2019
Higher School Certificate
Trial Examination

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formulae sheet, data sheet and a Periodic Table are provided
- Write your student number and/or name at the top of every page

Total marks – 100

Section I – Pages 2–10
20 marks
- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – Pages 11–29
80 marks
- Attempt Questions 21–38
- Allow about 2 hours and 25 minutes for this section

This paper MUST NOT be removed from the examination room

STUDENT NUMBER/NAME: .....

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Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

Select the alternative A, B, C or D that best answers the question and indicate your choice with a cross (X) in the appropriate space on the grid below.

	A	B	C	D
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	A	B	C	D
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1 Hydrofluoric acid has a Ka of $6.3 \times 10^{4-}$.

What is the pH of a 0.50 M solution of the acid?

(A) 0.30

(B) 1.75

(C) 2.90

(D) 3.20

2 The reaction of nitrogen with hydrogen to produce ammonia is represented by the following equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.4 \text{ kJ}$$

What is the effect of an increase in temperature on the forward reaction rate, the reverse reaction rate and the equilibrium constant?

	Forward rate	*Reverse rate*	*Equilibrium constant*
(A)	Increases	Increases	Increases
(B)	Decreases	Decreases	Decreases
(C)	Decreases	Increases	Decreases
(D)	Increases	Increases	Decreases

3 Water self-ionises as shown by the equation: $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$

This ionisation is temperature dependent.

Temperature (°C)	*Ionisation constant (K_w)*
5	1.9×10^{-15}
15	4.5×10^{-15}
25	1.0×10^{-14}
35	2.1×10^{-14}

What can be inferred from this data?

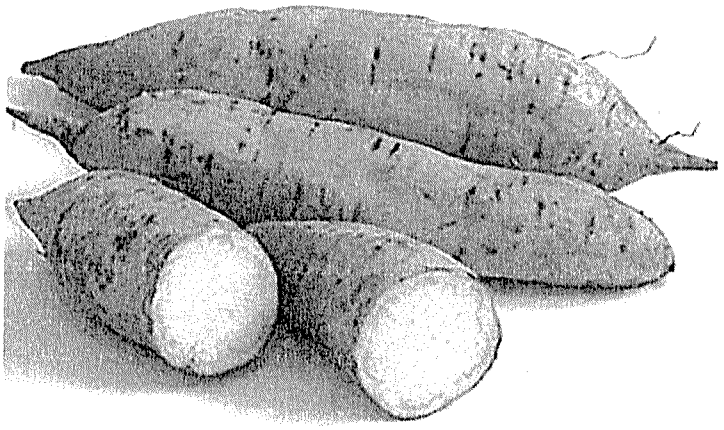
(A) The pH of pure water at 35°C is less than 7.

(B) The ionisation of water is an exothermic process.

(C) The equilibrium position lies well to the right.

(D) In pure water at 15°C $[OH^-]$ is lower than $[H_3O^+]$.

4 The peoples of the Tiwi islands in Northern Australia process yams (sweet potatoes) to make a food called bitter yam.



Which of the following is an example of the use of solution equilibria to remove toxins from these yams?

(A) Leaching.

(B) Fermentation

(C) Grinding to a powder

(D) Roasting

5 A conical flask containing 20.0 grams of barium chloride and 150.0 mL of water is mixed and left to stand for one hour on a laboratory bench.

Why after this time may the system be described as being in equilibrium?

(A) There is no lid on the flask.

(B) The temperature is constant.

(C) It is an open system which is at constant temperature.

(D) It is a closed system where a reversible reaction is taking place.

6 Chromate ions (CrO_4^{2-}) and hydrogen ions (H^+) are in equilibrium with dichromate ions ($Cr_2O_7^{2-}$) and water according to the following equation:

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

What would be the equilibrium expression, K_{eq}, for this reaction?

(A) $\dfrac{[CrO_4^{2-}] \times [H^+]}{[Cr_2O_7^{2-}]}$

(B) $\dfrac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}]^2 \times [H^+]^2}$

(C) $\dfrac{[Cr_2O_7^{2-}] \times [H_2O]}{[CrO_4^{2-}]^2 \times [H^+]^2}$

(D) $\dfrac{[CrO_4^{2-}]^2 \times [H^+]^2}{[Cr_2O_7^{2-}]^2 \times [H_2O]}$

7 Iron III ions and thiocyanate ions are in equilibrium with the iron III thiocyanate ion according to the following equation:

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

The system is then put under increased pressure.

What will this cause?

(A) $[Fe^{3+}]$ to increase

(B) $[SCN^-]$ to decrease

(C) $[Fe(SCN)^{2+}]$ to increase

(D) No change to the concentrations

8 Phosphorus pentachloride gas sets up an equilibrium with phosphorus trichloride and chlorine gas according to the following equation:

$$PCl_5(g) \rightleftarrows PCl_3(g) + Cl_2(g)$$

Initially 0.2 moles of phosphorus pentachloride was placed into a sealed 2 litre glass container so that equilibrium could be achieved. Data was collected and the container was found to hold 0.15 moles of chlorine gas.

What is the equilibrium constant expression, K_{eq}, for this reaction?

(A) 0.225

(B) 0.315

(C) 0.450

(D) 1.333

9 At a temperature of 25°C the K_{sp} for lead(II) bromide, $PbBr_2$ is 6.6×10^{-6}.

What is the solubility in water of $PbBr_2$?

(A) 6.6×10^{-6} mol L^{-1}

(B) 1.8×10^{-3} mol L^{-1}

(C) 0.012 mol L^{-1}

(D) 0.019 mol L^{-1}

10 Which of the following is amphiprotic?

(A) HCl

(B) Cl^-

(C) NH_4^+

(D) HCO_3^-

11 Which aqueous solution turns phenolphthalein indicator pink?

(A) H_2SO_4

(B) CH_3OH

(C) NaOH

(D) $CaCl_2$

12 What mass of solid sodium hydrogen carbonate is required to make 250 mL of 0.28 mol L^{-1} solution?

(A) 3.8 g

(B) 9.0 g

(C) 5.9 g

(D) 6.3 g

13 What volume of a 0.20 mol L^{-1} solution of calcium hydroxide would be required to neutralise 150 mL of 0.15 mol L^{-1} solution of hydrochloric acid?

(A) 11 mL

(B) 23 mL

(C) 45 mL

(D) 56 mL

14 Consider the following two compounds.

Compound X – CH_3COOH
Compound Y – $CH_3CH_2NH_2$

Which of the following best describes the properties of compounds X and Y?

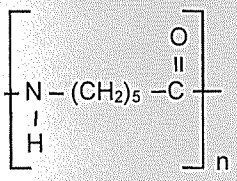
(A) Both compounds are acidic.

(B) Both compounds are basic.

(C) Compound X is basic and compound Y is acidic.

(D) Compound X is acidic and compound Y is basic.

15 Consider the polymer represented by the structure below.



Which alternative best names and describes this type of polymer?

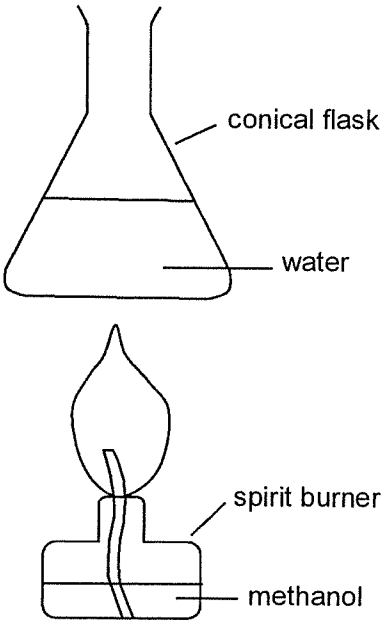
(A) Nylon, an addition polymer

(B) Nylon, a condensation polymer

(C) Polyester, an addition polymer

(D) Polyester, a condensation polymer

16 A student performed an experiment in which 100 mL of water was heated by burning methanol in a spirit burner as shown in the diagram below.



What is the maximum change in the temperature of the water when 0.500 grams of methanol is completely combusted? Assume all the heat from the flame is absorbed into the water. The enthalpy of combustion of methanol is -726 kJ mol^{-1}.

(A) 0.027°C

(B) 1.74°C

(C) 27.1°C

(D) 36.3°C

17 Which of the following ions produces a red flame in a flame test?

(A) Barium (Ba^{2+})

(B) Calcium (Ca^{2+})

(C) Iron (Fe^{2+})

(D) Copper (Cu^{2+})

18 A colourless aqueous solution contains a metal cation. Samples of this solution are tested with various anions:

Anion	*Observation*
Sulfate	White precipitate
Chloride	No precipitate
Carbonate	White Precipitate

Which of the following is most likely to be the cation?

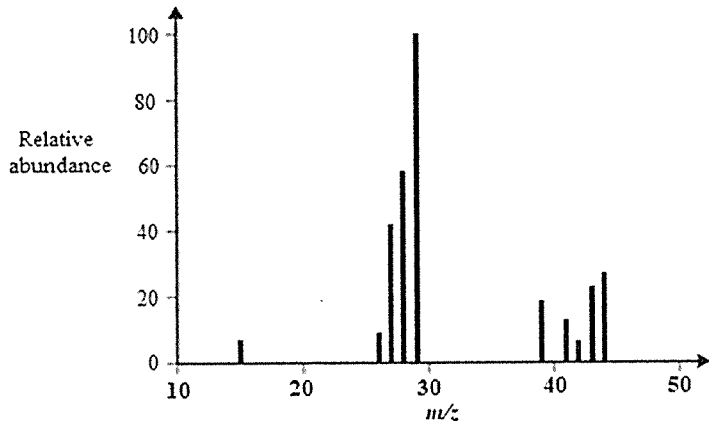
(A) $Ba^{2+}(aq)$

(B) $Na^{+}(aq)$

(C) $Cu^{2+}(aq)$

(D) $Fe^{3+}(aq)$

19 The mass spectrum of an unknown alkane is shown below.



What is this compound?

(A) Ethane

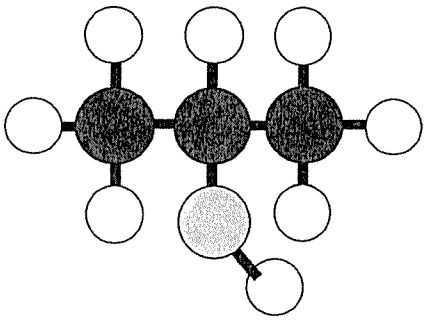
(B) Propane

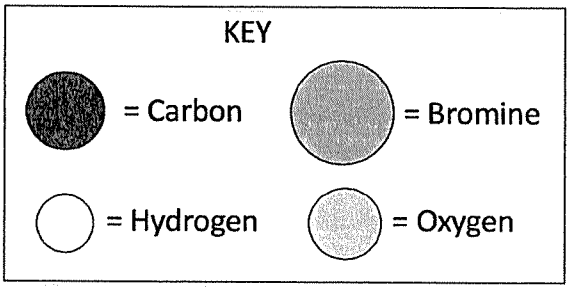
(C) Chloropropane

(D) Butane

20 Molecule X is reacted with hydrogen bromide in a *substitution* reaction.

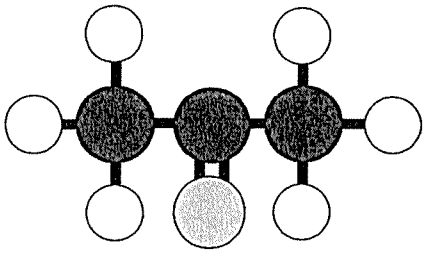
MOLECULE X



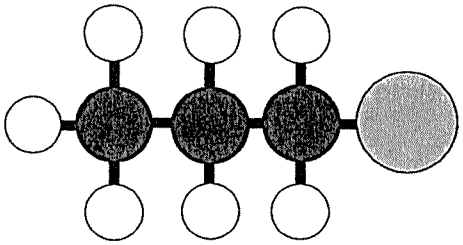


Which of the four options gives the most likely product?

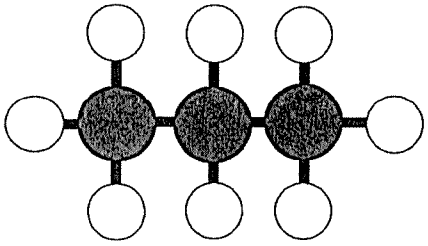
(A)



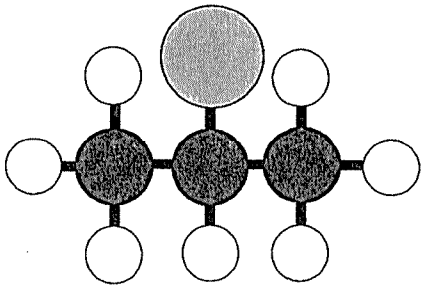
(B)



(C)



(D)



STUDENT NUMBER/NAME: .....

Section II

80 marks
Attempt Questions 21–38
Allow about 2 hours and 25 minutes for this section

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Question 21 (4 marks) **Marks**

(a) When an aqueous solution of iron(III) nitrate is added to an aqueous sodium phosphate solution, insoluble iron(III) phosphate is formed as one of the products. **1**

Write an equation (with states) that represents this reaction.

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(b) If aqueous thiocyanate ions are added to an aqueous solution of iron(III) ions a red colour is produced as an iron(III) thiocyanate complex establishes an equilibrium, releasing heat.

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

Yellow **Red**

(i) Explain why this equilibrium mixture is reddish at room temperature. **1**

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(ii) Describe what would happen if a solution containing phosphate ions was added to this mixture. **1**

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(iii) Explain the effect of a temperature rise on this equilibrium mixture. **1**

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Question 22 (5 marks) **Marks**

Carbon dioxide gas reacts with carbon tetrafluoride gas (CF_4) to form an equilibrium with carbonyl fluoride gas (COF_2). The molar equilibrium constant for this reaction is 0.5.

(a) Write the equation that represents this equilibrium reaction. **1**

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(b) Write the equilibrium constant expression for this reaction. **1**

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(c) A sample of 5 g of CO_2 gas and 29 g of CF_4 gas was injected into a sealed 5 L vessel. After a period of time the concentration of CF_4 gas was measured again and found to be 4 g L^{-1}. **3**

Determine if this mixture is in equilibrium.

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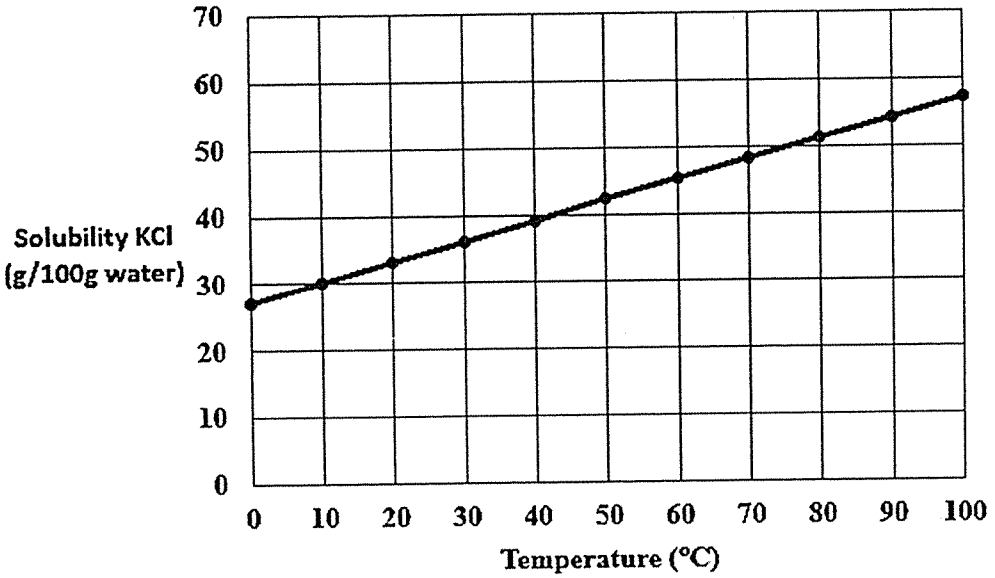
Question 23 (7 marks) **Marks**

The solubility graph of the ionic salt, potassium chloride is shown.



(a) Account for what a student would observe if 70 g of KCl was completely mixed in a beaker that contained 200 mL of water at a final temperature of 10°C. **2**

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Question 23 continues on the next page

Question 23 (continued) **Marks**

(b) Draw a labelled diagram to show what happens in terms of bonding when potassium chloride dissolves in water. **3**

(c) Explain why solids such as potassium chloride generally become more soluble as temperature increases. **2**

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End of Question 23

STUDENT NUMBER/NAME: .....

Question 24 (4 marks) **Marks**

For the salt silver chloride, AgCl, $K_{sp} = 1.77 \times 10^{-10}$ at 298 K.

A mixture is formed from 0.25 moles of $AgNO_3$ and 1.0 mole of NaCl in 1.0 L of water.

(a) Explain the meaning of K_{sp} for silver chloride. **1**

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(b) Calculate the concentration of silver ions, Ag^+, at equilibrium in this mixture. **3**

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Question 25 (4 marks)

A student takes a 100.0 mL sample from a saturated solution of barium hydroxide which was kept at 25°C.

(a) Write an equilibrium equation for barium hydroxide solid and its ions in solution. **1**

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(b) Calculate the mass of barium ions in the 100.0 mL sample. **3**

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Question 26 (6 marks) **Marks**

Barium sulfate is used in the medical imaging of the gastric and intestinal tract of humans. When a patient consumes a "barium meal" the pathway of the barium compound may be monitored using x-rays as it passes through the body.

(a) What property of this compound makes it very useful for following the pathway through the human body? **1**

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(b) A student mixes 50.0 mL of 0.02 mol L^{-1} sodium sulfate with 100.0 mL of 3.0×10^{-4} mol L^{-1} barium nitrate solution.

(i) Write a net ionic equation for the production of barium sulfate. **1**

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(ii) Calculate if a precipitate of barium sulfate will be produced if these two solutions are mixed. **4**

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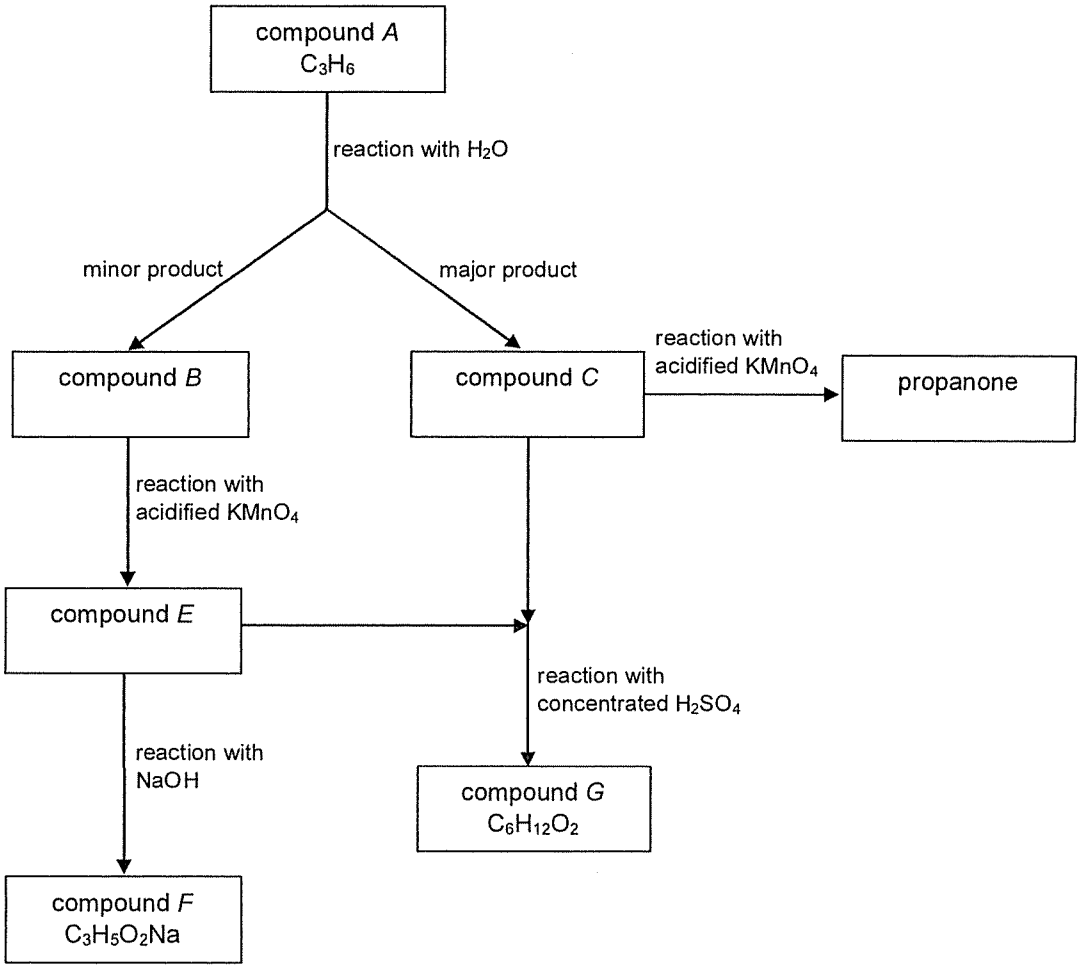
Question 27 (6 marks) **Marks**

Consider the following reaction sequence.



(a) How is compound *B* different from compound *C*? **1**

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Question 27 continues on the next page

Question 27 (continued) **Marks**

(b) Draw the structural formulas for compounds *A* and *E*. **2**

(c) Name the type of reaction producing compound *G*. **1**

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(d) Which of the above organic compounds would have the lowest boiling point? Give a reason for your answer. **2**

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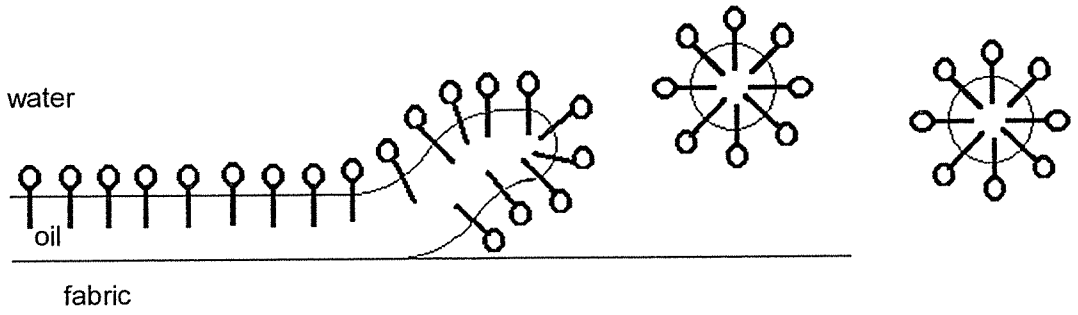
End of Question 27

Question 28 (3 marks) **Marks**



The above diagram was drawn and used by a student to describe the action of soap in emulsifying oil in water. **3**

Explain how the molecular structure of soap can result in oil being emulsified.

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Question 29 (4 marks)

Write a balanced equation for the following reactions and indicate any special conditions required for the reaction to take place.

(a) The fermentation of glucose producing ethanol. **2**

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(b) The production of chloroethane from ethane. **2**

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Question 30 (4 marks) **Marks**

The pH of 0.125 mol L^{-1} of ethanoic acid is 2.83.

(a) Calculate the Ka of the ethanoic acid. **2**

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(b) Calculate the pKa of the ethanoic acid. **1**

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(c) Calculate the percentage dissociation of the ethanoic acid. **1**

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Question 31 (4 marks) **Marks**

25.0 mL of 0.120 mol L^{-1} standardised barium hydroxide solution was titrated with nitric acid. The results are recorded in the following table.

Titration	*Volume of nitric acid used (mL)*
1	20.40
2	20.30
3	20.80
4	20.20

(a) Write the balanced equation for the reaction of barium hydroxide with nitric acid. **1**

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(b) Calculate the concentration of the nitric acid. **3**

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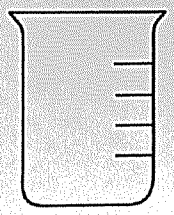
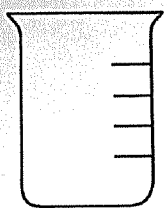
Question 32 (3 marks) **Marks**

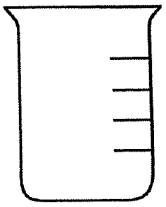
Solutions of nitric, ethanoic and sulphuric acids with the same concentrations (0.0125 mol L^{-1}) have been prepared. The pH of the ethanoic acid was 3.8.



0.0125 mol L^{-1}
nitric acid



0.0125 mol L^{-1}
ethanoic acid
pH = 3.8



0.0125 mol L^{-1}
sulfuric acid

(a) Calculate the pH of the nitric acid solution. **1**

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(b) Calculate the pH of the sulfuric acid solution. Compare this pH with the pH of the other acids. Justify your answer. **2**

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Question 33 (4 marks) **Marks**

The equilibrium involving two coloured cobalt species is shown below.

$$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$$

pink blue

(a) Outline a method that could be used to demonstrate that this is a dynamic equilibrium. Include expected observations. **2**

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(b) Cooling makes the solution more pink, while heating makes it more blue. **2**

Use this observation to explain whether the forward reaction is exothermic or endothermic.

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STUDENT NUMBER/NAME: .....

Question 34 (4 marks) **Marks**

Read the information below and convert it into a flowchart to show the steps involved in the synthesis of ethyl propanoate. **4**

Include the reagents necessary for the reactions involved.

- Ethene is converted to ethanol.
- Propan-1-ol is made from propene which is then converted to propanoic acid.
- Ethanol and propanoic acid are reacted to produce ethyl propanoate.

STUDENT NUMBER/NAME: .....

Question 35 (6 marks) **Marks**

There are a number of different qualitative investigations that can test for the presence of carbon–carbon double bonds, hydroxyl groups and carboxyl groups in organic molecules. **6**

Describe ONE test and state ONE observation for EACH of these THREE different functional groups.

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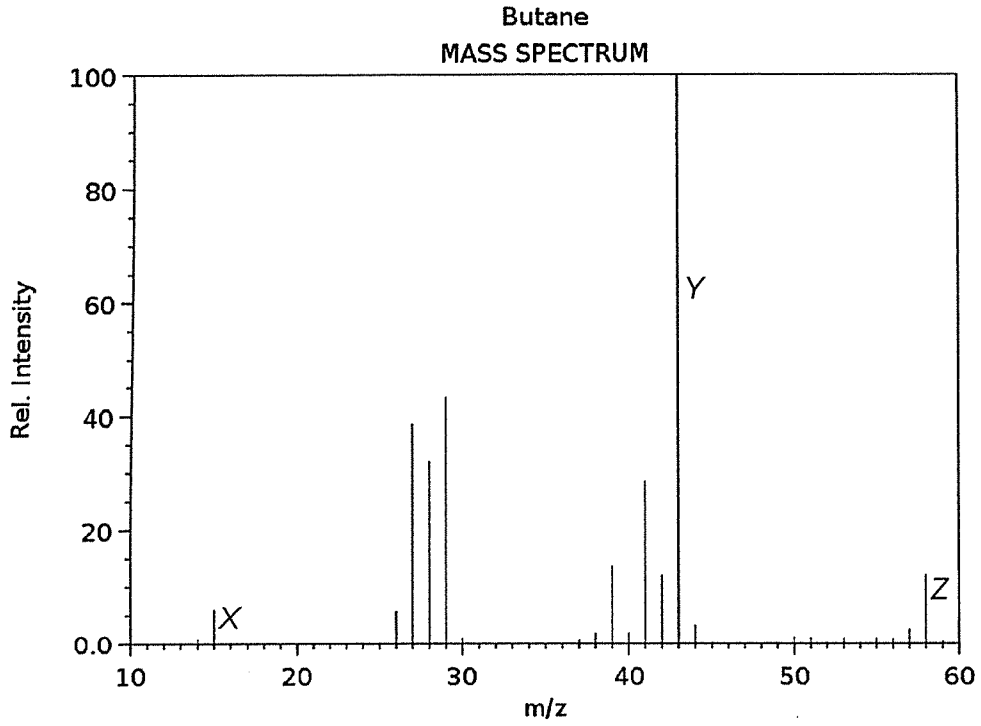
Question 36 (3 marks) **Marks**

The mass spectrum below is of butane (C_4H_{10}). Three of the peaks are labelled *X*, *Y* and *Z*. **3**



Identify and provide a reason for the chemical formulas for the THREE peaks labelled *X*, *Y* and *Z*.

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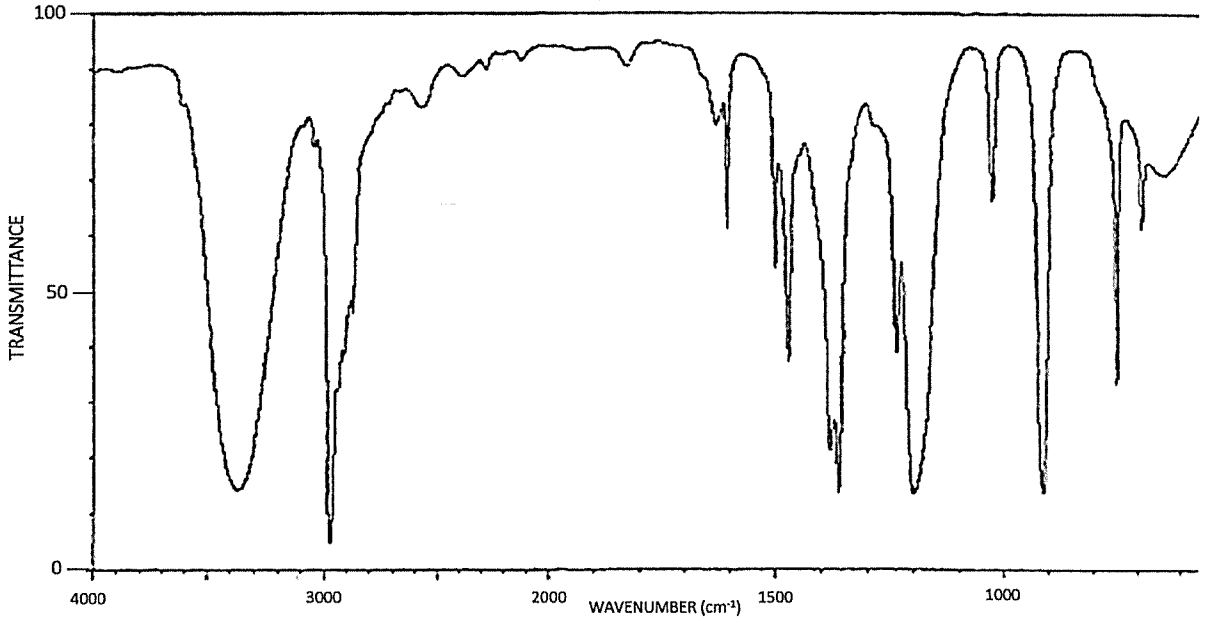
Question 37 (2 marks) **Marks**

The infrared spectrum of 2-methyl-2-propanol is shown below.



(a) In the space below, draw the structural formula of 2-methyl-2-propanol. **1**

(b) Identify the atoms, or groups of atoms, that are responsible for the low transmittance of infrared radiation at 2974 cm^{-1} and 3366 cm^{-1}. **1**

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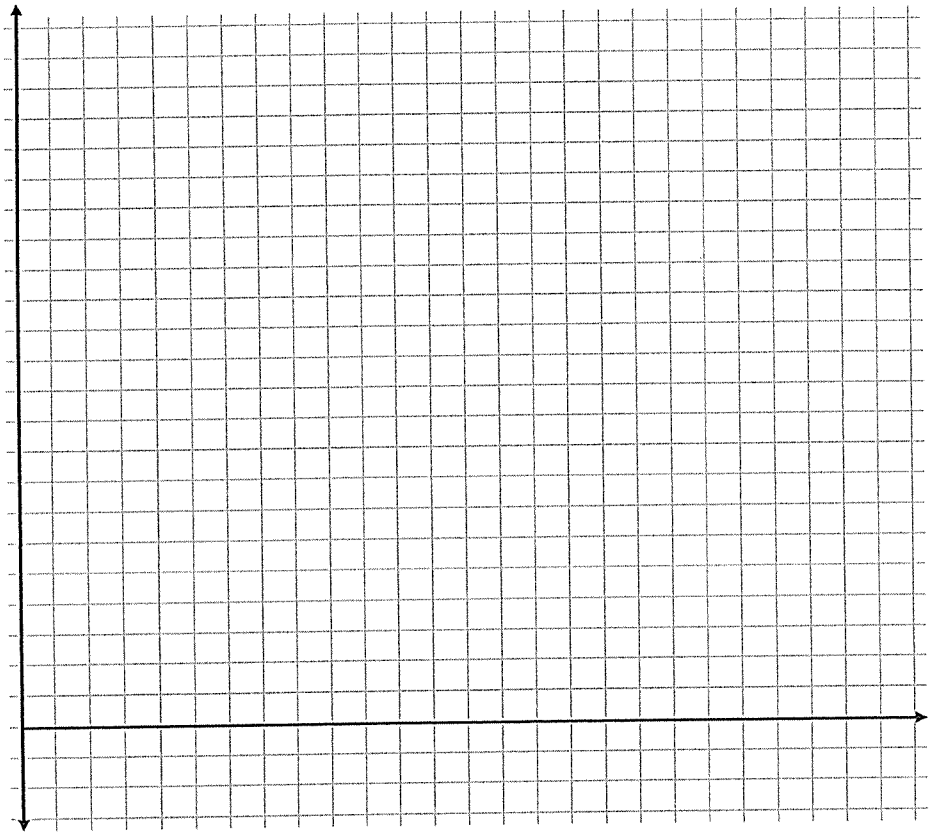
STUDENT NUMBER/NAME: .....

Question 38 (7 marks) **Marks**

The boiling points of six carboxylic acids and their related primary amines are listed in the table below.

Number of carbon atoms	*Carboxylic acid*	*Carboxylic acid boiling point (°C)*	*Amine*	*Amine boiling point (°C)*
1	Methanoic acid	101	Methanamine	−6.3
2	Ethanoic acid	118	Ethanamine	18
3	Propanoic acid	141	Propanamine	49
4	Butanoic acid	164	Butanamine	78
5	Pentanoic acid	186	Pentanamine	104
6	Hexanoic acid	205	Hexanamine	131

(a) On the graph below, label the horizontal axis "Number of carbon atoms" and the vertical axis "Boiling Point (°C)". Plot a line of best fit for the carboxylic acids and a separate distinct line of best fit for the amines onto this graph. **4**



Question 38 continues on the next page

Question 38 (continued) **Marks**

(b) Explain the trends that are evident in these graphs. **3**

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End of paper

NSW INDEPENDENT TRIAL EXAMS – 2019
CHEMISTRY TRIAL HSC EXAMINATION
MARKING GUIDELINES

Section I

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

Section I

Question 21(a)

Criteria	Mark
• Equation has correct formulas, is correctly balanced and has correct states	1

Sample answer: $Fe(NO_3)_3(aq) + Na_3PO_4(aq) \rightarrow FePO_4(s) + 3NaNO_3(aq)$

Question 21(b)(i)

Criteria	Mark
• Correctly explains why the equilibrium mixture is reddish at room temperature	1

Sample answer: At equilibrium this reaction is reddish because even though all three ions are present in the solution, the iron(III) thiocyanate ions $[FeSCN]^{2+}$ have the highest concentration. The equilibrium lies to the right at this temperature.

Question 21(b)(ii)

Criteria	Mark
• Correctly explains that the addition of phosphate ions would precipitate a solid and cause a shift in the equilibrium	1

Sample answer: If phosphate ions were added to this mixture they would react with the Fe^{3+} ions and form a solid. Since these ions are now removed from the solution the equilibrium would shift to the left and the mixture would become a lighter red or yellowish colour.

Question 21(b)(iii)

Criteria	Mark
• Refers to Le Chatelier's principle to explain that a temperature rise would shift the equilibrium to the left	1

Sample answer: Le Chatelier's principle states that if a reaction at equilibrium is disturbed it will shift in the direction that minimises that disturbance. Consequently, if the temperature of this equilibrium were increased it would shift to the left to minimise the effect of the temperature increase because the forward reaction is exothermic.

Question 22(a)

Criteria	Mark
• Equation is an equilibrium, has correct formulae and is correctly balanced	1

Sample answer: $CO_2 + CF_4 \rightleftharpoons 2COF_2$

Question 22(b)

Criteria	Mark
• Correctly writes the equilibrium constant expression for this reaction	1

Sample answer: $K = \dfrac{[COF_2]^2}{[CO_2] \times [CF_4]}$

Question 22(c)

Criteria	Mark
• Correctly determines that the mixture is not in equilibrium by correctly calculating concentrations and using an ICE table or equivalent	3
• Determines that the mixture is not in equilibrium by correctly calculating concentrations OR using an ICE table or equivalent	2
• Correctly calculates concentrations or uses an ICE table or a correct mathematical expression for K	1

Sample answer:

Initial $[CO_2] = 1.0 \text{ g L}^{-1} = 1 / (12.01 + 32) \text{ mol L}^{-1}$
$= 0.0227221086 \text{ mol L}^{-1}$

Initial $[CF_4] = 5.8 \text{ g L}^{-1} = 5.8 / [12.01 + (4 \times 19)] \text{ mol L}^{-1}$
$= 0.06590160209 \text{ mol L}^{-1}$

Final $[CF_4] = 4 \text{ g L}^{-1} = 4 / [12.01 + (4 \times 19)] \text{ mol L}^{-1}$
$= 0.04544938075 \text{ mol L}^{-1}$

	$[CO_2]$	$[CF_4]$	$[COF_2]$
Initial	**0.023**	**0.066**	0.00
Change	−0.021	−0.021	+0.042
Final	0.002	**0.045**	0.042

$$K_{eq} = \frac{[COF_2]^2}{[CO_2] \times [CF_4]} = \frac{(0.042)^2}{0.002 \times 0.045} = 19.6$$

K_{eq} is greater than 0.5. The mixture is not in equilibrium.

Question 23(a)

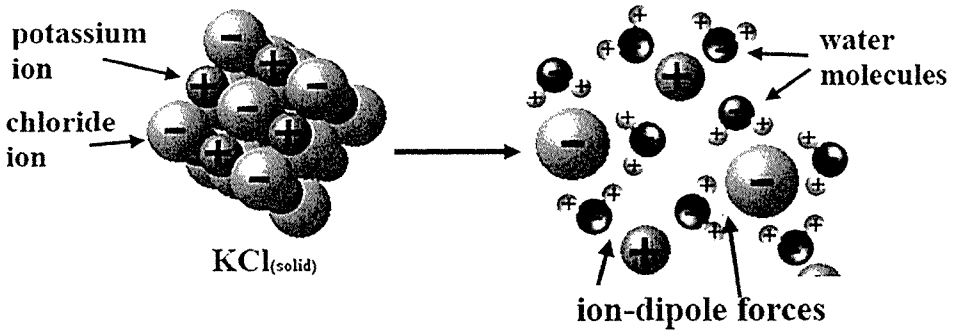
Criteria	Mark
• Accounts for the observations that most of the KCl dissolves and that a small amount of solid forms.	2
• States that most of the KCl would dissolve	1

Sample answer: The solubility curve for KCl indicates that at 10°C, 30 g of KCl dissolves in 100 g of water. Therefore, at this temperature 60 g would dissolve in 200 mL of water. The student should observe that most of the KCl dissolves and that a small amount of solid forms on the bottom of the beaker.

Question 23(b)

Criteria	Mark
• Draws a correct diagram to show what happens when a potassium chloride lattice dissolves in water and labels polar water molecules being attracted alternatively to positive potassium ions and negatively charged chloride ions by ion-dipole forces	3
• Draws a diagram to show what happens when potassium chloride dissolves in water and labels water molecules and separated ions	1–2

Sample answer:



Question 23(c)

Criteria	Mark
• Correctly explains why soluble solids such as potassium chloride become more soluble as temperature increases by referring to the increased kinetic energy of solute particles AND the increased potential to break bonds	2
• Correctly explains why soluble solids such as potassium chloride become more soluble as temperature increases by referring to the increased kinetic energy of solute particles OR the increased potential to break bonds	1

Sample answer: A temperature increase causes particles of the solute and solvent to gain more kinetic energy and this increase in energy makes it easier to break ionic bonds.

Question 24(a)

Criteria	Mark
• Correctly explains the meaning of K_{sp} by relating it to an equilibrium of ions in a saturated solution	1

Sample answer: K_{sp} is the solubility product constant. It is the equilibrium constant for an equilibrium between a solid and its respective ions in a saturated solution. Its value indicates the degree to which a compound dissociates in water.

Question 24(b)

Criteria	Mark
• Correctly calculates the concentration of silver ions at equilibrium in the solution	3
• Calculates a concentration of silver ions by referring to an excess of chloride ions and uses the correct K_{sp} expression	2
• Calculates a concentration of silver ions by referring to an excess of chloride ions OR uses the correct K_{sp} expression	1

Sample answer:

$AgNO_3$ is the limiting reagent, so moles AgCl formed = 0.25

$\therefore$ moles Cl^- remaining = 0.75

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

$$[Ag^+] = \frac{1.77 \times 10^{-10}}{[Cl^-]} = \frac{1.77 \times 10^{-10}}{0.75} = 2.36 \times 10^{-10} \text{ mol L}^{-1}$$

Question 25(a)

Criteria	Mark
• Provides a balanced equilibrium equation	1

Sample answer:

$$Ba(OH)_2 \rightleftharpoons Ba^{2+} + 2OH^-$$
$$-x \qquad x \qquad 2x$$

Question 25(b)

Criteria	Mark
• Selects the correct K_{sp} value from the data sheet • Relates the total concentration of ions in solution • Calculates the concentration of barium ions in solution • Calculates the mass of barium ions in solution	3
• Selects the correct K_{sp} value from the data sheet • Relates the total concentration of ions in solution • Calculates the concentration of barium ions in solution	2
• Selects the correct K_{sp} value from the data sheet • Relates the total concentration of ions in solution	1

Sample answer:

K_{sp} for barium hydroxide $= 2.55 \times 10^{-4} = [Ba^{2+}] \times [OH^-]^2$

$Ba(OH)_2 \rightleftarrows Ba^{2+} + 2OH^-$

At equilibrium: $-x \quad x \quad 2x$ where x is very small

$2.55 \times 10^{-4} = [Ba^{2+}] \times [OH^-]^2 = x \times (2x)^2$

$= 4x^3$

Now $x = \sqrt[3]{(2.55 \times 10^{-4}) / 4}$

$x = 3.995 \times 10^{-2}$ mol L^-

i.e. $[Ba^{2+}] = 3.995 \times 10^{-2}$ mol L^-

100.0 mL = 0.1 L

Since C = n/V then $n = C \times V = 3.995 \times 10^{-2} \times 0.1$

Moles of $Ba^{2+} = 3.995 \times 10^{-3}$

Molar mass of Ba = 137.3 g Since n = m/M then

mass of $Ba^{2+} = 3.995 \times 10^{-3} \times 137.3 = 0.549$ g

Question 26(a)

Criteria	Mark
• Provides a property	1

Sample answer: Barium sulfate is a sparingly soluble compound. It is dense and blocks X-rays.

Question 26(b)(i)

Criteria	Mark
• Provides a balanced net ionic equation	1

Sample answer: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightleftarrows BaSO_4(s)$

Question 26(b)(ii)

Criteria	Mark
• Determines the concentration of ions in initial solutions • Calculates the concentration of ions in final solution • Calculates the ion product correctly • Compares the ion product with K_{sp} to identify if a precipitate occurs	4
• Determines the concentration of ions in initial solution • Calculates a concentration of ions for final solution • Calculates an ion product OR • Compares an ion product with K_{sp} to identify if a precipitate occurs	3
• Determines the concentration of ions in final solution • Calculates the correct ion product OR • Compares an ion product with the correct K_{sp} value	2
• Determines the concentration of an ion in final solution OR • Compares an ion product with the correct K_{sp} value	1

Sample answer:

For original $[SO_4^{2-}]$: 50.0 mL of 0.02 mol L^{-1}

$n = C \times V = 0.02 \times 50.0 \times 10^{-3} = 0.001$ moles

Now total volume is 150.0 mL so $C = n / V = 0.001 / 150.0 \times 10^{-3} = 6.67 \times 10^{-3}$ mol L^{-1}

$[SO_4^{2-}] = 6.67 \times 10^{-3}$ mol L^{-1}

For original $[Ba^{2+}]$: 100.0 mL of 3.0×10^{-4} mol L^{-1}

$n = C / V = 3.0 \times 10^{-4} / 100.0 \times 10^{-3} = 3.0 \times 10^{-5}$ moles

Now total volume is 150.0 mL so $C = n / V = 3.0 \times 10^{-5} / 150 \times 10^{-3} = 2.0 \times 10^{-4}$ mol L^{-1}

$[Ba^{2+}] = 2.0 \times 10^{-4}$ mol L^{-1}

Now ion product $Q = [Ba^{2+}] \times [SO_4^{2-}] = 2 \times 10^{-4} \times 6.67 \times 10^{-3} = 1.33 \times 10^{-6}$

But K_{sp} for $BaSO_4 = 1.08 \times 10^{-10}$

Since $Q > K_{sp}$ a precipitate will form.

Question 27(a)

Criteria	Mark
• Correctly describes compound B as a primary alcohol and compound C as a secondary alcohol	1

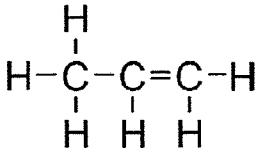
Sample answer: Compound B is a primary alcohol with its hydroxyl group attached to a carbon atom at the end of the three-carbon chain.

Compound C is a secondary alcohol with its hydroxyl group attached to the middle carbon atom of the three-carbon chain.

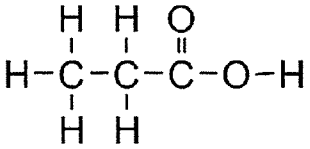
Question 27(b)

Criteria	Mark
• Gives the correct structural formula for both compound A and compound E	2
• Gives the correct structural formula for compound A OR for compound E	1

Sample answer:



Compound A



Compound E

Question 27(c)

Criteria	Mark
• Correctly names the reaction as esterification	1

Sample answer: The reaction is esterification.

Question 27(d)

Criteria	Mark
• Correctly identifies compound A as having the lowest boiling point and provides a correct reason	2
• Correctly identifies compound A as having the lowest boiling point OR • Correctly relates boiling point to intermolecular forces	1

Sample answer: Compound A (propene) has the lowest boiling point. Propene is a nonpolar substance with only very weak forces between molecules. All the other molecular compounds have oxygen atoms present making them polar substances and hence they have stronger forces between molecules giving them higher boiling points. Compound F is ionic and therefore has strong ionic bonds.

Question 28

Criteria	Mark
• Describes the structure of soap "molecules" AND • Explains the formation of micelles and • Describes the formation of an emulsion	3
• Any TWO of the above points	2
• Any ONE of the above points	1

Sample answer: Soap "molecules" have a negatively charged ionic end which is hydrophilic, and a nonpolar hydrophobic hydrocarbon chain at the other end. When soap molecules that are dissolved in water come into contact with oil, they will line up along the boundary between the water and oil with the hydrophilic ionic end in the water and the hydrophobic hydrocarbon chain end in the oil. When the mixture is agitated, the oil will break up into tiny droplets which become surrounded by the soap molecules. These tiny droplets, called micelles, all have the same negative charge around their surface, causing them to repel each other, preventing them from joining back together again. These micelles then remain suspended in the water producing an emulsion. Oil broken up into micelles that remain suspended in water is said to be emulsified.

Question 29(a)

Criteria	Mark
• Provides a correct balanced equation and at least THREE special conditions required	2
• Provides a correct balanced equation OR • Provides at least THREE special conditions required	1

Sample answer: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2(g)$
Conditions required include the presence of yeast, warmth and anaerobic conditions.

Question 29(b)

Criteria	Mark
• Provides a correct balanced equation and identifies the need for UV light	2
• Provides a correct balanced equation OR identifies the need for UV light	1

Sample answer: $CH_3CH_3 + Cl_2 \rightarrow CH_3CH_2Cl + HCl$
UV light is required.

Question 30(a)

Criteria	Mark
• Correctly calculates Ka	2
• Provides some correct information about how the final concentrations of each species is calculated	1

Sample answer:

$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$

$$Ka = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$$

$pH = 2.83$

$[H_3O^+] = 10^{-2.83} = 1.48 \times 10^{-3}\ mol\ L^{-1}$

	$CH_3COOH(aq) + H_2O(l)$	$CH_3COO^-(aq)$	$H_3O^+(aq)$
I	0.125	0	0
C	−x	+x	+x
E	0.125 − x	x	x

As $[H_3O^+] = 1.48 \times 10^{-3}\ mol\ L^{-1}$:

	$CH_3COOH(aq) + H_2O(l)$	$CH_3COO^-(aq)$	$H_3O^+(aq)$
I	0.125	0	0
C	-1.48×10^{-3}	$+1.48 \times 10^{-3}$	$+1.48 \times 10^{-3}$
E	$0.125 - 1.48 \times 10^{-3}$	1.48×10^{-3}	1.48×10^{-3}

$$Ka = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]} = \frac{(1.48 \times 10^{-3})(1.48 \times 10^{-3})}{(0.124)} = 1.77 \times 10^{-5}$$

Question 30(b)

Criteria	Mark
• Correctly calculates pKa	1

Sample answer:

$pKa = -\log_{10}[Ka]$

$pKa = \log_{10}[1.77 \times 10^{-5}] = 4.75$

Question 30(c)

Criteria	Mark
• Correctly calculates % dissociation	1

Sample answer: % dissociation $= \frac{[CH3COO^-]}{[CH_3COOH]} = \frac{0.00148}{0.125} \times 100 = 1.2\%$

Question 31(a)

Criteria	Mark
• Provides correct equation	1

Sample answer: $Ba(OH)_{2(aq)} + 2HNO_{3(aq)} \rightarrow Ba(NO_3)_{2(aq)} + 2H_2O_{(aq)}$

Question 31(b)

Criteria	Mark
• Accurately determines concentration of HNO_3	3
• Average volume of titre correctly calculated	2
• Provides some relevant information	1

Sample answer:

$V_{Ba(OH)2} = 25.0mL = 0.025L$

$C_{Ba(OH)2} = 0.12molL^{-1}$

$V_{HNO3} = \dfrac{20.40 + 20.30 + 20.20}{3} = 20.30\ mL = 0.0203\ L$

(Titration number 3 not included as it is not a concordant titre)

$C_{HNO3} = ?$

$N_{Ba(OH)2} = C \times V = 0.025 \times 0.12 = 0.00300\ mol$

$n_{HNO3} = n_{Mg(OH)2} \times 2 = 0.006\ mol$

$C_{HNO3} = = \dfrac{n}{V} = \dfrac{0.006}{0.0203} = 0.296\ mol\ L^{-1}$ *(to 3 significant figures)*

Question 32(a)

Criteria	Mark
• Accurately determines the pH of HNO_3	1

Sample answer: $C_{HNO3} = 0.0125\ mol\ L^{-1}$

$pH = -\log_{10}[H_3O^+] = -\log_{10}[0.0125] = 1.90$

Question 32(b)

Criteria	Mark
• Accurately calculates pH of sulfuric acid	2
• Provides some information about the diprotic nature of sulfuric acid	1

Sample answer:

$CH_2SO_4 = 0.0125\ mol\ L^{-1}$

$pH = -\log_{10}[2 \times H_3O^+] = -\log_{10}[2 \times 0.0125] = 1.60$

The pH of the sulfuric acid solution is lower than the pH of the nitric acid solution. Even though both acids are strong acids and fully dissociate in water, the sulfuric acid is diprotic which produces more hydronium ions in the solution. Hence lower pH.

Question 33(a)

Criteria	Mark
• A logical method is outlined that demonstrates equilibrium and clear observations are stated	2
• A logical method is outlined that demonstrates equilibrium OR clear observations are stated	1

Sample answer: Place about 2 mL of the pink cobalt species into a test tube. Add a small amount of sodium chloride (tip of a spatula) to the solution and mix to dissolve. The solution should change to blue. Adding water to the mixture should cause the solution to change to pink. Repeating these additions should cause the same colour changes and demonstrating that the equilibrium is dynamic as it is reversible.

Question 33(b)

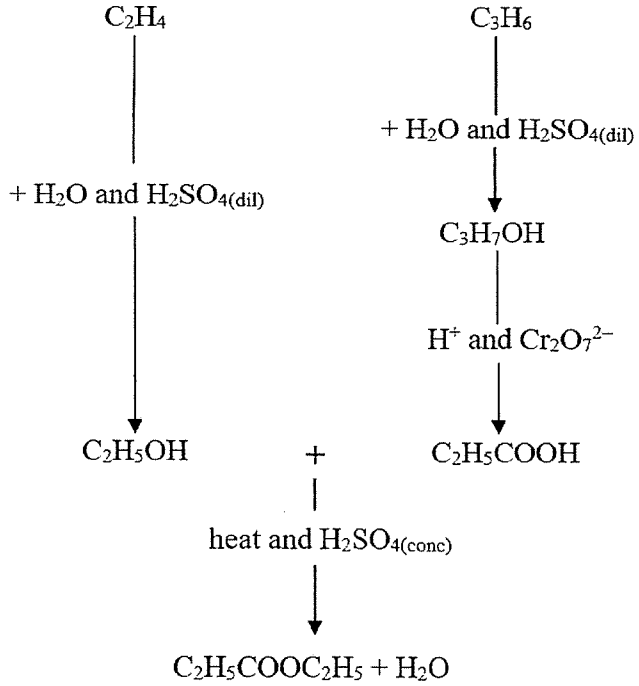
Criteria	Mark
• Forward reaction identified as being endothermic and explanation given	2
• Forward reaction identified as being endothermic	1

Sample answer: An increase in temperature causes a shift in the equilibrium to the right (forming the blue species). This means that heat is required for the forward reaction and it is therefore endothermic.

Question 34

Criteria	Mark
• FOUR reactions included, formulas correct, flowchart format	4
• THREE reactions included, THREE formulas correct, flowchart format	3
• TWO or more reactions included	2
• ONE reaction	1

Sample answer:



Question 35

Criteria	Mark
• Correct test for the carbon-carbon double bond • Correct observation for that test • Correct test for the hydroxyl group AND correct observation for that test • Correct test for the carboxylic acid functional group AND correct observation for that test	6
• FIVE of the above	5
• FOUR of the above	4
• THREE of the above	3
• TWO of the above	2
• ONE of the above	1

There are a variety of different tests for these functional groups, so the sample answer below is just one of many possible answers, e.g. either phosphorus pentachloride or sodium metal can be used to test for alcohols.

Sample answer: A test for the carbon–carbon double bond is the addition of bromine water to the substance. Bromine water is an orange-brown colour. When it reacts with the carbon–carbon double bond, the orange-brown colour disappears, i.e. the bromine water is "decolourised".

A test for the hydroxyl group (alcohol) is the addition of a carboxylic acid and some concentrated sulfuric acid to the substance and then gently warming the mixture. The alcohol, carboxylic acid and sulfuric acid combine to form an ester, which can be observed because it has a distinctive fruity smell.

A test for the carboxylic acid functional group is the addition of sodium carbonate. Carboxylic acids react with the carbonate ion to form carbon dioxide gas. This can be observed by the appearance of bubbles in the reacting mixture.

Question 36

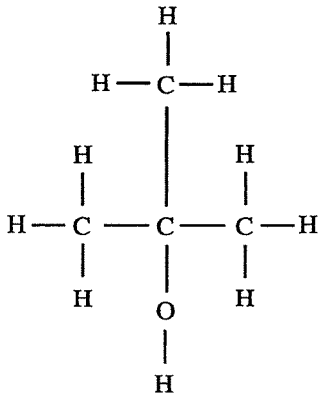
Criteria	Mark
• Identifies and explains X as CH_3 group • Identifies and explains Y as C_3H_7 group • Identifies and explains Z as C_4H_{10} group	3
• TWO of the above	2
• ONE of the above	1

Sample answer: Peak X has an m/z ratio of 15. This corresponds to a CH_3 group. Peak Y has an m/z ratio of 43. This corresponds to a C_3H_7 group, i.e. the butane molecule has had a CH_3 group broken off one end. Peak Z has an m/z ratio of 58. This corresponds to a C_4H_{10} group.

Question 37(a)

Criteria	Mark
• Correct structural formula for 2-methyl-2-propanol	1

Sample answer:



2-methyl-2-propanol

Question 37(b)

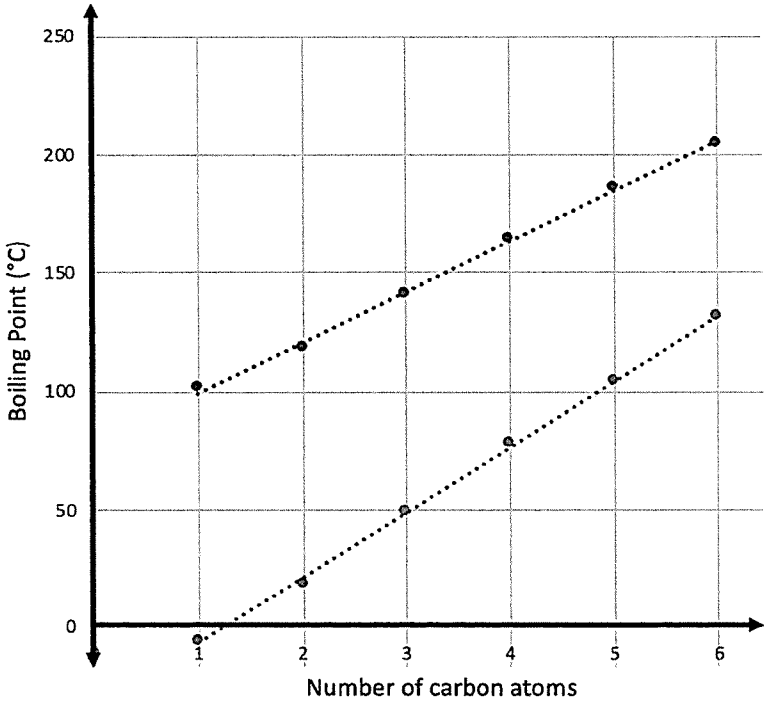
Criteria	Mark
• Correctly identifies both C–H and O–H bonds	1

Sample answer: The low transmittance of infrared radiation at 2974 cm^{-1} is due to the presence of C–H bonds. The low transmittance of infrared radiation at 3366 cm^{-1} is due to the presence of O–H bonds.

Question 38(a)

Criteria	Mark
• Correct scale and label on the vertical axis • Correct scale and label on the horizontal axis • Points plotted correctly • Lines of best fit plotted correctly	4
• THREE of the above	3
• TWO of the above	2
• ONE of the above	1

Sample answer:



Question 38(b)

Criteria	Mark
• Explains the relationship between the number of carbon atoms and the boiling point of the carboxylic acid • Explains the relationship between the number of carbon atoms and the boiling point of the amine • Explains that the carboxylic acid has a higher boiling point than the amine because the carboxylic acid group has a higher polarity. This results in stronger intermolecular forces and a higher boiling point	3
• THREE of the above	2
• TWO of the above	1

Sample answer: The boiling points of the carboxylic acids increase according to the increase in the molecular mass of each molecule. This increase produces greater dispersion forces between like molecules.
The boiling points of the amines increase according to the increase in the molecular mass of each molecule. This increase produces greater dispersion forces between like molecules.
The boiling point of the carboxylic acid is higher than the boiling point of the corresponding amine. This is because the carboxylic acid functional group has higher polarity than the amine functional group, leading to stronger intermolecular forces between the molecules.

The lines are approaching each other. This indicates that the size of the non-polar alkyl group is becoming increasingly important in determining the boiling point of the substance.

NB: there may be other valid trends that students could derive from the table or the graph.

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CHEMISTRY TRIAL HSC EXAMINATION
MAPPING GRID

Question	Marks	Content	Syllabus Outcomes	Target performance bands
Section I				
1	**1**	Mod 6 Quantitative analysis	CH11/12-5 CH 12-13	4-5
2	**1**	Mod 5 Factors that affect equilibrium	CH11/12-6 CH12-12	4-5
3	**1**	Mod 5 Calculating the equilibrium constant	CH11/12-5, CH11/12-6 CH12-12	5-6
4	**1**	Mod 5 Solution equilibria	CH11/12-5, CH12-12	2-3
5	**1**	Mod 5 Static and dynamic equilibrium	CH11/12-5, CH12-12	1-2
6	**1**	Mod 5 Calculating equilibrium constant	CH11/12-4, CH11/12-6 CH12-12	3
7	**1**	Mod 5 Factors that affect equilibrium	CH11/12-4, CH11/12-6 CH12-12	3-4
8	**1**	Mod 5 Calculating equilibrium constant	CH11/12-4, CH11/12-6 CH12-12	5-6
9	**1**	Mod 5 Solution equilibria	CH11/12-4, CH12-12	5-6
10	**1**	Mod 6 Using the Bronsted-Lowry theory	CH11/12-5, CH12-13	2-4
11	**1**	Mod 6 Properties of acids and bases	CH11/12-4, CH12-13	3
12	**1**	Mod 6 Quantitative analysis	CH11/12-5, CH12-13	3-4
13	**1**	Mod 6 Quantitative analysis	CH11/12-4, CH12-13	3-4
14	**1**	Mod 7 Reactions of organic acids and bases	CH11/12-4, CH12-14	4
15	**1**	Mod 7 Polymers	CH12-14	3-4
16	**1**	Mod 7 Alcohols	CH11/12-4, CH11/12-6, CH12-14	4-5
17	**1**	Mod 8 Analysis of inorganic substances	CH11/12-4, CH12-15	2-3
18	**1**	Mod 8 Analysis of inorganic substances	CH11/12-4, CH12-15	3
19	**1**	Mod 8 Analysis of organic substances	CH11/12-5, CH12-15	4-5
20	**1**	Mod 7 Products of reactions involving hydrocarbons	CH11/12-4, CH11/12-6 CH12-14	3-4

NSW INDEPENDENT TRIAL EXAMS – 2019
CHEMISTRY TRIAL HSC EXAMINATION
MAPPING GRID - cont'd

Section II				
Question	**Marks**	**Content**	**Syllabus Outcomes**	**Target performance bands**
21(a)	1	Mod 8 Analysis of inorganic substances	CH11/12-4, CH12-15	4
21(b)(i)	1	Mod 5 Factors that affect equilibrium	CH11/12-4, CH11/12-6 CH12-12	4-5
21(b)(ii)	1	Mod 5 Factors that affect equilibrium	CH11/12-4, CH11/12-6 CH12-12	4-6
21(b)(iii)	1	Mod 5 Factors that affect equilibrium	CH11/12-4, CH11/12-6 CH12-12	4-5
22(a)	1	Mod 5 Calculating equilibrium constant	CH11/12-4, CH12-12	2-3
22(b)	1	Mod 5 Calculating equilibrium constant	CH11/12-5, CH11/12-7 CH12-12	2-3
22(c)	3	Mod 5 Calculating equilibrium constant	CH11/12-4, CH11/12-5 CH11/12-6, CH12-12	5-6
23(a)	2	Mod 5 Solution equilibria	CH11/12-5, CH12-12	4-5
23(b)	3	Mod 5 Solution equilibria	CH11/12-7, CH12-12	5-6
23(c)	2	Mod 5 Solution equilibria	CH11/12-6, CH11/12-7 CH12-12	4-5
24(a)	1	Mod 5 Solution equilibria	CH12-12	5
24(b)	3	Mod 5 Solution equilibria	CH11/12-4, CH12-12	5-6
25(a)	1	Mod 5 Solution equilibria	CH12-12	2-3
25(b)	3	Mod 5 Solution equilibria	CH11/12-4, CH12-12	5-6
26(a)	1	Mod 5 Solution equilibria	CH11/12-6, CH12-12	2-3
26(b)(i)	1	Mod 5 Solution equilibria	CH12-12	3-4
26(b)(ii)	4	Mod 5 Solution equilibria	CH11/12-4, CH11/12-6 CH-1212	5-6
27(a)	1	Mod 7 Nomenclature Mod 7 Products of reactions involving hydrocarbons	CH12-14	3-5
27(b)	2	Mod 7 Nomenclature Mod 7 Products of reactions involving hydrocarbons	CH11/12-4, CH11/12-6, CH12-14	4-5
27(c)	1	Mod 7 Reactions of organic acids and bases	CH11/12-5, CH12-14	4
27(d)	2	Mod 7 Hydrocarbons	CH11/12-6, CH12-14	4-5
28	3	Module 7 Reactions of organic acids and bases	CH11/12-7, CH12-14	3-6
29(a)	2	Module 7 Alcohols	CH12-14	3-5
29(b)	2	Module 7 Products of reactions involving hydrocarbons	CH12-14	4
30(a)	2	Module 6 Quantitative analysis	CH11/12-4, CH12-13	4-6
30(b)	1	Module 6 Quantitative analysis	CH12-13	3
30(c)	1	Module 6 Quantitative analysis	CH11/12-4, CH12-13	4-5
31(a)	1	Module 6 Quantitative analysis	CH12-13	2-3
31(b)	3	Module 6 Quantitative analysis	CH11/12-4, CH11/12-5, CH12-13	4
32(a)	1	Mod 6 Using the Bronsted-Lowry theory	CH11/12-4, CH12-13	2-3
32(b)	2	Mod 6 Using the Bronsted-Lowry theory	CH11/12-4, CH11/12-7, CH12-13	3-4

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MAPPING GRID - cont'd

Question	Marks	Content	Syllabus Outcomes	Target performance bands
33(a)	2	Mod 5 Static and dynamic equilibrium, Mod 5 Factors that affect equilibrium	CH11/12-3, CH11/12-4, CH12-12	3-6
33(b)	2	Mod 5 Factors that affect equilibrium	CH11/12-5, CH11/12-6, CH12-12	4-6
34	4	Mod 7 Products of reactions involving hydrocarbons Mod 7 Reactions of organic acids and bases	CH11/12-4, CH11/12-7, CH12-14	4-6
35	6	Mod 8 Analysis of organic substances	CH11/12-2, CH11/12-7, CH12-15	5-6
36	3	Mod 8 Analysis of organic substances	CH11/12-5, CH11/12-6, CH12-15	4-6
37(a)	1	Mod 8 Analysis of organic substances	CH12-15	2-3
37(b)	1	Mod 8 Analysis of organic substances	CH11/12-4, CH12-15	5
38(a)	4	Mod 7 Hydrocarbons Mod 7 Reactions of organic acids and bases	CH11/12-4, CH11/12-5, CH12-14	4-6
38(b)	3	Mod 7 Hydrocarbons Mod 7 Reactions of organic acids and bases	CH11/12-5, CH11/12-7, CH12-14	5-6