NSW Education Standards Authority

2021 **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 3–12)

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

Section II – 80 marks (pages 13–32)

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

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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 Which pair of components must be equal for a chemical system to be at equilibrium?

A. The rate of the forward reaction and the rate of the reverse reaction

B. The concentrations of the reactants and the concentrations of the products

C. The enthalpy of the forward reaction and the enthalpy of the reverse reaction

D. The time that an atom exists in a reactant molecule and in a product molecule

2 Which ion can be detected using a precipitation reaction with silver nitrate?

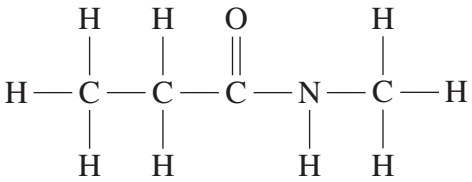
A. Ag^+

B. Cl^-

C. Mg^{2+}

D. NO_3^-

3 The structure of a compound is shown.



What is the preferred IUPAC name of this compound?

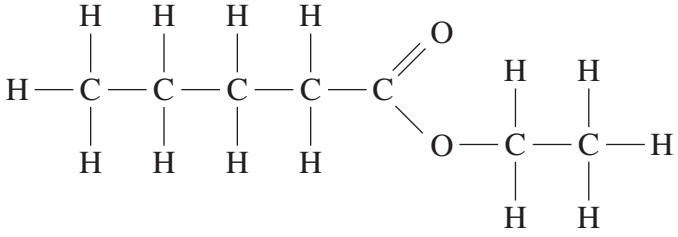
A. *N*-methylpropanamide

B. *N*-methylpropanamine

C. *N*-propanylamine

D. *N*-propylmethanamide

4 The structure of ethyl pentanoate is shown.



Which pair of chemicals would produce ethyl pentanoate by esterification?

A. Ethene and pentan-1-ol

B. Ethane and pentanoic acid

C. Ethanol and pentanoic acid

D. Ethanoic acid and pentan-1-ol

5 A student used the following method to titrate an acetic acid solution of unknown concentration with a standardised solution of dilute sodium hydroxide.

- Rinse burette with deionised water.
- Fill burette with sodium hydroxide solution.
- Rinse pipette and conical flask with acetic acid solution.
- Pipette 25.00 mL of acetic acid solution into conical flask.
- Add appropriate indicator to the conical flask.
- Titrate to endpoint and record volume of sodium hydroxide solution used.

Compared to the actual concentration of the acetic acid, the calculated concentration will be

A. lower.

B. higher.

C. the same.

D. different, but higher or lower cannot be predicted.

6 Which row of the table describes what happens when a solution of a weak acid is diluted? (Assume constant temperature.)

	K_a	*Extent of acid ionisation*
A.	Decreases	Increases
B.	Decreases	Decreases
C.	Remains the same	Increases
D.	Remains the same	Decreases

7 Methanol undergoes a substitution reaction using hydrogen bromide.

Compared to methanol, the product of this reaction has a

A. lower boiling point.

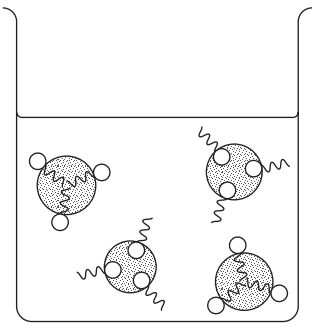
B. lower molecular mass.

C. greater solubility in water.

D. different molecular geometry at the carbon atom.

8 Which diagram shows the expected arrangement of soap anions in an emulsion?

A.



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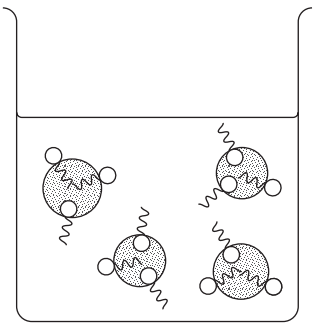

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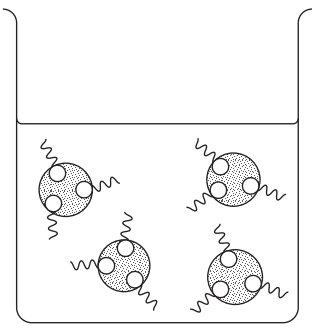

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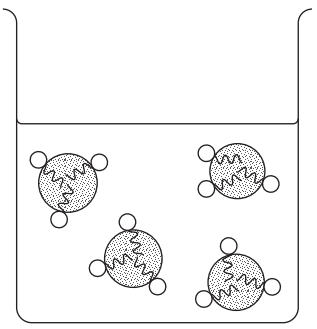
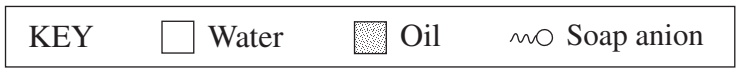
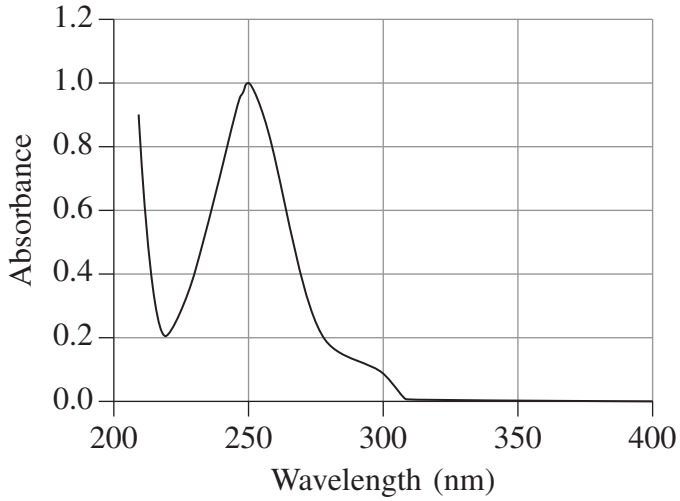




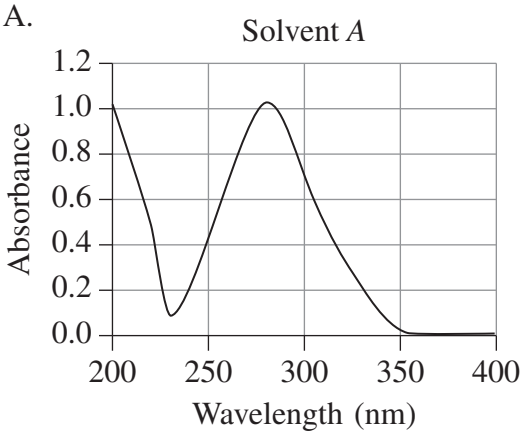
9 The amount of paracetamol in a sample needs to be determined.

The UV absorption spectrum of paracetamol is shown.



Based on the absorption spectra provided, which solvent should be used to determine the amount of paracetamol?

A.



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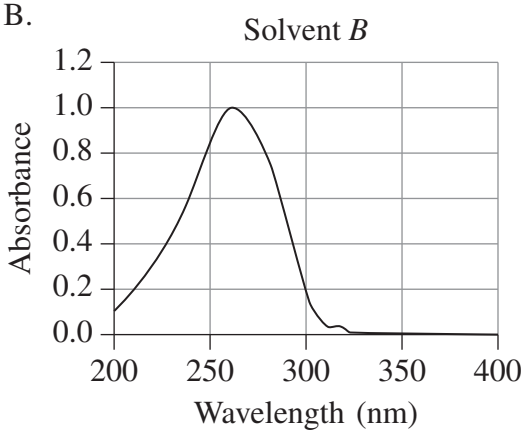

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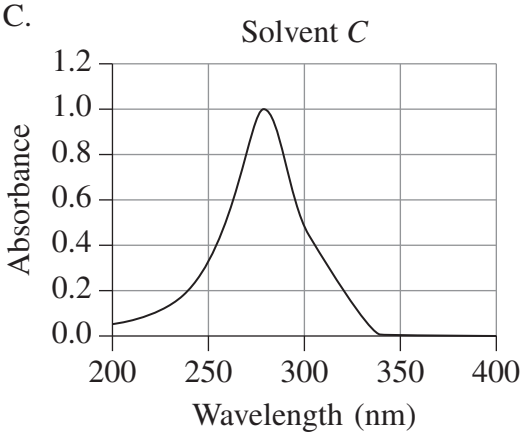

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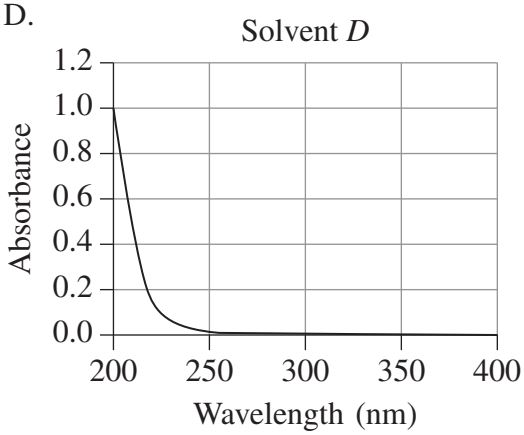
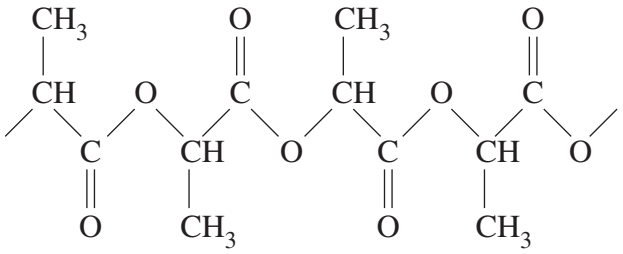
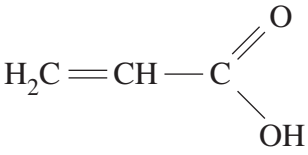


10 The structure of part of a polymer chain is shown.



Which is the monomer of this polymer?

A.



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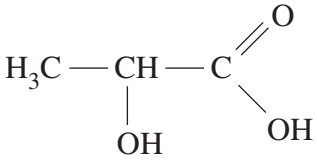

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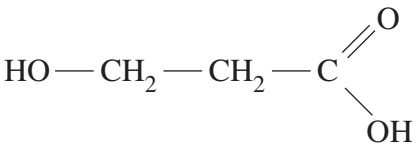

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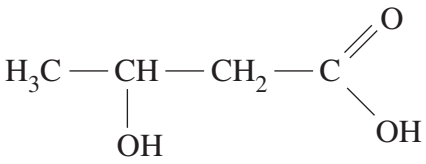


11 Consider this system in a fixed volume at constant temperature.

$$PCl_5(s) \rightleftharpoons PCl_3(l) + Cl_2(g)$$

This system is initially at equilibrium. A small amount of solid PCl_5 is added.

Which statement is correct?

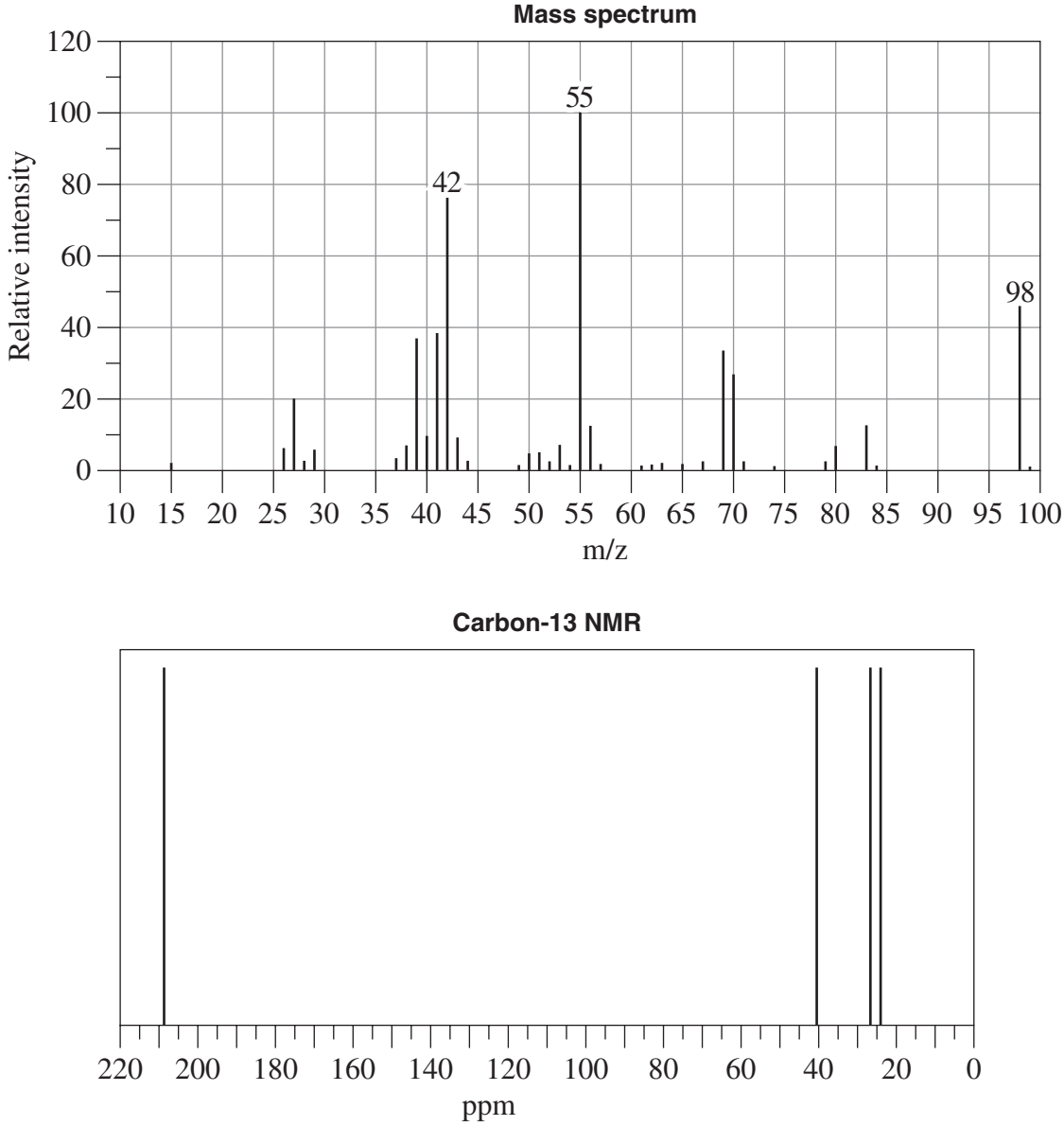
A. The amount of Cl_2 will increase.

B. The amount of PCl_3 will decrease.

C. The amount of Cl_2 will not change.

D. The amount of PCl_5 will increase then decrease.

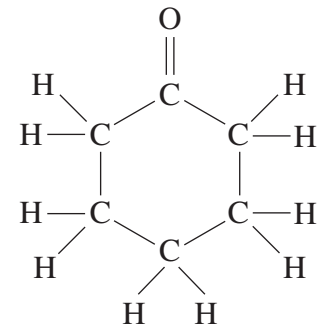
12 The mass spectrum and carbon-13 NMR for an organic compound are shown.



Question 12 continues on page 9

Which compound could produce the two spectra?

A.



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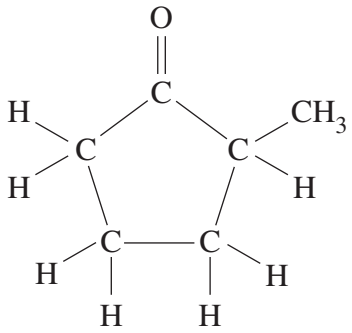

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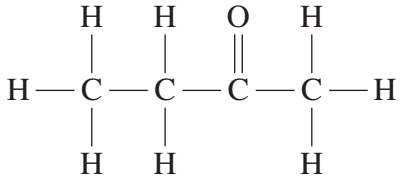

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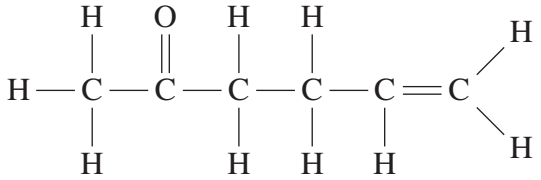


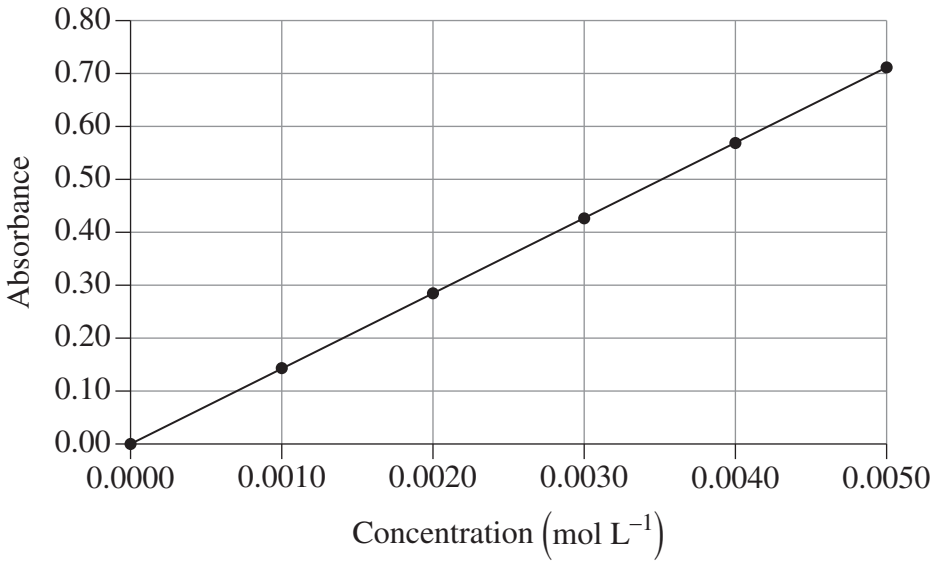
13 A chemist synthesises a substance using the following pathway.

$$\text{X} \xrightarrow{\text{hydration}} \text{Y} \xrightarrow{\text{oxidation}} \text{Z}$$

What are compounds X, Y and Z?

	X	Y	Z
A.	propane	propan-1-ol	propan-2-one
B.	propane	propan-1-ol	propanoic acid
C.	prop-1-ene	propan-2-ol	propan-2-one
D.	prop-1-ene	propan-2-ol	propanoic acid

14 A sample of nickel was dissolved in nitric acid to produce a solution with a volume of 50.00 mL. 10.00 mL of this solution was then diluted to 250.0 mL. This solution was subjected to colorimetric analysis. A calibration curve for this analysis is given.



The solution gave an absorbance value of 0.30.

What was the mass of the sample of nickel?

A. 0.0021 g

B. 0.031 g

C. 0.053 g

D. 0.15 g

15 What is the pH of the resultant solution after 20.0 mL of 0.20 mol L^{-1} HCl(*aq*) is mixed with 20.0 mL of 0.50 mol L^{-1} NaOH(*aq*)?

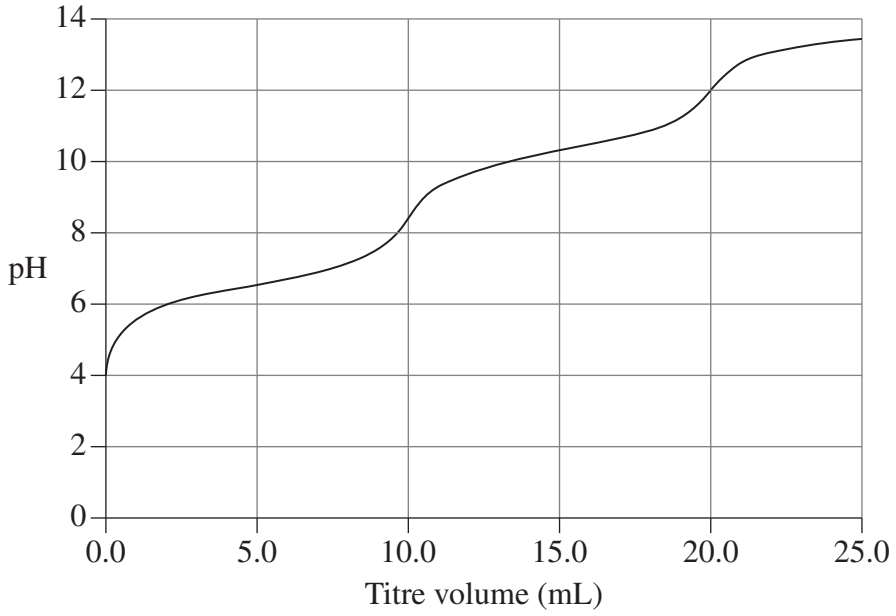
A. 11.8

B. 13.2

C. 13.5

D. 14.0

16 This titration curve is produced when an acid is titrated with a sodium hydroxide solution of the same concentration.



How many acidic protons does this acid possess?

A. 1

B. 2

C. 3

D. 4

17 A sample was contaminated with sodium phosphate. The sample was dissolved in water and added to an excess of acidified $(NH_4)_2MoO_4$ to produce a precipitate of $(NH_4)_3PO_4 \bullet 12MoO_3$ (MM = 1877 g mol^{-1}).

If 24.21 g of dry $(NH_4)_3PO_4 \bullet 12MoO_3$ was obtained, what was the mass of sodium phosphate in the original sample?

A. 1.225 g

B. 1.521 g

C. 1.818 g

D. 2.115 g

18 The table lists the information from a proton NMR spectrum.

Chemical shift (ppm)	*Multiplicity*	*Number of hydrogens*
1.0	Triplet	3
1.4	Singlet	3
1.8	Quartet	2

Which compound could have produced this spectrum?

A. 1,2,2-trichlorobutane

B. 1,3-dichloro-2-methylpropane

C. 2-chloro-2-methylbutane

D. 2,2-dichlorobutane

19 A quantity of silver nitrate is added to 250.0 mL of 0.100 mol L^{-1} potassium sulfate at 298 K in order to produce a precipitate. Silver nitrate has a molar mass of 169.9 g mol^{-1}.

What mass of silver nitrate will cause precipitation to start?

A. 0.00510 g

B. 0.186 g

C. 0.465 g

D. 0.854 g

20 The trimethylammonium ion, $[(CH_3)_3NH]^+$, is a weak acid. The acid dissociation equation is shown.

$$[(CH_3)_3NH]^+(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + (CH_3)_3N(aq) \qquad K_a = 1.55 \times 10^{-10}$$

At 20°C, a saturated solution of trimethylammonium chloride, $[(CH_3)_3NH]Cl$, has a pH of 4.46.

What is the K_{sp} of trimethylammonium chloride?

A. 1.26×10^{-9}

B. 7.76

C. 60.2

D. 5.01×10^{10}

2021 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.

Please turn over

Question 21 (6 marks)

Four organic liquids are used in an experiment. The four liquids are

- hexane
- hex-1-ene
- propan-1-ol
- propanoic acid.

(a) State ONE safety concern associated with organic liquids and suggest ONE way to address this safety concern. **2**

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(b) The organic liquids are held separately in four flasks but the flasks are not labelled. Tests were conducted to identify these liquids. The outcomes of the tests are summarised below. **2**

Flask	*Reaction with acidified oxidant* $\left(KMnO_4/H^+\right)$*?*	*Miscible with water?*
1	No	Yes
2	Yes	No
3	Yes	Yes
4	No	No

Identify the FOUR liquids.

Flask	*Liquid*
1	
2	
3	
4	

Question 21 continues on page 15

Question 21 (continued)

(c) What chemical test, other than those used in part (b), could be used to confirm the identification of ONE of the liquids? Include the expected observation in your answer. **2**

Liquid: .....

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End of Question 21

Please turn over

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Question 22 (3 marks)

Consider the following equilibrium system. **3**

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l) \quad \Delta H = -895 \text{ kJ mol}^{-1}$$

yellow *orange*

The solution is orange.

Justify TWO ways to shift the equilibrium to the left to change the colour of the solution.

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Question 23 (4 marks)

Methanoic acid reacts with aqueous potassium hydroxide. A salt is produced in this reaction.

(a) Write a balanced chemical equation for this reaction. **2**

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(b) Is the salt acidic, basic or neutral? Justify your answer. **2**

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Question 24 (4 marks)

A straight-chained alkane has a molar mass of 72.146 g mol^{-1}. **4**

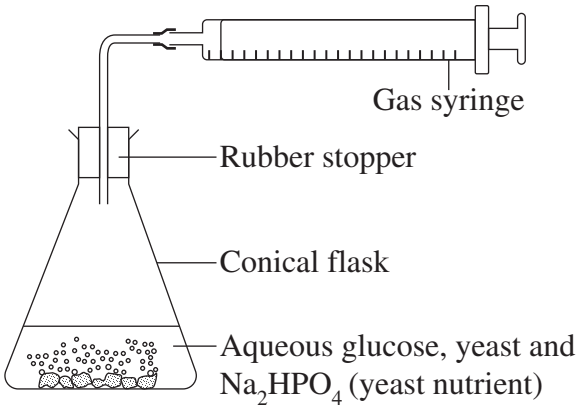
Provide the structural formulae for this alkane and all other isomers of it in the space provided.

Name these molecules using IUPAC conventions.

Structural formula	*Name*

Question 25 (4 marks)

A student conducted an experiment in the school laboratory under standard laboratory conditions (25°C, 100 kPa) to determine the volume of carbon dioxide gas produced during the fermentation of glucose. The following apparatus was set up. **4**



The following data were collected.

Day	*Total volume of gas* (mL)
1	489
2	677
3	899
4	1006
5	1006

Assume the total volume of gas produced was due to the production of carbon dioxide.

Calculate the mass of ethanol produced by the fermentation reaction. Include a relevant chemical equation in your answer.

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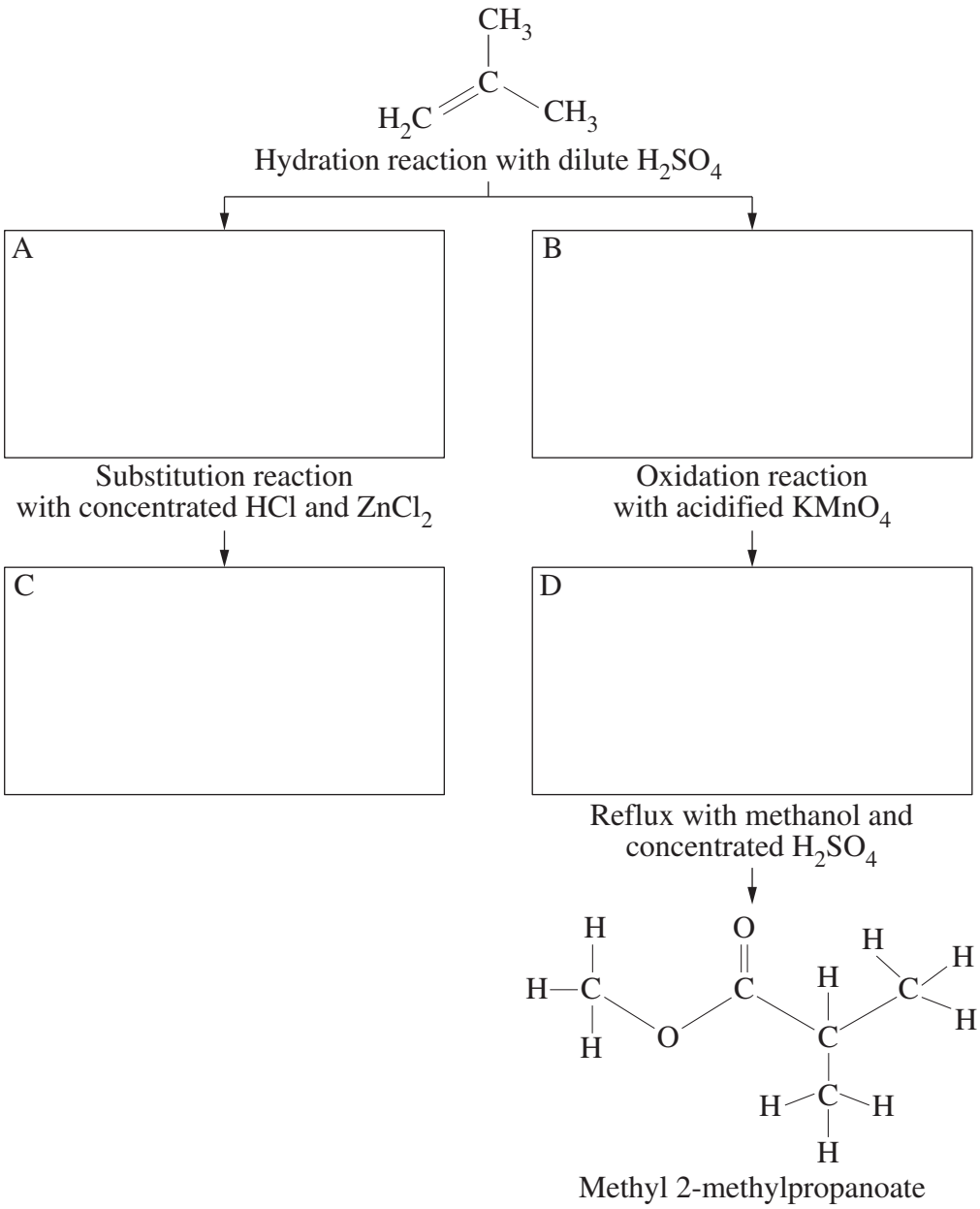
Question 26 (6 marks)

A sequence of chemical reactions, starting with 2-methylprop-1-ene, is shown in the flow chart.

(a) Complete the flow chart by drawing structural formulae for compounds A, B, C and D. **4**



(b) Reflux is used in the synthesis of methyl 2-methylpropanoate. **2**

Provide TWO reasons for using this technique.

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Question 27 (6 marks)

An experiment is carried out to determine the K_{sp} value for lithium phosphate (Li_3PO_4). Five samples of Li^+ ion solution were prepared, and a different solution of PO_4^{3-} was added to each of them. Columns 2 and 3 of the table show the values before any reaction occurs.

Sample	$[Li^+]$ (mol L^{-1})	$[PO_4^{3-}]$ (mol L^{-1})	*Observation*
1	0.15	0.00010	No precipitate
2	0.15	0.0010	No precipitate
3	0.15	0.010	No precipitate
4	0.15	0.10	White precipitate
5	0.15	1.00	Heavy white precipitate

(a) Calculate the range within which the K_{sp} value of lithium phosphate lies. **4**

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(b) Justify ONE way in which the procedure of this investigation could be improved to increase the accuracy of the calculated result. **2**

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Question 28 (4 marks)

A 5.30 g sample of an alkali metal hydroxide was dissolved in water. After mixing with excess $Cu(NO_3)_2$, the precipitate was collected, dried, measured and found to have a mass of 4.61 g. **4**

Identify the alkali metal hydroxide. Support your answer with calculations and a balanced equation.

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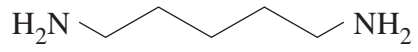
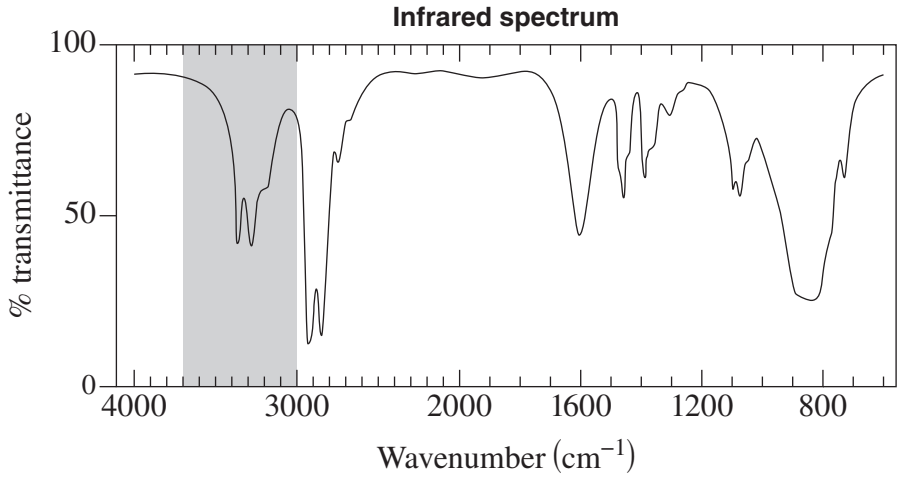
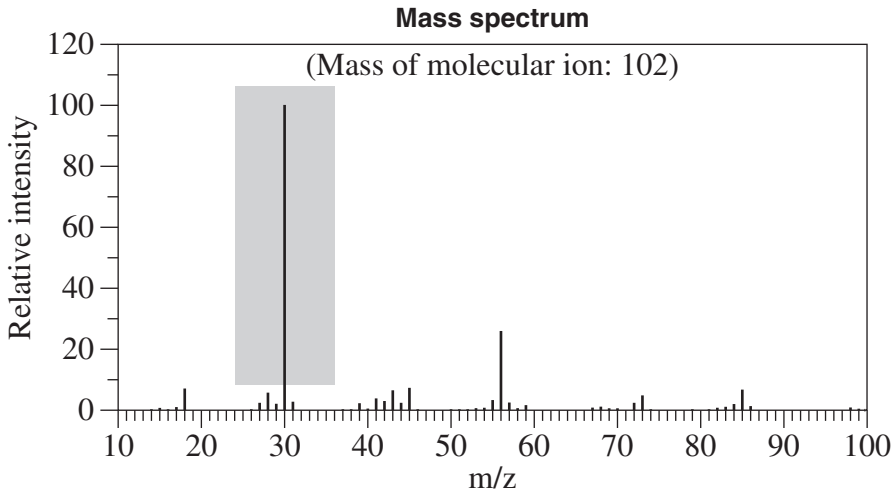
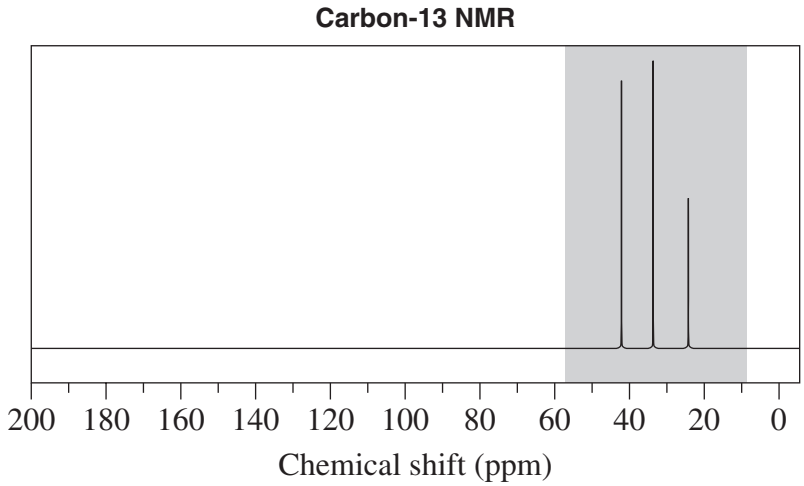
Question 29 (7 marks)

A chemist obtained spectral data of pentane-1,5-diamine ($C_5H_{14}N_2$). **7**



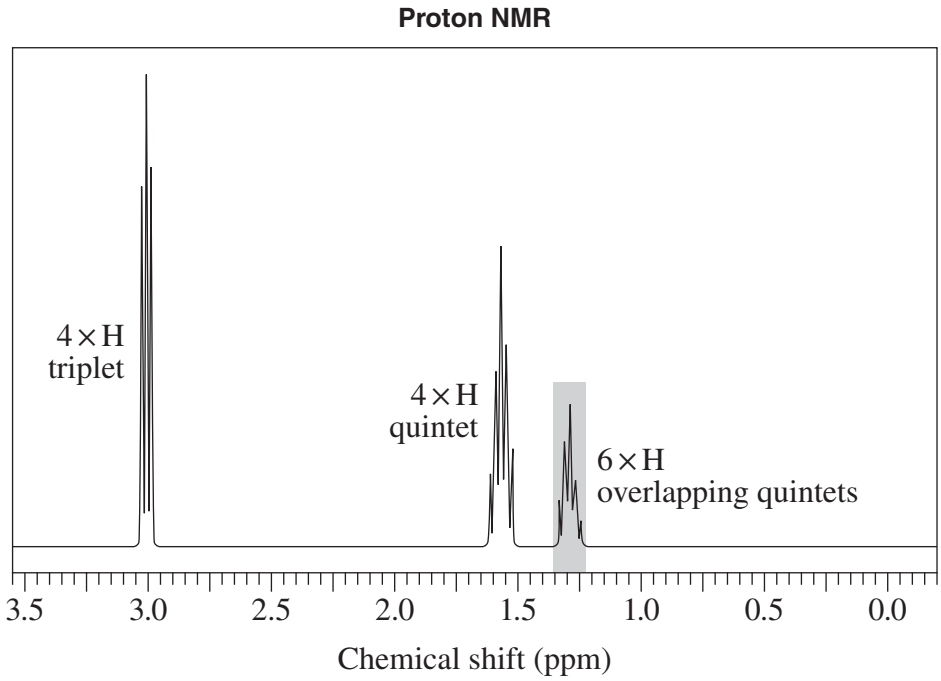






Question 29 continues on page 23

Question 29 (continued)



Relate the highlighted features of the spectra to the structure of pentane-1,5-diamine.

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Question 29 continues on page 24

Question 29 (continued)

End of Question 29

Question 30 (5 marks)

A student was trying to identify the ions present in a dilute aqueous solution. **5**

The solution contained ions of barium, calcium or magnesium, and ions of hydroxide or acetate.

The student performed the following tests and recorded their observations. A fresh sample of the solution was used for each test.

- When aqueous sodium chloride was added, no visible reaction was observed.
- When aqueous silver nitrate was added, brown precipitate was produced. The precipitate dissolved when dilute hydrochloric acid was added.
- When concentrated aqueous sodium sulfate was added, white precipitate was produced.

Evaluate this procedure as a method of identifying the ions.

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Question 31 (4 marks)

Ammonia is produced according to the following equilibrium equation. **4**

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

There are 4.50 moles of nitrogen gas, 1.00 mole of hydrogen gas and 5.80 moles of ammonia in a 10.0 L vessel. The system is at equilibrium at 298 K. The value of K_{eq} at this temperature is 748.

How many moles of nitrogen gas need to be added to the vessel to increase the amount of ammonia by 0.050 moles?

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Question 32 (4 marks)

The molar enthalpies of neutralisation of three reactions are given. **4**

Reaction 1:

$HCl(aq) + KOH(aq) \longrightarrow KCl(aq) + H_2O(l)$ $\Delta H = -57.6$ kJ mol^{-1}

Reaction 2:

$HNO_3(aq) + KOH(aq) \longrightarrow KNO_3(aq) + H_2O(l)$ $\Delta H = -57.6$ kJ mol^{-1}

Reaction 3:

$HCN(aq) + KOH(aq) \longrightarrow KCN(aq) + H_2O(l)$ $\Delta H = -12.0$ kJ mol^{-1}

Explain why the first two reactions have the same enthalpy value but the third reaction has a different value.

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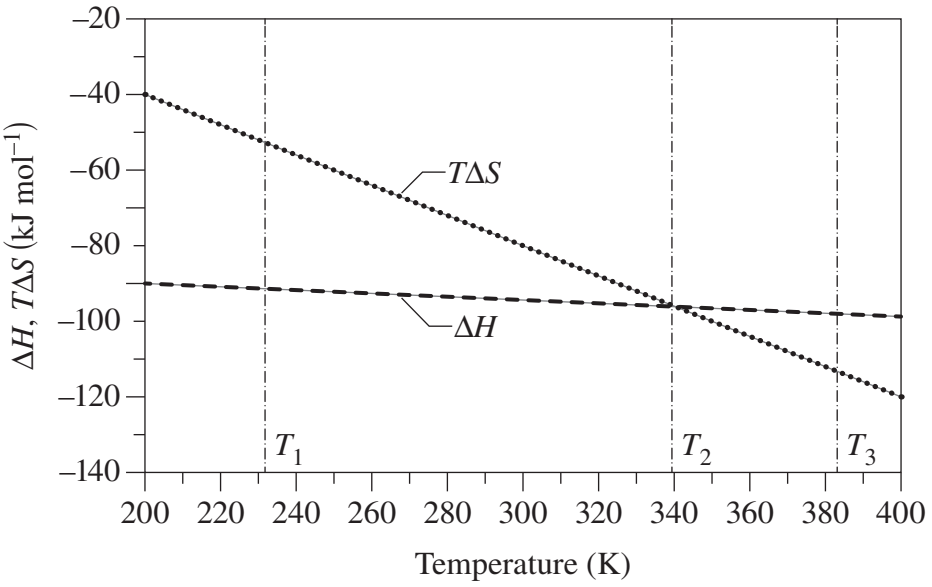
Question 33 (6 marks)

The relationships between ΔH and $T\Delta S$ with temperature for a chemical system are displayed in the graph.



(a) Calculate ΔG for this system at 300 K. **2**

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(b) What can be deduced about the system when the temperature is T_1, T_2 and T_3? Support your answer with reference to the graph. **4**

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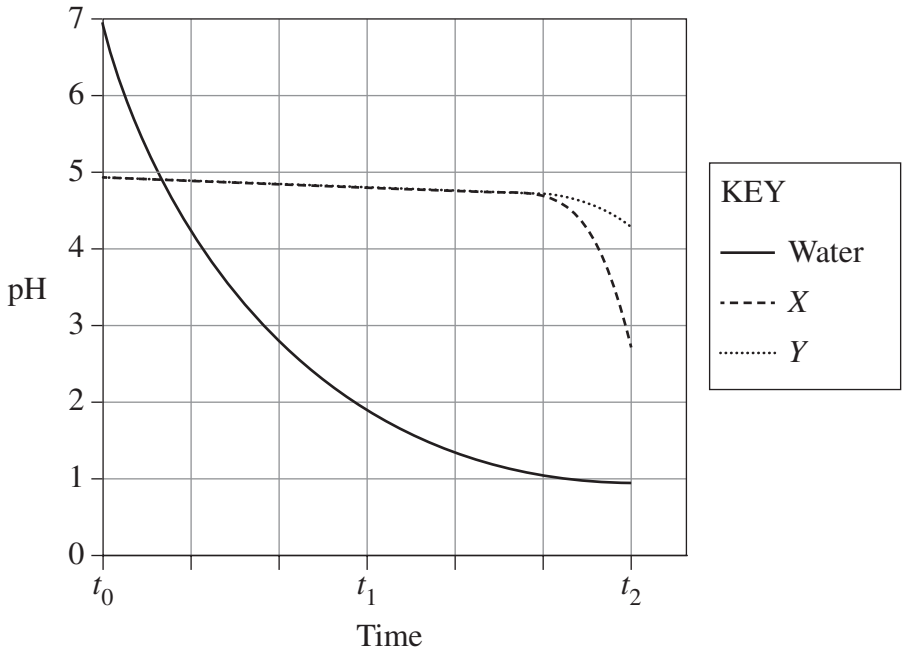
Question 34 (5 marks)

Gaseous HCl was bubbled into water and two solutions, *X* and *Y*. Solutions *X* and *Y* contain the same type of ions. The pH of each was monitored over time and recorded in the graph shown. **5**



Explain the observed pH of the water and each of the solutions at t_0, t_1 and t_2. Include a relevant balanced chemical equation in your answer.

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Question 35 (7 marks)

A manufacturer requires that its product contains at least 85% v/v ethanol. **7**

The concentration of ethanol in water can be determined by a back titration. Ethanol is first oxidised to ethanoic acid using an excess of acidified potassium dichromate solution.

$$3C_2H_5OH(aq) + 2Cr_2O_7^{2-}(aq) + 16H^+(aq) \longrightarrow 3CH_3COOH(aq) + 4Cr^{3+}(aq) + 11H_2O(l)$$

The remaining dichromate ions are reacted with excess iodide ions to produce iodine (I_2).

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6I^-(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 3I_2(aq)$$

The iodine produced is then titrated with sodium thiosulfate ($Na_2S_2O_3$).

$$I_2(aq) + 2S_2O_3^{2-}(aq) \longrightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

A 25.0 mL sample of the manufacturer's product was diluted with distilled water to 1.00 L. A 25.0 mL aliquot of the diluted solution was added to 20.0 mL of 0.500 mol L^{-1} acidified potassium dichromate solution in a conical flask. Potassium iodide (2.0 g)* was added and the solution titrated with 0.900 mol L^{-1} sodium thiosulfate. This was repeated three times.

**The quantity of potassium iodide should be 5.0 g. This is not required for the calculation.*

The following results were obtained.

Time	*Volume of* $Na_2S_2O_3(aq)$ *added* (mL)
1	29.9
2	28.7
3	28.4
4	28.6

The density of ethanol is 0.789 g mL^{-1}.

Question 35 continues on page 31

Question 35 (continued)

Does the sample meet the manufacturer's requirements? Support your answer with calculations.

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End of Question 35

Please turn over

Question 36 (5 marks)

The pK_a of sulfurous acid in the following reaction is 1.82. **5**

$$H_2SO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HSO_3^-(aq)$$

The pK_a of hydrogen sulfite in the following reaction is 7.17.

$$HSO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + SO_3^{2-}(aq)$$

Calculate the equilibrium constant for the following reaction:

$$H_2SO_3(aq) + 2H_2O(l) \rightleftharpoons 2H_3O^+(aq) + SO_3^{2-}(aq).$$

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End of paper

Chemistry

FORMULAE SHEET

$$n = \frac{m}{MM} \qquad c = \frac{n}{V} \qquad PV = nRT$$

$$q = mc\Delta T \qquad \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \qquad \text{pH} = -\log_{10}[\text{H}^+]$$

$$pK_a = -\log_{10}[K_a] \qquad A = \varepsilon lc = \log_{10}\frac{I_o}{I}$$

Avogadro constant, N_A ..... 6.022×10^{23} 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 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 ..... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

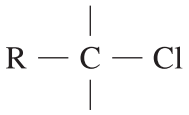
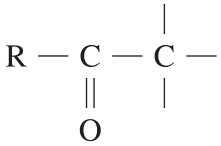
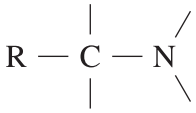
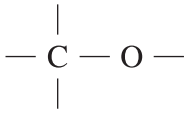
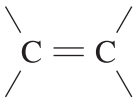
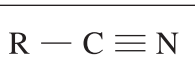
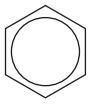
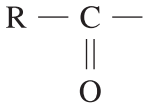
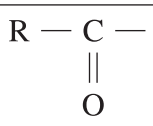
Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) 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
		5–40
		10–70
		20–50
		25–60
	alcohols, ethers or esters	50–90
		90–150
		110–125
		110–160
	esters or acids	160–185
	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.