 | Denise | Yeah, it is that there. So it's acidic, because there's two acidic groups. |
| 1562 | Jasmine | OK |
| 1563 | Denise | That's amide. |
| 1564 | Jasmine | How about that N? |
| 1565 | Kellie | That's amide too. |
| 1566 | Denise | Where's the O though? |
| 1567 | Jasmine | How about that one? |
| 1568 | Denise | Where's the O? |
| 1569 | Jasmine | Is that amide? But don't you need an O? Do you need an O to be amide? |
| 1570 | Denise | Yeah, you need an O. |
| 1571 | Denise | It still has to be connected to the double bond. |
| 1572 | Kellie | I thought it was just if it was sp3 hybridised. |
| 1573 | Jasmine | Oh, is it? |
| 1574 | Kellie | Yeah. |
| 1575 | Denise | Oh, the carbon? |
| 1576 | Kellie | Yeah, the carbon is. |
| 1577 | Jasmine | So will we ask her what |
| 1578 | Veronica | Carbon's $sp^3$ hybridised, er $sp^2$, $sp^2$. |
| 1579 | Denise | So it's amide |
| 1580 | Jasmine | I don't really understand what the $sp^2$ $sp^3$ mean. I mean, |
| 1581 | Kellie | It means double bond, the pi bond. |
| 1582 | Jasmine | Oh. |
| 1583 | Denise | Which one is $sp^2$? |
| 1584 | Kellie | $sp^2$ is like |
| 1585 | Alicia | $sp^2$ is the double bond |
| 1586 | Veronica | $sp^3$ is the tetrahedral shape. $sp^3$ is the tetrahedral shape. |
| 1587 | Veronica | And $sp^2$ is |
| 1588 | Kellie | Is it double bond? |
| 1589 | Veronica | Yeah, double bond. |
| 1590 | Denise | $sp^2$ is |
| 1591 | Jasmine | Then how come in this amide, the N isn't a double bond then? |
| 1592 | Kellie | No the C here is double bonded. |
| 1593 | Jasmine | Oh, we're talking about the C. |
| 1594 | Kellie | Yeah. |
| 1595 | Veronica | So when you're looking at the N, look at what C it's attached to. |
| 1596 | Jasmine | Taking up? |
| 1597 | Veronica | Yeah, attached to. |
| 1598 | Jasmine | Oh, OK. |
| 1599 | Veronica | Yeah, it depends on the C. |
| 1600 | Jasmine | Oh. So that's an amide then you say huh? |
| 1601 | Veronica | Mmm. |
| 1602 | Denise | So it's neither. |
| 1603 | Kellie | Yeah |
| 1604 | Veronica | Coz that depends. |

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| 1605 | Denise | That's basic N there. |
| 1606 | Jasmine | Yeah. I think so. |
| 1607 | Denise | Yeah. |
| 1608 | Veronica | What about the N? |
| 1609 | Jasmine | Yeah, do you think? |
| 1610 | Kellie | Yeah. |
| 1611 | Denise | The same for this one. The one in part of that ring. That's basic as well. |
| 1612 | Veronica | Why? |
| 1613 | Denise | Coz it's only got three things occupied. |
| 1614 | Jasmine | I think so. |
| 1615 | Veronica | Oh yeah |
| 1616 | Jasmine | Do you think? |
| 1617 | Denise | But then that's those Cs attached to the benzene ring, they're always changing, like |
| 1618 | Jasmine | Yeah, how about that C? |
| 1619 | Denise | those carbons there, $sp^2$ or $sp^3$ |
| 1620 | Kellie | Oh, which Cs? |
| 1621 | Jasmine | These ones. I'm sorry. They have double bonds. |
| 1622 | Denise | With the N attached to the C |
| 1623 | Jasmine | Oh, man |
| 1624 | Kellie | Mmmm |
| 1625 | Denise | Um, for this one, we're trying to work whether this N would be a like, amine or not? |
| 1626 | Tutor2 | No. |
| 1627 | Denise | Is that because it's attached to the C's and the |
| 1628 | Kellie | Coz it's in the ring? |
| 1629 | Tutor2 | Yeah. It's stuck into this cyclic structure, so it's not going to be an amine. |
| 1630 | Kellie | Is it amide? |
| 1631 | Denise | So even if the benzene ring's there? |
| 1632 | Tutor2 | Yeah |
| 1633 | Veronica | It's not amide. |
| 1634 | Tutor2 | Yep. |
| 1635 | Denise | Even if those weren't there. |
| 1636 | Tutor2 | For now, it's neither. For that. It's, it does have a proper name and I can't think of it right now, but to make it very simple, the answer is no, it's not an amine. |
| 1637 | Denise | So when it's in a ring? |
| 1638 | Tutor2 | yep. |
| 1639 | Jasmine | What makes it an amine? Is that when it's sp something hybridised, and? |
| 1640 | Denise | $sp^3$ hybridised |
| 1641 | Tutor2 | Yeah. |
| 1642 | Kellie | So how about amide? |
| 1643 | Tutor2 | Amide is connected to a carbon with a double bond O. |
| 1644 | Jasmine | So it has to have the double bond O. |
| 1645 | Kellie | So isn't that a carbon? |
| 1646 | Tutor2 | Yeah, that's what makes an amide. |
| 1647 | Chorus | Ohh |
| 1648 | Tutor2 | An amide is a nitrogen connected to a carbon with a double bond O. |
| 1649 | Denise | We thought it was just as long as the carbon was $sp^2$ hybridised? |
| 1650 | Tutor2 | Yeah. Coz it's got the double bond O. |
| 1651 | Kellie | Like these are only |
| 1652 | Jasmine | But in these examples, there's no O there. |
| 1653 | Tutor2 | There's no O there, |
| 1654 | Jasmine | So it's not an amide. |
| 1655 | Tutor2 | No. |
| 1656 | Denise | So this'd be basic. |
| 1657 | Kellie | Oh, so that's just nothing. |
| 1658 | Tutor2 | Yeah. |
| 1659 | Denise | Yeah |
| 1660 | Jasmine | Oh, really? |
| 1661 | Denise | That's basic |
| 1662 | Kellie | Oh, so it has to have an O. |
| 1663 | Tutor2 | It must have an O next to it. |
| 1664 | Veronica | I see it there. |

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| 1665 | Jasmine | Oh, God |
| 1666 | Tutor2 | That's how I remember amides. |
| 1667 | Denise | It's easier that way. |
| 1668 | Kellie | So even if it's a double bond, the C double bond |
| 1669 | Denise | That's an amine, like that. |
| 1670 | Kellie | It'd still be basic? |
| 1671 | Jasmine | But wouldn't that be basic, too? |
| 1672 | Kellie | No, coz it's like in the ring structure. |
| 1673 | Denise | The rings |
| 1674 | Jasmine | But there's a lone pair. |
| 1675 | Denise | Actually in this case I can see how it wouldn't be. |
| 1676 | Jasmine | Like why? |
| 1677 | Denise | These two benzene rings here, because the C's occupied. It's got double bonds. |
| 1678 | Jasmine | Yeah. |
| 1679 | Denise | Oh, OK, there's no Os. |
| 1680 | Kellie | Yeah. |
| 1681 | Denise | Pretty much |
| 1682 | Kellie | Veronica |
| 1683 | Jasmine | Just take her word. |
| 1684 | Denise | Coz it's in the ring. |
| 1685 | Kellie | But that's in a ring too. |
| 1686 | Jasmine | No. |
| 1687 | Denise | Just put it down and wait for her feedback. |
| 1688 | Jasmine | OK. As what? |
| 1689 | Denise | Do we get, oh |
| 1690 | Jasmine | Put it down as what? Whadya want? |
| 1691 | Veronica | Where, this one? |
| 1692 | Jasmine | This one. Is it basic? |
| 1693 | Veronica | No |
| 1694 | Denise | This is definitely basic, because that N down here's basic. |
| 1695 | Veronica | OK, yeah, that's right. Overall, it's basic. |
| 1696 | Jasmine | But how does that part go? |
| 1697 | Kellie | Yeah, that part where they, you know |
| 1698 | Jasmine | This part. |
| 1699 | Kellie | Well, she said it was neither. |
| 1700 | Jasmine | I'll put a question mark so we get feedback. |

## *Episode PC1.7*

| | | |
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| 1707 | Veronica | Didn't we have to draw the dissociation equilibria? |
| 1709 | Veronica | So you gotta put the watchamacallit |
| 1710 | Jasmine | Oh, that, that's good. |
| 1711 | Jasmine | Oh, we have to look at the pH, do we? |
| 1712 | Kellie | This one on top. There. It's there. |
| 1713 | Jasmine | Yeah, the pH, yeah. Isn't it like, the way that it dissociates is different according to the pH? |
| 1714 | Denise | Bye. |
| 1715 | Chorus | Bye |
| 1716 | Unknown | I don't want to do this any more. |
| 1717 | Jasmine | Oh! That one tells you whether it's an acidic drug or basic drug. And from that, then on, then you do different things to the carboxylic group, or whether it's basic or acidic groups. OK |
| 1718 | Kellie | OK. |
| 1719 | Jasmine | So this first one's an acidic drug. |
| 1720 | Alicia | ???? |
| 1721 | Alicia | It's almost the same |
| 1722 | Jasmine | Yeah, have a look, have a look. |
| 1723 | Alicia | Oh no, wait |
| 1724 | Kellie | This one |
| 1725 | Veronica | For the first one, just write RC double O minus. Coz remember it's um, accepted if you can just write it short. |

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| 1726 | Jasmine | Oh. |
| 1727 | Kellie | I thought you have to draw it. |
| 1728 | Jasmine | Do you? Oh. |
| 1729 | Veronica | No, you don't. No, no, no. Look, see that's |
| 1730 | Jasmine | Yeah, I remember that. |
| 1731 | Veronica | also acceptable. But for the other ones, you have to draw it. |
| 1732 | Kellie | Oh, how do you draw this one? |
| 1733 | Jasmine | You just go R C double O, huh? |
| 1734 | Alicia | Yeah. |
| 1735 | Kellie | The next one's basic. So then, um |
| 1736 | Alicia | OK. |
| 1737 | Jasmine | Then the N will accept a H. With the little plus on it. |
| 1738 | Kellie | So it becomes $NH_3$ |
| 1739 | Jasmine | Is that right? Oh, it becomes, um |
| 1740 | Kellie | $NH_2$ |
| 1741 | Jasmine | $NH_2$, with a plus. |
| 1742 | Veronica | What? |
| 1743 | Kellie | How about the other one, the other N? |
| 1744 | Jasmine | Oh God, I don't wanna draw it out. |
| 1745 | Veronica | Not the NH there. |
| 1746 | Kellie | Oh that one, that's right |
| 1747 | Veronica | It's that N that's plus. It's the second N, not the first one. |
| 1748 | Jasmine | But there's a lone pair there, too. |
| 1749 | Veronica | But then the carbon is not $sp^3$ hybridised. That's an amide. |
| 1750 | Jasmine | Is it amide? |
| 1751 | Alicia | Yeah. |
| 1752 | Jasmine | Oooh, the first one's amide, this one isn't amide. |
| 1753 | Kellie | Yes |
| 1754 | Veronica | Mm |
| 1755 | Jasmine | Sorry |
| 1756 | Kellie | Is that right? |
| 1757 | Jasmine | Oh, do I have to draw the whole thing? |
| 1758 | Kellie | You just add it in the middle. |
| 1759 | Veronica | Huh? I thought you just add an H. |
| 1760 | Kellie | Just one H, yeah. giggle |
| 1761 | Jasmine | So you just go NH and then brackets C – |
| 1762 | Kellie | CH, yeah. |
| 1763 | Jasmine | $H_2$, $CH_{3,\ 2}$ plus. With a plus. |
| 1764 | Kellie | On top of the N. |
| 1765 | Jasmine | Oh my God, what'd I do? Oh my goodness. |
| 1766 | Kellie | Oh, you have to do it in like - |
| 1767 | Jasmine | Three times. |
| 1768 | Kellie | Three steps, yeah. First you have to go to, what? |
| 1769 | Jasmine | What do you do? Oh. |
| 1770 | Veronica | There's only one step, since there's only one group that you're interested in, right? The last one, you're talking about the last one? |
| 1771 | Jasmine | Yeah. |
| 1772 | Veronica | Oh, OK, right. |
| 1773 | Jasmine | There's a phenol group. |
| 1774 | Veronica | Phenol and carboxylic. I don't know which one's the base, though. Is that $NH_2$ at the bottom? |
| 1775 | Jasmine | Yeah, what does it do? Why is it there? |
| 1776 | Veronica | It's just floating around. |
| 1777 | Jasmine | That's a amide in the N, don't worry. They're both amides, the N's, but how about the $NH_2$? |
| 1778 | Veronica | Maybe it's attached to the C on the top. |
| 1779 | Alicia | Yeah, maybe it's attached to the top |
| 1780 | Jasmine | One, two three |
| 1781 | Veronica | I think it's attached to the top |
| 1782 | Jasmine | Do you think? Like that? |
| 1783 | Alicia | Yeah |

| | | |
|---|---|---|
| 1784 | Veronica | Start with the protons attached. |
| 1785 | Kellie | Protons attached? |
| 1786 | Jasmine | OK, what happens? |
| 1787 | Veronica | So you do two point four, first. Coz that's the carboxylic acid, OK? |
| 1788 | Alicia | So, umm |
| 1789 | Jasmine | Oh, hold on. Is there a basic group somewhere? |
| 1790 | Veronica | $NH_2$. |
| 1791 | Jasmine | Oh, so it's all given. OK. |
| 1792 | Jasmine | The first one I'll do two point four, yeah? |
| 1793 | Veronica | Yep. |
| 1794 | Jasmine | Oh my God |
| 1795 | Kellie | Then what? Seven point four? |
| 1796 | Veronica | Then, yep. Seven point four. |
| 1797 | Jasmine | Can I go R C double O minus? |
| 1798 | Veronica | Yeah |
| 1799 | Alicia | Yeah, do that. |
| 1800 | Veronica | And then you can go |
| 1801 | Jasmine | And then what do you do? Seven point four or nine point four? |
| 1802 | Veronica | Seven point four first. |
| 1803 | Kellie | And then where does that go? |
| 1804 | Jasmine | Oh, I'll have to draw it out. |
| 1805 | Jasmine | Do I? |
| 1806 | Kellie | Umm. |
| 1807 | Veronica | But that's floating around, so just….. |
| 1808 | Kellie | We thought it was attached. |
| 1809 | Jasmine | We attached it. |
| 1810 | Veronica | Ohh. |
| 1811 | Jasmine | To the C now. |
| 1812 | Kellie | No, we attached it like that. |
| 1813 | Veronica | Oh, that way. Is that right? Oh yeah, it can't be attached to the ring. All right. |
| 1814 | Kellie | Then what do you write? What's the shorthand? |
| 1815 | Jasmine | I'm drawing it out now. |
| 1816 | Jasmine | Oh, hey, so does that group? OK, with the second bit, you know how seven point four happens |
| 1817 | Veronica | Mm |
| 1818 | Jasmine | Does the $COO^-$, is it |
| 1819 | Veronica | It's still minus. |
| 1820 | Jasmine | It's still minus? |
| 1821 | Veronica | Yes. |
| 1822 | Alicia | It's intermediate. |
| 1823 | Jasmine | Oh. |
| 1824 | Kellie | I still can't work out how |
| 1825 | Jasmine | It's the H. |
| 1826 | Kellie | I'm drawing your hand |
| 1827 | Jasmine | $NH_3$. $NH_3^+$, huh? |
| 1828 | Veronica | Yes. |
| 1829 | Jasmine | OK. And then we do nine point six? |
| 1830 | Veronica | Mmm. |
| 1831 | Jasmine | What would happen? Phenol group will |
| 1832 | Alicia | It will lose an H |
| 1833 | Jasmine | Will lose, yeah? Lose the H. |
| 1834 | Alicia | Yep |
| 1835 | Jasmine | I'm drawing it out again. |
| 1836 | Jasmine | No, I'll just go RC. Oh you can't |
| 1837 | Kellie | You can't. |
| 1838 | Veronica | Why not? |
| 1839 | Jasmine | Because there's another RCOO negative there, already. |
| 1840 | Kellie | But what is it supposed to do then? |
| 1841 | Veronica | Blah, blah. |
| 1842 | Jasmine | That bit goes to O minus. |
| 1843 | Kellie | O minus, right. |

| | | |
|---|---|---|
| 1844 | Jasmine | Yep. |
| 1845 | Veronica | So man. |
| 1846 | Kellie | And then everything stays the same? Like you got $COO^-$? |
| 1846a | Jasmine | Yeah, yeah |
| 1847 | Kellie | And the $NH_3^+$? |
| 1848 | Jasmine | Yeah, and the $NH_3^+$, yeah. |
| 1849 | Veronica | Bloody heck. Amoxycillin. Has a stupid house. |
| 1850 | Kellie | It's quite cute. Just gotta write C double O |

## *Episode PC1.8*

| | | |
|---|---|---|
| 1857 | Kellie | OK, for this one, um, we said it is neither. |
| 1858 | Alicia | Codeine, neither. |
| 1859 | Jasmine | Tell me the first one. |
| 1860 | Veronica | Neither, neither. |
| 1861 | Alicia | Neither |
| 1862 | Jasmine | Hey, how about the specific bits? |
| 1863 | Veronica | The two specific bits are neither, neither. |
| 1864 | Alicia | Yeah. |
| 1865 | Jasmine | Even that? |
| 1866 | Alicia | And that. |
| 1867 | Jasmine | That? |
| 1868 | Veronica | Yep. |
| 1869 | Alicia | But we don't even |
| 1870 | Veronica | OK. |
| 1871 | Jasmine | Second one? |
| 1872 | Veronica | Neither. |
| 1873 | Jasmine | Why? |
| 1874 | Veronica | Because the amide there, that you've circled, is neither. |
| 1875 | Jasmine | Don't worry about that. How about the N then? Didn't we say that was basic, before? Like that bit there? |
| 1876 | Veronica | What? |
| 1877 | Jasmine | We said that was a basic N, and that's exactly the same as that. |
| 1878 | Veronica | Oh |
| 1879 | Kellie | Oh, shivers. |
| 1880 | Veronica | Is it? |
| 1881 | Jasmine | Mmm hmm. |
| 1882 | Kellie | Coz there's no O there, right? |
| 1883 | Jasmine | Mmm. |
| 1884 | Jasmine | So it's basic. |
| 1885 | Jasmine | Is that right? |
| 1886 | Alicia | I think so, yep |
| 1887 | Kellie | OK, yeah |
| 1888 | Jasmine | We'll probably get it wrong, but, oh well. |
| 1889 | Veronica | We will learn from it. |
| 1890 | Alicia | Yeah |
| 1891 | Jasmine | How about the third one? |
| 1892 | Veronica | Acidic. |
| 1893 | Jasmine | Carboxylic acid. Yep? |
| 1894 | Kellie | Then basic. |
| 1895 | Jasmine | Amine neutral, that's basic, yep, good. |
| 1896 | Jasmine | That's amide neither. That's basic. |
| 1897 | Veronica | Basic |
| 1898 | Veronica | And the next one's |
| 1900 | Kellie | Neither. |
| 1901 | Veronica | Neither, because we don't know. And then, the last one is acidic. |
| 1902 | Alicia | ???? |
| 1903 | Jasmine | Why is that neither? |
| 1904 | Alicia | Coz it's basic and also acid |
| 1905 | Jasmine | Oh |
| 1906 | Kellie | Two weak acids and a basic. |

| | | |
|---|---|---|
| 1907 | Jasmine | So that's, OK. |
| 1908 | Jasmine | And that's basic. |
| 1909 | Kellie | Yes. |
| 1910 | Jasmine | OK. How about the next one? |
| 1911 | Alicia | Acid |
| 1912 | Veronica | Carboxylic acid. |
| 1913 | Alicia | Yep |
| 1914 | Jasmine | Yep. |
| 1915 | Veronica | So, it's acidic. |
| 1916 | Jasmine | Hey, that's, oh, OK. |
| 1917 | Kellie | There's an amide |
| 1918 | Alicia | That's an amide |
| 1919 | Jasmine | How about that? That's amide. That's amide. |
| 1920 | Veronica | Yeah. All those Ns are amides. |
| 1921 | Alicia | Yeah |
| 1922 | Jasmine | Ah, acidic. |

# Workshop 2

## *Episode PC2.1*

| | | |
|---|---|---|
| 421 | Veronica | So, do we use the forty mils, after that, to work out the concentration? |
| 422 | Kellie | Umm. |
| 423 | Veronica | Cos we've got no moles. |
| 424 | Kellie | Yeah, so concentration, yeah, equals moles over volume. |
| 425 | Veronica | Hmm. |
| 426 | Denise | A lot of funny numbers. |
| 427 | Veronica | One two three four five. OK, so we got that? |
| 428 | Kellie | Mmm, I didn't get that. |
| 429 | Veronica | What? |
| 430 | Kellie | Because you haven't put it in litres. |
| 431 | Veronica | Litres? |
| 432 | Kellie | Not in mils. |
| 433 | Veronica | Oopsy. Point four. Point zero four. |
| 434 | Jasmine | Yeah. Point zero four. |
| 435 | Veronica | Point zero four. |
| 436 | Kellie | And then, that's H A, or what? |
| 437 | Veronica | H A. |
| 438 | Veronica | Ah ha, total solubility. |
| 439 | Veronica | That's a function of pH. |
| 440 | Veronica | pH, pKa. |
| 441 | Veronica | What's log of A then? |
| 442 | Jasmine | Do we need that? |
| 443 | Veronica | What's the concentration of A, brackets? |
| 444 | Kellie | You work that out, after you find out what the total solubility is. So if you know total. |
| 445 | Veronica | Total solubility. |
| 446 | Kellie | But |
| 447 | Veronica | Oh, ohhh. |
| 448 | Kellie | And then you minus |

## *Episode PC2.2*

| | | |
|---|---|---|
| 1008 | Kellie | The equilibria. Yeah, we drew some last week. |
| 1009 | Veronica | Oh, yeah, Jasmine drew them. |
| 1010 | Jasmine | Oh, we got them wrong. |
| 1011 | Denise | But we didn't, there's no naproxen there. |
| 1013 | Veronica | So. OK, largely un-ionised or ionised, all right? Let's go. First one. OK, there's the naproxen. Do lignocaine. |
| 1014 | Kellie | Why don't you just look up the |
| 1015 | Jasmine | I can't find the first one. |
| 1016 | Veronica | Seven point nine |
| 1017 | Jasmine | We don't have it. |
| 1018 | Veronica | So, with a pH of nine |
| 1019 | Jasmine | Nine. That's basic, basic. |
| 1020 | Isabelle | I found naproxen. |
| 1021 | Denise | Oh, in there. |
| 1022 | Veronica | It would lead to the |
| 1023 | Isabelle | Here. |
| 1024 | Veronica | put the protonated form on the left. What? |
| 1025 | Veronica | So, it's unprotonated at ten. So that means it must be |
| 1026 | Kellie | At a higher pH it's more basic. |
| 1027 | Veronica | It must be ionised. |
| 1028 | Kellie | Why? |
| 1029 | Denise | Six point nine over |
| 1030 | Jasmine | It's ionised |
| 1031 | Denise | It's protonated at that pH. |

| | | |
|---|---|---|
| 1032 | Alicia | Protonated means basic, doesn't it? |
| 1033 | Veronica | Yeah. |
| 1034 | Jasmine | Protonated |
| 1035 | Kellie | It has a proton. |
| 1036 | Jasmine | That's acidic. |
| 1037 | Kellie | It's accepted a proton. |
| 1038 | Denise | Oh, OK. |
| 1039 | Veronica | That has not a proton. |
| 1040 | Denise | But I thought bases accept protons. And acids donate it. So protonated would mean it would have something added on. |
| 1041 | Kellie | Yeah. It's been added on. |
| 1042 | Denise | So, it's basic. |
| 1043 | Denise | So it says put a basic one on the left. |
| 1044 | Jasmine | Oh, yes, protonated means |
| 1045 | Kellie | It has the |
| 1046 | Jasmine | It's already gained a pH, a P, a H! |
| 1047 | Veronica | A H. |
| 1048 | Denise | A H. |
| 1049 | Jasmine | Plus. |
| 1050 | Denise | So this is the basic form. So the acid dissociates in solution, so this side is the acid |
| 1051 | Jasmine | I think it's ionised. What do you think? |
| 1052 | Veronica | That's why I said it's ionised. |
| 1053 | Alicia | It has a name. |
| 1054 | Jasmine | Do you guys agree? |
| 1055 | Kellie | What does ionised mean? |
| 1056 | Veronica | Ionised means that it's lost the H. |
| 1057 | Denise | It goes into the different ions. |
| 1058 | Jasmine | Ionised means |
| 1059 | Kellie | That means it's un-ionised. |
| 1060 | Jasmine | It's gained the H. |
| 1061 | Veronica | Wait, OK. This is basic, right? Ionised form means that, |
| 1062 | Jasmine | It's like that. |
| 1063 | Veronica | Oh, it's like that? |
| 1064 | Jasmine | Yeah. |
| 1065 | Veronica | It means that it's in its acidic form. |
| 1066 | Denise | So, it's un-ionised. |
| 1067 | Kellie | Yeah, it's unionised. |
| 1068 | Veronica | It's just un-ionised. |
| 1069 | Alicia | It starts off as acid. |
| 1070 | Kellie | It goes towards the base, the base. |
| 1071 | Jasmine | What do you think, Isabelle? |
| 1072 | Isabelle | I think it's pKa, or pH of, they gave a pKa |
| 1073 | Jasmine | What figure is that? |
| 1074 | Isabelle | That's one eighteen in the fourth handout. |
| 1075 | Jasmine | One eighteen. |
| 1076 | Isabelle | I think |
| 1077 | Denise | Hang on. They're at equilibriums, though, the pH and the pKa, aren't they? |
| 1078 | Isabelle | Ohhh. |
| 1079 | Veronica | Umm. |
| 1080 | Jasmine | I'm really worried about this now. One eighteen. |
| 1081 | Denise | Unionised |
| 1082 | Jasmine | That's the pH, I think. |
| 1083 | Isabelle | ???? |
| 1084 | Jasmine | Oh, pKa. |
| 1085 | Tutor | Is there anything I can do to help? Or you're not even at the stage of asking questions. |
| 1086 | Veronica | Yeah. |
| 1087 | Isabelle | Um, is the naproxen? |
| 1087a | Tutor | Yeah? |
| 1088 | Jasmine | Yeah. |
| 1089 | Isabelle | There's a naproxen acid pKa, right? |
| 1090 | Tutor | Yep. |

| | | |
|---|---|---|
| 1091 | Isabelle | And that's the pH. |
| 1092 | Tutor | Yep. |
| 1093 | Isabelle | But if it's in equilibrium, are they equal? |
| 1094 | Tutor | No. No, the pH is independent of the pKa. pKa is a characteristic of the drug. The pH is the environment, if you like, that the drug's put into. So, we might have a buffer system of pH three point eight, um, and the drug is put into that, and that buffer system of pH three point eight, um, makes the drug either go more ionised, or more un-ionised, depending on the relationship between the pH of the environment and the pKa of the drug. So the drug has a pKa, and the solution that it gets put into has a pH. The drug itself doesn't affect the pH, because it's a buffer system. So the pH determines how much the drug is ionised and how much is un-ionised. |
| 1095 | Isabelle | So we use these two values to find out? |
| 1096 | Tutor | Yeah. Yeah. |
| 1097 | Isabelle | OK. |
| 1098 | Tutor | Yeah. So, you've got like, the equilibrium here, where you've got the un-ionised form in equilibrium with the ionised form. And one of the things that I said, the easiest way to remember, um, which form predominates at any particular pH, it's probably easier for you if you look at this one, which is similar, is if we write the equilibrium out that way. |
| 1099 | Alicia | So it that the pKa? |
| 1100 | Tutor | That's the pKa. And we put the pKa on top of the arrows, then, wherever the number of the pH is, then that's the form that predominates. Or that is mostly there. So, if, for example, that said four point two, if this was naproxen, if that said four point two, and we wanted pH three point eight, then it would be three point eight is smaller than four point two. |
| 1101 | Jasmine | Ohh, OK. |
| 1102 | Denise | So, it's just on that side. |
| 1103 | Tutor | So three point eight is on that side of four point two, and so that form would be mostly present. |
| 1104 | Isabelle | So that's an easy way of remembering? |
| 1105 | Tutor | Yeah, that's by far the easiest way. |
| 1106 | Denise | So you always start with the acid one? |
| 1107 | Tutor | Yes. |
| 1108 | Denise | And then just put pKa in the middle and go with that. |
| 1109 | Tutor | Yes, that's right. That's what I meant down here I put 'put protonated form on the left', so that you're always looking at an acid dissociating. Whether it's the acidic form of an acid drug, or the conjugate acid of a basic drug, you always start with a proton attached, and then lose it, put the pKa on top of the arrows, and then wherever the pH is, |
| 1110 | Alicia | Oh, I see. |
| 1111 | Tutor | You can work out which form it is. |
| 1112 | Kellie | Right. |
| 1113 | Isabelle | So even if that was nine |
| 1114 | Tutor | Yeah. |
| 1115 | Jasmine | OK |
| 1116 | Isabelle | The, the pKa would be – |
| 1117 | Tutor | Be on that side, yeah. |
| 1118 | Isabelle | Thank you. |
| 1119 | Jasmine | Thank you. |
| 1120 | Tutor | OK. |
| 1121 | Isabelle | I have to write this down. I dunno where. |
| 1122 | Jasmine | I know, same. |
| 1123 | Isabelle | Maybe. |
| 1124 | Jasmine | I don't want any more! |
| 1125 | Kellie | So this is un-ionised. |
| 1126 | Denise | That's lignocaine. So, if it's on the basic side, like, its, pH is just higher than pKa. |
| 1127 | Kellie | It'd be un-ionised, greater than the pKa ???? |
| 1128 | Alicia | pH greater than pKa. |
| 1129 | Denise | Ionised. So it's ionised. There's more ionised than unionised. |
| 1130 | Kellie | Yeah. |
| 1131 | Denise | Oh, OK. |
| 1132 | Denise | So, its basic form is more ionised. |
| 1133 | Denise | It should be the other way round. |

| | | |
|---|---|---|
| 1134 | Jasmine | OK, then what happens when, when they don't give you the pKa? Like the second one, you can't |
| 1135 | Denise | Which one? They're all given. |
| 1136 | Jasmine | Yeah. Like the second one, how'd you do it? OK. |
| 1137 | Denise | No, OK, we're given the pKa here - seven point nine. |
| 1138 | Jasmine | Goodness. Where's that? |
| 1139 | Alicia | Just here. |
| 1140 | Jasmine | Oh, here. |
| 1141 | Alicia | Yeah. |
| 1142 | Jasmine | Cool. Thank you. |
| 1143 | Denise | Yeah, use the second bit. |
| 1144 | Jasmine | Is that my writing? Yes it is. OK. So start'd be, |
| 1145 | Veronica | Ionised. |
| 1146 | Alicia | Why? |
| 1147 | Veronica | Ions. |
| 1148 | Alicia | Oh, it's in this one. |
| 1149 | Kellie | Greater than the pKa. |
| 1150 | Jasmine | How do you know that was ionised? |
| 1151 | Denise | It's exactly the same as lignocaine. |
| 1152 | Kellie | Ibuprofen, yes? Unionised. |
| 1153 | Denise | pK is there, yeah. |
| 1154 | Veronica | Ibuprofen's four point four when it ionises. |
| 1155 | Denise | Yeah? |
| 1156 | Veronica | And since five point seven is greater than the pKa, shouldn't it be on the right side? |
| 1157 | Denise | It should be ionised, cos when it's |
| 1158 | Kellie | Yeah, on the right side. |
| 1159 | Veronica | So, they're ionised. |
| 1160 | Denise | So the lignocaine's also ionised. It makes more sense that way, because when it's going into base, |
| 1161 | Kellie | Ionised? |
| 1162 | Denise | Yeah. Hang on. |
| 1163 | Jasmine | So, that's un-ionised when, how you were saying. Cool. |
| 1164 | Denise | This is the basic formula ???? |
| 1165 | Veronica | No, because we did it the wrong way around. We didn't put the acidic form, |
| 1166 | Jasmine | Yeah. |
| 1167 | Veronica | For the lignocaine we didn't put the acidic form on the left. |
| 1168 | Jasmine | Yeah, we could have swapped that. |
| 1169 | Veronica | That's why it's un-ionised. |
| 1170 | Denise | No, they're both ionised, aren't they? |
| 1171 | Kellie | It's still greater than the pKa. |
| 1172 | Jasmine | What are you talking about? Which one? B? |
| 1173 | Kellie | Yeah. |
| 1174 | Jasmine | How come? |
| 1175 | Veronica | pH is greater than pKa. Which means it should be in |
| 1176 | Kellie | The basic form. |
| 1177 | Veronica | Ionised form. Basic form is ionised form. You know that. |
| 1178 | Kellie | Is that what you were asking? |
| 1179 | Veronica | So, ionised. |
| 1180 | Jasmine | Oh, man, this is bad. |
| 1181 | Veronica | So it's ionised. Got it! |
| 1182 | Denise | They're both ionised, like lignocaine and ibuprofen. Now we've gotta look at naproxen as well. Here. |
| 1183 | Jasmine | Why would you say that's ionised? Sorry, can you explain that to me? |
| 1184 | Denise | Cos like, you always start off with the acid, |
| 1185 | Jasmine | Yeah. |
| 1186 | Denise | Which is here, but the H is attached, it's protonated. And then at this pKa it dissolves, it starts dissolving. And then |
| 1187 | Jasmine | To the un-ionised one? |
| 1188 | Denise | Yeah, it goes to that plus, H plus. So, therefore it's ionising, it's going to the ions. |
| 1189 | Isabelle | It's both. |
| 1190 | Jasmine | Really? |

| | | |
|---|---|---|
| 1191 | Denise | Yeah. |
| 1192 | Isabelle | And amoxycillin is both. |
| 1193 | Denise | Yep. So, do you get that? And she said you always put the pKa there. So it it's nine, then it's on this side. |
| 1194 | Kellie | So |
| 1195 | Isabelle | Both ionised and unionised. |
| 1196 | Jasmine | Is this the un-ionised form? |
| 1197 | Denise | That's the ionised. |
| 1198 | Jasmine | Really? |
| 1199 | Denise | Yep. |
| 1200 | Jasmine | Isn't that ionised, cos there's $NH^+$? |
| 1201 | Isabelle | With this one, that's in the middle. |
| 1202 | Denise | That's un-ionised, cos it's still attached. When it ionises, it breaks up into like, $H^+$ and then the other thing. |
| 1203 | Jasmine | Oh. |
| 1204 | Tutor | Is it ionised? On either side? |
| 1205 | Denise | So it breaks up into this, and then $H^+$. |
| 1206 | Jasmine | Oh, that's what it means by ionised. |
| 1208 | Tutor | OK, is that form ionised? |
| 1209 | Isabelle | Mmm. |
| 1210 | Jasmine | Is that what ionised means? |
| 1211 | Tutor | This has got a plus there. What about this one? Is that ionised? |
| 1212 | Denise | Ionised, like, for example, if you had H two S O four, ionised means, $H^+$ $SO_4^{2-}$ in it. You can look at lignocaine, but that's more complicated. |
| 1213 | Jasmine | OK. Thanks. |
| 1214 | Denise | I'm pretty sure. |
| 1215 | Isabelle | With that? |
| 1216 | Tutor | Yeah, it's got a minus and a plus, so it's doubly ionised. What about that one? Is that ionised? |
| 1217 | Isabelle | Yeah. |
| 1218 | Tutor | OK, it's got a minus. That one? |
| 1219 | Denise | So the basic side is always, um |
| 1220 | Isabelle | Yeah. |
| 1221 | Tutor | So, it's got two minuses. So all forms of drugs that you've drawn there, for amoxycillin, they're all ionised in solution. When you put amoxycillin in solution, the only forms it can take on, have a charge. They don't all have the same charge, but they all have a charge. And so, drugs like amoxycillin are never un-ionised in solution. Once you put them into solution, they pick up a charge, somewhere, whatever the pH is. So, not only is it ionised at pH seven, it's completely ionised at pH seven, because it's completely ionised at all pHs. |
| 1222 | Denise | Can you say why again? Why |
| 1223 | Tutor | OK, it's only because the way that the equilibrium happens. This is in the answers but it's in your book as well. |
| 1224 | Denise | OK. |
| 1225 | Tutor | The first form has the charge on the nitrogen. Second has a charge on the nitrogen and the carboxylic acid. Third has a charge on the carboxylic acid and the fourth one has a charge on the carboxylic acid and the phenol. |
| 1226 | Denise | So they're always charged! |
| 1227 | Tutor | So there's always a charge. The charge varies, but as soon as you've got one charge on a molecule, that makes it ionised. It's like I've said to some of the other groups. It's like being pregnant. You can't be a little bit pregnant. You can't be a little bit ionised. As soon as there's a site of ionisation on the molecule, it's ionised. |
| 1228 | Denise | And is that always the basic form? |
| 1229 | Tutor | No, it's not necessarily. |
| 1230 | Denise | OK. |
| 1231 | Tutor | These ones here are, um are in the conjugate base form. This one here is in the conjugate acid. So it depends on whether the drug is |
| 1232 | Denise | So that means that ???? should be unionised. |
| 1233 | Isabelle | And those are in between. |
| 1234 | Tutor | Yeah. |
| 1235 | Denise | So these are both acidic? |

| | | |
|---|---|---|
| 1236 | Jasmine | Yeah. |
| 1237 | Tutor | We don't talk about them as acidic or basic. Remember when I said because they've got both functional groups, we don't call them acidic or basic? That's part of the reason why. It's cos it gets very confusing when they ionise. Cos their ionised forms aren't acidic or basic. They have conjugate acid functional groups, so you can talk about the functional groups being acidic or basic, but you can't talk about the whole drug as being an acid or a base cos it's a mixture of both. So you can't define it as one, because it doesn't behave like it all the time. So it doesn't always behave like an acid. Sometimes it behaves like a base. But you can't call it a base either. So it's in between, because it's got properties of both. |
| 1238 | Denise | So are there other drugs we should know, like that has the same properties as that? |
| 1239 | Tutor | You don't need to know it. All you need to do is to be able to look at the molecule, and to draw up those equilibria, and then it will, it should become obvious. That's what I hope it is, anyway. I don't know that, just by looking. I need to draw up the equilibria. Say oh, ionised, ionised, ionised, ionised. This one's the same. Ionised, ionised, ionised. But it depends on the specific structures, and so you have to actually draw up the equilibria for each one in order to work out whether it meets that pattern, or another one. |
| 1240 | Denise | And with this one, |
| 1241 | Tutor | Yeah. |
| 1242 | Denise | This particular one, we don't know the pKa of it. |
| 1243 | Tutor | Sorry? |
| 1244 | Denise | We don't know the pKa? |
| 1245 | Tutor | Ah |
| 1246 | Veronica | It's in the solution, in the worked solution. |
| 1247 | Tutor | Yeah. |
| 1248 | Denise | What is it? Two point five? |
| 1249 | Veronica | It's, um, two point five and three point four. |
| 1250 | Tutor | Yep. |
| 1251 | Isabelle | So that'll mean it's ionised. |
| 1252 | Tutor | Yeah. |
| 1253 | Denise | But both of them are ionised. |
| 1254 | Tutor | Yep. |
| 1255 | Isabelle | But it's three, so, under that and over that. |
| 1256 | Tutor | Yeah, so it's |
| 1257 | Denise | Oh, yeah, yeah. |
| 1258 | Tutor | It's well and truly over being, um, being the un-ionised form. So, it's partly that. There'd be some of all three types there, but more of it is in this form than in the un-ionised form. OK. So once it becomes ionised, it doesn't matter how many places it's ionised at, one two three four, it's still ionised. That's what I mean by being a little bit pregnant. You can't be partly pregnant, partly non-pregnant. You can't be partly ionised. It's either ionised or not. |
| 1259 | Jasmine | OK. |
| 1260 | Tutor | OK. |
| 1261 | Veronica | How about for Naproxen? We don't know that one. |
| 1262 | Denise | Actually it tells you, it's four point two. |
| 1263 | Veronica | Four point two. So, um |
| 1264 | Denise | Yeah. |
| 1265 | Jasmine | Denise, so is that what you just explained to me. Is that right, or? |
| 1266 | Denise | Like, just take it, if there's a charge, then it's ionised. |
| 1267 | Jasmine | So, is that ionised? |
| 1268 | Denise | Not charged. Oh. |
| 1269 | Jasmine | It's got a plus there. |
| 1270 | Veronica | For lignocaine. Are we talking about lignocaine? |
| 1271 | Denise | Oh, so this is the acidic? So does it have the H? I think it has to have the H. |
| 1272 | Denise | I think it has to have the H. |
| 1273 | Jasmine | Yeah, it's still in the buffer. |
| 1274 | Veronica | I think it's un-ionised. |
| 1275 | Denise | But doesn't it have to have the H attached? Coz this one, being like that, I thought that was |
| 1276 | Veronica | If you look at it here. |
| 1277 | Denise | Oh, that's the same as the basic N. |

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| 1278 | Veronica | The way she wrote it here. |
| 1279 | Kellie | This one. |
| 1280 | Veronica | That's, um, a basic form. |
| 1281 | Alicia | Yeah. |
| 1282 | Denise | Where does it lose the H to be ionised? |
| 1283 | Veronica | Basic form, this is the basic drug, then it's like, ionised |
| 1284 | Alicia | Here. If it loses the H here, shouldn't that be the basic form? |
| 1285 | Veronica | here, un-ionised here. But since it's number nine, that way should be unionised. |
| 1286 | Jasmine | It is un-ionised. |
| 1287 | Denise | So shouldn't that be acidic? And then basic. |
| 1288 | Veronica | Mmm. |
| 1289 | Jasmine | You have to take that plus as a ionised, ion, though. |
| 1290 | Veronica | Don't look at that. Look at this, the one that she did for us. Because that's confusing. See for here, that's, um the basic form. I mean, the ionised form. And that's the un-ionised form. So, nine would fall that way, so it should be un-ionised. |
| 1291 | Denise | But don't you always have to start with acidic? |
| 1292 | Veronica | Yeah. Yeah, here it is, with the H. |
| 1293 | Denise | Oh, that was the charged? |
| 1294 | Kellie | It's charged. |
| 1295 | Jasmine | Isabelle, did you get unionised for A? |
| 1296 | Isabelle | Yeah. |
| 1297 | Jasmine | And un-ionised for B? |
| 1298 | Veronica | So, un-, un-, ion, ion, ion. |
| 1299 | Isabelle | They're all ionised except for A. |
| 1300 | Jasmine | They're all ionised except for A. |
| 1301 | Kellie | And B? |
| 1302 | Jasmine | Uh oh. B is ionised. |
| 1303 | Kellie | But didn't we just say that? |
| 1304 | Denise | B is unionised. Because |
| 1305 | Veronica | Un-ionised. |
| 1306 | Kellie | Because it goes from the ionised to the unionised. |
| 1307 | Jasmine | Did you get your answers checked, are they right? |
| 1308 | Isabelle | Oh, I think they're right, but most of them, yeah. |
| 1309 | Denise | I thought it was un-ionised before as well. But it's got a charge on it, and she said whenever it's got a charge, then it's ionised. |
| 1310 | Isabelle | I think that's true, yeah. |
| 1311 | Jasmine | Let's check with her. That's just what I was about to say. |
| 1312 | Isabelle | ???? |
| 1313 | Denise | So then, and that's in the middle right? Like we were doing on this side. Cos that's ionised and that must be un-ionised. |
| 1314 | Jasmine | Sorry. |
| 1315 | Isabelle | But then |
| 1316 | Denise | Oh no. |
| 1317 | Jasmine | Celina! |
| 1318 | Tutor2 | Yes? |
| 1319 | Jasmine | When you, yeah, we were just thinking about this. Like, when you have that, is that, there's an H there, |
| 1320 | Tutor2 | Yeah |
| 1321 | Jasmine | and there's a plus, would you call that ionised or un-ionised? |
| 1322 | Tutor2 | What's the definition of something being ionised? |
| 1323 | Denise | Is it charged? |
| 1324 | Tutor2 | Yeah, it's got ions. So, it's got a free ion. |
| 1325 | Jasmine | So it is ionised. |
| 1326 | Tutor2 | Yeah, as opposed to un-ionised, which doesn't have one. |
| 1327 | Jasmine | So, it is un-ionised. The answer. |
| 1328 | Tutor2 | Wait there. It's ionised at nine. |
| 1329 | Denise | But at nine, this species would predominate. |
| 1330 | Kellie | No, I thought we wrote it the wrong way around. Oh cos you were looking at it that way. |
| 1331 | Tutor2 | Oh, cos you were looking at it that way. |
| 1332 | Alicia | This is acidic. |
| 1333 | Tutor2 | So, when you're talking about ionised, as against un-ionised, it doesn't matter if it's |

| | | |
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| | | positive or negative, as long as it's got ions. So, that's an ionised. So, it's got a charge. And the flipside is un-ionised. |
| 1334 | Jasmine | Because the H isn't there. And there's no charge. |
| 1335 | Denise | OK. |
| 1336 | Tutor2 | Well it has no plus. To say charge is the wrong word to use. |
| 1337 | Jasmine | OK. |
| 1338 | Kellie | Ohhh! |
| 1339 | Jasmine | It's un-ionised. It's gotta be un-ionised, cos I'm not changing it. |
| 1340 | Tutor2 | For which one? |
| 1341 | Jasmine | Un-ionised for that. |
| 1342 | Isabelle | For lignocaine. |
| 1343 | Tutor2 | No. |
| 1344 | Veronica | We'd better figure it out. |
| 1345 | Jasmine | OK. |
| 1346 | Kellie | Why? |
| 1347 | Tutor2 | It's a basic drug, right? That's the first thing. So like if you had to draw the equilibrium for a base, what does it look like? |
| 1348 | Jasmine | Like that? |
| 1349 | Tutor2 | OK. So you go from something that's ionised, to something that's un-ionised. So, is that, for lignocaine at pH nine, what's its pKa? – seven point eight – so the pH is greater or lower than the pKa? |
| 1350 | Chorus | Greater. |
| 1351 | Tutor2 | Greater. OK. So, according to this equation, if you had a higher pH, which would be the most prominent? This side or this side? |
| 1352 | Denise | Higher pH, so it's over there. |
| 1353 | Jasmine | Oh, mostly B, so it's on that side. |
| 1354 | Tutor2 | Yeah. So, it's un-ionised. You don't look at H, you look at B. |
| 1355 | Jasmine | Oh, oh, it's un-ionised. |
| 1356 | Tutor2 | You get that? |
| 1357 | Veronica | Yes, yes, yes. |
| 1358 | Jasmine | Ahh. Yeah. Thank you. |

## *Episode PC2.3*

| | | |
|---|---|---|
| 1917 | Kellie | "To which form or forms of the drug does this solubility apply?" |
| 1918 | Jasmine | The salt form of it |
| 1919 | Kellie | The overall |
| 1920 | Jasmine | is heavier than the other one. Well, of course, cos you add something else, to it. OK. |
| 1921 | Kellie | Salt forms always |
| 1922 | Jasmine | With the H, do you think? Cos it's heavier? Hold on |
| 1923 | Jasmine | Oh no. Oh no, OK. |
| 1924 | Jasmine | Two fifty four, minus two thirty two is twenty two. |
| 1925 | Veronica | Yeah. |
| 1926 | Jasmine | And sodium is twenty-three, yeah? |
| 1927 | Kellie | Yeah. |
| 1928 | Jasmine | So, in other words, this one, |
| 1929 | Kellie | Yah, and this |
| 1930 | Jasmine | So there's a Hydrogen, here, in the middle. Do you get it? |
| 1931 | Kellie | That means it's in the ionised.... |
| 1932 | Jasmine | OK, let me think. |
| 1933 | Veronica | Ooh. As in |
| 1934 | Jasmine | So this one, the salt form's, got the NH but without the H, the Na but without H. So that is the ionised form, the salt form. Do you think? |
| 1935 | Veronica | Mmm. |
| 1936 | Veronica | Yeah. |
| 1937 | Kellie | Yeah. |
| 1938 | Jasmine | Do you? |
| 1939 | Veronica | Has it a negative? No. Positive? |
| 1940 | Jasmine | Oh no, hold on. Negative. |
| 1941 | Veronica | Negative, yeah. |
| 1942 | Jasmine | Cos the H is gone, it doesn't make sense though. I mean, if the H is gone |

| | | |
|---|---|---|
| 1943 | Kellie | But it still has a negative charge. |
| 1944 | Jasmine | Why. |
| 1945 | Kellie | Because |
| 1946 | Jasmine | Oh. |
| 1947 | Kellie | It's like, there's a anion, right, has a negative charge, and there's a cation. Then they swap. |
| 1948 | Jasmine | Oh yeah, they swap. That means that it's neutral then, if they swapped. Do you think? Cos if the H left, then it's a minus, OK, but the Na came again, so it's zero. So it's un-ionised. |
| 1949 | Jasmine | Can we talk about it Kellie, what were you saying? |
| 1950 | Kellie | Oh, I don't know. I'm just making up stuff. |
| 1951 | Jasmine | Na is there, but the H is gone. So, it's un-ionised. |
| 1952 | Veronica | Shouldn't it be ionised? |
| 1953 | Jasmine | How come? |
| 1954 | Veronica | Because the H is gone. That means it has an ion. It has a charge. It wants an H. |
| 1955 | Jasmine | No, no, but the H is gone, but the Na came. |
| 1956 | Veronica | I don't get it. |
| 1957 | Jasmine | Would that mean that it took care of that one minus bit? |
| 1958 | Veronica | Oh, right. |
| 1959 | Jasmine | Talk back, talk back, cos I'm not sure. |

# Workshop 3

## *Episode PC3.1*

| | | |
|---|---|---|
| 612 | Veronica | Ibuprofen is like, acidic drug, so since pH is lower, it would be going to the unionised form more, HA, to the left. If you think about the dissociation |
| 613 | Denise | Mmm |
| 614 | Veronica | HA, and in the middle, equilibrium |
| 615 | Denise | Mmm |
| 616 | Veronica | and then H plus and then A minus |
| 617 | Kellie | Yeahhh |
| 618 | Denise | yeah |
| 619 | Denise | So it's unionised. |
| 620 | Veronica | It's on the left side |

# APPENDIX J IMPACT OF THE RECORDING EQUIPMENT

This section describes the individual beliefs about the impact of the presence of recording equipment on group dynamics and functioning. Summaries are included in chapter 7, section 7.5.

## Transient change group

### Janine's perspective

Janine did not think that the presence of the camera made any difference to her (3.418-3.436), and believed that her approach to working was not affected (3.443-3.446). Further, she believed that her learning had not been affected by the presence of the recording equipment (3.438), although membership of the group was seen as possibly detrimental to her learning (2.209-212). Janine overcame this potential detriment by working alone, both in class and in private study (2.134), and was comfortable that participation in the research study had not adversely affected her academic performance.

Janine did however believe that the presence of the recording equipment affected the others in her group, suggesting that they had reacted in an unduly negative way, but she perceived this as a sign of immaturity rather than disgruntlement with the study (3.418). In fact, she suggested that after the completion of their participation, their attitudes underwent a significant reversal: '*all my group who was complaining about it, now they think it's the best thing, and they talk about it, and they like laugh about it and stuff*' (3.426).

Janine was aware that tensions within the group were rising towards the end of the semester but explained it primarily as the pressure of approaching examinations and the increasing difficulty of the material (2.170). In her opinion, Larry's request that the final session not be recorded was the culmination of already existing tensions, with the presence of recording equipment an exacerbating factor rather than the underlying problem. Janine was unconcerned about being recorded, but felt that she was unable to argue with Larry's request (2.196). She did not believe that other members of the group were worried about the recording, but perceived that the group reacted in response to Larry's anxiety (2.188-2.194). Interestingly, Janine provided some perceived insight into the particular reason for the effect of the recording, and in doing so hinted at some of the motivation for her own behaviour in workshops: '*At the beginning when the material was easy, it's like all right, you can just discuss it, you're all fine, but when the material got harder and not everyone knew it, then you don't want, like they didn't want to come across as looking stupid, so they don't want to ask questions when maybe they would find it all right asking questions if the tape wasn't there*' (2.172-2.176). It is not clear the extent to which Janine' perceptions were mirrored by the other participants, but interview responses from Emma (Emma 2.172-2.182) suggested that Janine herself was motivated by a desire to be seen on the videotapes as knowledgeable and well performed. Specifically Emma perceived Janine's actions as '*doing races*' (Emma 2.172), describing her behaviour at the final

workshop as '*she had to make a show of the fact that she'd finished, and she slammed down her books, and organised, and talked, and then went "I'm leaving" really loudly*' (Emma 2.182).

## Geoffrey's perspective

Geoffrey did not find the camera particularly intrusive (3.1000-3.1002), although he thought that its presence had some effect on Larry (2.242-2.246). The only issue for Geoffrey was a trivial one which he made into a joke: '*just got to watch my language but (laughs) otherwise everything's fine*' (2.254).

## Larry's perspective

Larry's perception at the end of the teaching semester was that the presence of the recording equipment had been a significant source of stress for him, and indeed he had convinced the rest of his group to request that the final session not be recorded, as was their right. Certainly, Larry was the most agitated in the presence of the video, and he stated that it was affecting how he learned (2.36).

From the perspective of five months later, however, Larry had re-evaluated his perceptions, and reflected that his stress and the impact on his learning was not related to the presence of the recording equipment, but more to the group dynamics, and the way that interpersonal difficulties were affecting each individual (3.432-3.436). Larry's more highly-strung nature (he used terms such as '*stressed*', '*agitated*', and '*panicked*' in relation to himself more than any other group member) appeared to have sensitised him to anything out of the ordinary, and accentuated the response to any additional stressors. Janine expressed the opinion that members of her group did not want to appear stupid or ignorant in front of the camera (Janine 2.172-2.176), and the evidence suggests that she was probably referring to Larry in particular. His expressed desire to '*get it done so we could get it out of there and finished*' (2.36) appeared to be related to the generally high stress level he was experiencing as the exams approached (2.54, 2.78-2.80), his frustration with what he was struggling to understand, and the interpersonal tensions which were beginning to surface between the group members. It is therefore likely that the presence of the recording equipment provided him with an external focus for his internal frustrations and insecurities.

## Lucy's perspective

Lucy felt that the presence of the recording equipment did not cause any problems for her, although she agreed that Larry found it off-putting (2.56-2.58). She suggested, however, that it improved the way they spoke and reduced the amount of off-task activity, causing them to focus more on the assigned tasks (2.58-2.64). The latter perception is interesting in light of the relatively high extent of off-task activity that was observed (more than 25% of all spoken turns), and also some of the language which was used in the two recorded workshops. During the third interview, she suggested that she had been conscious of the presence of the recording equipment, and that she was

occasionally a little embarrassed by some of the things she was doing, but it did not appear to have been a significant problem (3.478-3.480).

### Emma's perspective

Emma did not experience any of the recorded workshop sessions, however her perspective was that the presence of the recording equipment made them act more seriously, and not '*screw around as much*' (3.540), although at least in the early sessions, they were trying to show off to some extent (3.534). She believed that she forgot its presence (2.264-2.266) although she felt that the group dynamics had been affected to some extent (2.268). In common with other group members she recognised the effect on Larry (2.266) and Janine (2.268), however her observation that the presence of the recording equipment meant that they stayed to finish everything on the worksheets (3.542) was not borne out by the evidence of the two recorded workshops.

## Persistent change group

### Veronica's perspective

Veronica perceived little impact from the presence of the recording equipment on the group's behaviours because they quickly became accustomed to its presence (2.116-2.120). It was not perceived as intrusive (3.726-3.730), particularly since the study was set in a tutorial (3.738), although Veronica felt that she would have been very nervous if the equipment had been recording her during practical sessions (3.734).

### Denise's perspective

Denise did not believe that the presence of the recording equipment had any detrimental effect: on the contrary, it provided motivation towards diligence (2.108-2.112, 2.114). She believed that participation in the study itself was beneficial to her learning, and she agreed that she had learned more by being involved (3.606-3.610). She indicated that being videotaped did not put her off, but that every now and then she was reminded of its presence (3.614-3.618).

### Isabelle's perspective

Isabelle did not believe that the presence of the recording equipment affected how she behaved or worked during the workshops, as she was accustomed to its presence by the time of the study (2.189-2.192). She '*knew it was there but didn't mind it*' (2.196), except that she felt self-conscious '*when I had to blow my nose (both laugh) coz I've got really bad allergies*' (2.198).

## Jasmine's perspective

Jasmine believed that the presence of the camera and cassette players had little impact on the group's work patterns once they became accustomed to their presence (2.178-2.180). The only noteworthy aspect was that the students responded to a request that they tie their hair back so that their faces could be seen (2.173-2.175), but Jasmine simply found this amusing.

## Kellie's perspective

Kellie was unconcerned about the presence of the recording equipment, and believed that it did not affect her or the other members of the group (2.112-2.116).

## Alicia's perspective

Alicia did not believe that the presence of the recording equipment affected her behaviour during the class (2.148). She was occasionally conscious of its presence, but she usually forgot that it was there (2.151-2.156). The major stimulus to remembering was '*if I had my hair down, then, oh, OK, I have to put it back up*' (2.156), but this was not of any great concern.