NSW GOVERNMENT

NSW Education Standards Authority

Centre Number

Student Number

2024 **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
- Write your Centre Number and Student Number at the top of this page

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 13–40)

- Attempt Questions 21–39
- 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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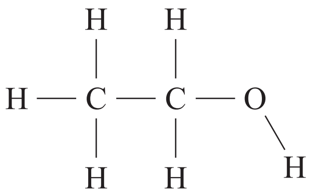
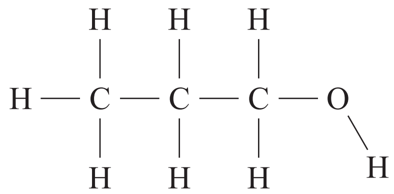
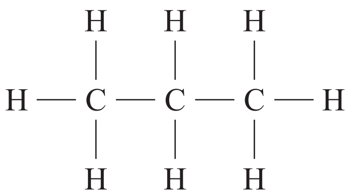
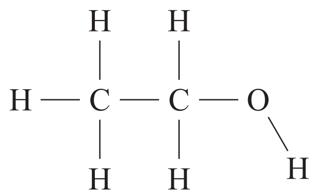
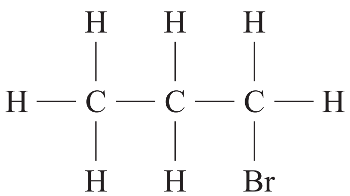
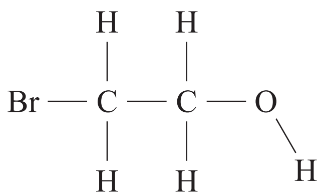
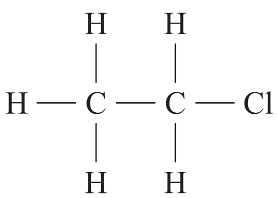
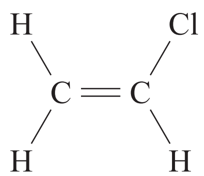
1 Which two substances are members of the same homologous series?

A.  

B.  

C.  

D.  

2 Aboriginal and Torres Strait Islander Peoples have used leaching in flowing water over several days to prepare various foods from plants that can be toxic to humans.

What was the reason for this?

A. To react with toxins

B. To dissolve low solubility toxins

C. To prevent the food from decomposing

D. To break down compounds that are difficult to digest

3 Which of the following compounds can be correctly described as an Arrhenius base when dissolved in water?

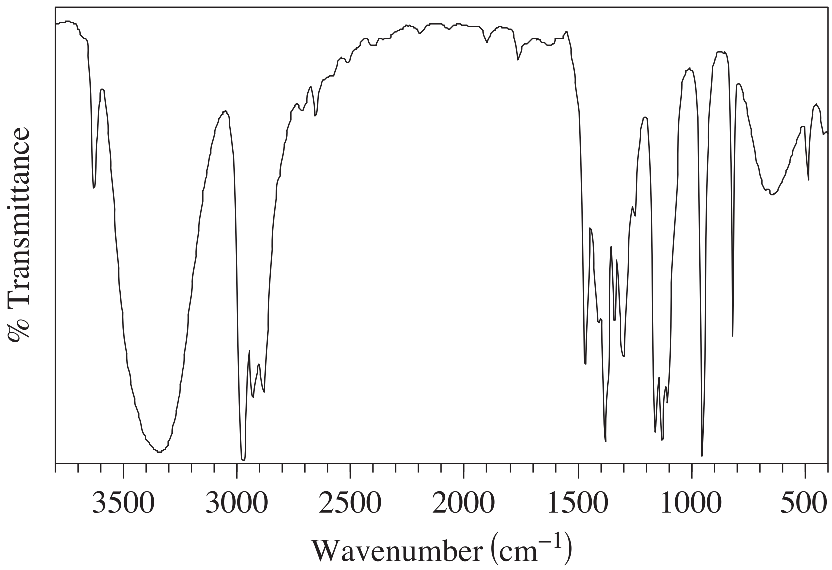
A. Sodium nitrate

B. Sodium sulfate

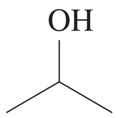
C. Sodium chloride

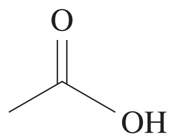
D. Sodium hydroxide

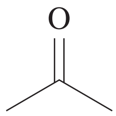
4 An infrared spectrum of an organic compound is shown.

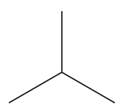


Which of the following compounds would produce the spectrum shown?

A. 

B. 

C. 

D. 

5 Which would be the best reagent to use to determine whether an unknown substance was 2-methylpropan-1-ol or 2-methylpropan-2-ol?

A. Bromine water

B. Potassium nitrate solution

C. Sodium carbonate solution

D. Acidified potassium permanganate solution

6 What is the hydroxide ion concentration of a solution of potassium hydroxide with a pH of 11?

A. 10^{-11} mol L^{-1}

B. 10^{-3} mol L^{-1}

C. 10^{3} mol L^{-1}

D. 10^{11} mol L^{-1}

7 The following equilibrium was established in a container.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -198 \text{ kJ mol}^{-1}$$

Which of the following would increase the yield of $SO_3(g)$?

A. Increasing the volume

B. Increasing the temperature

C. Removing the product as it is formed

D. Keeping temperature and volume constant

8 Which pair of ions produce different colours in a flame test?

A. Br^- and Cl^-

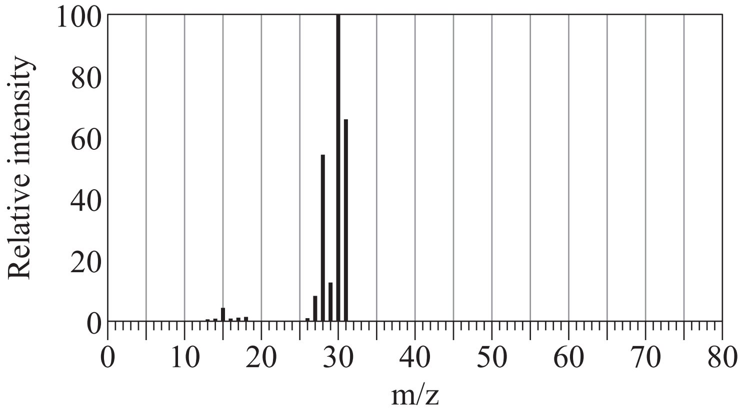
B. Ag^+ and OH^-

C. Cu^{2+} and Ca^{2+}

D. CH_3OOO^- and $H_2PO_4^-$

9 Which of the following is the mass spectrum of ethanamine?

A.



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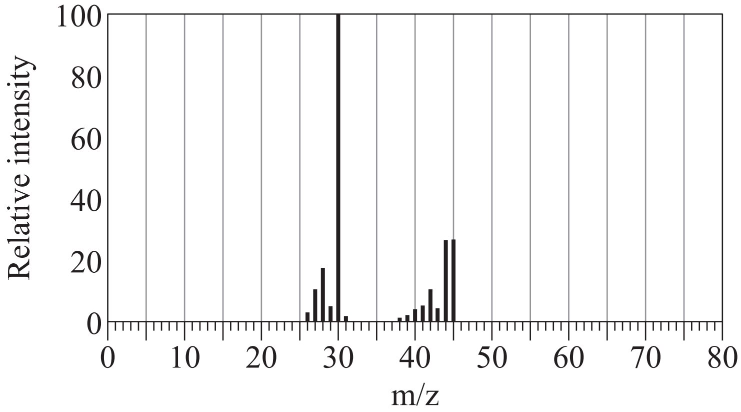

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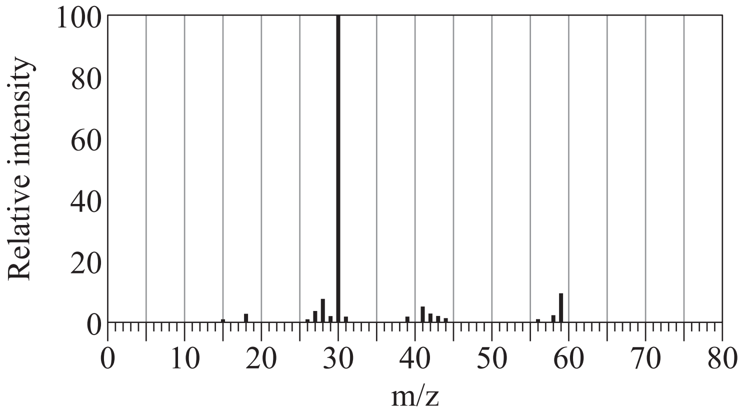

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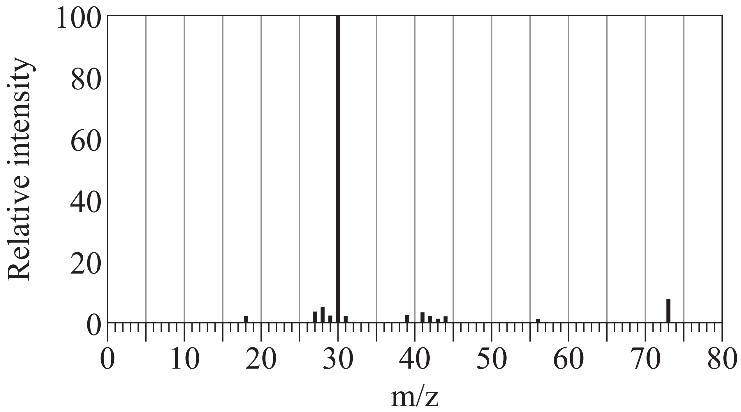


10 The following system is at equilibrium.

$$\underset{\text{propan-2-ol}}{CH_3CHOHCH_3(g)} \rightleftharpoons \underset{\text{propan-2-one}}{CH_3COCH_3(g)} + H_2(g)$$

A catalyst is added to the system.

Which row of the table correctly identifies the change in the yield of propan-2-one and the reaction rates?

	Yield of propan-2-one	*Reaction rates*
A.	Remains the same	Both forward and reverse rates are unchanged.
B.	Remains the same	Both forward and reverse rates increase equally.
C.	Decreases	Reverse rate increases more than the forward rate increases.
D.	Increases	Forward rate increases more than the reverse rate increases.

11 Which is the correct expression for calculating the solubility (in mol L^{-1}) of lead(II) iodide in a 0.1 mol L^{-1} solution of NaI at 25°C?

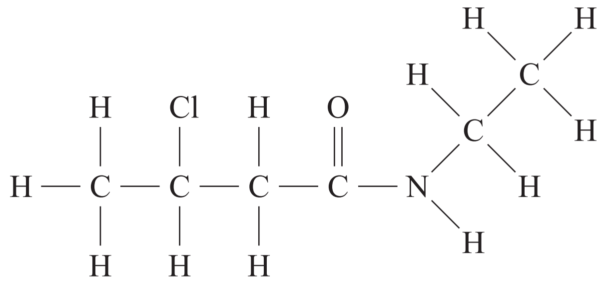
A. $\dfrac{9.8 \times 10^{-9}}{2 \times 0.1}$

B. $\dfrac{9.8 \times 10^{-9}}{(2 \times 0.1)^2}$

C. $\dfrac{9.8 \times 10^{-9}}{0.1}$

D. $\dfrac{9.8 \times 10^{-9}}{(0.1)^2}$

12 The structure of an organic substance is shown.



What is the preferred IUPAC name for this substance?

A. 2-chloro-1-ethylbutanamide

B. 2-chloro-*N*-ethylpropanamide

C. 3-chloro-*N*-ethylbutanamide

D. 3-chloro-1-ethylpropanamide

13 A fuel has these enthalpies of combustion: −2057.8 kJ mol^{-1} and −48.9 kJ g^{-1}.

Which of the following correctly identifies the fuel?

A. Ethanol $(MM = 46.1 \text{ g mol}^{-1})$

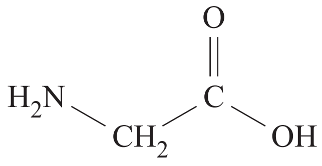
B. Propane $(MM = 44.1 \text{ g mol}^{-1})$

C. Propene $(MM = 42.1 \text{ g mol}^{-1})$

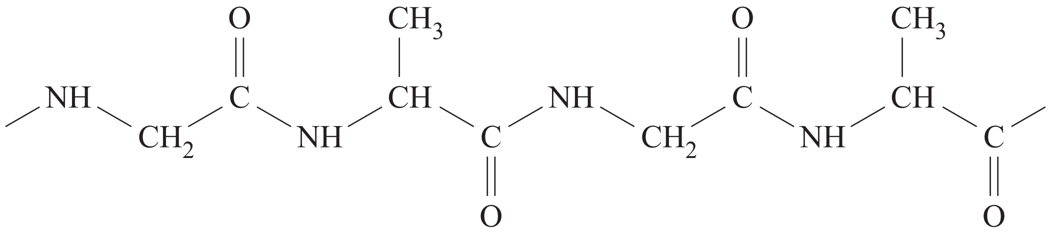
D. Hydrogen $(MM = 2.02 \text{ g mol}^{-1})$

14 Glycine, an amino acid, can react with itself or other amino acid monomers to form silk, a natural polymer.

Glycine has the structure:

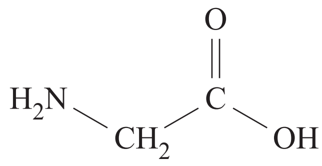


A section of silk polymer is shown.



Which monomer could react with glycine to form this section of silk polymer?

A.



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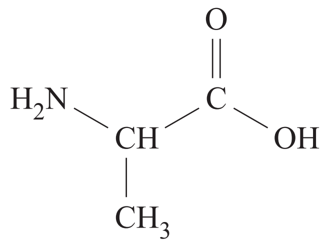

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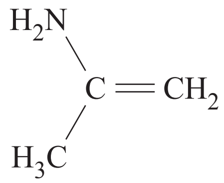

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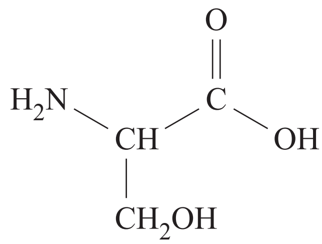


15 The thermal decomposition of lithium peroxide $\left(Li_2O_2\right)$ is given by the equation shown.

$$2Li_2O_2(s) \rightleftharpoons 2Li_2O(s) + O_2(g)$$

Mixtures of Li_2O_2, Li_2O and O_2 were allowed to reach equilibrium in two identical, closed containers, P and Q, at the same temperature. The amount of $Li_2O_2(s)$ in container P is double that in container Q. The amount of $Li_2O(s)$ is the same in each container.

What is the ratio of $\left[O_2(g)\right]$ in container P to $\left[O_2(g)\right]$ in container Q?

A. 1 : 1

B. 2 : 1

C. 3 : 2

D. 5 : 4

16 Which of the following is the overall reaction that takes place when a strong acid is added to a buffer containing equal amounts of acetic acid and acetate ions?

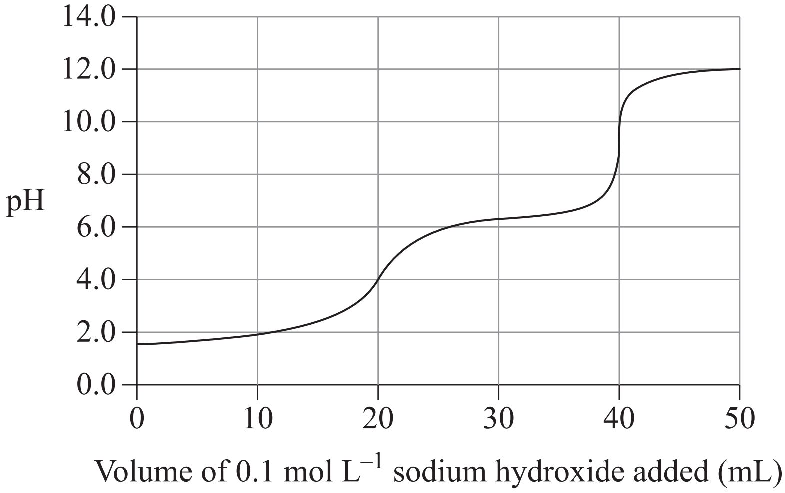
A. $HCOO^- + H_3O^+ \rightarrow HCOOH + H_2O$

B. $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$

C. $CH_3COO^- + H_3O^+ \rightarrow CH_3COOH + H_2O$

D. $CH_3COOH + H_3O^+ \rightarrow CH_3C(OH)_2{}^+ + H_2O$

17 20 mL of a 0.1 mol L^{-1} solution of an acid is titrated against a 0.1 mol L^{-1} solution of sodium hydroxide. A graph of pH against the volume of sodium hydroxide for this experiment is shown.



Which of the following acids was used in the titration?

	Acid	pK_{a1}	pK_{a2}
A.	1	4.76	–
B.	2	Strong	–
C.	3	1.91	6.30
D.	4	4.11	9.61

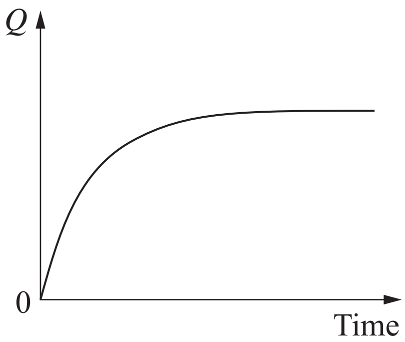
18 A reaction mixture, not at equilibrium, is composed of both $N_2O_4(g)$ and $NO_2(g)$ in a closed container. The reaction quotient for the system, Q, is given.

$$Q = \frac{[NO_2]^2}{[N_2O_4]}$$

The rate of the forward reaction is initially greater than the rate of the reverse reaction.

Which diagram shows how Q changes over time for this mixture?

A.



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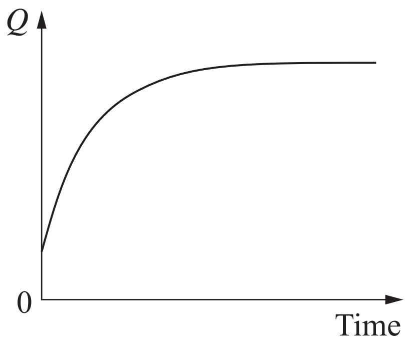

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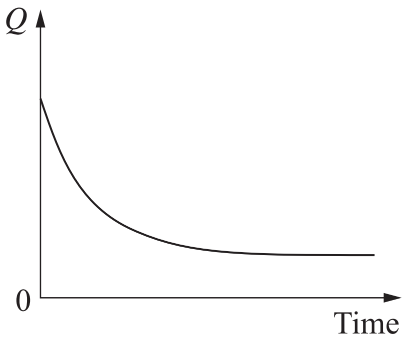

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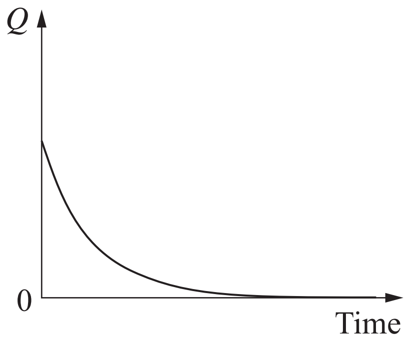
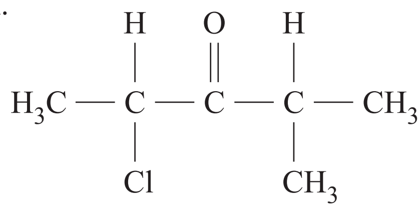


19 Which of the following compounds produces TWO doublets in the ^{1}H NMR spectrum?

A.



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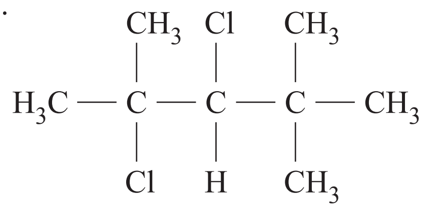

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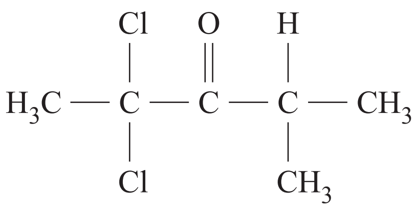

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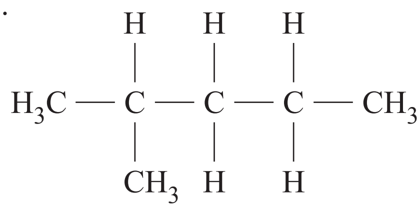


20 The concentration of ascorbic acid $\left(MM = 176.124 \text{ g mol}^{-1}\right)$ in solution A was determined by titration.

- A 25.00 mL sample of solution A was titrated with potassium hydroxide solution.
- 50.00 mg of ascorbic acid was added to a second 25.00 mL sample of solution A, which was titrated in the same way.

Titration volumes for both titrations are given.

Solution	*Titre* (mL)
25.00 mL solution A	17.50
25.00 mL solution A + 50.00 mg of ascorbic acid	33.10

What is the concentration of ascorbic acid in solution A?

A. 5.352×10^{-3} mol L^{-1}

B. 6.004×10^{-3} mol L^{-1}

C. 1.012×10^{-2} mol L^{-1}

D. 1.274×10^{-2} mol L^{-1}

Do NOT write in this area.

2024 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Student Number

Chemistry

Section II Answer Booklet

80 marks
Attempt Questions 21–39
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)

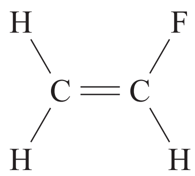
A solution of acetic acid reacts with magnesium metal. **2**

Write the names of the products of this reaction in the boxes provided.

acetic acid + magnesium → [ ] + [ ]

Question 22 (2 marks)

Vinyl fluoride can be polymerised. **2**



vinyl fluoride

In the box provided, draw the structural formula for a six-carbon section of the polymer formed from the polymerisation of vinyl fluoride.

Question 23 (3 marks)

Consider the following equilibrium system. **3**

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

$\left[Co(H_2O)_6\right]^{2+}(aq)$ is pink and $\left[CoCl_4\right]^{2-}(aq)$ is blue. When a solution of these ions and chloride ions is heated, the mixture becomes more blue.

Relate the observed colour change to the change in K_{eq}.

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Please turn over

Question 24 (7 marks)

The boiling points for two series of compounds are listed.

Amine	*Boiling point* (°C)
Methanamine	−6
Ethanamine	17
Propan-l-amine	48
Butan-l-amine	78

Alcohol	*Boiling point* (°C)
Methanol	65
Ethanol	78
Propan-l-ol	97
Butan-l-ol	118

(a) Plot the boiling points for each series of compounds against the number of carbon atoms per molecule. **3**

Question 24 continues on page 17

Do NOT write in this area.

Question 24 (continued)

(b) With reference to hydrogen bonding and dispersion forces, explain the trends in the boiling point data of these compounds, within each series and between the series. **4**

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End of Question 24

Please turn over

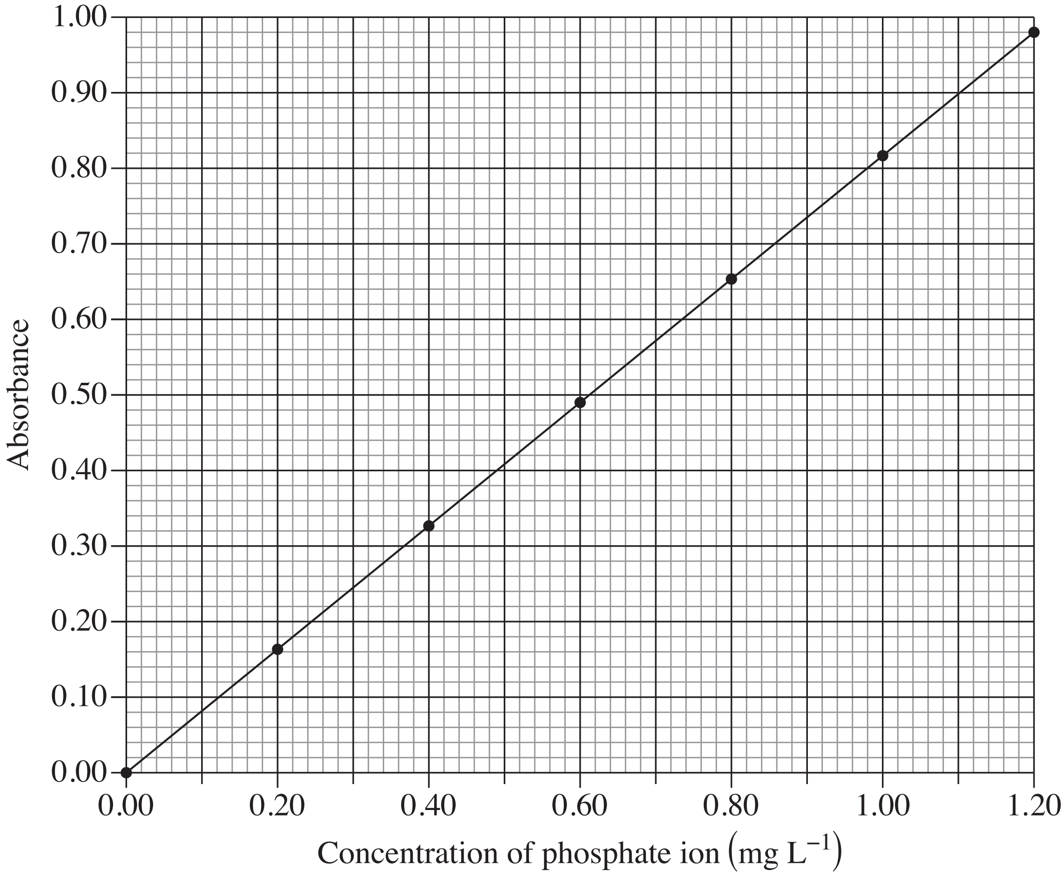
Question 25 (4 marks)

The concentration of phosphate ions in washing machine waste water can be determined using colourimetry. **4**

A sample of washing machine waste water was collected and diluted by quantitatively transferring 1.00 mL of the solution to a volumetric flask and making up the volume to 1.000 L with distilled water.

Standard phosphate solutions were prepared and analysed with a colourimeter using an accepted method.

The standard calibration graph is shown.



Question 25 continues on page 19

Question 25 (continued)

The diluted sample solution was then analysed using the same method as the standard solutions. The absorbance of this solution was found to be 0.64.

Determine the concentration of phosphate ions in the sample of washing machine waste water, in mol L^{-1}.

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End of Question 25

Please turn over

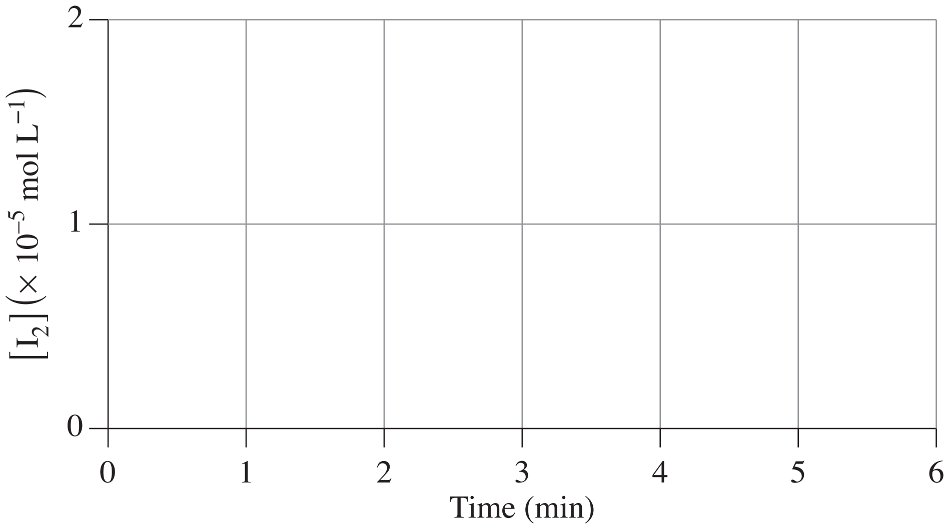
Question 26 (5 marks)

The equilibrium equation for the reaction of iodine with hydrogen cyanide in aqueous solution is given.

$$I_2(aq) + HCN(aq) \rightleftharpoons ICN(aq) + I^-(aq) + H^+(aq)$$

At $t = 0$ min, I_2 was added to a mixture of HCN, I^- and H^+, bringing $[I_2]$ to 2.0×10^{-5} mol L^{-1}. After 3 minutes, the system was at equilibrium, and an analysis of the mixture found that half of the I_2 had reacted.

(a) On the axes provided, sketch a graph to show how $[I_2]$ changes in the solution between $t = 0$ min and $t = 6$ min. **2**



(b) Using collision theory, explain the rate of reaction between $t = 0$ min and $t = 6$ min. Refer to the $[I_2]$ in your answer. **3**

Do NOT write in this area.

Question 27 (4 marks)

The following procedure is proposed to test for the presence of lead(II) and barium ions in water at concentrations of 0.1 mol L^{-1}. **4**

1. Add excess 0.1 mol L^{-1} sodium sulfate solution. If a precipitate is produced, then barium ions are present.
2. Filter any precipitate produced.
3. Add excess 0.1 mol L^{-1} sodium bromide solution to the filtrate. If a precipitate is produced, then lead(II) ions are present.

Explain why this procedure gives correct results when only barium ions are present, but not when both barium and lead(II) ions are present. Include ONE balanced chemical equation in your answer.

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Please turn over

Question 28 (3 marks)

Iodic acid and sulfamic acid are monoprotic acids. A 0.100 mol L^{-1} solution of iodic acid has a pH of 1.151, as does a 0.120 mol L^{-1} solution of sulfamic acid. **3**

Show that neither iodic acid nor sulfamic acid dissociates completely in water, and determine which is the stronger acid.

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Question 29 (4 marks)

150 mL of a 0.20 mol L^{-1} sodium hydroxide solution is added to 100 mL of a 0.10 mol L^{-1} sulfuric acid solution. **4**

Calculate the pH of the resulting solution, assuming that the volume of the resulting solution is 250 mL and that its temperature is 25°C.

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Please turn over

Question 30 (4 marks)

An equilibrium mixture of hydrogen, carbon dioxide, water and carbon monoxide is in a closed, 1 L container at a fixed temperature as shown: **4**

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g) \qquad K_{eq} = 1.600$$

The initial concentrations are $[H_2] = 1.000 \text{ mol L}^{-1}$, $[CO_2] = 0.500 \text{ mol L}^{-1}$, $[H_2O] = 0.400 \text{ mol L}^{-1}$ and $[CO] = 2.000 \text{ mol L}^{-1}$.

An unknown amount of $CO(g)$ was added to the same container, and the temperature was kept constant. After the new equilibrium had been established, the concentration of $H_2O(g)$ was found to be 0.200 mol L^{-1}.

Using this information, calculate the unknown amount (in mol) of $CO(g)$ that was added to the container.

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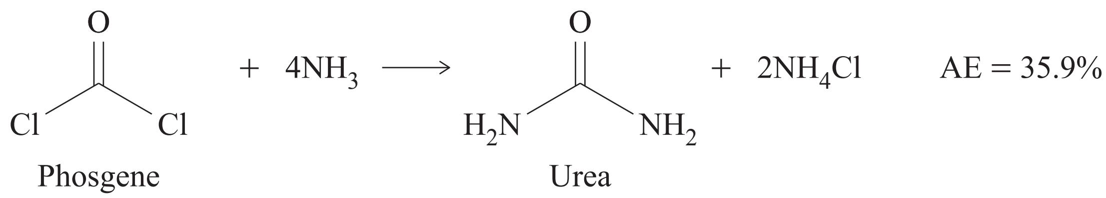
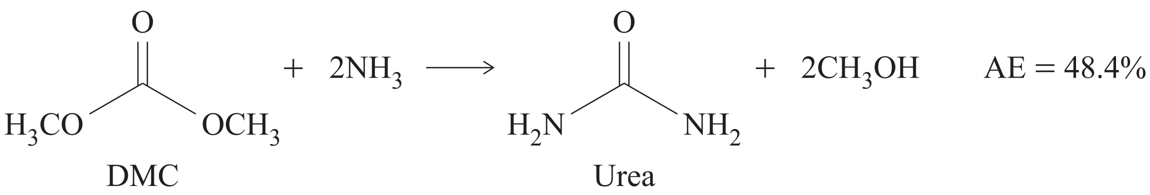
Question 31 (3 marks)

The atom economy (AE) of a reaction is a measure of the mass of atoms in the starting materials that are incorporated into the desired product. Higher AE means lower mass of waste products. **3**

Urea can be produced in a variety of ways. One way is to react ammonia (high toxicity) with phosgene (high toxicity). Another way is to react ammonia with dimethyl carbonate (DMC, low toxicity). The chemical equations and AE for these two processes are provided.





Which of these two processes is preferable for urea production? Justify your answer with reference to the information provided.

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Question 32 (4 marks)

Calculate the concentration of cadmium ions in a saturated solution of cadmium(II) phosphate, $Cd_3(PO_4)_2$, $K_{sp} = 2.53 \times 10^{-33}$. **4**

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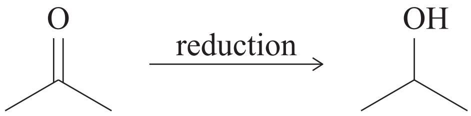
Question 33 (5 marks)

Acetone can be reduced, as shown.



(a) Identify the shape around the central carbon atom in each molecule. **2**

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(b) Explain how ^{13}C NMR spectroscopy could be used to monitor the progress of this reaction. **3**

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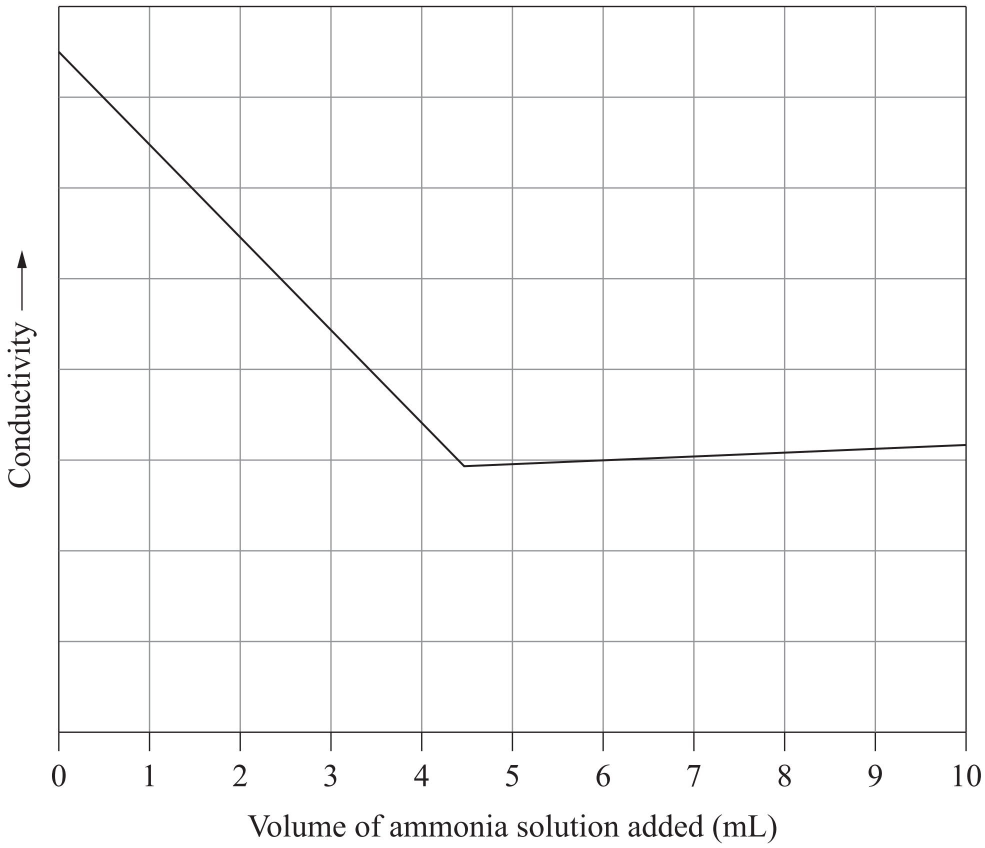
Question 34 (4 marks)

An aqueous solution of ammonia is added to a solution containing hydrochloric acid. A plot of conductivity against volume of ammonia solution added is shown. The temperature of the solution is kept constant throughout and the conductivity of the solution is corrected for dilution. **4**



The relative conductivities of some relevant ions are shown in the table.

Ion	*Relative conductivity*
H^+	4.76
OH^-	2.70
Cl^-	1.04
NH_4^+	1.00

Question 34 continues on page 29

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Question 34 (continued)

Explain the shape of the graph. Include TWO balanced chemical equations in your answer.

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End of Question 34

Please turn over

Question 35 (7 marks)

Unknown samples of three carboxylic acids, labelled X, Y and Z, are analysed to determine their identities. **7**

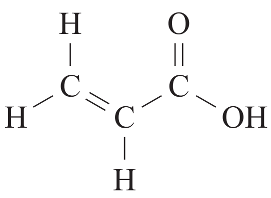
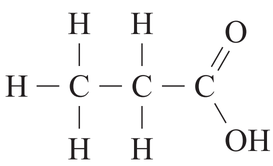
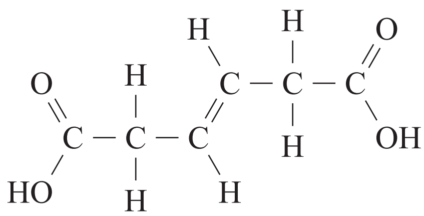
- Both Y and Z react rapidly with bromine in the absence of UV light, but X does not. A 0.100 g sample of Y reacts with the same amount of bromine as a 0.200 g sample of Z.

- Separate 0.100 g samples of X, Y and Z are titrated with 0.0617 mol L^{-1} sodium hydroxide solution. The titre volumes are shown.

Acid	X	Y	Z
Volume of NaOH (mL)	21.88	22.49	22.49

- Both Y and Z can undergo hydration reactions in the presence of a suitable catalyst. Two products are possible for the hydration of Y, but only one product is possible with Z.

Identify which structures 1, 2 and 3 in the table are acids X, Y and Z. Justify your answer with reference to the information provided.

	Structure 1	*Structure 2*	*Structure 3*
			
Molar mass $(g\ mol^{-1})$	72.062 g mol^{-1}	74.078 g mol^{-1}	144.124 g mol^{-1}
Acid (X, Y or Z)			

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Question 35 continues on page 31

End of Question 35

Question 36 (5 marks)

14.7 g of solid sodium hydrogen carbonate $(MM = 84.008 \text{ g mol}^{-1})$ was reacted with 120 mL of 1.50 mol L^{-1} hydrochloric acid solution $(\text{density } 1.02 \text{ g mL}^{-1})$ in a calorimeter. The temperature of the solution before and after reaction was recorded. **5**

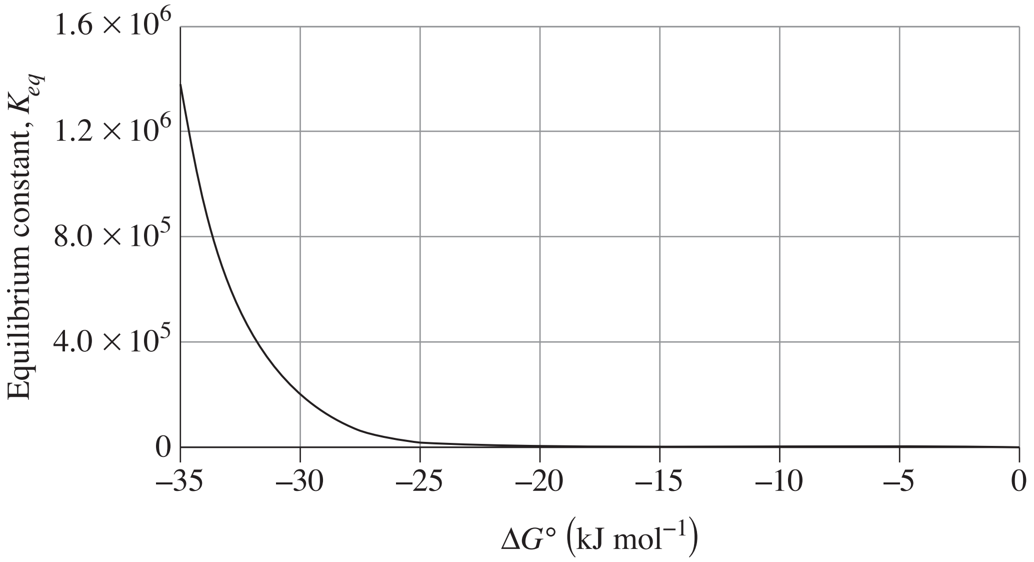
Initial temperature of hydrochloric acid solution (°C)	*Final temperature of reaction solution* (°C)
21.5	11.5

Assume that all CO_2 produced is lost from the reaction solution and that the specific heat capacity of the reaction solution is 3.80 J K^{-1} g^{-1}.

What is the enthalpy of reaction, in kJ mol^{-1}?

Question 37 (3 marks)

The relationship between the equilibrium constant, K_{eq}, and $\Delta G°$ for any reaction is shown in the graph, for a limited range of $\Delta G°$ values. **3**



The $\Delta H°$ and $T\Delta S°$ values for the reaction between copper(I) sulfide and oxygen are provided.

$$Cu_2S(s) + O_2(g) \longrightarrow 2Cu(s) + SO_2(g) \qquad \Delta H° = -217 \text{ kJ mol}^{-1} \quad T\Delta S° = -3 \text{ kJ mol}^{-1}$$

Explain, with reference to the information provided, why this reaction proceeds to completion rather than coming to equilibrium.

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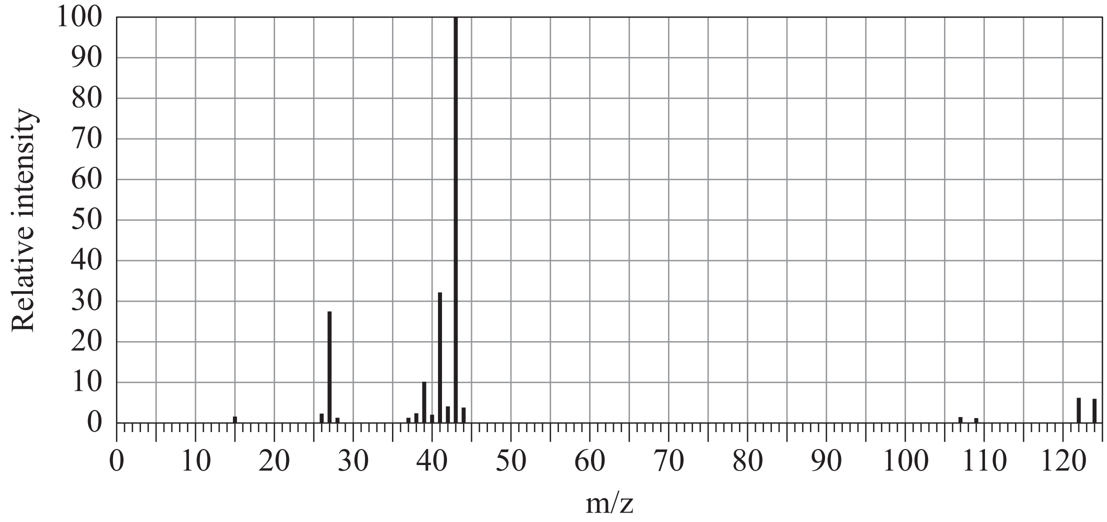
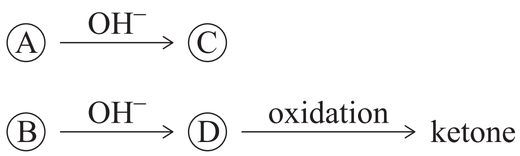
Question 38 (7 marks)

Compounds A and B are isomers with formula C_3H_7X, where X is a halogen. The mass spectrum for compound A is shown. **7**



Compounds A and B undergo substitution reactions in the presence of hydroxide ions, producing alcohols C and D. Compound D can be oxidised to a ketone; compound C can also be oxidised, but does not produce a ketone.



Compound E can be produced by refluxing 3-methylbutanoic acid, with one of the alcohols C or D, in the presence of a catalyst.

The ^1H NMR spectrum for compound E contains the following features.

^1H NMR spectrum data for compound E

Chemical shift (ppm)	*Integration*	*Peak splitting*
0.95	3	Triplet
0.96	6	Doublet
1.7	2	Multiplet
2.1	1	Multiplet
2.2	2	Doublet
4.0	2	Triplet

Reference ^1H chemical shift data

Type of proton	δ/ppm
—**CH**$_3$, —**CH**$_2$—, —**CH**—	0.7–2.1
H$_3$C—CO—, **H**$_2$C—CO—, **H**C—CO (aldehydes, ketones, carboxylic acids or esters)	2.2–2.6
H$_3$C—O—, **H**$_2$C—O—, **H**C—O— (alcohols or esters)	3.2–5.0

Question 38 continues on page 35

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Question 38 (continued)

Draw the structure of compounds A, B and E. Explain your answer with reference to the information provided.

Compound A
Compound B
Compound E

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Question 38 continues on page 36

Question 38 (continued)

End of Question 38

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Question 39 (4 marks)

Water and octan-1-ol do not mix. When an aqueous solution of bromoacetic acid $(BrCH_2COOH)$ is shaken with octan-1-ol, an equilibrium system is established between bromoacetic acid dissolved in the octan-1-ol and in the water. **4**

$$BrCH_2COOH(aq) \rightleftharpoons BrCH_2COOH(octan\text{-}1\text{-}ol)$$

The equilibrium constant expression for this system is

$$K_{eq} = \frac{[BrCH_2COOH(octan\text{-}1\text{-}ol)]}{[BrCH_2COOH(aq)]}.$$

An aqueous solution of bromoacetic acid with an initial concentration of 0.1000 mol L^{-1} is shaken with an equal volume of octan-1-ol. Bromoacetic acid does not dissociate in octan-1-ol but does dissociate in water, with $K_a = 1.29 \times 10^{-3}$. When the system has reached equilibrium, the $[H^+]$ is 9.18×10^{-3} mol L^{-1}.

Calculate the equilibrium concentration of aqueous bromoacetic acid and hence, or otherwise, calculate the K_{eq} for the octan-1-ol and water system.

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Chemistry

FORMULAE SHEET

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

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

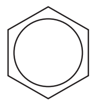
Solubility constants at 25°C

Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	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.