STUDENT NUMBER: ……..

PENRITH SELECTIVE HIGH SCHOOL

HSC CHEMISTY 2020

TRIAL EXAMINATION

General Instructions

- Reading time – 10 minutes
- Exam time – 3 hrs
- Board-approved calculators may be used
- Write using **blue or black** pen
- Answers written in pencil may be disqualified from review

SECTION I

Multiple Choice (20)

- Attempt Questions 1 – 20
- Allow about 30 minutes
- Use the multiple choice answer sheet found at the end of this paper

SECTION II

Free Response (80)

- Attempt Question 16 – 34
- Allow 2 hrs and 30 minutes

SECTION I - Multiple Choice Questions
Attempt Questions 1 – 20
Allow 30 minutes

The following information relates to Question 1 and 2.

Hydrogen is produced on an industrial scale from methane. The equation for the reaction is

$$2H_2O(g) + CH_4(g) \rightleftharpoons CO_2(g) + 4H_2(g)$$

Question 1

The expression for the equilibrium constant for the reverse reaction is:

(A) $K_{eq} = \frac{[H_2O]^2[CH_4]}{[H_2]^4[CO_2]}$

(B) $K_{eq} = \frac{[H_2]^4[CO_2]}{[H_2O]^2[CH_4]}$

(C) $K_{eq} = \frac{[H_2O]\,[CH_4]}{[H_2]\,[CO_2]}$

(D) $K_{eq} = \frac{4[H_2][CO_2]}{2[H_2O][CH_4]}$

Question 2
If an inert gas is added to the equilibrium system at a constant temperature and a constant volume the concentration of hydrogen will:

(A) Decrease and then increase

(B) Not change

(C) Increase

(D) Decrease.

Question 3

How can dynamic chemical equilibrium best be described?

(A) An open system in which all reactions have ceased and so the concentrations of all species remain constant.

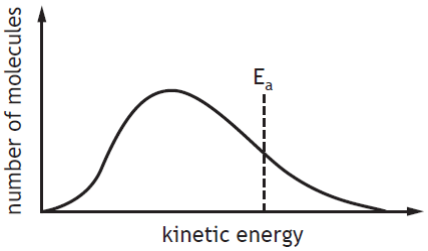
(B) An open system in which the rate of forward reaction is equal to the rate of reverse reaction.

(C) A closed system in which all reactions have ceased and so the concentrations of all of the species remain constant.

(D) A closed system in which the rate of forward reaction is equal to the rate of reverse reaction.

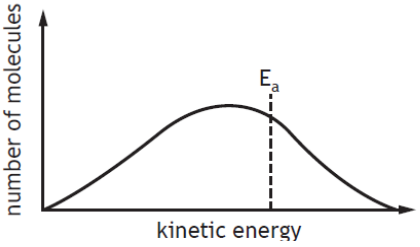
Question 4

The graph below shows the kinetic energies for a reaction involving two gases.



Which graph would show the effect of increasing temperature?

(A)



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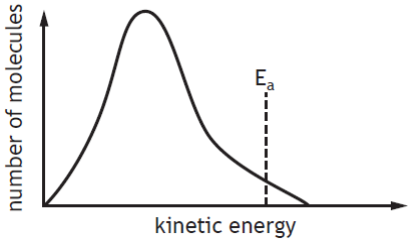

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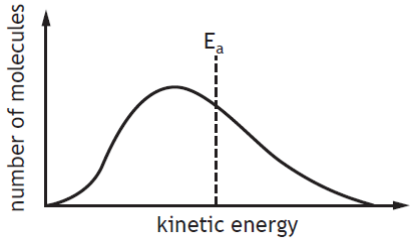
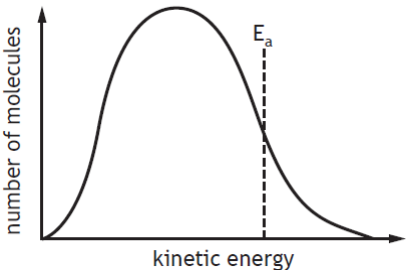


(D)



Question 5

Which of the following precipitates may form when equal volumes of 0.3 M $AgNO_3$, 0.3 M $BaCl_2$ and 0.3 M Na_2CO_3 are mixed together?

(A) $BaCO_3$ and AgCl

(B) $BaCO_3$, Ag_2CO_3 and AgCl

(C) $BaCO_3$ and Ag_2CO_3

(D) Ag_2CO_3 and AgCl

Question 6

The following table shows the pH of a number of different substances.

Substance	pH
Coffee	5.6
Drain Cleaner	12.4
Soft Drink	4.3
Sink Cleanser	11.1
Lemon Juice	4.1
Bicarb Soda	8.1

Which statement is correct about the table?

(A) Drain cleaner is more basic than bicarb soda

(B) Coffee is more acidic than soft drink

(C) Bicarb soda is more basic than sink cleanser

(D) Soft drink is more acidic than lemon juice

Question 7

What is the pH of a 0.010 moles/litre solution of sodium hydroxide?

(A) 2

(B) 5

(C) 9

(D) 12

Question 8

The following table shows the pH and colour change of several indicators

Indicator	***pH***	***Colour Change***
Phenolphthalein	8.1 – 9.7	Colourless – Scarlet Pink
Bromothymol Blue	6.0 – 7.6	Yellow – Blue
Litmus	7.0	Red – Blue
Alizarin Yellow	10.1 – 12.0	Yellow - Red
Methyl Orange	3.1 – 4.4	Red - Yellow

An unknown solution was tested using the indicators and the following colours identified

Indicator	***Colour of Unknown Solution***
Phenolphthalein	Colourless
Bromothymol Blue	Yellow
Litmus	Red
Alizarin Yellow	Yellow
Methyl Orange	Yellow

The pH of the unknown solution is between

(A) 3.1 and 7.0

(B) 4.4 and 6.0

(C) 7.6 and 8.1

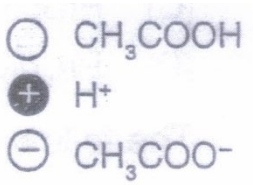
(D) 9.7 and 10.1

Question 9

The following models are representing acid solutions.

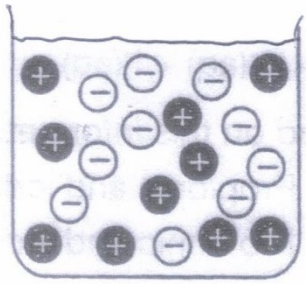
Acetic Acid (CH_3COOH) is a weak organic acid.

KEY:



Which model is correct for a concentrated solution of acetic acid?

(A)



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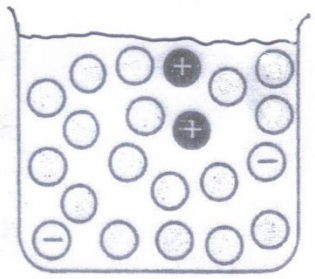

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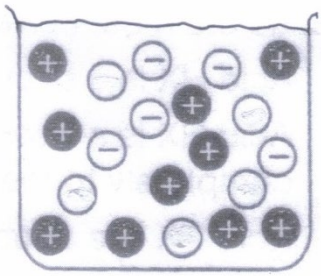
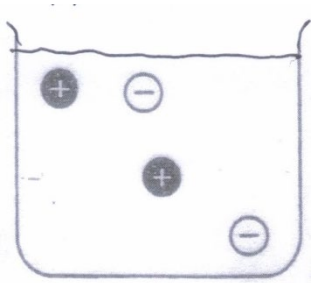
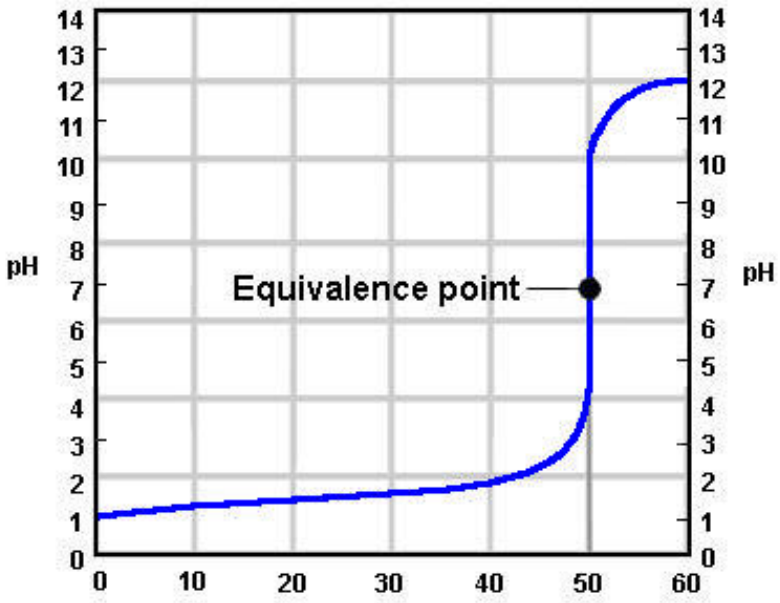


(D)



Question 10

A student performed a titration using an unknown solution of a base and 25.00 mL of a 0.100 M solution of hydrochloric acid. A data logger was used to record the pH during the titration.



Volume of base added (mL)

The data shown indicates that

(A) the base is strong and more concentrated than the hydrochloric acid

(B) the base is weak and more concentrated than the hydrochloric acid

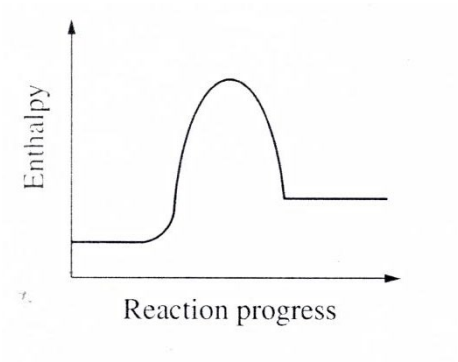
(C) the base is strong and less concentrated than the hydrochloric acid

(D) the base is weak and less concentrated than the hydrochloric acid

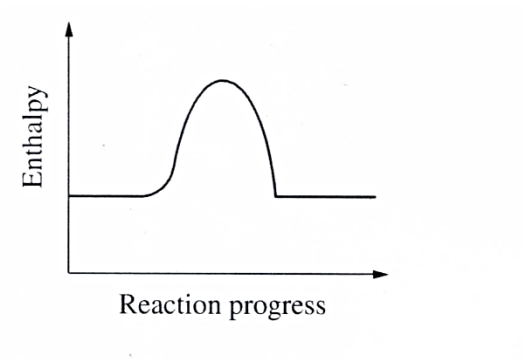
Question 11

Which graph represents the enthalpy change for an acid-base neutralisation reaction?

(A)



(B)



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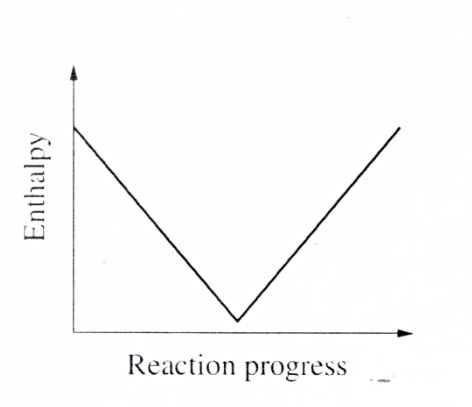
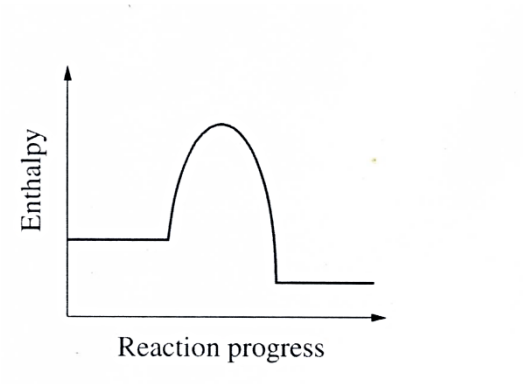


(D)



Question 12

Propanol and ethanoic acid are refluxed with concentrated H_2SO_4, and then NaOH is added to the mixture.

Which of the following organic products would be present in the final mixture?

(A) Sodium propanoate and sodium sulfate

(B) Ethyl propanoate and propyl ethanoate

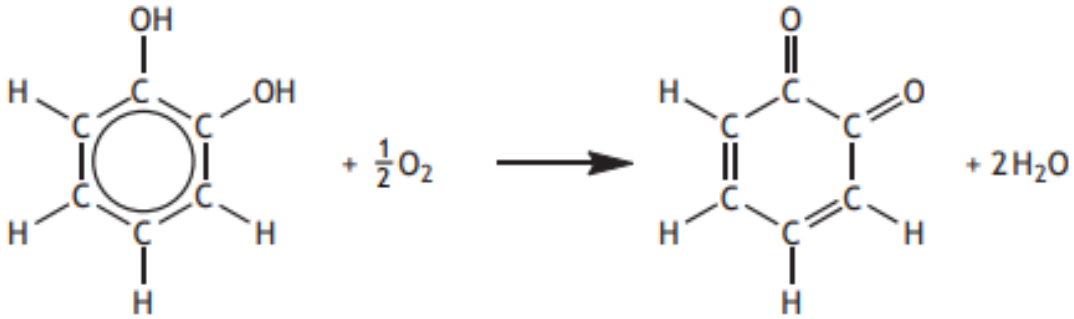
(C) Sodium ethanoate and propyl ethanoate

(D) Sodium propanoate and ethyl propanoate

Question 13

Enzymes are involved in the browning of cut fruit.

One reaction taking place is as follows:



Which of the following correctly identifies the type of reaction demonstrated above?

(A) Condensation

(B) Hydrolysis

(C) Reduction

(D) Oxidation

Question 14

Which of the following statements is CORRECT for ketones?

(A) They are formed by the oxidation of tertiary alcohols

(B) They contain the carbonyl functional group

(C) They contain a carboxyl functional group

(D) They can readily undergo oxidation

Question 15

Which of the following is an isomer of 2,2-dimethylpentan-1-ol?

(A) $CH_3CH_2CH_2CH(CH_3)CH_2OH$

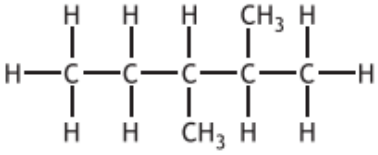
(B) $(CH_3)_3CCH(CH_3)CH_2OH$

(C) $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH$

(D) $(CH_3)_2CHC(CH_3)_2CH_2CH_2OH$

Question 16

The name of the compound below is



(A) 2, 3 – dimethylpentane

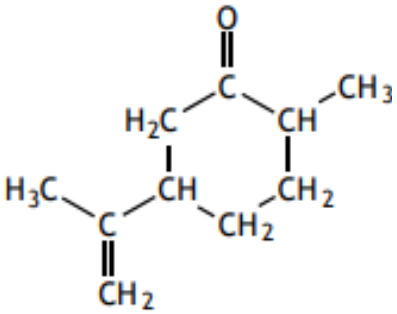
(B) 2, 3 – dimethylpropane

(C) 3, 4 – dimethylpropane

(D) 3, 4 - dimethylpentane

Observe the following structural formula of carvone to answer question 17 and 18.

Carvone is a natural product that can be extracted from orange peel.



Question 17

Which TWO functional groups are present in the compound?

(A) Aldehyde and alkene

(B) Alkene and ketone

(C) Amine and alkene

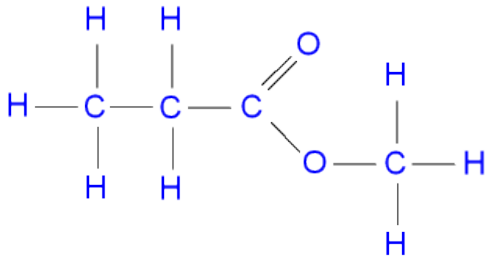
(D) Alkene and alcohol

Question 18

Which of the following CORRECTLY describes the reaction of carvone with bromine solution and with acidified potassium dichromate solution?

	Reaction with bromine solution	*Reaction with acidified potassium dichromate solution*
(A)	No reaction	No reaction
(B)	No reaction	Orange to green
(C)	Decolourises	Orange to green
(D)	Decolourises	No reaction

Question 19



The name of this compound is

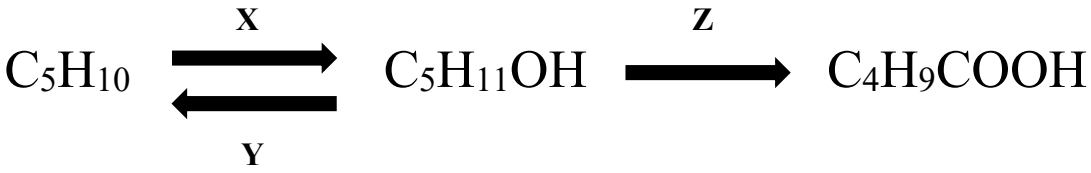
(A) 1-methylpropan-2-one

(B) 2-butanoic acid

(C) methylpropanoate

(D) propylmethanoate

Question 20



Which of the following conditions is CORRECT for the reaction pathway above?

	X	Y	Z
(A)	H_2O / conc. H_2SO_4	H_2O / conc. H_2SO_4	H+ / MnO_4^-
(B)	H_2O / dilute H_2SO_4	H_2O / conc. H_2SO_4	H+ / $Cr_2O_7^{2-}$ and heat
(C)	H_2O / conc. H_2SO_4	H_2O / conc. H_2SO_4	OH^-
(D)	H_2O / dilute H_2SO_4	H_2O / conc. H_2SO_4	CH_3COOH

SECTION II
Attempt questions 21 – 34
Allow 2.5 hours

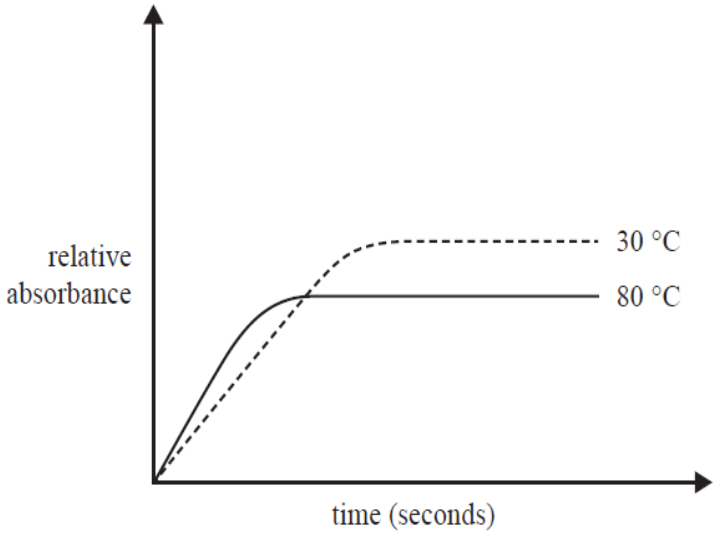
Question 21 **(9 marks)**

The cobalt (II) tetrachloride ion $CoCl_4^{-2}$ dissociates into the cobalt (II) ion Co^{+2} and chloride ions Cl^{-1} according to the following equation:

$$CoCl_4^{-2}(aq) \rightleftharpoons Co^{+2}(aq) + 4\ Cl^{-}(aq)$$
Blue Pink

20mL samples of the equilibrium mixture was heated to two temperatures, 30˚C and 80˚C. The intensity of the pink colour from the Co^{+2} product was recorded every 30 seconds by measuring the absorbance of the solution. The higher the intensity of the pink colour, the higher the absorbance.

The results of this experiment are shown in the graph below.



a) State whether the forward reaction is exothermic or endothermic. Justify your answer by referring to the graph. 2m

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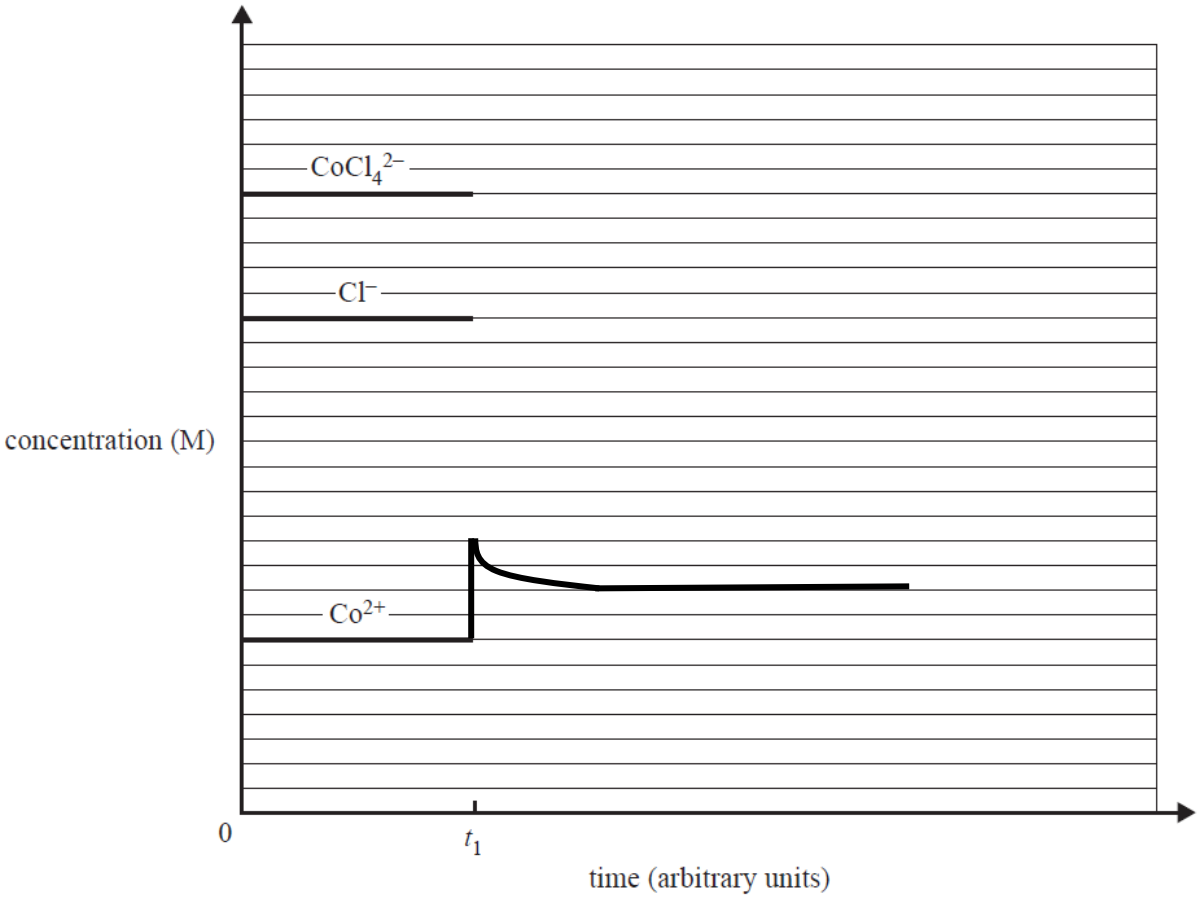
b) A concentration-time graph is shown below. The concentration of Co^{2+} is changed at time t_1. Complete the graph to show the appropriate changes for Cl^- and $CoCl_4^{2-}$. 3m



c) 5 drops of 0.10 M silver nitrate solution was added to the solution after equilibrium was re-established. Explain how this will affect the equilibrium. 2m

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d) Calculate the concentration of chloride ions that would remain in solution if the silver nitrate is added in excess. 2m

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Question 22 **(3 marks)**

For the process of photosynthesis the following data was collected at 298 K

$$6CO_2\ (g) + 6H_2O\ (l) \rightarrow C_6H_{12}O_6\ (s) + 6O_2\ (g)$$

$$\Delta H = 2795\ kJ/mol \qquad \Delta S = 218J/K/mol$$

Explain in terms of enthalpy, entropy and Gibbs free energy whether the reaction is spontaneous at 298K. 3m

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Question 23 **(4 marks)**

Methanol can be made by the reaction:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

At 100°C, an equilibrium mixture was found to have the following concentrations:

- $[CO] = 3.76 \times 10^{-3}$ mol L^{-1}
- $[H_2] = 4.30 \times 10^{-3}$ mol L^{-1}
- $[CH_3OH] = 4.17 \times 10^{-8}$ mol L^{-1}

a) Calculate the equilibrium constant for the reaction. 2m

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b) Describe the effect on the value for K if a catalyst was used for this reaction**.** 2m

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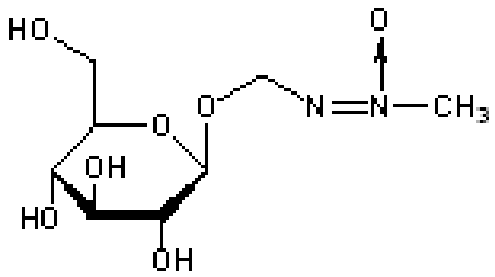
Question 24 **(6 marks)**

Cycasin is the active ingredient in plants such as *Macrozamia communis* – Burrawang.



The solubility of cycasin is around 56.6g/L. The chemical formula for this compound is $C_8H_{16}N_2O_7$.

a) Calculate the molarity of a cycasin solution when the maximum amount of cycasin has dissolved. 2m

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b) Assess the effectiveness of techniques used by Aboriginal and Torres Strait Islander people to utilise cycads as a food source. 4m

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Question 25 **(3 marks)**

Calculate the solubility of silver carbonate (Ag_2CO_3) in a 0.010 M solution of potassium carbonate (K_2CO_3).

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Question 26 **(5 marks)**

A buffer is prepared by mixing a solution of carbonic acid (H_2CO_3) and the salt sodium hydrogen carbonate ($NaHCO_3$).

a) Use equations and conjugate acid / base pairs to demonstrate how the hydrogen carbonate ion reacts with an acid and a base. 3m

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b) Explain why this buffer is able to control pH in living cells. 2m

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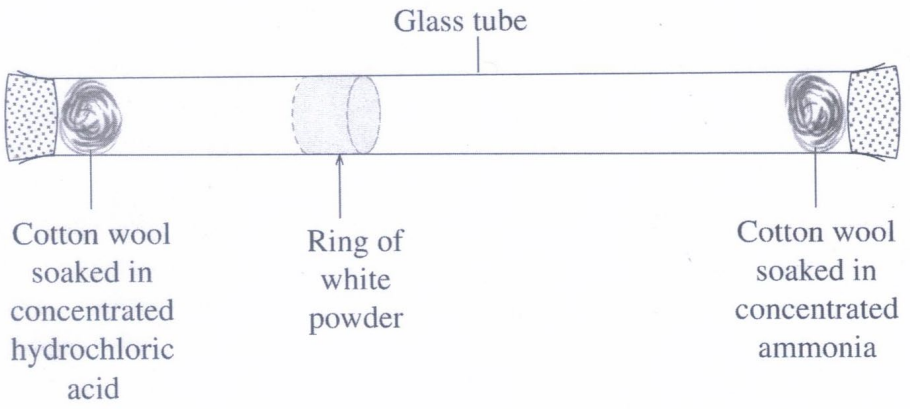
Question 27 **(7 marks)**

One cotton ball is soaked in a concentrated ammonia solution and the other in a concentrated hydrochloric acid solution. Inside the tube ammonia and hydrogen chloride gas are produced.

After some time a ring of white powder is seen to form on the inside of the tube.



a) Give the equation for this reaction 1m

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b) Describe why Arrhenius Theory is unable to explain this acid-base reaction. 2m

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c) Discuss the benefits of the Bronsted-Lowry Theory in explaining this reaction 4m

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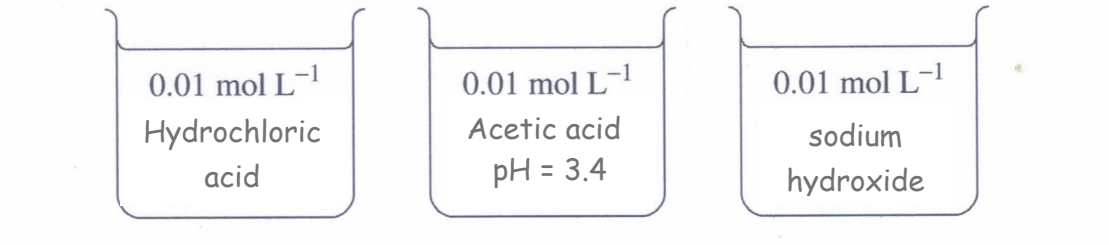
Question 28 **(8 marks)**

Three solutions of equal concentration are prepared and labelled.

The pH of the acetic acid solution is 3.4.



a) What is the pH of the hydrochloric acid solution? 1m

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b) Explain why the pH of the two acid solutions are different. 3m

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c) On the grid below sketch TWO titration curves to represent: 4m

- 25 ml HCl with 50ml NaOH.
- 25 ml CH_3COOH with 50ml NaOH

pH

Volume of NaOH (ml)

Question 29 **(7 marks)**

The enthalpy of neutralisation is based on the moles of water formed.

$$H^{+}_{(aq)} + OH^{-}_{(aq)} \rightarrow H_2O_{(l)} \qquad \Delta H_n = -56 \text{ kJ/mole of water formed}$$

a) Calculate the amount of heat generated when 50.0 mL of 0.0500 M hydrochloric acid is neutralised by 35.0 mL of 0.0600 M potassium hydroxide solution. 3m

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b) *Amphiprotic* substances are used to neutralise acid and base spills in industry.

Explain the use of a **named** amphiprotic substance in neutralising an acid spill and give a relevant equation. 4m

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Question 30 **(6 marks)**

Sodium carbonate is used in the manufacture of soaps, glass and paper as well as the treatment of water. One industrial process used to make sodium carbonate is the Solvay process.

The Solvay process involves several different chemical reactions.

Step 1: Brine purification
Brine is a concentrated sodium chloride solution which is achieved by evaporation. Impurities such as calcium, magnesium and iron are removed before it is filtered and the solution is passed through the ammonia tower to dissolve the ammonia.

Step 2: Sodium hydrogen carbonate formation in the Solvay tower
Carbon dioxide is produced by the thermal decomposition of limestone, $CaCO_3$, in the lime kiln.

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

The gas is bubbled through the ammoniated brine solution (from step 1) in the carbonating tower to produce bicarbonate ions and ammonium ions. The weak acid will react with the Na^+ in solution to form a precipitate of sodium hydrogen carbonate.

Step 3: Sodium carbonate formation
Sodium hydrogen carbonate is removed and heated at 300°C to produce sodium carbonate, carbon dioxide and water vapour. The carbon dioxide is recycled back into the carbonating tower.

Step 4: Ammonia recovery
Calcium oxide produced during the thermal decomposition of limestone (step 2) enters a lime slaker to react with water and form calcium hydroxide. The calcium hydroxide produced is reacted further with the ammonium chloride separated out of the carbonating tower by filtration.

$$Ca(OH)_{2(aq)} + 2NH_4Cl_{(aq)} \rightarrow CaCl_{2(aq)} + 2H_2O_{(l)} + 2NH_{3(g)}$$

The ammonia is recycled back into the process to form ammoniated brine. Calcium chloride is formed as a by-product of the Solvay process.

a) Write ONE equation to show the removal of ONE of the impurities in the brine. 1m

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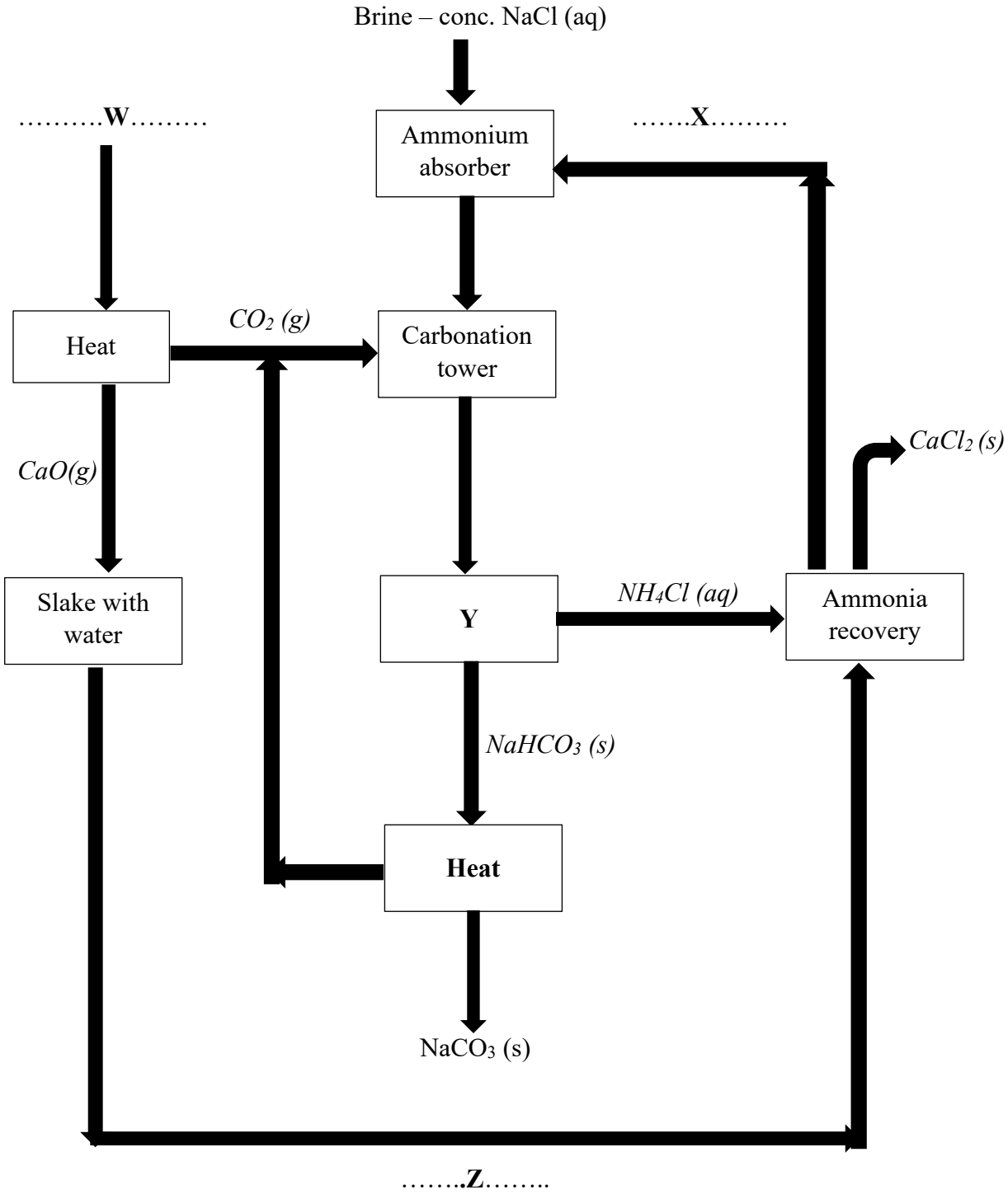
Question continued overleaf

b) Using the information provided, complete the flow chart. 2m



W = …… Y = ……

X = …… Z = ……

The reaction that produces the solid sodium hydrogen carbonate involves the following equilibrium:

$$HCO_3^-{}_{(aq)} + Na^+{}_{(aq)} \rightleftharpoons NaHCO_{3\,(s)}$$

Explain fully why using a concentrated sodium chloride solution encourages production of sodium hydrogen carbonate as a solid. 3m

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Question 31 **(10 marks)**

Mr Chabra provided the following spectrums to his students for an unknown compound with a chemical formula of $C_4H_8O_2$.

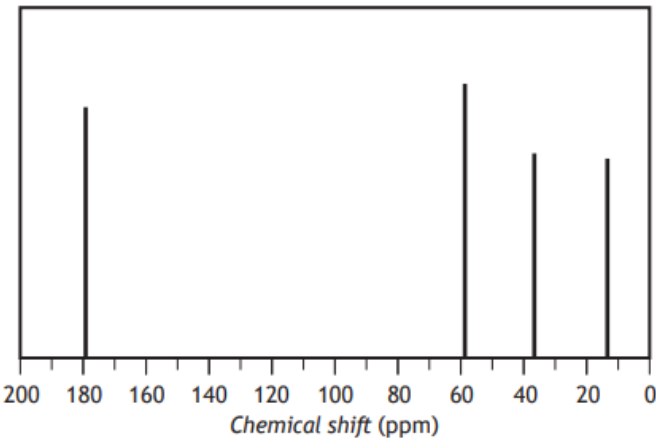


Figure 1. C13 NMR spectrum

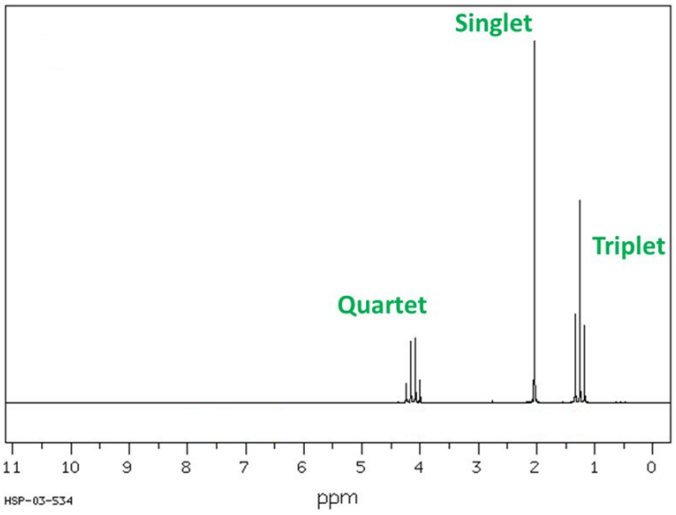


Figure 2. 1H NMR spectrum

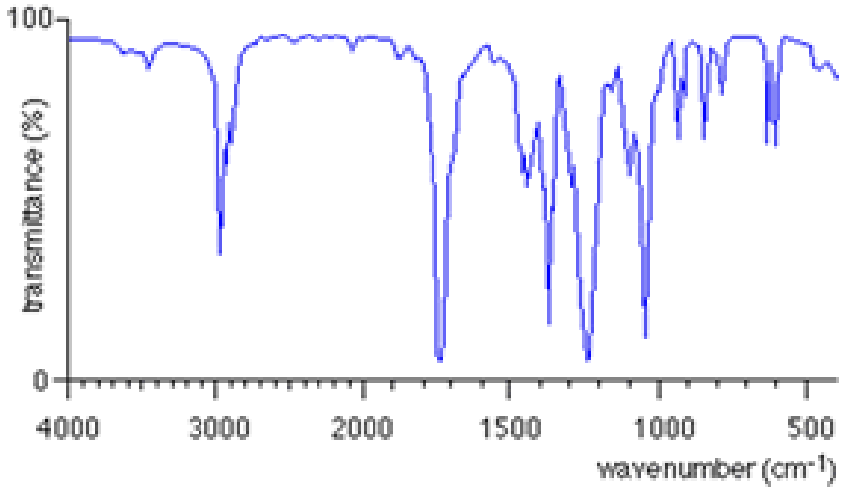
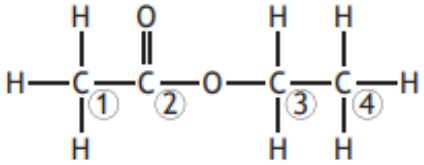


Figure 3. IR Spectrum

a) Jason predicts that the spectrums are showing ethyl ethanoate.
Label the peaks in the C13-NMR spectrum with a number to match the carbon atom in ethyl ethanoate, shown below. 1m



b) Anu observed the same compounds chemical formula and the spectrums provided. Anu suggests that the unknown compound could be a carboxylic acid.

Name and draw ONE structural formula to represent the possible isomer. 2m

c) Discuss the accuracy of each students' prediction with reference to each spectra. 5m

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d) Mr Chabra provided the students with a sample of the unknown compound. Describe ONE chemical test that Anu could conduct to confirm her suspicion. 2m

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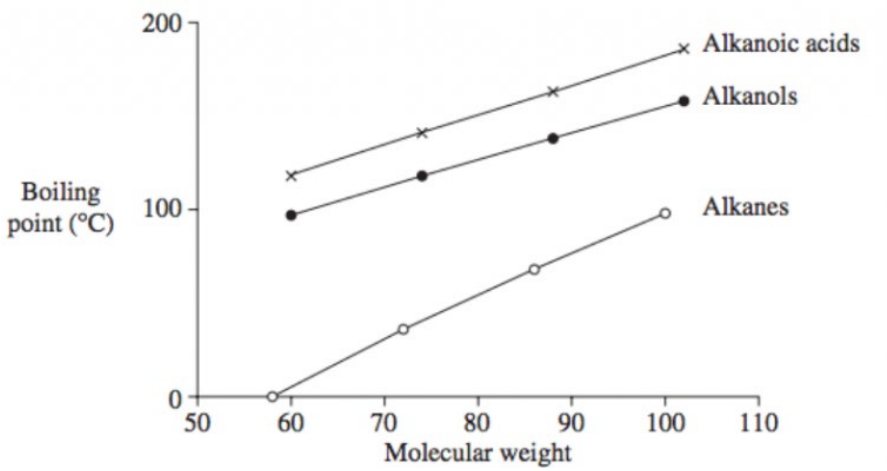
Question 32 **(4 marks)**

Observe the graph below.



Explain the trends in the boiling points as shown in the graph. 4m

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Question 33 **(4 marks)**

a) Define saponification 1m

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b) Account for the cleaning action of soap 3m

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Question 34 **(4 marks)**

Polyvinyl chloride is a polymer formed by addition polymerisation reaction.

a) Name the monomer unit used to produce polyvinyl chloride. 1m

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b) Explain the uses of polyvinyl chloride with respect to its properties. 3m

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END OF EXAM PAPER

Marking Schedule
Penrith High School
HSC Chemistry Trial 2020

Section A: Multiple Choice

1	**A**
2	**B**
3	**D**
4	**A**
5	**B**
6	**A**
7	**D**
8	**B**
9	**B**
10	**C**
11	**D**
12	**C**
13	**D**
14	**B**
15	**B**
16	**A**
17	**B**
18	**D**
19	**C**
20	**B**

Section B: Long Response Answers

Question 21

a) State whether forward reaction is endothermic or exothermic and justify why.

Marking Criteria	Mark
Correctly states nature of forward reaction and provides an appropriate reason	2
Correctly states nature of forward reaction	1

Sample answer

At a higher temperature (80^0C), the intensity of the pink colour is decreased relative to the intensity of the colour at 30^0C. This indicates that the reaction has moved to the left to absorb heat. Reactions that absorb heat when the temperature is increased are exothermic.

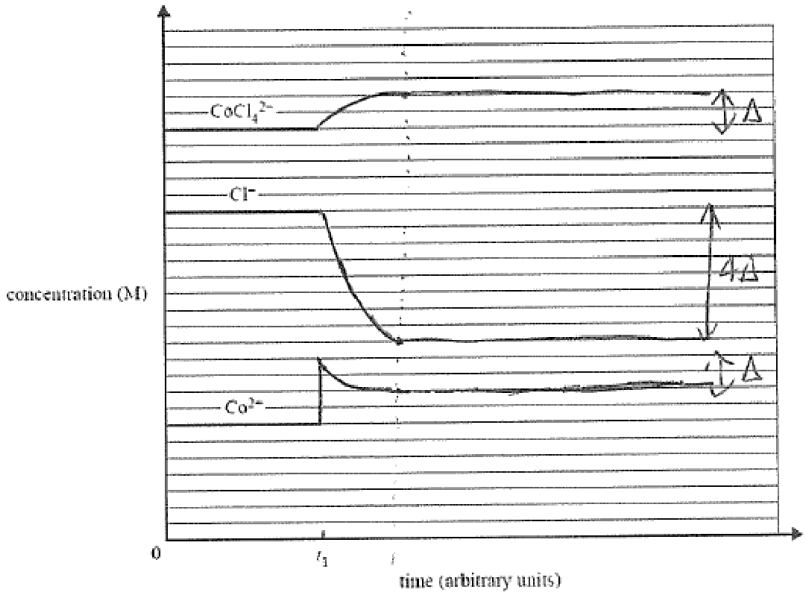
Markers comments

Students to need to review how to ascertain the nature of an equilibrium reaction when temperature is increased or decreased in a system. In an exothermic reaction if the temperature is increased then the system absorbs heat and moves to the left to increase the reactants. If the reaction is endothermic and the temperature is increased then the equilibrium will move to the right to increase the products and release heat from the system.

b) Complete the graph.

Marking Criteria	Mark
Correct direction for changes and differences to reach equilibrium given	3
Correct direction for changes and one correct change	2
Correct direction for changes OR correct direction for ONE change and difference	1

Sample answer



Markers comments

Many students correctly answered this question. Many understood that the change in Co^{2+} related to the change in Cl^- and $CoCl_4^{2-}$. Better students determined the ratio of changes and correctly illustrated these on the graph.

c) Explain effect on equilibrium

Marking Criteria	Mark
Correctly states a precipitate is formed and specifically how solution will be affected in terms of colour or concentration of specific ions	2
Correctly states a precipitate is formed	1

Sample answer

The Ag^+ will react with the Cl^- to form a precipitate of AgCl, meaning that the concentration of Cl^- decreases. To return the system to equilibrium $CoCl_4^{2-}$ will breakdown, the equilibrium will shift to the product side and produce MORE Co^{2+} and Cl^- will be produced, the solution will become pinker in colour.

Markers comments

Students need to state that a precipitate or solid was formed from the reaction of Ag^+ with Cl^-. Stating that the equilibrium will shift to the right is correct BUT students need to specify what actually happened, e.g. the solution became more pink in colour OR the concentration of Co^{2+} and/or Cl^- will increase.

d) Calculate concentration of ions in solution

Marking Criteria	Mark
Correctly writes Ksp equation and calculates the concentration that would remain in solution.	2
Correctly writes Ksp equation for substance produced	1

Sample answer

$Ksp = [Ag^+] [Cl^-] = 1.77 \times 10^{-10}$

Let $[Ag^+] = [Cl^-] = x$

$x^2 = 1.77 \times 10^{-10}$

$x = 1.33 \times 10^{-5}$ mol/L

Markers comments

Many students did not realise that when a precipitate forms the Ksp value allows us to determine how much of that substance is IN solution. Dynamic equilibrium occurs and a small amount of the substance is in solution.

Question 22

Spontaneity of a reaction in terms of enthalpy, entropy and Gibbs free energy

Marking Criteria	Mark
Correctly calculates value for Gibbs free energy. Indicates that reaction is non-spontaneous. Describes reaction as endothermic and decreasing in entropy	3
Calculates Gibbs free energy correctly and states reaction is non-spontaneous OR States the reaction is endothermic and decreases in entropy and is non-spontaneous	2
States Gibbs free energy equation OR States reaction is non-spontaneous AND endothermic OR entropy decreases	1

Sample Answer

$\Delta G = \Delta H - T\Delta S$

$\Delta G = 2795kJ/mol - 298K \times 0.218kJ/mol/K$

$\Delta G = 2729kJ/mol$

(The entropy value needs to be converted to kJ/mol/K)

The enthalpy change for this reaction indicates that the reaction is endothermic (absorbs heat). The entropy value for this reaction is a small positive value – looking at the equation there is a decrease in entropy as 12 molecules become 7 molecules (the system becomes more ordered). The reaction will be non-spontaneous as the overall Gibbs free energy has a positive value, the reaction requires heat to occur and the entropy has decreased.

Markers comments

Students who gained full marks in this question correctly calculated Gibbs free energy and explained how the reaction was endothermic and used the equation to state that entropy had decreased – the ΔS value is helpful but students need to examine the equation. Students are advised to review the concepts of Gibbs free energy as a question was asked about this in last year's HSC exam and there is specific reference to this concept in relation to combustion and photosynthesis in the syllabus.

Question 23

a) Calculates equilibrium constant

Marking Criteria	Mark
Correctly writes Keq expression and correctly calculates value	2
Correctly writes Keq expression correctly	1

Sample answer

$$K_{eq} = \frac{[CH_3OH]}{[CO]\,[H_2]^2} = \frac{[4.17 \times 10^{-8}]}{[3.76\times10^{-3}][4.30\times10^{-3}]^2} = 0.600$$

Markers comments

Almost all students correctly wrote the expression for this equation and calculated the correct value.

b) Effect of catalyst on Keq value

Marking Criteria	Mark
Correctly explains why K did not change and how catalyst effects reaction rate	2
Correctly explains how K does not change OR Catalyst increases speed of forward and reverse reaction OR decreases activation energy	1

Sample answer

A catalyst speeds up the rate of forward and reverse reaction but has no effect on K, K is only affected by temperature.

Markers comments

Most students correctly answered this question and showed a good understanding of how K is not effected by a catalyst.

Question 24

a) Calculate moles of cycasin in solution.

Marking Criteria	Mark
Correctly calculates molar mass of cycasin and molarity of solution with units	2
Correctly calculates molar mass of cycasin	1

Sample Answer:

Molar mass of cycasin = (8x12.01+16x1.008+2x14.01+7x16.00) grams

= 252.228 grams

Moles of cycasin in 56.6 grams = $\frac{56.6\text{g}}{252.228\text{ g/mol}}$ = 0.224 mol/L

Markers Comment:

Most students correctly calculated the molar mass and then the number of moles. Better students included units for concentration.

b) Asses effectiveness of techniques used by ASTI people.

Marking Criteria	Mark
States 2 methods of removing the toxin cycasin from cycad and discusses the effectiveness of these procedures	4
States 2 methods of removing the toxin cycasin from cycad and discusses the effectiveness of a procedure	3
States 2 methods to remove the toxin cycasin OR States a method of removing the toxin cycasin discusses the effectiveness of this procedure	2
States a method of removing the toxin cycasin	1

Sample answer

Cycasin can be removed from cycads by a number of different means. Scoring or cutting the fruit increases the surface area and allows the toxin to be removed more quickly from the fruit. Placing the fruit into a bag and then placing it in a fast flowing river will assist in removing the toxin, as the system does not reach a static equilibrium – a dynamic equilibrium occurs – the water does not become saturated with the cycasin toxin. The use of leaching is more effective than just scoring or cutting the fruit as it allows the soluble toxins to be removed through establishing an equilibrium.

Markers comments

Many students achieved full marks for this question, please ensure that you read the question as it stated techniques which implies more than 1. Most people who did not achieve full marks either mentioned only one technique or did not use metalanguage – the toxin is not “killed” by heating.

Question 25

Calculate solubility of Ag_2CO_3 in 0.010M K_2CO_3.

Marking Criteria	Mark
States correct Ksp equation Correctly calculates Ksp value stating x+0.010 = x as value of x is very small. Gives appropriate units	3
Correctly states Ksp equation and states that x +0.010 = 0.0100 as x value is very small OR Correctly states Ksp equation and calculates correct Ksp value	2
States correct Ksp equation for silver carbonate OR States that x + 0.010 = 0.010 as value for x is very small	1

Sample answer

The common ion between both substances is CO_3^{2-}. CO_3^{2-} from K_2CO_3 0.010M

Ksp for $Ag_2CO_3 = [Ag^+]^2[CO_3^{2-}]$ let $[Ag_2CO_3] = x$ $Ksp = 8.46 \times 10^{-12}$

$[Ag^+][CO_3^{2-}]$

I 2x x

C 0 0.010

E 2x x + 0.010

As x has a very small value assume that x+0.010 = 0.010

$Ksp = [Ag^+]^2[CO_3^{2-}] = [2x]^2[x+0.010]$

$= [2x]^2[0.010]$

$8.46 \times 10^{-12} = 4x^2 \times 0.010$

$x = 1.445 \times 10^{-5}$ mol/L

$= 1.4 \times 10^{-5}$ mol/L

Solubility of Ag_2CO_3 in 0.010M $K_2CO_3 = 1.4 \times 10^{-5}$ mol/L

Markers comments

Many students performed poorly in this question. Writing the correct expression for the Ksp of Ag_2CO_3 is required. Stating that this question relates to common ion effect for CO_3^{2-} would demonstrate some degree of understanding of the concept being examined. It is important to state that due to the small value for x from the Ksp value it can be assumed that x+0.010 = 0.010. Using the chemical formula of Ag_2CO_3 allows us to determine the ratio of Ag^+ to CO_3^{2-} is 2:1. Units need to be included in the answer.

Question 26 (a)

(a) Use equations to demonstrate how the hydrogen carbonate ion reacts with an acid and a base

Criteria	Marks
● Correct equilibrium equation for HCO_3^- and H_3O^+ ● Correct equilibrium equation for HCO_3^- and OH^- ● Identifies clearly the correct acid base conjugate pairs	3
● Equilibrium equation for HCO_3^- and H_3O^+ ● Equilibrium equation for HCO_3^- and OH^- OR ● Identifies clearly the acid base conjugate pairs	2
● Provides a correct equilibrium equation	1

Sample Answer

Addition of an Acid

conjugate pairs

$HCO_3^-{}_{(aq)} + H_3O^+{}_{(aq)} \rightleftharpoons H_2CO_3{}_{(aq)} + H_2O_{(l)}$

Base 1 Acid 2 Acid 1 Base 2

conjugate pairs

Addition of a Base

conjugate pairs

$HCO_3^-{}_{(aq)} + OH^-{}_{(aq)} \rightleftharpoons CO_3^{2-}{}_{(aq)} + H_2O_{(l)}$

Acid 1 Base 2 Base 1 Acid 2

conjugate pairs

Markers Comment:

Many students did not read the question properly or did not know how to show the effects of an acid or a base on a buffer system. It is important to clearly identify the acid/base conjugate pairs (differ by a proton) and equations which demonstrate an equilibrium system. Better students realised that for an acid you use H_3O^+ and for a base OH^- and that they need to be reactants in the equilibrium equation not products.

Question 26 (b)

(b) Explain why this buffer is able to control pH in living cells.

Criteria	Marks
● Provides a correct definition of a buffer ● Provides a cause and effect statement about the role of the HCO_3^- buffer in living cells.	2
● Provides a correct definition of a buffer OR ● Provides a cause and effect statement about the role of the HCO_3^- buffer.	1

Sample Answer

The HCO_3^- buffer in living cells consists of comparable amounts of a weak acid (H_2CO_3) and its conjugate base (HCO_3^-) according to the following equation

$$H_2CO_{3(aq)} + H_2O_{(l)} \rightleftharpoons HCO_3^-{}_{(aq)} + H_3O^+_{(aq)}$$

The buffer is able to maintain a relatively stable pH even when strong acid (H_3O^+) or a strong base (OH^-) is added. This allows living cells to maintain a stable pH environment for cellular processes.

Markers Comment:

Some students relied more on their biology understanding rather than their chemistry. Students could have given their definition of a buffer (make sure you use the words *comparable amounts*) and then related this to a stable pH.

Question 27 (a)

(a) Give the equation for this reaction

Criteria	Marks
• Correct equation for neutralisation reaction	1

Sample Answer

$$NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$$

Markers Comment:

Most students were able to give the correct equation. Many students had the wrong subscripts (this was a reaction between gases to produce a solid) but were not penalised. Some students gave the formation of the ions to better demonstrate the donation and acceptance of protons.

Question 27 (b)

(b) Describe why Arrhenius Theory is unable to explain this acid-base reaction

Criteria	Marks
• Defines the Arrhenius Theory • Describes that the reaction does not occur in aqueous solutions or have OH^- ions	2
• Defines the Arrhenius Theory OR • Describes that the reaction does not occur in aqueous solutions	1

Sample Answer

Arrhenius Theory of acids and bases is based on aqueous solutions in which acids ionise to produce H^+ ions and bases ionise to produce OH^- ions. This reaction does not occur in an aqueous state as both reactants are gases and form a solid product. Ammonia does not contain hydroxide ions and water is not produced as a product of this neutralisation reaction and contradicts the Arrhenius Theory.

Markers Comment:

Most students gave a suitable definition of the Arrhenius Theory and were able to identify that this reaction did not involve solutions. Students are still having difficulty linking their information to demonstrate a clear understanding of the concept.

Question 27 (c)

(c) Discuss the benefits of the Bronsted-Lowry Theory in explaining this reaction

Criteria	Marks
● Definition of Bronsted/Lowry Theory ● Describes the role of acid/base conjugate pairs ● Discusses TWO benefits of the B/L Theory	4
● Definition of Bronsted/Lowry Theory ● Discusses TWO benefits of the B/L Theory	3
● Definition of Bronsted/Lowry Theory ● Describes the role of acid/base conjugate pairs OR ● Discusses TWO benefits of the B/L Theory	2
● Definition of Bronsted/Lowry Theory	1

Sample Answer

The Bronsted-Lowry theory states that acids are proton donors and bases are proton acceptors. The theory is based on acid/base conjugate pairs to explain this donating and accepting of protons.

In this reaction HCl acts as a proton donor (acid) to form the Cl^- ion and NH_3 acts as a proton acceptor (base) to form the NH_4^+ ion.

The advantages of the Bronsted-Lowry theory include

- Does not need an aqueous solution to explain gaseous acids/bases
- Able to show that ammonia does not need to contain OH^- ions to be a base
- Able to explain the acidic nature of the salt formed (ammonium chloride)

Markers Comment:

Most students gave the correct definition of the Bronsted Lowry Theory for acids and bases and were able to give two advantages. Many students did not indicate the role of conjugate acid/base pairs in explaining the theory. Better students gave specific information about the acid and base in the reaction and how they related to Bronsted Lowry theory.

Question 28 (a)

(a) What is the pH of the hydrochloric acid solution?

Criteria	Marks
● Calculates the pH = 2	1

Sample Answer

$pH = - \log [H^+] = - \log 0.01 = 2$

Markers Comment:

Many students did not show a formula or a calculation for this response. Although this was not penalised here, in the HSC it may well be for not showing any data or how the pH was determined. Band 6 students ALWAYS show working.

Question 28 (b)

(b) Explain why the pH of the two acid solutions are different.

Criteria	Marks
● Identifies that pH is a measure of the $[H^+]$ ● Describes HCl as a monoprotic strong acid that fully ionises and that CH_3COOH is a monoprotic weak acid that only partially ionses in solution ● Relates the different $[H^+]$ to a higher or lower pH	3
● Identifies that pH is a measure of the $[H^+]$ ● Describes HCl as a strong acid that fully ionises and that CH_3COOH is a weak acid that only partially ionses in solution OR ● Relates the different $[H^+]$ to a higher or lower pH	2
● Identifies that pH is a measure of the $[H^+]$ OR ● Describes HCl as a monoprotic strong acid that fully ionises and that CH_3COOH is a monoprotic weak acid that only partially ionses in solution	1

Sample Answer

pH is related to the $[H^+]$ of an aqueous solution $pH = - \log[H^+]$. Though both acids have the same concentration, HCl is a monoprotic strong acid that fully dissociates into H^+ ions. Acetic acid is a monoprotic weak acid that only partially ionises. The $[H^+]$ is lower in acetic acid compared to HCl and a higher pH is produced for CH_3COOH

Markers Comment:

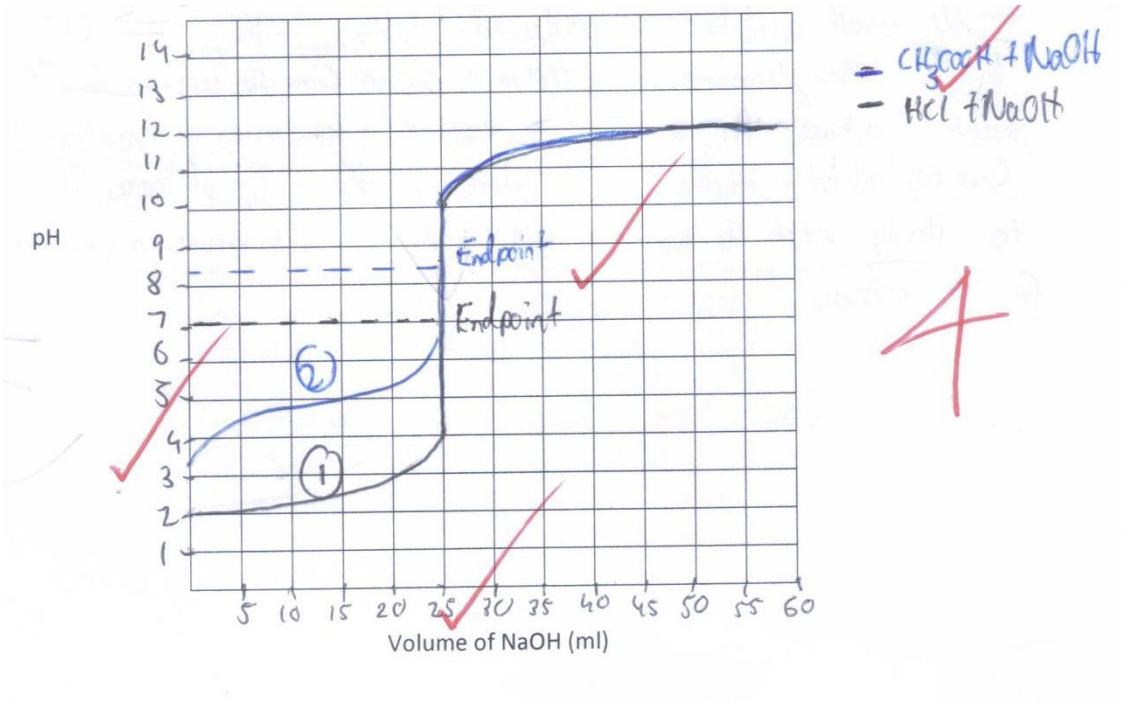
Most students identified that HCl was a strong acid and that acetic acid was a weak acid and that they dissociated differently in solution. Many students did not provide a link between the conc. of $[H^+]$ and pH and how that would increase or decrease pH.

Question 28 (c)

Titration curves for 25mL of a strong (HCl) and a weak acid (CH_3COOH) with 50mL of NaOH

Criteria	Marks
• Completes a correct scale for pH (1 to 14) and volume of NaOH (max 50mL) and a key for the two acids • Indicates on the graph that both acids reach endpoint at 25mL volume NaOH • Endpoint is labelled on the graph to show the different pH of the two acids at neutralisation • Initial pH of acids (2.0 and 3.4) correct and final pH of NaOH < 12	4
• 3 of the above	3
• 2 of the above	2
• 1 correct titration curve	1

Sample Answer



Markers Comment:

Many students did not understand that at the same concentration, strong and weak monoprotic acids require the same amount of base to neutralise them (25 mL). The maximum pH of the NaOH must be less than 12 (pH = 14 - -log[OH^-] = 14-2 =12). In fact it will be less as the NaOH has been diluted 1:2. Most students were able to give at least one appropriate titration curve but many had poor labels or did not indicate the pH at equivalence point to distinguish the two acids. Labelling needs to be complete.

Question 29 (a)

(a) Calculate the amount of heat generated when 50.0 mL of 0.0500 M hydrochloric acid is neutralised by 35.0 mL of 0.0600 M potassium hydroxide solution.

Criteria	Marks
● Calculates the moles of HCl (0.0025) and NaOH (00021) ● Identifies NaOH as the limiting reagent ● Multiplies the ΔH_n by the moles of water formed (0.0021) to calculate the energy released = 0.12 kJ of heat	3
● Calculates the moles of HCl (0.0025) and NaOH (00021) ● Identifies NaOH as the limiting reagent	2
● Calculates the moles of HCl (0.0025) OR NaOH (00021)	1

Sample Answer

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Moles of HCl = cv = 0.0025 moles

Moles of NaOH = cv = 0.0021 moles

NaOH is the limiting reagent. The ratio of reactants:products is 1:1

The number of moles of water formed = moles of NaOH = 0.0021 moles

Energy released = q x n = 56 kJ/mole x 0.0021 moles = 0.117 = 0.12 kJ

Markers Comment:

Most students correctly calculated the moles of HCl and NaOH using *C x V* and identified that NaOH was the limiting reagent. Some students then tried to subtract the two moles or divided the molar heat of neutralisation by the moles of water formed instead of multiplying. Students were not penalised for sig. fig but should have been given to two. Some students made silly mistakes in their conversion of kJ to J.

Question 29 (b)

Explain the use of a named amphiprotic substance in neutralising an acid spill and give a relevant equation.

Criteria	Marks
● Names an appropriate amphiprotic substance e.g. sodium hydrogen carbonate ● Defines an amphiprotic substance with a relevant equation for neutralisation with an acid ● Provides a benefit of using the amphiprotic substance to produce salt and water which is less harmful to the environment	4
● Gives the correct symbol for an amphiprotic substance ● Defines an amphiprotic substance with a relevant equation for neutralisation with an acid ● Provides a benefit of using the amphiprotic substance to produce salt and water which is less harmful to the environment	3

● Names an appropriate amphiprotic substance ● Defines an amphiprotic substance with a relevant equation for neutralisation with an acid OR ● Provides a benefit of using the amphiprotic substance	2
● Names an appropriate amphiprotic substance OR ● Defines an amphiprotic substance	1

Sample Answer

An amphiprotic substance is a substance that contains hydrogen and is able to accept or donate protons. Sodium hydrogen carbonate ($NaHCO_3$) is an example of an amphiprotic substance. It is a cheap, stable solid and can be used to neutralise both acidic and basic spills. In an acidic spill of hydrochloric acid the following reaction occurs.

$$NaHCO_{3(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

The production of salt and water (the CO_2 escapes as a gas) is less harmful to industry and the environment making it an ideal safe substance to use to neutralise an acid spill.

Markers Comment:

Many students did not understand the difference between equilibrium (buffer) and neutralisation of a carbonate (salt, carbon dioxide and water). Many students did not name the substance or only gave an ion rather than the formula for a suitable substance. Many students also gave an equilibrium equation rather than an equation for neutralisation. Most students were able to explain why these substances are used to neutralise acid spills

Question 30

a) Write ONE equation to show the removal of ONE of the impurities in the brine.

Marking Criteria	Mark
Provides a valid balanced chemical equation to show the removal of ONE of the impurities in the brine.	1

Sample answer

$Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$

Markers comments

The idea linked to using solubility rules to help precipitate the impurity out of the brine. A number of students need to

1) Review how to write net ionic equations to show precipitation reactions
2) Review the solubility rules as often students referred calcium chloride ($CaCl_2$) as being an insoluble solid but it is in fact soluble.

Unfortunately, this entry level question was done poorly. A number of students rewrote the equation provided in the text or did not even write an equation to remove one of the impurities mentioned in the text. PLEASE READ THE QUESTIONS CAREFULLY.

b) Complete the flow diagram

Marking Criteria	Mark
Correctly completes all aspects of the flow diagram	2
Correctly completes 1 – 3 aspects of the flow diagram	1

Answer

W = $CaCO_3$ (s)

X = NH_3 (g)

Y = Precipitation or filtration (both accepted)

Z = $Ca(OH)_2$ (s)

Markers comments

Only a small handful of students scored full marks here. Most could identify 2 to 3 of the missing information. Students need to look at flow charts carefully to pinpoint how the information is illustrated. The boxes in this flow chart represented a process whilst the arrows showed the products produced.

c) Explain fully why using a concentrated sodium chloride solution encourages production of sodium hydrogen carbonate as a solid.

Marking Criteria	Mark
Correctly states Le Chatelier's principle and LINKS this to explain the effect of an increase in concentration of sodium ion on the equilibrium reaction to encourage the production of solid $NaHCO_3$.	3
States Le Chatelier's principle and describes the production of solid $NaHCO_3$ with a minor error.	2
Provides 1 piece of relevant information with no reference to Le Chatelier's principle.	1

Answer

The concentration of NaCl solution means there is a ***high concentration of*** Na^+. According to ***Le Chatelier's principle a system at equilibrium if disturbed will readjust itself to re-establish equilibrium***. Therefore an increase in [Na^+] will ***favour the forward reaction*** to produce more solid $NaHCO_3$.

Markers comments

It was concerning that some students did not see this question to be linked to equilibrium reactions and Le Chatelier's principle. These students MUST REVIEW their understanding of these concepts.

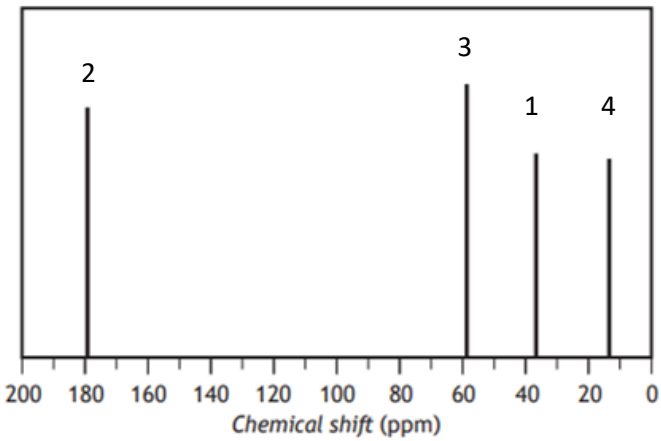
It was important that students identify that brine provides an increased concentration of sodium ions. The definition of Le Chatelier's principle must be correct – remember a NEW equilibrium isn't established (unless there is a change in temperature).

Question 31

a) Label the peaks in the C13-NMR spectrum with a number to match the carbon atom in ethyl ethanoate, shown below.

Marking Criteria	Mark
Correctly matches the carbon atoms to the C13-NMR spectrum	1

Answer



Markers comment

A number of students MISSED this question or did not attempt it altogether.

C2 must correspond to the 179 peak for the C=O bond.

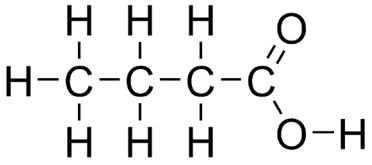
C3 must correspond to ~59 for the C-O bond in an ester.

The C-C bonds range between 5 – 40 but the C1 must correspond to ~38 as it is impacted by the neighbouring O while C4 is far enough to be remain affected and does not shift too greatly.

b) Name and draw ONE structural formula to represent the possible isomer.

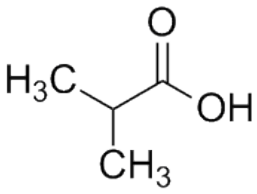
Marking Criteria	Mark
Correctly names and draws ONE structural formula to represent the possible isomer predicted to be a carboxylic acid	2
Correctly draws the structural formula of a possible isomer (acid)	1

Answer



Butanoic acid

OR



2-methylpropanoic acid

Markers comments

It is important that students READ the questions carefully to ensure they address the question as required to gain the necessary marks.

Common errors

- Students did not provide a name for the compound drawn
- Students did not know how to name the compound correctly using IUPAC nomenclature e.g. propanoic acid instead of butanoic OR 1-butanoic acid for which there is no such thing as the carboxyl group cannot be anywhere else in the chain for an acid
- Students drew the carboxyl group in the middle of the compound for an acid (?)
- Students forgot to check the number of bonds that C atoms can have and ended up having to many H-atoms

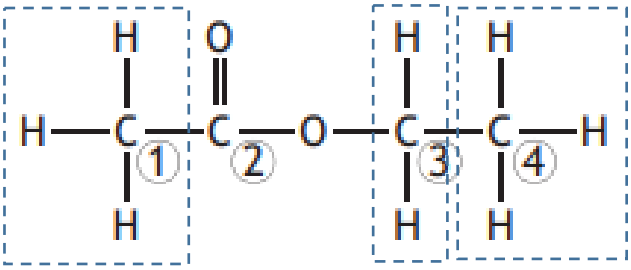
c) Discuss the accuracy of each students' prediction with reference to each spectra.

Marking Criteria	Mark
Extensive analysis of ALL THREE spectrums in reference to each of the students' predictions to suitably argue the accuracy of their predictions. Must show detailed evidence for and against with a final assessment of Jason and Anu's accuracy.	5
Thorough analysis of the spectrums with reference to each of the students' predictions with 1 minor information missing.	4
Sound analysis conducted on the spectrums with reference to each of the students' predictions with 1 minor information missing.	3
A brief or basic analysis conducted with 3 or more key information missing or incorrectly provided	2
Some relevant information provided	1

Sample answer

Anu predicts butanoic acid. This compound would have 4 C environment depicted by the spectra. The chemical shift at 180ppm would denote the C=O group in acids however, the peak at ~59ppm would not match any of the remaining C environments. The H-NMR shows 3 H environments but butanoic acid has 4 H environments (2 triplets, 1 sextet and 1 singlet). The IR spectrum does not represent a broad O-H stretch for an acid at 2500-3000 cm^{-1}. Therefore, Anu's prediction is not accurate.

Jason predicts ethyl ethanoate. The 4 C environments align with the peak in the spectra as shown in part a) with the C=O and C-O clearly indicated by the peak at 180ppm and ~59ppm respectively. The H-NMR has 3 peaks which matches those in ethyl ethanoate.



Singlet quartet triplet

The IR spectrum denotes a peak at 3000cm^{-1} which matches C-H bonds; 1750cm^{-1} coincides with C=O and 1250cm^{-1} for C-O. Therefore, Jason's prediction that the compound $C_4H_8O_2$ is ethyl ethanoate is accurate.

Markers comments

On average students conducted a sound analysis. Students need to be careful with providing their definition for accuracy which relates to experimental design – for which this question was NOT about.

Areas of focus to improve in future questions:

- Students should carefully analyse the chemical shifts in C-NMR (only a very small handful of students made the connection that Anu's prediction should not have a chemical shift at ~60ppm)
- Students should give proof using the chemistry data sheet to provide information on how they KNOW the spectrums match the compounds and refer specifically to the chemical shifts and/or wavelengths.
- Students need to CHECK they have quoted the correct data as there are TWO IR stretches for O-H, one for acids and the other for alcohols.
- Elaborate on the splitting of the H signals to strengthen your responses as it is asking for accuracy and being able to not only match the splitting signals will increase the accuracy of ones prediction

It was fine if students drew 2-methylpropanoic acid but their responses still needs to be correct with respect to the compound and spectrums provided. If you drew 2-methylpropanoic acid you should observe the following:

- 3 C environments
- No chemical shift at ~59 ppm
- 3 H environments
- Doublet; heptet and singlet
- Requires OH stretch at 2500 – 3000cm^{-1}

d) Describe ONE chemical test that Anu could conduct to confirm her suspicion.

Marking Criteria	Mark
Correctly identifies a chemical test and the observation required to confirm the suspicion	2
Provides a test but would not necessarily prove Anu to be correct	1

Sample answer

React the compound with a metal carbonate. If effervescence is observed CO2 is produced to prove it is an acid. OR bubble the gas into limewater to observe for a white precipitate/colour change.

Markers comments

Students were given a mark for providing the following tests

- pH test using blue litmus or bromothymol blue etc (issue is that esters are slightly acidic too)
- react with alcohol to make an ester (issue is an ester will be smelt regardless if Jason was correct)

No marks were awarded to students who wrote that the compound should be reacted with hot acidified KMnO or chromate as this is for the oxidation of alcohols or aldehydes to end up producing an acid.

Question 32

Explain the trends in the boiling points as shown in the graph.

Marking Criteria	Mark
States TWO trends and explicitly explains the trends with reference to the compounds molecular structure and intermolecular forces	4
States TWO trends and provides valid explanations with 1 error	3
States ONE trend with a relevant explanation OR States TWO trends and provides explanations with more than 1 error	2
States ONE trend with no explanation OR Some relevant information provided	1

Sample answer

The B.P observed for each homologous groups increases with increasing molecular weight due to increased dispersion forces. The B.P of alkanoic acid > alkanols > alkanes. Alkanes only experience weak dispersions therefore has the lowest B.P. Alkanols have the polar hydroxyl group –OH. The highly electronegative O-atom allows for H-bonding to exist between alkanols, making it stronger than alkanes. Alkanoic acids consist of the carboxylic acid group –COOH. The polar C=O and O-H bonds allows for dipole-dipole and more hydrogen bonds to exist between molecules, thus making its B.P higher than alkanols and alkanes.

Markers comments

Generally well answered by the cohort although students must be careful in stating trends explicitly and explaining WHY the hydroxyl or carboxyl group allows for H-bonding.

Question 33

a) Define saponification

Marking Criteria	Mark
Correctly defines the process of saponification	1

Sample answer

Saponification is the hydrolysis of fats/oils in the presence of a base (e.g. NaOH) to form soap (fatty acid salt) and glycerol.

Markers comments

Students either got this right or they didn't. Basic or incomplete responses were not awarded the mark.

b) Account for the cleaning action of soap

Marking Criteria	Mark
Describes the structure of soap and relates this to its ability to first dissolve in water and act as both a surfactant and an emulsifying agent to help clean surfaces.	3
Identifies the structure of soap and alludes to the action of soap as an emulsifying agent	2
Some basic and relevant information provided	1

Sample answer

Soap molecules consists of a non-polar hydrocarbon tail and a polar head. The soap head is hydrophilic and dissolves in water while the hydrocarbon tail is hydrophobic enabling it to dissolve in non-polar substances such as grease/oil. Soap is a surfactant, reducing the surface tension of water allowing to more easily wet particles. Upon agitation the grease lifts off the surface to form micelles suspended in water (an emulsion) to be easily washed away.

Markers comments

Generally well answered although many missed the fact that soap dissolves in water and is a surfactant.

Question 34

a) Name the monomer unit used to produce polyvinyl chloride.

Marking Criteria	Mark
Correctly names the monomer for polyvinyl chloride	1

Sample answer

Vinyl chloride or choroethene

Markers comments

Accepted both options as the question did not state for IUPAC nomenclature. It was important that students did not write 1-chloroethene as this is superfluous given that the Cl-atom could not be in any other position. In the HSC students would not gain marks if they inappropriately placed a position number for when it was not necessary.

Some students wrote tetrachloroethene or chloroethane – PLEASE REVIEW ALL THE POLYMERS IN THE SYLLABUS AND HENCE THEIR MONOMERS.

b) Explain the uses of polyvinyl chloride with respect to its properties.

Marking Criteria	Mark
Provides at least TWO uses and links these uses to the specific properties of PVC	3
Provides TWO uses with and identifies properties but no clear relationship is made OR Provides ONE use and clearly links this to the property of PVC	2
Provides the uses or property of PVC only.	1

Sample answer

PVC is a hard, lightweight plastic which can be used in underground piping materials. Its hardness allows it to withstand the pressure placed upon them while its weight is an advantage in terms of easy handling and installation. It is also impervious to water which makes it ideal in transporting water. PVC can be made flexible by the addition of plasticisers, thus allowing it to be used in the production of hoses. Its flexibility and being impervious to water enables the successful manoeuver of garden hoses to water plants or clean cars.

Markers comments

Students are advised to review each of the polymers listed in the chemistry syllabus for module 8. Students often could identify the uses and the properties associated but DID NOT LINK the properties to the uses specifically – i.e. WHY IS THIS PROPERTY IMPORTANT IN ITS USE?

Many students referred to the fact that PVC breaks down in the presence of UV and is hence used underground. While this is true it is NOT the driving reason for the use of PVC for piping. Many also stated that PVC is flexible, but it is not unless plasticisers are added (hence the inclusion in the sample answer to show this to students).

Other options students could explore in terms of properties

- Low coefficient of friction – great for pipes as it reduces fluid friction and resistance of flow
- Long polymer chain – this means pipes can be made to great lengths without breaking and requiring less joints when constructing / installing pipelines.
- Durability – resistant to weathering and corrosion, shock and abrasion therefore used in outdoor products such as plastic tables and chairs or bins
- Good insulator – wraps around cords to ensure safety of electrical leads.