Electronic Supplementary Material (ESI) for Chemistry Education Research and Practice.

Investigating the viability of a competency-based, qualitative laboratory assessment model in first-year undergraduate chemistry

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Appendices

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Appendix 1. 2016 KRA114 Rubric Used in Traditional Quantitative Assessment Model

School of Chemistry – Chemistry 1A Laboratory Report Marking Rubric

Student Name: _____ Student Number: _____

Experiment Number and Title: _____

Criteria	HD	DN	CR	PP	NN
	In your laboratory, you:	In your laboratory, you:	In your laboratory, you:	In your laboratory, you:	In your laboratory, you:
Completion of pre-laboratory requirements	• Correctly answered all prelab questions including the required calculations		• Correctly answered the majority of prelab questions including the required calculations	• Correctly answered at least half of the prelab questions including performing the required calculations.	• Failed to answer at least half of the prelab questions including performing the required calculations.
Work safely and efficiently within a laboratory Weighting 20%	• *Successfully* completed the laboratory with *no* incidents of safety concerning students or demonstrators.		• *Successfully* completed the laboratory with at most *minor* safety incidents.		• Demonstrated insufficient effort to meet the minimum safety requirements as detailed within the laboratory manual.
	• Completed the experiment and associated questions and calculations in a planned and *timely* manner.		• Completed the experiment and the majority of the associated questions and calculations in a *planned* manner within the allotted time frame.	• Completed the experiment, but not the associated questions and calculations, within the allotted time frame	• Did not complete the experiment within the time frame allotted.
Use of the correct techniques and calculations Weighting 40%	• Produced an *expected* outcome using the *correct* techniques and/or calculations with minimal guidance. *Applied* these to the concepts and principles associated with the laboratory.	• Produced an expected outcome using the *correct* techniques and/or calculations necessary for completion of the laboratory.	• Produced an expected outcome using the techniques and/or calculations necessary for the laboratory with some *minor* errors. *Moderate* guidance required.	• Produced an expected outcome. The techniques and calculations used were *partially* correct. *Significant* guidance was required.	• Achieved an unsatisfactory result with little understanding of the techniques and/or calculations used within the laboratory. *Significant* guidance was required.
Understanding of the concepts and principles Weighting 40%	• Demonstrated a *complete* understanding of the concepts and principles utilised within the laboratory.	• Demonstrated a *near complete* understanding of the concepts and principles utilised within the laboratory.	• Demonstrated a *partial* understanding of the concepts and principles utilised within the laboratory.	• Demonstrated a *basic* understanding of the concepts and principles utilised within the laboratory.	• Showed insufficient understanding of the concepts and principles utilised within the laboratory.
	• Used the *correct* number of significant figures and correct units in *all* calculations and recorded quantities		• Mostly used the *correct* number of significant figures and correct units in *all* calculations and recorded quantities		• Did not use the *correct* number of significant figures and correct units in calculations and recorded quantities
Comments:					**Grade:**

Appendix 2. ALTC National Chemistry TLOs for Undergraduate Chemistry

The Australian Council of Deans Teaching and Learning Centre National Chemistry's TLOs for undergraduate university-level chemistry in Australia (Australian Learning and Teaching Council, 2011).

1. Understanding the culture of chemistry
- demonstrating a knowledge of, and applying the principles and concepts of chemistry
- recognising that chemistry is a broad discipline that impacts on, and is influenced by, other scientific fields
- recognising that chemistry plays an essential role in society and underpins many industrial, technological and medical advances
- recognising the creative endeavour involved in acquiring knowledge, and the testable and contestable nature of the principles of chemistry.
2. Inquiry, problem solving and critical thinking
- formulating hypotheses, proposals and predictions and designing and undertaking experiments in a safe and responsible manner
- applying recognised methods and appropriate practical techniques and tools, and being able to adapt these techniques when necessary - collecting, recording and interpreting data and incorporating qualitative and quantitative evidence into scientifically defensible arguments
- synthesising and evaluating information from a range of sources, including traditional and emerging information technologies and methods
3. Communication
- appropriately documenting the essential details of procedures undertaken, key observations, results and conclusions
- presenting information, articulating arguments and conclusions, in a variety of modes, to diverse audiences, and for a range of purposes.
4. Personal and social responsibility
- recognising the relevant and required ethical conduct and behaviour within which chemistry is practised
- demonstrating a capacity for self-directed learning
- demonstrating a capacity for working responsibly and safely
- understanding and being able to articulate aspects of the place and importance of chemistry in the local and global community.

Appendix 3. 2017 KRA114 Competency-Based Laboratory Assessment Criteria

C1: Proficiency in Using Analytical Glassware. Numerous chemical techniques require dispensing or preparing materials of known, accurate concentration or to precisely determine the concentration of an unknown. You will be assessed in your ability to use analytical glassware such as volumetric flasks, pipettes and burettes in the context of accurately preparing solutions of known concentration and for the quantification of unknowns.
C2: Proficiency in Using Chemical Glassware. All chemical reactions and processes occur in a vessel of some form – typically glassware such as beakers and flasks. Similarly, glassware is used to perform reactions under conditions such as distillation and reflux (condensers) as well as to separate chemicals (separating funnel). You will be assessed in your ability to handle these common laboratory items safely and effectively.
C3: Experimental Accuracy. Chemistry is a precise and exact science. Throughout this course you will be assessed on your proficiency in weighing materials precisely (e.g. through the use of an analytical balance), using appropriate techniques such as weighing by difference, and demonstrating an ability to calculate specific quantities with low standard error.
C4: Recording Observations. Understanding chemical change relies on accurately observing and recording observations in the laboratory. This may be noting colour changes during chemical tests or the formation of a precipitate, or the accurate recording of data (e.g. temperature of a solution over time). You will be assessed in your ability to record your observations in a timely manner and making inferences from these observations.
C5: Mastering Chemical Calculations and Equations. A key skill in chemistry involves being able to perform basic arithmetic calculations (e.g. calculating reaction yields, concentrations of solutions, application of an equation, etc.) to understand the details of a particular chemical process. You will be assessed in your ability to understand and perform these calculations where relevant. Demonstrating proficiency in scientific graphing is also an important skill that will be assessed.
C6: Understanding and Applying Chemical Principles. The laboratory component of this course is designed to reinforce the application of key chemical principles, including reinforcing lecture content. Examples of the application of chemical principles include: identifying unknown materials through rational use of chemical tests; using spectrophotometry to quantify amounts of material; describing chemical change through reaction mechanisms; predicting the products of reaction; and identifying potential sources of error in experiments.
C7: Heating, Cooling and Isolation. Many chemical reactions occur at an elevated temperature, and a key skill is the ability to do this safely (i.e. through the use of hot plates, reflux condensers, distillation apparatus, etc.). The products of chemical reactions are often isolated by processes such as recrystallization and filtration; your ability to perform these techniques successfully will also be assessed in this criterion.
C8: Safety Awareness in a Chemical Laboratory. Safety is a critical skill in chemistry. You will learn to handle chemicals and perform chemical procedures and techniques in a safe manner, in addition to adhering to requirements with regard to personal protective equipment (PPE). It is of fundamental importance that you adhere to, and demonstrate an understanding of, standard laboratory operating procedures that ensure the safety of both yourself and your peers at all times. Safety also encompasses understanding risk and hazard reporting in the laboratory.
C9: Efficiency and Time Management. Each laboratory is designed to be comfortably completed within the timeframe of the laboratory session. You will be assessed on your efficiency and ability to conduct practical tasks, including data analysis, calculations and drawing conclusions from the experiment in a timely manner.
C10: Professionalism and Preparation. Working in a laboratory is like any workplace – success requires a professional attitude and preparation. Throughout the unit you will be assessed on your professional conduct in the lab, punctuality, and demonstrated performance in being prepared through completing your pre-laboratory questions prior to arriving in the lab. An important part of professionalism in the laboratory is leaving your work space (and shared work spaces) in a state suitable that you find it (i.e. ensuring that you clean up after yourself and return laboratory equipment

to the appropriate location).
C11: Collaboration and Teamwork. There are numerous examples in a professional setting where you will be required to work in small groups or as part of a team. This also occurs in a chemistry laboratory. You will be assessed on your ability to work collaboratively with your lab partner and communicate effectively.

Appendix 4. Representative 2017 KRA114 Laboratory Experiment

TAKEN FROM 2017 KRA114 LAB MANUAL

EXPERIMENT 3B SOLVENT EXTRACTION

Concepts and Principles

- *Understand the fundamentals of solvent extraction and its relevance in the isolation of organic compounds.*
- *Utilize correct techniques with the use of an extraction funnel.*

Relevant Skills-Based Assessment Criteria

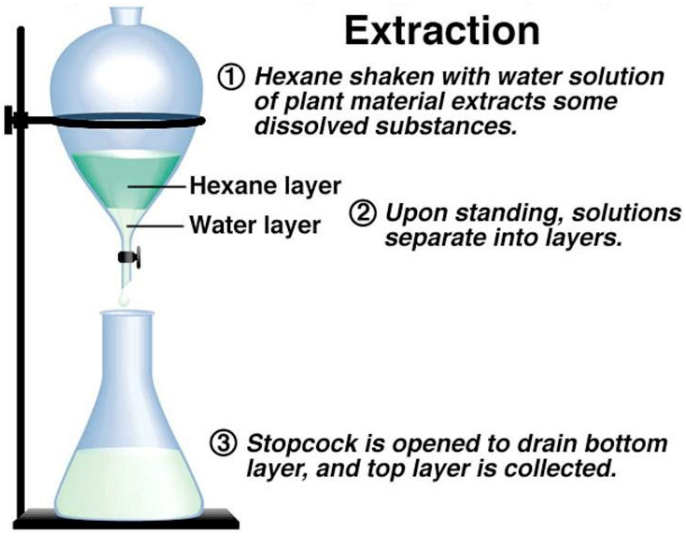
- C1: Proficiency in Using Analytical Glassware
- C2: Proficiency in Using Chemical Glassware
- C3: Experimental Accuracy
- C5: Mastering Chemical Calculations and Equations
- C6: Understanding and Applying Chemical Principles
- C8: Safety Awareness in a Chemical Laboratory
- C9: Efficiency and Time Management
- C10: Professionalism and Preparation
- C11: Collaboration and Teamwork

Aims

The aim of this experiment is to become familiar with the technique of solvent extraction as a means of separating components of a mixture, and isolating organic compounds from aqueous solution. You will compare a single and multiple extraction of propanoic acid from an aqueous solution into an organic phase (ethyl acetate), and calculate the concentration of propanoic acid in each phase after extraction.

Introduction

A common event in a laboratory dealing with organic compounds, be it for an aquaculture project, a medical or dietary analysis, organic synthesis, or many other applications, is the need to isolate a compound from an aqueous solution. If we wished to purify such a compound, distillation would be inappropriate. At other times the water solution of a biological sample, or the product of a reaction mixture, also contains inorganic compounds that the desired organic compounds require to be separated from.



It is sometimes necessary to remove an organic substance from a water solution by some process other than distillation. This may be accomplished by shaking the mixture with an immiscible solvent (one which is not soluble or does not mix with the primary solution) in a vessel as shown in the figure (right).

If the correct solvent (organic compound) has been selected most of the organic

substance will transfer from the water to the water-immiscible organic solvent. We can then collect the solute by separating the liquid layers and evaporating away the organic solvent. We say the solute is extracted by the solvent, and the process is thus called Solvent Extraction.

A good solvent for extraction purposes should allow little or no solubility in the water or in whatever substance is holding the desired organic material; it should also be volatile, so that it may be evaporated from the compound it has extracted. Above all, the organic substance should be very soluble in the extracting solvent, and much more soluble than it is in water. The solvent should not, of course, react with the water or with the material being extracted.

The most common solvents used in extraction work are diethyl ether, dichloromethane and ethyl acetate; all versatile solvents which dissolve a large number of organic compounds. They are inert to most materials and are easily removed from mixtures by simple distillation. However, ether and ethyl acetate are flammable and care needs to be taken when using these solvents.

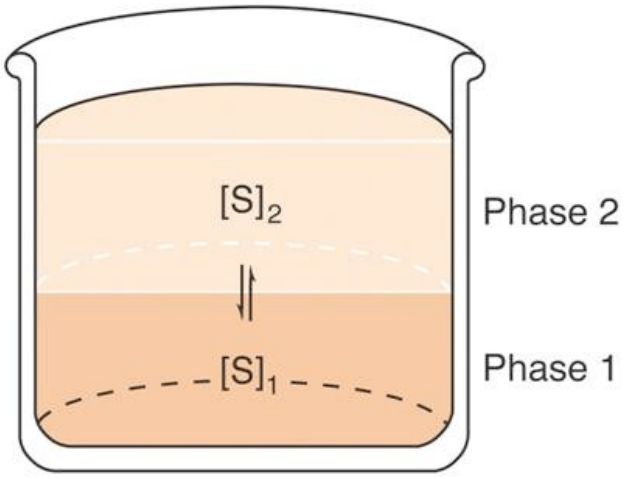
During the extraction process the solute distributes itself in both the water and the solvent, as shown in the figure below.

Phase 1 could be water and Phase 2 the organic solvent. The amount of solute in each phase depends on:

a. The solubility of the solute in each liquid, and

b. The volume of each liquid.

At any particular temperature, the solute distributes itself between the two immiscible solvents so that the ratio of its concentrations in each solvent remains constant, and is given by the partition coefficient, K_p.



$$K_p = \frac{[S]_2}{[S]_1} \qquad \text{(EQN 3-1)}$$

If $K_p = 4$, the solute is four times as soluble in the organic solvent as it is in water. Assume that for a certain extraction, $K_p = 4$ and the initial weight of solute is 20 g. the weight of solute which would be extracted from 100 mL of water by 35 mL of diethyl ether is calculated as shown below.

$K_p = \frac{[S]_2}{[S]_1}$ Remember that concentration can be expressed as g/mL, as well as mol/L. x is the mass of solute in the ether layer in grams.

$$4 = \frac{x/35}{(20-x)/100}$$

$x = 11.7$ g

We can demonstrate that two extractions, with 20 mL and 15 mL of diethyl ether would be more efficient than one extraction with 35 mL of solvent. This calculation is detailed below.

<u>First Extraction (20 mL of diethyl ether):</u>

$$K_p = \frac{[S]_2}{[S]_1}$$

$$4 = \frac{x/20}{(20-x)/100}$$

x = 8.9 g

This would leave 20.0 – 8.9 g or 11.1 g of solute in the water phase.

Second Extraction (15 mL of diethyl ether):

$$K_p = \frac{[S]_2}{[S]_1}$$

$$4 = \frac{x/15}{(11.1-x)/100}$$

x = 4.2 g

Thus, the two extractions yield a total of 8.9 + 4.2 g or 13.1 g of solute extracted from the water phase. On the other hand, a single 35 mL extraction with the same solvent only removed 11.7 g of the solute.

For multiple extractions we can use the general formula:

$$q_n = \left(\frac{V_1}{V_1 + K_p V_2}\right)^n \qquad \text{(EQN 3-2)}$$

where q_n is the fraction remaining in the water layer after n extractions, n is the number of extractions, V_1 is the volume of the sample(the aqueous layer), V_2 is the volume of each aliquot of extracting solvent (the organic layer), and K_p is the partition coefficient.

If the solute can exist in more than one form i.e. if it is a weak acid or weak base, then we must use the distribution coefficient (D)

$$D = \frac{\text{Total concentration of all forms of analyte in the organicphase}}{\text{Total concentration of all forms of analyte in the aqueousphase}} \qquad \text{(EQN 3-3)}$$

where

$$D = \frac{K_p[H^+]}{[H^+] + K_a} \qquad \text{(EQN 3-4)}$$

and EQN 3-2 becomes:

$$q_n = \left(\frac{V_1}{V_1 + DV_2}\right)^n \qquad \text{(EQN 3-5)}$$

Procedure

General

A separating funnel is most commonly employed. It may be supported on an iron ring clamped to a stand. The aqueous solution and the organic solvent are placed in the separatory funnel, the stopper secured, and with the stopper firmly held in with the palm of the hand the mixture is gently shaken by inverting the funnel and then returning it to its original position. It is also possible, with some practice, to grasp the funnel just above the stopcock and mix the contents using a swirling motion. Some heat may develop in the mixture, causing an increase in the pressure in the flask. This effect is very noticeable when diethyl ether is the solvent used. To release the pressure, invert the funnel and carefully open the stopcock making sure not to point the opening at anyone. When mixing is deemed complete, as indicated by no further increase in pressure in the funnel, return the funnel to the stand and allow the contents to separate into their respective layers. Once the separation has taken place, remove the stopper at the top in order to allow the liquid to flow freely when the stopcock is opened to remove the bottom layer of the mixture. The top layer can then be transferred into a separate vessel. When the extraction is complete, there remains the problem of deciding which is the organic layer.

Do not discard either layer until you are certain of the identity of both layers and that you have successfully extracted the organic compound!

One of the saddest stories in the laboratory is the one "I poured the wrong layer/solution down the sink". The denser layer, of course, will always be on the bottom. But what is its composition? Solvents of low density, such as diethyl ether and ethyl acetate, will usually be on top, while halogen containing solvents like dichloromethane are dense and reside in the bottom layer. However, the material going into the organic layer may change the density so that the solvent you expect to float may actually sink. If in doubt, take a couple of millilitres of what you think is the water layer and add a couple drops of water. If complete mixing occurs, the layer must be water; if it doesn't then the layer is the organic solvent.

Experimental Procedure

A solution containing 15 mL of propanoic acid (CH_3CH_2COOH 74.08 g/mol) added to 275 mL of water has been previously prepared. Propanoic acid is the compound that you will attempt to remove from the water solution by the process of solvent extraction. In order to assess the efficiency of each extraction we first must be able to measure how much propanoic acid is present before and after each extraction step. In this case we can do this conveniently by titrating the propanoic acid with a base.

Part 1: Titration of the stock solution

Obtain a 10.0 mL portion (volumetric pipette) of the prepared propanoic acid solution and titrate the acidity against the supplied 0.500 M sodium hydroxide (check the actual concentration) solution using phenolphthalein as the indicator. You should repeat this process in triplicate.

The propanoic acid solution is then extracted in two different ways.

Part 2: Simple extraction

Experimental Procedure

Place 25 mL of the solution (measuring cylinder) in a clean 100 mL separatory funnel and extract with 60 mL of ethyl acetate in the following manner:

1. Stopper the separatory funnel

2. Shake the funnel gently and turn it upside down

3. While the funnel is in this position, open the stopcock to release the internal pressure

4. Close the stopcock and shake the funnel vigorously, and again release the internal pressure

5. Repeat this procedure four or five times.

6. Place the separatory funnel upright in the support ring, let it stand undisturbed and remove the stopper

7. When the liquids have separated collect the lower aqueous layer into a clean conical beaker, being careful not to allow any of the top layer to pass through the tap.

8. Collect the top layer into a separate conical beaker by running it out of the tap of the separatory funnel.

Titrate a 10.0 mL portion (volumetric pipette) of the aqueous solution with the 0.100 M standard sodium hydroxide (check the actual concentration) solution using phenolphthalein as the indicator. Repeat with a second 10.0 mL portion.

Calculate:

a. The amount of propanoic acid left in the water layer

b. The amount of propanoic acid extracted by the ethyl acetate

c. The percentage of the propanoic acid left in the water

d. The percentage of the propanoic acid extracted by the ethyl acetate

e. The distribution coefficient, D.

Pour the ethyl acetate extract into a bottle labelled "Ethyl Acetate Extracts".

CAUTION: Ethyl acetate is a flammable solvent and must be manipulated with careful attention to fire hazards. Use both hands in operating the separatory funnel to avoid spills.

Part 3: Multiple extractions

Take a second 25 mL portion (measuring cylinder) of the original stock propanoic acid solution in a clean 100 mL separatory funnel and extract with 20 mL of ethyl acetate as described in Part 2. Separate the layers into two labelled conical beakers – remember which layer is on the top and which one is on the bottom. Return the aqueous layer to the separation funnel and extract a second time with a fresh 20 mL aliquot of the ethyl acetate, and again separate the two layers into the correctly labelled beakers. The aqueous layer is then extracted a third time with a fresh 20 mL portion of the ethyl acetate. After this third extraction the aqueous layer is drawn off into a clean conical beaker.

Titrate a 10 mL portion of the aqueous solution with the 0.100 M standard sodium hydroxide solution using phenolphthalein as the indicator. Repeat with a second 10 mL portion. *Calculate:*

a. The amount of propanoic acid left in the water layer

b. The amount of propanoic acid extracted by the ethyl acetate

c. The fraction and percentage of the propanoic acid left in the water

d. The fraction and percentage of the propanoic acid extracted by the ethyl acetate

e. The distribution coefficient, D

Compare the effectiveness of extraction with 60 mL of ethyl acetate by the two different procedures.

Also, comment on the two values of the partition coefficient you calculate. Pour the ethyl acetate extracts into a bottle labelled “Ethyl Acetate Extracts”.

School of Physical Sciences Materials Hazard Sheet
University of Tasmania

Expt 3B: Solvent Extraction

Name	Conc./ Amt	Poison	Flammable	Explosive	Corrosive	Oxidiser	Special Comments
Propanoic Acid	0.3M	Yes	No	No	Yes	No	
Sodium Hydroxide	0.5 and 0.1M	Yes	No	No	No	No	
Ethyl Acetate	neat	No	Yes	No	No	No	

Experimental Procedure:
Take a 10mL of a aqueous solution of propanoic acid, add a drop of indicator and titrate with 0.5 M NaOH. Repeat twice more.
Transfer 25 mL of the propanoic acid solution to a separating funnel and extract with 60 mL of ethyl acetate. Take 10 mL of the aqueous solution and titrate with 0.1 M NaOH. Repeat the titration.
Transfer 25 mL of the propanoic acid solution to a separating funnel and extract three times with 20 mL of ethyl acetate (60 mL total). Take 10 mL of the aqueous solution and titrate with 0.1M NaOH. Repeat the titration.

Handling Precautions:

Physical Precautions: WEAR SAFETY GLASSES, LAB COAT AND CLOSED SHOES

Fume cupboard:.	yes	**Open Bench**	Yes
Gloves	No		

Spill Instructions: ALWAYS ADVISE DEMONSTRATOR IMMEDIATELY.

Disposal Instructions: Into the waste container provided

Staff / Supervisor

Name _____

Signature _____

Student

Name _____

Signature _____

Pre-laboratory preparation: Solvent Extraction.

This section must be completed before arrival at the laboratory

- If your solvent extraction system contains an aqueous layer and a ethyl acetate organic layer, which one would be on the bottom? How could you test this?

- What are the potential hazards associated with this experiment?

- Consider an aqueous solution that contains 10 g of propanoic acid (74.08 g/mol) dissolved in 50 mL of water. This mixture was extracted with 100 mL of ethyl acetate, the layers separated. 10 mL of the aqueous layer was titrated with 0.100 M NaOH to determine the residual propanoic acid. 20 mL NaOH was required to reach the phenolphthalein endpoint.

What is the value of the distribution coefficient (D) for this extraction system?

- If a carboxylic acid, such as propanoic acid, was present as the carboxylate salt in an aqueous solution, how could you ensure that it was extracted into an organic solvent?

Demonstrator's initials

Expt 3B: Solvent Extraction.

Date:

Part 1: Titration of the stock solution

	1	**2**	**3**
Volume of acid solution (mL)	10.00	10.00	10.00
Volume of 0.500 M NaOH used (mL)			
Mol of NaOH used (mol)			
Mol of propanoic acid in solution (mol)			
[propanoic acid] in solution (M)			
Mass of propanoic acid in 10 mL of solution (g)			
Mass of propanoic acid in 25 mL of solution (g)			
Deviation in mass from the average			

Average mass of propanoic acid in 25 mL of solution = _ g

Average deviation = _ g

Precision, $\frac{\text{Av.deviation} \quad \text{x} \quad 100}{\text{Av.mass}}$ (%)

Mass of PA in 25 mL of solution = _ _ _ _ _ _ _ _ ± _ _ _ _ _ _ _ _ g

Part 2: Simple extraction

Volume of propanoic acid solution taken= _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ mL

	1	**2**
Volume of acid solution taken after extraction (mL)	10.00	10.00
Volume of 0.100 M NaOH used (mL)		
Mol of NaOH used (mol)		
Mol of propanoic acid in aliquot taken (mol)		
Mol of propanoic acid in the aqueous layer (mol)		
a). Mass of propanoic acid in the aqueous layer (g)		
b). Mass of propanoic acid in the organic layer (g)		
c). Fraction of propanoic acid in the aqueous layer (q_n)		
d). % propanoic acid in the aqueous layer (%)		
e) Fraction of propanoic acid in the organic layer		
f). % propanoic acid in the organic layer (%)		
g). D		

Average D for propanoic acid between water and ethyl acetate = _ _ _ _ _ _ _ _ _ _ _ _ _ _

Part 3: Multiple extractions

Volume of propanoic acid solution taken= _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ mL

	1	**2**
Volume of acid solution taken after extraction (mL)	10.00	10.00
Volume of 0.100 M NaOH used (mL)		
Mol of NaOH used (mol)		
Mol of propanoic acid in aliquot taken (mol)		
Mol of propanoic acid in the aqueous layer (mol)		
a). Mass of propanoic acid in the aqueous layer (g)		
b). Mass of propanoic acid in the organic layer (g)		
c). Fraction of propanoic acid in the aqueous layer (q_n)		
d) % propanoic acid in the aqueous layer (%)		
e). Fraction of propanoic acid in the organic layer		
f). % propanoic acid in the organic layer (%)		
g). D		

Average D for propanoic acid between water and ethyl acetate = _ _ _ _ _ _ _ _ _ _ _ _ _

Comment on your comparison between the results you achieved with the two procedures.

Comment on the two values of D you determined.

Skills Assessment (*Laboratory Demonstrator to complete*)

Skills-Based Assessment Criteria	Assessment (*tick all that apply*)
C1: Proficiency in Using Analytical Glassware	
Pipette – correct use	
Correct titration technique, setup of burette	
Swirling during addition and pale endpoint	
C2: Proficiency in Using Chemical Glassware	
Correct use of measuring cylinders, beakers and flasks	
Correct use of separating funnel	
C3: Experimental Accuracy	
Titration precision of 10 ppt (1 %).	
C5: Mastering Chemical Calculations & Equations	
Correct method & arithmetic	
Correct use of significant figures in calculations	
C6: Understanding & Applying Chemical Principles	
Applied appropriate chemical principle(s)	
Demonstrated an understanding of solvent extraction	
Demonstrated correct logic and explanation	
C8: Safety Awareness in a Chemical Laboratory	
Safety glasses & lab coat worn at all times	
SDS read & signed prior to entering the lab	
Procedures & techniques performed safely	
Waste disposed of safely & appropriately	
C9: Efficiency & Time Management	
Completed experiment in a timely manner	
C10: Professionalism & Preparation	
Arrived at laboratory on time	
Pre-lab questions attempted prior to entering the lab	
Demonstrated respect & consideration of others	
Workspace, locker and contents left clean	
C11: Collaboration & Teamwork	
Ability to work in collaboration with a lab partner & communicate effectively	

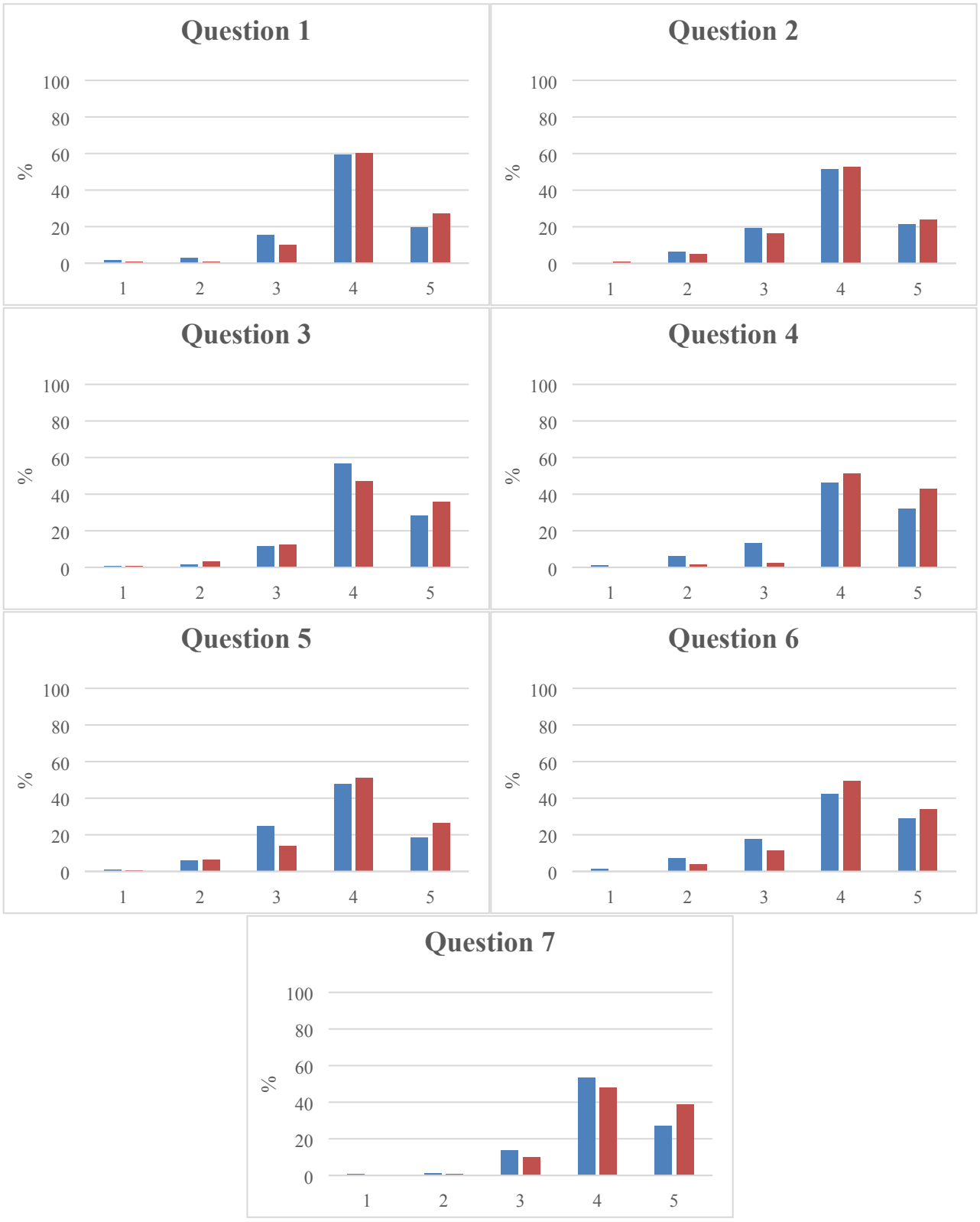
Demonstrator Comments:

Demonstrator Signature & Date

Appendix 5. KRA114 Quantitative Survey Student Response Breakdown

These data are represented in Figure 1.

Responses in blue indicate 2016, red indicates 2017.
1 = Strongly Disagree; 2 = Disagree; 3 = Neutral, 4 = Agree; 5 = Strongly Agree



Appendix 6. Detailed Description of Themes Presented in Figures 2 & 3

Theme	Description
Visual outcomes	Referring to obtaining an outcome or product that is visible to the naked eye.
Hands on/lab skills	Referring to general laboratory skills or hands on procedures undertaken.
Working with others	Working with other students within their laboratory group.
Experiment specific	Comments relating to particular experiments undertaken. For example, the synthesis of aspirin or crystal gardens.
Demonstrator	Referring to the interactions or assistance from the instructors (teaching assistants) present.
Linking to lectures	Comments relating to experiment content linking to the concepts covered in lectures.
Overall	Referring to the overall laboratory experience.
Equipment	Comments referring to the ability to operate equipment within a laboratory context.
Techniques (unspecified)	Comments relating to techniques learnt within the laboratory. No specific techniques mentioned.
Techniques (specified)	Comments relating to techniques learnt within the laboratory. Specific techniques mentioned including examples such as filtration, titration, and recrystallisation.
Mathematics	Referring to all components of the laboratory requiring mathematics.
Glassware use	The appropriate use of particular or general glassware within a laboratory context.
Theory into practice	Comments referring to theory being implemented in a practical setting.
Time management	The development of time management skills and efficiency within the laboratory.
Understand content	Developing a greater understanding of the chemistry content that has been presented through the laboratory course.
Group work	Comments referring to those experiments that required group work.
Planning/prep/organisation	The development of generic skills including the planning and preparation required before a laboratory and organizational skills both before and during.
Safety	Referring to the skills required to work safely within a laboratory.
Following instructions	The ability to take a set of instructions and produce a successful outcome.
Observations	Comments referring to the ability to take quality observations in a laboratory context.