Killara High School

2025 **Higher School Certificate Trial Examination**

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks (pages 2 - 11)

- Attempt Questions 1 - 20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 15 - 34)

- Attempt Questions 21 - 37
- Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Question 1-20
Allow 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1-20.

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1 Consider the reaction:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$$

If the total pressure is doubled at constant temperature, the position of equilibrium will

A. shift right then left.

B. shift right, favouring SO_3.

C. shift left, favouring SO_2 and O_2.

D. remain unchanged because the forward and reverse reaction rates increase equally.

2 Which of the following best describes the common ion effect?

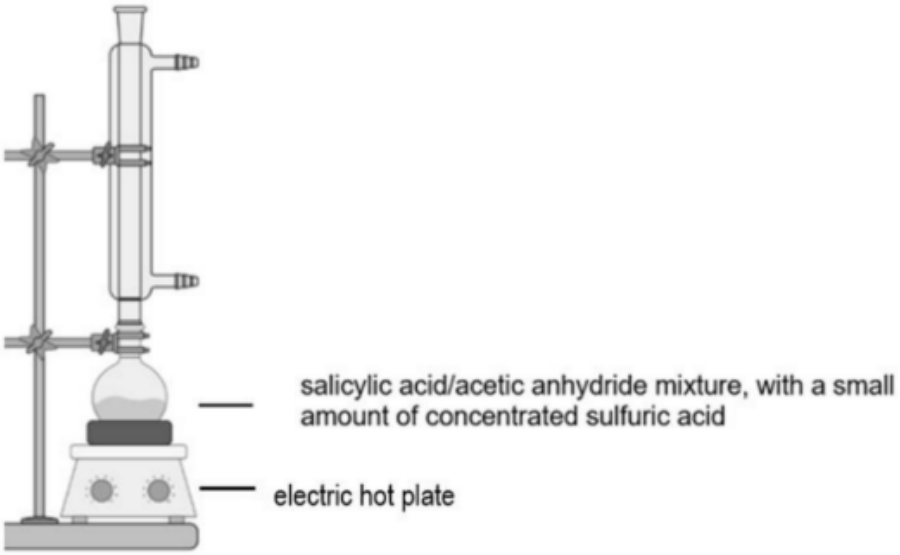
A. The change in colour of a solution when a common ion is added.

B. The complete dissociation of a salt in water regardless of other ions present.

C. The decrease in solubility of a salt when a solution already contains one of its ions.

D. The increase in solubility of a salt when a solution already contains one of its ions.

3 The synthesis of aspirin from a mixture of salicylic acid and acetic anhydride can be carried out in a typical school laboratory. A main step in the synthesis requires use of the following apparatus.



Why is the flask being heated in the manner shown in the diagram?

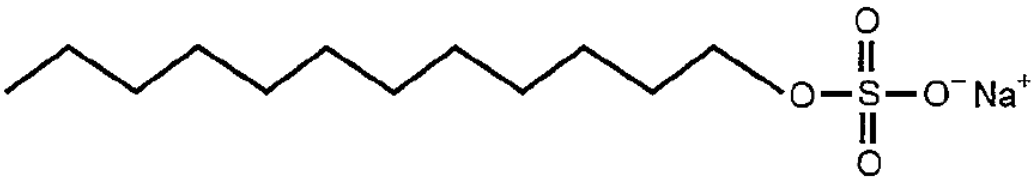
A. The hot plate reduces the time it takes for the mixture to come to a boil.

B. It is a safer way to heat the mixture and prevents loss of reactant and product.

C. It heats the solution to a higher temperature than a Bunsen burner allows.

D. All of the above.

4 The structure of a surfactant is shown.



Which term best describes this type of surfactant?

A. Anionic

B. Cationic

C. Amphoteric

D. Non-ionic

5 What are the products of the reaction between lithium metal and sulfuric acid?

A. Li_2SO_3 and H_2O

B. Li_2SO_4 and H_2

C. Li_2SO_3 and H_2

D. Li_2SO_4 and H_2O

6 Which is the correct definition of a chemical system that reaches equilibrium?

A. It is an open system where macroscopic properties remain constant.

B. It is a closed system where macroscopic properties constantly change.

C. It is an open system where concentrations of reactants and products are different.

D. It is a closed system where the concentrations of reactants and products remain constant.

7 Which is the expression for the solubility product constant, K_{sp}, for calcium phosphate $Ca_3(PO_4)_2$?

A. $[Ca^{2+}][PO_4^{3-}]$

B. $[Ca^{2+}]^3[PO_4^{3-}]^2$

C. $[Ca^{2+}]^2[PO_4^{3-}]^3$

D. $3[Ca^{2+}]2[PO_4^{3-}]$

8 Methanol can be produced by the following reaction:

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

At 450 K, the equilibrium mixture had the following concentrations:

[CO] (mol L^{-1})	*[H_2] (mol L^{-1})*	*[CH_3OH] (mol L^{-1})*
3.81×10^{-3} mol L^{-1}	4.27×10^{-3} mol L^{-1}	4.15×10^{-8} mol L^{-1}

The equilibrium constant for this reaction is

A. $K_{eq} = 8.12 \times 10^{-4}$

B. $K_{eq} = 2.55 \times 10^{-3}$

C. $K_{eq} = 1.67 \times 10^{-2}$

D. $K_{eq} = 5.97 \times 10^{-1}$

9 The properties below relate to the first 5 members of a homologous series.

All molecules:

- have boiling points below 50°C.
- react with bromine water in the presence of UV light.
- are unreactive with acidified $KMNO_4$.
- are unreactive with HCl

A. Alkanes

B. Alkenes

C. Alkynes

D. Primary Alcohols

10 The reaction of HNO_2 with HCO_3^- is shown below:

$$HCO_3^- + HNO_2 \rightleftharpoons H_2CO_3 + NO_2^-$$

Which of the following is the correctly identifies the acid/base conjugate pairs?

	Acid	Base	Conjugate Base	Conjugate Acid
A.	HCO_3^-	HNO_2	H_2CO_3	NO_2^-
B.	HNO_2	HCO_3^-	H_2CO_3	NO_2^-
C.	HNO_2	HCO_3^-	NO_2^-	H_2CO_3
D.	HCO_3^-	HNO_2	NO_2^-	H_2CO_3

11 A 0.020 mol L^{-1} solution of hydrochloric acid (HCl) is prepared. Assuming complete dissociation, what is the pOH of the solution?

A. 0.020

B. 1.70

C. 12.30

D. 13.00

12 In a titration, 25.0 mL of a 0.100 M solution of acetic acid (CH_3COOH) is required to neutralize 50.0 mL of an unknown sodium hydroxide (NaOH) solution.

What is the concentration of the sodium hydroxide solution?

A. 0.050 M

B. 0.100 M

C. 0.200 M

D. 0.2500 M

13 Markovnikov's rule states:

> *The halide component of HX bonds preferentially at the more highly substituted carbon of an alkene, forming the major product.*

Propene reacts with hydrogen bromide to form a mixture of organic products.

Which of the following identifies the 'major' product formed and number of signals on the proton NMR spectrum?

	Name	*Number of H-NMR Signals*
A.	1-bromopropane	1
B.	1-bromopropane	3
C.	2-bromopropane	2
D.	2-bromopropane	3

14 Gas X reacts with Gas Y to produce Gas Z. The value of the equilibrium constant is 3.4 at this temperature and pressure.

In a particular reaction, some Gas X and Gas Y are placed into a 2 L vessel where they begin to react.

When equilibrium is reached, the vessel is found to contain 4.0 moles of Gas X, 1.0 mole of Gas Y and 3.0 moles of Gas Z.

Which equation is consistent with the information provided above?

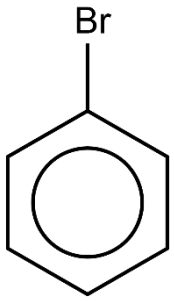
A. $X(g) + Y(g) \rightleftharpoons Z(g)$

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

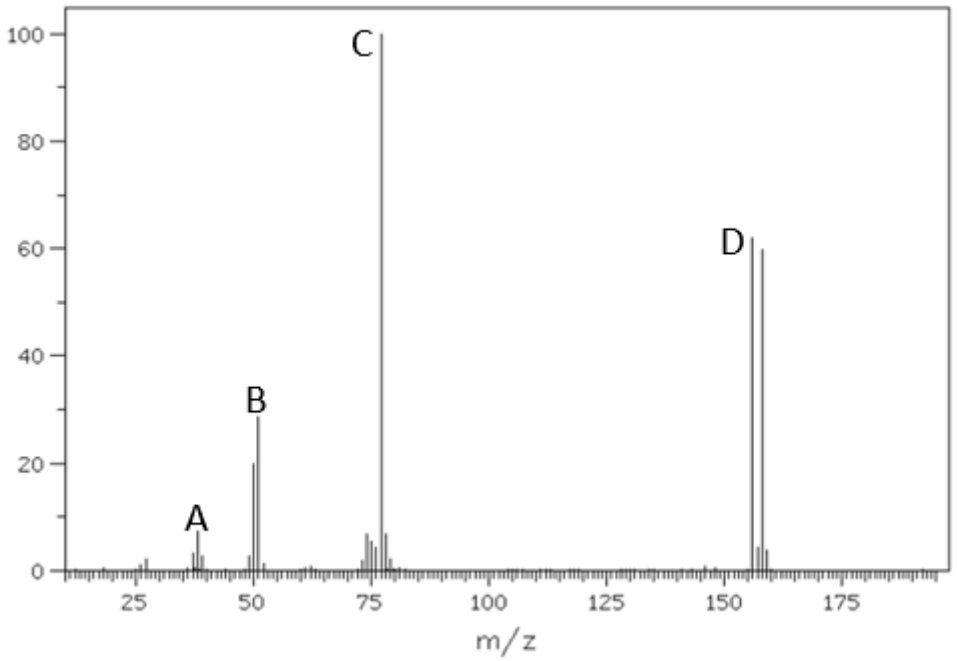
C. $X(g) + Y(g) \rightleftharpoons 3Z(g)$

D. $4X(g) + Y(g) \rightleftharpoons 3Z(g)$

15 Bromobenzene consists of a benzene ring substituted with a bromine atom.



The mass spectrum of bromobenzene is shown below.



Which fragment contains a bromine atom?

A. A

B. B

C. C

D. D

16 A 25.00 mL aliquot of 0.1050 mol L^{-1} sodium carbonate (Na_2CO_3) solution was titrated with hydrochloric acid (HCl) using methyl orange as the indicator.

Which of the following best explains why methyl orange is an appropriate choice for this titration?

A. Methyl orange changes colour at the equivalence point of a strong base–strong acid titration, which is typically around pH 7.

B. Methyl orange has a pH transition range that matches the second equivalence point in a diprotic titration of a weak base with a strong acid.

C. Methyl orange changes colour at a high pH, suitable for detecting the endpoint of weak base–weak acid reactions.

D. Methyl orange is suitable because it has a colour change range around pH 4.0, which corresponds to the acidic equivalence point of a weak base–strong acid titration.

17 Which is the correct K_b expression for the cyanide (CN^-) ion?

A. $\frac{[OH^-][HCN]}{[CN^-]}$

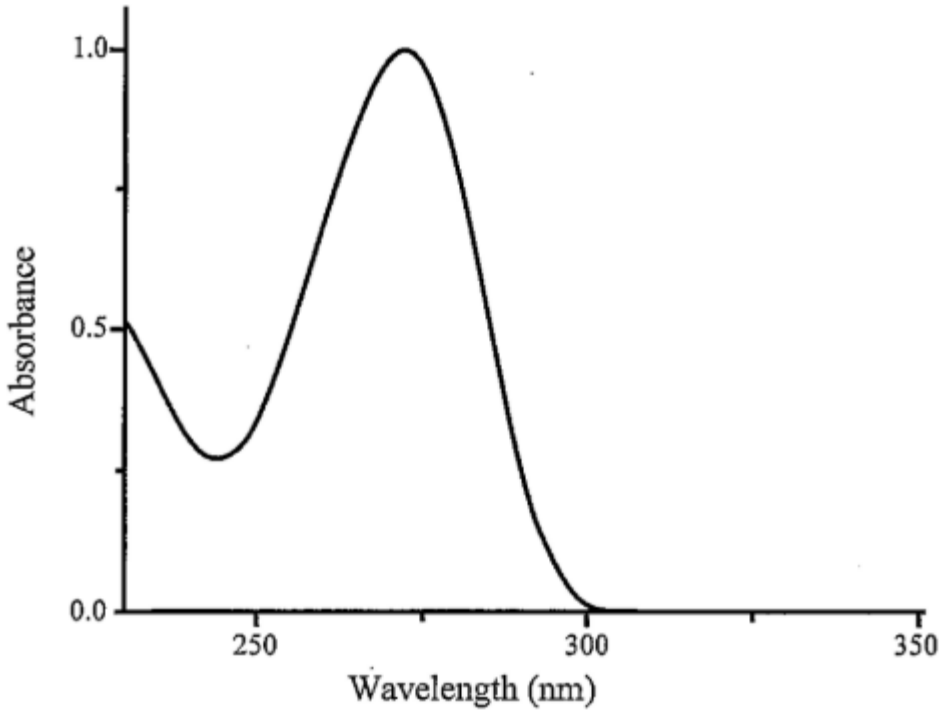
B. $\frac{[CN^-]}{[OH^-][HCN]}$

C. $[OH^-][HCN]$

D. $\frac{[C^{4-}][N^{3+}]}{[CN^-]}$

18 A scientist is tasked with determining the concentration of caffeine in a cup of coffee.

The UV-Vis spectrum of caffeine is shown below.



Consider the following statements about this compound and its UV-Vis spectrum.

I. The concentration of a solution of this compound can only be determined by UV-visible spectroscopy at approximately 220 nm.

II. The amount of light absorbed by a solution of this compound depends on its concentration.

III. This compound is coloured due to the absorbance at 275 nm.

IV. The wavelength selected for analysis is dependent on the absorbance of other species in the mixture.

Which statements are true?

A. II only

B. I and III

C. II and IV

D. I, II and IV

19 Consider the following compounds.

I - propanal
II - propanone
III - propanoic acid
IV - methyl ethanoate

Which pair/s of compounds are structural isomers?

A. I and II only

B. III and IV only

C. I and III - as well as - II and IV

D. I and II - as well as - III and IV

20 What is the percentage yield of a reaction producing 10.0 g of ethene gas from the sulfuric acid-catalysed dehydration of 25.0 g of ethanol?

A. 22 %

B. 33 %

C. 40 %

D. 66 %

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Student number

2025 **Higher School Certificate Trial Examination**

Multiple Choice Answer Sheet

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

2025 **Higher School Certificate Trial Examination**

Chemistry

Student number

Section II Answer Booklet

80 marks
Attempt Questions 21 - 37
Allow about 2 hours and 25 minutes for this section

Instructions

- Write your student number at the top of this page.
- 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.

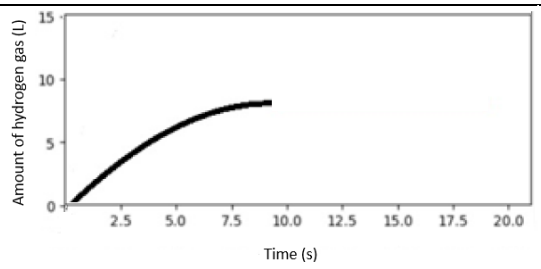
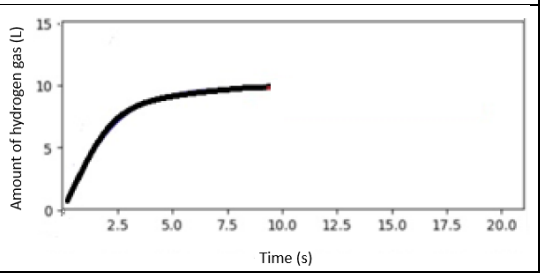
Please turn over

Question 21 (2 marks)

The graphs below show changing the amount of hydrogen gas in different systems after t = 0 s, when reactants were added.

For each system, a different reactant was added to each reaction vessel at t = 10 s:

- System I - additional HCl (aq) was added.
- System II – additional I_2 (g) was added.

System I	System II
$Zn(s) + HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)$	$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$
	

Complete the graphs to show the amount of hydrogen gas in each system up to 20 s. **2**

Question 22 (3 marks)

When concentrated ammonia is added to a solution of copper(II) sulfate, the solution gradually changes from pale blue to dark blue as the $[Cu(NH_3)_4]^{2+}$ ion forms:

$$Cu^{2+}(aq) + 4NH_3\ (aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}\ (aq)$$

pale blue dark blue

1.00 mL of 0.40 mol L^{-1} $CuSO_4$ solution was mixed with 5.00 mL of 0.30 mol L^{-1} NH_3 solution. After equilibrium was established, colorimetric analysis of the mixture showed that 1.8×10^{-4} mol of the $[Cu(NH_3)_4]^{2+}$ ion had formed.

What is the value of the equilibrium constant? Show all working. **3**

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Question 23 (5 marks)

A student investigated the heat released during the neutralisation of sulfuric acid with sodium hydroxide in the following experiment.

25.0 mL of 0.50 mol L^{-1} NaOH was mixed with 15.0 mL of 0.50 mol L^{-1} H_2SO_4 in an insulated container.

Both solutions were initially at 21.0 °C, and the final temperature of the mixture was 24.5 °C.

The solutions are assumed to have a density of 1.00 g mL^{-1}, and a specific heat capacity of 4.18×10^3 J kg^{-1} K.

(a) Calculate the experimental molar heat of neutralisation. **3**

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(b) The accepted molar heat of neutralisation is –57.3 kJ mol^{-1}.

Compare the difference between the experimental and accepted values and provide a reason for the difference between these two values. **2**

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Question 24 (3 marks)

A student is investigating the buffering capacity of blood. Blood acts as a buffer solution, primarily through the presence of carbonic acid and hydrogen carbonate.

A sample of blood is placed in a beaker and connected to a pH meter. Small amounts of 0.1 mol L^{-1} HCl(aq) and 0.1 mol L^{-1} NaOH(aq) are added separately.

The student observes that the pH changes very little in each case.

Using at least one equation to support your answer, explain the lack of change in pH. **3**

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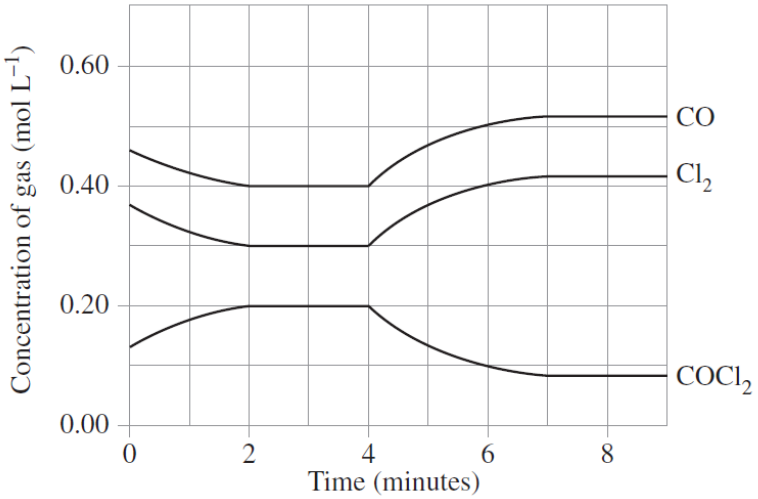
Question 25 (6 marks)

A mixture of carbon monoxide, chlorine and carbonyl dichloride ($COCl_2$) gases was placed in a closed container. The concentrations of the gases were monitored over time as shown in the diagram below.



(a) Write the chemical equation for this equilibrium. **1**

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(b) At what time does the system first reach equilibrium? Justify your answer. **2**

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(c) A change was introduced at four minutes. Explain how the change could impact the equilibrium constant for this reaction. **3**

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Question 26 (6 marks)

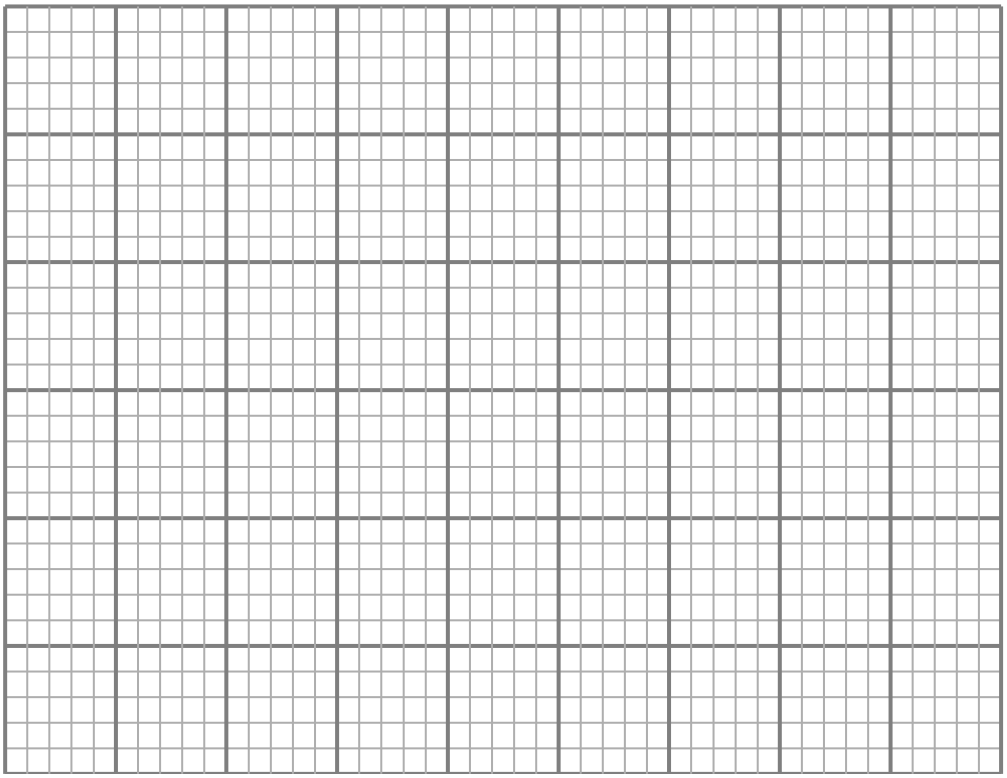
Atomic Absorption Spectroscopy (AAS) was used to determine the concentration of lead in groundwater soil samples.

The absorbances of lead samples of known concentration were also measured:

Concentration Pb^{2+} (ppm)	1.00	2.00	3.00	4.00	5.00	6.00
Absorbance	0.084	0.178	0.247	0.321	0.424	0.498

The absorbance of the analysed groundwater water was measured as 0.35. The safe concentration of lead in water is less than 0.0038 g/L.

Use the space below to graph the calibration curve and determine if the lead levels in the groundwater are safe. **6**



Concentration Pb^{2+} (ppm)

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Question 27 (3 marks)

The following table shows the pKa of three unknown acids.

Acid	A	B	C
pKa	4.76	3.8	2.6

Show how pKa relates to acid strength and identify which acid is the strongest. **3**

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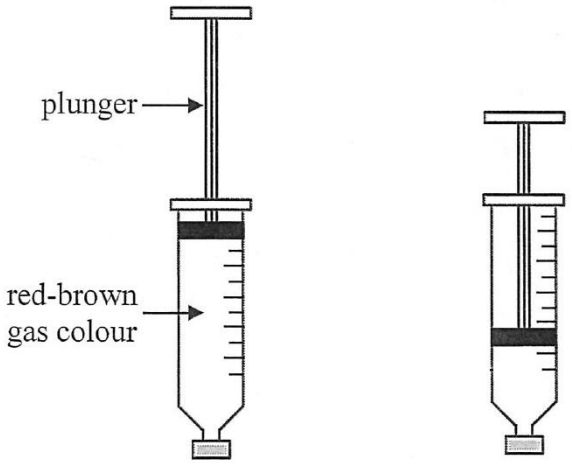
Question 28 (4 marks)

A student investigated the equilibrium between nitrogen dioxide which has a red-brown colour and dinitrogen tetroxide which is colourless.

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

They filled a syringe with nitrogen dioxide (Stage 1). Then they pushed the plunger down (Stage 2). They made one observation immediately after the plunger was pushed down and another observation a few minutes later.



Stage 1 Stage 2

Describe the observations the student made and explain the outcome with reference to collision theory. **4**

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Question 29 (4 marks)

X decomposes in the following equilibrium:

$$3X(g) \rightleftharpoons Y(g) + Z(g) \qquad K_{eq} = 0.64 \text{ at } 560 \text{ K}$$

A 2.00 L sealed vessel at a temperature of 560 K contains 4.0×10^{-3} moles of X, 3.7×10^{-6} moles of Y and 3.7×10^{-6} moles of Z.

The system is kept at constant volume and temperature. Determine, with the support of calculations, if the system will increase or decrease in pressure. **4**

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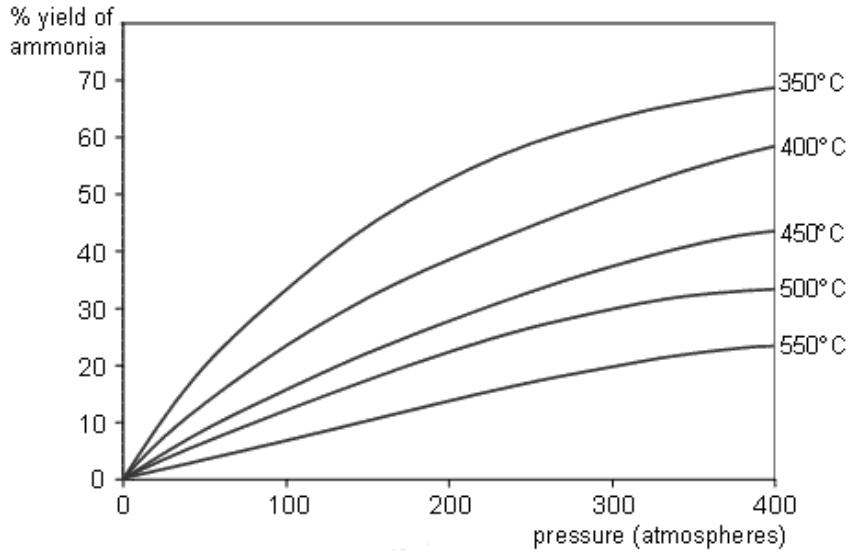
Question 30 (4 marks)

The Haber process is used to synthesise ammonia from the following reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

The graph below shows the percentage yield of ammonia for a variety of temperatures.



(a) In industrial settings the temperature is typically kept at around 450ºC. Discuss why this temperature is chosen, considering both reaction rate and equilibrium position. **2**

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(b) Justify another important condition that must be considered for this reaction. **2**

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Question 31 (7 marks)

A student spilled 2 mol L^{-1} sulfuric acid on the school laboratory floor. It was neutralised by adding solid sodium acetate (CH_3COONa) in excess.

(a) Sulfuric acid is a strong acid and sodium acetate is weakly basic. Write a balanced chemical equation for this reaction and draw a model of the species in the solution at each stage of the neutralisation. **4**

Balanced Chemical Equation	……..……

Before CH_3COONa *is added*	*Immediately after some* CH_3COONa *is added*	CH_3COONa *is added in excess*

(b) Weak bases are typically used to safely neutralise spills because they can be used in excess. **3**

The Keq values for CH_3COO^- are displayed below.

Ksp	*Kb*
210	5.6×10^{-10}

Assuming the products of neutralisation have a negligible impact on the system, determine the pH of the solution once sodium acetate no longer dissolves.

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Question 32 (3 marks)

A student tested the properties of potassium dihydrogen phosphate. She wrote the following observations as part of her testing. **3**

> *Solid potassium dihydrogen phosphate was added to a solution of HCl. An increase in pH was observed.*
>
> *Solid potassium dihydrogen phosphate was added to a solution of NaOH. A decrease in pH was observed.*

Explain the student's observations.

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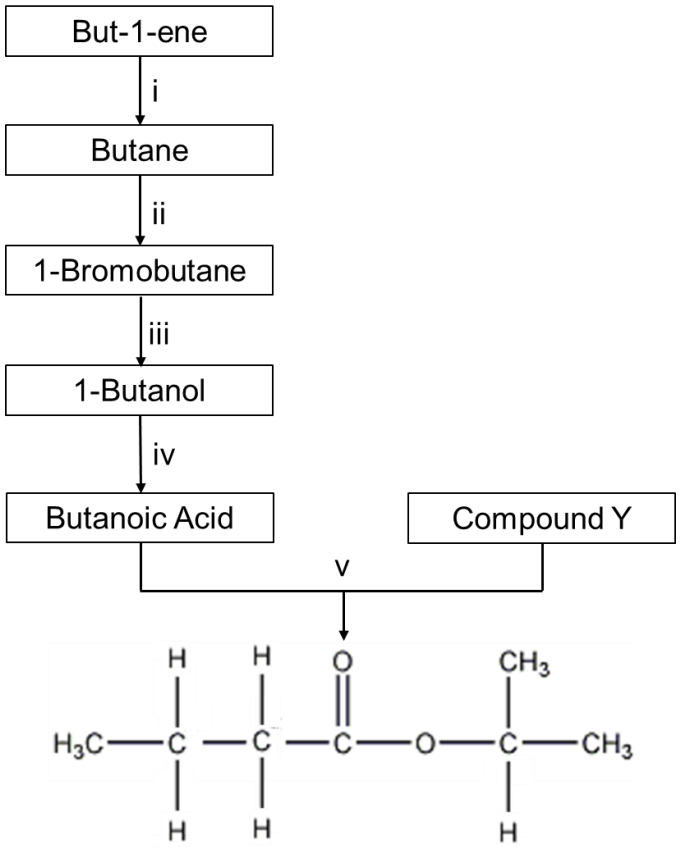
Question 33 (9 marks)

A student proposed a five-step synthesis pathway to convert but-1-ene into a product, as outlined in the flowchart below.



(a) Identify the reactants and conditions for reaction *i*. **1**

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(b) Identify the type of reaction for reaction *iv*. **1**

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(c) Provide the IUPAC name and draw the structure for Compound *Y*. **2**

Name	
Full structural formula	

Question 33 continues on the next page

(d) Assuming but-1-ene remains the starting reagent, explain one limitation of this reaction pathway and propose a modification to address it. Support your answer with a balanced chemical equation. **3**

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(e) Chemists often test starting reagents to ensure they have been supplied with the correct substance. **2**

Propose a chemical test and the expected results to determine that the starting reagent is but-1-ene, rather than butane.

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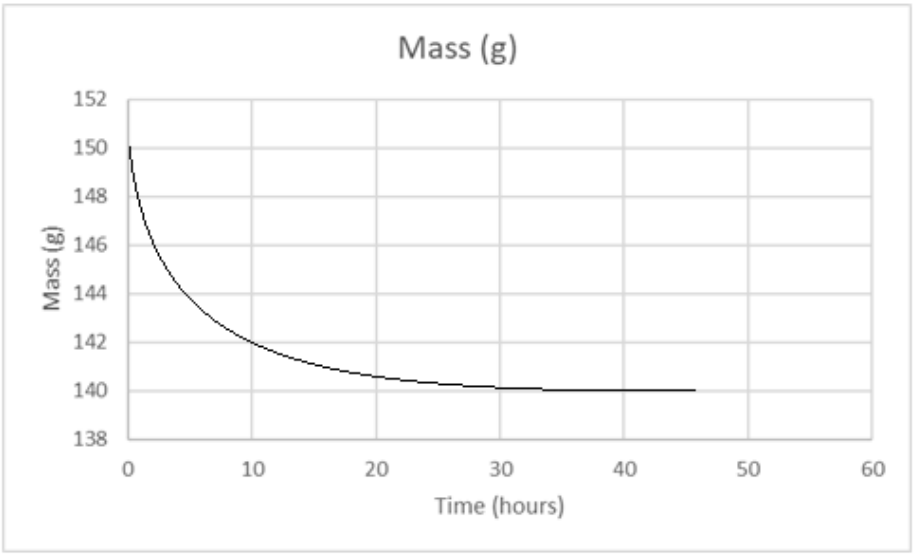
Question 34 (4 marks)

As part of a first-hand investigation relating to the fermentation of glucose ($C_6H_{12}O_6$), students added yeast to a solution of glucose, then plugged the top with cotton wool.

The apparatus was left at 30°C for 45 hours.

The graph below shows the change in mass of the flask over the 45-hour period.



Analysis of the reaction mixture after the 45 hours indicated the presence of unreacted glucose.

With the support of a balanced chemical equation, explain the shape of the graph. **4**

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Question 35 (5 marks)

Vitamin C, also known as ascorbic acid ($C_6H_8O_6$), is one of the most common supplements in the world.

It is titrated using an iodine (I_2) standard solution to a blue-black starch iodine endpoint.

$$C_6H_8O_6\,(aq) + I_2\,(aq) \rightarrow 2I^-\,(aq) + C_6H_6O_6\,(aq) + 2H^+(aq)$$

An analytical chemist determined the vitamin C composition in a tablet using the following method:

1. A 1.500 g tablet was crushed in a mortar and pestle and dissolved in 200.0 mL of distilled water.
2. 20.00 mL of the solution was pipetted into a 250 mL conical flask with a few drops of starch indicator.
3. It was titrated using 0.005000 $molL^{-1}$ iodine solution until 3 concordant results were achieved.

The average titre was recorded as 23.35 mL.

Determine the percentage (w/w) of vitamin C in the tablet. **5**

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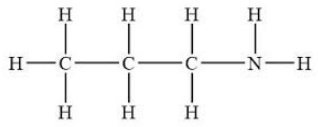
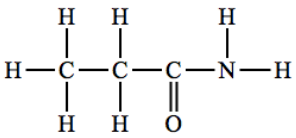
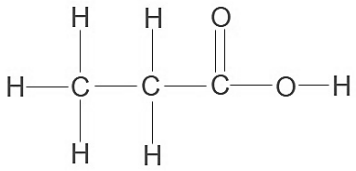
Question 36 (8 marks)

The table below contains the formula for propanamine, propanamide, and propanoic acid.

Propanamine	*Propanamide*	*Propanoic Acid*
		

(a) The properties of the three substances are displayed below.

Substance	A	B	C
pH	8	3	11
Boiling point (°C)	213	141	51

Determine the identity of each substance and analyse the differences in pH and boiling point. **5**

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Question 36 continues on the next page

(b) Identify relevant features of the infrared spectra that could be used to distinguish between the molecules. **3**

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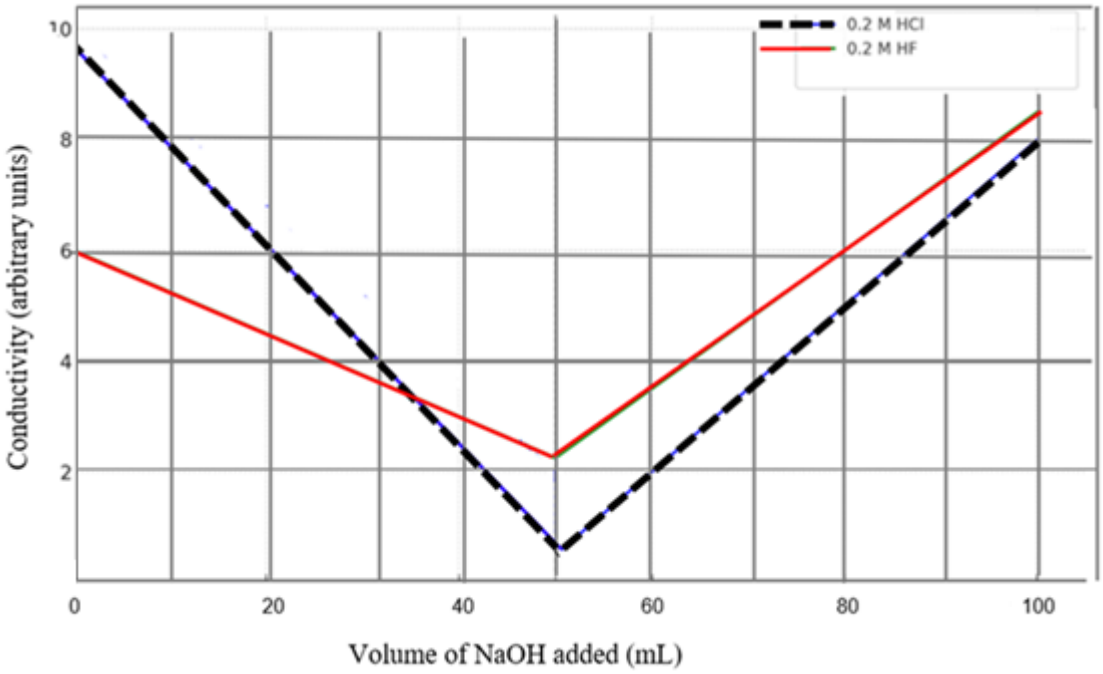
Question 37 (4 marks)

Two separate conductivity titrations were performed by gradually adding 0.1 mol L^{-1} NaOH to 25.0 mL separate samples of 0.2 mol L^{-1} hydrochloric acid (HCl) and hydrofluoric acid (HF).

The volume of NaOH added was recorded against the conductivity of the solution, producing two conductivity curves. Both graphs are shown below.



Explain the similarities and differences in the conductivity curves for the two acids. Include relevant equations to support your answer. **4**

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End of paper

Section II extra writing space

If you use this space, clearly indicate which question you are answering

Section II extra writing space

If you use this space, clearly indicate which question you are answering

Killara High School

2025 **Higher School Certificate Trial Examination**

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks (pages 2 - 11)

- Attempt Questions 1 - 20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 15 - 34)

- Attempt Questions 21 - 37
- Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Question 1-20
Allow 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1-20.

---

1 Consider the reaction:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$$

If the total pressure is doubled at constant temperature, the position of equilibrium will

A. shift right then left.

B. shift right, favouring SO_3.

C. shift left, favouring SO_2 and O_2.

D. remain unchanged because the forward and reverse reaction rates increase equally.

2 Which of the following best describes the common ion effect?

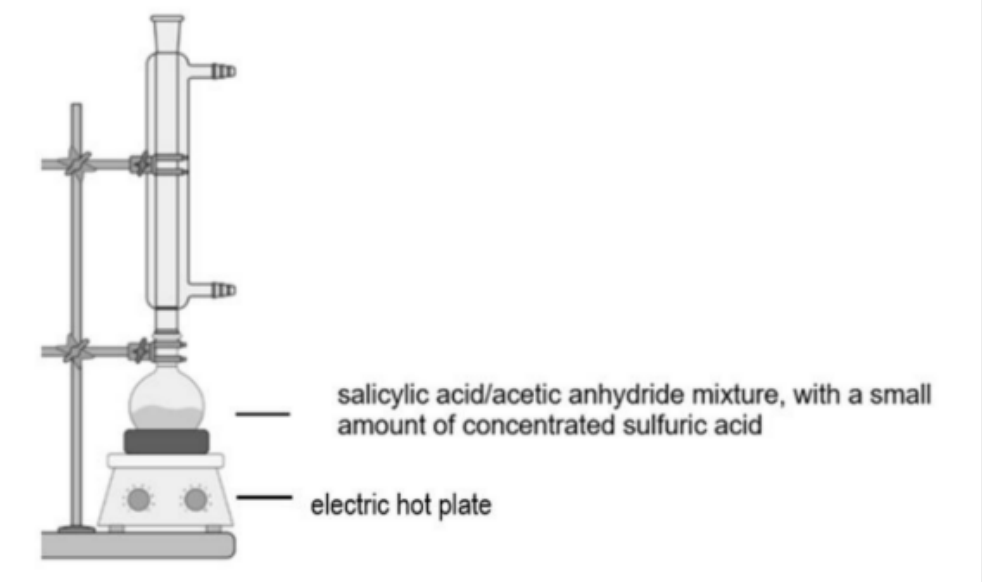
A. The change in colour of a solution when a common ion is added.

B. The complete dissociation of a salt in water regardless of other ions present.

C. The decrease in solubility of a salt when a solution already contains one of its ions.

D. The increase in solubility of a salt when a solution already contains one of its ions.

3 The synthesis of aspirin from a mixture of salicylic acid and acetic anhydride can be carried out in a typical school laboratory. A main step in the synthesis requires use of the following apparatus.



Why is the flask being heated in the manner shown in the diagram?

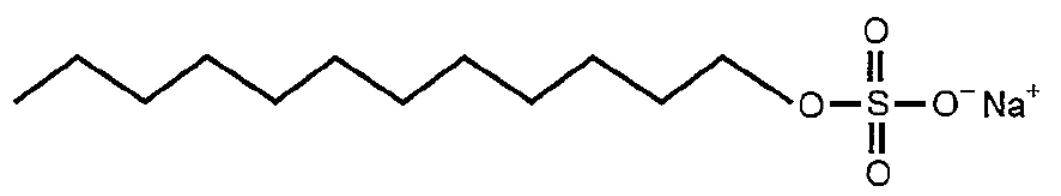
A. The hot plate reduces the time it takes for the mixture to come to a boil.

B. It is a safer way to heat the mixture and prevents loss of reactant and product.

C. It heats the solution to a higher temperature than a Bunsen burner allows.

D. All of the above.

4 The structure of a surfactant is shown.



Which term best describes this type of surfactant?

A. Anionic

B. Cationic

C. Amphoteric

D. Non-ionic

5 What are the products of the reaction between lithium metal and sulfuric acid?

A. Li_2SO_3 and H_2O

B. Li_2SO_4 and H_2

C. Li_2SO_3 and H_2

D. Li_2SO_4 and H_2O

6 Which is the correct definition of a chemical system that reaches equilibrium?

A. It is an open system where macroscopic properties remain constant.

B. It is a closed system where macroscopic properties constantly change.

C. It is an open system where concentrations of reactants and products are different.

D. It is a closed system where the concentrations of reactants and products remain constant.

7 Which is the expression for the solubility product constant, K_{sp}, for calcium phosphate $Ca_3(PO_4)_2$?

A. $[Ca^{2+}][PO_4^{3-}]$

B. $[Ca^{2+}]^3[PO_4^{3-}]^2$

C. $[Ca^{2+}]^2[PO_4^{3-}]^3$

D. $3[Ca^{2+}]2[PO_4^{3-}]$

8 Methanol can be produced by the following reaction:

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

At 450 K, the equilibrium mixture had the following concentrations:

[CO] (mol L^{-1})	*[H_2] (mol L^{-1})*	*[CH_3OH] (mol L^{-1})*
3.81×10^{-3} mol L^{-1}	4.27×10^{-3} mol L^{-1}	4.15×10^{-8} mol L^{-1}

The equilibrium constant for this reaction is

A. $K_{eq} = 8.12 \times 10^{-4}$

B. $K_{eq} = 2.55 \times 10^{-3}$

C. $K_{eq} = 1.67 \times 10^{-2}$

D. $K_{eq} = 5.97 \times 10^{-1}$

9 The properties below relate to the first 5 members of a homologous series.

All molecules:

- have boiling points below 50°C.
- react with bromine water in the presence of UV light.
- are unreactive with acidified $KMNO_4$.
- are unreactive with HCl

A. Alkanes

B. Alkenes

C. Alkynes

D. Primary Alcohols

10 The reaction of HNO_2 with HCO_3^- is shown below:

$$HCO_3^- + HNO_2 \rightleftharpoons H_2CO_3 + NO_2^-$$

Which of the following is the correctly identifies the acid/base conjugate pairs?

	Acid	Base	Conjugate Base	Conjugate Acid
A.	HCO_3^-	HNO_2	H_2CO_3	NO_2^-
B.	HNO_2	HCO_3^-	H_2CO_3	NO_2^-
C.	HNO_2	HCO_3^-	NO_2^-	H_2CO_3
D.	HCO_3^-	HNO_2	NO_2^-	H_2CO_3

11 A 0.020 mol L^{-1} solution of hydrochloric acid (HCl) is prepared. Assuming complete dissociation, what is the pOH of the solution?

A. 0.020

B. 1.70

C. 12.30

D. 13.00

12 In a titration, 25.0 mL of a 0.100 M solution of acetic acid (CH_3COOH) is required to neutralize 50.0 mL of an unknown sodium hydroxide (NaOH) solution.

What is the concentration of the sodium hydroxide solution?

A. 0.050 M

B. 0.100 M

C. 0.200 M

D. 0.2500 M

13 Markovnikov's rule states:

> *The halide component of HX bonds preferentially at the more highly substituted carbon of an alkene, forming the major product.*

Propene reacts with hydrogen bromide to form a mixture of organic products.

Which of the following identifies the 'major' product formed and number of signals on the proton NMR spectrum?

	Name	*Number of H-NMR Signals*
A.	1-bromopropane	1
B.	1-bromopropane	3
C.	2-bromopropane	2
D.	2-bromopropane	3

14 Gas X reacts with Gas Y to produce Gas Z. The value of the equilibrium constant is 3.4 at this temperature and pressure.

In a particular reaction, some Gas X and Gas Y are placed into a 2 L vessel where they begin to react.

When equilibrium is reached, the vessel is found to contain 4.0 moles of Gas X, 1.0 mole of Gas Y and 3.0 moles of Gas Z.

Which equation is consistent with the information provided above?

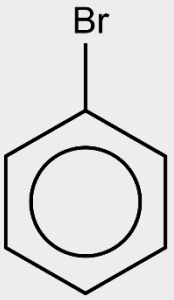
A. $X(g) + Y(g) \rightleftharpoons Z(g)$

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

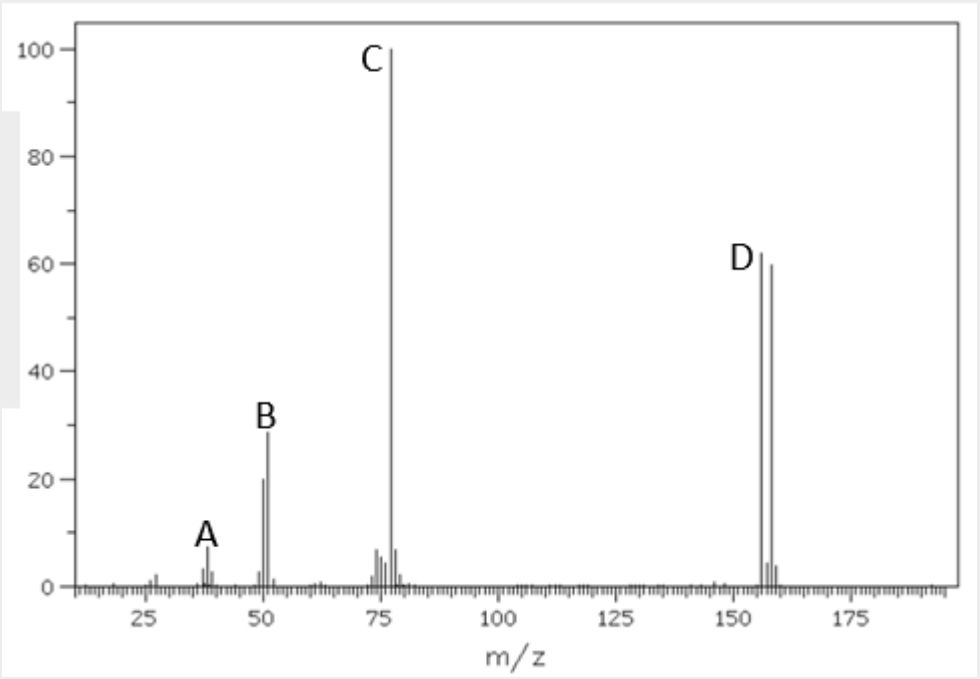
C. $X(g) + Y(g) \rightleftharpoons 3Z(g)$

D. $4X(g) + Y(g) \rightleftharpoons 3Z(g)$

15 Bromobenzene consists of a benzene ring substituted with a bromine atom.



The mass spectrum of bromobenzene is shown below.



Which fragment contains a bromine atom?

A. A

B. B

C. C

D. D

16 A 25.00 mL aliquot of 0.1050 mol L^{-1} sodium carbonate (Na_2CO_3) solution was titrated with hydrochloric acid (HCl) using methyl orange as the indicator.

Which of the following best explains why methyl orange is an appropriate choice for this titration?

A. Methyl orange changes colour at the equivalence point of a strong base–strong acid titration, which is typically around pH 7.

B. Methyl orange has a pH transition range that matches the second equivalence point in a diprotic titration of a weak base with a strong acid.

C. Methyl orange changes colour at a high pH, suitable for detecting the endpoint of weak base–weak acid reactions.

D. Methyl orange is suitable because it has a colour change range around pH 4.0, which corresponds to the acidic equivalence point of a weak base–strong acid titration.

17 Which is the correct K_b expression for the cyanide (CN^-) ion?

A. $\frac{[OH^-][HCN]}{[CN^-]}$

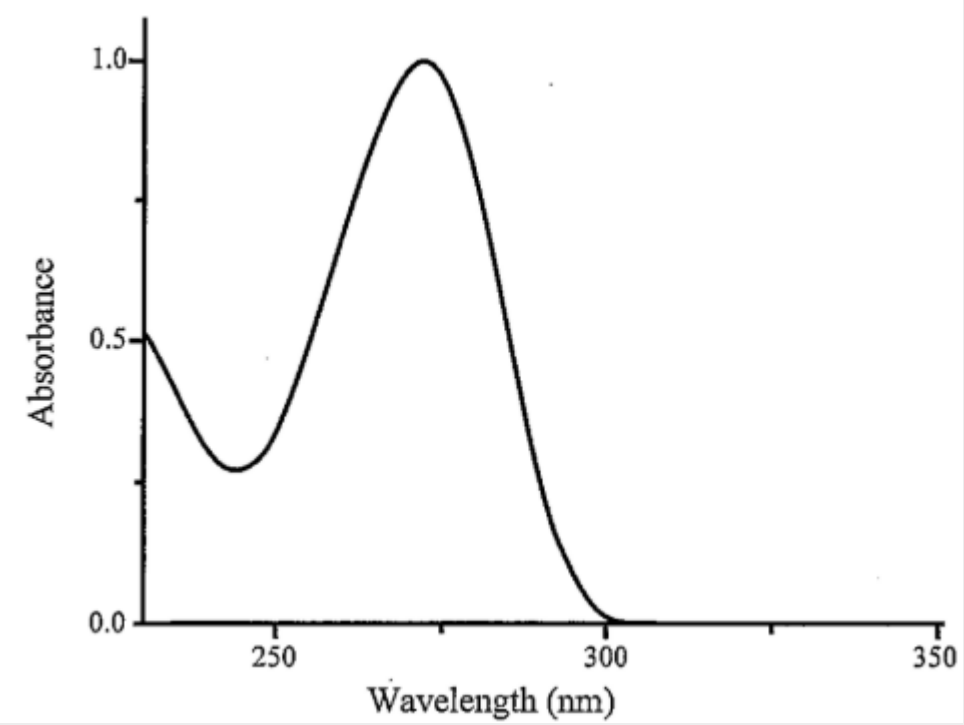
B. $\frac{[CN^-]}{[OH^-][HCN]}$

C. $[OH^-][HCN]$

D. $\frac{[C^{4-}][N^{3+}]}{[CN^-]}$

18 A scientist is tasked with determining the concentration of caffeine in a cup of coffee.

The UV-Vis spectrum of caffeine is shown below.



Consider the following statements about this compound and its UV-Vis spectrum.

I. The concentration of a solution of this compound can only be determined by UV-visible spectroscopy at approximately 220 nm.

II. The amount of light absorbed by a solution of this compound depends on its concentration.

III. This compound is coloured due to the absorbance at 275 nm.

IV. The wavelength selected for analysis is dependent on the absorbance of other species in the mixture.

Which statements are true?

A. II only

B. I and III

C. II and IV

D. I, II and IV

19 Consider the following compounds.

I - propanal
II - propanone
III - propanoic acid
IV - methyl ethanoate

Which pair/s of compounds are structural isomers?

A. I and II only

B. III and IV only

C. I and III - as well as - II and IV

D. I and II - as well as - III and IV

20 What is the percentage yield of a reaction producing 10.0 g of ethene gas from the sulfuric acid-catalysed dehydration of 25.0 g of ethanol?

A. 22 %

B. 33 %

C. 40 %

D. 66 %

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Student number

2025 **Higher School Certificate Trial Examination**

Multiple Choice Answer Sheet

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

2025 **Higher School Certificate Trial Examination**

Student number

Chemistry
Section II Answer Booklet

80 marks
Attempt Questions 21 - 37
Allow about 2 hours and 25 minutes for this section

Instructions

- Write your student number at the top of this page.
- 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.

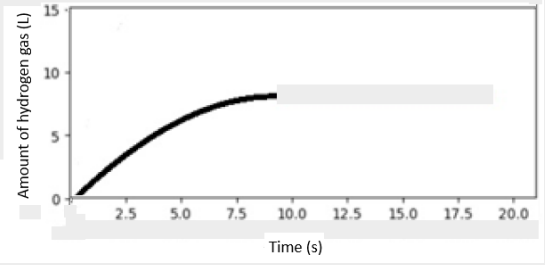
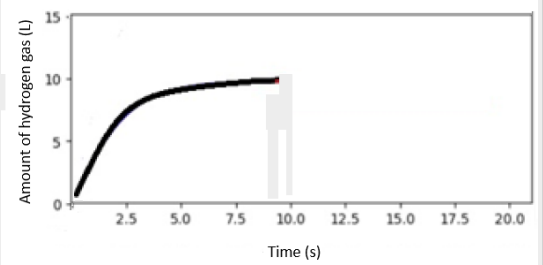
Please turn over

Question 21 (2 marks)

The graphs below show changing the amount of hydrogen gas in different systems after t = 0 s, when reactants were added.

For each system, a different reactant was added to each reaction vessel at t = 10 s:

- System I - additional HCl (aq) was added.
- System II – additional I_2 (g) was added.

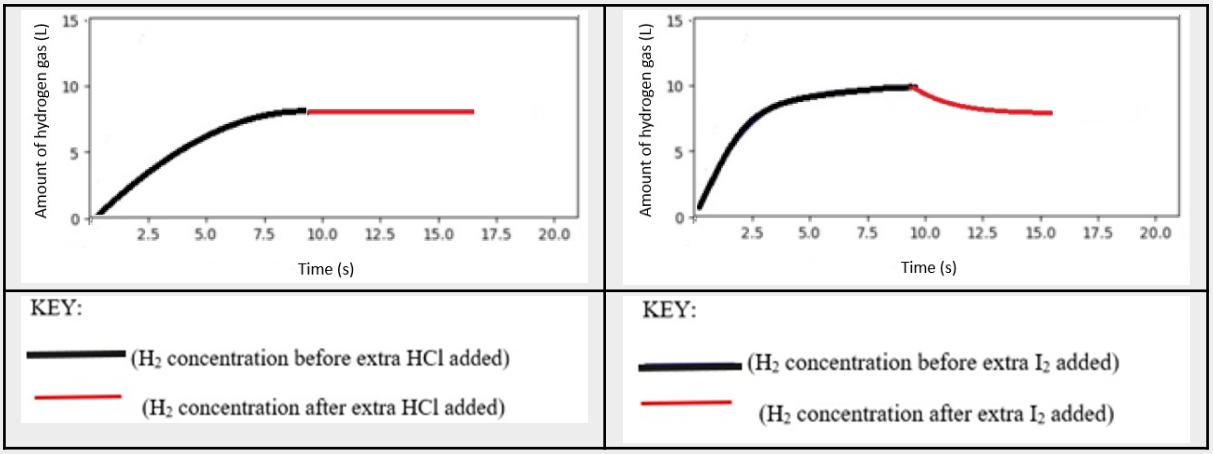
System I	System II
$Zn(s) + HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)$	$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$
	

Complete the graphs to show the amount of hydrogen gas in each system up to 20 s. **2**

Criteria	Marks
• Correctly draw the two curves after t=10 s	2
• Provides some relevant information	1

Sample answer

System I	System II
$Zn(s) + HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)$	$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$



Markers note: Many students got the first graph wrong as they did not recognise it is a non equilibrium system and one of the reactants was in excess resulting in no change to the system. Some students chose to redraw the graphs which is ill-advised for the future but were not penalised this time if they got it correct. The curvature (general shape) of the graph needed to be correct to get the mark. If the shape was off then students did not get the mark, i.e. a vertical shift.

Question 22 (3 marks)

When concentrated ammonia is added to a solution of copper(II) sulfate, the solution gradually changes from pale blue to dark blue as the $[Cu(NH_3)_4]^{2+}$ ion forms:

$$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq)$$

pale blue dark blue

1.00 mL of 0.40 mol L^{-1} $CuSO_4$ solution was mixed with 5.00 mL of 0.30 mol L^{-1} NH_3 solution. After equilibrium was established, colorimetric analysis of the mixture showed that 1.8×10^{-4} mol of the $[Cu(NH_3)_4]^{2+}$ ion had formed.

What is the value of the equilibrium constant? Show all working. **3**

Marking Criteria	**Marks**
• Calculates the value of Keq, showing all working.	**3**
• Completes most steps in the calculation, with one major error or omission OR two smaller errors.	**2**
• Completes any step in the calculation.	**1**

Sample answer:

Initial V of Cu^{2+}: 1.0 mL
Initial c of Cu^{2+} = 0.4M
n(Cu^{2+})= cV = 0.4 x 0.001= 0.0004 mol
Initial V of NH_3 = 5.0 mL
Initial c of NH_3 = 0.3 M
n(NH_3)= cV = 0.3 x05= 0.0015mol
n_{eq} ($[Cu(NH_3)_4]^{2+}$) = 0.00018

$$K = \frac{[Cu(NH_3)4R]^{2+}}{[Cu^{2+}] \times [NH_3]^4}$$

	Cu^{2+}	NH_3	$[Cu(NH_3)_4]^{2+}$
I	0.0004	0.0015	0
C	-0.00018	-0.00072	0.00018
E	0.004-0.0018	0.01-(4x0.0018) 0.00078	0.00018
$[\ ]_{eq}$ = n/V	0.00022/0.006 =0.03666	0.00078/0.006= 0.13	0.00018/0.006 =0.03

$$K = \frac{0.03}{[0.03666] \times [0.13]^4} = 2.86 \times 10^3$$

Markers note: The most efficient way to get to the answer is to create a RICE or ICE table (in moles) and then calculate the concentration at equilibrium to determine Keq. Common errors included: transcription errors from an earlier calculation, not realising the total volume of the solution is 6 mL and taking this into account for calculations, not converting all the units in the RICE table into either moles or mol/L, getting the stoichiometric ratios of the reactants and products wrong. Note that students did not need a RICE table to get full marks but it is generally easier to show working thai way.

Keq calculations HAVE TO use mol/L unit

Question 23 (5 marks)

A student investigated the heat released during the neutralisation of sulfuric acid with sodium hydroxide in the following experiment.

25.0 mL of 0.50 mol L^{-1} NaOH was mixed with 15.0 mL of 0.50 mol L^{-1} H_2SO_4 in an insulated container.

Both solutions were initially at 21.0 °C, and the final temperature of the mixture was 24.5 °C.

The solutions are assumed to have a density of 1.00 g mL^{-1}, and a specific heat capacity of $4.18\times10^{3}\ J\ kg^{-1}\ K$.

(a) Calculate the experimental molar heat of neutralisation. **3**

Marking Criteria	Marks
· Calculates the molar heat of neutralisation. (significant figures not marked) (positive and negative answers marked correct)	**3**
· Completes most steps in the calculation, with one major error or omission. error was carried for the final calculation of enthalpy change so long as sound logic was displayed in the calculation of the incorrect value (e.g. calculating and using moles of sulfuric acid instead of water)	**2**
· Correct step towards answer: e.g.	**1**

- q - n - states that NaOH is limiting - balanced chemical reaction	

Sample answer:

Note:

- enthalpy of neutralisation is based on moles of water formed

Limiting Reagent

n(NaOH)= cV = 0.5x0.025 = 0.0125 mol

$n(H_2SO_4)$ = cV = 0.5 x 0.015 = 0.0075 mol

By the equation for neutralisation: $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4\ (aq) + 2H_2O\ (l)$

Therefore, NaOH limits the reaction.

calculations

$q = mc\Delta T$

m(total solution) = 25 + 15 = 40 mL (Since d=1 g mL^{-1}, m= 40 g)

= 40 x 4.18 x (24.5-21) = 585.2J

Therefore, the experimental heat of neutralisation
= - q/n
= 0.5852/0.0125
= -46.8 $kJmol^{-1}$

(b) The accepted molar heat of neutralisation is –57.3 kJ mol^{-1}.

Compare the difference between the experimental and accepted values and provide a reason for the difference between these two values. **2**

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Marking Criteria	Marks
• notes either direction of difference, percentage difference or qualitative size of difference with logical reason	2
• provides relevant information e.g. - notes difference - provides sound logic	1

Sample Answer

experimental is lower due to heat loss to environment

OR

experimental is higher due to faulty temperature probe/inaccurate measurements of concentration/different specific heat capacities based on dissolved ions.

Question 24 (3 marks)

A student is investigating the buffering capacity of blood. Blood acts as a buffer solution, primarily through the presence of carbonic acid and hydrogen carbonate.

A sample of blood is placed in a beaker and connected to a pH meter. Small amounts of 0.1 mol L^{-1} HCl(aq) and 0.1 mol L^{-1} NaOH(aq) are added separately.

The student observes that the pH changes very little in each case.

Using at least one equation to support your answer, explain the lack of change in pH. **3**

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Criteria	Mark
• suitable equation • demonstrates thorough understanding of buffers Thorough Understanding: - states the effect for adding both acid and base - reference to equilibrium shift for at least one	3
• suitable equation • partial explanation • OR • complete explanation	2
• relevant information provided e.g. - weak acid/weak base - equilibrium - OH- reacts with… - H+ reacts with …	1
- 'buffer' (this is provided in the question) - neutralisation of HCl with NaOH - buffers resist changes in pH (this was provided in the question)	0

Marker's Note - Do not appeal without reading

- Many students improperly referred to a shift. Taking the reaction below as an example: adding OH- does NOT shift the equilibrium left. It is the disruption that increases pH, the equilibrium actually responds by shifting RIGHT - regenerating the [H+]
  - There are few ways to explain buffers based on the equilibrium equation used to describe this system. It is generally better to use 2 equations, but as the question only required 1 equation, slightly weaker explanations were still accepted. See the sample answer. The OH- addition is explained well, but the H+ addition is explained more poorly. So long as one related to equilibrium, I was willing to infer the other.
- Getting ion charges wrong excluded a mark of 3. So long as ONE buffer equation had the correct charges, incorrect charges were not marked down in another equation (provided it was not contradictory)

Sample Answer (weakest answer worth 3/3)

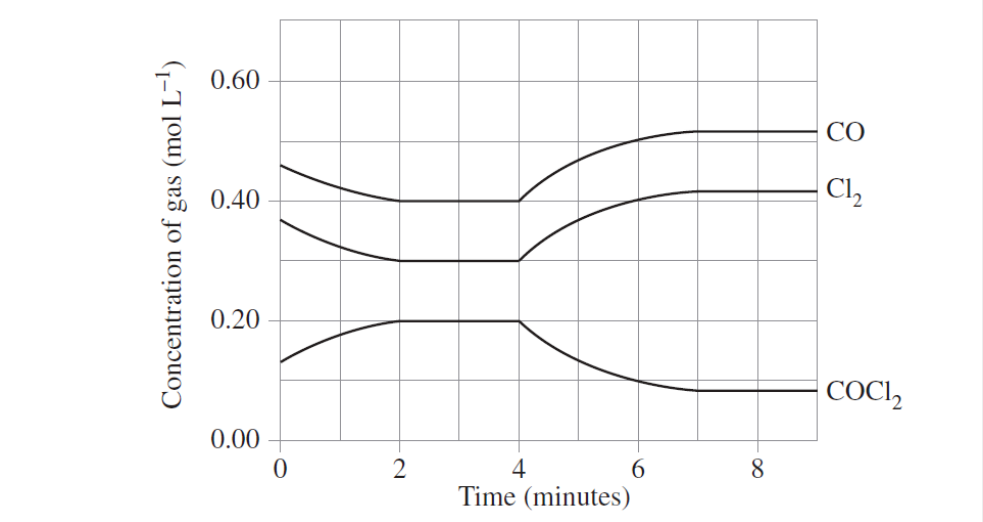
$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$

When NaOH is added, it consumes H+. The equilibrium shifts to the right to generate additional H+.

When H+ is added, it reacts with the HCO3-, and is consumed.

Question 25 (6 marks)

A mixture of carbon monoxide, chlorine and carbonyl dichloride ($COCl_2$) gases was placed in a closed container. The concentrations of the gases were monitored over time as shown in the diagram below.



(a) Write the chemical equation for this equilibrium. **1**

(b) At what time does the system first reach equilibrium? Justify your answer. **2**

(c) A change was introduced at four minutes. Explain how the change could impact the equilibrium constant for this reaction. **3**

a)

Marking Criteria	**Mark**
• Correct chemical equation with states	1
• Correct chemical equation with states with a minor mistake (state or reverse equation)	0.5

$$Cl_2(g) + CO\ (g) \rightleftharpoons COCl_2(g)$$

b)

Marking Criteria	Mark
• Identifies correct time with appropriate justification	2
• Shows relevant information	1

Sample answer:

At two minutes because the concentrations have stopped changing.

c)

Marking Criteria	Mark
• Justifies temperature was changed at four minutes. • Indicates the change in concentrations causes a decrease in K_{eq}.	3
• Indicates temperature was changed at four minutes • Indicates the change in concentrations causes a decrease in K_{eq}.	2
• Shows relevant information	1

Sample answer:

The concentration of each species changes gradually between four and seven minutes. This indicates that temperature was changed at four minutes.

A change in temperature does cause a change in the calculated equilibrium constant.

For an endothermic reaction, decreasing the temperature will shift the equilibrium towards the reactants and decrease the equilibrium constant.

For an exothermic reaction, increasing the temperature will shift the equilibrium towards the reactants therefore decrease the equilibrium constant.

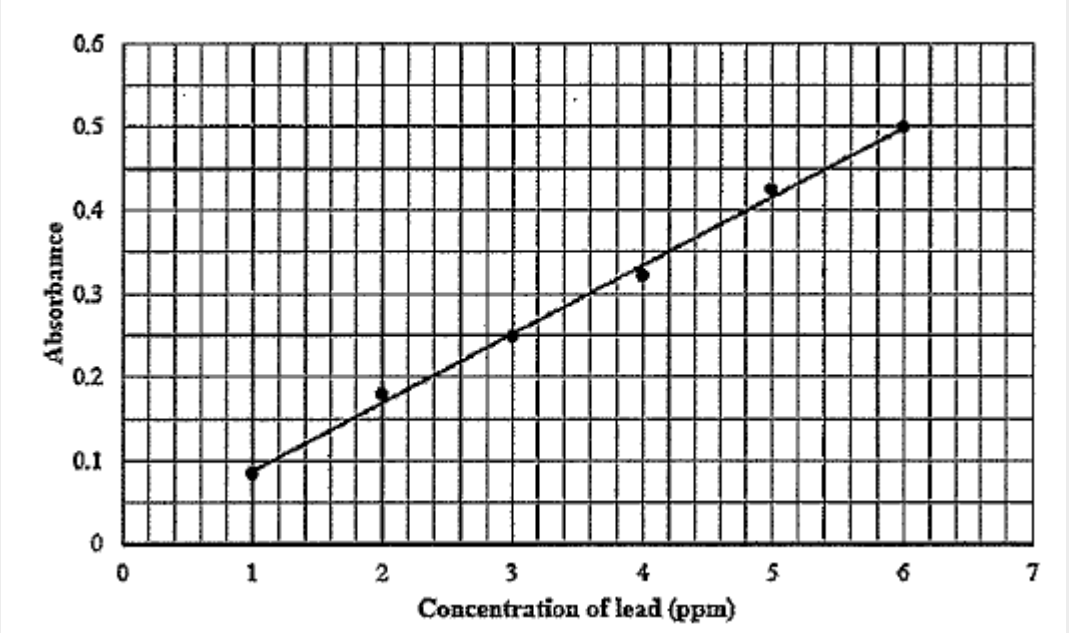
Question 26 (6 marks)

Atomic Absorption Spectroscopy (AAS) was used to determine the concentration of lead in groundwater soil samples.

The absorbances of lead samples of known concentration were also measured:

Concentration Pb^{2+} (ppm)	1.00	2.00	3.00	4.00	5.00	6.00
Absorbance	0.084	0.178	0.247	0.321	0.424	0.498

Criteria	**Mark**
• Correct y axis label • Appropriate x scale • Appropriate y scale • Data plotted correctly • Straight line of best fit	4
• 3-4 of above	3
• 2 of above	2
• Elements of a correct graph present	1



Response

Criteria	Mark
• Correct answer supported by calculation from line of best fit	2
• Conversion of ppm to g/L Or • Interpolation of ppm from graph	1

Sample Answer

$[Pb^{2+}]$ = 4.2 ppm

$[Pb^{2+}]$ = 4.2 ppm = 4.2 mg/L

$[Pb^{2+}]$ = 4.2/1000 = g/L

$[Pb^{2+}]$ = 0.0042 g/L

The groundwater is unsafe.

Markers note: Student who just wrote a judgement with no other supporting information received zero (out of a possible 2 marks) for this component of the question.

Question 27 (3 marks)

The following table shows the pKa of three unknown acids.

Acid	A	B	C
pKa	4.76	3.8	2.6

Show how pKa relates to acid strength and identify which acid is the strongest. **3**

Marking guideline

Criteria	**Marks**
Shows strong links how pKa and acid strength are related AND identifies the strongest acid in the list (Acid C).	**3**
Suggests some links to how pKa and acid strength are related AND identifies the strongest acid in the list (Acid C).	**2**
Provides any relevant information.	**1**

Sample Answer

An acid's strength refers to the amount of dissociation in water. This can be quantified using the acid dissociation constant, Ka. Where,

Ka = [A-][H3O+]/[HA], therefore a relatively small Ka results in very little dissociation. Since we end up with smaller numbers for Ka for weak acids, it is more convenient to express the relative strength of the acid using pKa. Where,

pKa = -logKa

So the smaller the pKa value the stronger the relative strength of the acid, as a small pKa corresponds to a large Ka. In this instance Acid C has a pKa value of 2.6 so it is the strongest of the three.

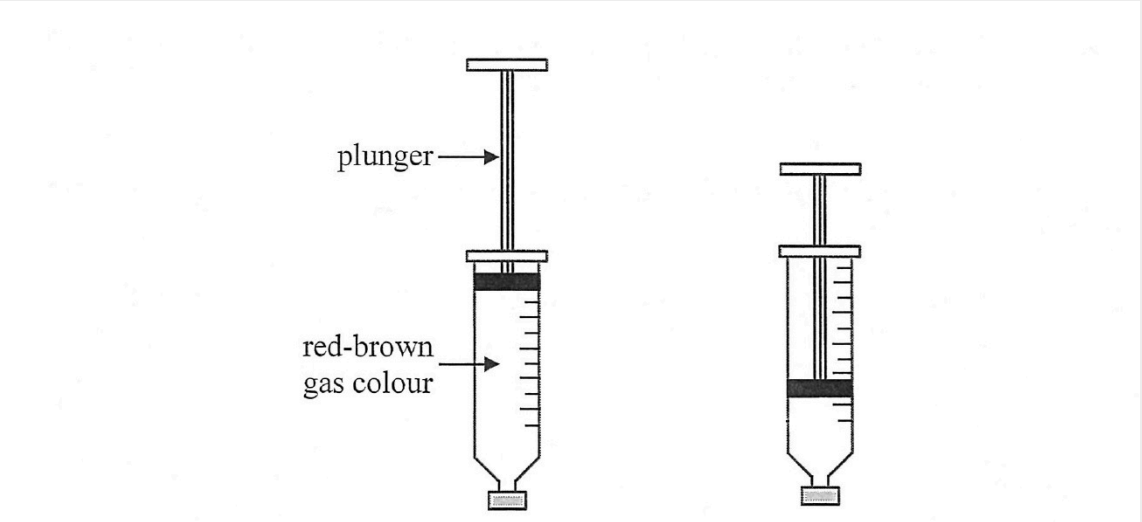
Markers note: Many students missed the first part of the questions where they had to relate pKa with acid strength. The most straightforward way to do this is pKa → Ka → degree of ionisation in water → relative strengths of acids. Whilst it is possible to get three marks without referring to the expressions of pKa or Ka it is difficult given the question. Students did not need to calculate Ka for each of the acids to get full marks either, in fact this was probably a waste of time pending how the question was answered. To access 2 or 3 marks students must identify Acid C as the strongest of the three.

Question 28 (4 marks)

A student investigated the equilibrium between nitrogen dioxide which has a red-brown colour and dinitrogen tetroxide which is colourless.

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

They filled a syringe with nitrogen dioxide (Stage 1). Then they pushed the plunger down (Stage 2). They made one observation immediately after the plunger was pushed down and another observation a few minutes later.



Stage 1 Stage 2

Describe the observations the student made and explain the outcome with reference to collision theory. **4**

Marking Criteria	**Mark**
• Identifies the different colour changes after the plunger was pushed down. • Relates the student's observations to collision theory.	4
• Identifies the different colour changes after the plunger was pushed down with minor omission. • Relates the student's observations to collision theory.	3
• Identifies a correct colour change after the plunger was pushed down. • Relates the student's observations to collision theory.	2

• Shows relevant information	1

Sample Answer

As the plunger is pushed down, the volume of the system is reduced. Initially there will be more red-brown gas molecules in a smaller volume therefore the colour of the syringe will be more intense and appear to be darker.

However, as the reaction is an equilibrium reaction, the colour will change afterwards. As the pressure of the system is increased when plunger is pushed down, there are more chances for the molecules which are at the required energy and correct orientation to collide. The equilibrium shifts to the right which has less molecules to minimise the effect of the increased pressure. The change produces more N_2O_4 molecules which are colourless. Hence the dark colour of the system would fade.

Marker note: This question was done poorly. Most students achieved around 2 marks. Students did not state the initial darker colour and then lighter when equilibrium is reached. Many misunderstood that the final colour is colourless.

Question 29 (4 marks)

X decomposes in the following equilibrium:

$$3X(g) \rightleftharpoons Y(g) + Z(g) \qquad K_{eq} = 0.64 \text{ at } 560 \text{ K}$$

A 2.00 L sealed vessel at a temperature of 560 K contains 4.0×10^{-3} moles of X, 3.7×10^{-6} moles of Y and 3.7×10^{-6} moles of Z.

The system is kept at constant volume and temperature. Determine, with the support of calculations, if the system will increase or decrease in pressure. **4**

Criteria	**Marks**
• Calculations are correct and qualifying statement made	4
• Calculations are mostly correct and qualifying statement made	3
• Calculations are attempted and qualifying statement made	2
• Provides some relevant information	1

Sample answer:

The equilibrium constant expression is:

$K_{eq} = \frac{[Y][Z]}{[X]^3}$

- $[X] = \frac{4.0 \times 10^{-3}}{2.00} = 2.00 \times 10^{-3}$ M
- $[Y] = \frac{3.7 \times 10^{-6}}{2.00} = 1.85 \times 10^{-6}$ M
- $[Z] = = \frac{3.7 \times 10^{-6}}{2.00} = 1.85 \times 10^{-6}$ M

$Q = \frac{[Y][Z]}{[X]^3} = \frac{1.85 \times 10^{-6} \times 1.85 \times 10^{-6}}{(2.00 \times 10^{-3})\text{^}3} = 4.3 \times 10^{-4}$

$Q = 4.3 \times 10^{-4}$

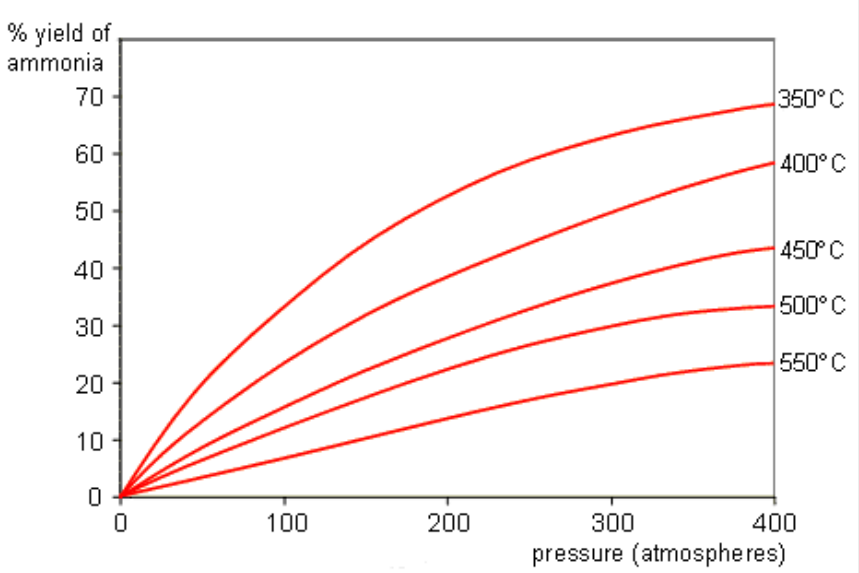
Since Q < Keq, the reaction is not at equilibrium and the equilibrium will shift to the right, decreasing pressure.

Question 30 (4 marks)

The Haber process is used to synthesise ammonia from the following reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

The graph below shows the percentage yield of ammonia for a variety of temperatures.



(a) In industrial settings the temperature is typically kept at around 450ºC. Discuss why this temperature is chosen, considering both reaction rate and equilibrium position. **2**

(b) Justify another important condition that must be considered for this reaction. **2**

(a)

Marking Criteria	**Marks**
• Explains the use of compromise temperature according to Le Chatelier's Principle	2
• Provides some relevant information	1

Sample answer:

While higher temperatures increase the reaction rate, they also shift the equilibrium towards the reactants (according to Le Chatelier's principle), so 450°C is a compromise temperature that balances an acceptable reaction rate with a reasonable yield of ammonia.

(b)

Criteria	Marks
• Identifies pressure affects the equilibrium and influences cost OR safety	2
• Provides some relevant information	1

Sample answer:

Increasing the pressure shifts the equilibrium towards the production of ammonia, as the ammonia side has fewer moles of gas. Thus, higher pressure increases the yield of ammonia.

Economically, higher pressure increases the rate of reaction, which allows for more ammonia to be produced in a shorter time, improving the efficiency of the process. However the cost of maintaining high pressure could be very high. (Strong student will also add 450-500 atm is used as a compromise between high yield and cost-effectiveness)

From a safety perspective, controlling pressure is crucial to prevent hazardous situations such as explosions. Ammonia is synthesised under high pressure, and improper control could cause equipment failure or accidents. Ensuring the pressure remains within safe limits ensures the structural integrity of reactors and avoids risks to workers and equipment.

Question 31 (7 marks)

A student spilled 2 mol L^{-1} sulfuric acid on the school laboratory floor. It was neutralised by adding solid sodium acetate (CH_3COONa) in excess.

(a) Sulfuric acid is a strong acid and sodium acetate is weakly basic. Write a balanced chemical equation for this reaction and draw a model of the species in the solution at each stage of the neutralisation. **4**

Balanced Chemical Equation	$2CH_3COONa + H_2SO_4 \rightarrow 2CH_3COOH + Na_2SO_4$

Before CH_3COONa *is added*	*Immediately after some* CH_3COONa *is added*	CH_3COONa *is added in excess*

(b) Weak bases are typically used to safely neutralise spills because they can be used in excess. **3**

The Keq values for CH_3COO^- are displayed below.

Ksp	*Kb*
210	5.6×10^{-10}

Assuming the products of neutralisation have a negligible impact on the system, determine the pH of the solution once sodium acetate no longer dissolves.

a)

$$2CH3COONa + H2SO4 \rightarrow 2CH3COOH + Na2SO4$$

Criteria	Marks
The model fairly and consistently represents the system AND correctly writes a balanced chemical equation.	4
The model fairly represents the system with limited errors or limitations AND correctly writes a balanced chemical equation.	3
Attempt made to represent the system at each stage of the process with significant limitations in the model.	2
Provides some relevant information.	1

Sample Answer

Models will vary, however the species present should be the same for each stage:

Before CH_3COONa *is added*	H^+ or H_3O^+, SO_4^{2-}
Immediately after some CH_3COONa *is added*	fewer H+, CH3COO-, CH3COOH, Na+, SO42-
CH_3COONa *is added in excess*	CH3COO- (excess), CH3COOH, Na+, SO42-

This was poorly answered. Many students did not correctly model ions in solution and recognise the solubility of the salts produced suggesting that some of the salts would crash out of solution instead of remaining in.

b) Many students struggled with this question.

Correct answer showing all working	3
Steps towards the correct answer with errors	2
Steps towards the correct answer OR relevant information	1

Ksp

CH3COONa(s) ⇌ CH3COO-(aq) + Na+(aq)

Ksp = [CH3COO-][Na+] = 210

x^2 = 210

x = sqrt(210) = 14.4913… , therefore [CH3COO-] = 14.49 mol/L

Hydrolysis of CH3Coo-

CH3COO- + H2O ⇌ CH3COOH + OH-

Kb = $\frac{[CH3COOH][OH-]}{[CH3COO-]} = 5.6\ x\ 10^{-10}$

At eq. [CH3COO-] = 14.49 mol/L , let c = [CH3COOH] = [OH-]so

Kb = $\frac{c^2}{14.49 - c} = 5.6\ x\ 10^{-10}$ and assume c<< 14.49

c^2 = 14.49 x 5.6 x 10^-10 = 8.1152 x 10^-9

c = 9.007996 x 10^-5

so pOH = -1og[OH-] = 4.0453…

pH = 9.95

Question 32 (3 marks)

A student tested the properties of potassium dihydrogen phosphate. She wrote the following observations as part of her testing. **3**

Solid potassium dihydrogen phosphate was added to a solution of HCl. An increase in pH was observed.

Solid potassium dihydrogen phosphate was added to a solution of NaOH. A decrease in pH was observed.

Explain the student's observations.

Criteria	Marks
Explains the impact of adding solid potassium dihydrogen phosphate to an acid and a base.	**3**
Partially explains the impact of adding solid potassium dihydrogen phosphate to an acid and a base.	**2**
Provides some relevant information.	**1**

Marker notes: Whilst it was possible to get full marks for this question without providing relevant chemical equations it was difficult.

Use equations where relevant in a Chemistry exam.

Sample answer

Potassium dihydrogen phosphate (KH_2PO_4) contains the dihydrogen phosphate ion ($H_2PO_4^-$), which is amphiprotic. This means it can act as both an acid (proton donor) and a base (proton acceptor) depending on its chemical environment.

When solid KH_2PO_4 was added to a solution of HCl (which is strongly acidic), the $H_2PO_4^-$ ion acted as a base. It accepted protons (H^+) from the solution:

H2PO4- + H+ → H3PO4

This reaction reduced the concentration of free H^+ ions in the solution, resulting in an increase in pH.

When KH_2PO_4 was added to a NaOH solution (which is strongly basic), the $H_2PO_4^-$ ion acted as an acid. It donated a proton to the hydroxide ions (OH^-):

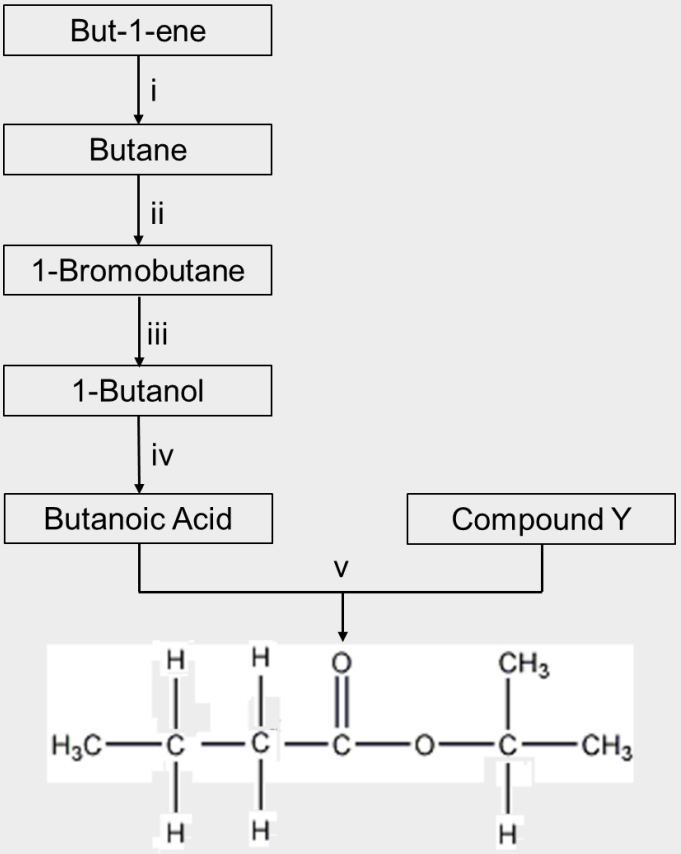
H2PO4- + OH- → HPO42- +H2O

This reaction consumed OH^- ions, decreasing the basicity of the solution and causing the pH to decrease.

Therefore, the student observed an increase in pH when KH_2PO_4 was added to an acidic solution and a decrease in pH when it was added to a basic solution because the dihydrogen phosphate ion acts as both a weak acid and a weak base, depending on the conditions.

Question 33 (9 marks)

A student proposed a five-step synthesis pathway to convert but-1-ene into a product, as outlined in the flowchart below.



(a) Identify the reactants and conditions for reaction *i*. **1**

Marking Criteria	Marks
• Correct answer	1
• provides reagent or catalyst	0.5

Sample Answer

H_2 & Pd/C

(b) Identify the type of reaction for reaction *iv*. **1**

Marking Criteria	Marks
• Correct answer	1

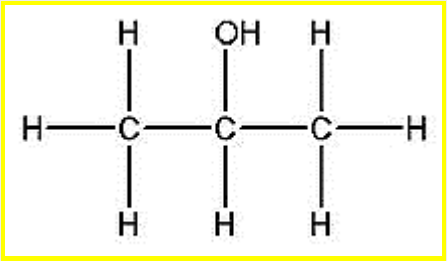
Sample Answer

Oxidation 'oxidisation' was accepted, but is a weaker response

(c) Provide the IUPAC name and draw the structure for Compound *Y*. **2**

Marking Criteria	Marks
• Correct name and structure	2
• One of the above OR • Recognition that Compound Y is an alcohol	1

Sample Answer

Name	propan-2-ol
Full Structural Formula	 Forgetting the O-H bond was accepted, but a better answer would include it.

Question 33 continues on the next page

(d) Assuming but-1-ene remains the starting reagent, explain one limitation of this reaction pathway and propose a modification to address it. Support your answer with a balanced chemical equation. **3**

Marking Criteria	Marks
• Explains a limitation and modification • Supports answer with a balanced chemical equation (may be a reaction that needs to be changed or a proposed new step)	3
• Explains a limitation and proposes a modification OR • Identifies a limitation or modification supported by a balanced chemical equation/reaction pathway	2
• Provides relevant information e.g. - states a limitation - suggests an alternate reaction - write an alternate pathway/equation - writes a pathway/equation for any of the reactions - 'too many steps'	1

- Students need to read the question carefully. 'balanced chemical equation' needs reactants on the reactant side, not on the arrow like in a reaction pathway. - 'efficient by making it shorter' was accepted - but was still weaker than the above.
- Explaining a limitation could be related to byproducts forming, yield, costs, time, etc. - 'shortening' or 'making more simple' is not sufficient for 3/3

Sample Answer

Reaction ii is a substitution reaction that is difficult to control. Several undesirable products could be formed, lowering yield. 1-bromobutane could instead be formed from but-1-ene with HBr.

$C_4H_8 + HBr \rightarrow C_4H_9Br$

(e) Chemists often test starting reagents to ensure they have been supplied with the correct substance. **2**

Propose a chemical test and the expected results to determine that the starting reagent is but-1-ene, rather than butane.

Marking Criteria	Marks
• Proposes a chemical test with expected results	2
• Provides relevant information	1

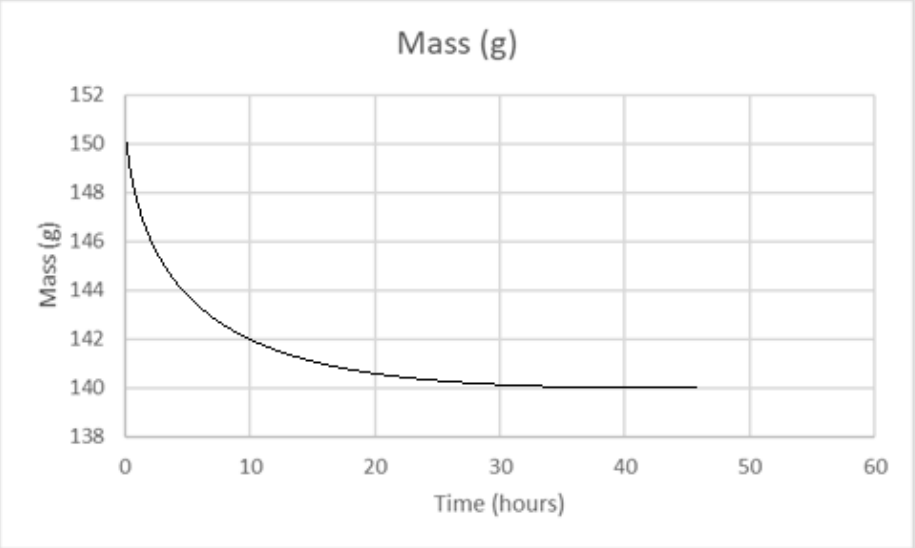
Sample Answer
Add bromine water to the reagent. If it decolourises in the absence of UV light, it is an alkene.

Question 34 (4 marks)

As part of a first-hand investigation relating to the fermentation of glucose ($C_6H_{12}O_6$), students added yeast to a solution of glucose, then plugged the top with cotton wool.

The apparatus was left at 30°C for 45 hours.

The graph below shows the change in mass of the flask over the 45-hour period.



Analysis of the reaction mixture after the 45 hours indicated the presence of unreacted glucose.

With the support of a balanced chemical equation, explain the shape of the graph. **4**

Marking Criteria	Marks
• Correct balanced chemical equation (states NOT required) • Demonstrates thorough understanding of fermentation and reaction rate	**4**
• Fully explains 2 features of the curve	**3**
• appropriate word/chemical equation • Partially explains a relevant aspect of the curve or reaction OR • Explains a relevant aspect of the curve OR • Partially explains 2 features	**2**
• Provides relevant information For example: ○ Word equation or balanced equation ○ Identifies a product ○ Describes the **rate of reaction** at a point in the curve ○ yeast is a catalyst ○ notes 'gas escapes leading to mass decrease' - 'CO_2 escapes leading to mass decrease' would be worth 2/4 ○ reaction stops when yeast is 'used up' - this is incorrect, but at least shows some understanding of why there is unreacted glucose (the yeast dies)	**1**
• mass decreases over time	**zero**

Sample Answer

$C_6H_{12}O_6$ (aq)	yeast →	$2C_2H_5OH$ (aq) + $2CO_2$ (g)

The fermentation of glucose forms carbon dioxide which escapes, resulting in a decrease in mass over time. Initially, the glucose concentration is high, resulting in a high reaction rate and therefore a sharp decline in mass. As the [glucose] decreases, rate decreases, decreasing the change in mass over time. The reaction ceases when the concentration of ethanol product reaches too high a level, killing the yeast - seen by the unchanging mass

Question 35 (5 marks)

Vitamin C, also known as ascorbic acid ($C_6H_8O_6$), is one of the most common supplements in the world.

It is titrated using an iodine (I_2) standard solution to a blue-black starch iodine endpoint.

$$C_6H_8O_6\,(aq) + I_2\,(aq) \rightarrow 2I^-\,(aq) + C_6H_6O_6\,(aq) + 2H^+(aq)$$

An analytical chemist determined the vitamin C composition in a tablet using the following method:

1. A 1.500 g tablet was crushed in a mortar and pestle and dissolved in 200.0 mL of distilled water.
2. 20.00 mL of the solution was pipetted into a 250 mL conical flask with a few drops of starch indicator.
3. It was titrated using 0.005000 $molL^{-1}$ iodine solution until 3 concordant results were achieved.

The average titre was recorded as 23.35 mL.

5

Determine the percentage (w/w) of vitamin C in the tablet.

……

Criteria	Marks
Calculates correctly the percentage of ascorbic acid in the tablet with all required steps and working out shown.	**5**
Calculates correctly the percentage of ascorbic acid in the tablet with some steps and working out missing.	**4**
Calculates correctly the percentage of ascorbic acid in the tablet with many steps and working out missing.	**3**
Attempts some steps to calculate the percentage of ascorbic acid in the tablet.	**2**
Provides some relevant calculations.	**1**

Sample answer:

1. Number of mols of iodine solution:

$n(I_2) = 0.005000 \times 0.02335 = 1.1675 \times 10^{-4}$ mol

2. n(ascorbic acid) = $n(I_2)$ (1:1 ratio) = 1.1675×10^{-4} mol
3. Molar mass of ascorbic acid

$MM(C_6H_8O_6) = 6\times12.01+8\times1.008+6\times16.00 = 176.124$ g mol^{-1}

4. Mass of ascorbic acid in 20.00 mL solution

$m(C_6H_8O_6) = n \times MM = 1.1675 \times 10^{-4} \times 176.124 = 0.020562$ g

5. Mass of ascorbic acid in 200.0 mL solution

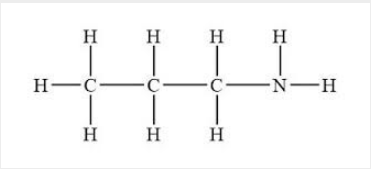
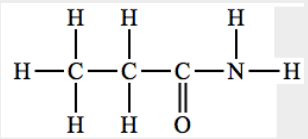
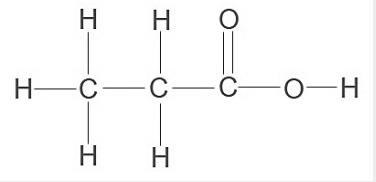
$m = 0.020562 \times 10 = 0.20562$ g

6. Percentage of ascorbic acid in the tablet

   $0.20562/1.500 \times 100 = 13.71\%$

Question 36 (8 marks)

The table below contains the formula for propanamine, propanamide, and propanoic acid.

Propanamine	*Propanamide*	*Propanoic Acid*
		

(a) The properties of the three substances are displayed below.

Substance	A	B	C
pH	8	3	11
Boiling point (°C)	213	141	51

Determine the identity of each substance and analyse the differences in pH and boiling point. **5**

Marking Criteria	Marks
• Correctly identifies each molecule • Demonstrates thorough understanding of the factors affecting the boiling points and pH of carboxylic acids, amines and amides MUST mention dimers	**5**
• Correctly identifies each molecule • Demonstrates strong understanding of the factors affecting the boiling points and pH of carboxylic acids, amines and amides	**4**
• Demonstrates some understanding of boiling point and pH as they relate to the three molecules	**3**
• Demonstrates understanding of boiling point and pH as it relates to organic molecules OR • Provides justification for the identity of one/some substances with references to at least 2 pieces of structural information/data OR • Correctly identifies all substances	**2**
• Provides relevant information	**1**

Sample Answer

A - propanamide, B - Propanoic Acid, C - Propanamine

Propanoic acid has the lowest pH as it is acidic due to the loss of H attached to the -COOH group. Propanamine is basic (pH of 11), due to the nitrogen electronegative nitrogen attracting protons. The propanamide is slightly basic (pH 8) for the same reason. It is less basic as the oxygen in the carbonyl draws away electron density.

Propanamide and propanoic acid have higher boiling points than propanamine. These molecules form dimers, linked by strong hydrogen bonds, which increases the strength of dispersion forces, requiring additional energy to separate. The amide forms stronger forces between dimers as it has 2 hydrogen bond donors (NH2), causing a higher boiling point.

Question 36 continues on the next page

(b) Identify relevant features of the infrared spectra that could be used to distinguish between the molecules. **3**

Marking Criteria	Marks
• Relates structural features to the corresponding IR data to distinguish between molecules	**3**
• Relates structural features to relevant IR data	**2**
• Provides relevant information	**1**

Sample Answer

The carboxylic acid has an OH group that would produce a strong, broad absorbance at 2500-3000 cm^{-1} and a C=O strong narrow absorbance at 1680-1750 cm^{-1}.

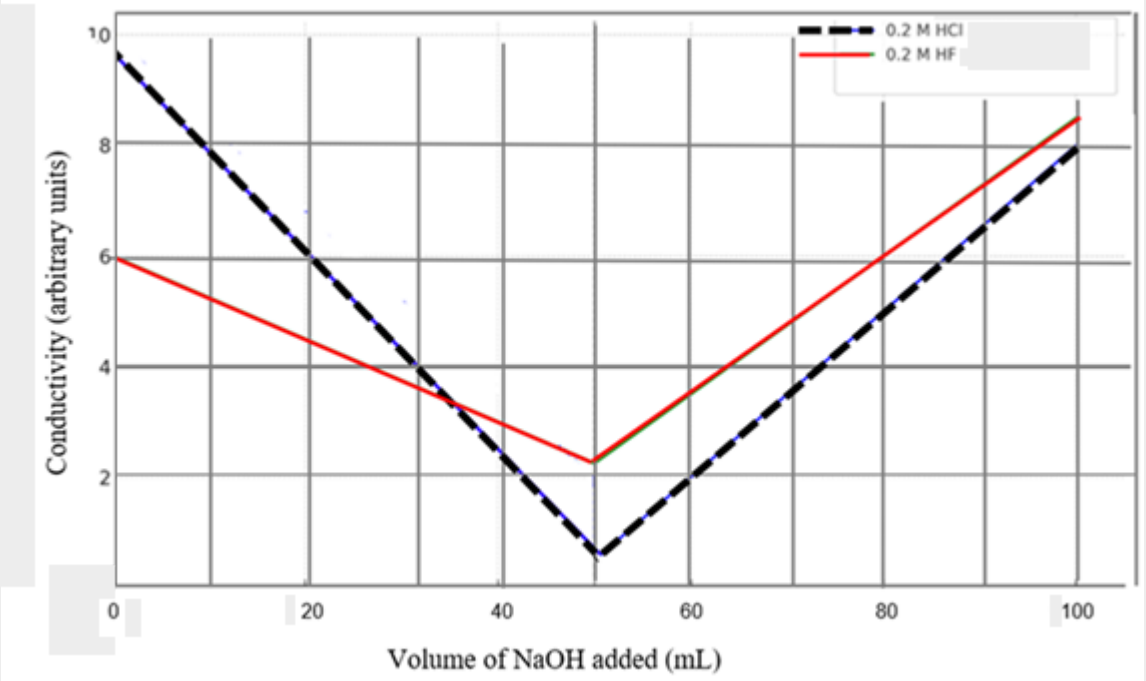
The amide would also have a C=O strong narrow absorbance at 1680-1750 cm^{-1}, but have a narrower absorbance at 3300-3500 cm^{-1}, due to the NH group

The amine would lack the strong narrow absorbance due to C=O. It would have a 3300-3500 cm^{-1} trough, due to the NH group.

Question 37 (4 marks)

Two separate conductivity titrations were performed by gradually adding 0.1 mol L^{-1} NaOH to 25.0 mL separate samples of 0.2 mol L^{-1} hydrochloric acid (HCl) and hydrofluoric acid (HF).

The volume of NaOH added was recorded against the conductivity of the solution, producing two conductivity curves. Both graphs are shown below.



Explain the similarities and differences in the conductivity curves for the two acids. Include relevant equations to support your answer. **4**

Marking Criteria	Marks
· Explains the similarities and differences in the shapes of the two curves, including: - why both curves start high but HCl is higher - why both curves decrease as NaOH is added - includes a chemical equation for one of the reactions - explains why both rise after the equivalence point	**4**
· Explains the similarities and differences in the shapes of the two curves, including 3 of the above, but answer may contain an error or omission.	**3**

· Identifies some similarities and differences AND · Accounts for one of the similarities or differences.	**2**
· Provides some relevant information.	**1**

Sample answer:

Similarities:

Both HCl and HF react with NaOH in a 1:1 mole ratio to form water and a salt:

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

For HF: $HF+NaOH \rightarrow NaF+H_2O$

The conductivity of both acids starts high, due to the presence of H^+ and either Cl^- or F^- ions, but as the HCl is stronger and highly ionised, its conductivity begins at a higher level, than the weaker HF acid.

End Point: At the equivalence point, the conductivity decreases as the highly conductive H^+ ions are neutralized by OH^- to form water, which is a poor conductor.

As both acids have the same initial volume and concentration i.e. the same number of moles, they require the same moles of NaOH to reach the equivalence point (25mL).

Differences:

HCl: The conductivity decreases steadily as NaOH is added, reaching a minimum at the equivalence point. After the equivalence point, the conductivity increases again due to the excess OH^- ions from NaOH.

HF: The initial decrease in conductivity is less steep due to partial dissociation. The curve may show a more gradual change around the equivalence point. After the equivalence point, the increase in conductivity is similar to that for HCl, due to excess OH^- ions.

At the equivalence point:

- For the HF vs NaOH: the HF solution is now just Na^+, F^- and water, conductivity = 2.3 (ish)
- For the HCl vs NaOH, the HCl solution is now just Na^+, Cl^- and water, conductivity = 0.5 (ish)
- The reason for this difference in conductivity is that F^- is a much smaller ion than Cl^-, therefore more mobile, and therefore more conductive in a solution.

This explains why the minimum for both acids occurs when 50mL of NaOH is added.

End of paper