Exam Choice

Student Number

2022 | TRIAL EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes.
- Working time – 3 hours.
- Write using black pen.
- Draw diagrams using pencil.
- For questions in Section II, show all relevant working in questions involving calculations.
- NESA approved calculators may be used.

Total marks: 100

Section I – 20 marks (pages 3 – 13)

- Attempt questions 1 – 20.
- Allow about 35 minutes for this section.

Section II – 80 marks (pages 14 – 32)

- Attempt questions 21 – 33
- Allow about 2 hours and 25 minutes for this section.

Section I – 20 marks

Attempt Questions 1-20

Allow about 35 minutes for this section

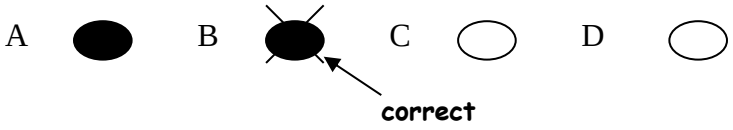
Use the multiple-choice answer sheet.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.



1. What is a function of the lamp in atomic absorption spectroscopy (AAS)?

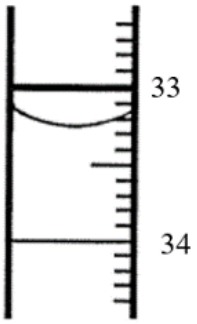
(A) To amplify the light signal to increase sensitivity.

(B) To filter out unwanted colours of light from the flame.

(C) To provide light to be absorbed by the vaporised atoms.

(D) To vaporise the sample to produce neutral atoms in the flame.

2. The diagram below shows the NaOH (aq) level in a burette at the endpoint of a titration.



What is the correct reading for the volume shown in this burette?

(A) 33.22 mL

(B) 33.25 mL

(C) 34.82 mL

(D) 34.85 mL

3. The table below shows the pH range of four acid-base indicators.

Indicator	pH range
W	3.3 - 4.3
X	6.2- 7.5
Y	7.8 -10.3
Z	8.1 - 9.8

Which indicator would be the best choice for a titration between potassium hydroxide and ethanoic acid?

(A) W

(B) X

(C) Y

(D) Z

4. Which one of the following compounds would react with calcium carbonate powder?

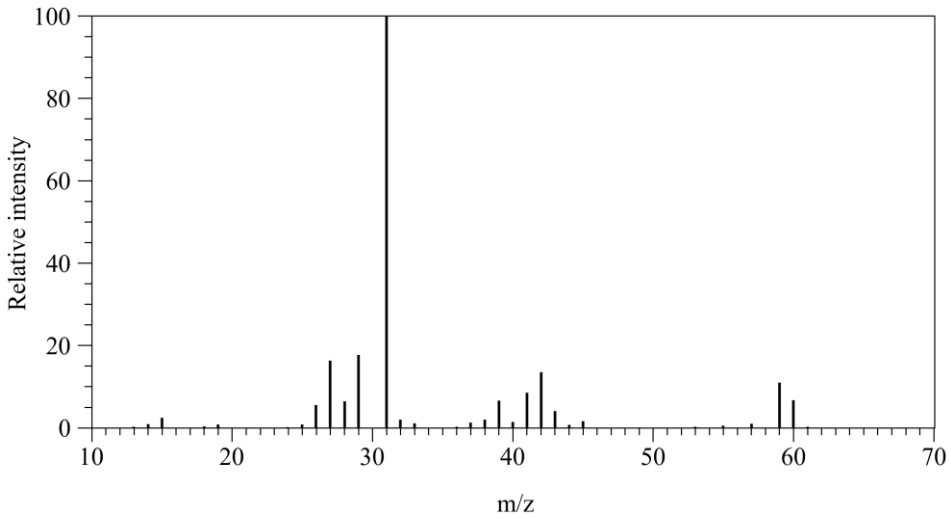
(A) CH_3OH

(B) HCOOH

(C) $C_2H_5NH_2$

(D) $CH_3COOCH_2CH_3$

5. The mass spectrum of an alkanol is shown below.



What is the mass to charge ratio of the fragment responsible for the base peak?

(A) 15

(B) 31

(C) 59

(D) 60

6. Which of the following statements explains how soaps act as effective emulsifiers?

(A) Soap decreases the surface tension of water.

(B) Oil and water can form an emulsion when soap is present.

(C) Soap molecules have a hydrophilic end and a hydrophobic end.

(D) Soaps are the products of the hydrolysis of esters followed by neutralisation.

7. Which of the following compounds requires two moles of bromine (Br_2) for a complete reaction with one mole of the compound?

(A) propyne

(B) pentan-1-ol

(C) ethanal

(D) but-2-ene

8. Ammonium chloride has a relatively high solubility of 28.3g/100g H_2O.

Which type of attraction accounts for the dissolving of this compound in water?

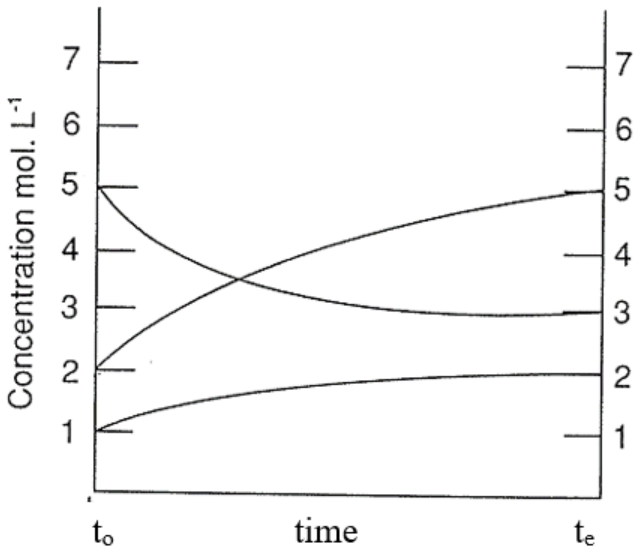
(A) hydrogen bonds
(B) covalent bonds
(C) ion-dipole bonds
(D) dispersion forces

9. Which one of the following **empirical formulae** could be that of a linear molecule?

(A) CH
(B) CH_2
(C) CH_3
(D) CH_4

10. The graph below shows the variation of molarities of substances X, Y and Z, against time, at constant temperatures, for the following reaction.

$$2X\ (aq) \Leftrightarrow Y\ (aq) + 3Z\ (aq)$$



Use the data provided to estimate the value of K at time = t_e for the following reaction, at the same temperature.

$$Y\ (aq) + 3Z\ (aq) \Leftrightarrow 2X\ (aq)$$

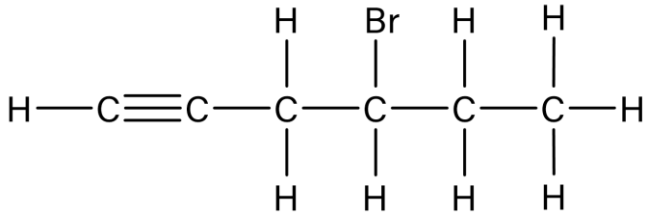
(A) 0.036

(B) 0.225

(C) 4.44

(D) 27.8

Questions 11 and 12 refer to the structure of compound X shown below.



11. What is the systematic name for this compound?

(A) 4-bromo-1-hexyne

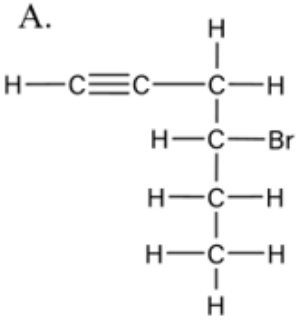
(B) 3-bromo-5-hexyne

(C) 4-bromo-2-hexyne

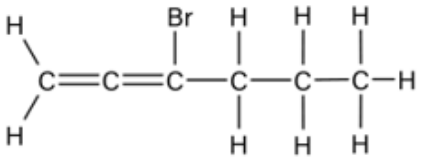
(D) 3-bromo-6-hexyne

12. Which one of the structures below is a chain isomer of compound X?

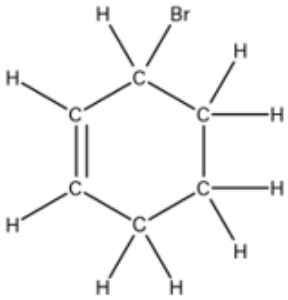
A.



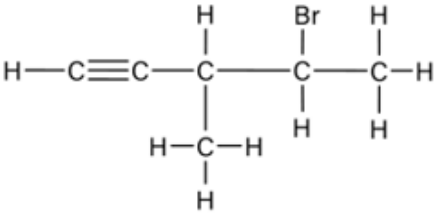
B.



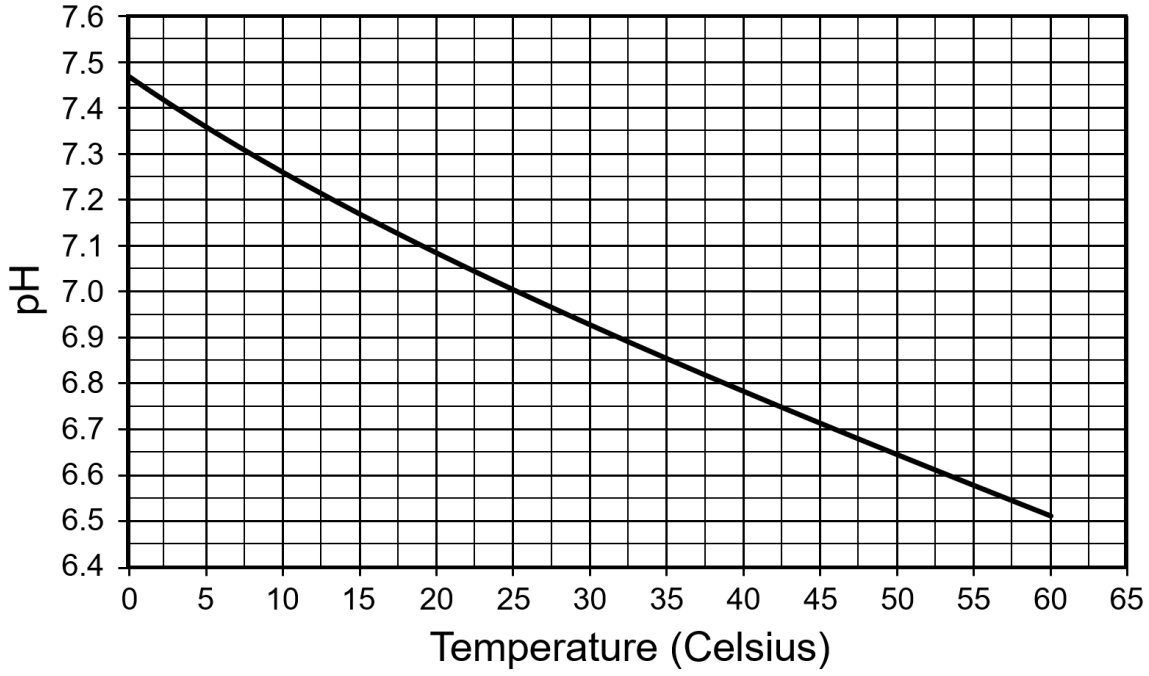
C.



D.



Questions 13 and 14 relate to the graph below, which shows how the pH of pure water changes with temperature.



13. From the graph, what is the best estimate of the value of K_w at 15°C?

(A) 4.0×10^{-15}

(B) 5.0×10^{-15}

(C) 6.3×10^{-15}

(D) 1.0×10^{-15}

14. Which of the following is a valid conclusion which can be drawn from the graph?

(A) Water becomes slightly acidic as it is heated.

(B) Pure water is only neutral when its pH is exactly 7.

(C) The conductivity of pure water would decrease as it is heated.

(D) The self-ionisation of water absorbs energy from its surroundings.

15. When 14.00g of $MgSO_4.7H_2O$ is dissolved in 100.0g of water, the density of the solution is found to be 1.060 g mL^{-1}.

What is the molarity of $MgSO_4$ in this solution?

(A) 0.53 mol L^{-1}

(B) 0.57 mol L^{-1}

(C) 0.94 mol L^{-1}

(D) 1.08 mol L^{-1}

16. Which one of the following pairs of solution, when mixed to form a 1L solution, would form an effective buffer?

(A) 0.2 mol of NaOH and 0.2 mol of HCl.

(B) 0.2 mol of KOH and 0.4 mol of HF

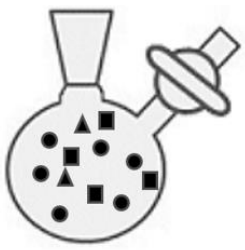
(C) 0.4 mol of HCl and 0.2 mol of NH_3

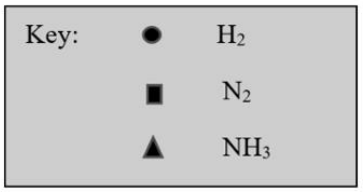
(D) 0.4 mol of CH_3COOH and 6 mol of NaOH

17. The reaction between hydrogen and nitrogen gas to form ammonia is reversible and may come to equilibrium under suitable conditions.

$$N_2(g) + 3H_2(g) \Leftrightarrow 2NH_3(g) \quad DH = -92kJ\ mol^{-1}$$

The diagram below represents the initial equilibrium mixture of this system at 25°C.

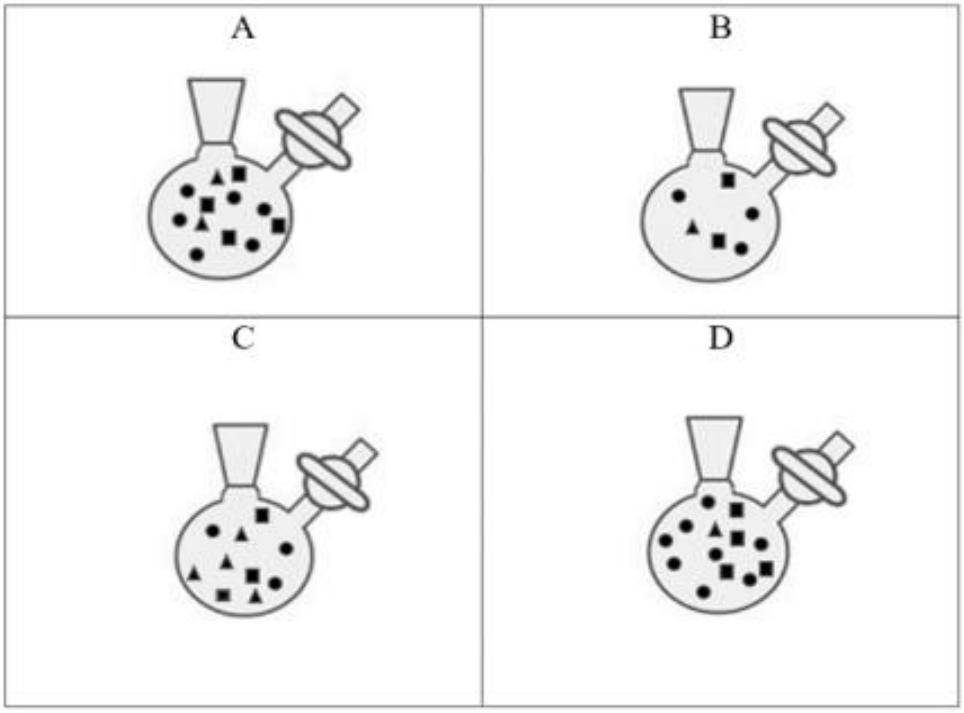




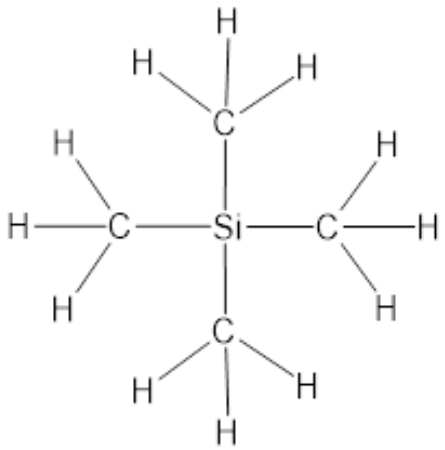
Initial equilibrium mixture (25°C)

At time = t_1, the flask was placed in an ice bath and cooled.
At time = t_2, the system came to equilibrium at a constant temperature of 4°C.

Which diagram best represents the composition of the flask at equilibrium at t_2?



18. Tetramethylsilane (TMS, shown below) is often used to calibrate both ^{13}C and ^{1}H NMR spectra.



Which signals are caused by TMS in ^{13}C NMR and ^{1}H NMR spectra?

	^{13}C NMR spectrum	***^{1}H NMR spectrum***
(A)	one peak, a quartet (4)	one peak, a quartet (4)
(B)	one peak, a singlet (no splitting)	one peak, a singlet (no splitting)
(C)	four peaks, each a singlet (no splitting)	one peak, a nonet (9)
(D)	four peaks, each a quartet (4)	one peak, a decet (10)

19. 10.0 mL of 1.0 $molL^{-1}$ NaOH in a conical flask is titrated against 1.0 $molL^{-1}$ HCl.

What volume of HCl must be added to bring the mixture in the flask to a pH of 2?

(A) 10.2 mL

(B) 11.2 mL

(C) 20.2 mL

(D) 22.2 mL

20. UV-Visible spectroscopy is a quantitative analytical technique for measuring the concentration of solutions containing a species which absorbs in the ultraviolet or visible region of the spectrum.

The absorbance of a solution can be calculated from the Beer-Lambert equation.

$$A = \varepsilon c l$$

A specially designed cell known as a cuvette is filled with the solution to be analysed. The cuvette is then inserted into a U-V Visible spectrometer, which measures the absorbance of a specific wavelength known to have maximum absorbance for the solution being analysed.

The concentration of an unknown solution can be estimated by interpolation of a calibration graph.

The box below lists some procedural errors which a poorly trained technician might make while performing an analysis.

i.	Overfilling the cuvette and not removing droplets of the solution from the outside surface of the cuvette.
ii.	Poor measurement of the width of the cuvette, obtaining a value lower than its correct width.
iii.	Measuring the absorbance of the unknown solution at a wavelength other than its maximum.
iv.	Rinsing the cuvette with distilled water just before filling it with the solution to be analysed.

Which of the procedural mistakes listed above would always result in obtaining a value for the concentration of an unknown solution which is too high?

(A) i and ii

(B) ii and iii

(C) ii and iv

(D) iii and iv

2022 | TRIAL EXAMINATION

Chemistry

Section II
Answer Booklet

80 marks

Attempt Questions 21 – 33

Allow about 2 hours and 25 minutes for this part

Instructions

- 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 questions you are answering.

Marks

Question 21 (8 marks)

*NH_4Cl is an example of a **salt**, according to one theory of acids and bases, and an **acid**, according to a more modern theory.*

(a) Justify the above statement, supporting your answer with relevant balanced equations. **3**

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(b) The hydrogen phosphate ion is an example of an amphiprotic species.

Define the term *amphiprotic* and explain how the chemical composition of this ion relates to its amphiprotic nature. **2**

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(c) The K_a of the hydrogen phosphate ion is 4.2×10^{-13} at 25^oC.

Should a 0.1M solution of sodium hydrogen phosphate be classed as a strong or weak acid? Justify your choice, supporting your answer with an appropriate calculation. **3**

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Marks

Question 22 (5 marks)

(a) A solution is known to contain **one of** either Fe^{2+}, Ag^{+} or Cu^{2+} ions.

Outline the tests and expected observations that could be used to determine which ion is present. **3**

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(b) Identify one test and the expected results that could distinguish between two solutions, one containing Ba^{2+} ions, and the other Ca^{2+} ions. **2**

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Marks

Question 23 (6 marks)

Methanol can be produced from methane using two reactions in order:

Reaction 1: $CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H = +210 \text{ kJ mol}^{-1}$

Reaction 2: $2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$ $\Delta H = -91 \text{ kJ mol}^{-1}$

Explain the reaction conditions necessary to ensure the industrial production of methanol from CH_4(g) and H_2O (l) is economically viable. **6**

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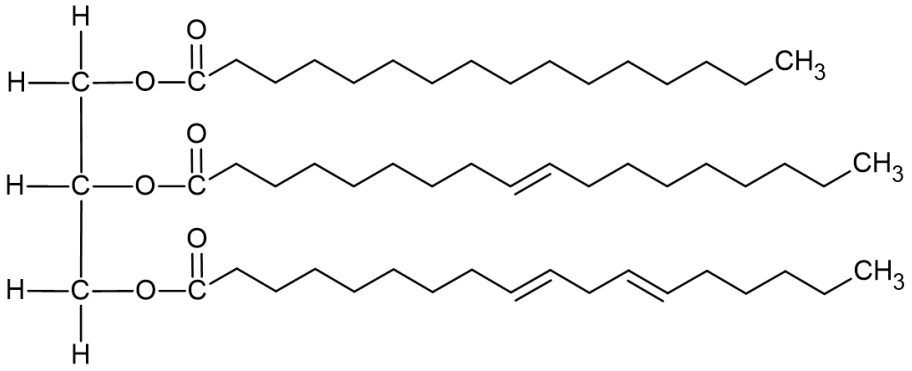
Marks

Question 24 (8 marks)

Linseed oil is a mixture of triesters. It is used for many purposes including as a protective layer for wooden furniture and as an ingredient in some cuisines. The structure below shows a typical triester found in linseed oil.



When the compound shown above undergoes de-esterification (the opposite of esterification), three fatty acids are produced:

- palmitic acid
- linoleic acid
- oleic acid

corresponding to the three long chains in the diagram listed from top to bottom.

(a) Why are compounds like the one depicted above called triesters? **1**

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(b) In addition to the three acids listed above, two other products result from the de-esterification of the compound.

Identify them and state the number of moles of each that would be produced from the complete de-esterification of one mole of the compound shown. **3**

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Question 24 continues on page 19.

Marks

Question 24 (continued)

(c) Castor oil is another natural product that may find a use as a component in biofuel.

It has a gravimetric energy density of 39.5 MJ kg^{-1}.

When 2.00 L of castor oil was combusted in a home-made engine 59.3 MJ of energy was released.

The density of castor oil is 0.96 g mL^{-1}.

What is the efficiency of the engine? **2**

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(d) Explain how **TWO** risks associated with heating volatile organic compounds are reduced by using a reflux apparatus with a heating mantle. **2**

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Marks

Question 25 (5 marks)

Magnesium chloride is an ionic compound which is highly soluble in water.

(a) Write the equation, including state symbols, for the process of forming a saturated solution of magnesium chloride in water. **1**

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(b) The table below shows some thermochemical data related to the dissolving of magnesium chloride solid in water.

Energy required to overcome the lattice forces to form free Mg^{2+} and Cl^- ions.	= +2493 kJ mol^{-1}
Energy released upon hydration of Mg^{2+} ions	= –1920 kJ mol^{-1}
Energy released upon hydration of Cl^- ions	= –364 kJ mol^{-1}

Use these data to calculate the standard enthalpy of solution of magnesium chloride. **2**

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(c) Use your answer to part **(b)** to deduce how the solubility of $MgCl_2$ changes as the temperature is increased. **1**

Justify your answer.

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Marks

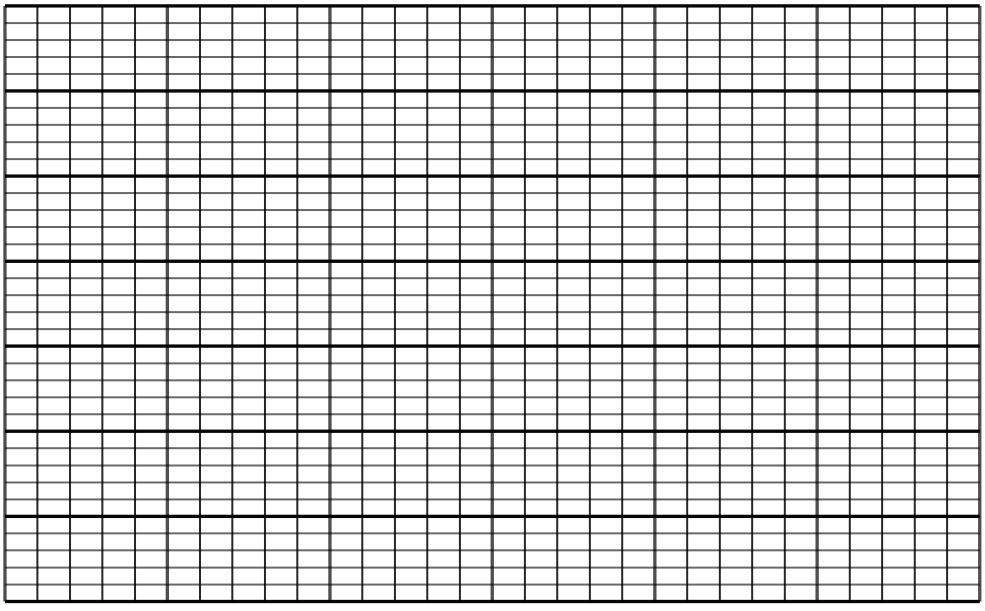
Question 26 (8 marks)

A solution of 4-chlorobutanoic acid was titrated against standardised sodium hydroxide solution. Small volumes of sodium hydroxide solution were added, and the pH was measured after each addition. The data collected are shown in the table below.

Volume of NaOH added (mL)	0	5	10	15	18	19	20	21	22	25	30
pH	3.8	4.3	4.6	4.5	4.7	5.0	12.1	12.5	13.3	13.0	13.0

(a) Draw the structural formula of 4-chlorobutanoic acid. **1**

(b) Plot the values of the pH of the solution against the volume of NaOH and draw a smooth curve of best fit, ignoring possible outliers. **4**



Question 26 continues on page 22.

Marks

Question 26 (continued)

(c) Estimate the pH at the equivalence point in this titration. **1**

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(d) The pK_a of a weak acid is equal to the pH of the solution in which half of the weak acid has been neutralised.

Use your graph to estimate a value of K_a for 4-chlorobutanoic acid. **2**

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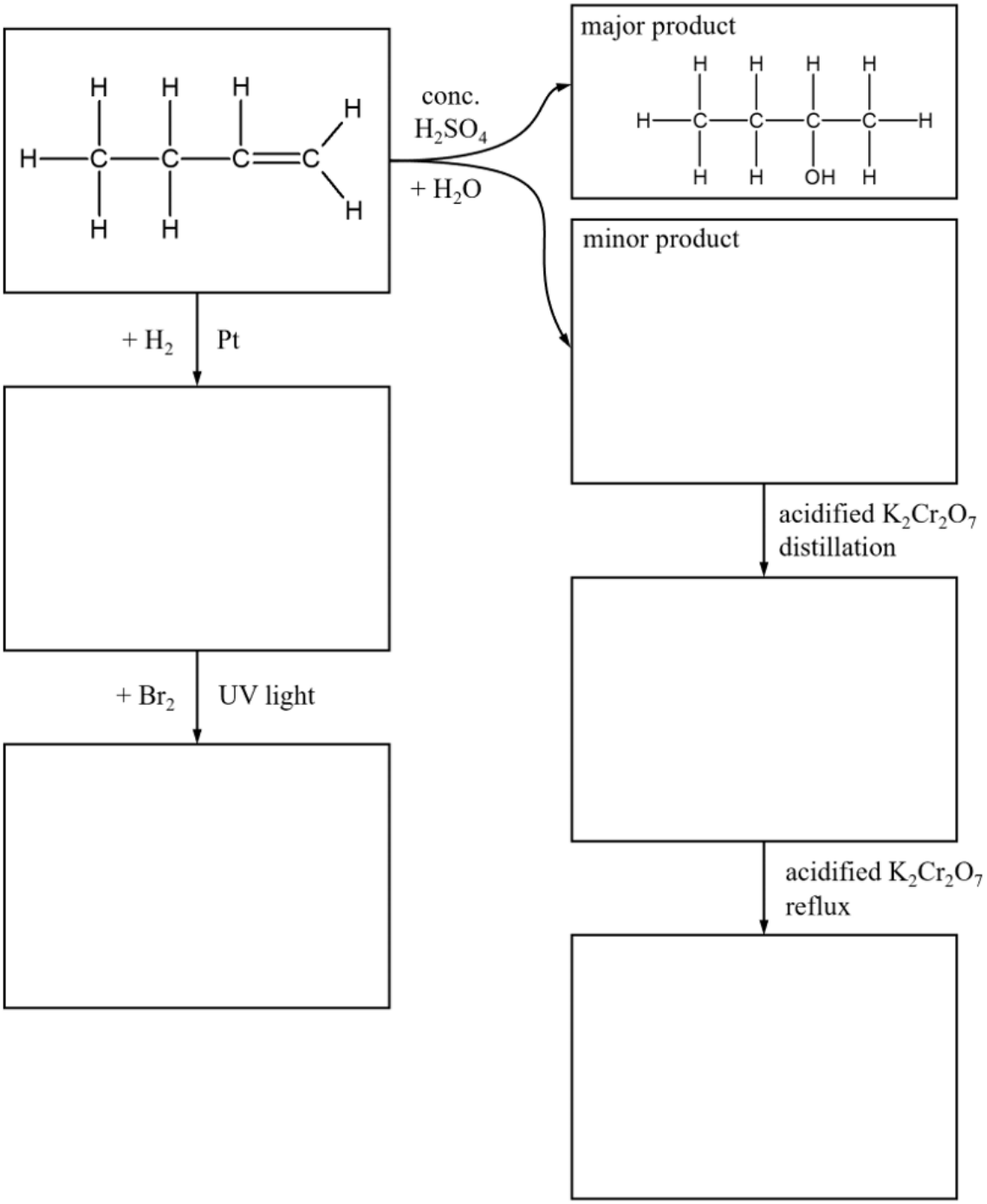
Marks

Question 27 (5 marks)

Draw structures to fill in the chart that shows series of reactions beginning with 1-butene. **5**

The major product from one reaction has been drawn for you.

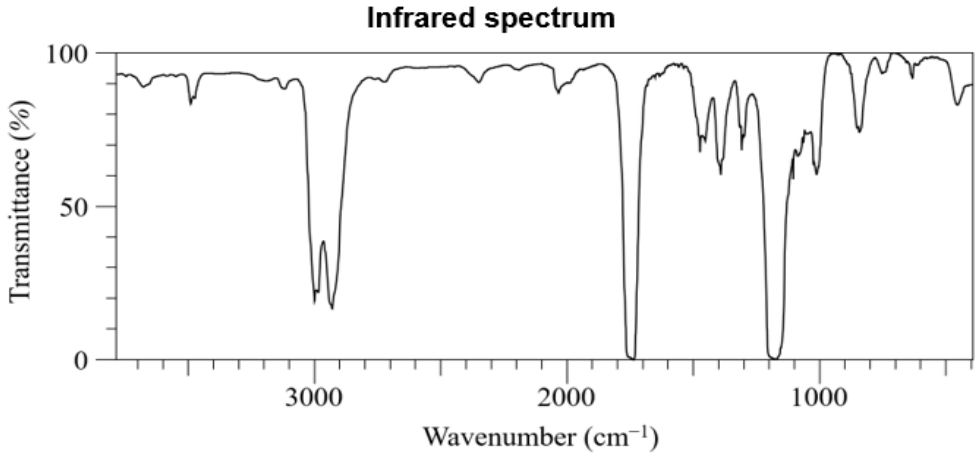


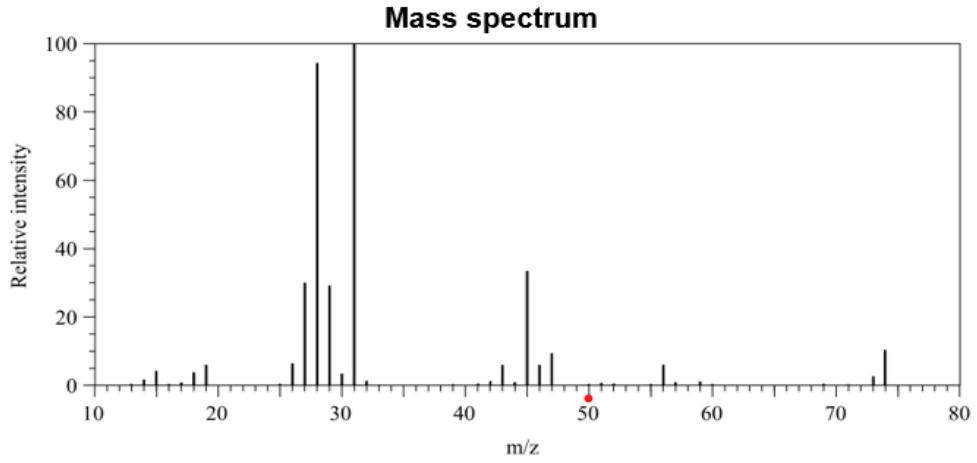
Marks

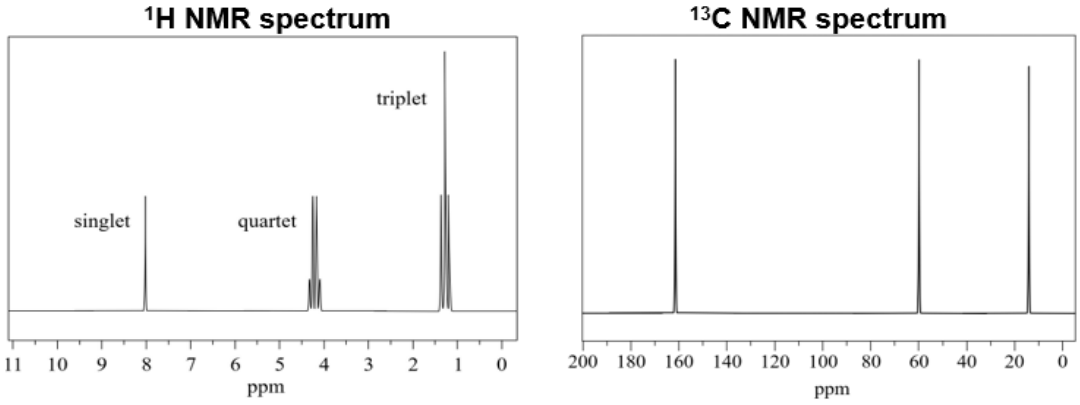
Question 28 (7 marks)

A student discovered a bottle containing a sweet-smelling liquid. The label on the bottle said '$C_xH_yO_z$'.

The infrared, mass, ^1H and ^{13}C NMR spectra of the liquid were recorded and are shown below.







Marks

Question 28 (continued)

Data from ^{1}H NMR spectrum

Chemical shift	*Relative peak area*	*Splitting pattern*
1.3	3	triplet
4.2	2	quartet
8.0	1	singlet

Draw a structural formula for the unknown compound below. **7**

Justify your answer by referring to the information provided.

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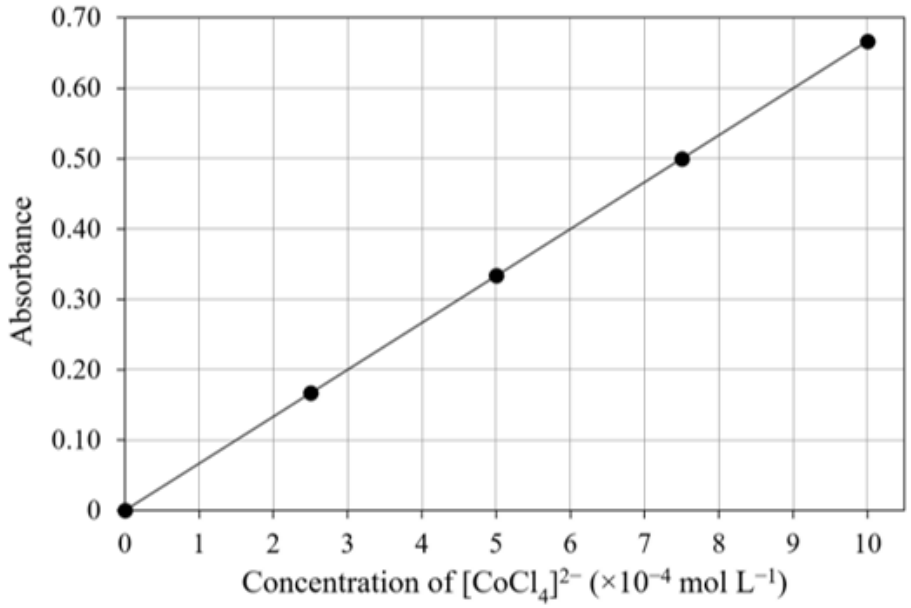
Marks

Question 29 (4 marks)

Two differently coloured complex ions of cobalt(II), $[Co(H_2O)_6]^{2+}$ (pink) and $[CoCl_4]^{2-}$ (blue), exist in equilibrium in solution when chloride ions are present:

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

Various concentrations of $[CoCl_4]^{2-}$ were placed in a cuvette. A UV-Vis spectrometer tuned to a blue wavelength recorded the following calibration graph.



An identical cuvette was filled with an aqueous 0.9900 mol L^{-1} sodium chloride solution. Sodium ions play no part in this equilibrium.

After about 1.6 seconds, $[Co(H_2O)_6]^{2+}$ was added so to achieve an initial concentration in the cuvette of 0.3600 mol L^{-1}.

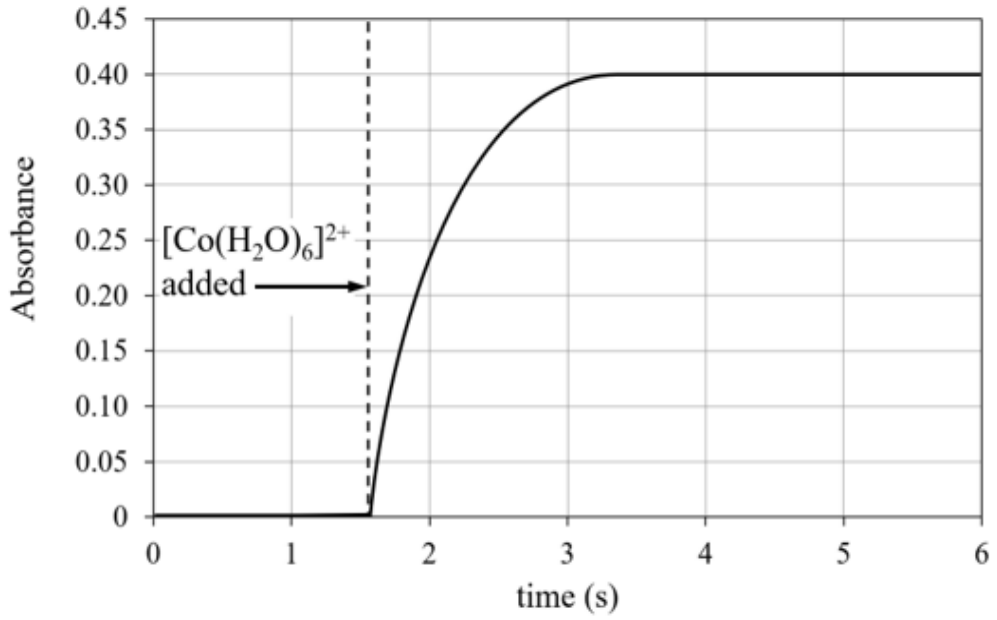
The spectrometer continuously recorded the absorbance at the same blue wavelength. The temperature was held constant.

The data are plotted over the page.

Question 29 continues on page 27.

Marks

Question 29 (continued)



Calculate K_{eq} for the equilibrium reaction as written at the start of the question. **4**

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Marks

Question 30 (9 marks)

In aqueous solution, sulfuric acid acts as a strong acid.

(a) If sulfuric acid fully ionises, calculate the theoretical pH of a 0.0050M solution of the acid. **1**

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(b) The H_2SO_4 has a high degree of ionisation to form HSO_4^- ions and H^+ ions.

The HSO_4^- ions act as a much weaker acid.

Give an equation to show each stage in the ionisation of sulfuric acid in aqueous solution. Include appropriate arrows in your equations. **2**

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Question 30 continues on page 29.

Marks

Question 30 (continued)

(c) A student makes 250.0 mL of an aqueous solution that contains an accurately measured mass of sodium hydrogen sulfate ($NaHSO_4$).

Describe the method that the student should use to make this solution. **3**

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(d) A solution that contains 605 mg of $NaHSO_4$ in 100 mL of solution has a pH of 1.72

Calculate the value of K_b for the sulfate ion. **3**

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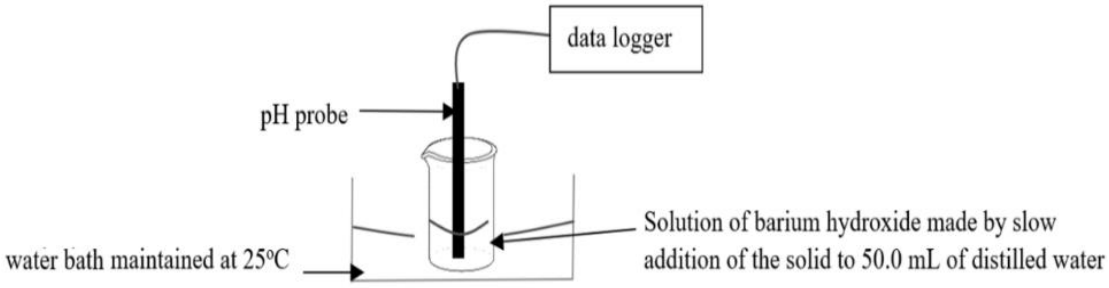
Marks

Question 31 (6 marks)

A student slowly added a small mass of solid calcium hydroxide to 50.0mL of distilled water in a beaker placed in a water bath of temperature 25ºC. The solution was stirred continuously and the pH of the solution constantly measured with a probe and data logger.



30 s after the addition, the student thought they observed a slight cloudiness in the solution and assumed the solution was saturated. The pH of the mixture at this time was measured at 11.8 on the data logger.

(a) Use the data recorded by the student to determine if the solution at 30s was saturated. Show your working. **3**

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(b) Calculate the concentration of Ca^{2+} ions in a saturated solution of calcium hydroxide at 25ºC, in parts per million (ppm). **3**

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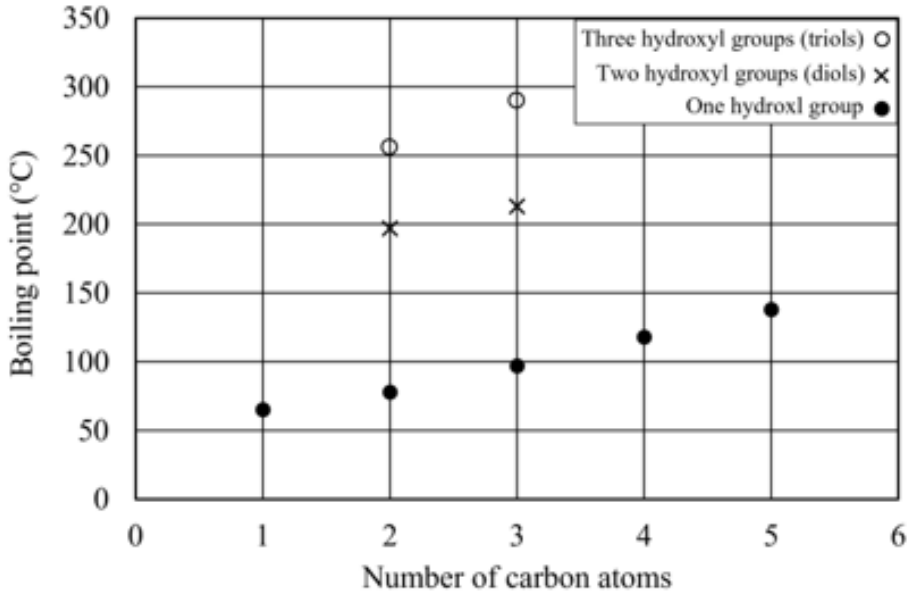
Marks

Question 32 (4 marks)

The graph below shows the boiling points of the tabulated compounds:

One hydroxyl group	*Two hydroxyl groups*	*Three hydroxyl groups*
methanol ethanol propan-1-ol butan-1-ol pentan-1-ol	ethane-1,1-diol propane-1,3-diol	ethane-1,1,2-triol propane-1,2,3-triol



Explain both horizontal and vertical trends in the boiling points shown in the graph. **4**

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Marks

Question 33 (5 marks)

A 2.00g sample of anhydrous sodium carbonate was known to be contaminated with a small mass of barium sulfate.

To determine the % purity of the sodium carbonate mixture, the 2.00 g sample was transferred to a clean conical flask. 25.0 mL of distilled water was added, producing a slighly white, opaque mixture in the flask upon swirling. A few drops of methyl orange indicator were added to the flask.

This mixture was titrated against standadrised 1.500 mol L^{-1} hydrochloric acid solution. An average titre of 15.75 mL was required to reach the end-point of the titration.

(a) Calculate the % (w/w) purity of the contaminated sodium carbonate sample. **3**

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(b) Could the same procedure be employed if the contaminant in the sample was ammonium sulfate, rather than barium sulfate? Justify your answer. **2**

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Exam Choice

2022 Chemistry Trial Examination.

Marking Guidelines and Model Answers.

Section I Multiple Choice

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

Section II

21.a.

Marking Criteria	Marks
• Justifies each aspect of the statement by demonstrating knowledge of the Arrhenius and Bronsted-Lowry theories of acids and bases AND • Includes TWO relevant balanced equations to support the answer.	**3**
• Describes aspects of either the Arrhenius and Bronsted-Lowry theories of acids and bases AND • Includes ONE relevant balanced equation to support the answer.	**2**
• Provides some relevant information.	**1**

According to the Arrhenius theory of acids and bases, a salt and water is produced when an acid is neutralised by a base.

If a solution of ammonia (NH_4OH) is reacted with hydrochloric acid, the salt NH_4Cl is formed, hence it is an example of an ionic salt, as shown below.

$NH_4OH\ (aq) + HCl\ (aq) \rightarrow NH_4Cl\ (aq) + H_2O\ (l)$

According to the Bronsted Lowry theory of acids and bases, an acid acts as a proton donor.

In a solution of NH_4Cl, the NH_4^+ will donate a proton, acting as an acid, while the Cl^- is such a weak base, it will not effect the pH significantly. Thus a solution of NH_4Cl is acidic.

$NH_4^+\ (aq) + H_2O\ (l) \Leftrightarrow NH_3\ (aq) + H_3O^+\ (aq)$

21.b.

Marking Criteria	Marks
• Provides a meaning for the term *amphiprotic* and shows how the chemical formula of the hydrogen phosphate ion allows it to act as an amphiprotic species	**2**
• Provides some relevant information (eg defines the term *amphiprotic*)	**1**

An amphiprotic species can act as both a proton donor and a proton acceptor.

The chemical formula for the hydrogen phosphate ion is HPO_4^{2-}. Since this species contains a H which will leave the species (hence allowing it to act as a proton donor) as well as bonding capacity to accept a proton (hence allowing it to act as a proton acceptor), it is an example of an amphiprotic species.

21.c.

Marking Criteria	Marks
• Identifies the acid as a weak acid AND • Demonstrates a knowledge of the term 'acid strength' and • Shows by some correct calculation the degree of ionisation for the acid is low.	**3**
Any TWO of the following: • Identifies the acid as a weak acid AND • Demonstrates a knowledge of the term 'acid strength' and • Shows by some correct calculation the degree of ionisation for the acid is low.	**2**
• Provides some relevant information.	**1**

A strong acid is one which ionises fully (or to a large extent), thus its degree of ionisation is very high. If this acid was 100% ionised (very strong), the $[H_3O^+]$ would be 0.1M

The size of K_a for an acid provides a measure of its strength. For a weak acid, the $[H^+]$ in solution can be estimated as follows:

Acid X is monoprotic, $HPO_4^{-2} + H_2O \rightleftharpoons H_3O^+ + PO_4^{3-}$

$$K_a = 4.2 \times 10^{-13} = ¿¿$$

(0.1-x would approximate 0.1 for a weak acid)

$4.2 \times 10^{-13} = x^2 / 0.1$

$x = [H_3O^+] = 2.04 \times 10^{-7}$ which is significantly less than 0.1M. Hence the ion should be classed as a very weak acid.

22.a.

Marking Criteria	Marks
• Outlines tests and observations that lead to a unique identification for all ions	**3**
• Outlines tests and expected observations that could distinguish some ions	**2**
• Provides some relevant information	**1**

Transfer ~1 mL of the unknown sample to a test tube.

Add a few drops of 1 M NaCl to the test tube.

White precipitate → Ag^+ ions present.

No precipitate → keep testing.

To a new test tube of unused unknown sample add a few drops of 1 M NaOH

Green precipitate → Fe^{2+} ions present

Blue precipitate → Cu^{2+} ions present

22.b.

Marking Criteria	Marks
• Identifies a suitable test for both ions eg flame test and states expected colours for both ions	**2**
• Provides a suitable test for one of the ions.	**1**

A flame test on the unknown sample would show apple green for Ba^{2+} ions and brick red for Ca^{2+} ions. The solutions may need to be evaporated to concentrate the ions and then a sample is collected on a metal loop and heated in a Blue Bunsen flame.

23

Marking Criteria	Marks
• Identifies several reaction conditions which ensure the process is economically viable, and explains each condition in terms of yield and/or rate, demonstrating thorough knowledge of equilibrium principles	**6**
• Identifies reaction conditions which ensure the process is economically viable, and explains each condition in terms of yield and/or rate, demonstrating sound knowledge of equilibrium principles.	**5**
• Identifies and explains the optimum conditions for both reactions in terms of Le Chatelier's principle	**4**
• Identifies all conditions and explains some conditions in terms of Le Chatelier's principle	**3**
• Identifies and attempts to explain some conditions	**2**
• Some relevant information	**1**

Reaction 1 is endothermic (it has a positive ΔH) and thus absorbs heat. According to Le Chatelier's principle (LCP) an increase in temperature favours the endothermic process which will absorb some heat and thereby minimise the effect of the disturbance, thus increasing the yield of the reaction. Therefore, Reaction 1 should be kept at a high temperature to increase yield. High temperatures will also increase the rate of the reaction, as reactant molecules gain KE when heated, and hence more of them will possess the required activation energy.

Reaction 1 converts two moles of gas into four moles of gas. According to LCP, a reaction will respond to changes in conditions in such a way as to minimise this disturbance. Therefore, Reaction 1 should be carried out at low pressure to increase yield. However, low pressure may reduce the number of collisions and hence the rate, so a compromise pressure, to give a good yield at an acceptable rate, may be chosen.

Reaction 2 is essentially the opposite of Reaction 1 in terms of its ΔH (negative) and conversion of moles of gas (three to one). Therefore, to maximise the yield of methanol, LCP indicates that this should be carried out at a low temperature and a high pressure. The temperature should not be too low, however, as this may reduce the rate appreciably. A compromise temperature (moderate temp) may be used, and a catalyst added to allow the rate to be sufficient in the absence of very high temperatures.

24.a.

Marking Criteria	Marks
• Provides a correct explanation	1

There are three ester linkages in the molecule. Each ester linkage looks like this:

24.b.

Marking Criteria	Marks
• Identifies both products and states the number of moles of each produced	3
• Identifies one product and states the number of moles of it	2
• Provides Some relevant information	1

Three moles of water and one mole of propane-1,2,3-triol.

24.c.

Marking Criteria	Marks
• Calculates the efficiency	2
• Some correct working	1

2.00 L of castor oil weighs 0.96 × 2000 = 1920 grams = 1.92 kg

The energy content is therefore 1.92 × 39.5 = 75.84 MJ

efficiency ¿ $\frac{59.3}{75.84} = 78\%$

24.d.

Marking Criteria	Marks
• Explains how two risks are reduced by using reflux and a heating mantle	2
• Some relevant information	1

Many organic compounds are flammable. Volatile compounds evaporate readily. Using a Bunsen burner may start a fire if the vapour makes contact with the flame. A heating mantle does not have a flame, and the reflux setup condenses vapours so that they do not escape the reaction vessel as much.

Heating volatile organics in a sealed container could cause an explosion if the pressure builds up. Instead of sealing the vapours to keep the products and reactants within, a reflux setup condenses them on the cooled inner wall, preventing losses without the risk of explosion.

25.a.

Marking Criteria	Marks
• Writes a correctly balanced equation for the dissolving process.	**1**

$MgCl_2$ (s) ⇔ Mg^{2+} (aq) + $2Cl^-$ (aq)

25.b.

Marking Criteria	Marks
• Uses the data to calculate the ΔH_{sol} applying ideas of bond breaking and forming.	**2**
• Provides some relevant information.	**1**

ΔH_{sol} = Σbonds broken - Σbonds formed

= 2493 – (1920 + 2×364) = –155 kJ mol^{-1}

25.c.

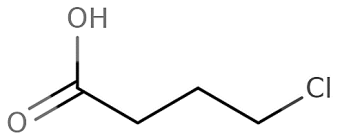
Marking Criteria	Marks
• Uses the answer provided in (b) to explain how the solubility of the compound will change as the temperature is increased.	**2**
• Provides some relevant information.	**1**

Heating favours endothermic processes, which will absorb some of the added heat and thereby minimise the effect of the distrubance (by LCP). Since the dissolving process is exothermic, heating will favour the reverse reaction, and thus the solubility of $MgCl_2$ is predicted to decreases as the temperature increases.

26.a.

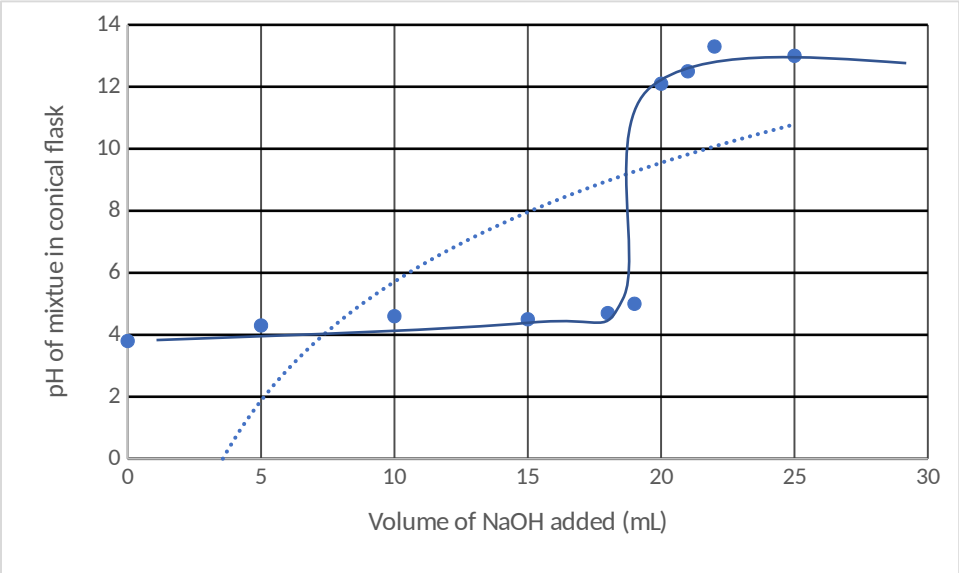
Marking Criteria	Marks

• Draws the correct structural formula	**1**



26.b.

Marking Criteria	Marks
• Plots each point accurately and connects them with a smooth curve of best fit, demonstrating excellent graphing skills and following conventions for formatting graphs.	**4**
• Plots most points accurately and connects them with a smooth curve of best fit (but may include outliers), demonstrating sound graphing skills and following most conventions for formatting graphs.	**3**
• Plots most points accurately and demonstrates satisfactory graphing skills, following some conventions for formatting graphs.	**2**
• Plots some points accurately and demonstrates limited graphing skills, following some conventions for formatting graphs.	**1**



26.c.

Marking Criteria	Marks
• Estimates the pH at the equivalence point.	**1**

pH at equivalence point = approx 8.5- 9

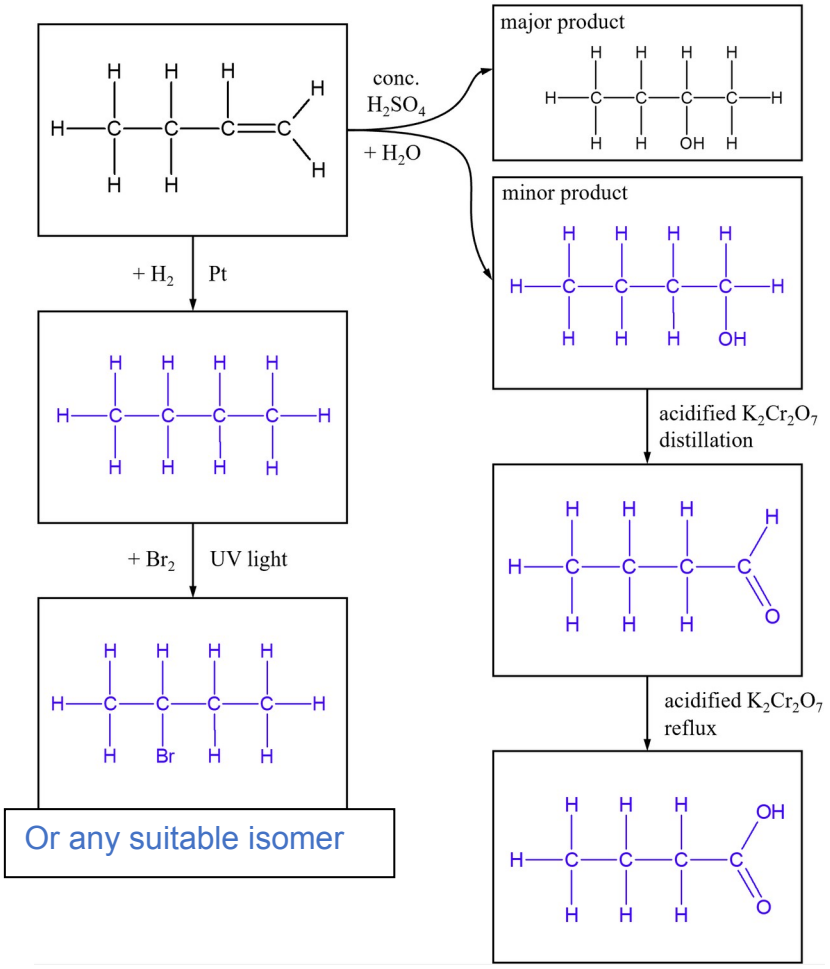
26.d.

Marking Criteria	Marks
• Uses the graph to estimate the pK_a of 4-chlorobutanoic acid and hence calculates the K_a of the acid.	**2**
• Uses the graph to estimate the pK_a of 4-chlorobutanoic acid or calculates the K_a of the acid from an incorrect estimate of pK_a	**1**

From the graph, the pH when half of the acid has been neutralised = approx 4.5
Hence $K_a = 10^{-4.5} = 3.2 \times 10^{-5}$

27.

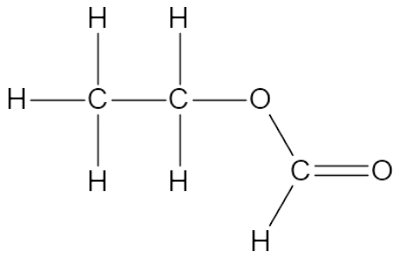
Marking Criteria	Marks
• Draws correct structural formulae for all compounds	5
• Draws correct structural formulae for four compounds	4
• Draws correct structural formulae for three compounds	3
• Draws structural formula that demonstrate an understanding of some reactions	2
• Some relevant information	1



28.

Marking Criteria	Marks
• Draws the structural formula for ethyl methanoate (name unnecessary) • Justifies structure demonstrating extensive understanding of data in all spectra and in the question stem • Refers to features of each spectrum specifically	7
• Draws the structural formula for an isomer of ethyl methanoate • Justifies structure demonstrating thorough understanding of data in all spectra and in the question stem Refers to relevant features in the spectra	6
• Demonstrates a sound understanding of most types of spectroscopy in the question • Justifies structure that has been drawn with reference to data in spectra	4−5
• Demonstrates some understanding of the information that can be determined from different types of spectra	2−3
• Some relevant information	1

The compound is described as smelling sweet and contains only C, H, and O. It is likely an ester.



Mass

- Parent ion peak at m/z = 74
- If an ester, it must contain at least two O atoms, so empirical formula could be $C_3H_6O_2$
- Base peak at 31 could be CH_3O indicating methyl… ester

Infrared

- Narrow peak near 3000 cm^{-1} → no OH, more likely to be CH
- Peak at 1750 cm^{-1} → C=O bond
- Peak near 1200 cm^{-1} → C−O bond

Proton NMR

- Singlet with relative peak area = 1 → one H atom well separated from others
- Quartet with relative peak area = 2 → two H atoms neighbouring a set of three
- Triplet with relative peak area = 3 → three H atoms neighbouring a set of two
  The last two points indicate that the molecule has $-CH_2-CH_3$, which appears in the MS at m/z = 29

^{13}C NMR

- Three peaks → three different carbon atom environments
- Peak at ~160 ppm → C=O, could be ester or acid (but OH ruled out by IR spectrum), so ester
- Peak at ~60 ppm → amine (ruled out, empirical formula has no nitrogen), alcohol (already ruled out) ether (but there must also be a C=O bond), or ester, supported by other data above.

The spectra indicate that the compound has $-CH_2-CH_3$ bound to O−CH=O in an ester. The chain lengths are 2 and 1 carbons as indicated by the ^1H NMR spectrum and the mass spectrum.

29.

Marking Criteria	Marks
• Correctly calculates K_{eq} showing working	4
• Completes most steps of the calculations	3
• Correctly carries out some steps of the calculations	2
• Provides some relevant information	1

Initial concentrations of reactants given in question. Concentration of (liquid) water is unchanging and is unnecessary to calculate K_{eq}. Initial concentration of $[CoCl_4]^{2-}$ is zero (absorption starts at zero). Final absorbance of $[CoCl_4]^{2-}$is 0.40 which corresponds to a concentration of 6×10^{-4} mol L^{-1}.

Concentrations are in mol L^{-1}	$[Co(H_2O)_6]^{2+}(aq)$ + $4Cl^-(aq)$ ⇌ $[CoCl_4]^{2-}(aq)$ + ~~$6H_2O(l)$~~		
Initial	0.36	0.99	0
Change	-6×10^{-4}	$-4 \times (6 \times 10^{-4})$	$+6 \times 10^{-4}$
Final	0.3594	0.9876	6×10^{-4}

$$K_{eq} = ¿¿$$

30.a.

Marking Criteria	Marks
• Calculates the pH of sulfuric acid.	1

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$
$[H^+] = 0.005 \times 2 = 0.01M$
$pH = -\log[H^+] = -\log 0.01 = 2$

30.b.

Marking Criteria	Marks
• Provides two correctly balanced chemical equations.	**2**
• Provides one correctly balanced chemical equation.	**1**

H_2SO_4 (aq) → HSO_4^- (aq) + H^+(aq)

HSO_4^- (aq) ⇔ SO_4^{2-} (aq) + H^+ (aq)

30.c.

Marking Criteria	Marks
• Provides a thorough description of the procedure to make a standard solution, including all necessary equipment.	**3**
• Provides a sound description of the procedure to make a standard solution, including most of the necessary equipment.	**2**
• Provides some relevant information.	**1**

1. Weigh some solid $NaHSO_4$ on an electronic balance into a clean beaker.

2. Dissolve the solid in some distilled water and transfer to a clean, dry 250 mL volumetric flask using a filter funnel. Rinse the beaker a few times and transfer liquid to flask to ensure all of the dissolved $NaHCO_3$ is transferred to flask.
3. Add sufficient distilled water so that the bottom of the meniscus is on the calibration line.

30.d.

Marking Criteria	Marks
• Calculates the K_b of the SO_4^{2-} ion	**3**
• As above with one error or omission.	**2**
• Completes one correct step in the calculation to determine the concentration of the K_b of the SO_4^{2-} ion	**1**

Initial n ($NaHSO_4$) = m/MM = 0.605 / 120.068 = 5.0388×10^{-3} mol

Initial $[HSO_4^-]$ = n/V = 5.0388×10^{-3} / 0.1 = 0.050388 M

pH=1.72
$[H^+] = 10^{-1.72} = 0.0191$

$K_a = [H^+][SO_4^{2-}] / [HSO_4^-] = 0.01912^2 / (0.050388 - 0.0191) = 0.01912^2 / 0.031288 = 0.0117$

$K_b (SO_4^{2-}) = 1x10^{-14} / 0.0117 = 8.55 \times 10^{-13}$

31.a.

Marking Criteria	Marks
• Calculates the value of Q and demonstrates that the solution is not saturated at 30s.	**3**
• As above with one error or omission	**2**
• Completes one correct step in the calculation.	**1**

$Ca(OH)_2$ (s) → Ca^{2+} (aq) + $2OH^-$ (aq)

pH (at 30s) = 11.8 Thus pOH = 14-11.8 = 2.2

$[OH^-] = 10^{-2.2} = 6.30 \times 10^{-3}$

Thus $[Ca^{2+}] = 3.15 \times 10^{-3}$

$Q = [Ca^{2+}][OH^-]^2 = 3.15x\ 10^{-3} x\ (6.30 \times 10^{-3})^2 = 1.25x10^{-7}$

K_{sp} ($Ca(OH)_2$)= 5.02×10^{-6}

Since Q is just lower than K_{sp}, the solution is not yet saturated.

31.b.

Marking Criteria	Marks
• Calculates the concentration of Ca^{2+} in a saturated solution of calcium hydroxide in ppm.	**3**
• As above with one error or omission	**2**
• Completes one correct step in the calculation.	**1**

K_{sp} ($Ca(OH)_2$)= 5.02×10^{-6}

Let the molar solubility of calcium hydroxide be ‘s’.

$5.02 \times 10^{-6} = s \times (2s)^2$
$= 4s^3$
Solve for 's' = $[Ca^{2+}]$ in saturated solution = 0.010786 mol/L

m (Ca^{2+}) in 1L = n x MM = 0.010786 x 40.08 = 0.4323236 g L^{-1} = 432 mgL^{-1} = 432 ppm

32.

Marking Criteria	Marks
• Refers to the data in the graph and demonstrates thorough knowledge of intermolecular forces to explain trends in boiling point due to chain length and number of OH groups	4
• Demonstrates good knowledge of intermolecular forces to explain trends in boiling point due to chain length and number of OH groups	3
• Explains a trend in terms of intermolecular forces	2
• Some relevant information	1

Boiling points are determined by the strength of the intermolecular forces.

Trend 1: boiling point increases as length of carbon chain increases, e.g.,
boiling points: methanol < ethanol < propan-1-ol < etc.

Dispersion forces are present in all molecules. The strength of dispersion forces increases with the size of the molecule. Therefore, as the chain length increases in a homologous series, the boiling point increases.

Trend 2: boiling point increases as the number of OH groups increases, e.g.,
boiling points: propan-1-ol < propane-1,3-diol < propane-1,2,3-triol

The hydroxyl group features a hydrogen atom attached to an oxygen atom, which is strongly electronegative. This makes hydrogen bonding possible. Hydrogen bonds are very strong. The more OH groups, the stronger the intermolecular forces are between molecules.

The trends are both explained by factors that increase the strength of the intermolecular forces which in turn increase the boiling point.

33a

Marking Criteria	Marks
• Calculates the % purity of sodium carbonate in the sample to 3 sig. figs and includes appropriate working.	**3**
• Carries out TWO steps in the calculation correctly-may have follow-on errors.	**2**
• Provides some relevant information.	**1**

$Na_2CO_3(aq) + 2HCl(aq) \rightarrow Na_2CO_3(aq) + CO_2(g) + H_2O(l)$
$n(HCl) = c \times V = 1.5 \times 0.01575 = 2.3625 \times 10^{-2}$ mol
$n(Na_2CO_3) = 2.3625 \times 10^{-2} / 2 = 1.18125 \times 10^{-2}$ mol
$m(Na_2CO_3) = nxMM = (1.18125 \times 10^{-2}) \times 105.99 = 1.25g$

% = 1.25/2 x 100 =62.6%

33b

Marking Criteria	Marks
• Explains why the procedure would not be valid if the contaminant was ammonium sulfate.	**2**
• Identifies one issue with the procedure if the contaminant was ammonium sulfate.	**1**

The same procedure could not be used if the contaminant was ammonium sulfate, as ammonium sulfate is highly soluble in water and the NH_4^+ ion in solution is acidic and would react with some of the carbonate ions, and thus affect the volume of HCl required to reach the endpoint.