2020 HSC Study Day Series

AURORA COLLEGE

HSC Chemistry

HSC 2020

NSW Department of Education

www.aurora.nsw.edu.au

2020 HSC Study Day Series

AURORA COLLEGE

Details

Date: Wednesday 17th June, 2020

Time: 8:50am – 3:10 pm

Location: Adobe Connect room https://connect.schools.nsw.edu.au/aurora-hsc-study1/

Materials: Available to download via this Dropbox link

Recordings: The sessions will be recorded and accessible for registered participants after the event via the same Dropbox link above. These recordings will be accessible until the HSC exam.

Program

Time	Session
8:50 – 9:00 am	**Welcome**
9:00 – 9:40 am	**Moving up a mark range** *Sharon Davis, Hurlstone Agricultural School*
9:45 – 10:45 am	**Module 5 – Equilibrium & Acid Reactions** *Fiona Boneham, Aurora College & West Wyalong High School*
10:45 – 11:15 am	Morning tea break
11:15 – 12:15 pm	**Module 6 – Acid/Base Reactions** *Anthony Scarman, Aurora College*
12:20 – 1:20 pm	**Module 7 – Organic Chemistry** *Joshua Westerway, Learning and Teaching Directorate*
1:20 – 2:00 pm	Lunch break
2:00 – 3:00 pm	**Module 8 – Applying Chemical Ideas** *Joshua Westerway, Learning and Teaching Directorate*
3:00 – 3:10 pm	**Conclusion**

Image on front cover attribution: Sourced from https://www.drugtargetreview.com/news/48519/ai-predict-outcomes-complex-chemical-reactions/

2020 HSC Study Day Series

AURORA COLLEGE

Setting up Adobe Connect

Teachers will need:

- A good, stable Dept of Ed internet connection using an ethernet cable (wifi not recommended)
- Data projector
- Speakers

The sessions will be held via Adobe Connect. Please ensure there is only one connection per school. The presentation can be displayed on a data projector through any computer with an ethernet cable and speakers. The information below will help with setting up if you are not familiar with Adobe Connect.

- You will need to perform all necessary setup in advance of your online session so that you have time to resolve any connection or access issues. The Adobe room will be opened 30 mins prior to commencing to allow time for set up.
- Test your computer prior to accessing your online room by going to the Meeting Connection Diagnostic. Ensure you install any add-ins, if prompted to do so by the connection test.
- The following guide may also be useful Quick Start Guide for Participants.

Entering the Adobe room

Teachers log in once for their class. Students are NOT to log in individually. To enter your online room, click on the Adobe Connect link provided above. Enter by typing in your Department of Education ID (eg: *jane.citizen@detnsw)* in the *Username* field then your DoE password in the *Password* field. The first thing you should do when you enter the room is complete the audio setup wizard. ('Meeting' drop down menu-> Audio Setup Wizard)

For technical help:

If you are having any issues with technology, please contact the Aurora College IT Support Team on 1300 610 733 or support@aurora.nsw.edu.au

Rights and responsibilities

Duty of care for students throughout the day remains with the registered schools and their respective teachers. Please ensure adequate supervision is provided during the day. Respectful and active participation in the event is strongly encouraged through the 'chat' pod.

Evaluation

Constructive feedback is essential, links to online surveys will also be distributed during and shortly after the event. There are two surveys and they both close on 21st September:

- Teachers https://www.surveymonkey.com/r/HSCSTUDYDAYSTEACHER2020
- Students https://www.surveymonkey.com/r/HSCSTUDYDAYSSTUDENT2020

We look forward to your participation.

MOVING UP A MARK RANGE

HSC CHEMISTRY

Band 6

- demonstrates an extensive knowledge and understanding of scientific concepts, including complex and abstract ideas
- communicates scientific understanding succinctly, logically, and consistently using correct and precise scientific terms and application of nomenclature in a variety of formats and wide range of contexts
- designs and plans investigations to obtain accurate, reliable, valid and relevant primary and secondary data, evaluating risks, mitigating where applicable, and making modifications in response to new evidence
- selects, processes, and interprets accurate, reliable, valid, and relevant qualitative and quantitative, primary or secondary data, and represents it using a range of scientific formats to derive trends, show patterns and relationships, explain phenomena, and make predictions
- designs solutions to scientific problems, questions, or hypotheses using selected accurate, reliable, valid, and relevant primary and secondary data, and scientific evidence, by applying processes, modelling and formats
- applies knowledge and information to unfamiliar situations to propose comprehensive solutions or explanations for scientific issues or scenarios

WHAT CAN YOU DO?….

……AND SOME MISTAKES TO AVOID

BECOME A SYLLABUS EXPERT!

- HAVE A COPY OF THE SYLLABUS
- USE THIS TO GUIDE YOUR STUDY AT ALL TIMES
- REFER TO PAGES 14 & 15 FOR COURSE OUTCOMES
- FAMILIARISE YOURSELF WITH THE CONTENT FOCUS AND WORKING SCIENTIFICALLY FOCUS.

KEY TERMINOLOGY

……PARTICULARLY THOSE ASSOCIATED WITH FHI

VALIDITY

IN AN EXPERIMENT

"Validity refers to whether the measurements you are taking are caused by the phenomena you are interested in"

An experiment can be valid if it is designed to test the aim or hypothesis

ASK YOURSELF.....

Does my procedure experiment actually test the hypothesis that I want it to? What variables have I identified and controlled?

WHEN LOOKING AT SECONDARY SOURCES OF INFO

"Students might consider the degree to which evidence supports the assertion or claim being evaluated"

ASK YOURSELF.....

How was the information gathered? Do the findings relate to the hypothesis or problem?

RELIABILITY

A first hand investigation is reliable **if when repeated a consistent pattern of results** is obtained for each repetition

ASK YOURSELF.....

Have I tested with repetition?

To assess reliability of secondary data it is best **to make comparisons between data and claims of a number of reputable sources**

ASK YOURSELF.....

How consistent is the information with information from other reputable sources?

ACCURACY AND PRECISION

In the fields of science, engineering, industry, and statistics, the **accuracy** of a measurement system is the degree of closeness of measurements of a quantity to that quantity's actual (true) value

The **precision** of a measurement system, also called reproducibility or repeatability, is the degree to which repeated measurements under unchanged conditions show the same results

ACCURACY V'S PRECISION

DESTRUCTIVE AND NON-DESTRUCTIVE TESTING

- Destructive testing **does cause damage** to the material
- Non destructive testing involves analysis of a material **without causing damage**

Is testing alkanes and alkenes with bromine water destructive or non destructive testing?

Is pH testing destructive or non-destructive?

IDENTIFIED HAZARDS

- You will need to be able to identify hazards, complete a risk assessment (with the use of SDS) and describe procedures that minimise hazards
- Think about the difference between a safety hazard (something that poses a risk) and safety precaution (a procedural step to prevent injury).

"Common safety precautions in school laboratories include the use of safety glasses, gloves and lab coats. Justify the use of another safety precaution specifically required to safely make ethyl butanoate."

CAN YOU JUSTIFY THE PROCEDURE, MATERIALS ETC?

- **What** did you use? **Why** did you use it? **How and why** did you use it that way?

"In the preparation of this compound a few drops of concentrated sulfuric acid were added to the starting materials. The mixture was then refluxed for a period of time. Why was it necessary to reflux the mixture?"

COMMON MISTAKES TO AVOID

#1 MISTAKE – MISINTERPRETING !

- Be careful to ONLY give the type of response requested in the question.
- Use the mark allocation (about 1.5 minutes per mark) and the amount of space provided in the answer book as a guide to how much you should write.

SO WHAT ABOUT 'ASSESS'?

- 'Make a judgement of value, quality, outcomes, results or size'
- Make your own judgement clear and support this using specific arguments identified in the planning stage

SO WHAT ABOUT 'EVALUATE'?

- 'Make a judgement based on criteria; determine the value of'
- Explicitly state your judgement (your conclusion) and support it, based on criteria.

AND ANALYSE?

- 'Identify the components and list two or more of these and link them'
- Clearly identify the components (implications) and show how the components are related to each other and how they effect each other.

PLEASE EXPLAIN!!

- 'Relate cause and effect; make the relationship between things evident; provide why and/or how in your answer'
- Identify the cause and effect and link them using terms such as....because.....resulting in.....in response to.....will mean.....etc

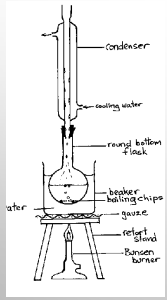
2 MISTAKE – TOO MANY ANSWERS

- Make sure you decide on your answer and give it, without contradictions.
- Make sure you avoid answers that reword the question.

3 MISTAKE – IRRELEVANT INFO

- Answer the question asked, avoid adding extra info just because you know it.

4 MISTAKE – SILLY DRAWINGS



- Diagrams can help clarify answers, BUT keep them 2D and accurate
- Label critical parts, with a simple line down one side
- Use a ruler for straight parts and draw with a pencil
- Keep open apparatus, open
- Diagram shown is an example of a good one…..BUT how would you change it?

5 MISTAKES – BAD EQUATIONS

- To achieve full marks on an equation it must ;

1. Contain the correct formula
2. Be balanced
3. Have the correct states of matter

6 MISTAKE – SOLUBILITY RULES

- Know your solubility rules (this helps you write in states of matter)
- No shortcuts…….Just remember them and know how to use the solubility data sheet information

Soluble Compounds	**Insoluble exceptions**
Group 1 metals and ammonium	
Nitrates and acetates	
Chlorides, bromides and iodides	Silver, lead and mercury
sulfates	Silver, lead, mercury, barium, strontium and calcium
Insoluble compounds	**Soluble exceptions**
Carbonates, sulphites and phosphates	Group 1 metals and ammonium
hydroxides	Group 1 metals, ammonium, calcium and barium
sulfides	Group 1 and 2 metals and ammonium
oxides	Group 1 metals, ammonium, calcium and barium

7 MISTAKE – SIG FIGS

- The final answer of a calculation must have the correct significant figures.
- The answer he should only be as precise as the least precise value
- BUT don't round off until the very end of a calculation

1. All non-zero digits are significant. For example, 123 has 3 significant figures and 123.456 has 6 significant figures
2. All zeros between non-zero digits are significant. For example 102 has 3 significant figures and 12.03 has 4 significant figures
3. All zeros on the right of the decimal point or a non-zero digit after a decimal point are significant. For example, 12.000 has 5 significant figures but 0.12 has 2 significant figures and 0.00012000 has 5 significant figures. The first 4 zeros are not significant.

HOW MANY SIGNIFICANT FIGURES?

- 21.02 TO 1 SIGNIFICANT FIGURES?
- 656943.4 TO 5 SIGNIFICANT FIGURES?
- 0.000682929 TO 3 SIGNIFICANT FIGURES?

8 MISTAKE – POOR WORKING

- Calculations make up 20 – 25% of a HSC Chemistry exam.
- It is important to practise these, using good, demonstrated working
- Notation should use proper symbols
- E.g. n = number of moles, n(NaCl)

WHAT CAN I DO NOW? (OVERVIEW)

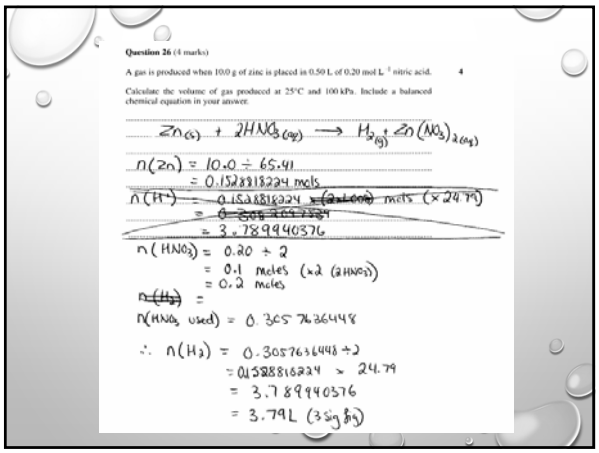
- Prepare for your trial like it's the HSC
- But....Keep your efforts sustainable
- Now? Summaries and lots and lots and lots of practise questions (both completed AND analysed)

MAKE YOUR PREPARATIONS COUNT!

- STUDY IN GROUPS – EXPLAIN CONCEPTS TO EACH OTHER
- SHARE PRACTICE QUESTIONS AND ANALYSE RESPONSES TOGETHER IN REFERENCE TO MARKING GUIDELINES

BEFORE YOUR EXAMS

- Become familiar with phrases that use succinct terminology that demonstrate your knowledge
- Memorise key equations you need
- Do lots and lots of questions that are analysed in comparison to marking guidelines and markers comments



Question 26 (4 marks)

A gas is produced when 10.0 g of zinc is placed in 0.50 L of 0.20 mol L^{-1} nitric acid. **4**

Calculate the volume of gas produced at 25°C and 100 kPa. Include a balanced chemical equation in your answer.

$Zn_{(s)} + 2HNO_{3(aq)} \longrightarrow H_{2(g)} + Zn(NO_3)_{2(aq)}$

$n(Zn) = 10.0 \div 65.41$

$= 0.1528818224$ mols

$n(H^+) = 0.1528818224 \times (2 \times 1.008)$ mols $(\times 24.79)$

$= 0.305763644$

$= 3.789940376$

$n(HNO_3) = 0.20 \div 2$

$= 0.1$ moles $(\times 2\ (2HNO_3))$

$= 0.2$ moles

$n(H_2) =$

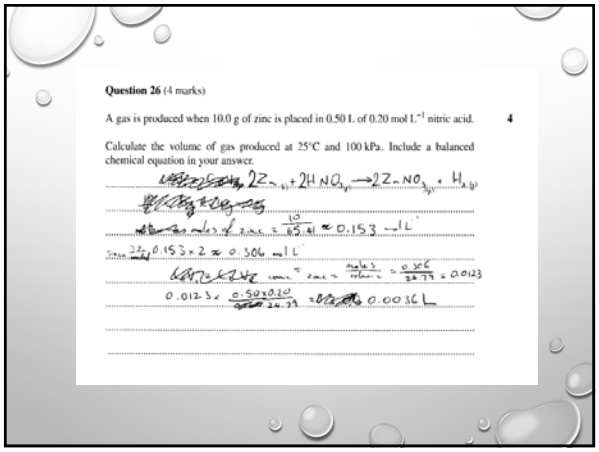
$n(HNO_3$ used$) = 0.305763644$

$\therefore n(H_2) = 0.305763644 \div 2$

$= 0.1528816224 \times 24.79$

$= 3.789940376$

$= 3.79$ L (3 sig fig)



Question 26 (4 marks)

A gas is produced when 10.0 g of zinc is placed in 0.50 L of 0.20 mol L^{-1} nitric acid. **4**

Calculate the volume of gas produced at 25°C and 100 kPa. Include a balanced chemical equation in your answer.

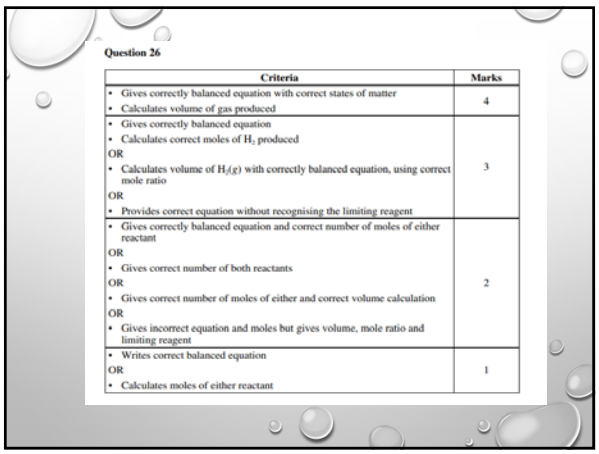
$Zn_{(s)} + 2HNO_{3(aq)} \longrightarrow Zn(NO_3)_{2(aq)} + H_{2(g)}$

$\frac{10}{65.41} \approx 0.153$ mol

$0.153 \times 2 \approx 0.306$ mol

$\frac{0.306}{24.79} = 0.0123$

$0.0123 \times \frac{0.50 \times 0.20}{24.79} = 0.0036$ L



Question 26

Criteria	Marks
• Gives correctly balanced equation with correct states of matter • Calculates volume of gas produced	4
• Gives correctly balanced equation • Calculates correct moles of H_2 produced OR • Calculates volume of $H_2(g)$ with correctly balanced equation, using correct mole ratio OR • Provides correct equation without recognising the limiting reagent	3
• Gives correctly balanced equation and correct number of moles of either reactant OR • Gives correct number of both reactants OR • Gives correct number of moles of either and correct volume calculation OR • Gives incorrect equation and moles but gives volume, mole ratio and limiting reagent	2
• Writes correct balanced equation OR • Calculates moles of either reactant	1

Question 26

The best responses clearly set out working, provided a balanced chemical equation and included correct states. Zinc was recognised as being in excess and nitric acid was described as a limiting reagent. Most responses contained accurately transcribed values from the periodic table and data sheet and showed the mole ratios from the equation provided. Weaker responses contained incorrect formulae for nitric acid and unbalanced equations.

IN THE EXAM

- Read the question……reading time
- Determine what is being asked, look at equations, units and sig figs
- Formulate your answer by considering the NESA key word
- Use correct terminology IN CONTEXT
- Keep your work neat and tidy – you can ask for additional paper if required, just leave a note with where your answer can be found.

AFTER TRIALS…..

- You are no longer competitive as an individual……You are all competing against the state.
- If the students from your school achieve better marks in the HSC, then everyone's overall mark will improve.

Moving Up A Mark Range

Where are we aiming for? Check the Performance Band Descriptors.

Band 6

- demonstrates an extensive knowledge and understanding of scientific concepts, including complex and abstract ideas
- communicates scientific understanding succinctly, logically, and consistently using correct and precise scientific terms and application of nomenclature in a variety of formats and wide range of contexts
- designs and plans investigations to obtain accurate, reliable, valid and relevant primary and secondary data, evaluating risks, mitigating where applicable, and making modifications in response to new evidence
- selects, processes, and interprets accurate, reliable, valid, and relevant qualitative and quantitative, primary or secondary data, and represents it using a range of scientific formats to derive trends, show patterns and relationships, explain phenomena, and make predictions
- designs solutions to scientific problems, questions, or hypotheses using selected accurate, reliable, valid, and relevant primary and secondary data, and scientific evidence, by applying processes, modelling and formats
- applies knowledge and information to unfamiliar situations to propose comprehensive solutions or explanations for scientific issues or scenarios

See the 2019 course report here (includes performance descript[tors and distribution of last years candidates https://www.boardofstudies.nsw.edu.au/ebos/static/BD1065943.PDF

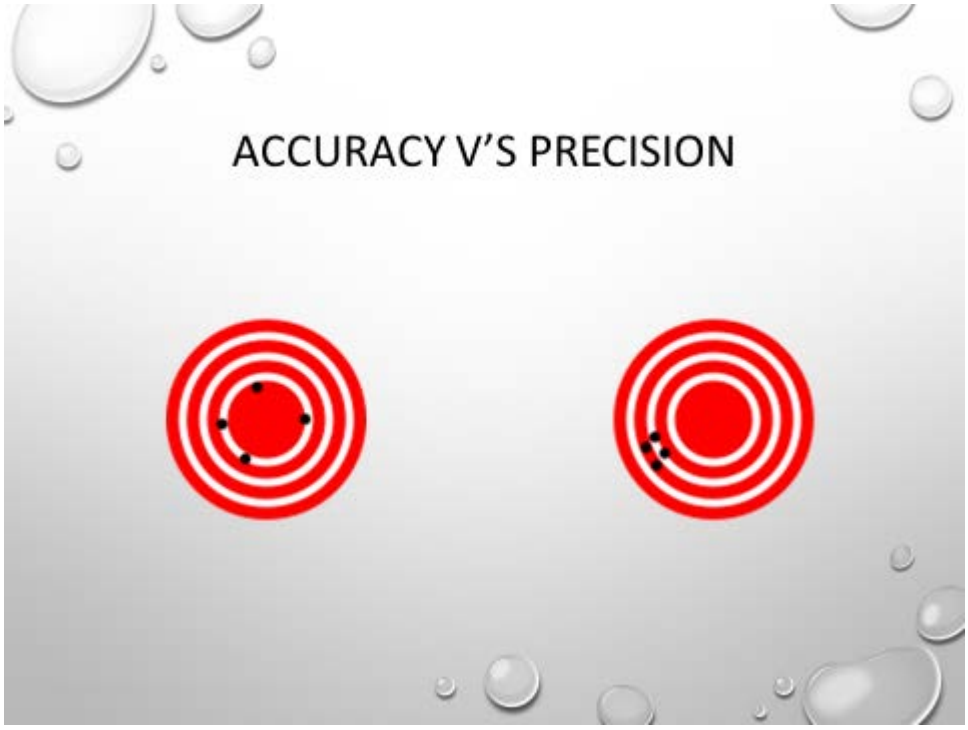
What can we do now?

- Become a syllabus expert (Use this as a guide for studying; refer to the outcomes on pages 14&15, ensure you familiarise yourself with the content focus and the working scientifically focus)
- Familiarise yourselves with key terminology, concentrating firstly on those in FHI

Terminology

- Validity -"Validity refers to whether the measurements you are taking are caused by the phenomena you are interested in"

- Reliability - A first hand investigation is reliable if when repeated a consistent pattern of results is obtained for each repetition
- Accuracy - In the fields of science, engineering, industry, and statistics, the accuracy of a measurement system is the degree of closeness of measurements of a quantity to that quantity's actual (true) value
- Precision - The precision of a measurement system, also called reproducibility or repeatability, is the degree to which repeated measurements under unchanged conditions show the same results
- Which bullseye demonstrates accuracy and which one is precise?



- Is testing alkanes and alkenes with bromine water destructive or non - destructive testing? Justify.

  _____

- Is pH testing destructive or non-destructive? Justify.

  _____

- Safety hazard (something that poses a risk) and safety precaution (a procedural step to prevent injury).
- Can you justify the procedure, materials etc you have used in a FHI? What did you use? Why did you use it? How and why did you use it that way?

Common mistakes to avoid

- Misinterpreting the question – only give one type of response (as requested in the question) Use the mark allocation and the amount of space provided in the answer booklet as a guide to how much you should write.
  Assess – make a CLEAR judgement of value, quality, outcomes, results or size that you support with specific arguments.
  Evaluate – make a judgement based on criteria; determine the value of. Explicitly state your judgement (conclusion) and support it, based on the criteria stated or implied in the question.
  Analyse – identify the components and list two or more of these and link them.
  Explain – relate the cause and effect; make the relationship between things evident; provide why and/or how in your answer.
- Giving too many answers – decide on your answer and give it, no contradictions. Avoid rewording the questions.
- Providing irrelevant information – avoid the extra information, just because you know it.
- Silly drawings – diagrams help clarify answers but should be 2D, labelled, drawn with a ruler and a pencil. Apparatus that is open should be left that way.

- Writing incorrect equations - make sure they are balanced, contain correct formula and have the correct states of matter
- Not know your solubility rules – ensuring you know these this helps with content around solubility as well as writing states of matter. Using Ksp data on the data sheet can assist.
- Using incorrect significant figures. Answers to calculations should not be more precise than the data in the question. Do not round off until the end of calculations.
  Round off the following data as described?
  1. 21.02 to 1 significant figure _____

  2. 656943.4 to 5 significant figures_____

  3. 0.000682929 to 3 significant figures _____
- Poor working out – use clear working out in calculations. Give all steps and consider using sub titles to show what is being calculated at each point. Use correct notation and symbols in equations.

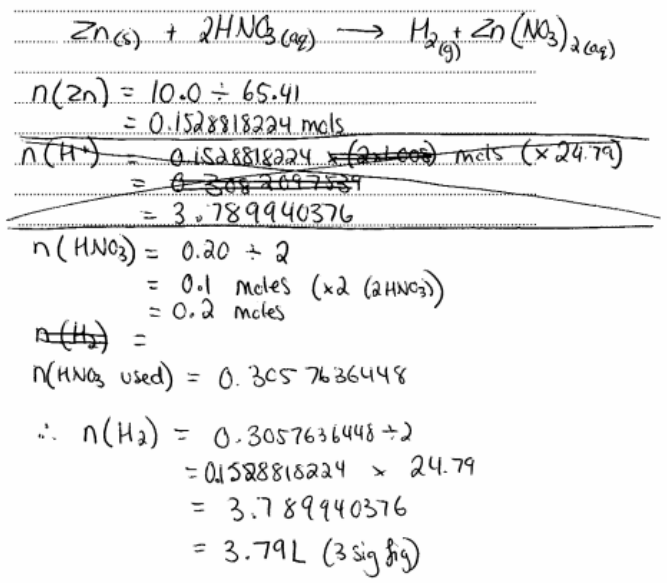
What can I do now?

- Prepare for the trial like it is the HSC
- Keep efforts sustainable
- Write you summaries in preparation for study but move into active study by completing questions.
- Compare your responses to the marking guidelines and markers comments (see the next page for activity)
- In the exam – read the question, determine what has been asked, examine at your equations and significant figures. Formulate the response, considering NESA key words. Use correct terminology in context. Keep your work neat and tidy and leave notes on the question page if you use additional paper. (e.g. Additional answer for Q21 can be found in additional answer booklet….etc)
- After the trials, work closely with your classmates and build your collective knowledge and skills – everyone will benefit!

Question 26 (4 marks)

A gas is produced when 10.0 g of zinc is placed in 0.50 L of 0.20 mol L^{-1} nitric acid. **4**

Calculate the volume of gas produced at 25°C and 100 kPa. Include a balanced chemical equation in your answer.



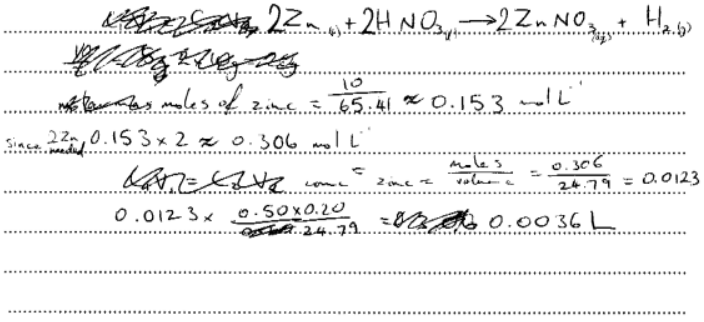
Question 26

Criteria	Marks
• Gives correctly balanced equation with correct states of matter • Calculates volume of gas produced	4
• Gives correctly balanced equation • Calculates correct moles of H_2 produced OR • Calculates volume of $H_2(g)$ with correctly balanced equation, using correct mole ratio OR • Provides correct equation without recognising the limiting reagent	3
• Gives correctly balanced equation and correct number of moles of either reactant OR • Gives correct number of both reactants OR • Gives correct number of moles of either and correct volume calculation OR • Gives incorrect equation and moles but gives volume, mole ratio and limiting reagent	2
• Writes correct balanced equation OR • Calculates moles of either reactant	1

Question 26 (4 marks)

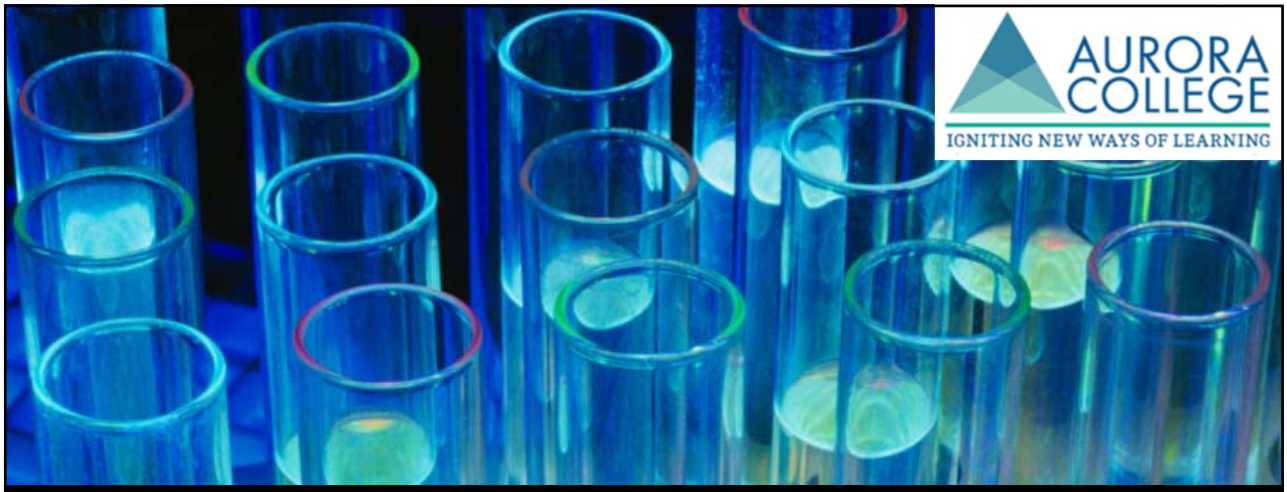
A gas is produced when 10.0 g of zinc is placed in 0.50 L of 0.20 mol L^{-1} nitric acid. **4**

Calculate the volume of gas produced at 25°C and 100 kPa. Include a balanced chemical equation in your answer.



Question 26

The best responses clearly set out working, provided a balanced chemical equation and included correct states. Zinc was recognised as being in excess and nitric acid was described as a limiting reagent. Most responses contained accurately transcribed values from the periodic table and data sheet and showed the mole ratios from the equation provided. Weaker responses contained incorrect formulae for nitric acid and unbalanced equations.



Equilibrium and Acid Reactions

Module 5 HSC Chemistry: 2020 HSC study day Aurora College

Inquiry questions and how to use them!

What happens when chemical reactions don't go through to completion?
What factors affect equilibrium and how?
How can the position of equilibrium be described and what does the equilibrium constant represent?
How does solubility relate to chemical equilibrium?

Inquiry questions in this module allow students to think critically about the content and context!

Static and Dynamic Equilibrium

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

Equilibrium: In chemical reactions, the state in which the conversion of reactants into products and the conversion of products back into reactants occur simultaneously at the same rate; state of balance

What happens when chemical reactions do not go through to completion?

Example: The reaction between Iron (III) nitrate and potassium thiocyanate .

Qu 1: When solutions of $Fe(NO_3)_3$ and KSCN are mixed a red solution is formed due to the presence of Iron Thiocyanate ions.

a) Write a balanced ionic equation for this reaction

b) Predict the change in equilibrium of adding a small volume of Ag NO_3 which will react to form insoluble AgSCN

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

The Haber Process- An important industrial equilibrium reaction

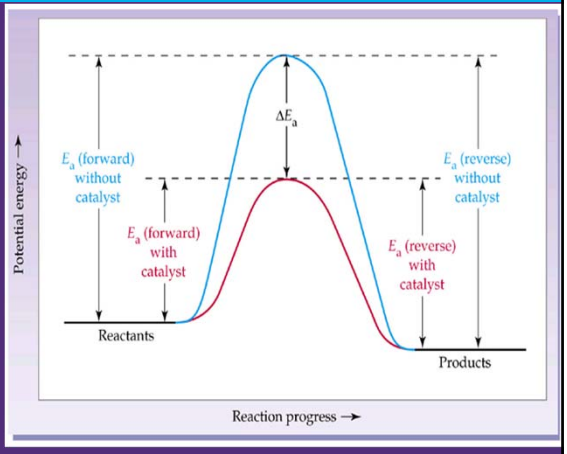
AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

Qu 2: a) Recall the balanced equation for the Haber process for the synthesis ammonia.

b) Explain using enthalpy the exothermic nature of this process and how this effects the equilibrium of the reaction using Le Chatelier's Principle.

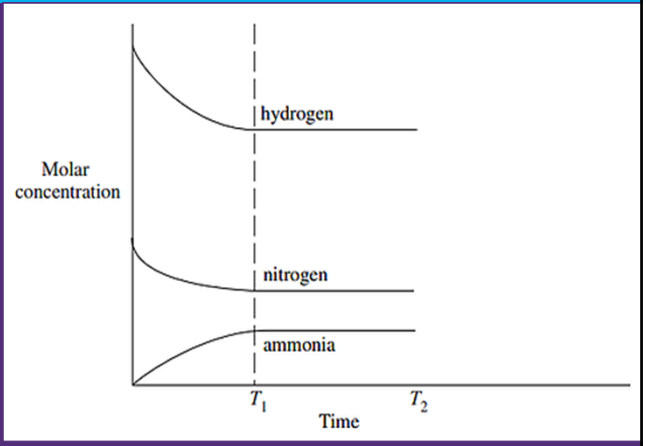
c) Explain using the diagram how activation energy is affected by the addition of a catalyst not the yield.

d) Analyse why we use high temperature and pressure in a Haber plant?



Le Chatelier's Principle

- **Le Châtelier's Principle**: When a chemical system at equilibrium is disturbed, it returns to equilibrium by counteracting the disturbance.
- Qu 3: Indicate on the graph and explain in terms of equilibrium the change in the concentrations of the three gases if at T2, most of the ammonia was removed by dissolving it in water.



Factors that affect Equilibrium

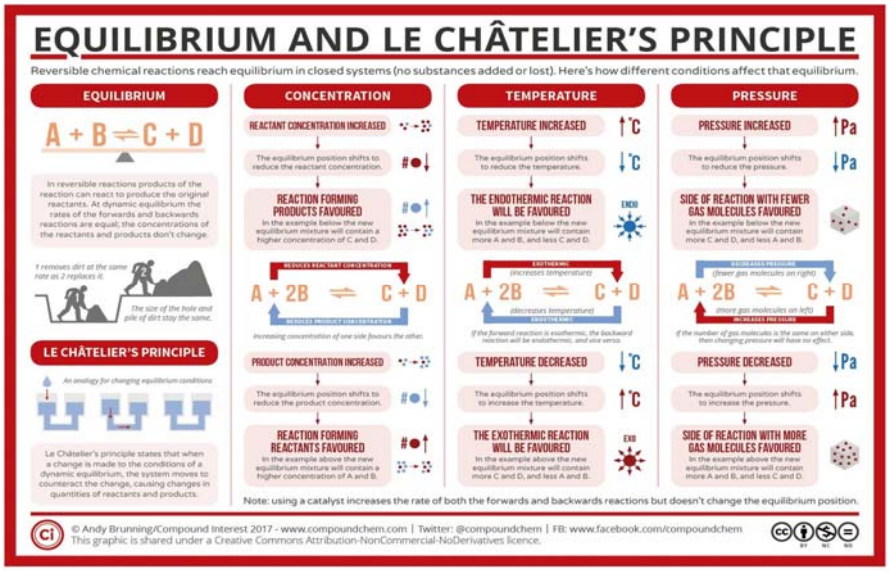
Temperature	Concentration	Volume/Pressure
• When the temperature changes we need to look at the enthalpy of the reaction to decide in which direction the reaction will respond.	• Changing the concentration will push the reaction to respond to lower the one in excess and this will affect all the other species.	• A volume change will affect a gaseous reaction by lowering the number of particles to move towards the side with the least number of moles of gas.

Le Chatelier's Principle

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

LE CHATELIER'S PRINCIPLE

STRESS	SHIFT	WHY?
increase concentration of a substance	*away* from substance	extra concentration needs to be used up
decrease concentration of a substance	*towards* substance	need to produce more of substance to make up for what was removed
increase pressure of system	towards *fewer* moles of gas	for gas: pressure increase = volume decrease
decrease pressure of system	towards *more* moles of gas	for gas: pressure decrease = volume increase
increase temperature of system	*away* from heat/ energy *exothermic* reaction is favored	extra heat/ energy must be used up
decrease temperature of system	*towards* heat/ energy *exothermic* reaction is favored	more heat/ energy needs to be produced to make up for the loss
add a catalyst	NO SHIFT	The rates of both the forward and reverse reactions are increased by the same amount.



AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

LE CHATELIER
RELIEVING STRESS SINCE 1884

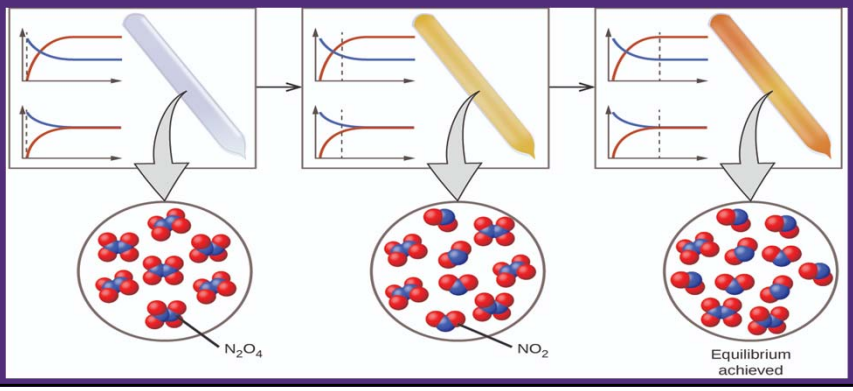
Making your own infographic such as the CI one shown here helps to consolidate the concept.

Calculating the equilibrium constant

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

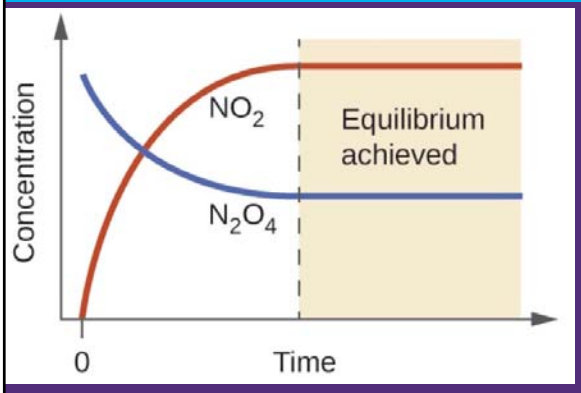
$$K_{eq} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Qu 5: For the reaction where dinitrogen pentoxide decomposes into nitrogen dioxide and oxygen gas
a) Write a balanced chemical equation
b) Write the equilibrium expression



The obvious change in colour to show equilibrium shift due to a change in temp.

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING



c) If N_2O_4 is a colourless gas and it decomposes into the reddish brown gas NO_2 as it is heated in a sealed ampule describe and explain what this means for the enthalpy of this reaction.

https://opentextbc.ca/chemistry/chapter/13-1-chemical-equilibria/ (good website to explain this reaction)

Temperature change and equilibrium

Qu 6

Mod 5 – Question 3

Nitrogen dioxide (a brown gas) and dinitrogen tetroxide (a colourless gas) are both forms of oxides of nitrogen. They are in equilibrium according to the equation

$$2NO_2(g) \rightleftharpoons N_2O_4(g).$$

An equilibrium mixture of the two gases at room temperature is light brown but at higher temperatures the colour becomes a much deeper brown.

What conclusion can be drawn from this observation?

A. The reverse reaction in the equation is endothermic.

B. The forward reaction in the equation is endothermic.

C. The brown colour is due to the strong nitrogen–oxygen bonds in NO_2.

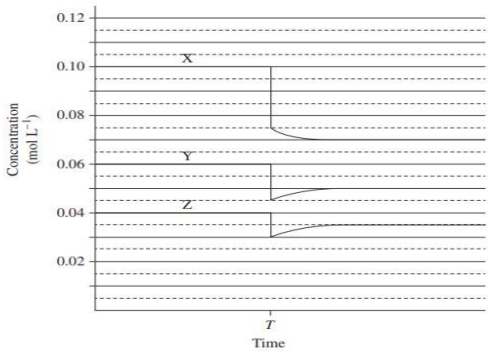
D. The equilibrium concentration of N_2O_4 is not dependent on temperature.

Conc. V's Time Graphs

Qu7

Mod 5 – Question 4

Three gases X, Y and Z were mixed in a closed container and allowed to reach equilibrium. A change was imposed at time *T* and the equilibrium was re-established. The concentration of each gas is plotted against time.



Which reaction does the graph represent?

A. $X(g) + Y(g) \rightleftharpoons 2Z(g)$

B. $2X(g) \rightleftharpoons Y(g) + Z(g)$

C. $2X(g) \rightleftharpoons Y(g) + 3Z(g)$

D. $X(g) \rightleftharpoons Y(g) + Z(g)$

Equilibrium conditions

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

Qu 8

16 The equation describes an equilibrium reaction occurring in a closed system.

$$X(g) + Y(g) \rightleftharpoons 4Z(g) \qquad \Delta H = +58 \text{ kJ}$$

Under which set of conditions would the highest yield of Z(*g*) be obtained?

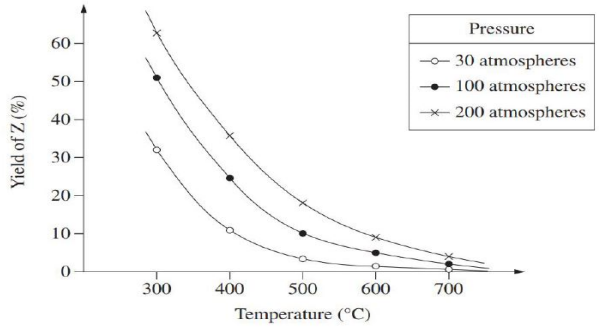
	Temperature (°C)	*Pressure* (kPa)
(A)	50	100
(B)	50	200
(C)	300	100
(D)	300	200

Reading graphs on equilibrium

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

Qu 9

20 This graph represents the yield of an equilibrium reaction at different temperature and pressure conditions inside a reaction vessel.



Which of the following reactions could produce the trends shown in the graph?

(A) $X(g) + Y(g) \rightleftharpoons 3Z(g)$ $\Delta H = +100$ kJ

(B) $X(g) + Y(g) \rightleftharpoons 2Z(g)$ $\Delta H = -100$ kJ

(C) $2X(g) + 2Y(g) \rightleftharpoons Z(g)$ $\Delta H = +100$ kJ

(D) $4X(g) + 2Y(g) \rightleftharpoons 3Z(g)$ $\Delta H = -100$ kJ

Equilibrium and energy profile diagrams

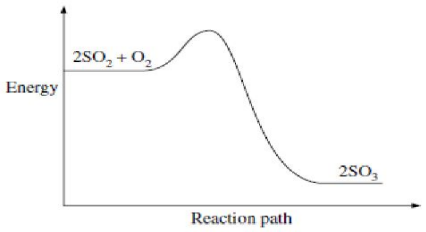
AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

Qu10

15 Sulfur trioxide (SO_3) is used industrially to prepare sulfuric acid. It is formed by combining sulfur dioxide (SO_2) with an excess of air. Vanadium pentoxide (V_2O_5) may be used as a catalyst for this reaction.

$$2SO_2(g) + O_2(g) \xrightleftharpoons{V_2O_5} 2SO_3(g)$$

The energy profile for this reaction is shown below.



Which of the following would alter the equilibrium in favour of the formation of sulfur trioxide AND also increase the rate of reaction?

(A) Decreasing the volume of the reaction vessel at constant temperature.
(B) Increasing the temperature of the reaction vessel at constant pressure.
(C) Decreasing the temperature of the reaction vessel at constant pressure.
(D) Increasing the amount of vanadium pentoxide.

Interpreting concentration v's time graph

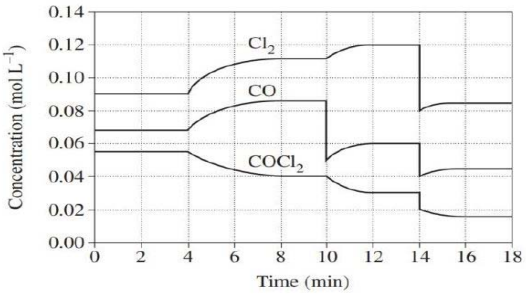
AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

Qu 11

Question 23 (6 marks)

The graph shows the variation in concentration of reactant and products as a function of time for the following system. **6**

$$COCl_2(g) \rightleftharpoons Cl_2(g) + CO(g) \quad \Delta H = +108 \text{ kJ}$$



Identify and explain each of the changes in conditions that have shaped the curves during the time the system was observed.

.....

Equilibrium constant expression

Qu 12

28. Methane and hydrogen sulfide were reacted together in a 2·00 L vessel at a constant high temperature. The following reaction occurred:

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

At equilibrium, the following concentrations were determined:

$[CH_4] = 1{\cdot}242 \text{ mol L}^{-1}$ $[H_2S] = 1{\cdot}543 \text{ mol L}^{-1}$

$[CS_2] = 0{\cdot}016 \text{ mol L}^{-1}$ $[H_2] = 0{\cdot}064 \text{ mol L}^{-1}$

(a) Write down the equilibrium constant expression for this reaction.

(b) Calculate the equilibrium constant for the reaction under these conditions.

(c) Explain why all reactions appear to have stopped at equilibrium.

(d) More methane is added to the equilibrium reaction without changing the temperature or volume of the system. Equilibrium is re-established. What effect does this addition have on the value of the equilibrium constant?

(e) The reaction takes place in the presence of a catalyst. What is the function of the catalyst?

Equilibrium constant calculation

Qu 13

(b) Nitrosyl chloride is introduced into an empty container. It then dissociates into nitric oxide and chlorine according to the equation:

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

The reaction is endothermic.

(i) Explain the effect on the yield of $NO(g)$ if the temperature is increased. **2**

(ii) The equilibrium constant, K, for the reaction is 0.028. **3**

Calculate the equilibrium concentration of $NOCl(g)$ if the equilibrium concentration of $Cl_2(g)$ is 0.17 mol L^{-1}.

Equilibrium Constant cont.

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

Qu 14

(b) The equilibrium constant expression for a gaseous reaction is as follows:

$$K = \frac{[N_2][O_2]}{[NO]^2}$$

(i) Write the equation for this reaction. **1**

(ii) 0.400 moles of NO was placed in a 1.00 L vessel at 2000°C. The equilibrium concentration of N_2 was found to be 0.198 mol L^{-1}. **3**

Calculate the equilibrium constant for this reaction and use this value to describe the position of the equilibrium.

(iii) What could be changed that would result in a different value of K for this equilibrium? **1**

Solubility product expressions from the equation

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

Solubility Products

Consider the equilibrium that exists in a saturated solution of $BaSO_4$ in water:

$$BaSO_{4(s)} \rightleftharpoons Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$$

The equilibrium constant expression for this equilibrium is

$$K_{sp} = [Ba^{2+}]\,[SO_4^{2-}]$$

where the equilibrium constant, K_{sp}, is called the solubility product.

Solubility equilibria and common ion

Qu 15

22. A student prepared a saturated solution of calcium hydroxide by dissolving excess solid in water.

(a) The student claimed: 'In this saturated solution, the amount of solid dissolved does not change but ionic bonds continue to be broken'.

Is this student correct? Explain your answer.

(b) Calcium hydroxide is an ionic compound. Write an equation for the equilibrium that exists between solid calcium hydroxide and its ions in solution.

(c) What would be the effect of adding a concentrated sodium hydroxide solution to the equilibrium in part (b)?

Solubility Constant K_{sp}

Qu 16

Mod 5 – Question 14 (3 marks)

When a sample of solid silver chloride is added to a 1.00×10^{-2} mol L^{-1} sodium chloride solution, only some of the silver chloride dissolves. **3**

Calculate the equilibrium concentration of silver ions in the resulting solution, given that the K_{sp} of silver chloride is 1.80×10^{-10}.

Saturated solutions

Qu 17

A saturated solution of barium carbonate was stored in a flask. Solid barium carbonate containing radioactive carbon-14 was added to the solution. The mixture was allowed to stand for several days and was then filtered.

Radioactivity could reasonably be expected to be found in

A. the filtrate only.

B. the residue only.

C. both residue and filtrate.

D. neither residue nor filtrate.

Factors affecting solubility

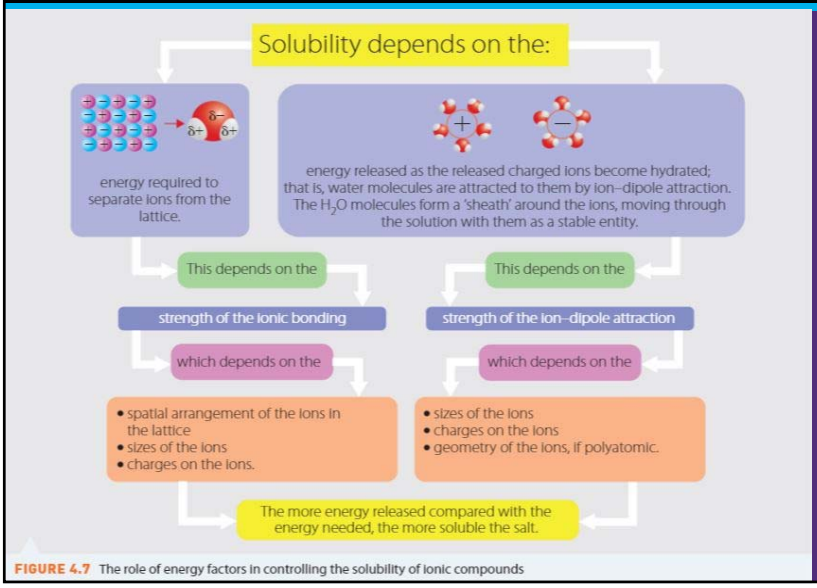


FIGURE 4.7 The role of energy factors in controlling the solubility of ionic compounds

Most ionic compounds are soluble in water but they do not all dissolve to the same extent.
Even substances that are classed as insoluble will usually dissolve to a small extent.
A saturated solution is one where the limit of solute that will dissolve has been reached but things are still happening at the ionic level.

Image: Extracted from Chemistry in Focus Year 12 (Page 86)

Solubility rules- Learn them!

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

SOLUBLE ANIONS	EXCEPTIONS	INSOLUBLE ANIONS	EXCEPTIONS
NO_3^-	None	OH^-	Group 1, NH_4^+, Ba^{2+}, Sr^{2+} soluble; Ca^{2+} slightly soluble
CH_3COO^-	Ag^+ slightly soluble	O^{2-}	Group 1, NH_4^+, Ba^{2+}, Sr^{2+}, Ca^{2+} soluble
Cl^-	Ag^+ insoluble Pb^{2+} slightly soluble	S^{2-}	Groups 1 and 2, NH_4^+ soluble
Br^-	Ag^+ insoluble Pb^{2+} slightly soluble	CO_3^{2-}	Group 1, NH_4^+ soluble
I^-	Ag^+, Pb^{2+} insoluble	SO_3^{2-}	Group 1, NH_4^+ soluble
SO_4^{2-}	Ba^{2+}, Pb^{2+}, Sr^{2+} insoluble Ag^+, Ca^{2+} slightly soluble	PO_4^{3-}	Group 1, NH_4^+ soluble

Solubility constants, On the Data sheet!

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

Solubility constants at 25°C

Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	Silver iodide	8.52×10^{-17}
		Silver phosphate	8.89×10^{-17}
		Silver sulfate	1.20×10^{-5}

Tips!!!

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

- Read deeply about the content to extend your understanding, don't be afraid to read from a wide variety of sources
- Practice many many exam style questions and get someone to give you feedback on your responses
- Produce dynamic summaries of the topic and try to put all the content into context include practicals
- Produce posters and infographics or digital stimulus materials to help recall information
- Use models to build complex molecules

Handy Resources and summaries

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

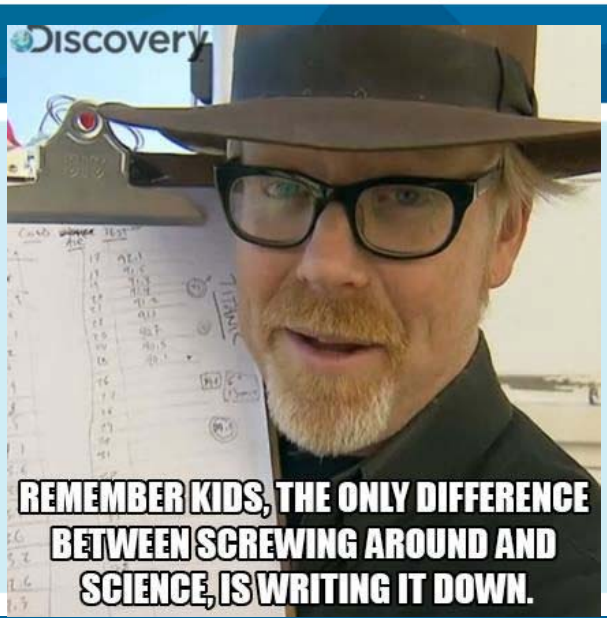
- Conquer HSC Chemistry: https://www.conquerhsc.com/hsc-chemistry-syllabus-notes/
- Tutor Pro: https://tutorpro.com.au/le-chatelier-principle-equilibrium-guide/
- Dux College: https://dc.edu.au/hsc-chemistry-topic-1-equillbrium-and-acid-reactions/
- Col Harrison YouTube video's: https://www.youtube.com/channel/UCkdi7YOXBGAapx_dR40UoFQ
- Khan Academy: https://www.khanacademy.org/science/chemistry/chemical-equilibrium
- NESA Sample questions: https://syllabus.nesa.nsw.edu.au/assets/chemistry/files/sample-questions-new-hsc-chemistry-exam-2019.pdf
- ATAR Notes: https://atarnotes.com/hsc-resources-atar-notes/

AURORA COLLEGE
IGNITING NEW WAYS OF LEARNING

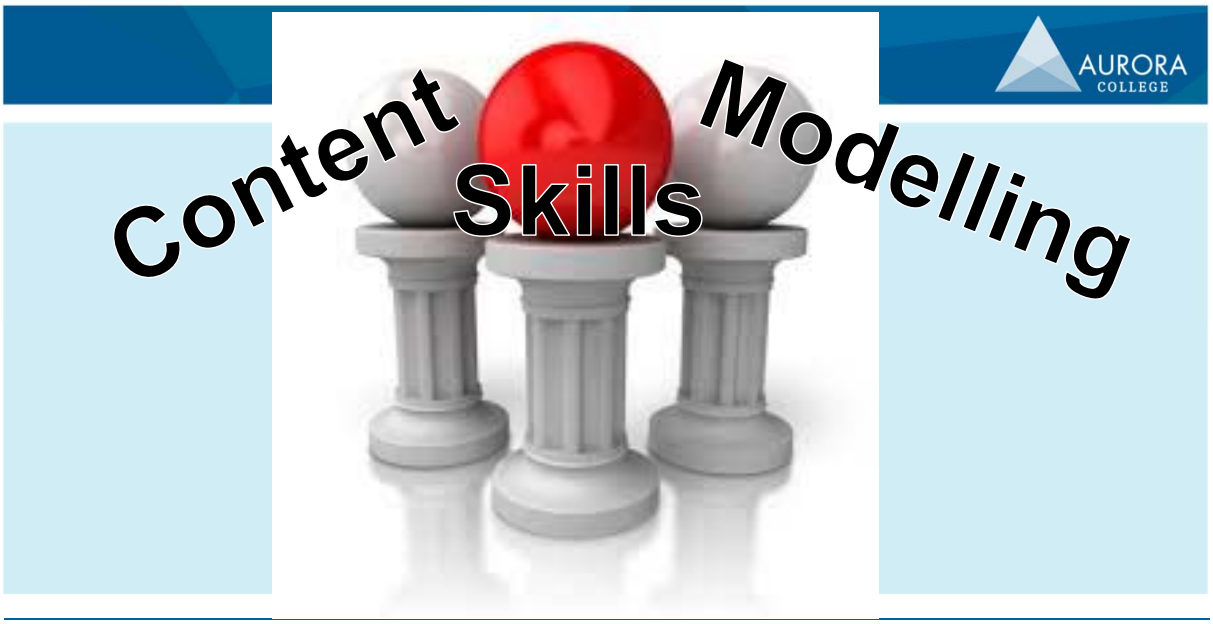
Thursday 27 June 2019

Module 6:

Dr Anthony Scarman, Gorokan High School



Aurora College | Igniting new ways of learning www.aurora.nsw.edu.au



Module 6

Expectations

- How and why the definitions of an acid/base have changed over time
- Acids react in particular ways to a variety of substances
- Acid/base reactions are used extensively in everyday life and the human body,
- Industry and the environment
- Qualitative and quantitative monitoring
- pH, buffers and stoichiometry

Module 6

Criteria	Marks
• Provides TWO substantially correct structural formulae	2
• Provides some relevant information	1

Module 6

Criteria	Marks
• Provides correct steps in the calculation of the equilibrium concentration of HI	4
• Solves equilibrium expression, using appropriate equilibrium concentrations	3
• Provides some relevant calculations steps	2
• Provides some relevant information	1

Aurora College | Igniting new ways of learning www.aurora.nsw.edu.au

Module 6

AURORA COLLEGE

Criteria	Marks
• Shows how emission spectroscopy and chromatography are similar and/or different in the analysis of small samples in forensic investigations • Shows a thorough understanding of emission spectroscopy and chromatography in this aspect	7
• Shows how emission spectroscopy and chromatography are similar and/or different in the analysis of small samples in forensic investigations • Shows a sound understanding of emission spectroscopy and chromatography in this aspect	6
• Describes emission spectroscopy and/or chromatography in relation to the analysis of small samples in forensic investigations	4–5
• Outlines features of emissions spectroscopy and/or chromatography	2–3
• Provides some relevant information	1

Module 6

AURORA COLLEGE

How do I get full marks?

- TXXX
  - Topic
  - Explain
  - Expand
  - Example/Equation
- SPUCHEB
  - Significant figures
  - Phases
  - Units
  - Conditions
  - Hazards
  - Equations
  - Balanced!

Aurora College | Igniting new ways of learning www.aurora.nsw.edu.au

Module 6: Content

- **Investigate** the correct IUPAC nomenclature and properties of common inorganic acids and bases (ACSCH067)
- **Predict** the products of acid reactions and write balanced equations to represent: acids and bases, acids and carbonates, acids and metals (ACSCH067)
- **Investigate** applications of neutralisation reactions in everyday life and industrial processes

Module 6: Content

- **Explore** the changes in definitions and models of an acid and a base over time to explain the limitations of each model, including but not limited to: Arrhenius' theory, Bronstead-Lowry theory (ACSCH064, ACSCH067) (*and Modelling)*
- **Calculate** pH, pOH, hydrogen ion concentration([H+]) and hydroxide ion concentration ([OH-]) for a range of solutions (ACSCH102)
- **Write** ionic equations to represent the dissociation of acids and bases in water, conjugate acid/base pairs in solution and amphiprotic nature of some salts, for example: sodium hydrogen carbonate, potassium dihydrogen phosphate

Module 6: Content

- **Calculate** the pH of the resultant solution when solutions of acids and/or
- bases are diluted or mixed

Investigate titration curves and conductivity graphs to analyse data to indicate characteristic reaction profiles, for example:
Strong acid/strong base
Strong acid weak base
Weak acid strong base (ACSCH080, ACSCH102)

Calculate and apply the dissociation constant (K_a) and pK_a to determine the difference between strong and weak acids (ACSCH098)

Module 6: Content

Explore acid/base analysis techniques that are applied:
in industries
by Aboriginal and Torres Strait Islander Peoples
Using digital probes and instruments

describe the importance of buffers in natural systems (ACSCH098, ACSCH102)

Aurora College | Igniting new ways of learning www.aurora.nsw.edu.au

Module 6: Skills

- **Conduct** an investigation to demonstrate the preparation and use of
- indicators as illustrators of the characteristics and properties of acids
- and bases and their reversible reactions (ACSCH101)

- **Conduct** a practical investigation to measure the enthalpy of
- neutralisation (ACSCH093)

- **Conduct** a practical investigation to measure the pH of a range of acids
- and bases

Module 6: Skills

Conduct an investigation to demonstrate the use of pH to indicate the differences between strength of acids and bases (ACSCH102)

Conduct practical investigations to analyse the concentration of an unknown acid or base by titration

Conduct a chemical analysis of a common household substance for its acidity or basicity (ACSCH080), for example: Soft drink, wine, juice, medicine

conduct a practical investigation to prepare a buffer and demonstrate its properties (ACSH080)

Module 6: Modelling

- **Explore** the changes in definitions and models of an acid and a
- Base over time to explain the limitations of each model,
- including but not limited to: Arrhenius' theory, Bronstead-Lowry
- theory (ACSCH064, ACSCH067) (*and Content)*

- **Construct** models and/or animations to communicate the differences
- between strong, weak concentrated and dilute acids and bases (ACSCH099)

- **Model** neutralisation of strong and weak acids and bases using a variety of
- media

Module 6: Question: Content

Mod 6 – Question 4

Which of the following is the conjugate base of the dihydrogen phosphate ion ($H_2PO_4^{-1}$)?

A. H_3PO_4

B. HPO_4^{-2}

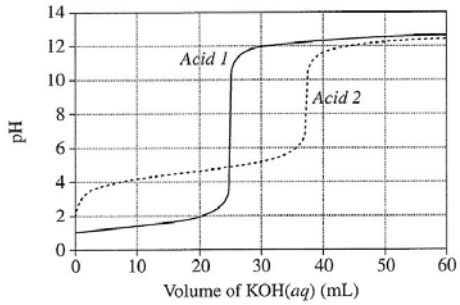
C. PO_4^{-3}

D. OH^{-1}

Module 6: Question: Content

Mod 6 – Question 11 (3 marks)

The graph shows changes in pH for the titrations of equal volumes of solutions of two monoprotic acids, *Acid 1* and *Acid 2*.



Explain the differences between *Acid 1* and *Acid 2* in terms of their relative strengths and concentrations.

Module 6: Question: Content

Write a general expression for the acid dissociation constant of the following reaction, a dissociation of ethanoic acid:

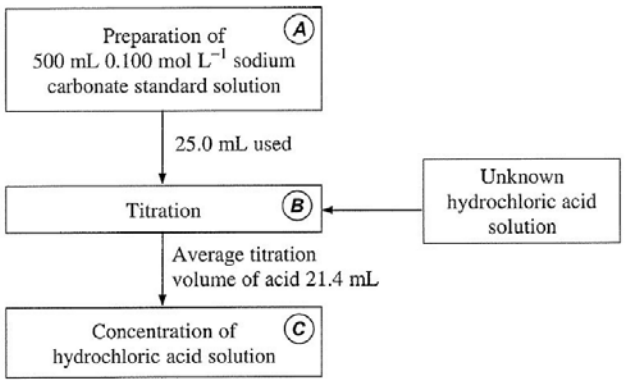
$CH_3COOH + H_2O \rightarrow H_3O^+ + CH_3COO^-$

Then calculate its actual value if $[CH_3COOH] = 2.34 \times 10^{-4}$ and $[CH_3COO^-] = 6.51 \times 10^{-5}$.

Module 6: Question: Skills

Mod 6 – Question 14 (8 marks)

The flowchart shown outlines the sequence of steps used to determine the concentration of an unknown hydrochloric acid solution.

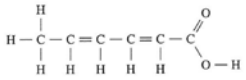


Describe steps A, B and C including correct techniques, equipment and appropriate calculations. Determine the concentration of the hydrochloric acid.

Module 6: Question: Modelling

Mod 6 – Question 1

The structure of an organic compound is shown.

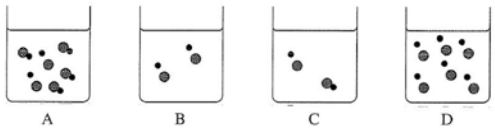


Which row of the table correctly shows how this compound reacts with bromine water and with blue litmus?

	Bromine water	*Blue litmus*
A.	No reaction	No reaction
B.	No reaction	Turns red
C.	Decolourises	No reaction
D.	Decolourises	Turns red

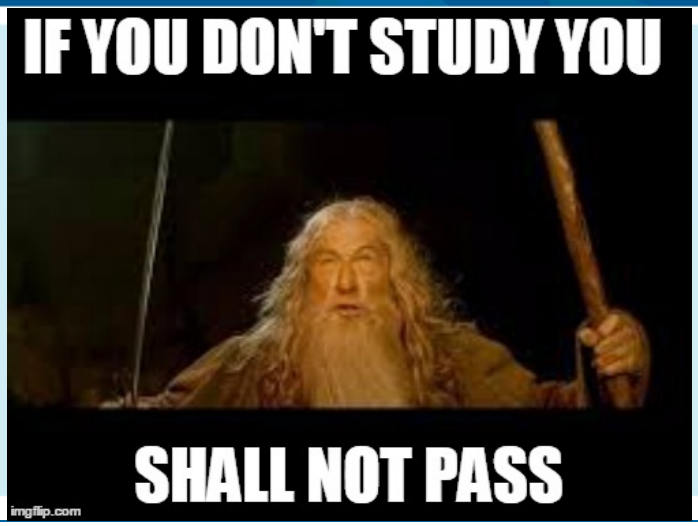
Mod 6 – Question 3

Which beaker contains a concentrated strong acid?



Module 6

- Remember:
- Be able to draw/read graphs
- Spend more time studying the things you don't know so well – "Strengthen your weaknesses"
- Make a list of the equations you'll need to know (include SPUCHEB)
- Make a list of the pracs that you carried out and their details


IF YOU DON'T STUDY YOU
SHALL NOT PASS
imgflip.com

HSC Chemistry

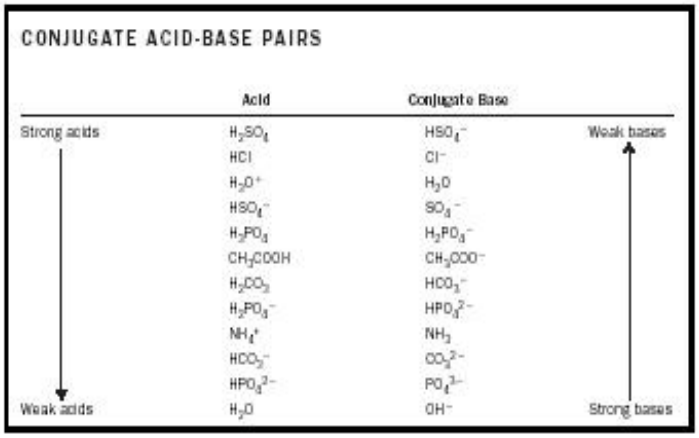
Module 6: Acid/Base reactions

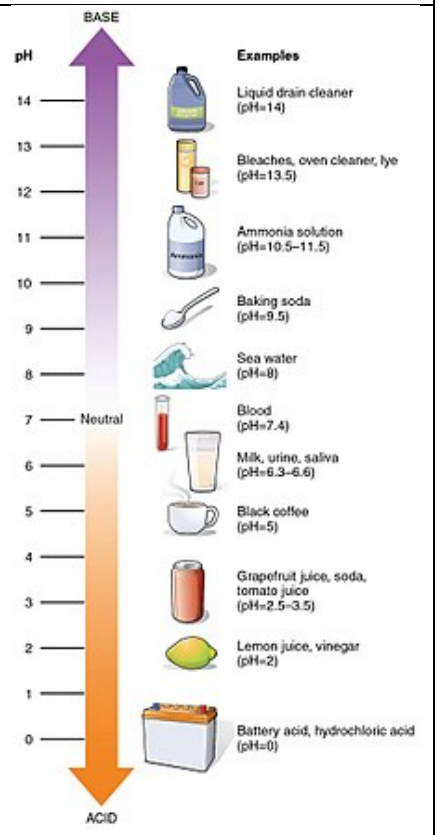
Properties of Acids and Bases

Enquiry question: What is an acid and what is a base?

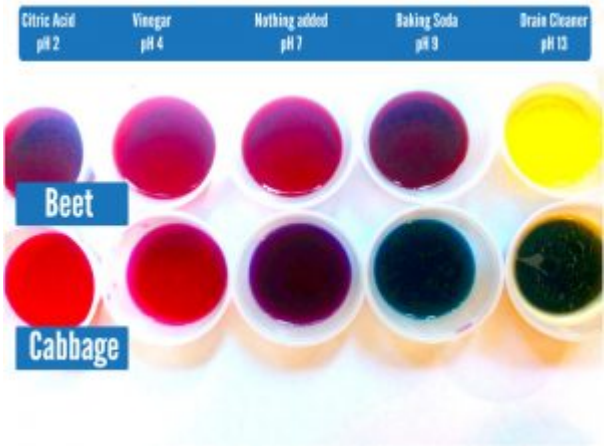
- **Investigate** the correct IUPAC nomenclature and properties of common inorganic acids and bases (ACSCH067)

6 Strong Acids		6 Strong Bases	
$HClO_4$	perchloric acid	LiOH	lithium hydroxide
HCl	hydrochloric acid	NaOH	sodium hydroxide
HBr	hydrobromic acid	KOH	potassium hydroxide
HI	hydroiodic acid	$Ca(OH)_2$	calcium hydroxide
HNO_3	nitric acid	$Sr(OH)_2$	strontium hydroxide
H_2SO_4	sulfuric acid	$Ba(OH)_2$	barium hydroxide





- **Conduct** an investigation to demonstrate the preparation and use of indicators as illustrators of the characteristics and properties of acids and bases and their reversible reactions (ACSCH101)



- **Predict** the products of acid reactions and write balanced equations to represent: acids and bases, acids and carbonates, acids and metals (ACSCH067)

Reactants	Products	Method
Soluble base + Acid (dil)	Salt + water	Neutralisation Titration
Metal + Non-metal	Salt (soluble/insoluble)	Direct Combination
Insoluble base +	Salt (soluble) + water	……
Active metal + Acid (dil)	Salt + Hydrogen	Displacement
Soluble salt solution (A) + Soluble salt solution (B)	Precipitated salt + Soluble salt	Precipitation
Carbonate /bicarbonate + Acid (dil)	Salt + Water+ Carbon dioxide	Decomposition of carbonate
Chlorides/nitrates + Acid (conc)	Acid salt + HCl/HNO_3	Decomposition of chlorides and nitrates

- **Investigate** applications of neutralisation reactions in everyday life and industrial processes
  - **Antacids**
  - **Soil (basic or acidic)**
  - **Wasp stings (vinegar)**
  - **Bee stings (Baking powder)**
  - **Toothpaste (alkaline)**
  - **Commercial: acidic effluents (electroplating industry)**
  - **Commercial: acidic gas (energy production)**

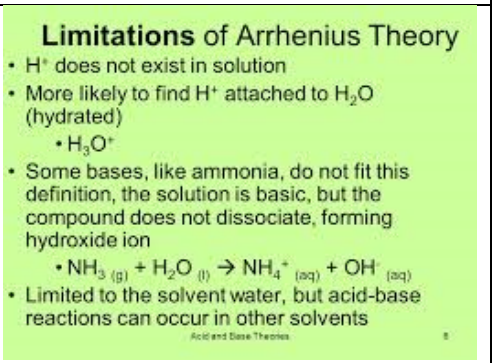
- **Conduct** a practical investigation to measure the enthalpy of neutralisation (ACSCH093)
  - **Measure** accurately volume of acidic and basic solutions; MUST know concentrations.
  - **Place** one solution in calorimeter, record temperature.
  - **Add** the other solution stir
  - **Record** the highest temperature reached
  - **Calculate** the enthalpy of neutralisation:
  - $\triangle H$ = -mass of water x specific heat x temperature change (Specific heat of water = 4.18 Jg^-1K^-1)

- **Explore** the changes in definitions and models of an acid and a base over time to explain the limitations of each model, including but not limited to: Arrhenius' theory, Bronstead-Lowry theory (ACSCH064, ACSCH067)

Antoine Lavoisier: His idea was that acidity was caused by the presence of oxygen in the compound.

Humphry Davy: reacted many metals and non-metals with oxymuriatic acid and never obtained oxygen nor did he obtain any oxygen compounds; hydrogen confers the generic property of acid.

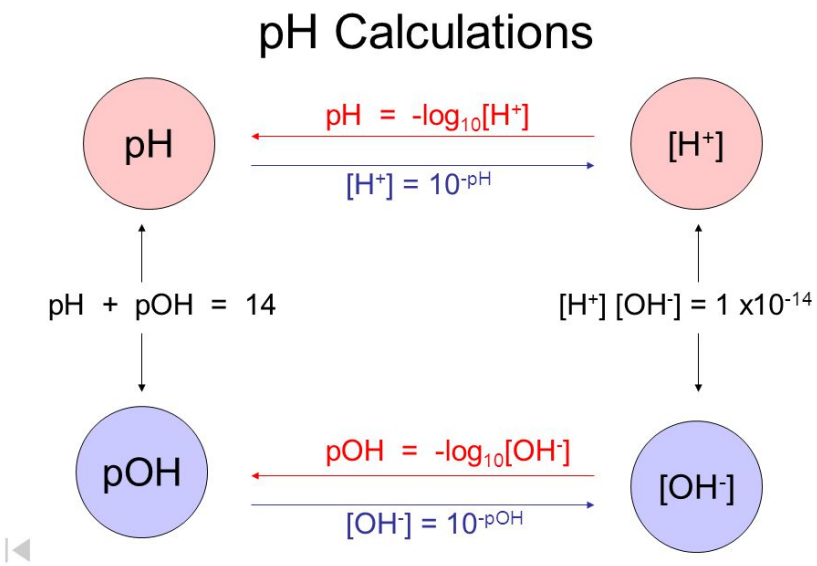
Arrhenius theory: acids are neutral substances that dissolve in water and dissociate to form positive hydrogen ions and a negative ion.



Bronsted-Lowry theory: acid donates a proton (hydrogen ion) to a base; base accepts a proton from an acid. Does not have to be in water. Every acid is a conjugate pair (substances that have one proton less that the acid eg HCL ←→ Cl^-). Substances that can act as both Bronsted-Lowry acid and base (eg water) are said to be amphiprotic.

Using Bronsted-Lowry Theory

Inquiry question: What is the role of water in solutions of acids and bases?

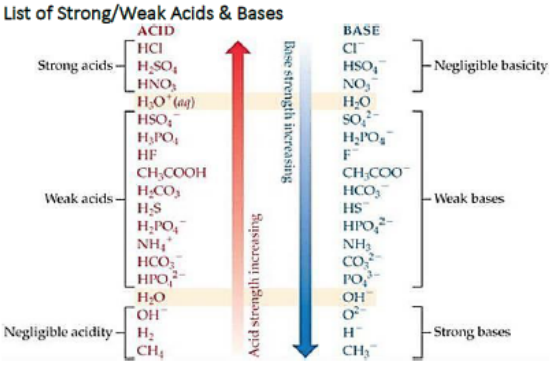
• **Conduct** a practical investigation to measure the pH of a range of acids and bases	**Procedure**: 400-mL beaker, ring stand, wire gauze, Bunsen burner, large test tubes, dropper pipet, stirring rod, wash bottle with distilled water, laboratory pH meter, 0.1 M acetic acid, 0.1 M hydrochloric acid, 0.1 M sodium hydroxide, pH paper • Prepare pH indicator and pH standards • Qualitative Analysis for pH Values of Everyday Chemicals (pH paper) • Quantitative Analysis for pH Values of Everyday Chemicals (probe) • Effect of Buffers on pH
• Calculate pH, pOH, hydrogen ion concentration([H+]) and hydroxide ion concentration ([OH-]) for a range of solutions (ACSCH102)	

- **Conduct** an investigation to demonstrate the use of pH to indicate the differences between strength of acids and bases (ACSCH102)

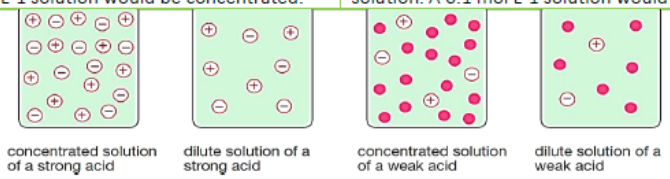
Strong Vs Weak Bases

	Strong	Weak
Extent of ionisation	Undergoes full dissociation '→'	Undergoes partial dissociation '⇌'
Ionisation equation	$BOH_{(aq)} \rightarrow B^+_{(aq)} + OH^-_{(aq)}$	$B_{(aq)} + H_2O_{(l)} \rightleftharpoons BH^+_{(aq)} + OH^-_{(aq)}$
Description	0% base intact, 100% ions ∴ No equilibrium	80-99% base intact, 1-20% ions ∴ Equilibrium lies well to the left
Examples	NaOH, KOH, $Ba(OH)_2$, $Mg(OH)_2$,$Ca(OH)_2$,	NH_3, NH_4OH, NaF, Na_2SO_4, $NaCH_3COO$, Na_2CO_3, $NaHCO_3$, Na_3PO_4

List of Strong/Weak Acids & Bases



Concentrated Vs Dilute

	Concentrated	Dilute
Definition	Contains a large amount of solute in a given amount of solution. A 5 mol L-1 solution would be concentrated.	Contains a small amount of solute in a given amount of solution. A 0.1 mol L-1 solution would be dilute.
Description	 concentrated solution of a strong acid; dilute solution of a strong acid; concentrated solution of a weak acid; dilute solution of a weak acid ○ A concentrated solution of a strong acid has a larger number of ions than a dilute solution of the same acid. ○ A concentrated solution of a weak acid has a high number of un-ionised molecules and few ions. A dilute solution of a weak acid has fewer particles than the concentrated weak solution, but the degree of ionisation is still the same.	

- **Write** ionic equations to represent the dissociation of acids and bases in water, conjugate acid/base pairs in solution and amphiprotic nature of some salts, for example:
  * sodium hydrogen carbonate,
  * potassium dihydrogen phosphate

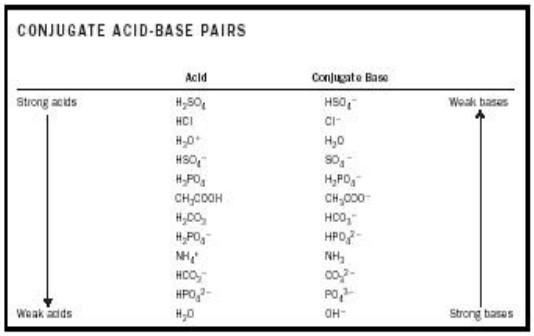
Net Ionic Equation

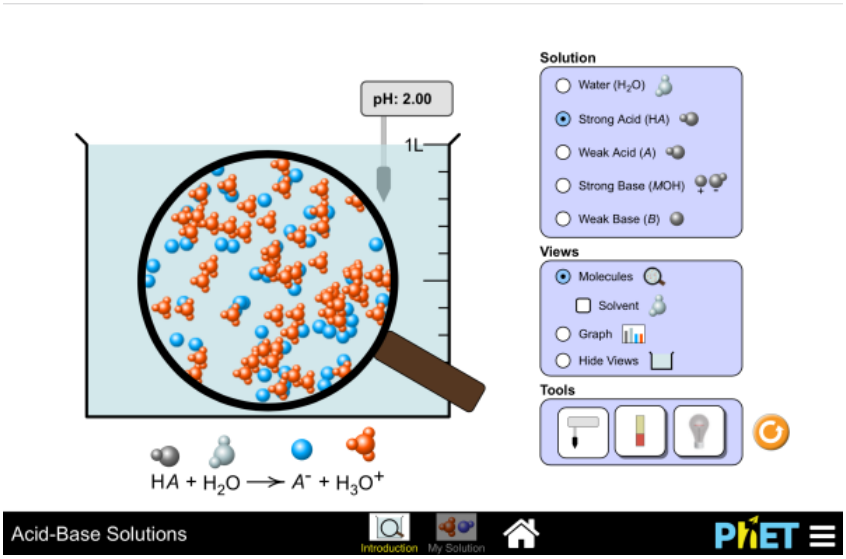
- Net ionic equations are used to show only the chemicals and ions involved in a chemical reaction in order to simplify information about a reaction.
- The ions that are not involved in the reaction are called spectator ions and are removed from the reaction.

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

$Na^+ + OH^- + H^+ + Cl^- \rightarrow Na^+ + Cl^- + H_2O(l)$

$OH^- + H^+ \rightarrow H_2O(l)$

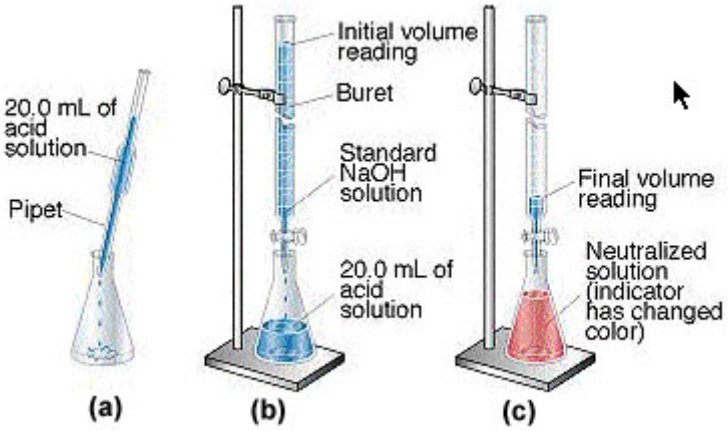


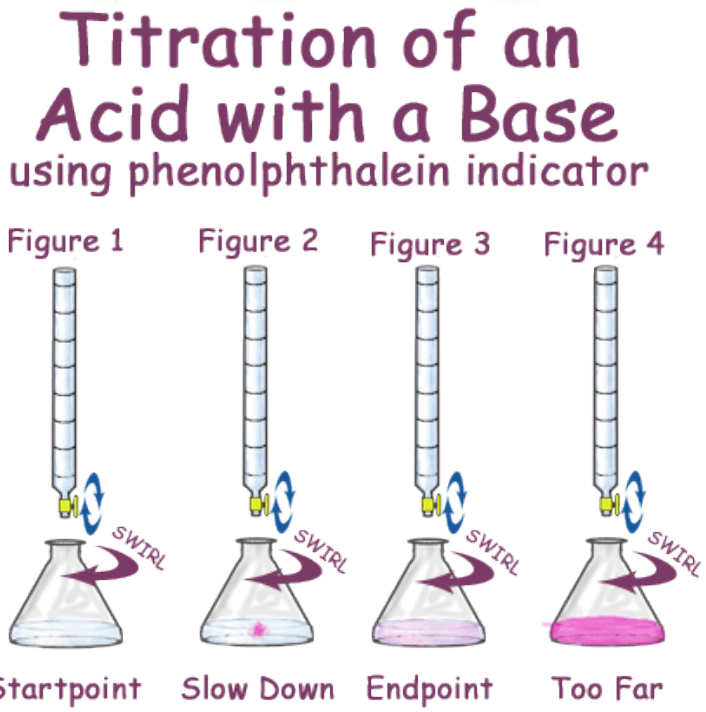
	Amphiprotic Compounds • A substance that is capable of both donating and accepting a proton is an ***amphiprotic*** compound. • $NaHCO_3$ is an example: – $HCl(aq) + NaHCO_3(aq) \rightarrow NaCl(aq) + H_2CO_3(aq)$ – $NaOH(aq) + NaHCO_3(aq) \rightarrow Na_2CO_3(aq) + H_2O(l)$ • **$NaHCO_3$** accepts a proton from HCl in the first reaction and donates a proton to NaOH in the second reaction. 24 **Dihydrogen phosphate $H_2PO_4^-$** is another important **amphoteric** ion. **as acid** $H_2PO_4^- \rightleftharpoons HPO_4^{-2} + H^+$ **as base** $H_2PO_4^- + H^+ \rightleftharpoons H_3PO_4$
• **Construct** models and/or animations to communicate the differences between strong, weak concentrated and dilute acids and bases (ACSCH099)	
• **Calculate** the pH of the resultant solution when solutions of acids and/or bases are diluted or mixed	**Diluting an acid or alkali** pH of diluted strong acid $[H^+] = [H^+]_{old} \times \frac{\text{old volume}}{\text{new volume}}$ $pH = -\log [H^+]$ pH of diluted base $[OH^-] = [OH^-]_{old} \times \frac{\text{old volume}}{\text{new volume}}$ $[H^+] = \frac{K_w}{[OH^-]}$ $pH = -\log [H^+]$ **Example 11** Calculate the new pH when 50.0 cm^3 of 0.150 mol dm^{-3} HCl is mixed with 500 cm^3 of water. $[H^+] = [H^+]_{old} \times \frac{\text{old volume}}{\text{new volume}}$ $[H^+_{(aq)}] = 0.150 \times \frac{0.05}{0.55}$ $[H^+_{(aq)}] = 0.0136$ $pH = -\log [H^+]$ $= -\log 0.0136$ $= 1.87$

Quantitative Analysis

Inquiry question: How are solutions of acids and bases analysed?

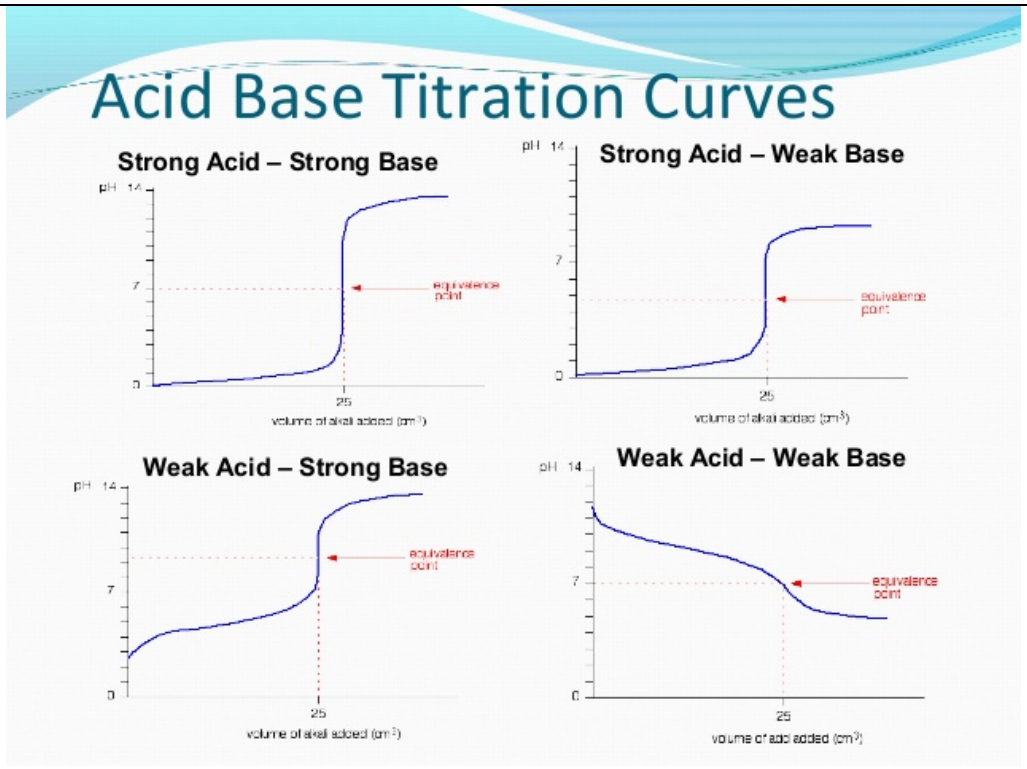
- **Conduct** practical investigations to analyse the concentration of an unknown acid or base by titration



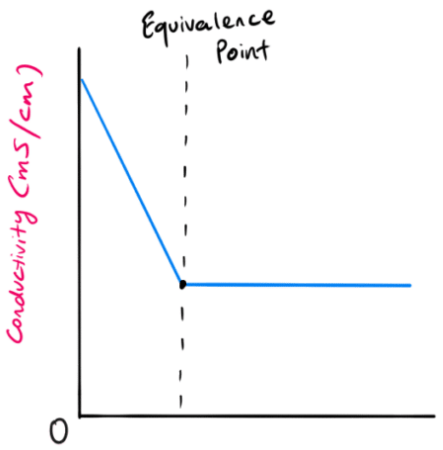


- **Investigate** titration curves and conductivity graphs to analyse data to indicate characteristic reaction profiles, for example:

Strong acid/strong base
Strong acid weak base
Weak acid strong base
(ACSCH080, ACSCH102)

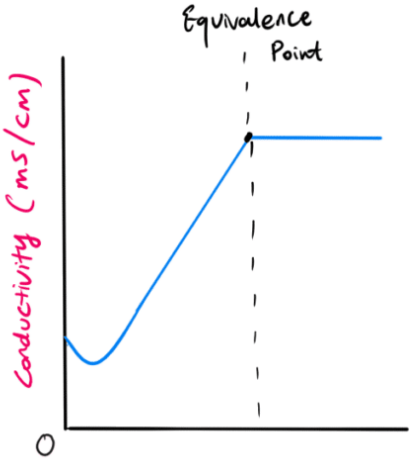


STRONG ACID W/ WEAK BASE



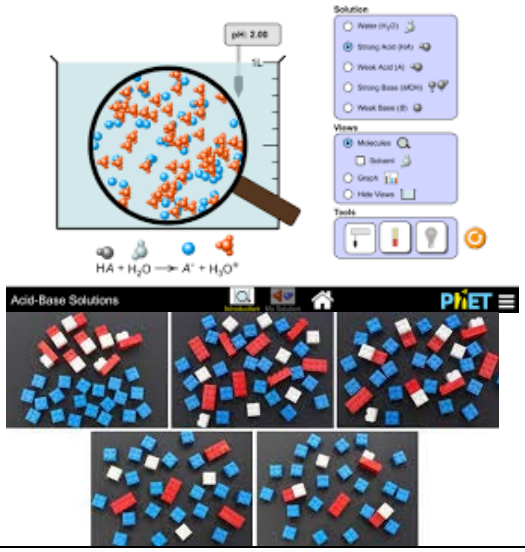
Volume of WEAK BASE added (mL)

WEAK ACID W/ WEAK BASE



Volume of WEAK BASE added (mL)

- **Model** neutralisation of strong and weak acids and bases using a variety of media



- **Calculate** and apply the dissociation constant (K_a) and pK_a to determine the difference between strong and weak acids (ACSCH098)

pH of Weak Acids and Bases

Acid Dissociation Constant, K_a

- Weak Acid dissociates partially in water :
- $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$
- The acid dissociation constant, K_a :

$$K_a = \frac{[H_3O^+]\,[A^-]\ \text{mol dm}^{-3}}{[HA]}$$

$$pK_a = -\log 10\, K_a$$

- The K_a value is the measure of the **strength of acids.**
- Larger K_a value (smaller pK_a), stronger acid.

acid	K_a	pK_a	relative strength
CH_3COOH	1.8×10^{-5}	4.7	acid becomes stronger
C_6H_5COOH	6.5×10^{-5}	4.2	
$HCOOH$	1.8×10^{-4}	3.7	
$ClCH_2COOH$	1.5×10^{-3}	2.8	

8-2 Weak Acids and Bases

- **Weak acid/base *do not* completely dissociate**
  - Dissociation constant (K_a) for the weak acid HA:

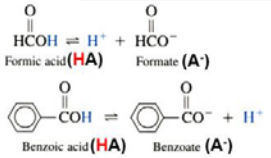
$$HA \overset{K_a}{=} H^+ + A^- \qquad K_a = \frac{[H^+][A^-]}{[HA]} \qquad (8\text{-}3)$$

  - Base Hydrolysis constant (K_b) for the weak base B:

$$B + H_2O \overset{K_b}{=} BH^+ + OH^- \qquad K_b = \frac{[BH^+][OH^-]}{[B]} \qquad (8\text{-}4)$$

$pK_a = -\log K_a \qquad pK_b = -\log K_b$

- As K_a or K_b increase → pK_a or pK_b decrease
- *Smaller pK_a → stronger acid*



$K_a = 1.80 \times 10^{-4}$, $pK_a = 3.744$

$K_a = 6.28 \times 10^{-5}$, $pK_a = 4.202$

Formic acid stronger acid than benzoic acid

- **Conjugate acid-base pair** $K_a \cdot K_b = K_w$ (8-5)

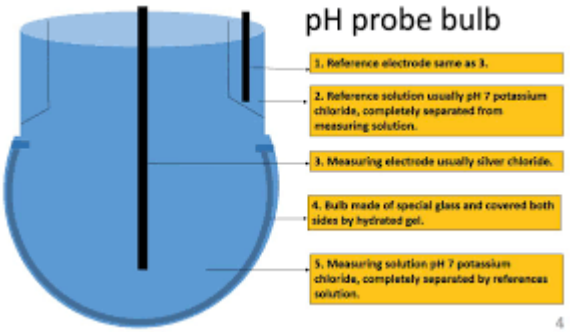
- **Explore** acid/base analysis techniques that are applied:
- in industries
- by Aboriginal and Torres Strait Islander Peoples
- Using digital probes and instruments

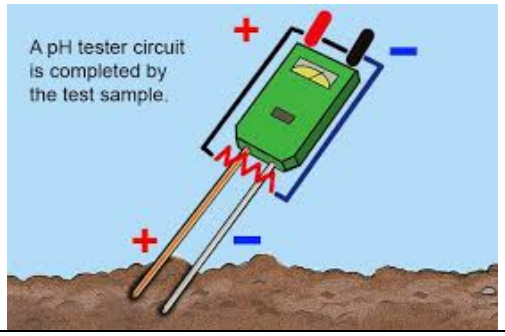
Chemical Industry
Food and Beverage Industry
Electroplating
Pharmaceutical
Petrochemical
Environmental

INDUSTRY

PIGMENT MIXTURES
TRADITIONAL FOOD AND MEDICINES
SOIL MANAGEMENT

ABORIGINAL AND TORRES STRAIT ISLANDER PEOPLES





- **Conduct** a chemical analysis of a common household substance for its acidity or basicity (ACSCH080), for example:
- Soft drink
- wine
- juice
- medicine

pH Determination of Household Products

Objectives:

1. Predict the pH value of substances & estimate the pH value by using the red cabbage juice indicator
2. Use the indicator to identify acidic, basic, and neutral substances found in any home
3. Classify household items as acids and bases
4. Collect and analyze data
5. Organize and analyze results in tables and graphs
   a. **Hypothesis/prediction:** All items used to clean will be more like (acids/bases) because _____ _____ and items used as foods will be more like (acids/bases) because _____.
   b. The **indicator** being used is _____.
   c. The **independent variable** is _____ and the **dependent variable** is _____.

Materials: **Test Solutions:**

7 test tubes
Test tube rack
10 mL graduated cylinder
50 mL beaker

1. White grape juice
2. Sprite
3. Vinegar
4. Seltzer water
5. Hand sanitizer
6. Baking soda
7. Bubbles

PROCEDURE

Create a Data Table: *Read the procedure to decide what information you should include!*

Estimating pH values with red cabbage indicator

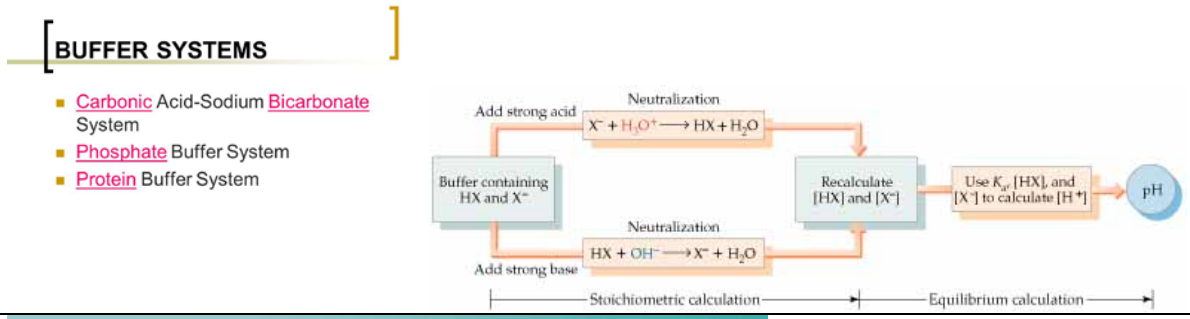
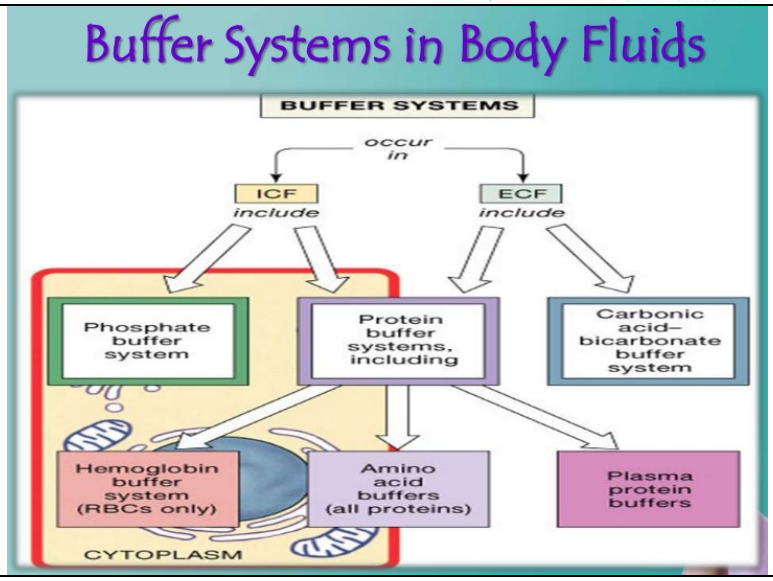
1. Write the name of each household product to be tested in your data table.
2. predict each substance as basic, neutral, or acidic
3. put on your safety goggles
4. In a 50mL beaker, obtain about 30 mL of the red cabbage indicator, record its color in your data table
5. place a piece of white paper under the test tube rack, write the number of each substance to be tested (*based on the the way you numbered them on the data table*) on the paper in front of each of the seven test tubes.
6. Add about 3 mL of red cabbage indicator to all the test tubes. (*use a 10 mL graduated cylinder*)
6. To each test tube with indicator, add drop by drop (*using a different plastic pipet for each substance*) up to 3 mL of (*1mL = 16 drops*) the substance to be tested & record the color change of the indicator.
7. Organize all test tubes from most acidic to most basic using the pH scale for red cabbage juice as a guide. *(red cabbage pH scale provided on the back of this page)*
8. Estimate the pH value of each substance by using the pH scale for red cabbage juice
9. Classify each product as acid, base, or neutral!

CLEAN UP! Pour all substances into the sink followed by water. Rinse each used test tube. After removing the white paper from below the test tube rack, set a clean paper towel below it. Set the rinsed test tubes upside-down in the test tube rack.

Example Data Table

DATA Table 1 **pH of Common Household Products**

Household Product	**Prediction → Acid, Base, Neutral**	*Initial color of product*	*Initial color of indicator*	*Final color*	**Estimated pH Values**	**Acid**	**Base**	**Neutral**
1.								

• **conduct** a practical investigation to prepare a buffer and demonstrate its properties (ACSH080)	
• **describe** the importance of buffers in natural systems (ACSCH098, ACSCH102)	

•	**Remember: TXXX** • **Topic** • **Explain** • **Expand** • **Example/Equation**
•	**Remember: SPUCHEB** • **Significant figures** • **Phases** • **Units** • **Conditions** • **Hazards** • **Equations** • **Balanced!**

NSW Department of Education

Stage 6 Chemistry Module 7

Joshua Westerway

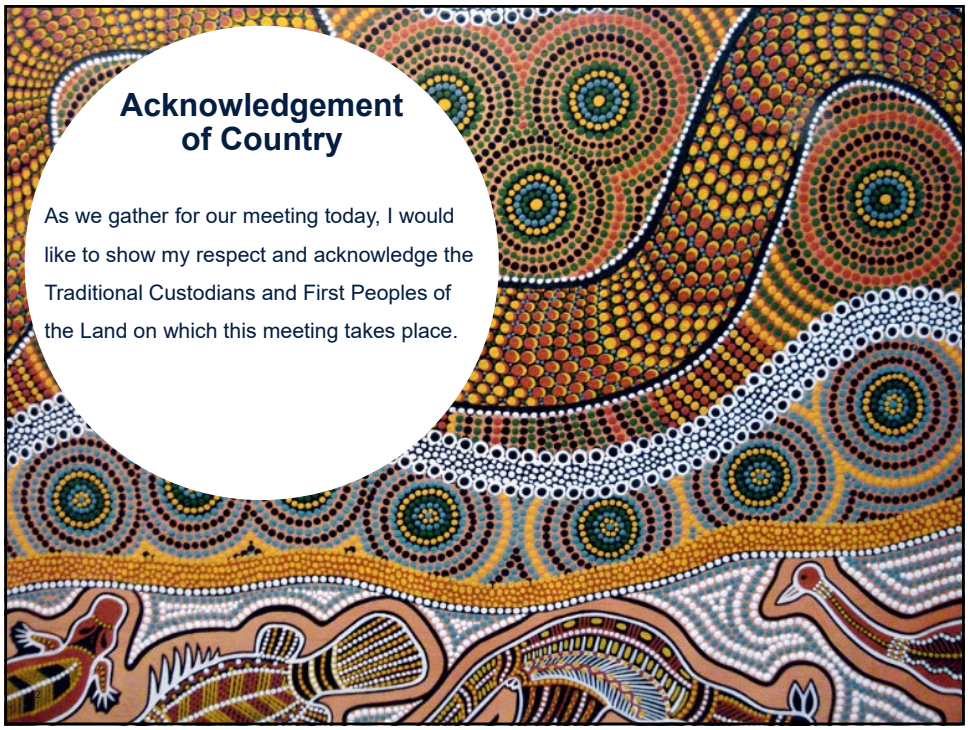
Curriculum Support Project Officer Science 7-12

NSW GOVERNMENT

1

Acknowledgement of Country

As we gather for our meeting today, I would like to show my respect and acknowledge the Traditional Custodians and First Peoples of the Land on which this meeting takes place.



2

NSW Department of Education

1) How do we systematically name organic chemical compounds?

General principles

- Irrespective of functional group
- Naming priority (ext)
- Cyclic and aromatic (ext)

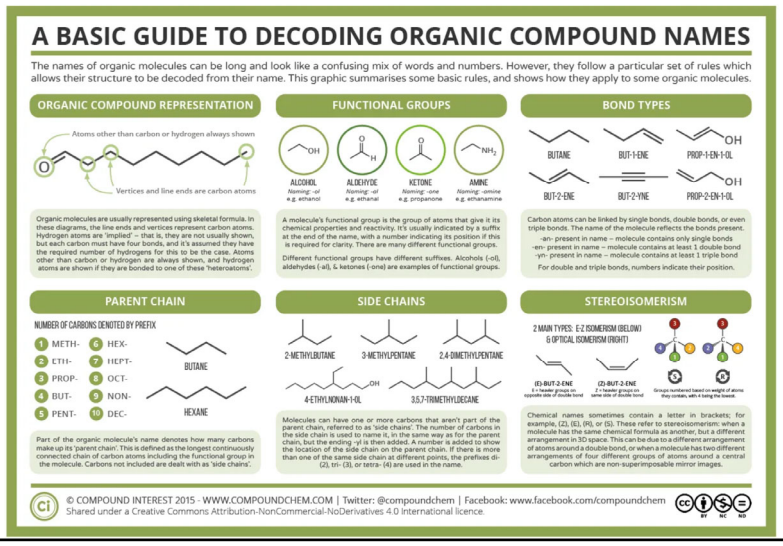
Prefix	Carbons	Prefix	Carbons
meth-	1	undec-	11
eth-	2	dodec-	12
prop-	3	tridec-	13
but-	4	tetradec-	14
pent-	5	pentadec-	15
hex-	6	hexadec-	16
hept-	7	heptadec-	17
oct-	8	octadec-	18
non-	9	nonadec-	19
dec-	10	eicos-	20

1. Identify the parent chain (longest carbon chain)
2. Identify the functional group (prefix/suffix)
3. Allocate locant numbers for functional groups on the parent chain (lowest first point of difference)
4. Name the compound backwards: locant-prefix, parent-locant-suffix

NSW Department of Education

How do we systematically name organic chemical compounds?

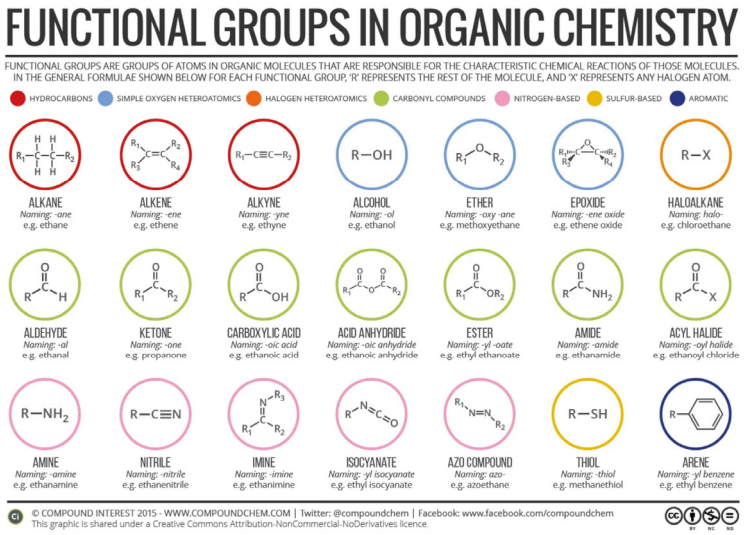
Basic guides



NSW Department of Education

How do we systematically name organic chemical compounds?

Functional groups

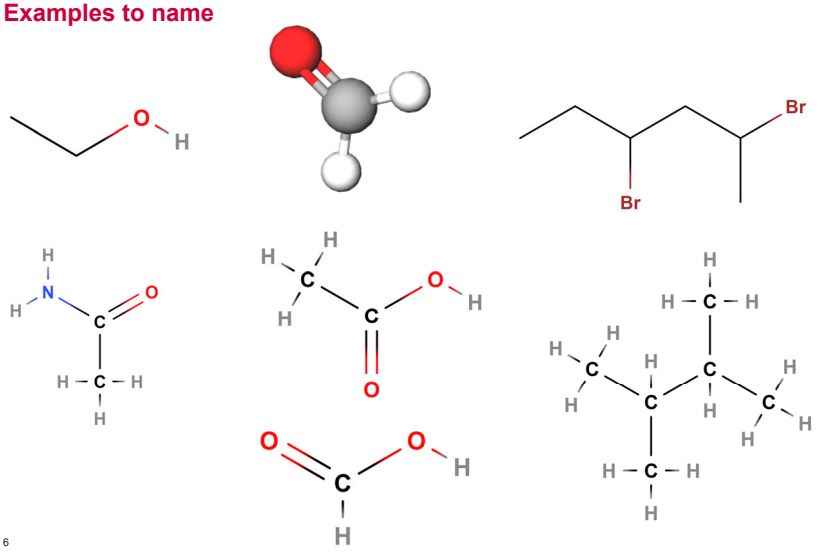


5

NSW Department of Education

How do we systematically name organic chemical compounds?

Examples to name



6

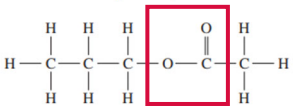
NSW Department of Education

Exam question

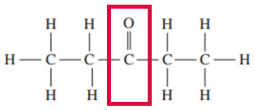
2019 Chemistry exam Q1

1 Which structural formula represents pentan-2-one?

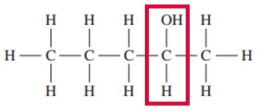
A.



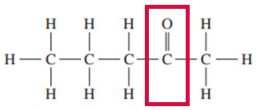
B.



C.



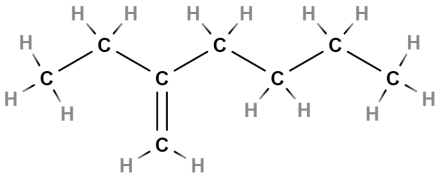
D.

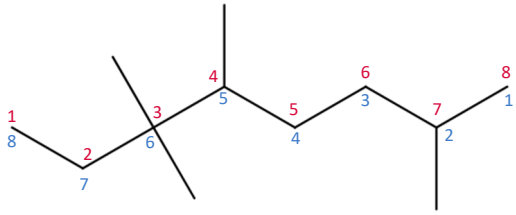


NSW Department of Education

How do we systematically name organic chemical compounds?

More complex examples





NSW Department of Education

How do we systematically name organic chemical compounds?

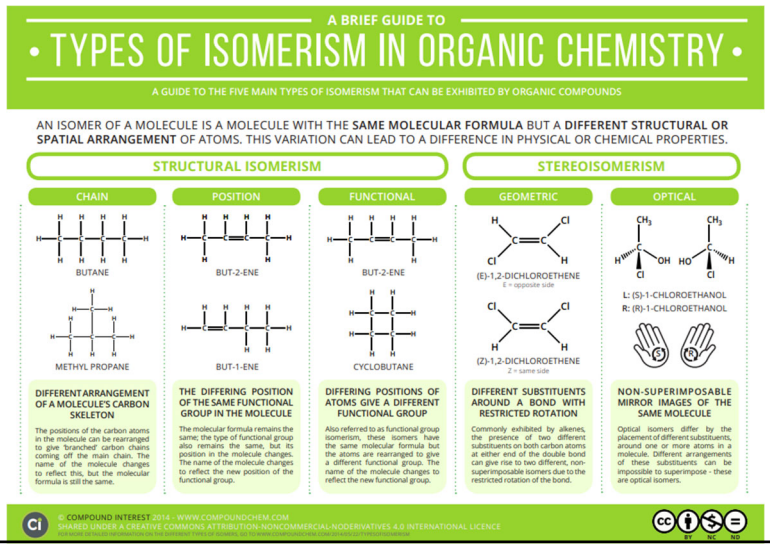
Isomers

- Isomers? Think about family members. Some can be closer relations than others.
- First step – what is the molecular formula?
  - Same = family = isomers of some type
  - Different = non-family = not isomers
- Second step – what is different about the family member?

NSW Department of Education

How do we systematically name organic chemical compounds?

Isomers

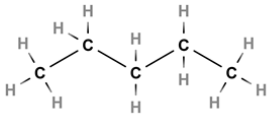


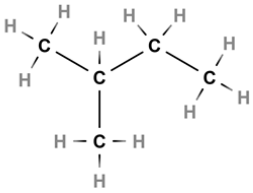
NSW Department of Education

How do we systematically name organic chemical compounds?

Chain isomers

- Connection only = chain, very close relatives e.g. siblings as many will have very similar physical/chemical properties





NSW Department of Education

Exam question

Chemistry specimen exam Q4

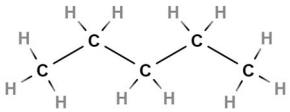
4 How many chain isomers does pentane have?

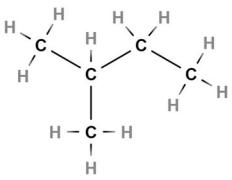
A. 1

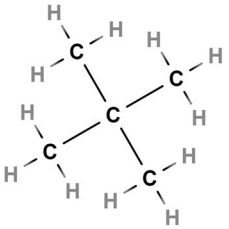
B. 2

C. 3

D. 4





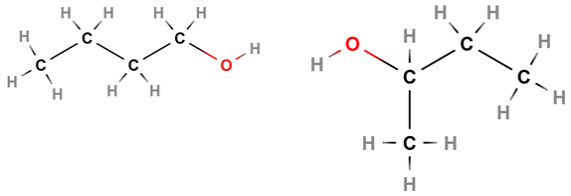


NSW Department of Education

How do we systematically name organic chemical compounds?

Positional isomers

- Connection of a functional group = positional, close relatives e.g. uncle/aunt, similar properties but can differ by larger amounts

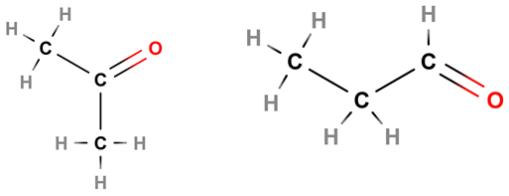


NSW Department of Education

How do we systematically name organic chemical compounds?

Functional group isomers

- Functional group = functional group, related family members but further apart e.g. cousins as once the functional group changes this can make the chemical/physical properties differ to larger amounts.

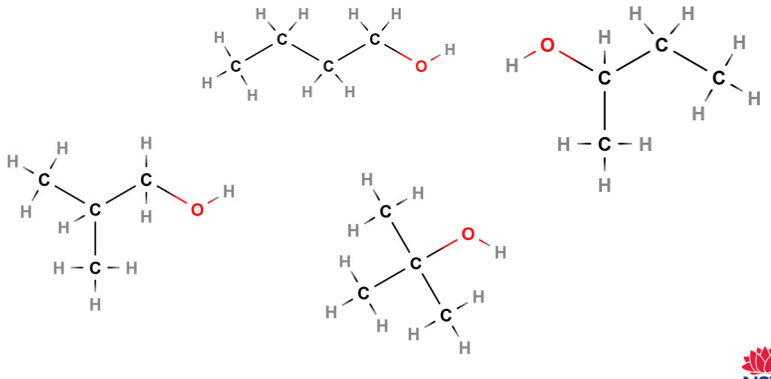


NSW Department of Education

How do we systematically name organic chemical compounds?

Isomers of butanol

- Combination – online calculator
- C_4H_9OH



NSW Department of Education

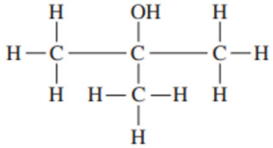
Exam question

2019 Chemistry exam Q21

Question 21 (7 marks)

(a) The structural formula for 2-methylpropan-2-ol is shown in the table. **2**

Draw one structural isomer of this alcohol and state its name.

	Alcohol	*Isomer*
Structure		
Name	2-methylpropan-2-ol	

NSW Department of Education

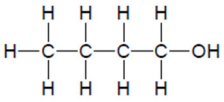
Exam question

2019 Chemistry exam Q21

Question 21 (a)

Criteria	Marks
• Provides an acceptable structure and name	2
• Provides some relevant information	1

Sample answer:



butan-1-ol

Answers could include:

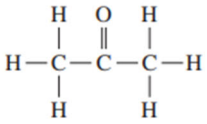
Condensed or skeletal formulae. Other unambiguous systematic names are acceptable, eg 1-butanol.

NSW Department of Education

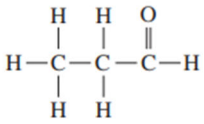
Exam question

2019 Chemistry exam Q21

(b) The structural formulae for two compounds are shown below. **2**



Isomer A



Isomer B

Why are these two compounds classed as functional group isomers?

Exam question

2019 Chemistry exam Q21

Question 21 (b)

Criteria	Marks
• States why the two compounds are classed as functional group isomers	2
• Provides some relevant information	1

Sample answer:

Both compounds have the same molecular formula (C_3H_6O) but have different functional groups.

Exam question

2019 Chemistry exam Q21

(c) A chemical test is required to distinguish between the isomers in part (b). **3**

Identify a suitable test and explain the expected observations.

Exam question

2019 Chemistry exam Q21

Question 21 (c)

Criteria	Marks
• Identifies a suitable test • Provides the appropriate observations • Explains the observations	3
• Identifies the observations and the test reagent OR • Explains the observations	2
• Provides some relevant information	1

Sample answer:

Tollens' test could be used to distinguish between Isomer A (ketone) and Isomer B (aldehyde). Aldehydes are readily oxidised to carboxylic acids whereas ketones are not. Isomer B will therefore reduce the silver ions in the Tollens' reagent to form a silver mirror inside the test tube whereas Isomer A will not react.

Answers could include:

Other oxidants that can oxidise Isomer B but not Isomer A, eg $Cr_2O_7^{2-}$, MnO_4^-.

I_2/OH^- will give iodoform with Isomer A but not with Isomer B.

The orange dichromate solution will change to green.

The purple permanganate solution will decolourise.

Exam question

2019 Chemistry exam Q21

Question 21

In better responses, students were able to:

- draw the correct structural isomer and name it (a)
- identify the compounds and state they were examples of ketones and aldehydes and that they were functional isomers (b)
- provide examples of chemical tests that could be used to distinguish between the ketone and aldehyde (c)
- include the name of a suitable reagent, the expected results and an explanation of the chemistry involved (c).

Areas for students to improve include:

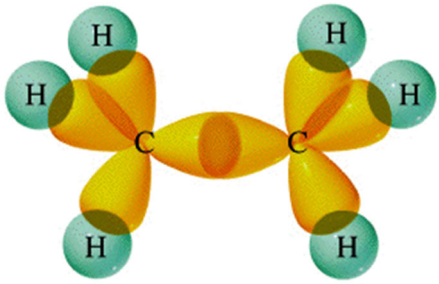
- distinguishing between a structural isomer and a functional isomer (a)
- reading the question carefully to include chemical tests not physical tests.

NSW Department of Education

2) How can hydrocarbons be classified based on their structure and reactivity?

Alkanes

- Alkane – geometry is drawings is vital. Generally $C_nH_{(2n+2)}$
  - Alkane = sigma (regular covalent – tetrahedral 109.5°)
  - Octane



23

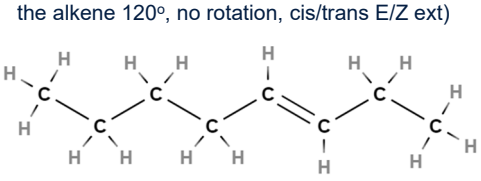
NSW Government

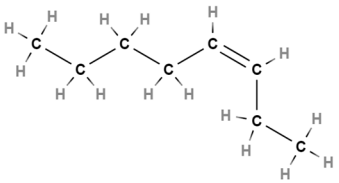
NSW Department of Education

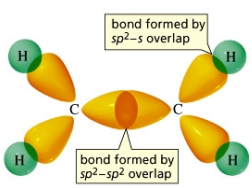
How can hydrocarbons be classified based on their structure and reactivity?

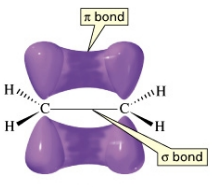
Alkenes

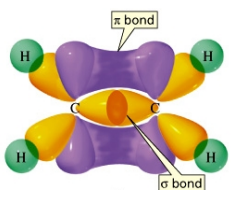
- Alkene – geometry is drawings is vital. Generally $C_nH_{(2n)}$
  - Alkene = sigma + pi (single plane overlap, imparts rigidity, trigonal planar at each end of the alkene 120°, no rotation, cis/trans E/Z ext)











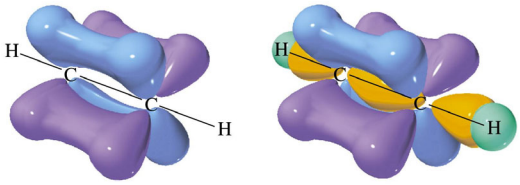
NSW Government

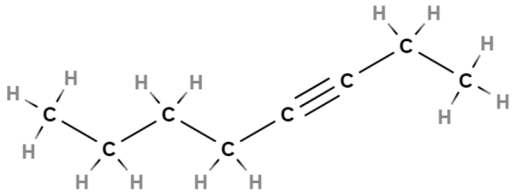
NSW Department of Education

How can hydrocarbons be classified based on their structure and reactivity?

Alkynes

- Alkyne – geometry is drawings is vital. Generally $C_nH_{(2n-2)}$
  - Alkyne = sigma + 2(Pi) (double plane overlap 90° opposed, produces a linear structure, 180° across and beyond the alkyne)
  - 3-octyne





25

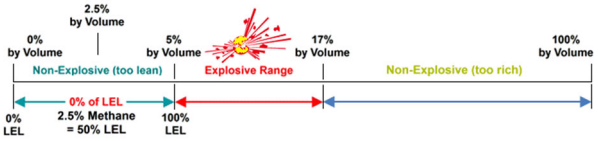
NSW Department of Education

How can hydrocarbons be classified based on their structure and reactivity?

Handling and disposal

- Handling (and storage) of hydrocarbons – non-polar, low density, highly flammable gases and liquids (C1-C8) with low flashpoints and autoignition temps, low LEL and broad explosive limit. Glass bottles, ventilated storage, spark free.

Methane - LEL: 5% by volume in Air / UEL: 17% by volume in Air



- Disposal of hydrocarbons - typical hydrocarbon wastes are highly contaminated due to their normal uses as solvents. Incompatible with sewer systems.

NSW Department of Education

How can hydrocarbons be classified based on their structure and reactivity?

Economic and sociocultural

- Economic – driver of the industrial revolution, modernisation of global transport and manufacturing systems. Energy density of gasoline 46.5MJ/Kg, Ethanol 29.8MJ/Kg, Wood* 20.6MJ/Kg. Mass equivalence of 1Kg of gasoline is 1.56Kg Ethanol and 2.26Kg of wood.
- Sociocultural – changing the face of societies across the globe, create economic tensions and conflict, built nations in scarcely inhabitable parts of the world, brought global travel within reach of many, distance for transport of goods, global trade markets.

27

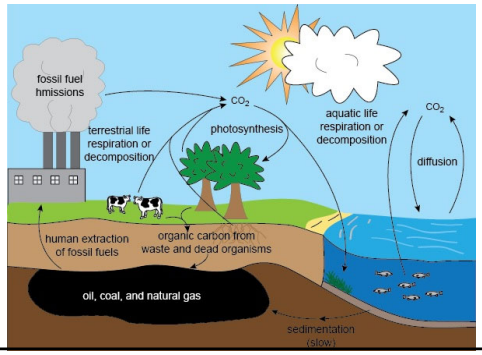
27

NSW Department of Education

How can hydrocarbons be classified based on their structure and reactivity?

Environmental

- Environmental – long list, from extraction to purification, modification, use and disposal. Global carbon economy shift with combustion of hydrocarbons from the Earth (long term carbon storage in carbon cycle being released).



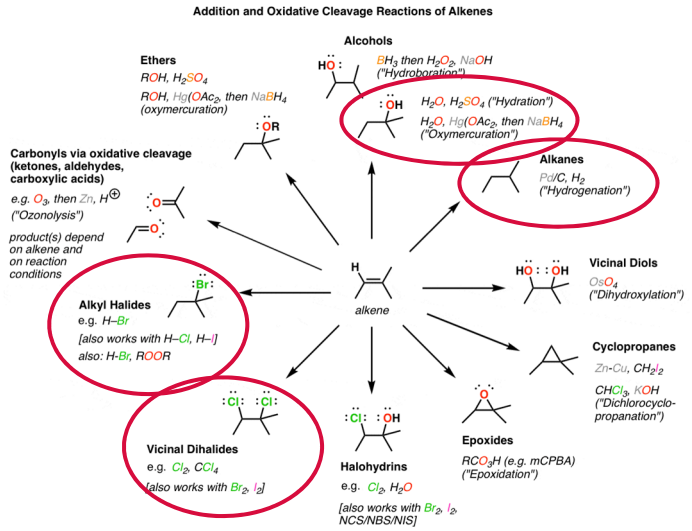
28

28

NSW Department of Education

3) What are the products of reactions of hydrocarbons and how do they react?

Reactions of alkenes



29

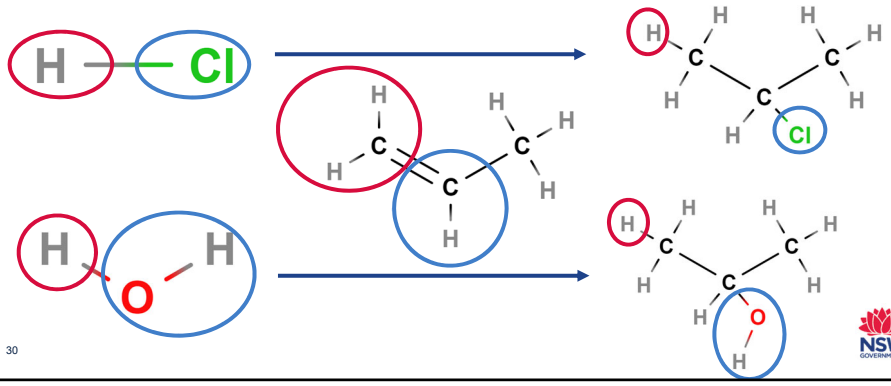
29

NSW Department of Education

3) What are the products of reactions of hydrocarbons and how do they react?

Reactions of alkenes

- Markovnikov's rule states that the hydrogen from the adding group will go to the side of the alkene (and alkyne) with the most existing hydrogens. Does not apply to H_2 and X_2 addition.



30

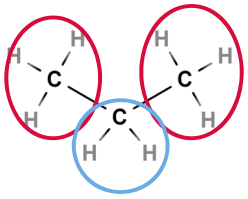
30

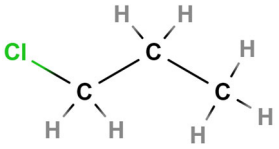
NSW Department of Education

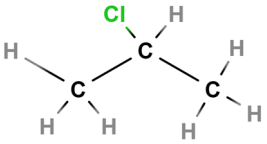
What are the products of reactions of hydrocarbons and how do they react?

Alkane reactions with halogens

- Catalysed by light, halogens (mainly Cl and Br, F reacts violently and I is scarcely reactive) can add to alkanes (no unsaturation electrophilic target).
- Primary targets are secondary hydrogens (blue) to substitute once producing a haloalkane and hydrogen halide. Primary hydrogens (red) are also targeted but the product is less abundant than would be expected by the ratio of hydrogens present in the compound (6:2, 3:1 ratio, product 45:55).







31

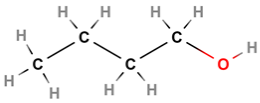
31

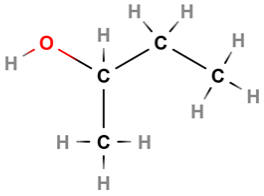
NSW Department of Education

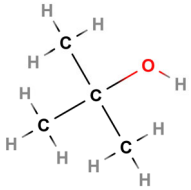
4) How can alcohols be produced and what are their properties?

Isomers

- Primary (1°), secondary (2°) and tertiary (3°) alcohols. The particular carbon arrangement to which the OH is connected. Impacts reactivity and properties of the alcohol significantly.
- No difference to structural formula, isomers. Polar OH, non-polar carbon backbone.







32

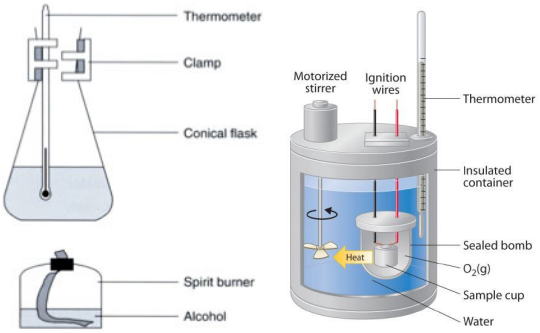
32

NSW Department of Education

How can alcohols be produced and what are their properties?

Enthalpy of combustion

- Enthalpy of combustion (ΔH_c) is the measure of energy (J) per mole of a substance. Combustion is always exothermic so this value is always negative, more negative = more energy released in the combustion.
- Simple practical to complete but fraught with reliability issues.
- $q_{(w)} = -q_{(fuel)}$
- $-q_{(fuel)} = m_{(w)}C_{(w)}\Delta T_{(w)}$
- $\Delta H_c = q_{(fuel)} / n_{(fuel)}$



NSW Department of Education

How can alcohols be produced and what are their properties?

Calculation 1

- Example forward calculation:
  - 10g of ethanol is completely combusted to heat 100g of water from 20°C to 47.5°C. Calculate ΔH_c for ethanol.
    - » Assuming $q_{(w)} = -q_{(fuel)}$
    - » $-q_{(fuel)} = m_{(w)}C_{(w)}\Delta T_{(w)} = 100g \times 4.18 \times (47.5 - 20) = 11495J = -11.495kJ$
    - » $n_{(fuel)} = m_{(fuel)} / MW_{(fuel)} = 10g / 46.068gmol^{-1} = 0.217mol$ ethanol
    - » $\Delta H_c = q_{(fuel)} / n_{(fuel)} = -11.495J / 0.217mol = -52.97kJmol^{-1}$
    - » Given theoretical ΔH_c for ethanol = $-1360kJmol^{-1}$ calculate the amount of heat lost to the surroundings (go back to the -11495J and calculate the equivalent value in theory, reverse the $\Delta H_c = q_{(fuel)} / n_{(fuel)}$ calculation to give $q_{(fuel)}$ and determine the difference).

How can alcohols be produced and what are their properties?

Calculation 2

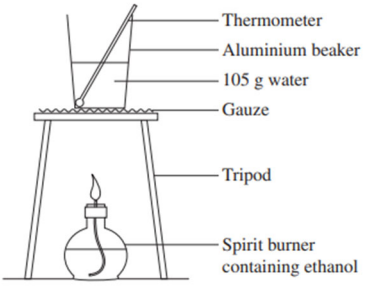
- Example backward calculation:
  - 1-propanol is completely combusted to heat 150g of water from 15°C to 35°C. Given the ΔH_c for 1-propanol is -2021kJmol^{-1} calculate the mass of 1-propanol which was combusted.
    - » Assuming $q_{(w)} = -q_{(fuel)}$
    - » $-q_{(fuel)} = m_{(w)}C_{(w)}\Delta T_{(w)}$ = 150g x 4.18 x (35 - 15) = 12540J = -12.54kJ
    - » $\Delta H_c = q_{(fuel)} / n_{(fuel)} \rightarrow n_{(fuel)} = q_{(fuel)} / \Delta H_c$ = -12.54kJ / -2021kJmol^{-1} = 0.0062mol
    - » $n_{(fuel)} = m_{(fuel)} / MW_{(fuel)} \rightarrow m_{(fuel)} = n_{(fuel)}$ x $MW_{(fuel)}$ = 0.0062mol x 60.094gmol^{-1} = 0.373g
    - » If the calorimeter only passed 15% of the heat to the water, calculate the new mass of 1-propanol that was combusted (go back to the 12540J value representing 15% and calculate the 100% value to account for the heat lost to surroundings, re do the remaining calculation steps)

Exam question

2019 Chemistry exam Q23

Question 23 (6 marks)

The following apparatus was used in an experiment to determine the molar enthalpy of combustion of ethanol.



(a) Calculate the experimental molar enthalpy of combustion $(\Delta_c H)$ of ethanol when 0.370 g ethanol was used to raise the water temperature from 18.5°C to 30.0°C. **4**

Exam question

2019 Chemistry exam Q23

Question 23 (a)

Criteria	Marks
• Correctly calculates $\triangle_c H$ with units • Uses correct significant figures	4
• Provides substantially correct working	3
• Provides some relevant steps	2
• Provides some relevant information	1

Sample answer:

Moles ethanol (n) $= 0.370\ \text{g} / (12.01 \times 2 + 1.008 \times 6 + 16.00\ \text{g mol}^{-1})$
$= 0.008032\ \text{mol}$

$q = mC\triangle T$

$= 105\ \text{g} \times 4.18\ \text{J g}^{-1}\text{K}^{-1} \times (30 - 18.5)\ \text{K}$

$= 5047.35\ \text{J}$

$$\triangle_c H = -\frac{q}{n} = -\frac{5047.35\ \text{J}}{0.008032\ \text{mol}}$$

$= -628405\ \text{J mol}^{-1}$

$= -628\ \text{kJ mol}^{-1}$ (3 significant figures)

Exam question

2019 Chemistry exam Q23

(b) Upon replication, the molar enthalpy of combustion obtained in the experiment was consistently much lower than the accepted value. **2**

Explain ONE change that could be made to the experiment that would improve the accuracy of the obtained value.

Exam question

2019 Chemistry exam Q23

Question 23 (b)

Criteria	Marks
• Provides a change that would improve accuracy • Gives a reason for the low molar enthalpy of combustion related to the change	2
• Provides some relevant information	1

Sample answer:

The experimental value for the molar enthalpy of combustion is low, primarily due to heat loss to the environment.

A change that would reduce heat loss and improve accuracy is moving the spirit burner closer to the beaker.

(There are many other possible improvements that are acceptable.)

Exam question

2019 Chemistry exam Q23

Question 23

In better responses, students were able to:

- use correct mass in mcΔT
- calculate the moles of ethanol correctly
- give the answer with correct significant figures and units.

Areas for students to improve include:

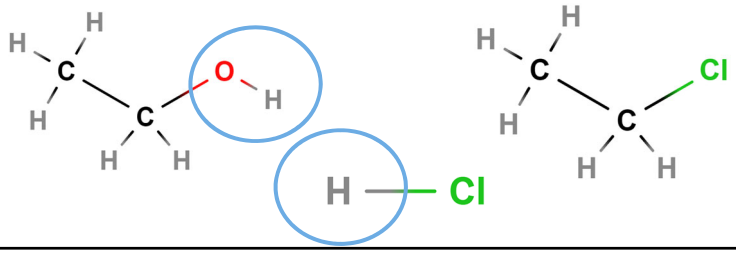
- using the mass of water and not ethanol in mcΔT
- knowing the formula for ethanol
- using atomic mass values from the periodic table.

NSW Department of Education

How can alcohols be produced and what are their properties?

Combustion and substitution

- Combustion is the reaction with oxygen to produce oxides of carbon and hydrogen.
  - Complete combustion = CO_2 and water products only
  - Incomplete combustion = some mixture of CO_2/CO/C and water.
- Substitution = HX swap, OH swaps for X producing haloalkane and water.



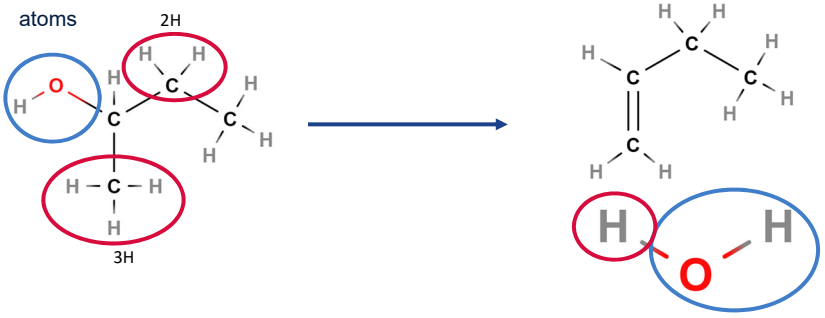
41

NSW Department of Education

How can alcohols be produced and what are their properties?

Dehydration

- Dehydration = removal of water (OH + adjacent carbon H) producing alkene
  - Zaitsev's rule, this is the corresponding elimination rule to Markovnikov's rule for addition. This states the hydrogen removed (to form water with the alcohol functional group also removed) will come from the adjacent carbon with the least number of existing hydrogen atoms



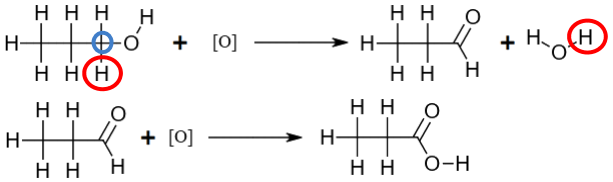
42

NSW Department of Education

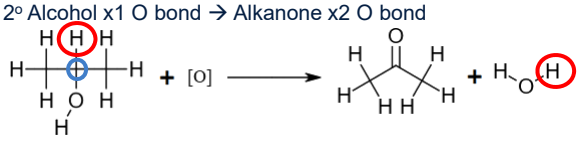
How can alcohols be produced and what are their properties?

Oxidation

- Oxidation = step up carbon-oxygen bonding. Depends on the type of alcohol:
  - 1º Alcohol x1 O bond → Alkanal x2 O bond → Alkanoic acid x3 O bond



  - 2º Alcohol x1 O bond → Alkanone x2 O bond

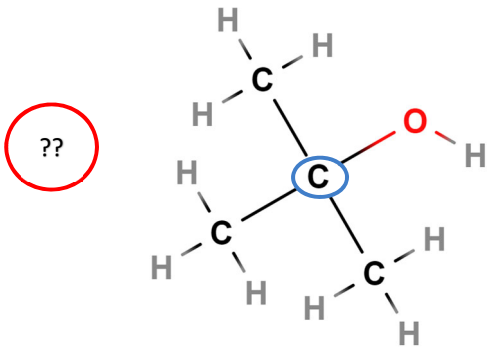


NSW Department of Education

How can alcohols be produced and what are their properties?

Oxidation

- Oxidation = step up oxygen bonding. Depends on the type of alcohol:
  - 3º Alcohol → no reaction



NSW Department of Education

How can alcohols be produced and what are their properties?

Substitution and fermentation

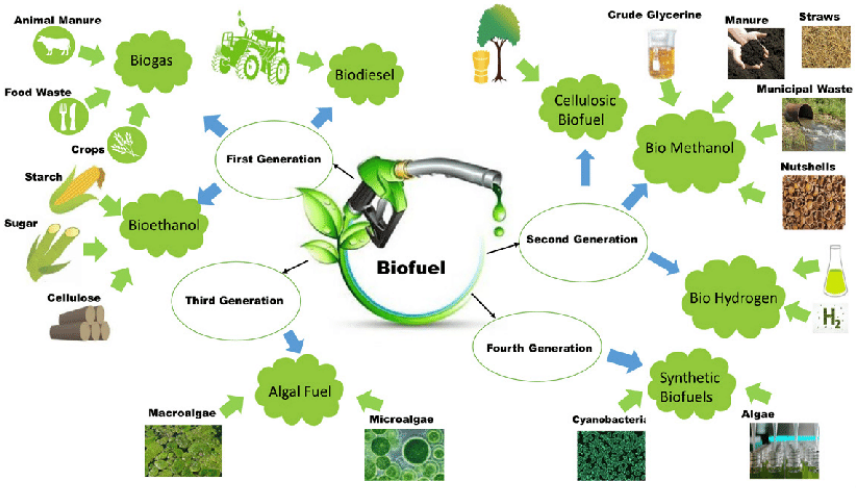
- Substitution = OH swap (opposite of HX swap covered before), OH from NaOH swaps for X producing alcohol and NaX.
- Fermentation – yeast used to consume a glucose source and following a short period of respiration will undergo fermentation to produce ethanol.
  - Respiration consumes oxygen and produces carbon dioxide and water from glucose to release energy for the organism to use. This continues until all the oxygen in the container is consumed.
  - Fermentation occurs without oxygen and consumes glucose to release carbon dioxide and ethanol but releases less energy. This is a backup energy source for yeast in an anoxic environment. Ethanol concentration eventually kills the yeast.

$$C_6H_{12}O_{6\,(aq)} \xrightarrow{yeast} 2C_2H_5OH_{(aq)} + 2CO_{2\,(g)}$$

NSW Department of Education

How can alcohols be produced and what are their properties?

Biofuels

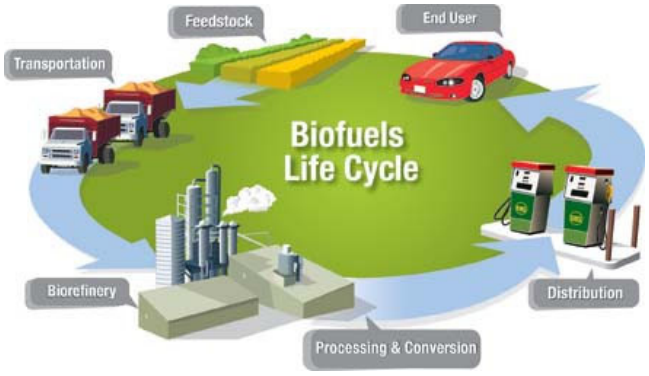


NSW Department of Education

How can alcohols be produced and what are their properties?

Biofuels

- Heat of combustion comparison? Petrol/Diesel/E10/E85/Hydrogen
- Energy density
- Closed loop?



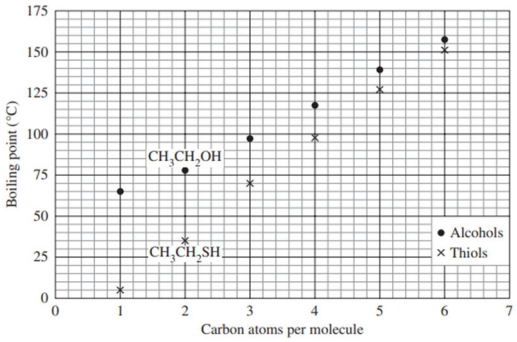
NSW Department of Education

Exam question

2019 Chemistry exam Q32

Question 32 (4 marks)

Thiols are the sulfur analogues of alcohols in that the oxygen atom of the alcohol is replaced by a sulfur atom. For example, methanethiol (CH_3SH) is the analogue of methanol (CH_3OH). The boiling points of some straight chain alcohols and thiols are given in the following graph. **4**



Explain the patterns of the boiling points shown in the graph.

Exam question

2019 Chemistry exam Q32

Question 32

Criteria	Marks
• Explains patterns in the boiling points	4
• Explains most of the patterns in the boiling points	3
• Describes the patterns in the boiling point OR • Explains a pattern in the boiling points	2
• Provides some relevant information	1

Sample answer:

Boiling points for both series increase with increasing number of carbon atoms. This is due to dispersion forces increasing with increasing chain length.

The boiling point of the alcohol is always higher than the analogous thiol. This is due to hydrogen bonding between alcohols being stronger than the dispersion forces between thiols.

The difference between the boiling points of analogous alcohols and thiols decreases with increasing chain length. This is due to the hydrogen bonding having a smaller and smaller contribution to total intermolecular forces as chain length increases.

Exam question

2019 Chemistry exam Q32

Question 32

In better responses, students were able to:

- identify the three trends in the graph
- explain each of the trends
- use correct chemical terminology to identify the forces of attraction that caused each trend.

Areas for students to improve include:

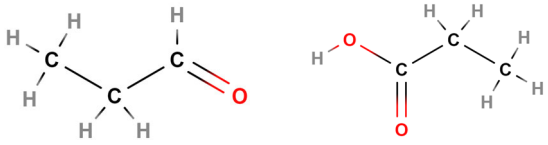
- identifying and explaining the forces of attraction influencing boiling point
- understanding the difference between a hydroxyl group and hydroxide ion
- explaining what effects the strength of dispersion forces have on trends.

NSW Department of Education

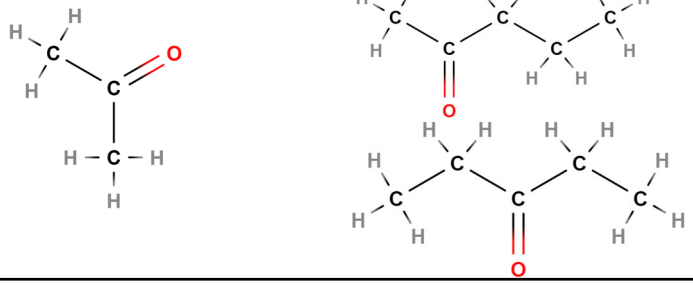
What are the properties of organic acids and bases?

Aldehydes, ketones and carboxylic acids

- Aldehydes (CHO) and carboxylic acids (COOH) – only on terminal carbons



- Ketones (CO) – only non-terminal carbons



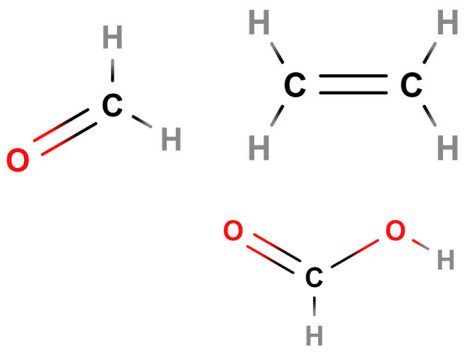
NSW Department of Education

Exam question

2019 Chemistry exam Q10

10 Which class of organic compound must contain at least three carbon atoms?

A. Aldehydes
B. Alkenes
C. Carboxylic acids
D. Ketones

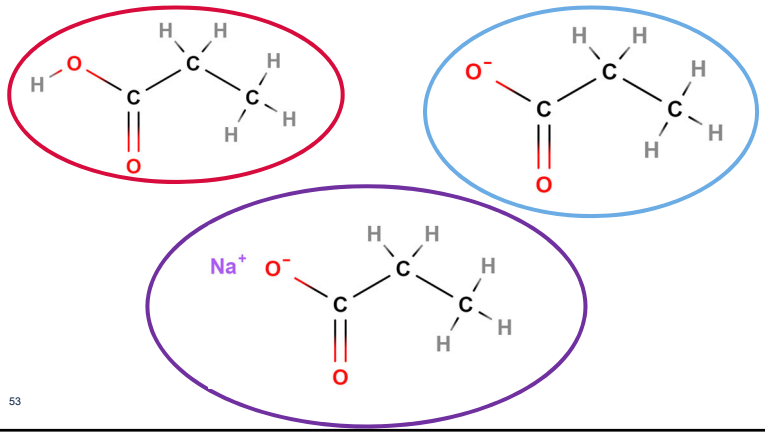


NSW Department of Education

What are the properties of organic acids and bases?

Carboxylic acid properties

- Carboxylic acids – proton donors, weak acids pH < 7, form carboxylate ions as conjugate base and named suffix 'alkylanoate' as the salt formed in neutralisation.



53

NSW GOVERNMENT

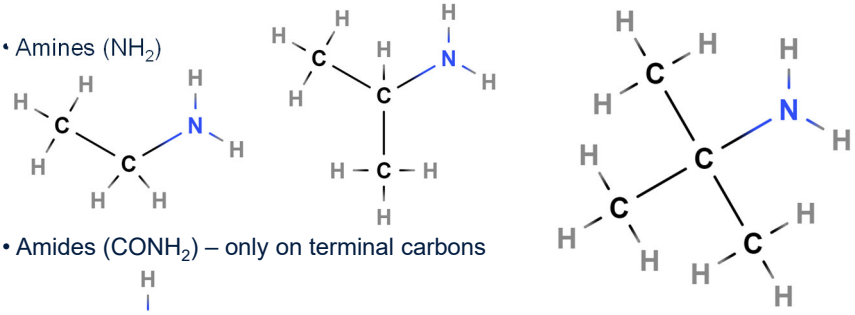
53

NSW Department of Education

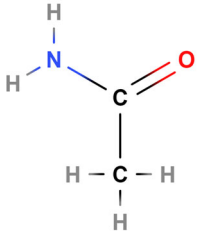
What are the properties of organic acids and bases?

Amines and amides

- Amines (NH_2)



- Amides ($CONH_2$) – only on terminal carbons



54

NSW GOVERNMENT

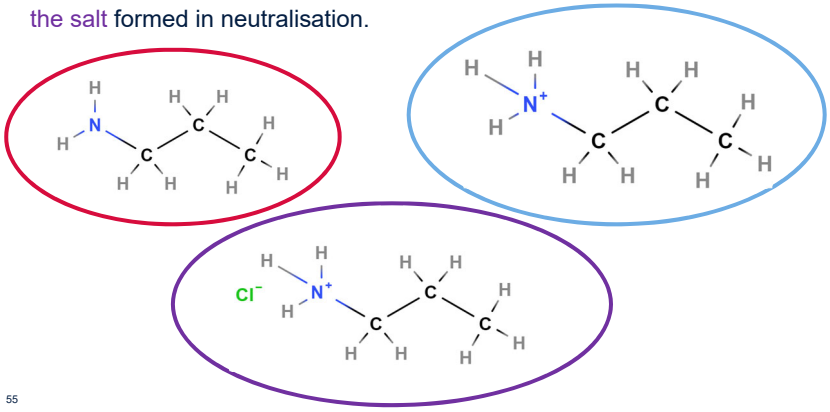
54

NSW Department of Education

What are the properties of organic acids and bases?

Amines

- Amines – proton acceptors with lone pair on the nitrogen, weak base pH > 7, form alkylammonium ions as the conjugate acid and named prefix ‘alkyammonium’ as the salt formed in neutralisation.



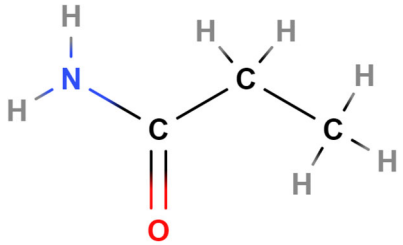
55

NSW Department of Education

What are the properties of organic acids and bases?

Amides

- Amides – tricky. Normally able to act as a base with N lone pair (same as amine) but this is so weak in amides it is ignored. The O delocalises (draws away) the lone pair on N and this stabilises the whole functional group (no electron dense region to attack). The N hydrogens are also unable to be donated so there is also no normal acidic behavior.
- Only under strong basic or acidic conditions can this be forced either way.



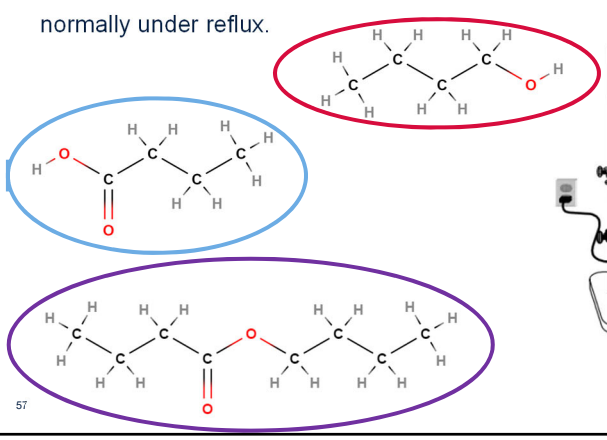
56

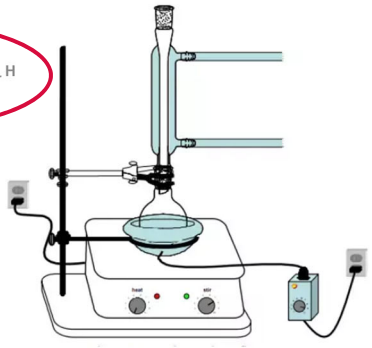
NSW Department of Education

What are the properties of organic acids and bases?

Esterification

- Esterification – condensation reaction of an alkanol and an alkanoic acid, producing water and alkyl alkanoate. Catalysed by a strong acid and performed normally under reflux.



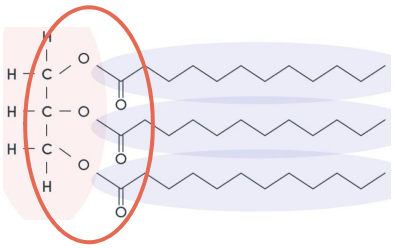


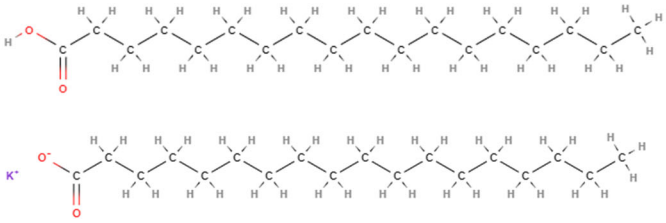
NSW Department of Education

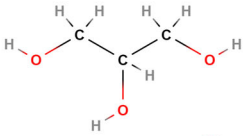
What are the properties of organic acids and bases?

Structure of soaps

- Soaps are the salt of a fatty acid, normally potassium. KOH is used to 'saponify' triglycerides forming soap and glycerol. This is the opposite of esterification.
- Natural origins from plant/animal fats/oils





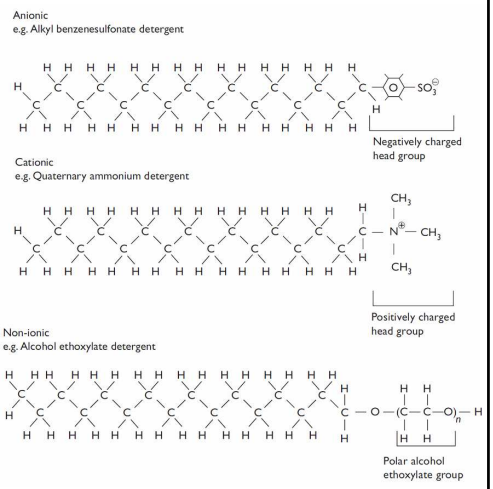


NSW Department of Education

What are the properties of organic acids and bases?

Structure of detergents

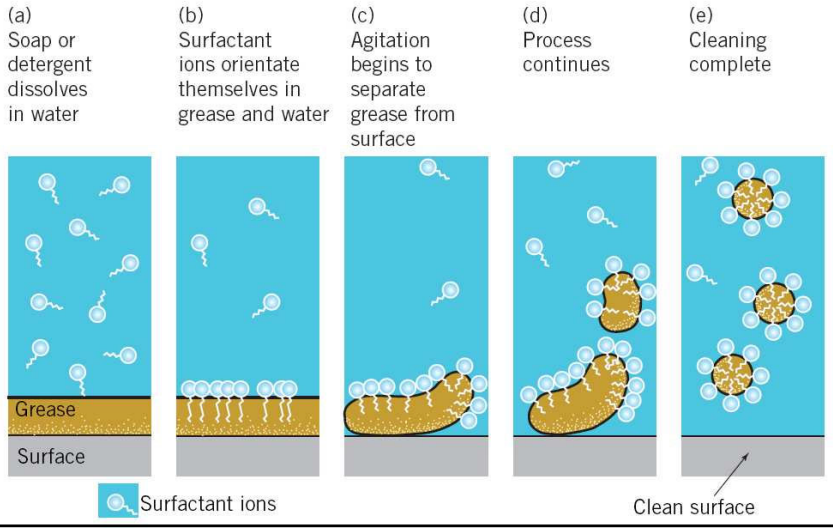
- Similar as soaps, different head group options. Can be negative (anionic), positive (cationic) or neutral (non-ionic). Each have distinct properties and related uses.
- Synthetic origins from petrochemicals (typically).



NSW Department of Education

What are the properties of organic acids and bases?

Action of soaps and detergents

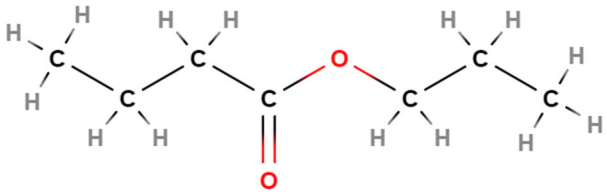


NSW Department of Education

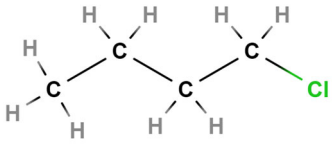
What are the properties of organic acids and bases?

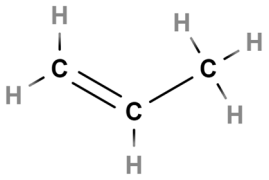
Reaction pathways

- Produce 1-propyl butanoate from 1-chlorobutane and propene.
- Target



- Stock





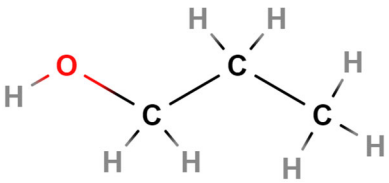
61

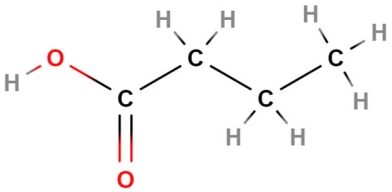
NSW Department of Education

What are the properties of organic acids and bases?

Reaction pathways

- Final reactants needed – 1-propanol and butanoic acid (reverse the esterification)





- Link stock reagents to target reagents for the final product.

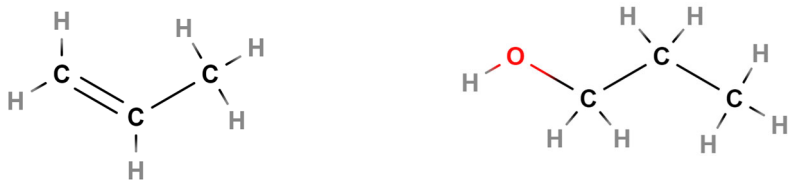
62

NSW Department of Education

What are the properties of organic acids and bases?

Reaction pathways

- Conversion of propene to 1-propanol



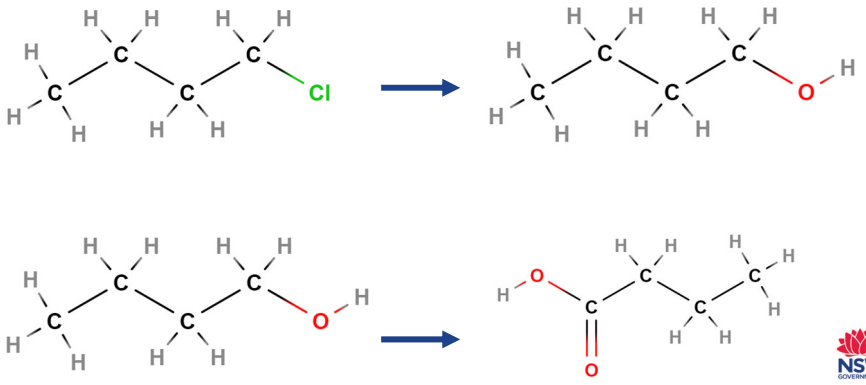
63

NSW Department of Education

What are the properties of organic acids and bases?

Reaction pathways

- Conversion of 1-chlorobutane to butanoic acid

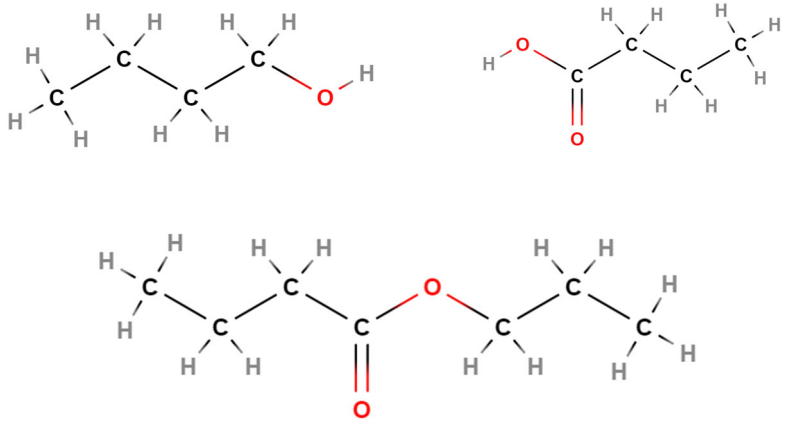


64

What are the properties of organic acids and bases?

Reaction pathways

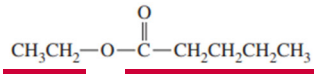
- Esterification of 1-propanol and butanoic acid



Exam question

2019 Chemistry exam Q8

8 The structure of an organic compound is shown.



Which row of the table correctly gives the name of the compound and one of the reactants used to produce it in a one-step reaction?

	Name	*Reactant*
A.	Ethyl pentanoate	Ethanol
B.	Ethyl pentanoate	Pentan-1-ol
C.	Pent-1-yl ethanoate	Ethanol
D.	Pent-1-yl ethanoate	Pentan-1-ol

Exam question

2019 Chemistry exam Q9

9 All of the following compounds have similar molar masses.

Which has the highest boiling point?

A. Butane

B. Ethanoic acid

C. Propan-1-ol

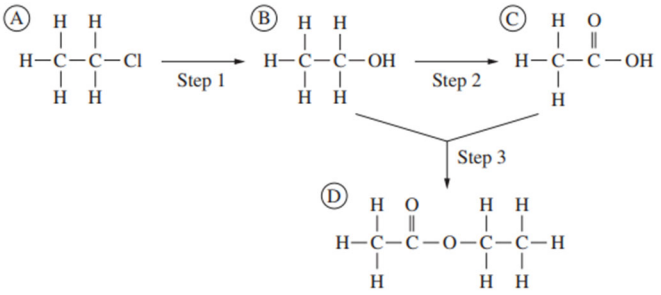
D. Propanone

Exam question

2019 Chemistry exam Q34

Question 34 (7 marks)

The following reaction scheme can be used to synthesise ethyl ethanoate. **7**



Outline the reagents and conditions required for each step and how the product of each step could be identified.

NSW Department of Education

Exam question

2019 Chemistry exam Q34

Question 34

Criteria	Marks
• Outlines the appropriate reagents and conditions • Outlines differences in chemical reactivity or spectroscopic data for products of all three steps	7
• Outlines the appropriate reagents and conditions • Outlines differences in chemical reactivity or spectroscopic data for products of two steps	6
• Outlines some appropriate reagents and conditions • Outlines chemical reactivity or spectroscopic data for the products of some steps	4–5
• Outlines an appropriate reagent and/or condition AND/OR • Outlines chemical reactivity or spectroscopic data for the products	2–3
• Provides some relevant information	1

Sample answer:

In step 1, chloroethane (A) can be converted to ethanol (B) by heating with dilute aqueous potassium hydroxide. The mass spectrum of ethanol will have a single molecular ion peak at m/z = 46, whereas chloroethane will give two peaks at m/z 64 and 66.

In step 2, ethanol (B) can be converted to ethanoic acid (C) using a strong oxidant, for example: acidified potassium permanganate. A C=O peak will appear in the IR spectrum (1680–1750 cm^{-1}) or in the ^{13}C NMR spectrum (160–185 ppm); ethanol will show neither peak.

In step 3, ethyl ethanoate (D) can be synthesised by heating a mixture of ethanol, ethanoic acid and concentrated sulfuric acid under reflux. The ^{1}H NMR spectrum of ethyl ethanoate will have 3 signals, whereas both ethanol and ethanoic acid will have 2.

Answers could include:

Ethanol (B) can be identified in a number of ways, for example:

- Reactivity tests eg turns acidified potassium dichromate solution from orange to green, or decolourises acidified potassium permanganate solution from purple. Also gives a red colour with ceric ammonium nitrate, or gives hydrogen gas with sodium. Chloroethane reacts with none of these reagents.
- An O–H peak will appear in the IR spectrum (broad peak at 3230–3550 cm^{-1}) and in the ^{1}H NMR spectrum (variable chemical shift, 1–6 ppm, concentration-dependent); the IR spectrum of chloroethane will not contain this peak.
- The ^{1}H NMR spectrum of ethanol will have 3 signals, whereas that of chloroethane will have 2.
- The mass spectrum of ethanol will have a single molecular ion peak at m/z = 46, whereas chloroethane will give two peaks at m/z 64 and 66.

NSW Department of Education

Exam question

2019 Chemistry exam Q34

Question 34

In better responses, students were able to:

- demonstrate a clear understanding of the reagents, conditions and chemical reactivity of the product for each step
- succinctly outline the reagents, conditions and chemical reactivity tests for each step
- identify acidified reagents for Step 2
- identify the change in colour for indicators/acidified reagents if used as chemical reactivity tests
- identify that concentrated sulfuric is used in esterification.

Areas for students to improve include:

- understanding reactions of haloalkanes
- addressing all parts of the question, including chemical reactivity
- using specific spectroscopic data to identify specific products, including the wavelengths when using the data
- naming organic compounds
- annotating the stimulus diagrams with the name of the compounds and reagents before writing a response.

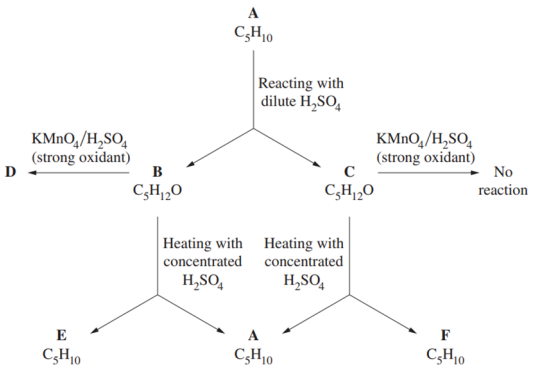
NSW Department of Education

Exam question

Chemistry specimen exam Q27

Question 27 (7 marks)

This flow chart shows the reactions involving six different organic compounds (**A** to **F**). **7**



Draw the structures of compounds **A** to **F**, justifying your answers with reference to the information provided.

71

71

NSW Department of Education

Exam question

Chemistry specimen exam Q27

Question 27

Criteria	Marks
• Correctly draws the structures of the six compounds and provides a justification for each compound	7
• Correctly draws most of the structures with relevant justifications	6
• Correctly draws some of the structures with relevant justifications	4–5
• Identifies some characteristics of the compound(s)	2–3
• Provides some relevant information	1

72

72

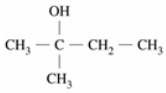
Exam question

Chemistry specimen exam Q27

Sample answer:

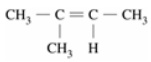
A is alkene because it undergoes an addition reaction with water across the double bond to form an alkanol. B and C are different alcohols. C is tertiary alcohol since it does not undergo oxidation.

The only tertiary alcohol with $C_5H_{10}O$ is

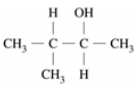


which is C.

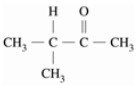
C is dehydrated to A using concentrated H_2SO_4. A must be a non-terminal alkene as two products with addition of water are possible (B and C).

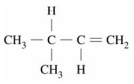
Therefore A is 

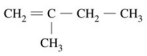
B must be another alcohol formed by addition of water to A.



B is a secondary alkanol. Oxidation produces a ketone D.



B dehydrates to either A or E. So E is 

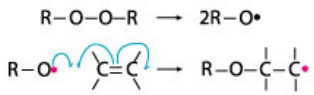
C dehydrates to either A or F. So F is 

What are the properties and uses of polymers?

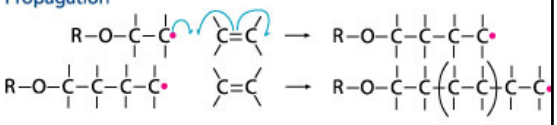
Addition polymers

- Poly = many, polymer is the umbrella term that covers many macromolecules both synthetic (plastics) and natural (fibres).
- Poly is the prefix in front of the repeating unit used in the chain structure.
- Each monomer adds to the chain with no other products normally produced.

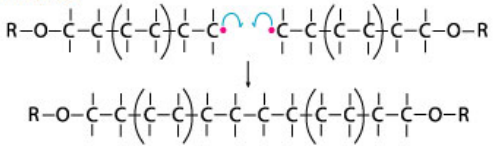
Initiation



Propagation



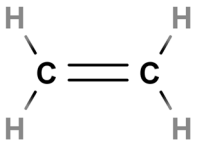
Termination

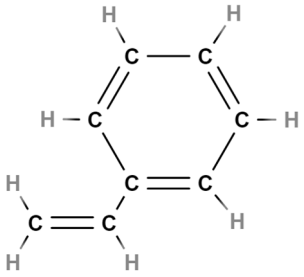


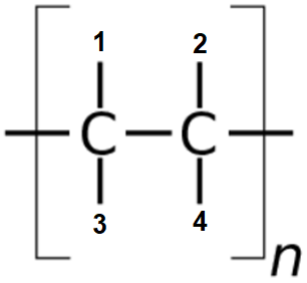
NSW Department of Education

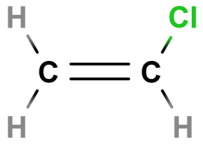
What are the properties and uses of polymers?

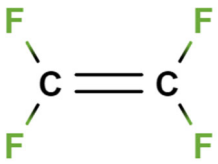
Addition polymers









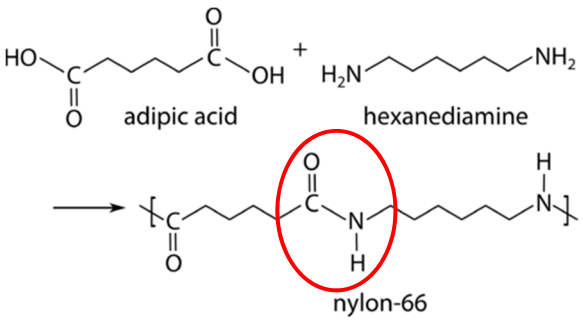


NSW Department of Education

What are the properties and uses of polymers?

Condensation polymers

- Condensation polymers link monomers or dimers with the byproduct of water.
- Nylon is an umbrella term for many different iterations, this is a polyamide which is a dimer of a diamine and dioic acid e.g. Nylon-6,6 is the combo of 1,6-diaminohexane and hexanedioic acid (6,6 because both monomers have 6 carbons each)

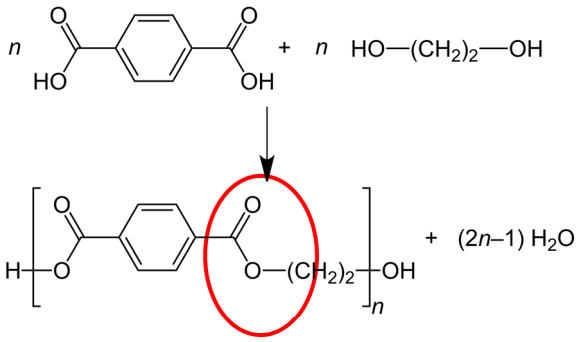


NSW Department of Education

What are the properties and uses of polymers?

Condensation polymers

- Condensation polymers link monomers or dimers with the byproduct of water.
- Polyesters are polymers of ester bonds between diols and dioic acids e.g. Terephthalic acid and Ethylene glycol yields PET(PETE) which is common for soft drink bottles.



77

NSW Department of Education

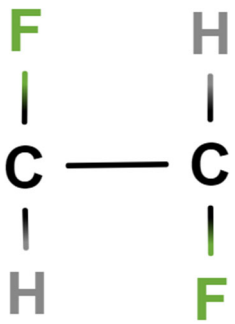
Exam question

2019 Chemistry exam Q13

13 A sample of polydifluoroethylene is determined to have an average molar mass of 4.8×10^4 g mol^{-1}.

Approximately how many carbon atoms are there in an average molecule?

A. 750
B. 1500
C. 2500
D. 4000



78

NSW Department of Education

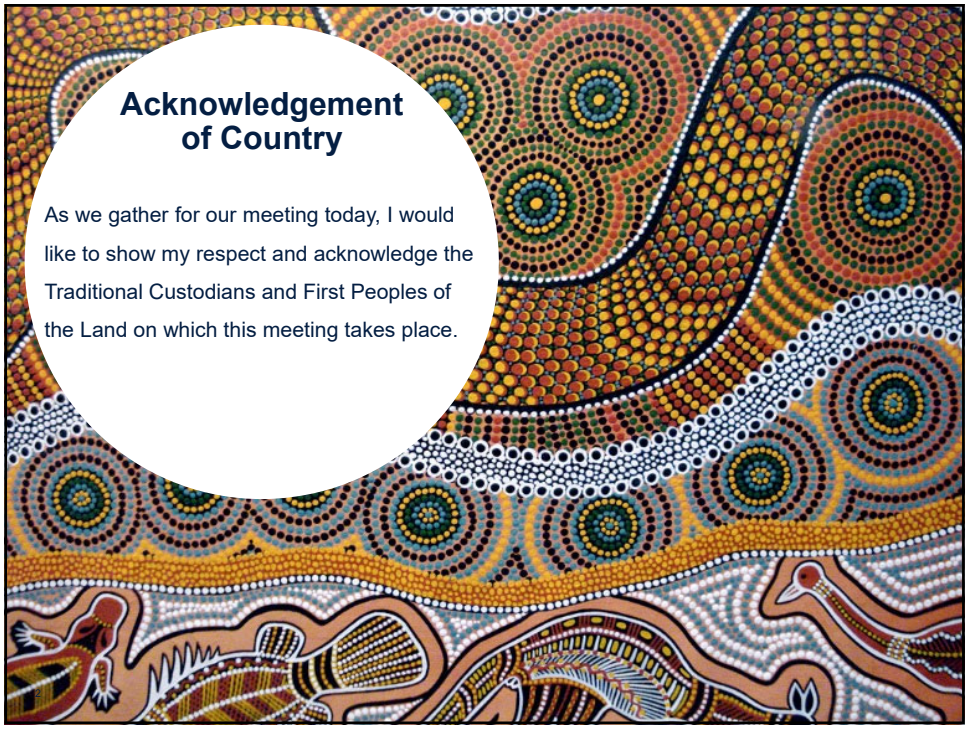
Stage 6 Chemistry Module 8

Joshua Westerway

Curriculum Support Project Officer Science 7-12

NSW GOVERNMENT

1



2

NSW Department of Education

How are ions present in the environment identified and measured?

Environmental monitoring

- WHY monitor the environment?
- Monitor WHAT?
  - Soil, water, air (EPA resources)
- GIS mapping tools for soils, water, air
- National Map and MDBA maps
- Drinking water guidelines from NHMRC
- Decision on analytes to be measured, agreed analysis techniques and allowable limits, reporting structures/units/variance/errors.

3

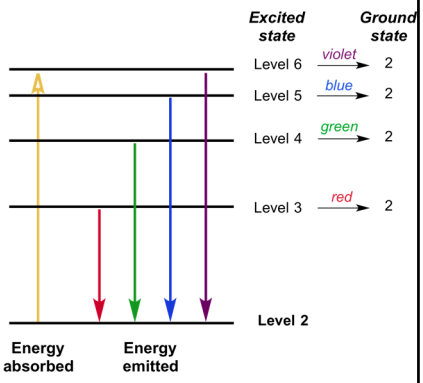
3

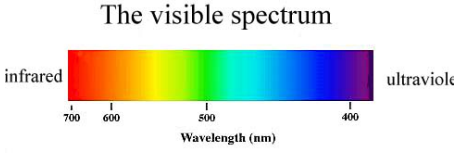
NSW Department of Education

How are ions present in the environment identified and measured?

Flame tests

- Qualitative analysis – yes/no presence, higher concentrations needed for visual assessment
- Flame tests, cation analysis, some anion effects but not characteristic for accurate identification. Electron excitation/relaxation process. Frequency of emission is determined by the size of the relaxation.





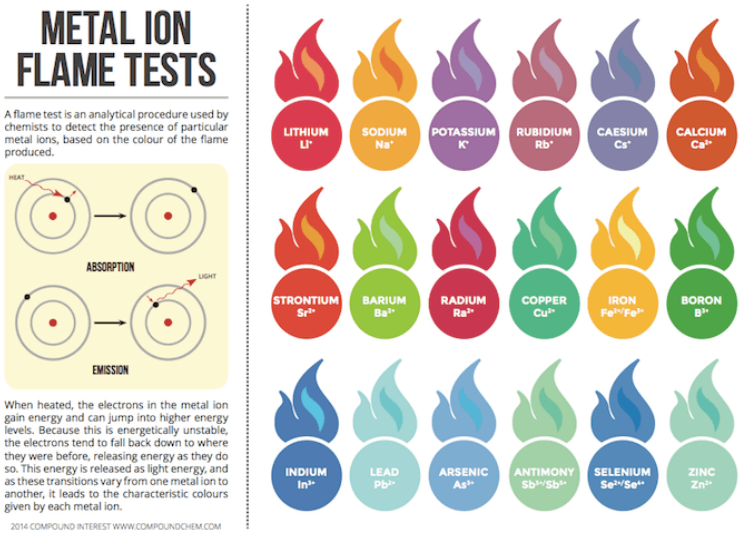
4

4

NSW Department of Education

How are ions present in the environment identified and measured?

Flame tests



5

5

NSW Department of Education

How are ions present in the environment identified and measured?

Precipitation and complexation reactions

- Qualitative analysis still….
- Solubility “rules”
  - NAGSAG – all **N**itrates, **A**cetates, **G**roup one (alkali metals), **S**ulfates, **A**mmonium and **G**roup seven (halogens) are **soluble**
  - CHOPS – all **C**arbonates, **H**ydroxides, **O**xides, **P**hosphates and **S**ulfides are **insoluble**
  - **Soluble rule overrides the insoluble rule**

6

6

NSW Department of Education

How are ions present in the environment identified and measured?

Precipitation reactions of cations

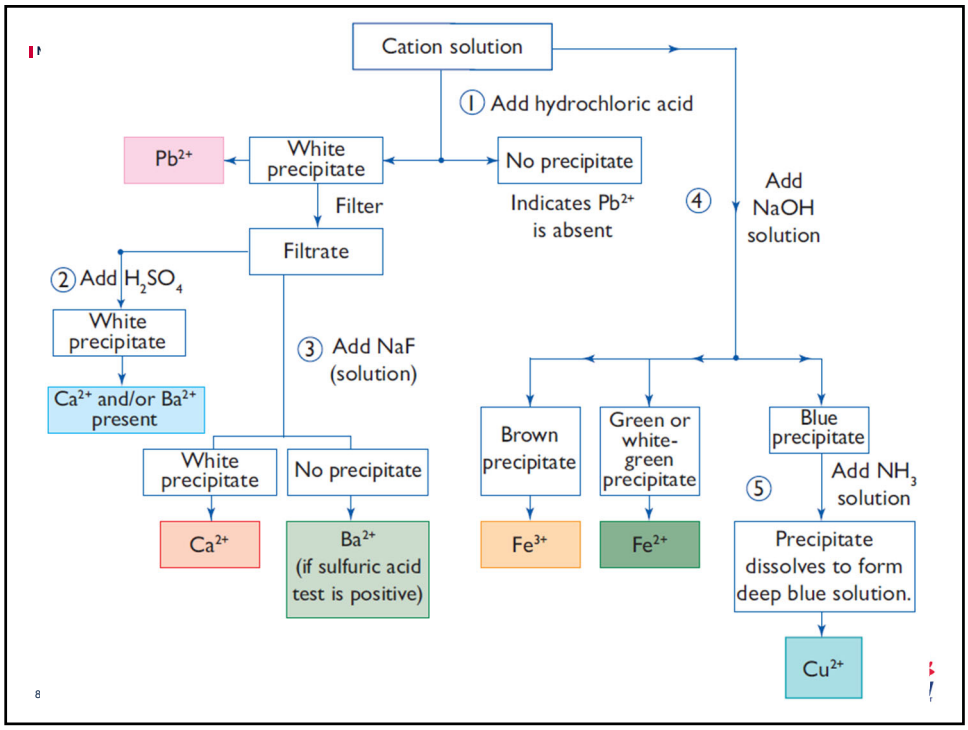
Remember the cations you are required to test for and those which are extra, consideration for ion mixtures. Coloured precipitates are preferred but not always possible.

- Barium – white chloride, yellow chromate, orange dichromate (acidified)
- Calcium – white carbonate (with NH_4CO_3)
- Magnesium – white hydroxide (with NaOH)
- Lead(II) – yellow iodide precipitate (with KI/NaI)
- Silver – white chloride, black sulfide, brown oxide (with ammonia or NaOH)

Linking of cation precipitation and flame test data is important to discern commonly coloured precipitates.

7

7



8

8

NSW Department of Education

Exam question

Chemistry specimen exam Q28

Question 28 (9 marks)

Limestone ($CaCO_3$) contributes to the hardness of water by releasing Ca^{2+} ions. The chemical equation for this reaction is represented below. **9**

$$CaCO_3(s) + H_2O(l) + CO_2(g) \rightleftharpoons Ca^{2+}(aq) + 2HCO_3^-(aq) \qquad (\Delta H < 0)$$

It has been suggested that heating water reduces its hardness.

Explain how this suggestion can be tested accurately, validly and reliably.

9

9

NSW Department of Education

Exam question

Chemistry specimen exam Q28

Question 28

Criteria	Marks
• Explains how the suggestion can be tested • Includes measures to ensure accuracy, validity and reliability of data	9
• Describes a process for testing the suggestion • Addresses at least two of these areas: accuracy, validity, reliability	7–8
• Outlines relevant steps for testing the suggestion • Shows some understanding of accuracy, validity or reliability	5–6
• Outlines relevant step(s) for testing the suggestion AND/OR • Shows some understanding of accuracy, validity or reliability	3–4
• Identifies relevant step(s) for testing the suggestion AND/OR • Shows a basic understanding of accuracy, validity or reliability	1–2

10

10

NSW Department of Education

Exam question

Chemistry specimen exam Q28

Sample answer:

Atomic absorption spectroscopy (AAS), which is used to detect concentrations of metal ions in solutions, can be used to test the suggestion. AAS can be used to determine the concentration of Ca^{2+} in both heated and non-heated samples of water. If heating water can reduce its hardness, the concentration of Ca^{2+} should be less for the heated sample.

To do this, prepare a series of standard solutions of known concentration of Ca^{2+} and measure the absorbance of the standard solutions. Plot the concentrations and absorbance of the standard solutions and draw a line of best fit (the calibration curve). Next, measure the absorbance of two water samples – one before heating and one after. Using the absorbance and the calibration curve, calculate the concentration of Ca^{2+} in each sample and compare the concentrations between the heated and unheated samples.

AAS when calibrated correctly is very accurate. Concentrations of calcium ions at the parts per million level (ppm) can be easily measured. To ensure that AAS is correctly calibrated, the standard solutions need to be accurately prepared. Solids should be carefully weighed and solutions can be transported using a pipette or a similar tool to ensure accuracy. Tap water is usually full of ions such as Na^{+} and Ca^{2+}, so deionised water should be used. To enhance reliability, ensure that sufficient calibration samples are used and that the measurement of absorbance is repeated. It is possible to produce reliable results that fall closely to the line of best fit of the calibration curve with only a very small margin of error.

To further improve reliability, many samples of heated and non-heated water can be used to make sure that the concentrations of Ca^{2+} in the heated water samples are consistently lower than the concentrations of Ca^{2+} in the unheated water samples.

AAS also allows the suggestion to be validly tested. When a lamp specific for calcium is shone through the solution, only calcium ions will absorb the specific frequency as each element has its own unique fingerprint. This enables the experiment to measure what is intended so that an accurate and valid conclusion can be made.

Answers could include:

Use of gravimetric analysis or other chemical analysis.

11

11

NSW Department of Education

How are ions present in the environment identified and measured?

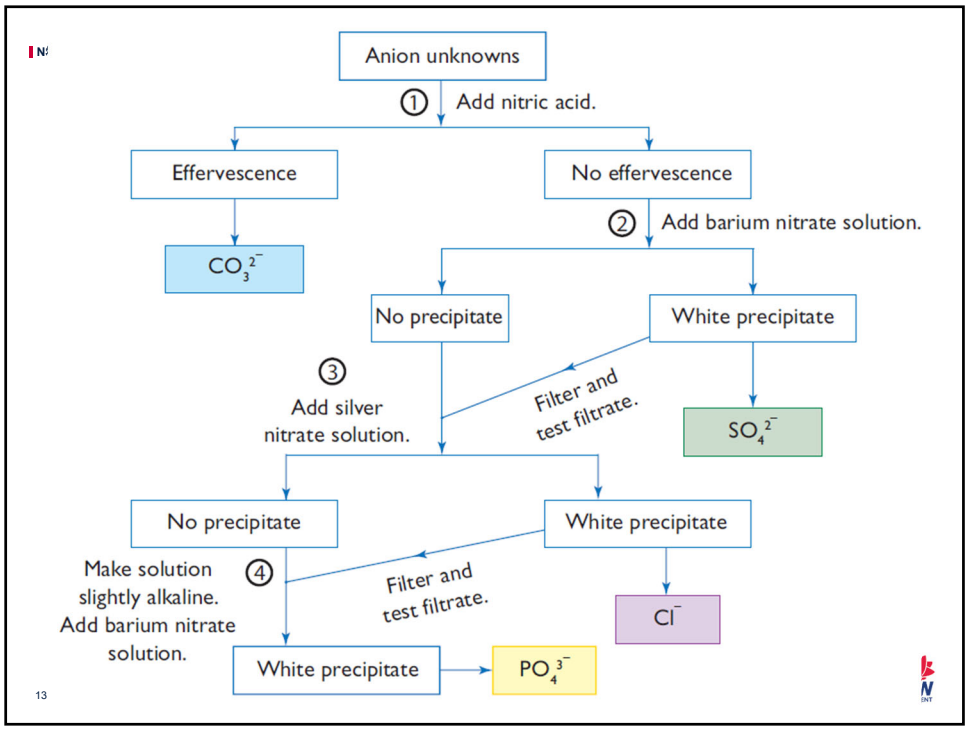
Precipitation reactions of anions

Remember the anions you are required to test for and those which are extra, consideration for ion mixtures. Coloured precipitates are preferred but not always possible.

- Chloride, Bromide, Iodide (halides) - ?? Pb/Ag
- Hydroxide - ?? Cu/Fe/Ag
- Acetate – dilute hydrochloric acid causes acetate ions form acetic acid or complex with copper to form blue/green solution of copper(II) acetate.
- Carbonate – all white, confirm with nitric acid to form visible CO_2 bubbles
- Sulfate – all white, no bubbles with nitric acid
- Phosphate – silver phosphate is yellow

12

12



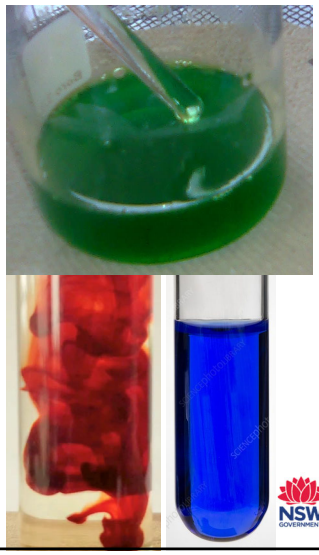
13

NSW Department of Education

How are ions present in the environment identified and measured?

Complexation reactions

- Copper(II) and this site – deep blue complex ion with excess ammonia, green with excess chloride
- Iron(II) – original colour blue/green, hydroxide or ammonia causes oxidation to Iron(III) and below resultant colours at the surface (oxygen exposure) complex ions
- Iron(III) – original colour yellow/orange, deep red thiocyanate and orange hydroxide complex ions
- Again, flame test data will also support decisions made from these reactions.



14

NSW Department of Education

How are ions present in the environment identified and measured?

Gravimetric analysis

- Gravimetric analysis – precipitation and filtration, assay by mass

Figure 1

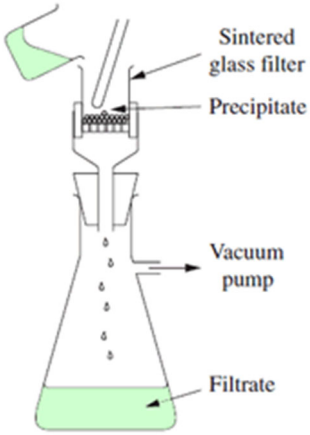


Figure 2

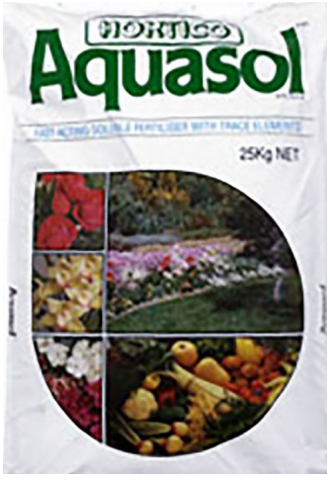
15

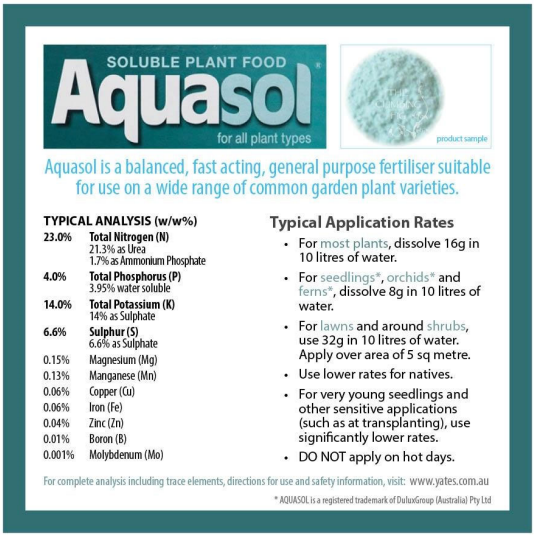
15

NSW Department of Education

How are ions present in the environment identified and measured?

Gravimetric analysis





16

16

NSW Department of Education

How are ions present in the environment identified and measured?

Gravimetric analysis – example calculation

- 15g of fertiliser produces 3.1g of barium sulfate precipitate. Calculate the % w/w of sulfate in the fertiliser, account for deviation from the labelled sulfate content.
- $BaSO_4$ = 233.38 g/mol and SO_4^{2-} 96.06 g/mol
- $BaSO_4$ → Ba^{2+} + SO_4^{2-} (equimolar)
- 3.1g / 233.38 g/mol = 0.013 mol = 0.013 mol SO_4^{2-}
- 0.013 mol x 96.06 g/mol = 1.2g SO_4^{2-}
- 1.2g / 15g x 100 = **8% w/w SO_4^{2-}**
- Label = **6.6% w/w SO_4^{2-}**

17

17

NSW Department of Education

How are ions present in the environment identified and measured?

Precipitation titration

- Precipitation titration – analyte is precipitated from the solution using an indicator to determine the end of precipitation. Example analysis of chloride using Volhard's method or Mohr's method depending on the sample pH.
- Mohr's is simpler to undertake (Volhard's involves a back titration) in the classroom. Chloride in the sample is soluble and potassium **chromate** is added as the indicator. Silver nitrate is dropped in through a burette (standard solution).
- Silver chloride (white)

  1.33×10^{-5}M solubility
- Silver chromate (orange)

  7.54×10^{-5}M solubility

18

18

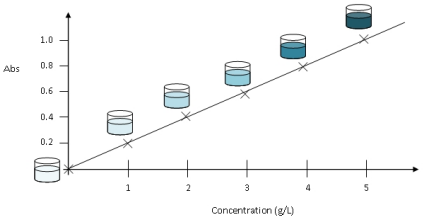
NSW Department of Education

How are ions present in the environment identified and measured?

Spectrometry

$$A = \varepsilon lc = \log_{10}\frac{I_o}{I}$$

- Applies to colourimetry, UV-VIS and AAS.
- Beer-lambert law gives proportionality between concentration and absorbance (limitations exist).
- Absorbance is measured between 0→1 representing a proportion of the light intensity which reaches the detector.
- ε = molar absorptivity constant (ratio of a particular wavelength's absorption to path length of sample) in units of $Lmol^{-1}cm^{-1}$
- l = length in cm of the cuvette (path of light through the sample)
- c = concentration of the analyte in the sample in $molL^{-1}$
- I_o = original intensity of the light source
- I = intensity of light recorded at the detector



19

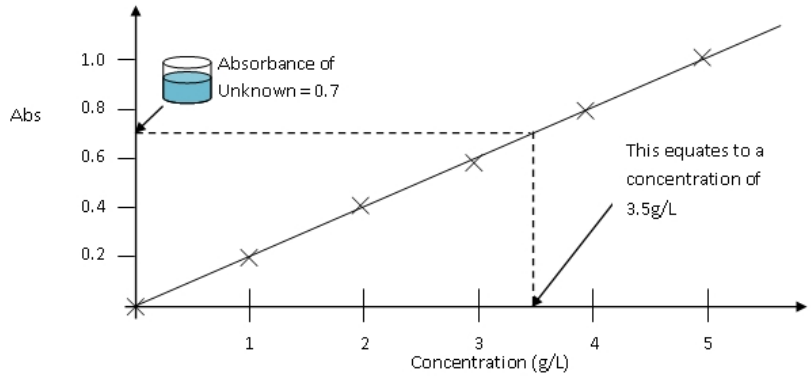
19

NSW Department of Education

How are ions present in the environment identified and measured?

Spectrometry

- Standard comparison



20

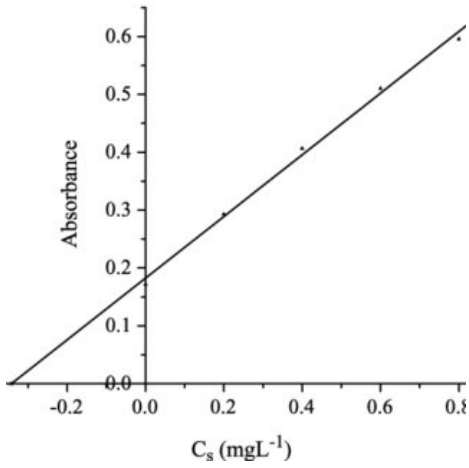
20

NSW Department of Education

How are ions present in the environment identified and measured?

Spectrometry

- Standard addition



21

21

NSW Department of Education

Exam question

2019 Chemistry exam Q20

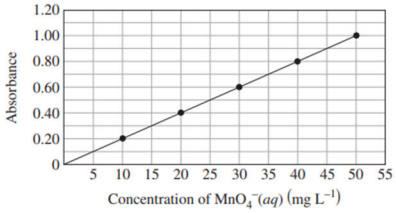
20 The manganese content in a 12.0-gram sample of steel was determined by measuring the absorbance of permanganate (MnO_4^-) using the following process.

The steel sample was dissolved in nitric acid and the $Mn^{2+}(aq)$ ions produced were oxidised to $MnO_4^-(aq)$ by periodate ions, $IO_4^-(aq)$, according to the following equation.

$$2Mn^{2+}(aq) + 5IO_4^-(aq) + 3H_2O(l) \rightarrow 2MnO_4^-(aq) + 5IO_3^-(aq) + 6H^+(aq)$$

The resulting solution was made up to a volume of 1.00 L, then 20.0 mL of this solution was diluted to 100.0 mL. The absorbance at 525 nm of the resulting solution was 0.50.

A calibration curve for $MnO_4^-(aq)$ was constructed and is shown below.



What was the percentage by mass of manganese in the steel sample?

A. 0.019%
B. 0.096%
C. 0.48%
D. 1.0%

22

22

NSW Department of Education

How are ions present in the environment identified and measured?

Colourimetry

23

23

NSW Department of Education

Exam question

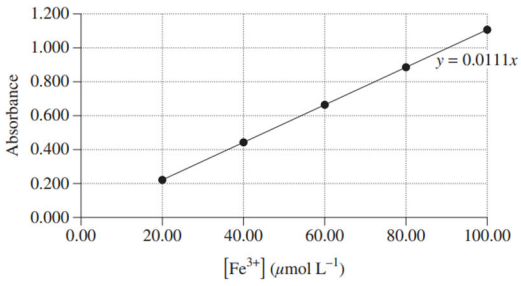
Chemistry specimen exam Q5

5 A colorimeter was used to calculate the percentage of iron in a 0.200 gram tablet. The tablet was dissolved and oxidised, then reacted with thiosulfate according to the equation

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightarrow [FeSCN]^{2+}(aq).$$

The resulting solution was made up to 200 mL with distilled water. The absorbance of the final solution was measured to be 0.6105.

The calibration curve below shows the absorbance of various concentrations of Fe^{3+}.



How much iron was in the tablet?

A. 1.10×10^{-5} g

B. 5.50×10^{-5} g

C. 6.14×10^{-4} g

D. 3.07×10^{-3} g

24

24

NSW Department of Education

Exam question

Chemistry specimen exam Q24

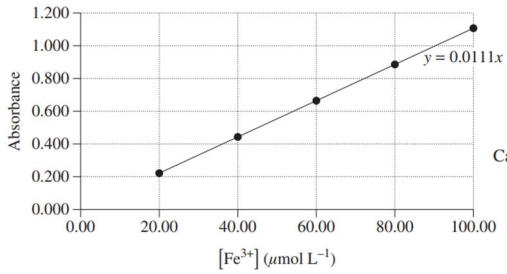
Question 24 (3 marks)

A colorimeter was used to calculate the percentage of iron in a 0.200 gram tablet. The tablet was dissolved and oxidised, then reacted with thiosulfate according to the equation **3**

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightarrow [FeSCN]^{2+}(aq).$$

The resulting solution was made up to 200 mL with distilled water. The absorbance of the final solution was measured to be 0.6105.

The calibration curve below shows the absorbance of various concentrations of Fe^{3+}.



Calculate the percentage of iron in the tablet.

25

25

NSW Department of Education

Exam question

Chemistry specimen exam Q24

Question 24

Criteria	Marks
• Correctly calculates the percentage of iron showing appropriate working	3
• Provides the main steps of the calculation	2
• Provides some relevant information	1

Sample answer:

Using the equation, concentration $= 0.6105/0.0111\ \mu mol\ L^{-1}$

$= 5.5 \times 10^{-5}\ mol\ L^{-1}$

To calculate moles of Fe^{3+}: $n = cV$

$= 5.5 \times 10^{-5}\ mol\ L^{-1} \times 0.2\ L$

$= 1.1 \times 10^{-5}\ mol$

Mass of iron $= 55.85\ g\ mol^{-1} \times 1.1 \times 10^{-5}\ mol$

$= 6.14 \times 10^{-4}\ g$

Percentage of iron $= \frac{6.14 \times 10^{-4}}{0.200} \times 100\%$

$= 0.307\%$

Answers could include:

Concentration may also be obtained by reading the graph.

26

26

NSW Department of Education

How are ions present in the environment identified and measured?

Ultraviolet visible spectrophotometry

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

27

27

NSW Department of Education

How are ions present in the environment identified and measured?

Atomic absorption spectroscopy

28

28

NSW Department of Education

Exam question

Chemistry specimen exam Q25

Question 25 (6 marks)

Fe^{2+} and X react to form an ionic compound according to the general equation

$$a\,Fe^{2+} + b\,X \rightleftharpoons [Fe_a(X)_b]^{2a+}$$

where a and b are numbers representing the ratio in which Fe^{2+} and X combine.

Spectrophotometry was used to determine the stoichiometric ratio between Fe^{2+} and X. To do this, eight 10 mL samples were prepared by reacting solutions of Fe^{2+} with solutions of X in varying ratios. All Fe^{2+} and X solutions had the same concentration. The absorbance of the samples is tabulated below.

	Samples							
Volume of Fe^{2+} solution (mL)	0.00	1.00	2.00	3.00	4.00	5.00	6.00	10.00
Volume of X solution (mL)	10.00	9.00	8.00	7.00	6.00	5.00	4.00	0.00
Absorbance at 508 nm	0.00	0.42	0.84	0.98	0.84	0.70	0.56	0.00

(a) On the grid, construct a graph of absorbance against volume of Fe^{2+} solution from 0.00 mL to 6.00 mL, and draw TWO lines of best fit. **3**

29

29

NSW Department of Education

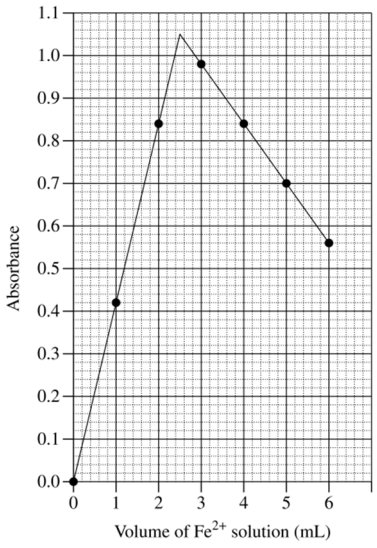
Exam question

Chemistry specimen exam Q25

Question 25 (a)

Criteria	Marks
• Uses appropriate scale • Labels axes correctly with units • Plots points accurately • Draws lines of best fit	3
• Provides a substantially correct graph	2
• Provides some basic features of the graph	1

Sample answer:



30

30

NSW Department of Education

Exam question

Chemistry specimen exam Q25

(b) The reaction proceeds according to the general equation **3**

$$a\,Fe^{2+} + b\,X \rightleftharpoons [Fe_a(X)_b]^{2a+}.$$

Find the values of a and b. Justify your answer with reference to the data given and the graph in part (a).

31

31

NSW Department of Education

Exam question

Chemistry specimen exam Q25

Question 25 (b)

Criteria	Marks
• Identifies a and b • Justifies answer with reference to the data given and the graph	3
• Identifies a and b with some justification OR • Provides some explanation of the reactions with reference to the data given and/or the graph	2
• Provides some relevant information	1

Sample answer:

The graph shows an increase in Fe^{2+} ions as the amount of compound X decreases, indicating an excess of Fe^{2+} ions limiting the products. It reaches a maximum when the correct stoichiometric ratio for the equation is obtained. This occurs when 2.5 mL Fe^{2+} to 7.5 mL compound X are reacted. As the concentrations of the initial solutions are equal, equal volumes produce equal moles. Hence $a = 1$ and $b = 3$. The curve then decreases as there is less Fe^{2+}.

32

32

NSW Department of Education

How are ions present in the environment identified and measured?

Atomic absorption spectroscopy

33

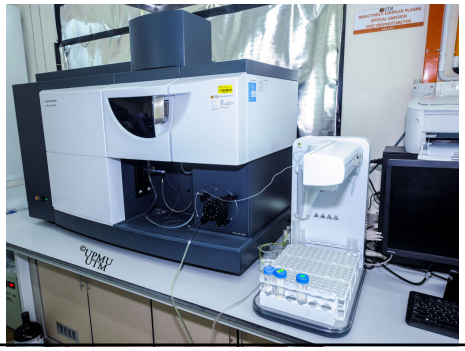
33

NSW Department of Education

How are ions present in the environment identified and measured?

Other inorganic spectroscopy?

- ICP-OES – new technique which is more convenient than AAS/AES and can be used to detect multiple analytes in the sample simultaneously. Massive costs to buy one and maintain but is rather simple and quick to operate (cost offset). Broader range of analytes that are suitable for testing and comparable detection limits and accuracy to AAS.



34

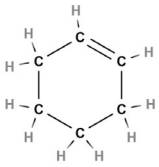
34

NSW Department of Education

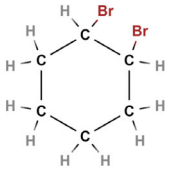
How is information about the reactivity and structure of organic compounds obtained?

Chemical Tests - alkenes

- Bromine test for unsaturation with cyclohexene giving 1,2-dibromocyclohexane:



$+Br_{2(aq)} \leftrightarrow$



- Bromine test with cyclohexane gives no reaction. This reaction is also photosensitive, bromine can react and substitute for hydrogen on alkanes in the presence of UV light giving a false positive result. It is therefore important to protect the test from light.

35

35

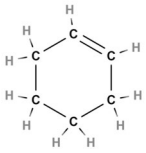
NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

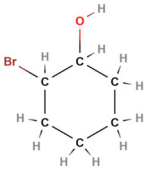
Chemical Tests - alkenes

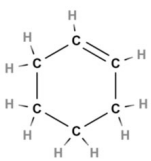
$$Br_{2(aq)} + H_2O_{(l)} \leftrightarrow HOBr_{(aq)} + HBr_{(aq)}$$

- Bromine water contains hydrobromous acid and hydrobromic acid (due to the reaction of Bromine with water) that provide alternative products in this addition reaction. Although the positive and negative test results are identical and the 1,2-dibromocyclohexane product is still produced, it is not the most common product in this circumstance:

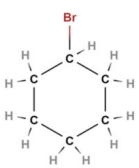


$+HOBr_{(aq)} \leftrightarrow$





$+HBr_{(aq)} \leftrightarrow$



36

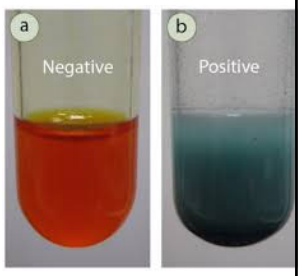
36

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Chemical Tests - alkanols

- Jones' oxidation test for primary/secondary alcohols using acidified potassium dichromate. Positive test is a green/blue colour showing the alcohol has been oxidised to its corresponding aldehyde/ketone. Tertiary alcohols are unable to be oxidised so will return a negative result (stays orange).
- Lucas' reagent to detect tertiary alcohols – $ZnCl_2$ + HCl. Haloalkane product and cloudy appearance. Slow reaction with secondary, no reaction to primary.



37

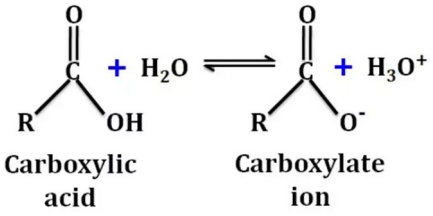
37

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Chemical Tests – alkanoic acids

- Acid pH, can use any indicator for this which gives a colour to pH < 7.
- Sodium carbonate test gives CO_2 emission.



38

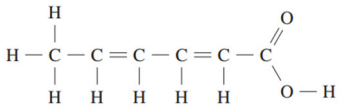
38

NSW Department of Education

Exam question

Chemistry specimen exam Q1

1 The structure of an organic compound is shown.



Which row of the table correctly shows how this compound reacts with bromine water and with blue litmus?

	Bromine water	*Blue litmus*
A.	No reaction	No reaction
B.	No reaction	Turns red
C.	Decolourises	No reaction
D.	Decolourises	Turns red

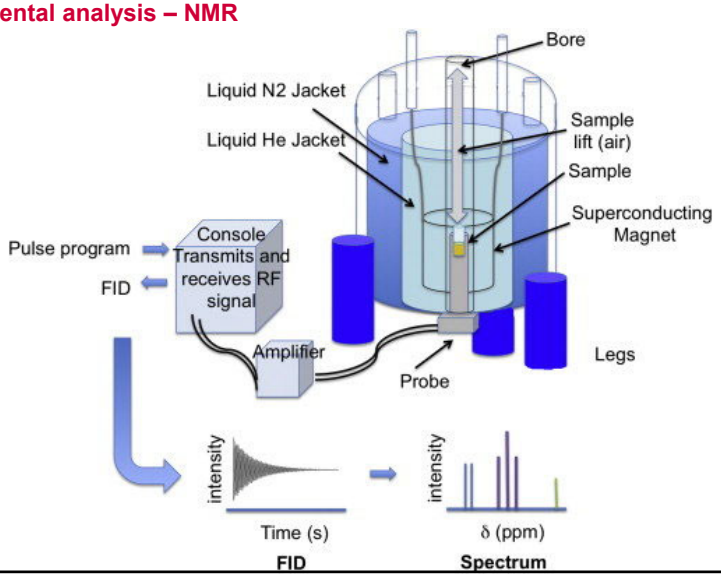
39

39

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis – NMR



40

40

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis – NMR

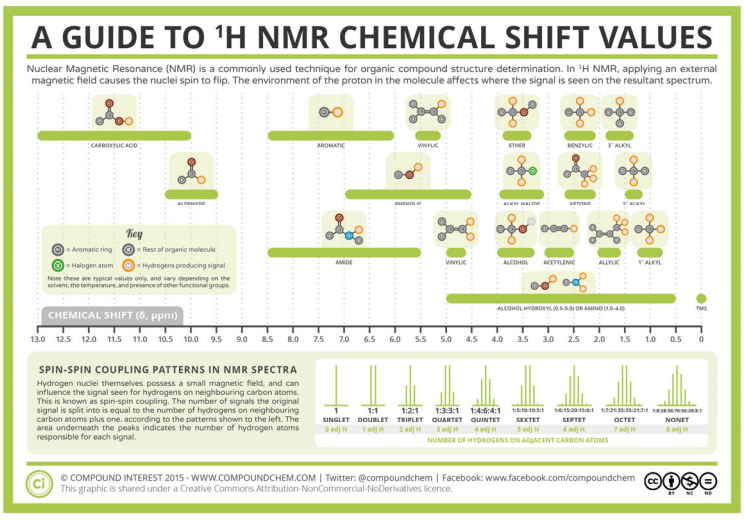
41

41

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis – Proton NMR



42

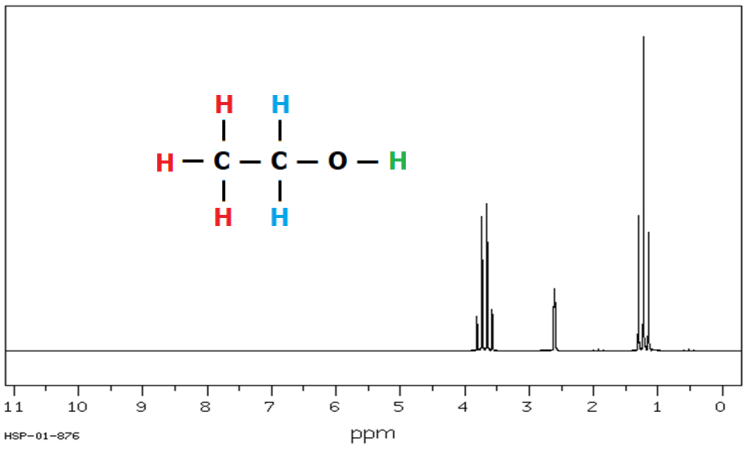
42

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis – Proton NMR

- Proton NMR spectra for ethanol



43

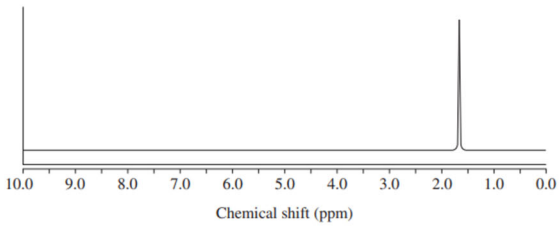
43

NSW Department of Education

Exam question

2019 Chemistry exam Q14

14 A molecule, C_4H_9Cl, is analysed. The ^1H NMR spectrum of this molecule is shown.



What is the structural formula of this molecule?

A. $CH_3-\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{|}{\underset{|}{C}}}}-Cl$

B. $CH_3-\underset{\displaystyle CH_3}{CH}-CH_2-Cl$

C. $CH_3-CH_2-\underset{\displaystyle Cl}{CH}-CH_3$

D. $CH_3-CH_2-CH_2-CH_2-Cl$

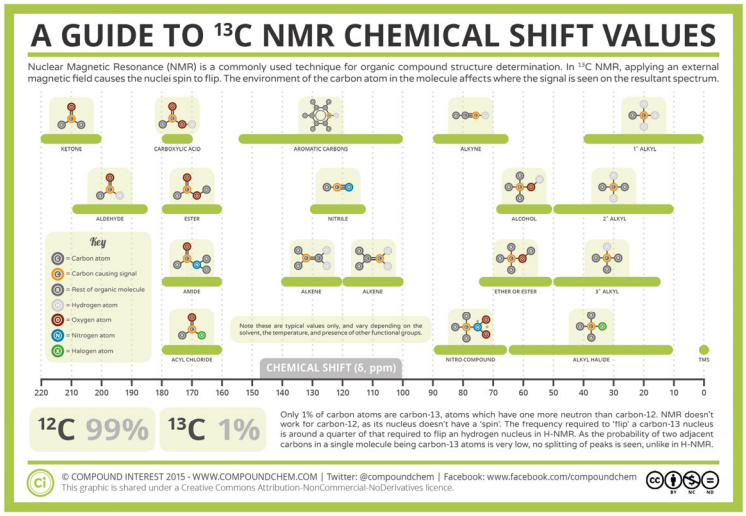
44

44

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis – 13C NMR



45

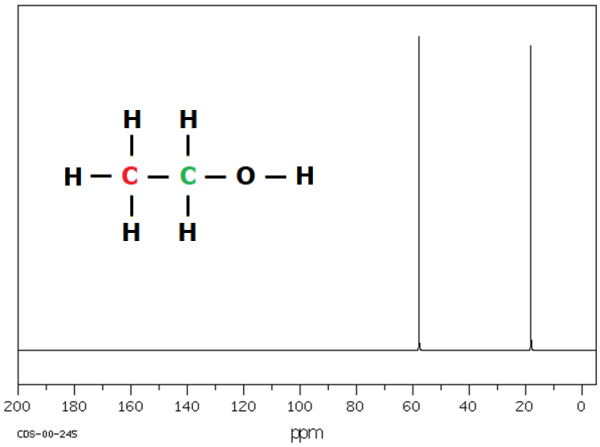
45

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis – 13C NMR

- Carbon-13 NMR spectra for ethanol



¹³C NMR chemical shift data

Type of carbon	δ/ppm
— C — C —	5–40
R — C — Cl or Br	10–70
R — C — C — (C=O)	20–50
R — C — N	25–60
— C — O — alcohols, ethers or esters	50–90
C = C	90–150
R — C ≡ N	110–125
aromatic ring	110–160
R — C — (C=O) esters or acids	160–185
R — C — (C=O) aldehydes or ketones	190–220

46

46

NSW Department of Education

Exam question

2019 Chemistry exam Q19

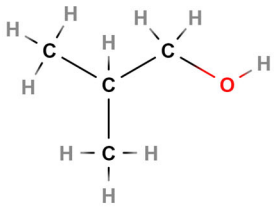
19 Compound X shows three signals in its ^{13}C NMR spectrum.

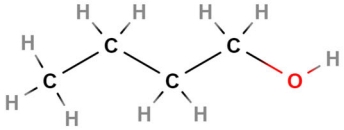
Treatment of X with hot acidified potassium permanganate produces a compound Y. Compound Y turns blue litmus red.

Compound X produces compound Z upon reaction with hot concentrated sulfuric acid.

Which of the following correctly identifies compounds X, Y and Z?

	Compound X	*Compound Y*	*Compound Z*
A.	butan-1-ol	butanoic acid	but-1-ene
B.	butan-2-ol	butanone	but-2-ene
C.	methyl ethanoate	methanoic acid	ethene
D.	2-methylpropan-1-ol	2-methylpropanoic acid	2-methylprop-1-ene





47

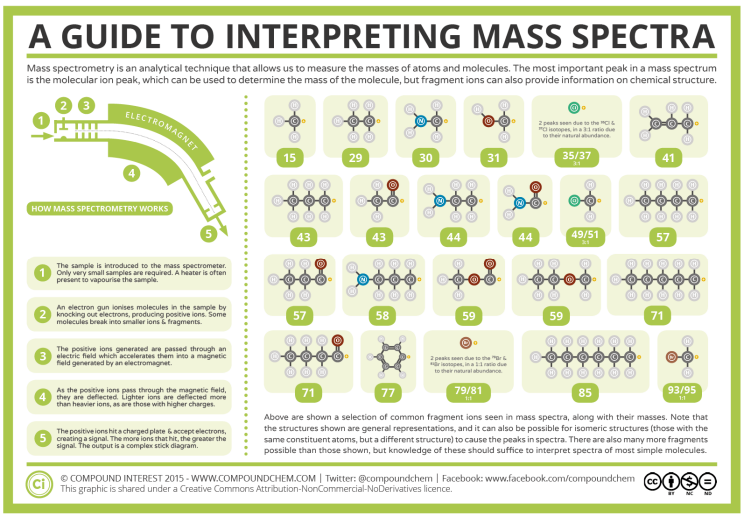
NSW GOVERNMENT

47

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis - MS



NSW GOVERNMENT

48

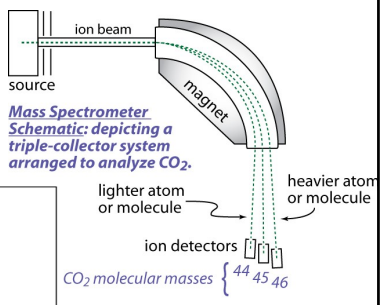
48

NSW Department of Education

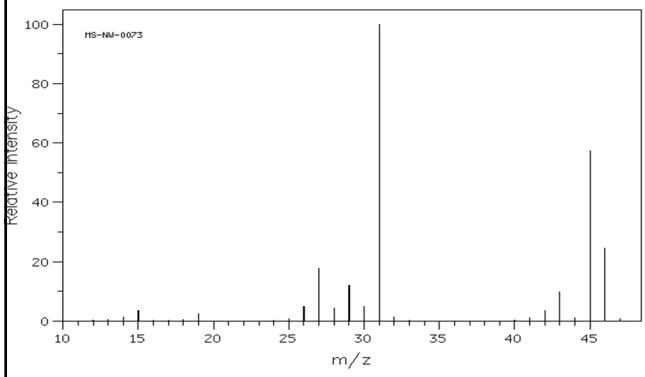
How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis - MS

- Mass spectrum for ethanol



Mass Spectrometer Schematic: depicting a triple-collector system arranged to analyze CO_2.



49

NSW GOVERNMENT

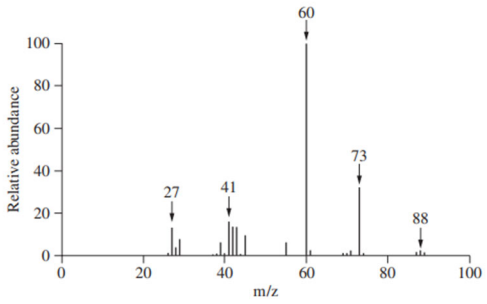
49

NSW Department of Education

Exam question

2019 Chemistry exam Q4

4 The diagram shows the mass spectrum of an organic compound.



Which compound was analysed?

A. Butan-1-amine
B. Butanoic acid
C. Ethanoic acid
D. Iron(II) sulfide

50

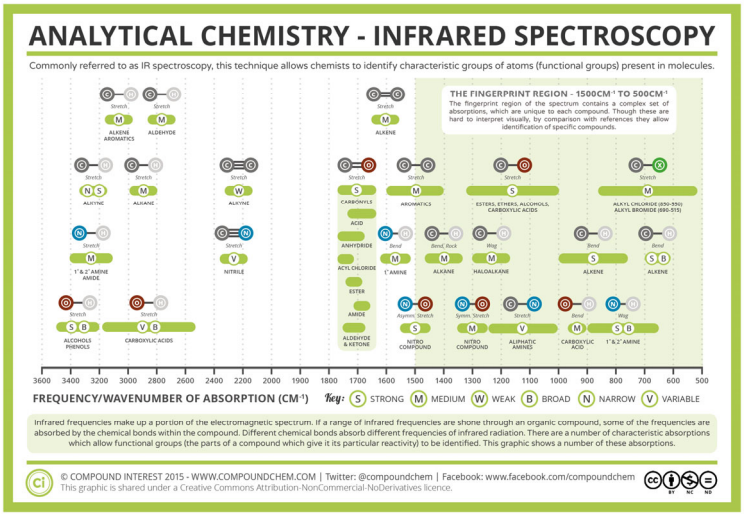
NSW GOVERNMENT

50

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis - IR



51

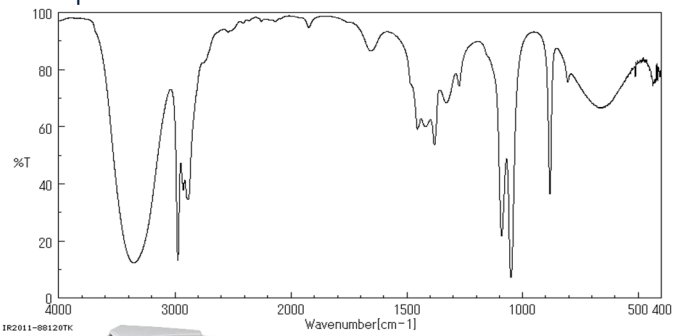
51

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Instrumental analysis - IR

- IR spectrum for ethanol



Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

52

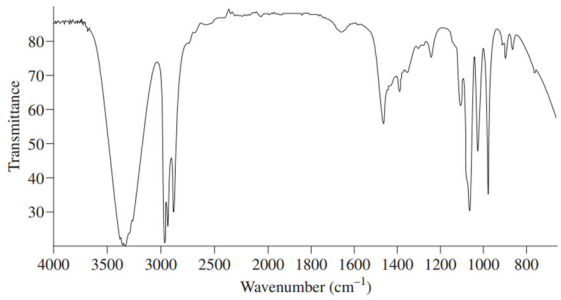
52

NSW Department of Education

Exam question

Chemistry specimen exam Q3

3 The diagram shows the infrared spectrum of a compound.



Which compound was analysed?

A. Butane
B. Propanol
C. Propanal
D. Butanoic acid

53

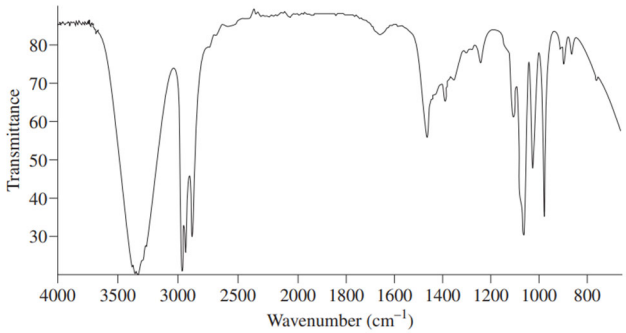
NSW Department of Education

Exam question

Chemistry specimen exam Q23

Question 23 (4 marks)

The diagram shows the infrared spectrum of a compound. **4**



The molecular weight of the compound analysed is approximately 60 g mol^{-1}. Suggest TWO possible compounds that could fit this spectrum and justify your selection.

54

NSW Department of Education

Exam question

Chemistry specimen exam Q23

Question 23

Criteria	Marks
• Suggests two possible compounds with justification	4
• Suggests at least one possible compound and shows a sound understanding of infrared spectra and functional groups	3
• Suggests possible compound(s) and/or shows some understanding of infrared spectra and/or functional groups	2
• Provides some relevant information	1

55

55

NSW Department of Education

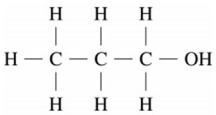
Exam question

Chemistry specimen exam Q23

Sample answer:

The first set of absorbance forms a broad trough maximising at around 3400 cm^{-1} and spread from around 3100–3600 cm^{-1}. Based on the infrared absorption data provided, this suggests that a hydroxyl group is likely to be present. The second trough occurs between 2700 and 3100 cm^{-1} and the intensity trough is not broad, which closely matches the data for the C—H bond. There is little absorbance between 2500–1500 cm^{-1} suggesting the lack of a C=0 group. Therefore, neither a carboxylic acid nor ketone is being analysed. The peak for the C—O bond occurs at 1250–1050 cm^{-1} suggesting it is present.

The structural formula for propanol is



and contains bonds as shown.

The molecular weight of propanol is 60.01 g mol^{-1} again consistent with the data. There are therefore 2 isomers of propanol. The spectrum could be of either propan-1-ol or propan-2-ol. Each would give a similar spectrum.

56

56

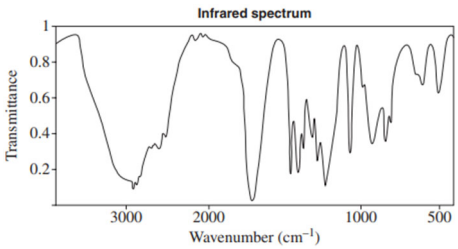
NSW Department of Education

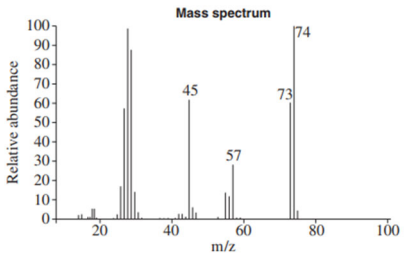
Exam question

2019 Chemistry exam Q26

Question 26 (8 marks)

The following data were obtained for an organic compound containing carbon, hydrogen and oxygen. The compound is a colourless liquid that reacts with sodium carbonate powder to produce bubbles.





57

57

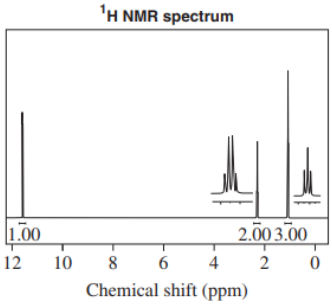
NSW Department of Education

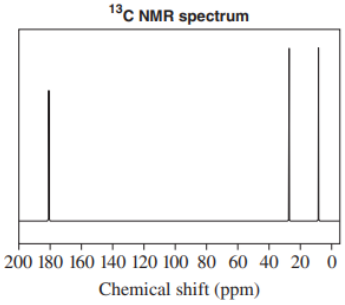
Exam question

2019 Chemistry exam Q26

Question 26 (8 marks)

The following data were obtained for an organic compound containing carbon, hydrogen and oxygen. The compound is a colourless liquid that reacts with sodium carbonate powder to produce bubbles.





58

58

NSW Department of Education

Exam question

2019 Chemistry exam Q26

Question 26 (continued)

(a) What is the structural formula of this compound? Justify your answer with reference to the information given on its reactivity and to at least THREE of the provided spectra. **5**

59

59

NSW Department of Education

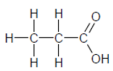
Exam question

2019 Chemistry exam Q26

Question 26 (a)

Criteria	Marks
• Gives correct structure and justifies using reactivity and at least three spectra	5
• Gives substantially correct structure and justifies using reactivity and at least two spectra OR • Gives a correct structure and justifies using at least three spectra	4
• Gives substantially correct structure and some correct analyses OR • Gives substantially correct analyses with incorrect structure	2–3
• Provides some relevant information	1

Sample answer:



Reaction with sodium carbonate implies that it is an organic acid as shown.

The ^{13}C NMR spectrum has three peaks; the peak at 180 ppm confirms the presence of a COOH group.

The ^{1}H NMR spectrum shows 3 separate proton environments – the splitting and integration indicate a CH_3 group and a CH_2 group.

The mass spectrum has a parent ion at 74, indicating that the compound must have a molar mass of 74 g mol^{-1}.

Answers could include:

Condensed or skeletal formula.

Could use infrared to confirm the presence of a carboxylic acid group.

60

60

NSW Department of Education

Exam question

2019 Chemistry exam Q26

(b) Explain why a chemist should use more than one spectroscopic technique to identify an organic compound. Use TWO spectroscopic techniques to support your answer. **3**

61

NSW Department of Education

Exam question

2019 Chemistry exam Q26

Question 26 (b)

Criteria	Marks
• Explains why more than one spectroscopic technique should be used • Supports answer with two spectroscopic techniques	3
• Outlines why more than one spectroscopic technique should be used • Supports answer with at least one spectroscopic technique	2
• Provides some relevant information	1

Sample answer:

Different techniques are used in the identification of organic molecules but give different information about structure.

For example, ^{1}H NMR provides information about the chemical environment and relative number of hydrogen nuclei. This can be used to identify functional groups and distinguish between isomers.

Mass spectrometry gives information about the molecular weight of a molecule and its characteristic fragments.

62

NSW Department of Education

Exam question

2019 Chemistry exam Q26

Question 26

In better responses, students were able to:

- draw a clear structure of propanoic acid
- use the information in the question to link the reactivity with sodium carbonate producing bubbles to justify that the compound is a carboxylic acid
- correctly use information shown in three of the four spectra given to justify the structure of propanoic acid
- clearly show how two spectroscopic techniques can be used in the identification of an organic compound.

Areas for students to improve include:

- reading the question more carefully to ensure that they include all the necessary information in their response
- reading from the spectra provided and relating the values to the data sheet provided to determine the structure of the compound
- knowing the key use for each of the spectroscopic techniques and then indicating how multiple spectra work together in the identification of an organic compound.

63

63

NSW Department of Education

Exam question

2019 Chemistry exam Q29

Question 29 (11 marks)

Stormwater from a mine site has been found to be contaminated with copper(II) and lead(II) ions. The required discharge limit is 1.0 mg L^{-1} for each metal ion. Treatment of the stormwater with $Ca(OH)_2$ solid to remove the metal ions is recommended.

(a) Explain the recommended treatment with reference to solubility. Include a relevant chemical equation. **2**

(b) Explain why atomic absorption spectroscopy can be used to determine the concentrations of Cu^{2+} and Pb^{2+} ions in a solution containing both species. **2**

64

64

NSW Department of Education

Exam question

2019 Chemistry exam Q29

Question 29 (a)

Criteria	Marks
• Explains the treatment with reference to solubility • Provides a correct chemical equation	2
• Provides some relevant information	1

Sample answer:

Calcium hydroxide, $Ca(OH)_2$, is slightly soluble in water. Copper(II) hydroxide and lead(II) hydroxide are both very insoluble in water shown by their small K_{sp} values, which will result in most of the metal ions precipitating.

A chemical equation $Cu(OH)_2(s) \rightleftharpoons Cu^{2+}(aq) + 2OH^-(aq)$

Answers could include:

Alternative chemical equations:

$Pb(OH)_2(s) \rightleftharpoons Pb^{2+}(aq) + 2OH^-(aq)$

$M(OH)_n(s) \rightleftharpoons M^{n+}(aq) + nOH^-(aq)$

65

65

NSW Department of Education

Exam question

2019 Chemistry exam Q29

Question 29 (b)

Criteria	Marks
• Provides a valid explanation	2
• Provides some relevant information	1

Sample answer:

AAS determines the concentration of metal ions by measuring the absorbance of light at different characteristic wavelengths for each metal. This allows the determination of the concentration of one metal without interference from the other metal.

66

66

NSW Department of Education

Exam question

2019 Chemistry exam Q29

(c) The data below were obtained after treatment of the stormwater. **7**

Data from atomic absorption spectroscopy

Concentration ($\times 10^{-5}$ mol L^{-1}) Cu^{2+} or Pb^{2+}	*Absorbance*	
	Cu^{2+}	Pb^{2+}
0.0	0.000	0.000
1.0	0.140	0.090
2.0	0.310	0.180
4.0	0.520	0.390
6.0	0.840	0.530
Water sample before treatment	0.820	0.440
Water sample after treatment	0.040	0.080

To what extent is the treatment effective in meeting the required discharge limit of 1.0 mg L^{-1} for each metal ion? Support your conclusion with calibration curves and calculations.

67

NSW Department of Education

Exam question

2019 Chemistry exam Q29

Question 29 (c)

Criteria	Marks
• Provides correct graph – Labels axes correctly, including units – Uses appropriate scale – Plots both sets of data – Draws two lines of best fit – Provides a key • Provides correct concentration values • Converts concentration data from mol L^{-1} to mg L^{-1} • Compares to discharge limit and makes correct judgement of treatment success	7
• Provides a substantially correct answer with a minor error	6
• Provides correct graph, provides correct concentration values and applies conversion OR • Provides a substantially correct graph, provides concentration values, applies conversion and attempts judgement	5
• Provides correct graph and provides correct concentration values OR • Provides a graph with some correct features, provides concentration values and applies conversion	4
• Provides correct graph OR • Provides a graph with some correct features and provides some concentration values	3
• Provides a substantially correct graph OR • Provides a graph with two correct features and extracts some relevant sample data OR • Provides a graph with one correct feature, extracts some relevant sample data and attempts a relevant conversion	2
• Provides some relevant information	1

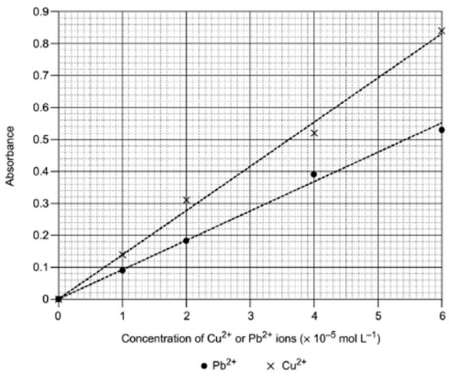
68

NSW Department of Education

Exam question

2019 Chemistry exam Q29

Sample answer:



Concentrations of metals ions in mol L^{-1}

Sample	$Cu^{2+} \times 10^{-5}$ mol L^{-1}	$Pb^{2+} \times 10^{-5}$ mol L^{-1}
Water sample pre-treatment	5.95	4.75
Water sample post-treatment	0.25	0.85

The copper and lead concentrations have both been lowered by the treatment. To compare the post treatment concentrations to the discharge standard, the sample concentrations need to be converted to mg L^{-1}.

Cu^{2+}: 5.95×10^{-5} mol $L^{-1} \times 63.55$ g $mol^{-1} \times 1000$ mg $g^{-1} = 3.78$ mg L^{-1}
0.25×10^{-5} mol $L^{-1} \times 63.55$ g $mol^{-1} \times 1000$ mg $g^{-1} = 0.20$ mg L^{-1}

Pb^{2+}: 4.75×10^{-5} mol $L^{-1} \times 207.2$ g $mol^{-1} \times 1000$ mg $g^{-1} = 9.84$ mg L^{-1}
0.85×10^{-5} mol $L^{-1} \times 207.2$ g $mol^{-1} \times 1000$ mg $g^{-1} = 1.8$ mg L^{-1}

Conclusion: The copper ion concentration has been successfully lowered to less than the discharge limit. However, the lead ion concentration, although reduced, remains above the discharge limit. The treatment is only partially successful.

69

69

NSW Department of Education

Exam question

2019 Chemistry exam Q29

Question 29

In better responses, students were able to:

- relate the K_{sp} values to the differences in solubility of the substances
- write correctly balanced ionic equations
- demonstrate their understanding of AAS relevant to detecting different metals in solution
- make the link between each different metal ion being able to absorb a wavelength that is specific to that ion
- construct graphs with correctly plotted points, a key to identify each ion, labelled axes (with correct units), appropriate scales and accurately ruled lines of best fit
- use the graph to find (interpolate) concentration values given the absorbance
- correctly convert concentration in $molL^{-1}$ to mass in milligrams with the correct orders of magnitude and units.

Areas for students to improve include:

- demonstrating a clear understanding of differences in solubility, for example, using K_{sp} values to support the response
- using relevant terminology for AAS rather than providing generalised information
- demonstrating a clear understanding of AAS
- answering 'why' rather than 'how' AAS works
- accurately plotting points on a graph and drawing lines of best fit rather than connecting the dots
- interpolating data from a graph
- correctly converting $molL^{-1}$ to mgL^{-1}
- not making careless mathematical or transcription errors such as putting the decimal point in the wrong place.

70

70

NSW Department of Education

How is information about the reactivity and structure of organic compounds obtained?

Other organic spectroscopy?

- Raman spectroscopy – uses laser illumination and detecting the scattered radiation (gross oversimplification) spectrum which is unique to the analyte, coolest version is “Spatially offset Raman spectroscopy” which can detect through containers. Some units can be handheld and portable for onsite testing. No real trick to using them (setup is a different story).

71

71

NSW Department of Education

What are the implications for society of chemical synthesis and design?

Availability of reagents

- If you do not have the reagents available then production is impossible. Reagents must be available in the quantity and quality needed for the production process. Different grades of purity (and hence cost):
  - Reagent Grade [Analytical Reagent (AR), Guaranteed Reagent (GR), UNIVAR, AnalaR, Premium Reagent (PR)]
  - Laboratory Grade [Laboratory Reagent (LR), UNILAB, Chemically Pure (CP)]
  - Technical Grade [Tech Grade (TG), Commercial Grade]
  - Other Grades [These grades are application specific, extensive data is available from key manufacturers and distributors]

  Example: Development of Haber process for ammonia due to no access to South America for guano shipments. Calcium Carbonate for Solvay process. Sulfuric acid contact process.

72

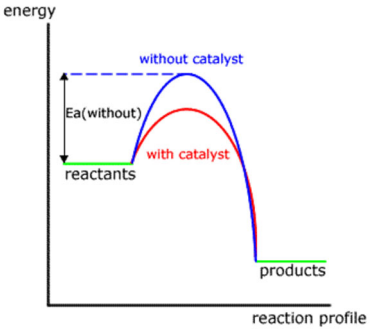
72

NSW Department of Education

What are the implications for society of chemical synthesis and design?

Reaction conditions

- Time of reaction to produce the required yield (links to profitability of product)
- Catalysts – not consumed in the reaction, reduced activation energy
- Enthalpy, entropy of reaction (and hence G)



	$\Delta H < 0$	$\Delta H > 0$
$\Delta S > 0$	Spontaneous at all T ($\Delta G < 0$)	Spontaneous at high T (when $T\Delta S$ is large)
$\Delta S < 0$	Spontaneous at low T (when $T\Delta S$ is small)	Non-spontaneous at all T ($\Delta G > 0$)

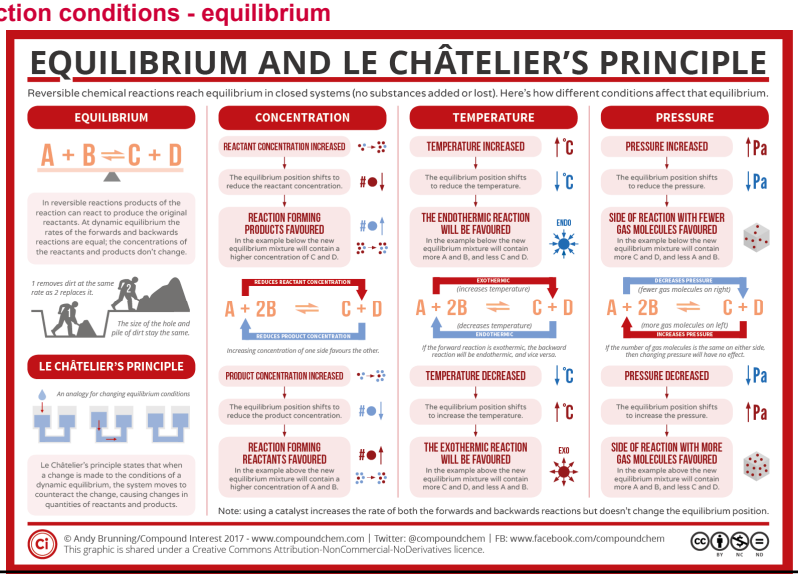
73

73

NSW Department of Education

What are the implications for society of chemical synthesis and design?

Reaction conditions - equilibrium



74

74

NSW Department of Education

What are the implications for society of chemical synthesis and design?

Yield and purity

- Yield is linked to the efficiency of your process to account for losses in production compared to the maximum that is stoichiometrically possible

$$\%\ Yield = \frac{Actual\ Yield}{Theoretical\ Yield} \times 100\%$$

$$\%\ Yield = \frac{55\ g\ CO_2}{66\ g\ CO_2} \times 100\% = 83\%$$

$$\%\ \boldsymbol{Yield = 83\%}$$

- Purity is linked to the side reactions and processes during production introducing contamination.
  - Subsequent steps required to clean up the product add to cost of the product so can not exceed the needs of the end use. Only needed if contaminant is problematic for end use.
  - Important to know what type of contamination exists in the final product. Chemical grade assigned based on the amount of and confidence in the impurity identification. Implications for cost of product.
  - Purity can also effect shelf-life of the product so used to inform expiry dates etc. Some products require other materials to retain stability. Hydrogen peroxide usually contains 25-250mgL^{-1} sodium pyrophosphate.

75

75

NSW Department of Education

What are the implications for society of chemical synthesis and design?

Industrial uses

- What is the product intended to be used for?

- What quantities is it consumed in?

- How far does it have to be transported from production to consumers?

76

76

NSW Department of Education

What are the implications for society of chemical synthesis and design?

Environmental, social and economic issues

- Need to think about product AND production processes
- Environmental – wastes?
  Chemical/Biological/Radiological wastes are particularly tricky with regulation and diversity of treatments required
- Social – employment, risk, cost/benefit analysis
- Economic – everything in reality comes down to profit margins. Is the product via its production method able to generate a suitable profit for the company?

77

77

NSW Department of Education

What are the implications for society of chemical synthesis and design?

Other factors – Green chemistry principles

- P – Prevent wastes
- R – Renewable materials
- O – Omit derivatisation steps
- D – Degradable chemical products
- U – Use of safe synthetic methods
- C – Catalytic reagents
- T – Temperature, Pressure ambient
- I – In-Process monitoring
- V – Very few auxiliary substrates
- E – E-factor, maximise feed in product
- L – Low toxicity of chemical products
- Y – Yes, it is safe

$$\text{Percent yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\%$$

$$\text{Atom Economy} = \frac{\text{FW of desired product(s)}}{\text{Combined FW of starting materials}} \times 100\ \%$$

$$\text{E-factor} = \frac{\text{kgs of waste produced}}{\text{kgs of desired product}}$$

$$\text{EMY} = \frac{\text{mass of desired product}}{\text{mass of non-benign reagents}} \times 100\ \%$$

78

78

NSW Department of Education

What are the implications for society of chemical synthesis and design?

Case study possibilities

- Contact process for Sulfuric acid
- Haber process for Ammonia
- Membrane process for Sodium Hydroxide
- Polymerisation for HDPE/LDPE/PETE
- Various medications (ext for many compound structures)

79

79

NSW Department of Education

What are the implications for society of chemical synthesis and design?

Case study – Solvay process for sodium carbonate

1. $NaCl_{(aq)} + NH_{3(g)} + CO_{2(g)} + H_2O_{(l)} \rightarrow NaHCO_{3(s)} + NH_4Cl_{(aq)}$

   $\Delta H = -158 kJmol^{-1}$

2. $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

   $\Delta H = +178 kJmol^{-1}$

3. $2NH_4Cl_{(aq)} + CaO_{(s)} \rightarrow 2NH_{3(g)} + CaCl_{2(aq)} + H_2O_{(l)}$

   $\Delta H = -85 kJmol^{-1}$

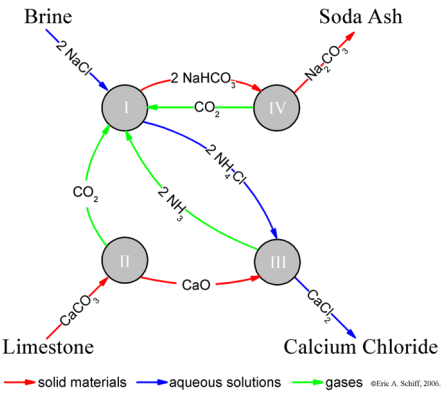
4. $2NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$

   $\Delta H = +85 kJmol^{-1}$

Overall reaction is:

$2NaCl_{(aq)} + CaCO_{3(s)} \rightarrow Na_2CO_{3(s)} + CaCl_{2(aq)}$

$\Delta H = +20 kJmol^{-1}$ & $\Delta G = +60 kJmol^{-1}$



80

80