NSW GOVERNMENT

NSW Education Standards Authority

2022 **HIGHER SCHOOL CERTIFICATE 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 2–12)

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

Section II – 80 marks (pages 13–36)

- Attempt Questions 21–36
- 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 for Questions 1–20.

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1 What term is used to define the repeating unit of a polymer?

A. Dimer

B. Isomer

C. Monomer

D. Primer

2 When a solution of a primary standard is prepared for titration, which of the following is required?

A. A burette

B. A balance

C. An indicator

D. A condenser

3 Which of the following features is NOT a characteristic of a state of equilibrium?

A. Equilibrium is achieved in a closed system.

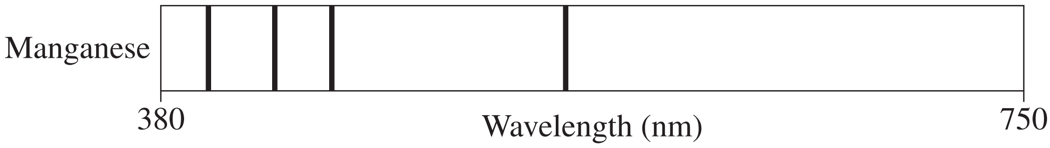
B. Equilibrium position depends on temperature.

C. Equilibrium can be reached from either direction.

D. Equilibrium concentrations of reactants and products are equal.

4 An analytical chemist was using atomic absorption spectroscopy (AAS) to determine the manganese concentration in a sample.

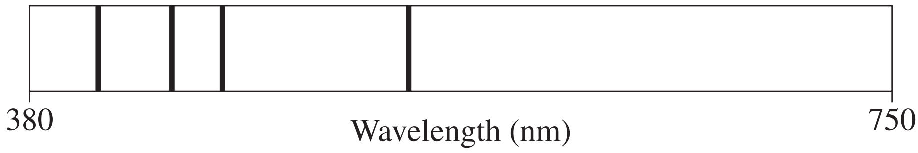
The following diagram shows the absorbance lines of manganese.



The diagrams below show the emission spectra of four AAS lamps.

Which lamp should be used to determine the manganese concentration in the sample?

A.



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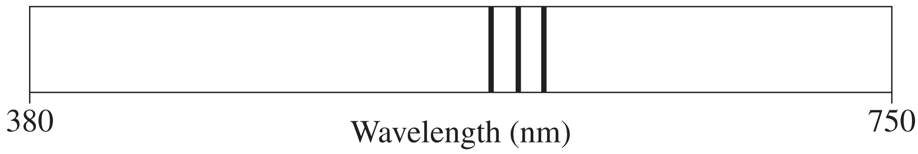

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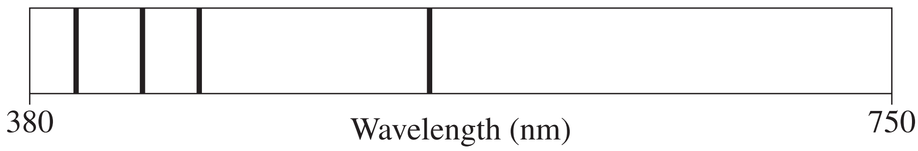

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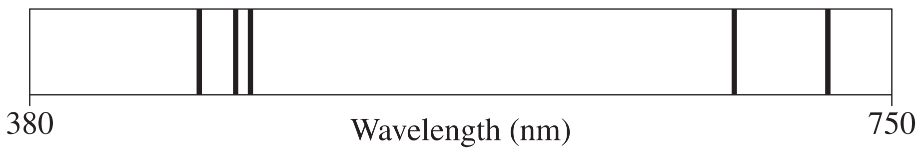


5 Which pair of ions can be distinguished using a flame test in the school laboratory?

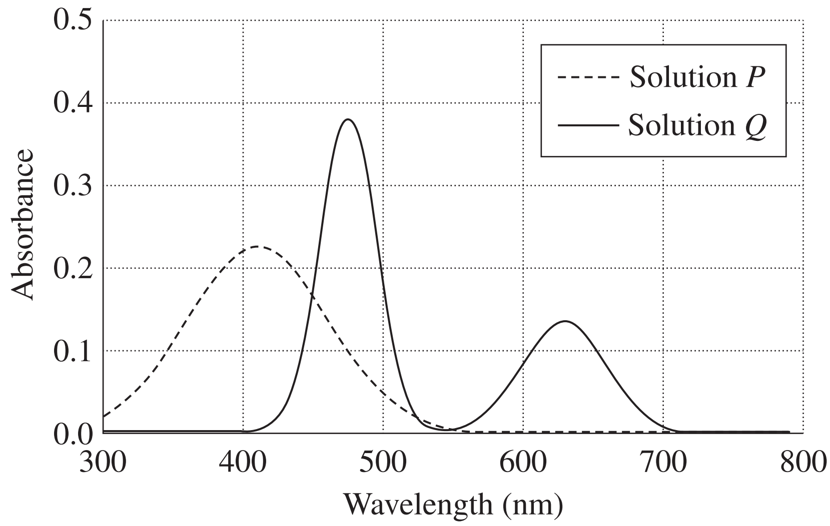
A. Ag^{+} and Mg^{2+}

B. Ba^{2+} and Ca^{2+}

C. Br^{-} and Cl^{-}

D. Fe^{2+} and Fe^{3+}

6 A UV-visible spectrometer was used to obtain the spectra of solutions of substances *P* and *Q*. The absorbance spectra are shown.



Which wavelength would be appropriate to determine the concentration of *Q* in a mixture of the two solutions?

A. 410 nm

B. 475 nm

C. 550 nm

D. 630 nm

7 The name 2-ethyl-3-chlorohexane does not follow IUPAC conventions.

What is the systematic name of this organic compound?

A. 3-chloro-2-ethylhexane

B. 4-chloro-3-methylheptane

C. 4-chloro-5-ethylhexane

D. 5-methyl-4-chloroheptane

8 A system is described as follows.

$$2NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

What is the equilibrium expression for this system?

A. $K_{eq} = [CO_2]$

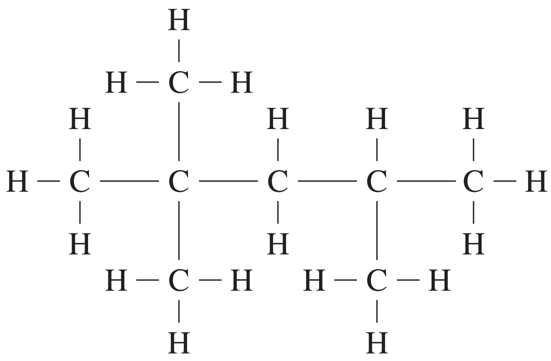
B. $K_{eq} = [CO_2][H_2O]$

C. $K_{eq} = \dfrac{1}{[CO_2][H_2O]}$

D. $K_{eq} = \dfrac{[Na_2CO_3][CO_2][H_2O]}{[NaHCO_3]^2}$

9 What is the structure of $CH_3C\left(CH_3\right)_2CH_2CH\left(CH_3\right)_2$?

A.



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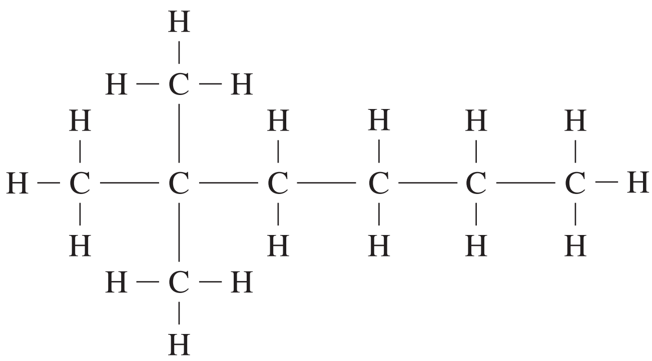

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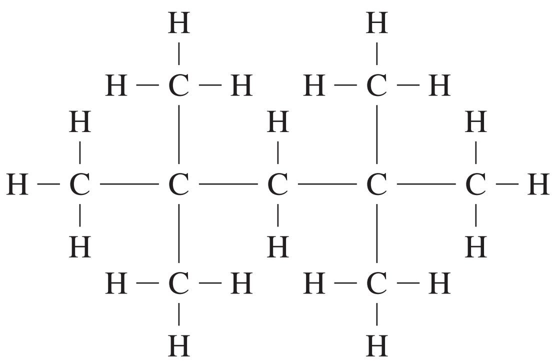
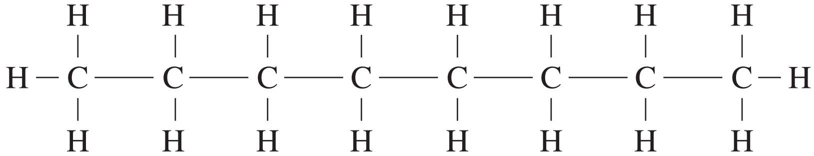


D.



10 Which equation shows the hydrogen carbonate ion acting as a Brønsted–Lowry acid?

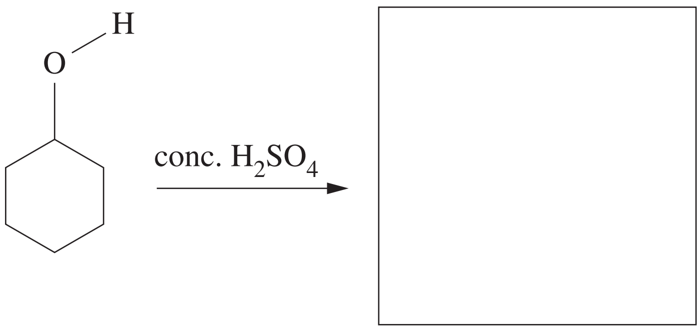
A. $HCO_3^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H^+(aq)$

B. $HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$

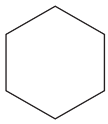
C. $HCO_3^-(aq) + NH_3(aq) \rightleftharpoons CO_3^{2-}(aq) + NH_4^+(aq)$

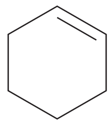
D. $HCO_3^-(aq) + HCOOH(aq) \rightleftharpoons HCOO^-(aq) + H_2CO_3(aq)$

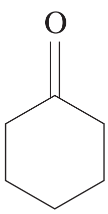
11 Cyclohexanol is an alcohol and undergoes a dehydration reaction with sulfuric acid as shown.

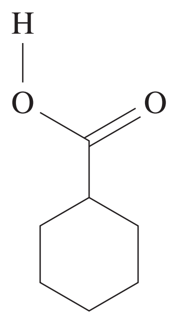


What is the major organic product of this reaction?

A. 

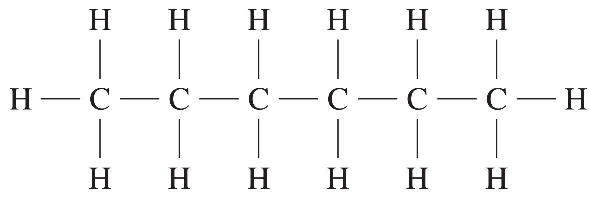
B. 

C. 

D. 

12 Which isomer of C_6H_{14} would have the fewest signals in ^{13}C NMR?

A.



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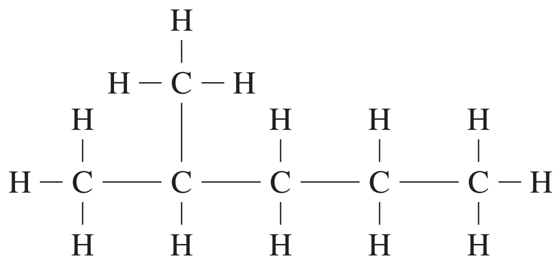

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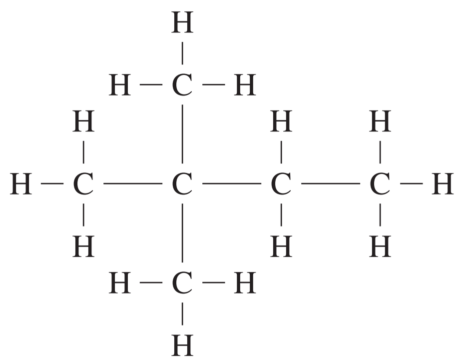

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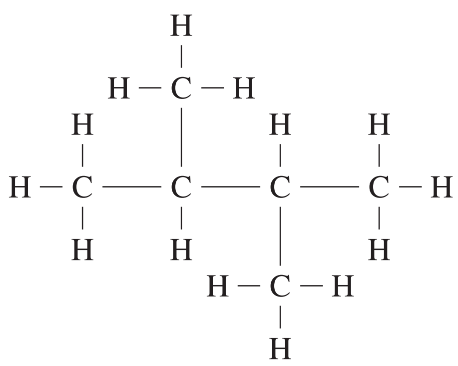


13 Nitrosyl bromide decomposes according to the following equation.

$$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g)$$

A 0.64 mol sample of NOBr is placed in an evacuated 1.00 L flask. After the system comes to equilibrium, the flask contains 0.46 mol NOBr.

What are the concentrations of NO and Br_2 in the flask at equilibrium?

	$[NO]$ (mol L^{-1})	$[Br_2]$ (mol L^{-1})
A.	0.18	0.09
B.	0.18	0.18
C.	0.36	0.18
D.	0.92	0.46

14 Nitrogen dioxide can react with itself to produce dinitrogen tetroxide.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad K_{eq} = 0.010$$

In an experiment, 100.0 cm^3 of NO_2 is placed in a syringe. The plunger is then pushed in until the volume is 50.0 cm^3, while maintaining a constant temperature. The system is allowed to return to equilibrium.

Which statement is true for the system at equilibrium?

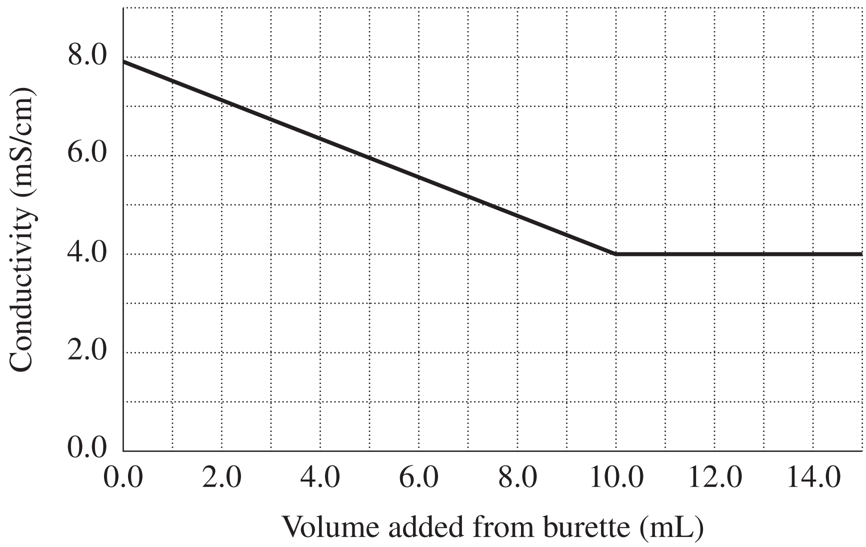
A. The value of K_{eq} has increased.

B. The ratio $\frac{[NO_2]}{[N_2O_4]}$ has decreased.

C. The concentration of N_2O_4 has decreased.

D. The concentrations of NO_2 and N_2O_4 have doubled.

15 A 25.00 mL sample of 0.1131 mol L^{-1} $HCl(aq)$ was titrated with an aqueous ammonia solution. The conductivity of the solution was measured throughout the titration and the results graphed.



What was the concentration of the ammonia solution?

A. 0.0452 mol L^{-1}

B. 0.189 mol L^{-1}

C. 0.283 mol L^{-1}

D. 0.690 mol L^{-1}

16 A blue solution of copper(II) sulfate was investigated using colourimetry. Orange light (λ = 630 nm) was used and the pathlength was 1.00 cm.

Which change would result in a higher absorbance value?

A. Diluting the solution

B. Using a higher intensity lamp

C. Using blue light (λ = 450 nm)

D. Setting the pathlength to 2.00 cm

17 A 2.0 g sample of silver carbonate (*MM* = 275.81 g mol^{-1}) was added to 100.0 mL of water in a beaker. The solubility of silver carbonate at this temperature is 1.2×10^{-4} mol L^{-1}. It was then diluted by adding another 100.0 mL of water.

What is the ratio of the concentration of silver ions in solution before and after dilution?

A. 1 : 1

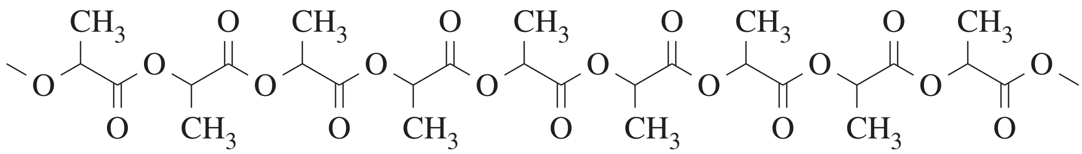
B. 1 : 2

C. 2 : 1

D. 4 : 1

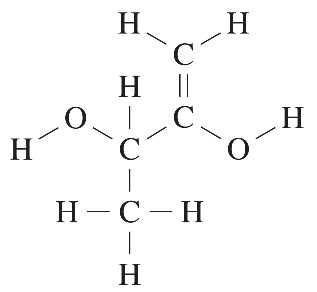
18 A low molecular weight biopolymer is being investigated for its suitability for medical use. In one trial a molecular weight of 2900 ± 100 g mol^{-1} proved to be optimum.

A section of this biopolymer is shown.



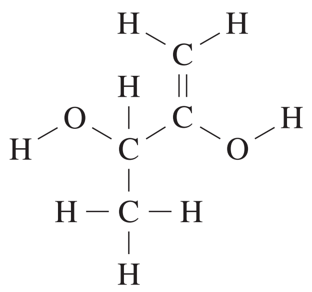
Which will produce the suitable biopolymer?

A.



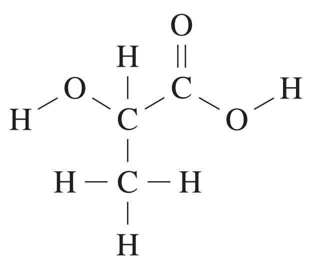
Molar mass: 88.01 g mol^{-1}
Number of units: 42

B.



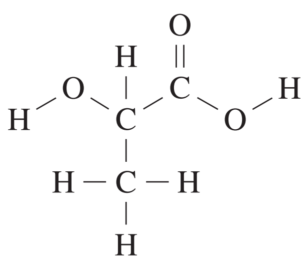
Molar mass: 88.01 g mol^{-1}
Number of units: 33

C.



Molar mass: 90.078 g mol^{-1}
Number of units: 32

D.



Molar mass: 90.078 g mol^{-1}
Number of units: 40

19 What is the molar solubility of iron(II) hydroxide?

A. 2.3×10^{-6} mol L^{-1}

B. 2.9×10^{-6} mol L^{-1}

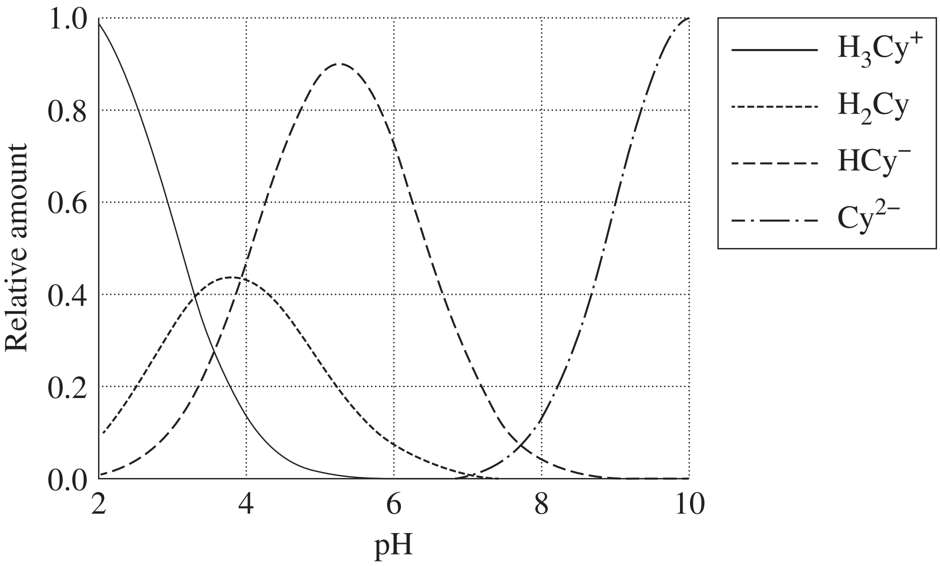
C. 3.7×10^{-6} mol L^{-1}

D. 4.9×10^{-9} mol L^{-1}

20 Cyanidin is a plant pigment that may be used as a pH indicator. It has four levels of protonation, each with a different colour, represented by these equilibria:

$$\underset{\text{Red}}{H_3Cy^+} \underset{+H^+}{\overset{-H^+}{\rightleftharpoons}} \underset{\text{Colourless}}{H_2Cy} \underset{+H^+}{\overset{-H^+}{\rightleftharpoons}} \underset{\text{Purple}}{HCy^-} \underset{+H^+}{\overset{-H^+}{\rightleftharpoons}} \underset{\text{Blue}}{Cy^{2-}}$$

The following graph shows the relative amount of each species present at different pH values.



What colour would the indicator be if added to a 0.75 mol L^{-1} solution of hypoiodous acid, HIO (pK_a = 10.64)?

A. Red

B. Colourless

C. Purple

D. Blue

Do NOT write in this area.

2022 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–36
Allow about 2 hours and 25 minutes for this section

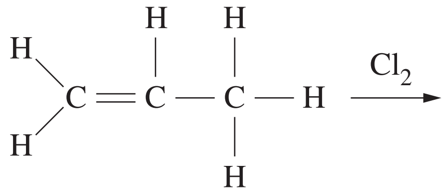
Instructions

- Write your Centre Number and 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)

Prop-1-ene reacts with Cl_2 in an addition reaction. In the box given, draw the structural formula of the product of this reaction. **2**



Question 22 (2 marks)

The following equation describes an equilibrium reaction. **2**

$$HF(aq) + PO_4^{3-}(aq) \rightleftharpoons HPO_4^{2-}(aq) + F^-(aq)$$

Identify ONE base and its conjugate acid in the above equation.

Base	*Conjugate acid*

Please turn over

Question 23 (6 marks)

Consider the following system which is at equilibrium in a rigid, sealed container.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -950 \text{ kJ mol}^{-1}$$

(a) Identify what would happen to the amount of $NO(g)$ if the temperature was increased. **1**

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(b) Explain why a catalyst does not affect the equilibrium position of this system. **2**

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(c) Using collision theory, explain what would happen to the concentration of $NO(g)$ if $H_2O(g)$ was removed from the system. **3**

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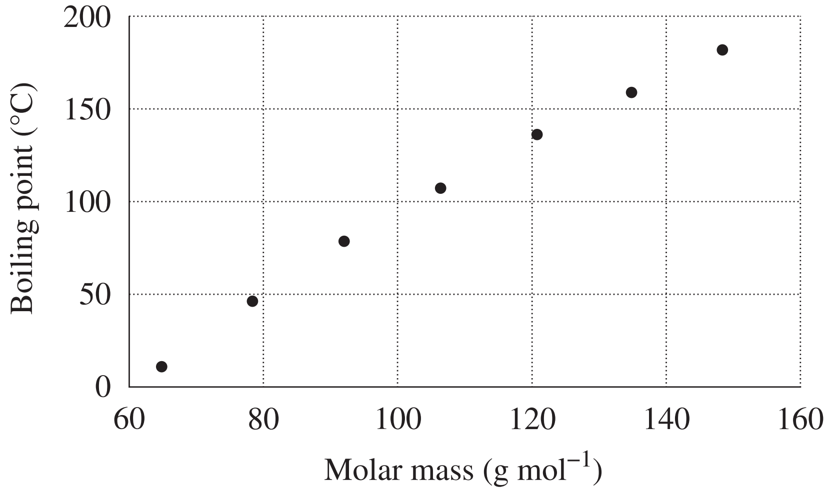
Question 24 (3 marks)

The following graph shows the boiling points of some 1-chloroalkanes. **3**



Explain the trend shown in the graph.

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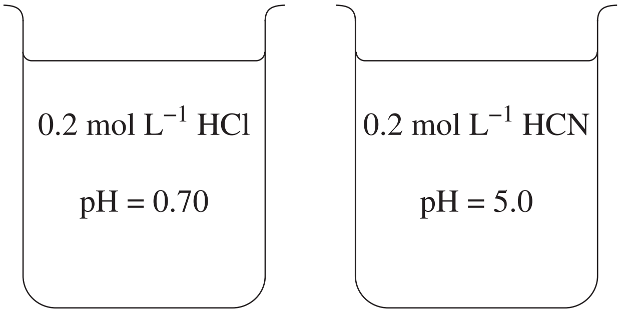
Question 25 (3 marks)

The pH of two aqueous solutions was compared. **3**



Explain why the HCN(*aq*) solution has a higher pH than the HCl(*aq*) solution. Include a relevant chemical equation for the HCN(*aq*) solution.

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Question 26 (4 marks)

Students conducted an experiment to determine ΔH for the reaction between sodium hydroxide and hydrochloric acid.

The data from one student are shown in the table below.

Mass of 100.0 mL of 0.50 mol L^{-1} HCl	100.7 g
Mass of 100.0 mL of 0.50 mol L^{-1} NaOH	102.0 g
Initial temperature of HCl solution	21.0°C
Initial temperature of NaOH solution	21.2°C
Final temperature of mixture	24.4°C

Assume that all the solutions have the same specific heat capacity as water.

(a) Calculate the heat energy released in this experiment. **2**

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(b) A second student using the same procedure obtained 2.6×10^3 J for the heat energy released in their experiment. **2**

Use this value to determine the enthalpy of neutralisation, ΔH, in kJ mol^{-1}, for the reaction shown.

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

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Question 27 (7 marks)

A bottle labelled 'propanol' contains one of two isomers of propanol.

(a) Draw the TWO isomers of propanol. **2**

(b) Describe how ^{13}C NMR spectroscopy might be used to identify which isomer is in the bottle. **2**

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(c) Each isomer produces a different product when oxidised. **3**

Write equations to represent the oxidation reactions of the two isomers. Include reaction conditions.

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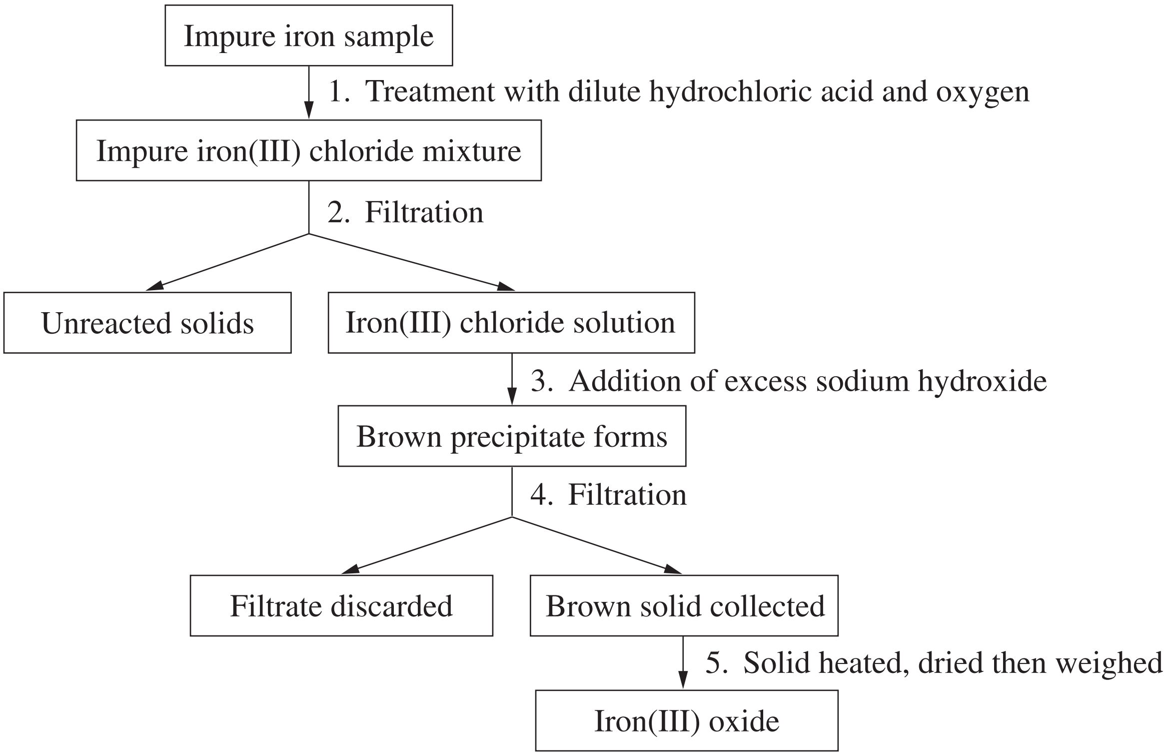
Question 28 (5 marks)

The iron content of an impure sample (4.32 g) was determined by the process shown in the flow chart.



(a) Identify the brown precipitate formed at the end of step 3. **1**

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(b) Calculate the percentage of iron in the original impure sample if 4.21 g of iron(III) oxide (Fe_2O_3) was collected. Assume that all the iron was converted to iron(III) oxide. **4**

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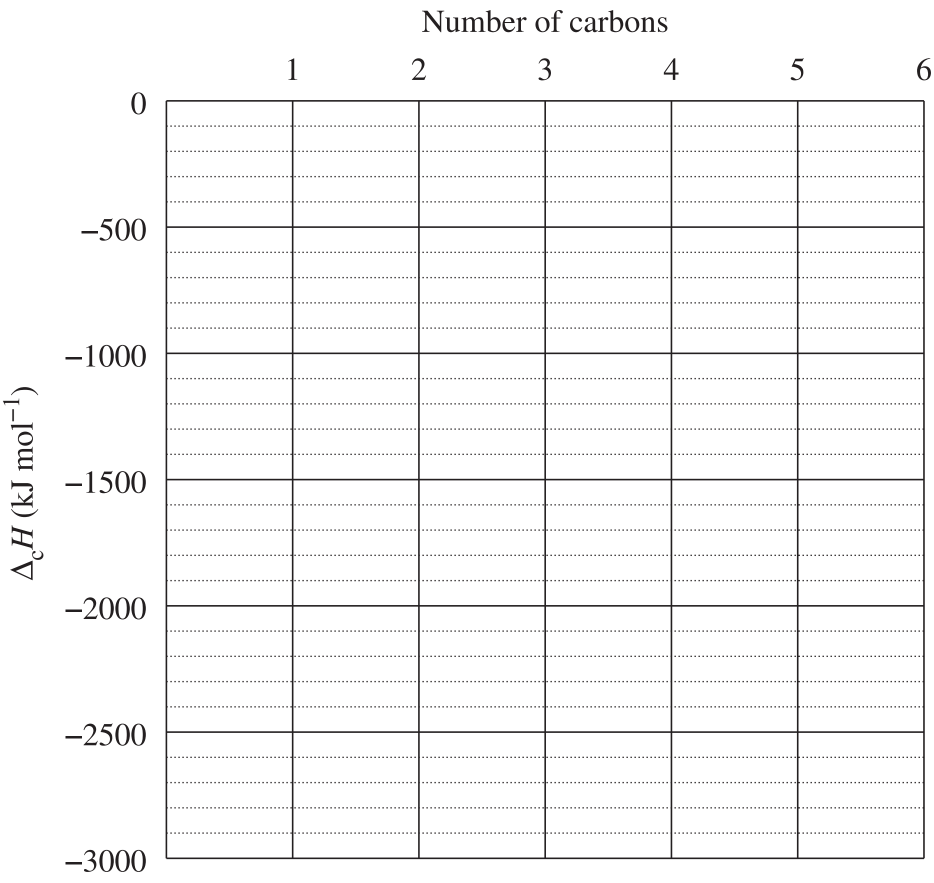
Question 29 (5 marks)

The enthalpies of combustion of four alcohols were determined in a school laboratory.

The results are shown in the table.

Alcohol	$\Delta_c H$ (kJ mol^{-1})
Methanol	−596
Ethanol	−978
Propan-1-ol	−1507
Pentan-1-ol	−2910

(a) Plot the results, including a curved line of best fit, to estimate the enthalpy of combustion of butan-1-ol. **3**



Enthalpy of combustion of butan-1-ol

Question 29 continues on page 23

Question 29 (continued)

(b) The published value for the enthalpy of combustion of pentan-1-ol is closer to -3331 kJ mol^{-1}. **2**

Justify ONE possible reason for the difference between the school's results and published values.

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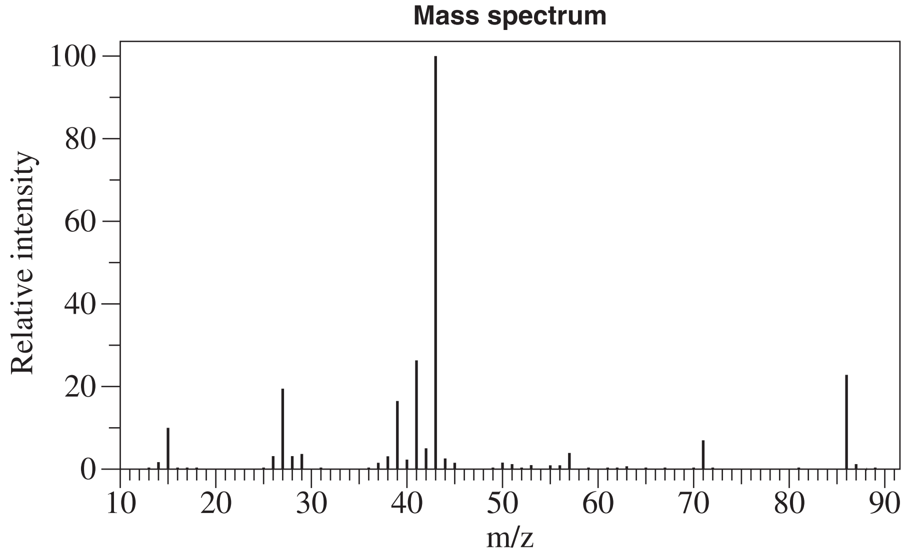
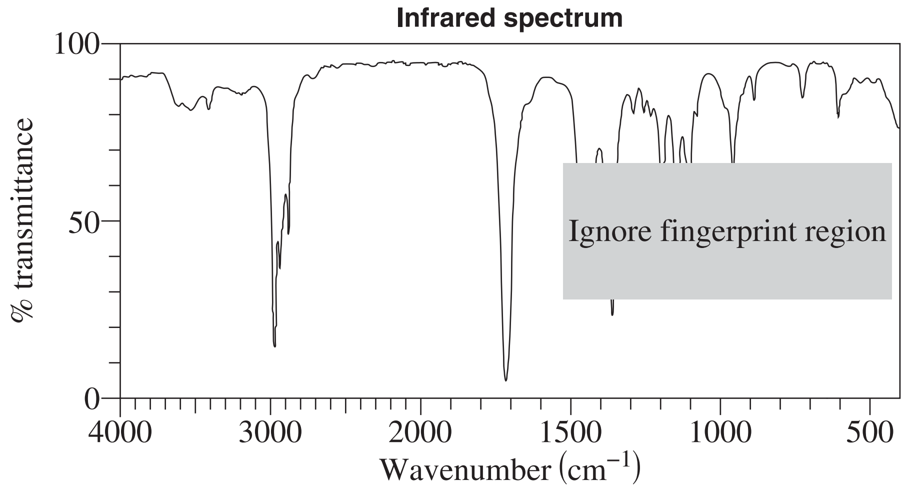
End of Question 29

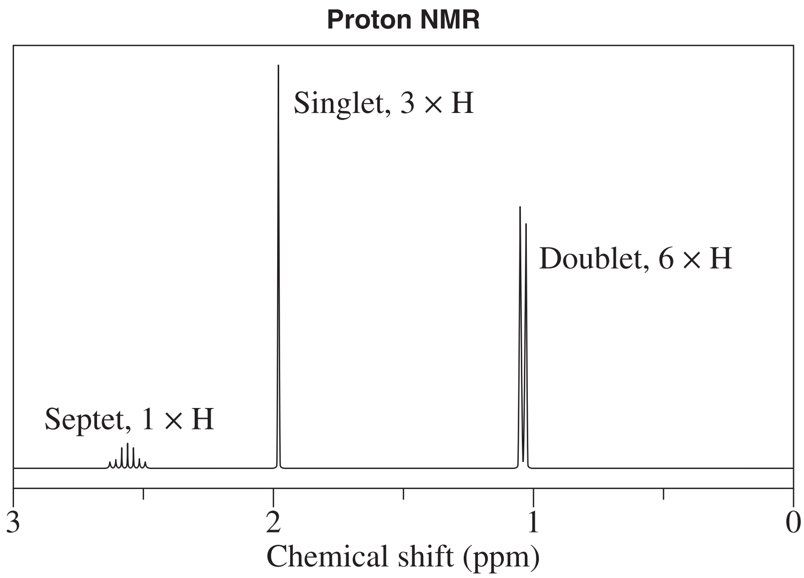
Please turn over

Question 30 (7 marks)

The following spectra were obtained for an unknown organic compound. **7**

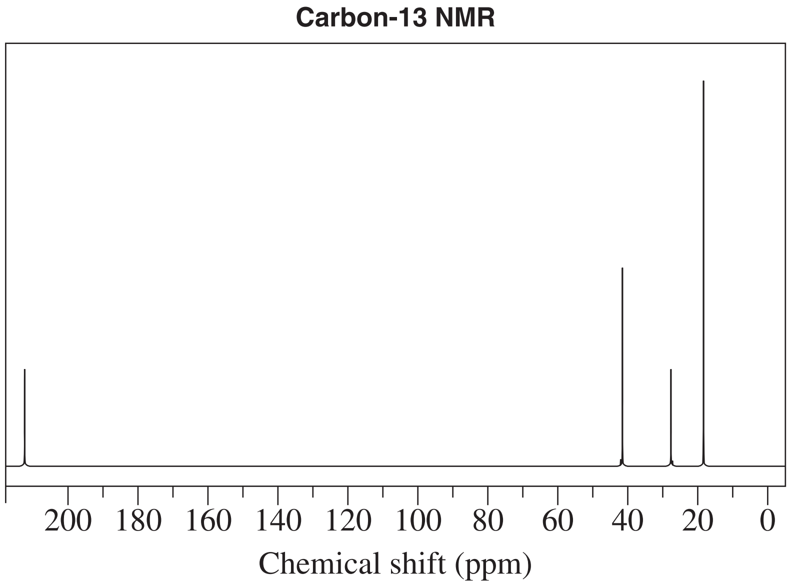






Question 30 continues on page 25

Question 30 (continued)



In the space provided, draw and name the unknown compound that is consistent with all the information provided. Justify your answer with reference to the information provided.

Structure:

Name: ....

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Question 30 continues on page 26

Question 30 (continued)

End of Question 30

Do NOT write in this area.

Question 31 (7 marks)

Silver ions form the following complex with ammonia solution.

$$Ag^{+}(aq) + 2NH_3(aq) \rightleftharpoons \left[Ag\left(NH_3\right)_2\right]^{+}(aq)$$

The equilibrium constant is 1.6×10^{7} at 25°C.

(a) In order to determine the free Ag^{+} concentration in an aqueous ammonia solution, a student carried out a precipitation titration with $NaI(aq)$ as the titrant. **3**

Evaluate the suitability of this method.

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(b) If 0.010% of the total silver ions in solution are present as $Ag^{+}(aq)$ at equilibrium, calculate the equilibrium concentration of aqueous ammonia in this solution. **4**

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Question 32 (8 marks)

The concentration of citric acid, a triprotic acid, in a carbonated soft drink was to be determined.

Step 1: A solution of NaOH(*aq*) was standardised by titrating it against 25.00 mL aliquots of a solution of the monoprotic acid potassium hydrogen phthalate (KHP). The KHP solution was produced by dissolving 4.989 g in enough water to make 100.0 mL of solution. The molar mass of KHP is 204.22 g mol^{-1}.

The results of the standardisation titration are given in the table.

Titration	*Volume NaOH* (mL)
1	28.60
2	27.40
3	27.20
4	27.60

Step 2: A 75.00 mL bottle of the drink was opened and the contents quantitatively transferred to a beaker. The soft drink was gently heated to remove CO_2.

Step 3: The cooled drink was quantitatively transferred to a 250.0 mL volumetric flask and distilled water was added up to the mark.

Step 4: 25.00 mL samples of the solution were titrated with the NaOH(*aq*) solution. The average volume of NaOH(*aq*) used was 13.10 mL.

Question 32 continues on page 29

Question 32 (continued)

(a) Calculate the concentration of the triprotic citric acid in the soft drink. **6**

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(b) Explain how your answer to part (a) would be different if the carbon dioxide was not removed from the soft drink. **2**

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End of Question 32

Question 33 (8 marks)

Analyse how a student could design a chemical synthesis process to be undertaken in the school laboratory. In your response, use a specific process relating to the synthesis of an organic compound, including a chemical equation, and refer to: **8**

- selection of reagent(s)
- reaction conditions
- any potential hazards and any safety precautions to minimise the risk
- yield and purity of the product(s).

Question 33 continues on page 31

End of Question 33

Please turn over

Question 34 (4 marks)

Sodium hypochlorite (NaOCl) is the active ingredient in pool chlorine. It completely dissolves in water to produce the hypochlorite ion (OCl^-), which undergoes hydrolysis according to the following equilibrium. **4**

$$OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$$

The equilibrium constant for this reaction at 25°C is 3.33×10^{-7}.

For pool chlorine to be effective the pH is maintained by a different buffer at 7.5 and the hypochlorous acid (HOCl) concentration should be 1.3×10^{-4} mol L^{-1}.

Calculate the volume of 2.0 mol L^{-1} sodium hypochlorite solution that needs to be added to a 1.00×10^4 L pool to meet the required conditions.

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Question 35 (5 marks)

A precipitate of strontium hydroxide $Sr(OH)_2$, (MM = 121.63 g mol^{-1}) was produced when 80.0 mL of 1.50 mol L^{-1} strontium nitrate solution was mixed with 80.0 mL of 0.855 mol L^{-1} sodium hydroxide solution. The mass of the dried precipitate was 3.93 g. **5**

What is the K_{sp} of strontium hydroxide?

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Please turn over

Question 36 (4 marks)

Consider the equilibrium system shown. **4**

$$H_2O(l) \rightleftharpoons H_2O(g)$$

In a laboratory at 23°C, a 100 mL sample of water is held in a beaker and another 100 mL sample is held in a sealed bottle.

Explain the differences in evaporation for these TWO samples. In your answer, consider changes in enthalpy and entropy for this process.

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End of paper

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Section II extra writing space

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Section II extra writing space

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

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Chemistry

FORMULAE SHEET

$n = \dfrac{m}{MM}$	$c = \dfrac{n}{V}$	$PV = nRT$
$q = mc\Delta T$	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	$\mathrm{pH} = -\log_{10}\left[\mathrm{H^+}\right]$
$pK_a = -\log_{10}\left[K_a\right]$	$A = \varepsilon lc = \log_{10}\dfrac{I_o}{I}$	

Avogadro constant, N_A .... $6.022 \times 10^{23}\ \mathrm{mol^{-1}}$

Volume of 1 mole ideal gas: at 100 kPa and
at 0°C (273.15 K) .... 22.71 L
at 25°C (298.15 K) .... 24.79 L

Gas constant .... $8.314\ \mathrm{J\ mol^{-1}\ K^{-1}}$

Ionisation constant for water at 25°C (298.15 K), K_w .... 1.0×10^{-14}

Specific heat capacity of water .... $4.18 \times 10^{3}\ \mathrm{J\ kg^{-1}\ K^{-1}}$

DATA SHEET

Solubility constants at 25°C

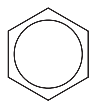
Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) hydroxide	2.2×10^{-20}
Copper(II) phosphate	1.40×10^{-37}
Iron(II) carbonate	3.13×10^{-11}
Iron(II) hydroxide	4.87×10^{-17}
Iron(III) hydroxide	2.79×10^{-39}
Iron(III) phosphate	9.91×10^{-16}

Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
Silver iodide	8.52×10^{-17}
Silver phosphate	8.89×10^{-17}
Silver sulfate	1.20×10^{-5}

Infrared absorption data

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

^{13}C NMR chemical shift data

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

UV absorption

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

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

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

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for the standard potentials. Some data may have been modified for examination purposes.

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

2022 HSC Chemistry
Marking Guidelines

Section I

Multiple-choice Answer Key

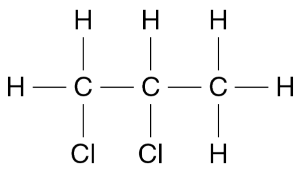
Question	Answer
1	C
2	B
3	D
4	C
5	B
6	D
7	B
8	B
9	A
10	C
11	B
12	D
13	A
14	B
15	C
16	D
17	A
18	D
19	A
20	C

Section II

Question 21

Criteria	Marks
• Provides the correct structure	2
• Structure drawn with an addition of at least one chlorine atom	1

Sample answer:



Question 22

Criteria	Marks
• Provides a correct base and its conjugate acid	2
• Provides a correct base or conjugate acid from the reaction	1

Sample answer:

Base	*Conjugate acid*
PO_4^{3-}	HPO_4^{2-}

OR

Base	*Conjugate acid*
F^-	HF

Question 23 (a)

Criteria	Marks
• Identifies what would happen to the amount of NO(*g*)	1

Sample answer:

Amount of NO would decrease.

Question 23 (b)

Criteria	Marks
• Explains why a catalyst does not affect equilibrium position in terms of reaction rates	2
• Provides some relevant information	1

Sample answer:

A catalyst will increase the rate of the forward and reverse reactions of this system. As both rates increase, the overall equilibrium position is unchanged.

Question 23 (c)

Criteria	Marks
• Identifies the change in NO concentration • Explains the change in terms of collision theory	3
• Shows some understanding of the relationship between collision theory and equilibrium concentrations	2
• Provides some relevant information	1

Sample answer:

When $H_2O(g)$ is removed, there are fewer $H_2O(g)$ molecules to collide with NO in the reverse reaction which decreases the rate. The rate of the forward reaction is therefore proportionally higher. As a result [NO] increases.

Question 24

Criteria	Marks
• Provides a thorough explanation of the trend with reference to dispersion forces	3
• Provides some explanation of the trend	2
• Provides some relevant information	1

Sample answer:

As molar mass increases, the boiling point increases. As molar mass increases, the number of electrons increases which increases the strength of the dispersion forces between molecules. Stronger intermolecular forces require more energy to break and therefore a higher boiling point.

Question 25

Criteria	Marks
• Provides a balanced chemical equation • Explains the difference in pH in terms of weak and strong acids and their relative ionisation	3
• Demonstrates some understanding of weak and strong acids	2
• Provides some relevant information	1

Sample answer:

$HCN(aq)$ is a weak acid, so partially ionises: $HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$. $HCl(aq)$ is a strong acid and ionises completely. So the $[H^+]$ of the $HCN(aq)$ solution will be lower than the $[H^+]$ of the $HCl(aq)$ solution. As $pH = -\log[H^+]$, the $HCN(aq)$ solution will have a higher pH.

Question 26 (a)

Criteria	Marks
• Correctly calculates the heat energy released	2
• Provides some relevant information	1

Sample answer:

$T_{i(\text{av})} = 21.1°\text{C}$

$\Delta T = 24.4 - 21.1 = 3.3 \text{ K}$

Specific heat capacity of water $= 4.18 \times 10^3 \text{ J K}^{-1} \text{ kg}^{-1}$

Mass of final solution $= 100.7 \text{ g} + 102.0 \text{ g} = 202.7 \text{ g}$

$q = mc\Delta T = 0.2027 \text{ kg} \times 4.18 \times 10^3 \text{ J K}^{-1} \text{ kg}^{-1} \times 3.3 \text{ K} = 2796 \text{ J} = 2.796 \text{ kJ} = 2.8 \text{ kJ}$

Question 26 (b)

Criteria	Marks
• Correctly calculates enthalpy of neutralisation	2
• Provides some relevant information or working	1

Sample answer:

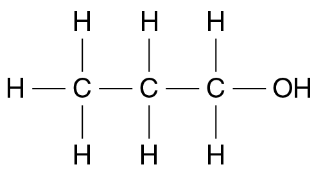
mol of H_2O formed = mol of HCl reacted $= 0.1000 \text{ L} \times 0.50 \text{ mol} = 0.050 \text{ mol}$

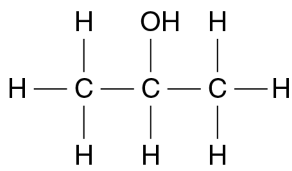
$$\Delta H = \frac{2.6 \text{ kJ}}{0.050 \text{ mol}} = -52 \text{ kJ mol}^{-1}$$

Question 27 (a)

Criteria	Marks
• Draws the correct structure for both isomers of propanol	2
• Draws the correct structure for one isomer of propanol OR • Demonstrates an understanding of the structure of the isomer(s)	1

Sample answer:





Answers could include:

Other representations

Question 27 (b)

Criteria	Marks
• Describes the use of ^{13}C NMR to identify that the two isomers have different signals and could thus be used to identify the isomer	2
• Provides some relevant information	1

Sample answer:

If the spectrum produced by ^{13}C NMR has 2 signals, then the isomer that is in the labelled bottle is propan-2-ol and if it has three then it is propan-1-ol.

Question 27 (c)

Criteria	**Marks**
• Writes TWO correct equations with correct products and includes correct reaction conditions	3
• Writes ONE correct equation, with correct product and correct reaction conditions OR • Writes TWO equations with correct product and does not include or includes incorrect reaction conditions	2
• Provides some relevant information	1

Sample answer:

$$CH_3CH_2CH_2OH \xrightarrow{H^+/Cr_2O_7^{2-}} CH_3CH_2COOH$$

$$CH_3CHOHCH_3 \xrightarrow{H^+/Cr_2O_7^{2-}} CH_3COCH_3$$

Answers could include:

- Word equations
- Other representations including skeletal structures
- Other appropriate reagents and corresponding products.

Question 28 (a)

Criteria	Marks
• Correctly identifies the brown precipitate formed	1

Sample answer:

Iron(III) hydroxide

Question 28 (b)

Criteria	Marks
• Correctly calculates the percentage of iron including significant figures	4
• Provides the main steps of the calculation	3
• Provides some relevant steps of the calculation	2
• Provides some relevant information or working	1

Sample answer:

Molar mass of iron(III) oxide (Fe_2O_3) = 159.70 g mol^{-1}

Amount of Fe_2O_3 produced = $\dfrac{4.21\ \text{g}}{159.70\ \text{g mol}^{-1}} = 0.026362$ mol

Amount of Fe = 2 × moles Fe_2O_3 = 2 × 0.026362 = 0.052724 mol

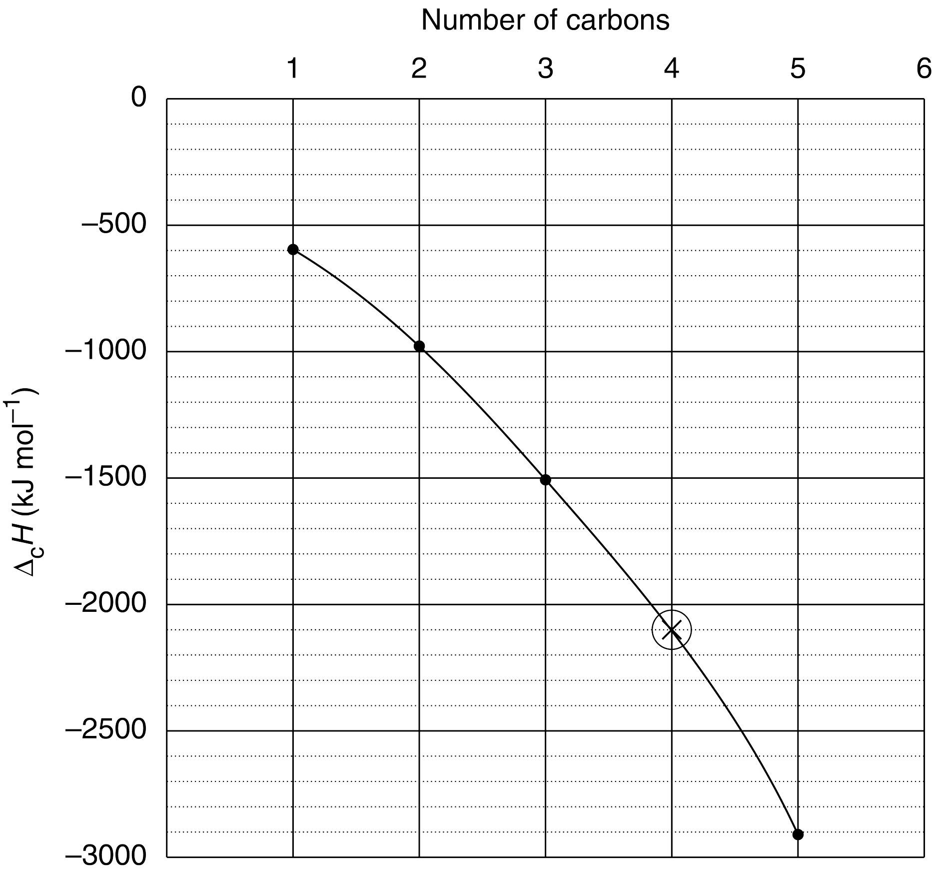
Mass of Fe in sample = 0.052724 mol × 55.85 g mol^{-1} = 2.9446 g

% Fe in original impure sample = $\dfrac{2.9446\ \text{g}}{4.32\ \text{g}} \times 100\% = 68.163\% = 68.2\%$

Question 29 (a)

Criteria	Marks
• Plots the points on the graph correctly, draws a curved line of best fit and estimates the enthalpy of combustion of butan-1-ol including units and negative sign	3
• Provides a substantially correct graph with appropriate estimation OR • Provides a correct graph	2
• Provides some relevant information	1

Sample answer:



Enthalpy of combustion of butan-1-ol ≈ –2100 kJ mol^{-1}

Question 29 (b)

Criteria	Marks
• Provides a justification	2
• Provides some relevant information	1

Sample answer:

In a school laboratory, the calorimeters used are often simple, such as a tin can. There will be significant heat loss as some of the heat is lost to the environment or equipment. The published value is obtained using more appropriate equipment in a standard environment.

Answers could include:

- Incomplete combustion of the alcohol – this produces less heat energy than complete combustion.
- Heat not evenly distributed in water measured and therefore measured to be less than the amount of heat energy produced.

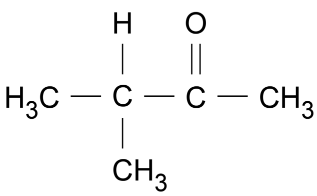
Question 30

Criteria	Marks
• Names and draws correct structure of 3-methylbutan-2-one • Justifies the correct structure showing an extensive understanding of the interpretation of spectroscopic data • Refers explicitly to the relevant spectroscopic data	7
• Draws correct structure for 3-methylbutan-2-one • Justifies the structure showing a thorough understanding of the interpretation of spectroscopic data • Refers to relevant spectroscopic data	6
• Shows a sound understanding of the interpretation of spectroscopic data • Uses relevant information presented in the question to justify the structure of the compound • Provides a name or structural formula consistent with the analysis	4–5
• Demonstrates some understanding of the interpretation of spectroscopic data	2–3
• Provides some relevant information	1

Answers could include:

Structural formula and *name*

3-methylbutan-2-one



Mass spectrum

- Parent molecular ion at M/Z = 86 which is consistent with the named molecule
- The base peak at M/Z = 43 is consistent with fragmentation adjacent to a carbonyl group CH_3CO^+.

IR spectrum

- Strong absorption at 1700 cm^{-1} which is consistent with carbonyl group
- Absence of broad OH stretch between 2500−3000 cm^{-1} eliminates carboxylic acids.

Carbon-13 NMR

- There are five carbons in the molecule, but the spectrum only has four different carbon environments so two carbons must have identical environments
- The signal at 220 ppm is consistent with a carbonyl group
- The signals between 18 and 40 ppm are consistent with CH and CH_3 groups.

Proton NMR

- There are three distinct hydrogen environments
- The septet (1H) is consistent with a CH adjacent to two CH_3 groups
- The singlet (3H) is consistent with a methyl group with no hydrogens on the adjacent carbon. This is consistent with CH_3CO
- The doublet (6H) is consistent with two methyl groups with one neighbouring hydrogen.

Question 31 (a)

Criteria	Marks
• Evaluates the suitability of the method	3
• Demonstrates a sound understanding of the suitability of the method	2
• Provides some relevant information	1

Sample answer:

Le Chatelier's Principle predicts that as the silver ions precipitate, the complex will decompose to release more silver ions. This disturbs the equilibrium to the left.

$$Ag^{+}(aq) + 2NH_3(aq) \rightleftharpoons \left[Ag\left(NH_3\right)_2\right]^{+}(aq)$$

This will continue until all of the complex is broken up into its ions, so the value obtained from the titration would be the total of both the free and complex silver ions rather than just the free. Therefore the method is unsuitable.

Question 31 (b)

Criteria	Marks
• Correctly calculates the concentration of ammonia	4
• Provides substantially correct calculations	3
• Provides some correct calculations	2
• Provides some relevant information or working	1

Sample answer:

$$K_{eq} = \frac{\left[\left[Ag(NH_3)_2\right]^+\right]}{\left[Ag^+\right]\left[NH_3\right]^2} = 1.6 \times 10^7$$

$$1.6 \times 10^7 \times \left[NH_3\right]^2 = \frac{\left[\left[Ag(NH_3)_2\right]^+\right]}{\left[Ag^+\right]}$$

Since the concentration of free silver is very low, assume the ratio of free to complex silver is approximately equal to 0.010% (1.0×10^{-4}).

$$\frac{\left[Ag^+\right]}{\left[\left[Ag(NH_3)_2\right]^+\right]} = 1.0 \times 10^{-4}$$

$$\frac{\left[\left[Ag(NH_3)_2\right]^+\right]}{\left[Ag^+\right]} = 1.0 \times 10^{4}$$

$$1.6 \times 10^7 \times \left[NH_3\right]^2 = 1.0 \times 10^4$$

$$\left[NH_3\right]^2 = 6.25 \times 10^{-4}$$

$$\left[NH_3\right] = 2.5 \times 10^{-2} \text{ mol L}^{-1}$$

Question 32 (a)

Criteria	Marks
• Correctly calculates the concentration of the citric acid in the undiluted bottle of carbonated soft drink in mol L^{-1}	6
• Provides substantially correct steps for calculating the concentration of the citric acid	5
• Provides the main calculation steps	4
• Provides some calculation steps	2–3
• Provides some relevant information	1

Sample answer:

Titration 1:

Amount of KHP = 4.989 g ÷ 204.22 g mol^{-1} = 0.02442953677 moles

Concentration of KHP = 0.02442953677 moles ÷ 0.1000 L = 0.2442953677 mol L^{-1}

Volume KHP = 25.00 mL
Concentration KHP = 0.2442953677 mol L^{-1}
Amount of KHP = 0.2442953677 mol L^{-1} × 0.02500 L = 0.00610738419 moles

Volume NaOH = 27.40 mL
Amount of NaOH = moles KHP = 0.00610738419 moles
Concentration NaOH = 0.00610738419 moles ÷ 0.02740 L = 0.2228972333 mol L^{-1}

Titration 2:

Volume NaOH = 13.10 mL
Concentration of NaOH = 0. 2228972333 mol L^{-1}
Amount of NaOH = 0.2228972333 mol L^{-1} × 0.01310 L = 0.00291995375 moles

Volume of citric acid = 25.00 mL
The ratio of citric acid to NaOH is 1 : 3
Amount of citric acid = moles NaOH ÷ 3 = 0.00097331791 moles (in 25 mL)
Amount of citric acid in 250 mL = 0.00097331791 moles × $\frac{250.00 \text{ mL}}{25.00 \text{ mL}}$ = 0.0097331791 moles
Amount of citric acid = 0.0097331791 moles (in 75 mL)

Concentration of citric acid =

$$c = \frac{0.0097331791 \text{ mol}}{0.07500 \text{ L}}$$

$$c = 0.1297757213 = 0.1298 \text{ mol L}^{-1}$$

Question 32 (b)

Criteria	Marks
• Correctly explains the effect of not removing the carbon dioxide on the calculated concentration of citric acid	2
• Provides some relevant information	1

Sample answer:

Carbon dioxide would react with the NaOH during the titration. A greater volume of NaOH would then have been used than was necessary to neutralise the citric acid resulting in a higher calculated concentration of the citric acid than was correct.

Question 33

Criteria	Marks
• Provides an extensive explanation of the selection of reagents, the reaction conditions, any potential hazards and any safety precautions and the yield and purity of the product produced in the chemical synthesis process • Provides correct and relevant chemical equation • Communicates an extensive understanding succinctly and logically	8
• Demonstrates a thorough knowledge of the factors to consider when designing a chemical synthesis process • Succinct and logical response	6–7
• Demonstrates a sound knowledge of at least two factors to consider when designing a chemical synthesis process	4–5
• Demonstrates basic knowledge of the factors to consider when designing a chemical synthesis process	2–3
• Provides some relevant information	1

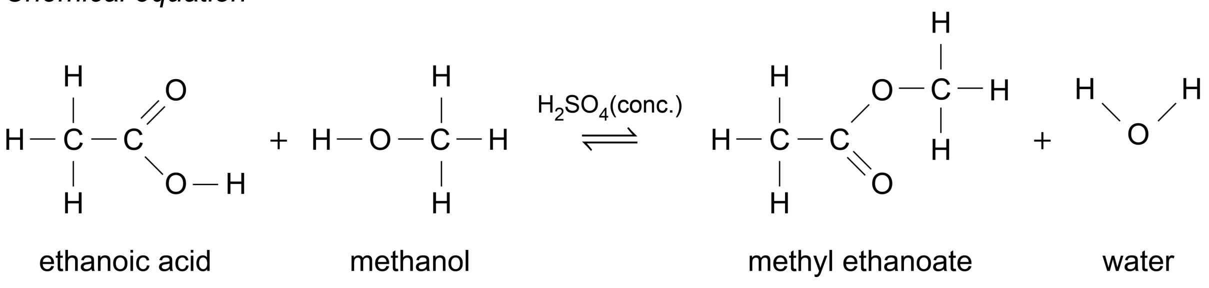
Answers could include:

Process: Esterification

Esterification can be performed in the school laboratory for the acid-catalysed reaction between an alcohol and a carboxylic acid. A student would need to choose an alcohol and carboxylic acid that are relatively non-toxic and readily available. Methanol and ethanoic acid meet these criteria. The reaction also requires an acid catalyst to speed up the reaction, and the acid should be a dehydrating agent as water is produced in the reaction. Concentrated sulfuric acid is therefore suitable.

The reaction between methanol and ethanoic acid produces the ester methyl ethanoate and water.

Chemical equation



Reaction conditions

The conditions for the process must also be considered. In addition to the small amount of concentrated sulfuric acid catalyst, the reaction should be performed under reflux by heating the alcohol, carboxylic acid and concentrated sulfuric acid in a vessel with a condenser tube attached. Reflux enables heat to be used to speed up the reaction without loss of volatile reactants or products and without the build-up of pressure that occurs with a closed vessel reaction.

Safety hazards

- Alcohols are flammable, so do not use open flames. A heating mantle should be used instead of a Bunsen burner.
- Liquid carboxylic acids are corrosive, so wear safety glasses to avoid contact with eyes.
- Concentrated sulfuric acid is corrosive, so only small quantities should be used, and safety glasses must be worn.

Yield and purity

The yield of the reaction is maximised by using a high temperature and reflux for a sufficient time (approximately 30−60 min) but as it is an equilibrium process the reaction mixture will contain methanol, ethanoic acid, water and sulfuric acid as well as the desired methyl ethanoate. This means that the reaction mixture needs to be purified to obtain the methyl ethanoate.

Question 34

Criteria	Marks
• Correctly calculates the volume of solution required	4
• Writes a correct equilibrium expression • Substantially correct calculation	3
• Writes an equilibrium expression and substitutes two correct values	2
• Provides some relevant information	1

Sample answer:

Total NaOCl = $HOCl_{pool} + OCl^{-}{}_{pool}$

$$pOH = 14 - pH = 14 - 7.5 = 6.5$$

$$\left[OH^{-}\right] = 10^{-6.5} = 3.16 \times 10^{-7} \text{ mol L}^{-1}$$

$$\left[HOCl\right] = 1.3 \times 10^{-4}$$

$$K_{eq} = 3.33 \times 10^{-7} = \frac{\left[OH^{-}\right]\left[HOCl\right]}{\left[OCl^{-}\right]}$$

$$\left[OCl^{-}\right] = \frac{\left[10^{-6.5}\right] \times \left[1.3 \times 10^{-4}\right]}{\left[3.33 \times 10^{-7}\right]}$$

$$\left[OCl^{-}\right] = 1.23 \times 10^{-4} \text{ mol L}^{-1}$$

$$\left[\text{Cl species}\right] = 1.3 \times 10^{-4} \text{ mol L}^{-1} + 1.23 \times 10^{-4} \text{ mol L}^{-1}$$

$$\left[\text{Cl species}\right] = 2.53 \times 10^{-4} \text{ mol L}^{-1}$$

$$c_1V_1 = c_2V_2$$

$$V_1 = \frac{c_2V_2}{c_1}$$

$$V_1 = V_2 \times \frac{c_2}{c_1} = 1 \times 10^{-4} \text{L} \times \frac{2.53 \times 10^{-4} \text{ mol L}^{-1}}{2.0 \text{ mol L}^{-1}}$$

$$V_1 = 1.3 \text{ L} = 1 \text{ L}$$

Question 35

Criteria	Marks
• Correctly calculates the K_{sp} value	5
• Provides substantially correct calculation	4
• Provides some relevant steps	2–3
• Provides some relevant working	1

Sample answer:

$n\left(Sr\left(OH\right)_2\right)$ precipitate = 3.93 g ÷ 121.63 g mol^{-1} = 0.03231 mol

$n\left(Sr^{2+}\right)$ in initial solution = 1.50 mol L^{-1} × 0.0800 L = 0.120 mol

$n\left(Sr^{2+}\right)$ at equilibrium = 0.120 mol − 0.03231 mol = 0.08769 mol

$\left[Sr^{2+}\right]$ at equilibrium = 0.8769 mol ÷ 0.1600 L = 0.5481 mol L^{-1}

$n\left(OH^{-}\right)$ in initial solution = 0.855 mol L^{-1} × 0.0800 L = 0.0684 mol

$n\left(OH^{-}\right)$ at equilibrium = 0.0684 mol – (2 × 0.03231 mol) = 0.00378 mol

$\left[OH^{-}\right]$ at equilibrium = 0.00378 mol ÷ 0.1600 L = 0.02363 mol L^{-1}

$K_{sp} = \left[Sr^{2+}\right]\left[OH^{-}\right]^2 = 0.5481 \times (0.02363)^2 = 3.06 \times 10^{-4} = 3.1 \times 10^{-4}$

Question 36

Criteria	Marks
• Provides an explanation for the differences in evaporation for the two systems • Considers changes in enthalpy and entropy	4
• Shows a sound understanding of the differences in evaporation of the two systems • Considers changes in enthalpy AND/OR entropy	3
• Shows some understanding of the differences in evaporation of the two systems AND/OR changes in enthalpy AND/OR entropy	2
• Provides some relevant information	1

Sample answer:

At room temperature the water from the beaker will evaporate, and the water in the bottle will not appear to evaporate. The forward reaction is endothermic. □*S* would be positive as $H_2O(g)$ has higher entropy than the condensed phase. The forward reaction is non-spontaneous, because □*H* > *T*□*S*. The water in the beaker is not at standard conditions. In equilibrium expression terms $Q = [H_2O(g)]$ where $[H_2O(g)]$ is low and therefore $Q < K_{eq}$. Q will remain less than K_{eq} due to the dilution of the evaporated water thus continuously driving the reaction in the forward direction. In the case of the bottle, the $[H_2O(g)]$ will reach a value of $Q = K_{eq}$ and an equilibrium will be established.

2022 HSC Chemistry Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	Mod 7 Polymers	12-7, 12-14
2	1	Mod 6 Quantitative Analysis	12-3, 12-13
3	1	Mod 5 Static and Dynamic Equilibria	12-1, 12-12
4	1	Mod 8 Analysis of Inorganic Substances	12-4, 12-15
5	1	Mod 8 Analysis of Inorganic Substances	12-3, 12-15
6	1	Mod 8 Analysis of Inorganic Substances	12-5, 12-15
7	1	Mod 7 Hydrocarbons	12-7, 12-14
8	1	Mod 5 Calculating the Equilibrium Constant	12-6, 12-12
9	1	Mod 7 Nomenclature	12-7, 12-14
10	1	Mod 6 Using Brønsted−Lowry Theory	12-5, 12-13
11	1	Mod 7 Alcohols	12-6, 12-14
12	1	Mod 8 Analysis of Organic Substances	12-6, 12-15
13	1	Mod 5 Calculating the Equilibrium Constant	12-6, 12-12
14	1	Mod 5 Factors that Affect Equilibrium	12-5, 12-12
15	1	Mod 6 Quantitative Analysis	12-6, 12-13
16	1	Mod 8 Analysis of Inorganic Substances	12-6, 12-15
17	1	Mod 5 Solution Equilibria	12-6, 12-12
18	1	Mod 7 Polymers	12-6, 12-14
19	1	Mod 5 Solution Equilibria	12-6, 12-12
20	1	Mod 6 Quantitative Analysis Mod 6 Using Brønsted−Lowry Theory	12-6, 12-13

Section II

Question	Marks	Content	Syllabus outcomes
21	2	Mod 7 Nomenclature Mod 7 Products of Reactions Involving Hydrocarbons	12-7,12-14
22	2	Mod 6 Using Brønsted−Lowry Theory	12-6, 12-13
23 (a)	1	Mod 5 Factors that Affect Equilibrium	12-6, 12-12
23 (b)	2	Mod 5 Factors that Affect Equilibrium	12-7, 12-12
23 (c)	3	Mod 5 Factors that Affect Equilibrium	12-7, 12-12
24	3	Mod 7 Hydrocarbons	12-5, 12-7, 12-14
25	3	Mod 6 Using Brønsted−Lowry Theory Mod 6 Quantitative Analysis	12-5, 12-7, 12-13
26 (a)	2	Mod 6 Quantitative Analysis	12-4, 12-13
26 (b)	2	Mod 6 Quantitative Analysis	12-6, 12-13
27 (a)	2	Mod 6 Nomenclature Mod 6 Alcohols	12-7, 12-14

Question	Marks	Content	Syllabus outcomes
27 (b)	2	Mod 8 Analysis of Organic Substances	12-6, 12-15
27 (c)	3	Mod 7 Alcohols	12-7, 12-14
28 (a)	1	Mod 8 Analysis of Inorganic Substances	12-5, 12-15
28 (b)	4	Mod 8 Analysis of Inorganic Substances	12-4, 12-15
29 (a)	3	Mod 7 Alcohols	12-6, 12-14
29 (b)	2	Mod 7 Alcohols	12-5, 12-14
30	7	Mod 8 Analysis of Organic Substances	12-5, 12-6, 12-7, 12-15
31 (a)	3	Mod 8 Analysis of Inorganic Substances	12-6, 12-15
31 (b)	4	Mod 5 Solution Equilibria	12-5, 12-12
32 (a)	6	Mod 6 Quantitative Analysis	12-2, 12-13
32 (b)	2	Mod 6 Quantitative Analysis	12-13
33	8	Mod 7 Products of Reactions Involving Hydrocarbons Mod 7 Alcohols Mod 7 Reactions of Organic Acids and Bases Mod 8 Chemical Synthesis and Design	12-7, 12-15, 12-14
34	4	Mod 6 Using Brønsted−Lowry Theory Mod 6 Quantitative Analysis	12-4, 12-13
35	5	Mod 5 Solution Equilibria	12-4, 12-12
36	4	Mod 5 Static and Dynamic Equilibria	12-6, 12-7, 12-12