

PLUMI PRACTICE PACK

A Level Chemistry A

OCR-style practice pack (H432)

Question paper | 30 questions: Periodic table, elements and physical chemistry; Synthesis and analytical techniques; Unified chemistry

Name	Class	Date
------	-------	------

You must have: the Data Sheet for Chemistry A (the data you need are on pages 2 to 4)

You can use: a scientific or graphical calculator, a ruler (cm/mm)

Suggested time: about 8 hours, in three sittings (one per section)

Total marks

370

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. Show all your working.
- Answer **all** the questions, in the spaces provided.
- Marks may be given for a correct method even if the final answer is wrong.
- Give numerical answers to an appropriate number of significant figures, and include units where they are not printed.

INFORMATION

- The total mark for this pack is 370. The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- Questions get harder through each section; the last three in each section are stretch-and-challenge questions.

Section	Content	Questions	Marks
A: Periodic Table, Elements And Physical Chemistry	Modules 2, 3 and 5, with practical skills	1 to 10	131
B: Synthesis And Analytical Techniques	Modules 2, 4 and 6, with practical skills	11 to 20	123
C: Unified Chemistry	Synoptic questions across all modules, with practical skills	21 to 30	116



Plumi

Practise questions like these on iPad: Plumi marks your handwritten answers against each question's own mark scheme.

Free on the App Store · tryplumi.app



OCR-style practice written by Plumi. Not produced or endorsed by OCR.

Turn over



Data Sheet

General information and infrared data as on the OCR Data Sheet for Chemistry A. The NMR charts are redrawn in the style of the OCR Data Sheet; ranges are approximate. Any other data you need are given in the question.

General information

1 mol of gas molecules occupies 24.0 dm ³ at room temperature and pressure, RTP	
Avogadro constant, N_A	$6.02 \times 10^{23} \text{ mol}^{-1}$
Specific heat capacity of water, c	$4.18 \text{ J g}^{-1} \text{ K}^{-1}$
Ionic product of water, K_w	$1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ at 298 K
Gas constant, R	$8.314 \text{ J mol}^{-1} \text{ K}^{-1}$
1 tonne	10^6 g
Arrhenius equation	$k = Ae^{-E_a/RT}$ or $\ln k = -E_a/RT + \ln A$

Characteristic infrared absorptions in organic molecules

bond	location	wavenumber / cm^{-1}
C–C	alkanes, alkyl chains	750-1100
C–X	haloalkanes (X = Cl, Br, I)	500-800
C–F	fluoroalkanes	1000-1350
C–O	alcohols, esters, carboxylic acids	1000-1300
C=C	alkenes	1620-1680
C=O	aldehydes, ketones, carboxylic acids, esters, amides, acyl chlorides and acid anhydrides	1630-1820
aromatic C=C	arenes	several peaks in range 1450-1650 (variable)
C≡N	nitriles	2220-2260
C–H	alkyl groups, alkenes, arenes	2850-3100
O–H	carboxylic acids	2500-3300 (broad)
N–H	amines, amides	3300-3500
O–H	alcohols, phenols	3200-3600

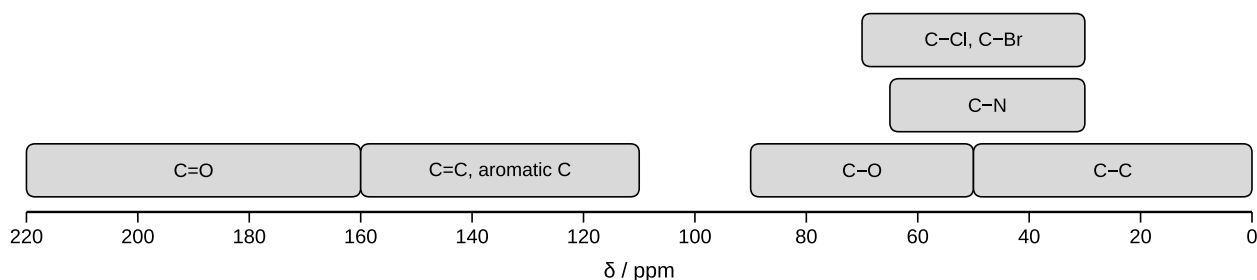
Turn over



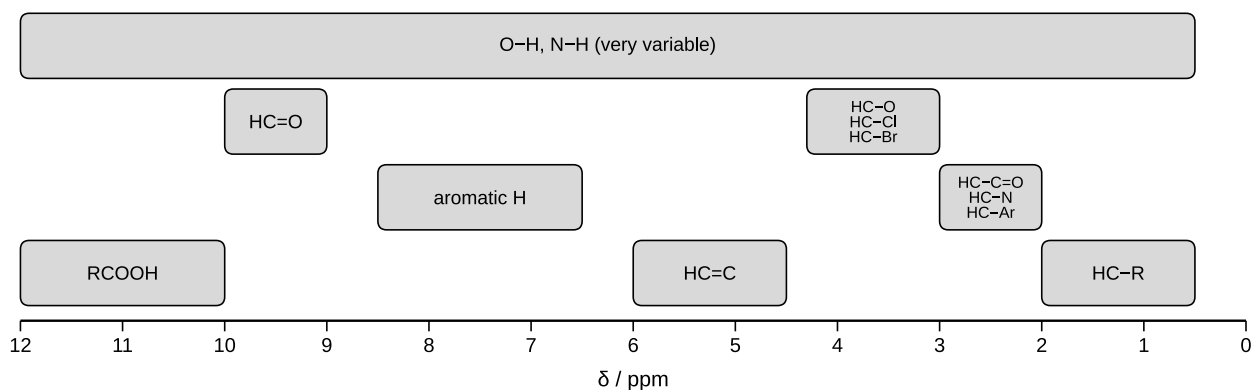
Data Sheet (continued): NMR chemical shifts

Redrawn in the style of the OCR Data Sheet for Chemistry A; ranges are approximate.

^{13}C NMR chemical shifts relative to TMS



^1H NMR chemical shifts relative to TMS



Chemical shifts are variable and can vary depending on the solvent, concentration and substituents. As a result, shifts may be outside the ranges indicated.

OH and NH chemical shifts are very variable and are often broad. Signals are not usually seen as split peaks.

Note that CH bonded to 'shifting groups' on either side, e.g. $\text{O}-\text{CH}_2-\text{C}=\text{O}$, may be shifted more than indicated.

Turn over



The Periodic Table of the Elements

Relative atomic masses as printed on the OCR Data Sheet (to one decimal place). Elements 104 onwards and the lanthanoids and actinoids are not shown.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H hydrogen 1.0																	2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57-71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium	89-103 actinoids															

Key: atomic number (top left); symbol; name; relative atomic mass (bottom).

Turn over



SECTION A: PERIODIC TABLE, ELEMENTS AND PHYSICAL CHEMISTRY

Modules 2, 3 and 5, with practical skills

- 1 Magnesium is an element in Group 2 of the periodic table. Fig. 1.1 shows the mass spectrum of a sample of magnesium.

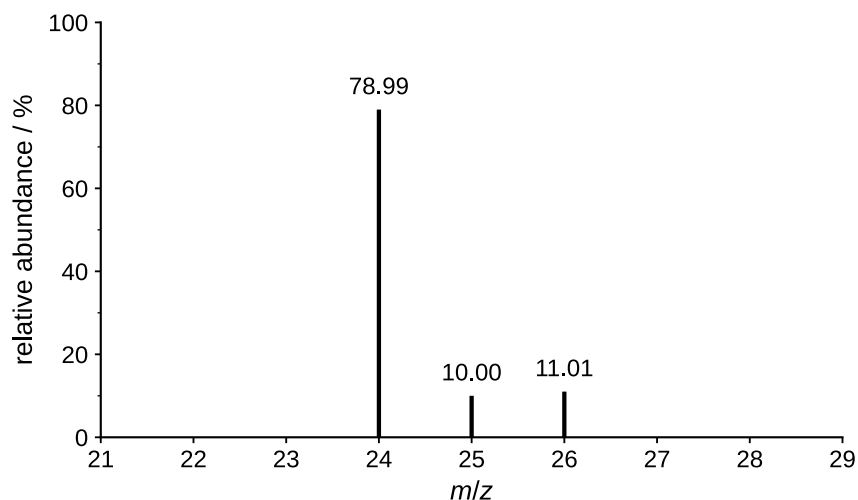


Fig. 1.1

- (a) Calculate the relative atomic mass of the magnesium in this sample.
Give your answer to **two** decimal places.

relative atomic mass = ... [2]

- (b) State the numbers of protons, neutrons and electrons in a $^{25}\text{Mg}^{2+}$ ion.

protons = ...

neutrons = ...

electrons = ... [1]

- (c) Write the full electron configuration of a magnesium atom.

..... [1]

- (d) Magnesium reacts with steam.

Write an equation, including state symbols, for this reaction.

..... [1]

Turn over



- (e) 0.486 g of magnesium is added to an excess of dilute hydrochloric acid.
Calculate the volume, in cm^3 , of hydrogen gas formed at room temperature and pressure (RTP).

volume = ... cm^3 [2]

- (f) Explain why the first ionisation energy of calcium is lower than the first ionisation energy of magnesium.

.....

.....

.....

.....

.....

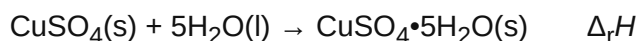
.....

..... [3]

Turn over



- 2 Anhydrous copper(II) sulfate reacts with water to form hydrated copper(II) sulfate:



$\Delta_r H$ cannot be measured directly. A student finds it from two enthalpy changes of solution.

Experiment 1

The student places 50.0 cm^3 of water in a polystyrene cup and measures the temperature every half minute. At 3.0 minutes the student adds 3.99 g of anhydrous CuSO_4 , stirs, and continues to measure the temperature every half minute until 8.0 minutes. Fig. 2.1 shows the results.

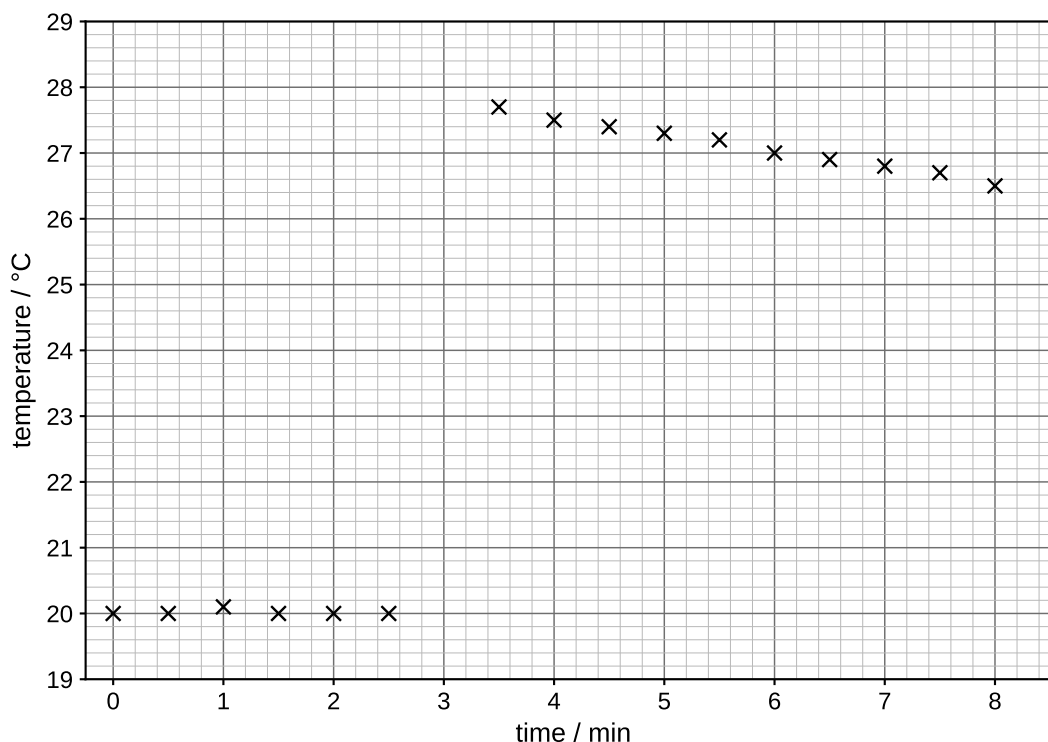


Fig. 2.1

- (a) Suggest why $\Delta_r H$ cannot be measured directly.

..... [1]

- (b) (i) Use Fig. 2.1 to determine the temperature change, ΔT , in Experiment 1. Show your working on Fig. 2.1.

$\Delta T = \dots\dots\dots$ °C [1]

Turn over

- (ii) Explain why the temperature change is not taken as the highest recorded temperature minus the starting temperature.

.....
 [1]

- (c) Calculate the enthalpy change of solution of anhydrous copper(II) sulfate, $\Delta_{\text{sol}}H(\text{CuSO}_4)$, in kJ mol^{-1} .
 Give your answer to **three** significant figures.

$\Delta_{\text{sol}}H = \text{..... kJ mol}^{-1}$ [3]

Experiment 2

The student repeats the method using 6.24 g of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in 50.0 cm^3 of water. The temperature falls by 1.4 $^{\circ}\text{C}$.

- (d) Determine Δ_rH , in kJ mol^{-1} .

$\Delta_rH = \text{..... kJ mol}^{-1}$ [3]

- (e) Each thermometer reading has an uncertainty of $\pm 0.1^{\circ}\text{C}$.
 (i) Calculate the percentage uncertainty in the temperature change in Experiment 2.

percentage uncertainty = ... % [1]

- (ii) Suggest one change to the method of Experiment 2 that would reduce this percentage uncertainty, using the same apparatus.

.....
 [1]

Turn over



- 3 Dinitrogen tetroxide, N_2O_4 , is colourless. It dissociates to form brown nitrogen dioxide, NO_2 :



A chemist seals 0.200 mol of N_2O_4 in a container and heats it to 320 K. At equilibrium the container holds 0.120 mol of NO_2 , and the total pressure is 180 kPa.

- (a) Write an expression for K_p for this equilibrium.

.....

.....

..... [1]

- (b) Calculate K_p at 320 K. Give the units of K_p .

$K_p =$

units = ... [4]

- (c) Calculate the volume, in dm^3 , of the container.

volume = ... dm^3 [2]

- (d) The volume of the container is decreased at constant temperature, and the mixture reaches equilibrium again.

- (i) State and explain the effect on the amount of NO_2 in the mixture.

.....

.....

.....

..... [2]

Turn over



(ii) State the effect, if any, on the value of K_p .

..... [1]

- (e) The container is then heated to a higher temperature at constant volume. The mixture becomes a darker brown.

Explain this observation, and state the effect on the value of K_p .

..... [2]

Turn over



- 4 A student determines the value of x in hydrated barium chloride, $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$, by heating a sample in a crucible to remove the water of crystallisation. Table 4.1 shows the results.

Table 4.1

	mass / g
empty crucible	18.235
crucible + hydrated barium chloride	20.678
crucible + contents after first heating	20.381
crucible + contents after second heating	20.319
crucible + contents after third heating	20.318

- (a) Explain why the student heats the crucible and contents more than once.

..... [1]

- (b) Determine the value of x .

$x =$ [3]

- (c) Another student heats a sample only once, and uses the mass after the first heating. Calculate the value of x this student would obtain. Explain why it is different from your answer to (b).

..... [2]

- (d) Aqueous barium chloride is used to test for sulfate ions.

- (i) Write an ionic equation, including state symbols, for the reaction in a positive test.

..... [1]

Turn over



- (ii) Explain why the solution being tested is acidified with dilute nitric acid before the barium chloride is added.

.....
..... [1]

- (e) 0.137 g of barium reacts completely with water. The solution formed is made up to 100.0 cm³ with water.

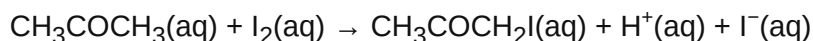
Calculate the pH of this solution at 298 K.

pH = ... [3]

Turn over



5 Propanone reacts with iodine in the presence of an acid catalyst:



A student follows the reaction with a colorimeter. At the start, the mixture contains propanone at $0.400 \text{ mol dm}^{-3}$, $\text{H}^+(\text{aq})$ at $0.200 \text{ mol dm}^{-3}$ and iodine at $2.00 \times 10^{-3} \text{ mol dm}^{-3}$. The student converts the colorimeter readings into concentrations of iodine. Fig. 5.1 shows the results.

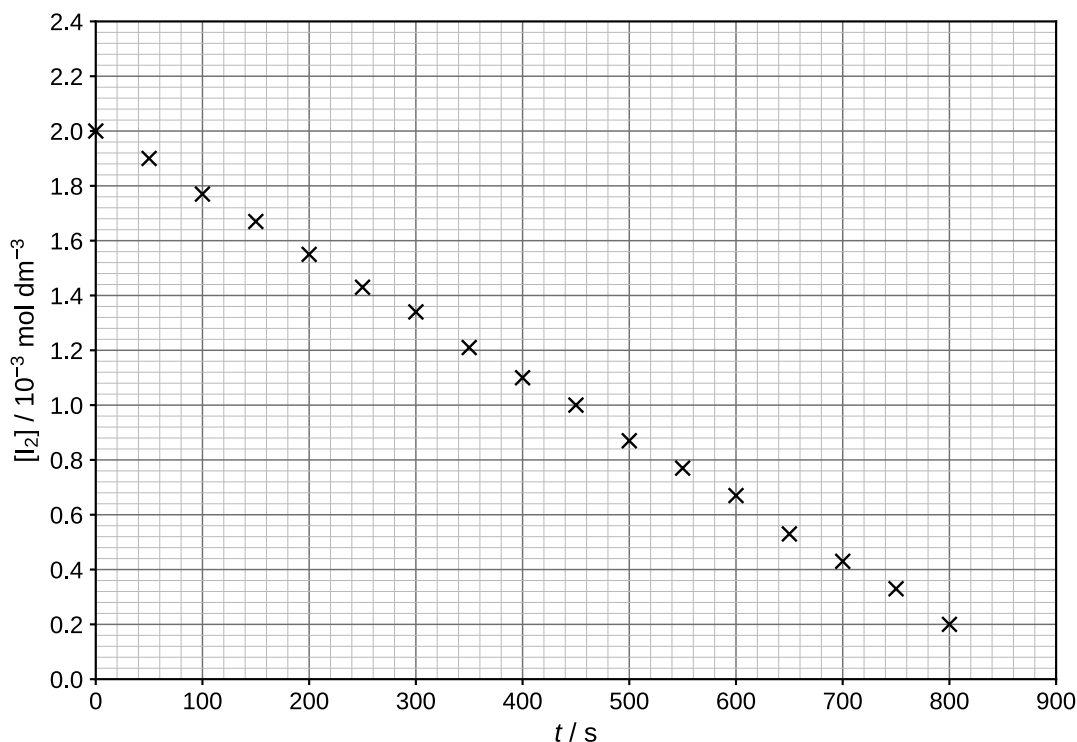


Fig. 5.1

- (a) Explain why the concentrations of propanone and H^+ are much greater than the concentration of iodine in this experiment.

..... [1]

- (b) (i) Deduce the order of reaction with respect to iodine. Explain your answer.

..... [2]

- (ii) Determine the rate of reaction, in $\text{mol dm}^{-3} \text{ s}^{-1}$. Show your working on Fig. 5.1.

rate = ... $\text{mol dm}^{-3} \text{ s}^{-1}$ [2]

Turn over

Table 5.1 shows further experiments at the same temperature.

Table 5.1

Experiment	$[\text{CH}_3\text{COCH}_3] / \text{mol dm}^{-3}$	$[\text{I}_2] / \text{mol dm}^{-3}$	$[\text{H}^+] / \text{mol dm}^{-3}$	initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$
1 (Fig. 5.1)	0.400	2.00×10^{-3}	0.200	your answer to (b)(ii)
2	0.800	2.00×10^{-3}	0.200	4.48×10^{-6}
3	0.800	4.00×10^{-3}	0.400	8.96×10^{-6}

- (c) (i) Deduce the rate equation for the reaction. Explain your reasoning.

.....

.....

.....

.....

.....

..... [3]

- (ii) Calculate the rate constant, k . Give its units.

$k =$

units = ... [2]

- (d) Suggest what the rate equation shows about the mechanism of this reaction.

.....

.....

.....

..... [2]

- (e) The student repeats Experiment 1 with an initial iodine concentration of $3.00 \times 10^{-3} \text{ mol dm}^{-3}$. All other conditions are unchanged.
Calculate the time taken for the iodine concentration to fall to half of its initial value.

time = ... s [2]

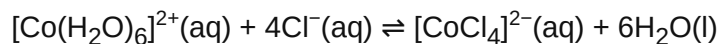
Turn over



- 6 (a) Write the electron configuration of a Co^{2+} ion.

[1]

When concentrated hydrochloric acid is added to a pink solution containing $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ ions, the solution turns blue as $[\text{CoCl}_4]^{2-}$ ions form:



- (b) (i) State the shape of each complex ion and the bond angle in each.

[2]

- (ii) A pink equilibrium mixture turns blue when it is warmed.

Deduce the sign of the enthalpy change for the forward reaction. Explain your answer.

[2]

- (iii) For the forward reaction, the magnitude of ΔH is 50 kJ mol^{-1} and $\Delta S = +150 \text{ J K}^{-1} \text{ mol}^{-1}$.

Explain why ΔS is positive. Calculate the temperature above which the forward reaction is feasible.

temperature = ... K

[3]

Cobalt(III) forms two compounds with ammonia and chloride ions: X, $\text{CoCl}_3 \cdot 5\text{NH}_3$, and Y, $\text{CoCl}_3 \cdot 4\text{NH}_3$. A solution containing 0.500 g of each compound is treated with an excess of aqueous silver nitrate. The precipitate of silver chloride is filtered, washed and dried. mass of silver chloride from X = 0.573 g; mass of silver chloride from Y = 0.307 g Chloride ligands bonded to cobalt do not react with silver nitrate.

- (c) (i) Deduce the formulae of the complex ions in X and in Y. Show your working.

Turn over



[4]

- (ii) Only one of the two complex ions shows stereoisomerism.
Draw 3D diagrams of the stereoisomers of this complex ion and label each one.
Explain why the other complex ion has no stereoisomers.

[3]

Turn over



7 Table 7.1 shows some standard electrode potentials.

Table 7.1

half-equation	$E^\ominus / \text{V}$
$\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+1.00
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{VO}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.34
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-0.14
$\text{V}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{V}^{2+}(\text{aq})$	-0.26
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76

The colours of the vanadium ions are: VO_2^+ yellow, VO^{2+} blue, V^{3+} green and V^{2+} violet.

(a) Deduce the oxidation number of vanadium in VO_2^+ and in VO^{2+} .

$\text{VO}_2^+ =$

$\text{VO}^{2+} =$ [1]

Fig. 7.1 shows a cell set up under standard conditions. The right-hand half-cell contains $\text{VO}_2^+(\text{aq})$ and $\text{VO}^{2+}(\text{aq})$, each at 1.00 mol dm^{-3} , in $1.00 \text{ mol dm}^{-3} \text{H}^+(\text{aq})$.

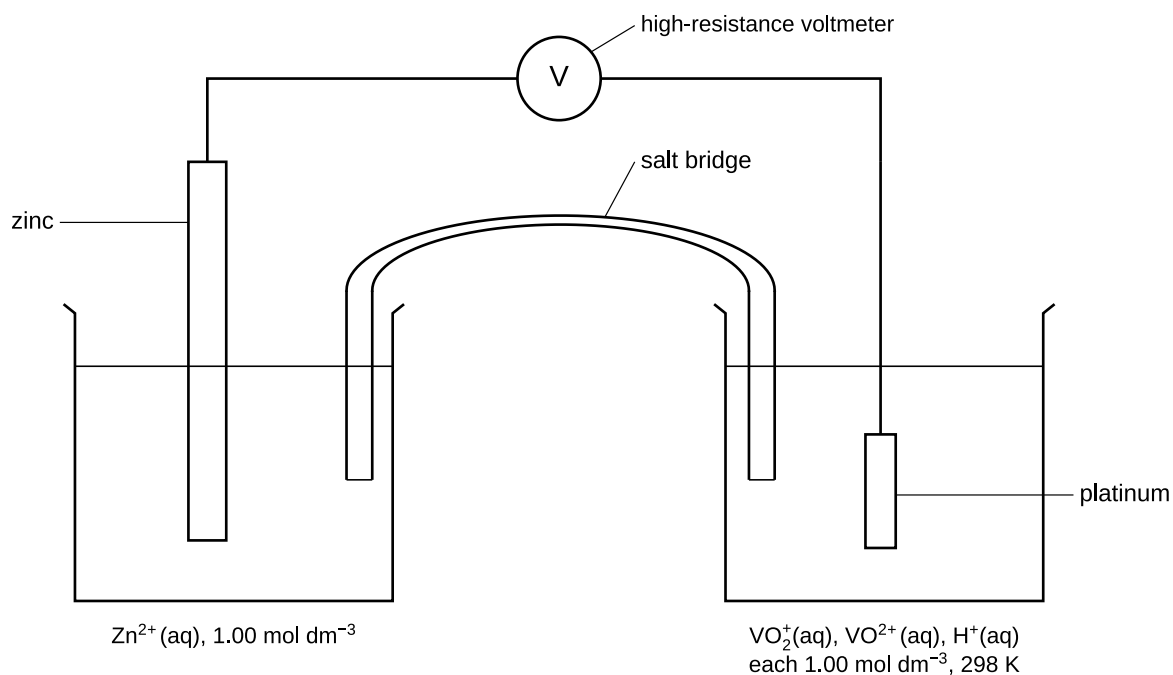


Fig. 7.1

(b) Explain why platinum is used as the electrode in the right-hand half-cell.

.....
 [1]

Turn over

- (c) Determine the standard cell potential of the cell in Fig. 7.1, and write the overall equation for the cell reaction.

.....

.....

..... [2]

- (d) When an excess of zinc is added to an acidified solution of VO_2^+ ions, the colour changes from yellow, through blue and green, to violet. When an excess of tin is used instead, the final colour is green.

Use Table 7.1 to explain these observations.

.....

.....

.....

.....

.....

.....

..... [3]

- (e) An excess of $\text{Fe}^{3+}(\text{aq})$ is added to an acidified solution of $\text{V}^{2+}(\text{aq})$. Predict the vanadium species present when the reaction is complete. Explain your answer.

.....

.....

.....

..... [2]

- (f) A vanadium redox flow battery uses the $\text{VO}_2^+/\text{VO}^{2+}$ and $\text{V}^{3+}/\text{V}^{2+}$ systems in its two half-cells.

- (i) Calculate the standard cell potential of the flow battery.

$$E_{\text{cell}} = \text{..... V [1]}$$

- (ii) When fully charged, the voltage of the flow battery is 1.40 V. Suggest why this is different from your answer to (f)(i).

.....

..... [2]

Turn over



- 8 Table 8.1 shows enthalpy changes for potassium chloride, KCl. Table 8.2 shows standard entropies at 298 K.

Table 8.1

process	$\Delta H / \text{kJ mol}^{-1}$
$\text{K(s)} \rightarrow \text{K(g)}$	+89
$\text{K(g)} \rightarrow \text{K}^+(\text{g}) + \text{e}^-$	+419
$\frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{Cl(g)}$	+122
$\text{Cl(g)} + \text{e}^- \rightarrow \text{Cl}^-(\text{g})$	-349
$\text{K(s)} + \frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{KCl(s)}$	-437
$\text{K}^+(\text{g}) \rightarrow \text{K}^+(\text{aq})$	-322
$\text{Cl}^-(\text{g}) \rightarrow \text{Cl}^-(\text{aq})$	-378

Table 8.2

substance	KCl(s)	$\text{K}^+(\text{aq})$	$\text{Cl}^-(\text{aq})$	LiF(s)	$\text{Li}^+(\text{aq})$	$\text{F}^-(\text{aq})$
$S / \text{J K}^{-1} \text{mol}^{-1}$	82.6	102.5	56.5	35.7	13.4	-13.8

Entropies of aqueous ions are measured relative to $\text{H}^+(\text{aq})$, so some values are negative.

Fig. 8.1 shows an incomplete Born-Haber cycle for potassium chloride.

Turn over



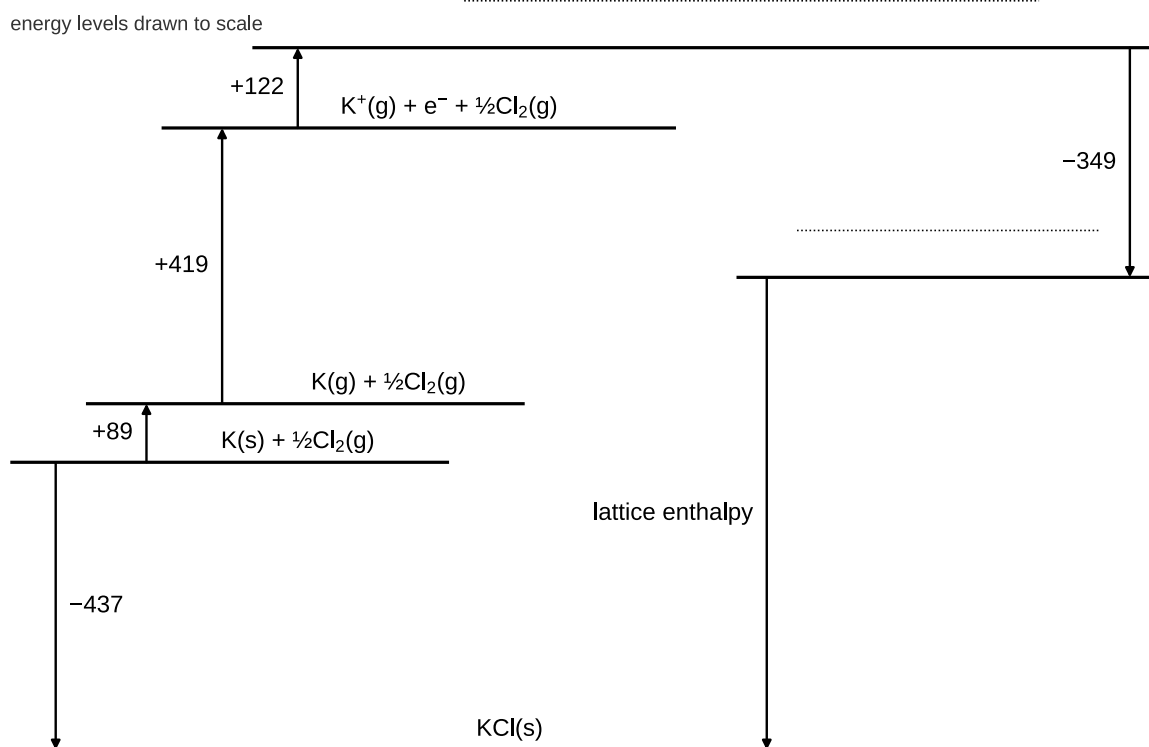


Fig. 8.1

(a) Complete Fig. 8.1 by writing the species, with state symbols, on the two blank lines.

[2]

(b) Determine the enthalpy change of solution of potassium chloride.

$$\Delta_{\text{sol}}H = \text{.....} \text{ kJ mol}^{-1} \quad [3]$$

(c) Determine the range of temperatures over which the dissolving of potassium chloride is feasible.

.....

.....

.....

.....

Turn over



[4]

Data for lithium fluoride, LiF:

lattice enthalpy = $-1036 \text{ kJ mol}^{-1}$; $\Delta_{\text{hyd}}H(\text{Li}^+) = -519 \text{ kJ mol}^{-1}$; $\Delta_{\text{hyd}}H(\text{F}^-) = -512 \text{ kJ mol}^{-1}$.

Entropies are in Table 8.2.

- (d) A student claims: 'Dissolving LiF is less endothermic than dissolving KCl, so LiF must be more soluble in water than KCl.'

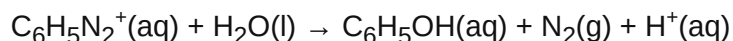
Evaluate this claim, using calculations at 298 K. Suggest why the entropy change of solution of LiF is negative.

[5]

Turn over



- 9 Benzenediazonium ions decompose in warm aqueous solution, releasing nitrogen:



A student investigates the rate of this reaction at 50.0 °C using the apparatus in Fig. 9.1. The gas syringe is outside the water bath, so gas volumes are measured at room temperature and pressure.

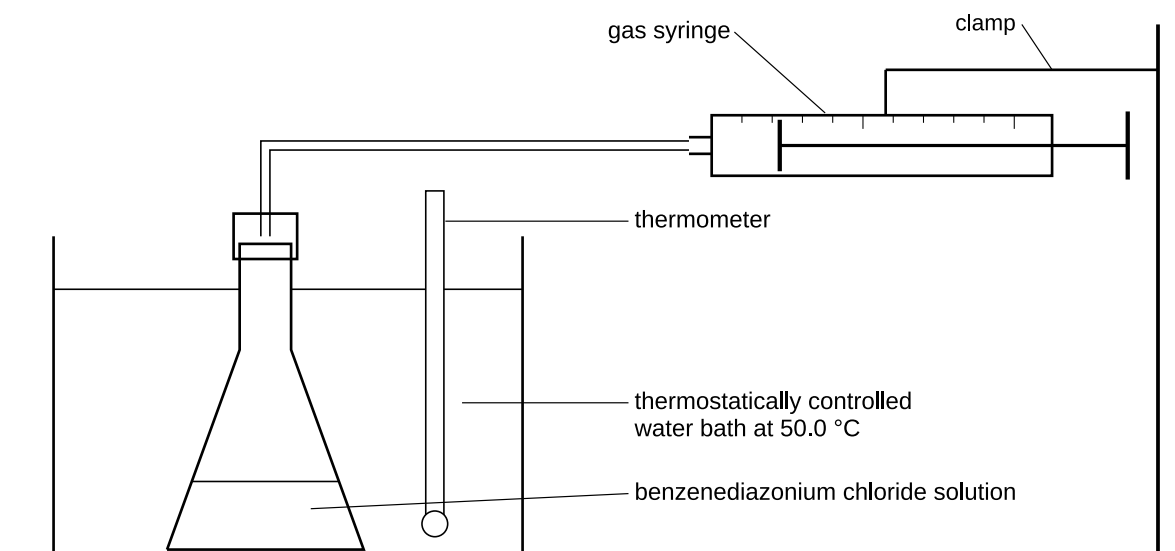


Fig. 9.1

- (a)* Describe how the student should carry out the experiment to obtain reliable results at 50.0 °C, and explain how the results can be processed to determine the order of reaction with respect to the benzenediazonium ion.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Turn over

[6]

Additional answer space if required

Turn over



The student uses 50.0 cm^3 of $0.0800 \text{ mol dm}^{-3}$ benzenediazonium chloride solution. Fig. 9.2 shows the student's results.

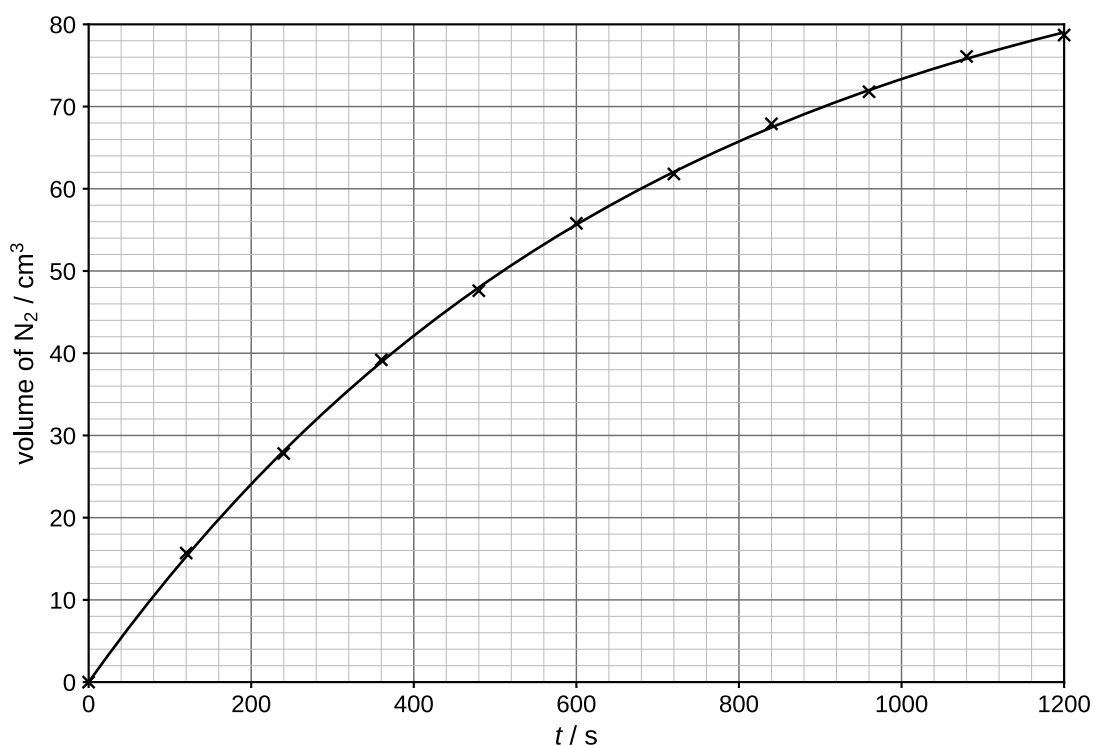


Fig. 9.2

- (b) Use Fig. 9.2 to deduce the order of reaction with respect to the benzenediazonium ion, and to determine the rate constant, k , at 50.0°C . Show your working on Fig. 9.2.

$k =$
 units = ... [5]

Turn over



- (c) At 40.0 °C the half-life of the reaction is 1780 s.
Calculate the activation energy, E_a , of the reaction, in kJ mol^{-1} .

$E_a =$ kJ mol^{-1} [3]

- (d) Estimate the temperature, in °C, at which the half-life of the reaction would be 60 s.

temperature = ... °C [2]

Turn over



- 10 A student is given a sample of an acid, A. It is known to be one of the acids in Table 10.1.

Table 10.1

acid	structure	pK_a
hydroxyethanoic acid	HOCH_2COOH	3.83
2-hydroxypropanoic acid	$\text{CH}_3\text{CH}(\text{OH})\text{COOH}$	3.86
3-hydroxypropanoic acid	$\text{HOCH}_2\text{CH}_2\text{COOH}$	4.51
methoxyethanoic acid	$\text{CH}_3\text{OCH}_2\text{COOH}$	3.57

The student dissolves 1.35 g of A in water and makes the solution up to 250.0 cm^3 . The student titrates 25.0 cm^3 of this solution with $0.0500 \text{ mol dm}^{-3} \text{ NaOH(aq)}$, measuring the pH with a pH meter. Fig. 10.1 shows the titration curve.

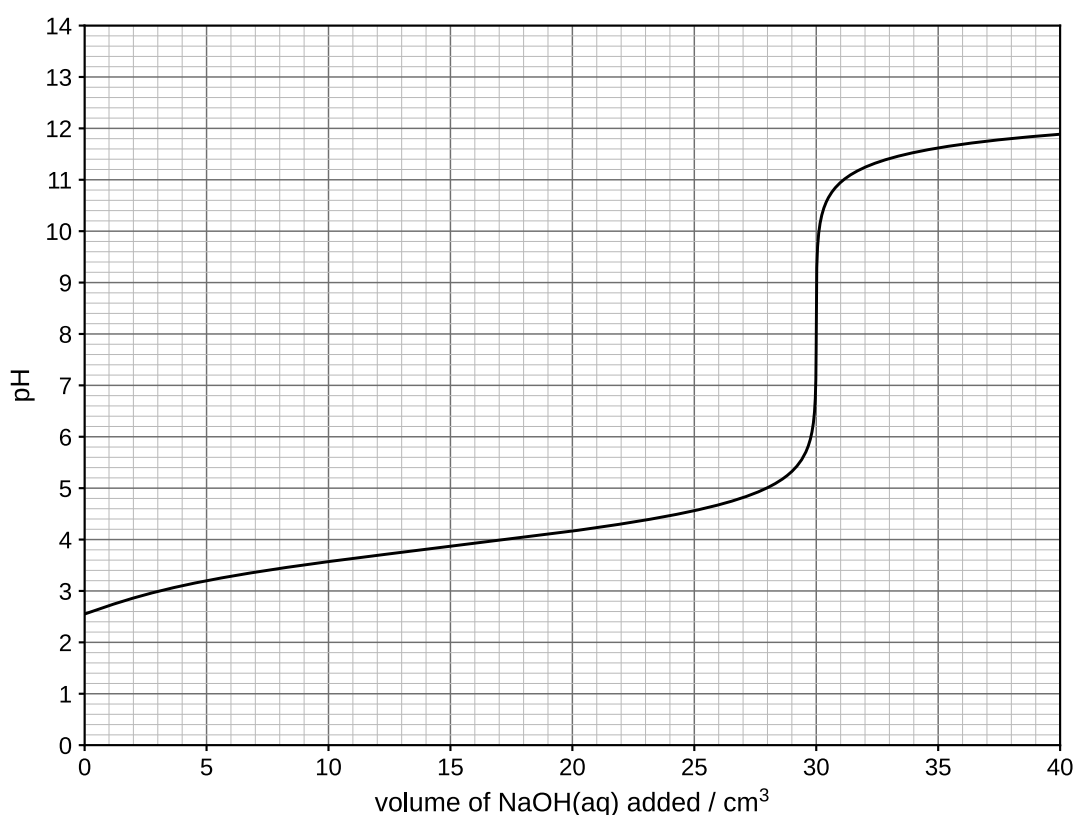


Fig. 10.1

- (a) Identify A. Show all your reasoning.

Turn over



.....

.....

.....

.....

..... [5]

- (b) Explain why the pH changes only slowly between 5 cm³ and 25 cm³ of NaOH(aq) added.

.....

.....

.....

..... [2]

- (c) Calculate the pH of the solution of A before any NaOH(aq) is added. State one assumption you make.

pH = ...

.....

..... [3]

- (d) Calculate the pH of the mixture after 10.0 cm³ of NaOH(aq) has been added.

pH = ... [3]

Turn over



- (e) The student wants to make a buffer solution with a pH of 4.50 by adding $0.0500 \text{ mol dm}^{-3}$ NaOH(aq) to 25.0 cm^3 of the solution of A.
Calculate the volume of NaOH(aq) needed.

volume = ... cm^3 [3]

Turn over



SECTION B: SYNTHESIS AND ANALYTICAL TECHNIQUES

Modules 2, 4 and 6, with practical skills

- 11** Fig. 11.1 shows the skeletal formulae of three alkenes, A, B and C. They are structural isomers with molecular formula C_4H_8 .

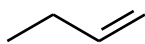
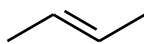
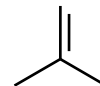
**A****B****C**

Fig. 11.1

- (a) Name alkene C.

[1]

- (b) Alkene B shows *E/Z* isomerism but alkene A does not. Explain why.

[2]

- (c) Alkene C reacts with hydrogen bromide to form two organic products. One is the major product.

- (i) Name the type of mechanism.

[1]

- (ii) Draw the structure of the major product. Explain why it is the major product.

[2]

- (d) Draw the repeat unit of the addition polymer formed from alkene C.

[1]

Turn over



- (e) Calculate the volume, in dm^3 , of carbon dioxide formed at RTP when 1.40 g of alkene A burns completely in oxygen.

volume = ... dm^3 [2]

Turn over



- 12** Butan-1-ol can be oxidised by heating with acidified potassium dichromate(VI). Fig. 12.1 shows the apparatus a student uses to oxidise butan-1-ol to butanoic acid.

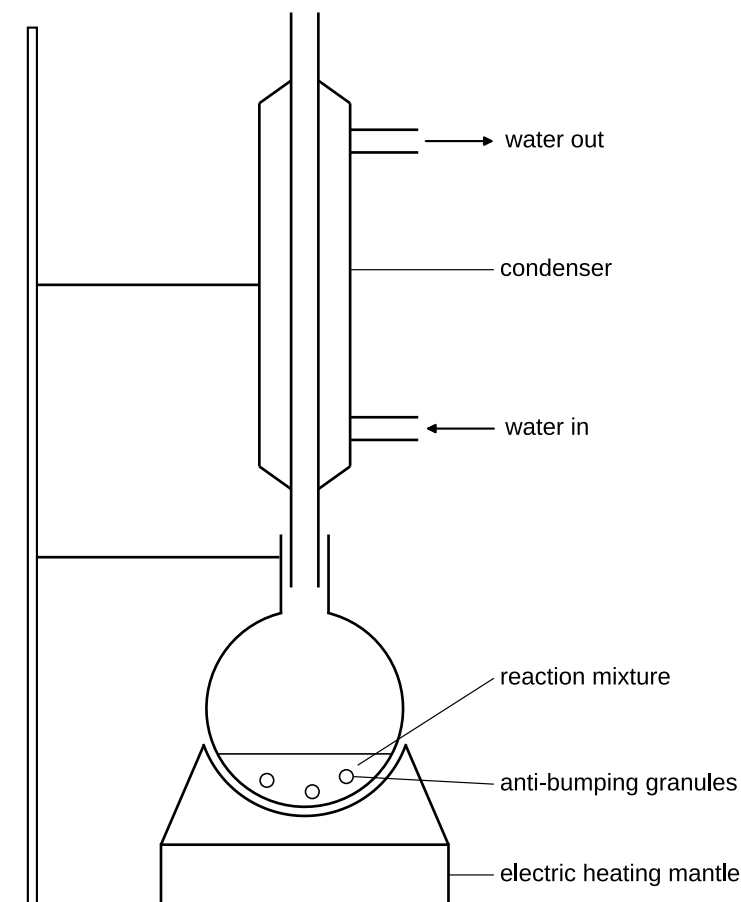


Fig. 12.1

- (a) Name the technique shown in Fig. 12.1. Explain why it is used for this preparation.

.....

.....

.....

..... [2]

- (b) Write an equation for the oxidation of butan-1-ol to butanoic acid. Use [O] to represent the oxidising agent.

.....

..... [1]

- (c) State the colour change of the reaction mixture.

..... [1]

Turn over

In a second preparation, the student heats 7.40 g of butan-1-ol with acidified dichromate(VI) and distils off the product as it forms. The student collects 4.32 g of distillate. Fig. 12.2 shows the infrared spectrum of the distillate.

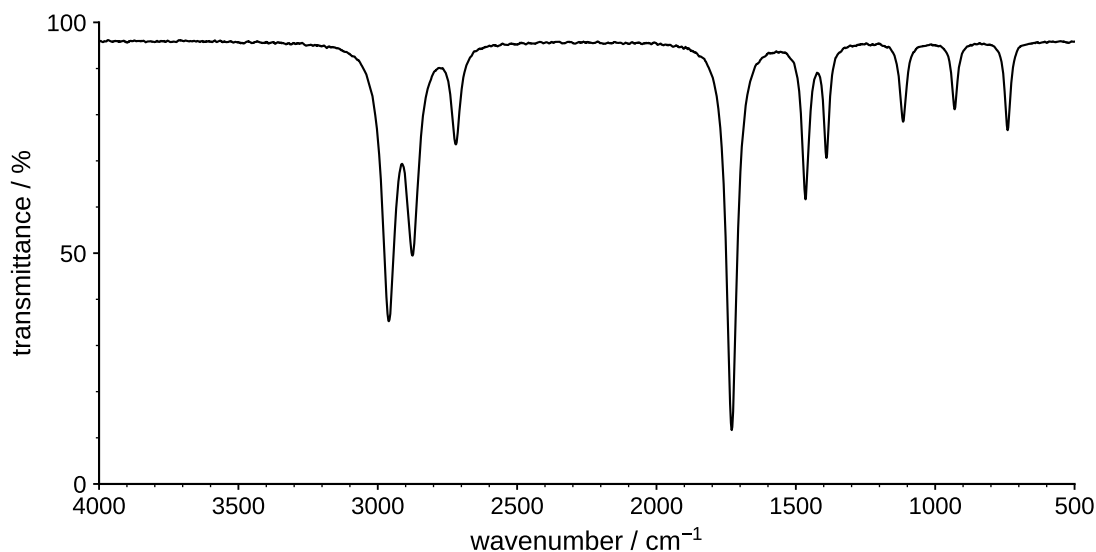


Fig. 12.2

- (d) Use Fig. 12.2 to identify the distillate. Explain your answer.

.....

.....

.....

..... [2]

- (e) Calculate the percentage yield of the distillate.

percentage yield = ... % [2]

- (f) The boiling point of the distillate is 75 °C. The boiling point of butan-1-ol is 117 °C. Explain why the distillate has a lower boiling point than butan-1-ol.

.....

.....

.....

..... [2]

Turn over

- (g) State why 2-methylpropan-2-ol is not oxidised by acidified potassium dichromate(VI).

.....
..... [1]

Turn over



- 13** A student compares the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane. The student adds 5 drops of each haloalkane to 1 cm³ of ethanol in separate test tubes, warms them to 50 °C, adds 1 cm³ of aqueous silver nitrate at 50 °C to each, and times how long a precipitate takes to appear.

Table 13.1 shows the results.

Table 13.1

haloalkane	1-chlorobutane	1-bromobutane	1-iodobutane
time for a precipitate to appear / s	no precipitate after 1800	210	35

Table 13.2 shows some data about the carbon-halogen bonds. The electronegativity of carbon is 2.5.

Table 13.2

bond	C–Cl	C–Br	C–I
bond enthalpy / kJ mol ⁻¹	346	290	228
electronegativity of the halogen	3.0	2.8	2.5

- (a) Explain why ethanol is used in this experiment.
- [1]
- (b) State the colour of the precipitate formed with 1-iodobutane.
- [1]
- (c) Outline the mechanism for the hydrolysis of 1-bromobutane by hydroxide ions, OH⁻. Show curly arrows and relevant dipoles.
- [3]
- (d) Use Tables 13.1 and 13.2 to explain the order of reactivity of the haloalkanes. Explain why the data do not support an explanation based on bond polarity.
- [3]

Turn over



(e) Chlorofluorocarbons, such as CCl_2F_2 , break down in the stratosphere to form chlorine radicals, which catalyse the breakdown of ozone.

(i) Write two equations to show how chlorine radicals catalyse the breakdown of ozone.

.....

.....

..... [2]

(ii) Suggest why CCl_2F_2 forms chlorine radicals rather than fluorine radicals.

.....

..... [1]

Turn over



- 14** Methyl benzoate is nitrated using a mixture of concentrated nitric acid and concentrated sulfuric acid, kept below 10 °C. The main organic product is methyl 3-nitrobenzoate, as shown in Fig. 14.1.

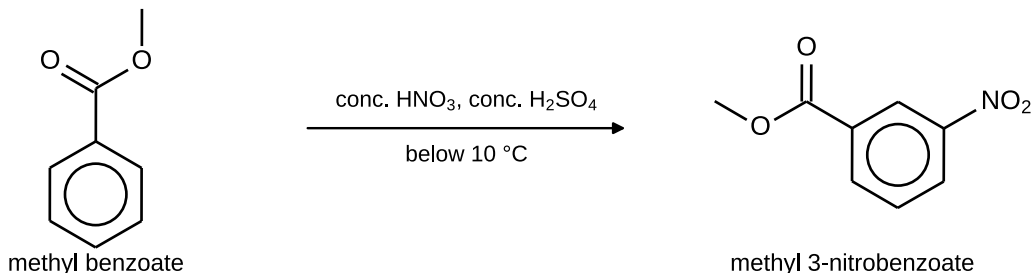


Fig. 14.1

- (a) Write an equation to show how the electrophile forms from nitric acid and sulfuric acid.

- (b) Outline the mechanism for the formation of methyl 3-nitrobenzoate from methyl benzoate. Show curly arrows and the structure of the intermediate.

Suggest why the mixture is kept below 10 °C.

[1]

- (c) Suggest why the mixture is kept below 10 °C.

A student uses 2.72 g of methyl benzoate and obtains 2.44 g of crude methyl 3-nitrobenzoate.

- (d) Calculate the percentage yield.

percentage yield = ... % [2]

- (e) The student purifies the crude product by recrystallisation from ethanol.

Turn over

- (i) Describe how the student should carry out the recrystallisation and obtain a dry sample.

.....

.....

.....

.....

.....

..... [3]

- (ii) The recrystallised product melts at 76 to 78 °C. The data-book melting point is 78 °C. Explain what this shows.

.....

..... [1]

Turn over



15 Compounds K and L are structural isomers with molecular formula C_4H_8O .

- Both K and L form an orange precipitate with 2,4-dinitrophenylhydrazine.
- K forms a silver mirror when warmed with Tollens' reagent; L does not.
- The ^{13}C NMR spectrum of K has three peaks.

(a) Identify K and L. Explain your reasoning.

.....

.....

.....

.....

.....

[4]

(b) L reacts with $NaCN(aq)$ and dilute sulfuric acid to form compound M, C_5H_9NO .

Outline the mechanism for this reaction. Show curly arrows, relevant dipoles and the structure of the intermediate.

[4]

(c) M is formed as a racemic mixture.
Explain why.

.....

.....

.....

[2]

(d) M is heated under reflux with dilute hydrochloric acid to form a carboxylic acid, N.
Write an equation for the formation of N from M. Use structural formulae.

.....

.....

.....

[2]

Turn over



- (e) N is heated with concentrated sulfuric acid. Three isomeric unsaturated carboxylic acids, $C_5H_8O_2$, form.

Draw the structures of the three products. Label any *E* and *Z* isomers.

[3]

Turn over



- 16 Aspartame is an artificial sweetener. Fig. 16.1 shows its structure.

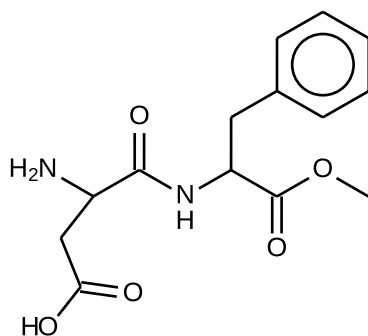


Fig. 16.1

- (a) Label each chiral centre in Fig. 16.1 with an asterisk (*).

[1]

- (b) Aspartame is hydrolysed by heating it under reflux with an excess of dilute hydrochloric acid. Three organic products form.
Draw the structures of the three organic products.

[3]

Turn over

A student neutralises the hydrolysis mixture and analyses it by thin-layer chromatography (TLC). On the same plate the student runs three reference samples: aspartic acid (A), glycine (G) and phenylalanine (P). Fig. 16.2 shows the chromatogram after the spots have been located.

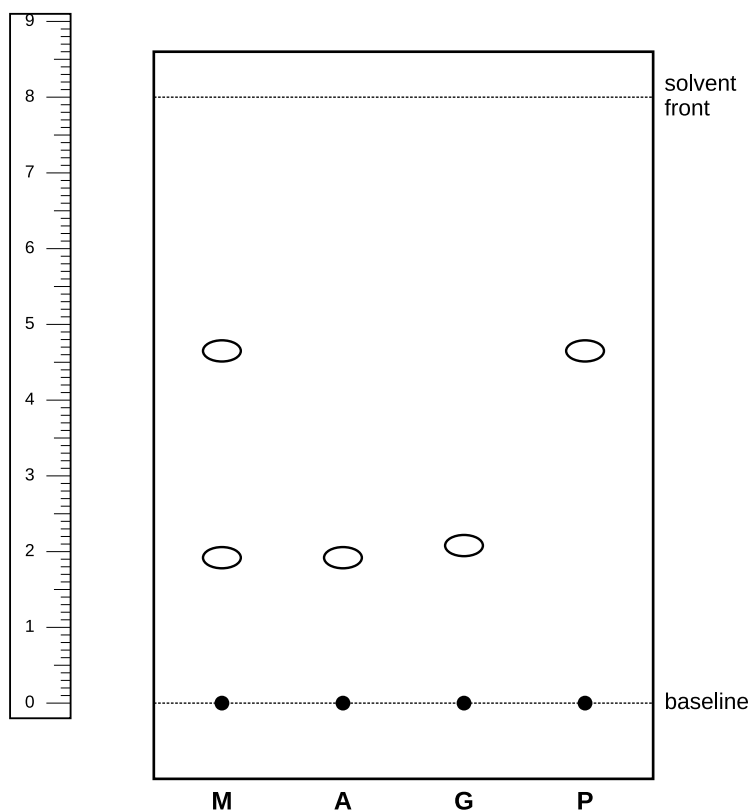


Fig. 16.2

- (c) Use Fig. 16.2 to identify the amino acids in the hydrolysis mixture, M. Calculate the R_f value of each spot in lane M.

[3]

Turn over

- (d) A student says that the reference lanes were unnecessary, because R_f values for amino acids are listed in data books.

Use Fig. 16.2 to explain why running the reference samples on the same plate is more reliable.

- (e) Aspartame can also be hydrolysed by heating it under reflux with an excess of NaOH(aq). Draw the structures of the organic products formed.

[3]

- (f) 6-Aminohexanoic acid, $\text{H}_2\text{N}(\text{CH}_2)_5\text{COOH}$, forms a polymer used as a fibre.

Draw the repeat unit of this polymer and name the type of polymerisation.

[2]

Turn over



17 Paracetamol is made from phenol in three steps, as shown in Fig. 17.1.

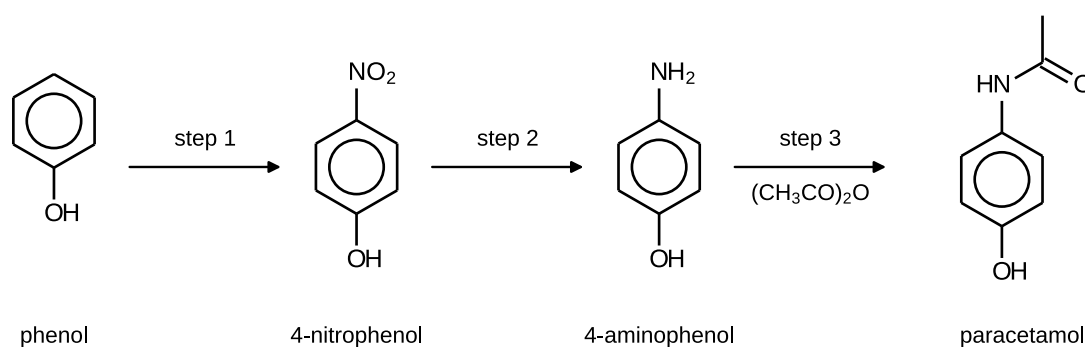


Fig. 17.1

(a) State the reagents and conditions for step 1 and step 2.

.....

.....

.....

.....

[3]

(b) Explain why phenol reacts with nitric acid much more readily than benzene does.

.....

.....

.....

.....

[2]

(c) Step 1 also forms 2-nitrophenol, which is separated. The percentage yields are: step 1, 38% (of 4-nitrophenol); step 2, 80%; step 3, 75%.

Calculate the mass of phenol needed to make 10.0 g of paracetamol.

mass = ... g [3]

Turn over

- (d) Ethanoyl chloride could be used in step 3 instead of ethanoic anhydride. Compare the atom economies of the two methods. Suggest why manufacturers use ethanoic anhydride.

[3]

- (e) Paracetamol, like phenol, is a weak acid.
Write an equation for the reaction of paracetamol with cold, dilute NaOH(aq) . Explain how aqueous sodium carbonate could be used to show that paracetamol contains a phenol group and not a carboxylic acid group.

[3]

Turn over



- 18** Compound P contains carbon, hydrogen and oxygen only. Its percentage composition by mass is C, 62.1%; H, 10.3%.

Fig. 18.1 shows the mass spectrum of P.

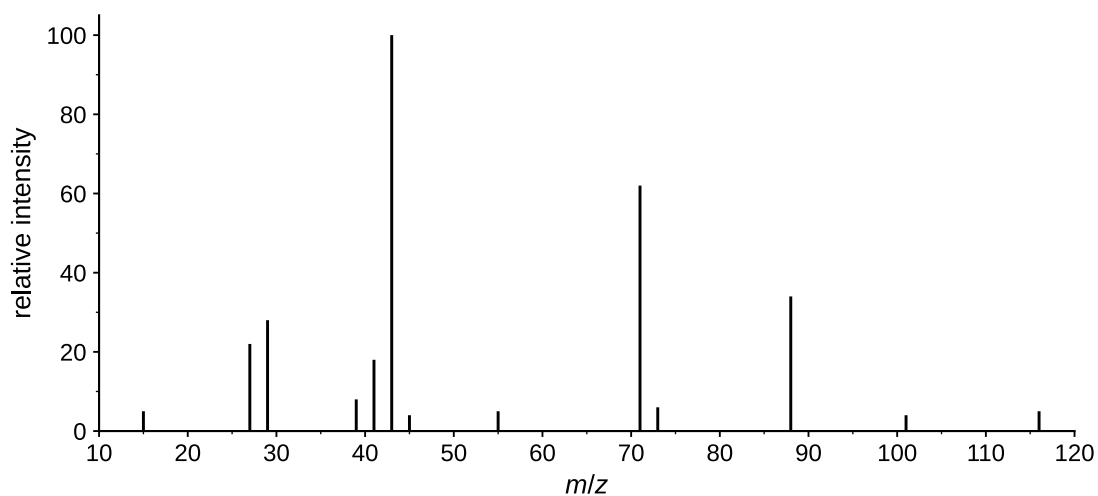


Fig. 18.1

- (a) Determine the molecular formula of P.

.....

.....

.....

.....

.....

.....

.....

[3]

Turn over



Fig. 18.2 shows the infrared spectrum of P.

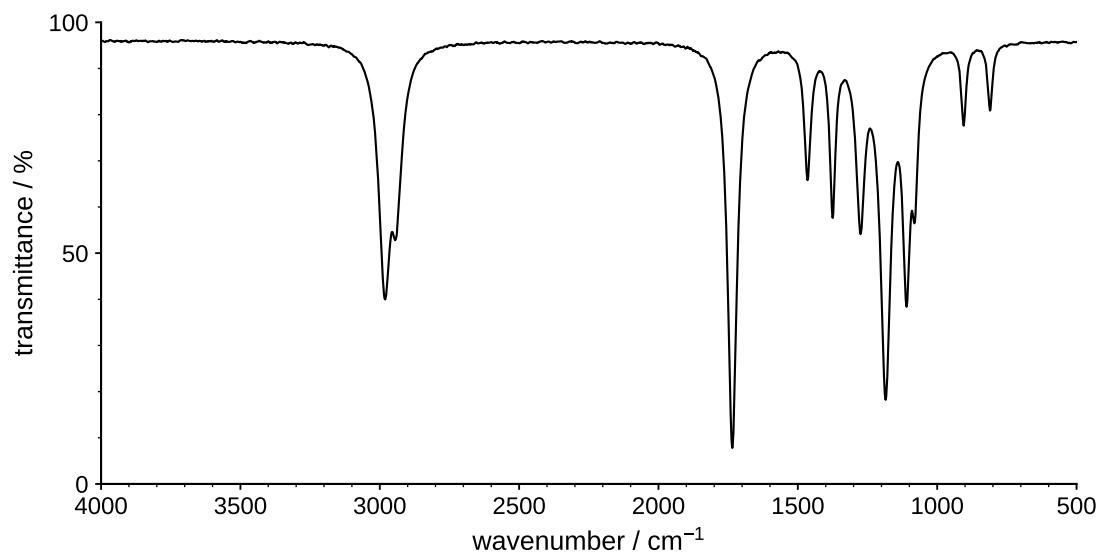


Fig. 18.2

(b) Use Fig. 18.2 to deduce the functional group in P. Explain why P is not a carboxylic acid.

.....

.....

.....

.....

[2]

Fig. 18.3 shows the ^1H NMR spectrum of P. The numbers by the peaks are the relative peak areas.

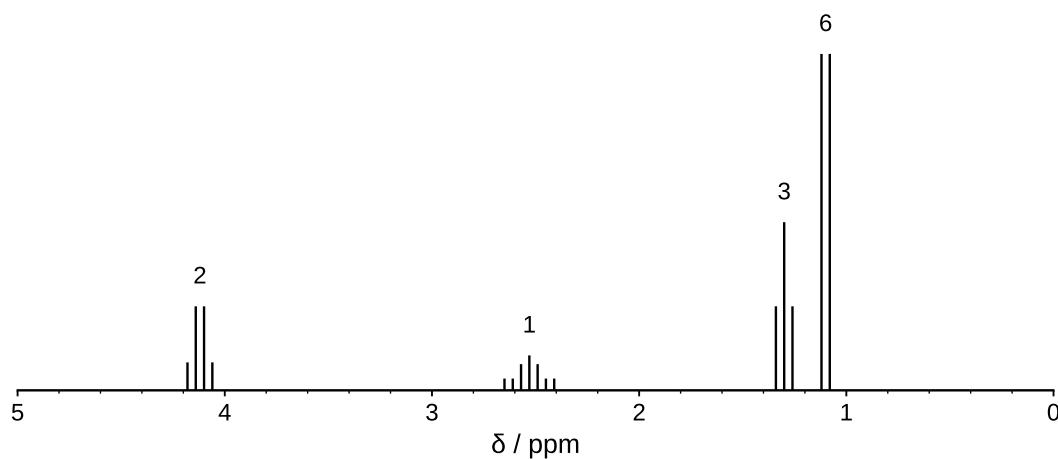


Fig. 18.3

Turn over

- (c) Deduce the structure of P. Explain how each peak in Fig. 18.3 supports your structure.

[4]

- (d) Explain why the splitting patterns and relative peak areas in Fig. 18.3 do not, by themselves, prove the structure of P.
Name and draw an isomer of P that gives the same splitting pattern and relative peak areas, and explain how Fig. 18.3 and Fig. 18.1 show that P is not this isomer.

[4]

- (e) Predict the number of peaks in the ^{13}C NMR spectrum of P.

[1]

Turn over



19 Compound Q, *N*-propylbutanamide, is shown in Fig. 19.1.

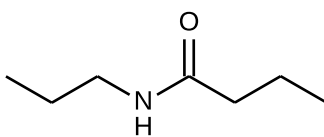


Fig. 19.1

- (a)* Plan a synthesis of Q in which 1-bromopropane is the **only** organic starting material. In your answer, include reagents and conditions for each step, the structures of the organic intermediates, and the type of reaction in each step.

[illegible]

Turn over



Additional answer space if required

- (b) Calculate the maximum mass of Q that could be made from 24.6 g of 1-bromopropane.

maximum mass = ... g [3]

- (c) Predict the number of peaks in the ^1H NMR spectrum of Q, and the splitting pattern of the peak due to the CH_2 group bonded to $\text{C}=\text{O}$.

State how the spectrum changes when D_2O is added. Explain your answer.

[3]

Turn over



- 20 Polymer Z is used to make stitches that dissolve in the body. Z is a copolymer made from two different monomers. Fig. 20.1 shows a short section of Z. The two types of repeat unit are arranged randomly along the chain; this section is not representative of the composition of the whole polymer.

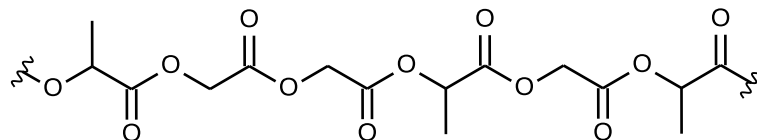


Fig. 20.1

- (a) Draw the structures of the two organic products formed when Z is completely hydrolysed by heating with an excess of NaOH(aq).

[2]

A student heats 1.00 g of Z under reflux with 25.0 cm³ of 1.00 mol dm⁻³ NaOH(aq) until hydrolysis is complete. The student cools the mixture and makes it up to 100.0 cm³ with water. 25.0 cm³ portions of this solution are titrated with 0.100 mol dm⁻³ HCl(aq). The mean titre is 26.00 cm³.

- (b) Determine the percentage of the repeat units in Z that contain a methyl group.

percentage = ... % [5]

Turn over

A sample of the hydrolysis mixture is acidified and dissolved in D_2O . Fig. 20.2 shows its ^1H NMR spectrum. The numbers by the peaks are the relative peak areas.

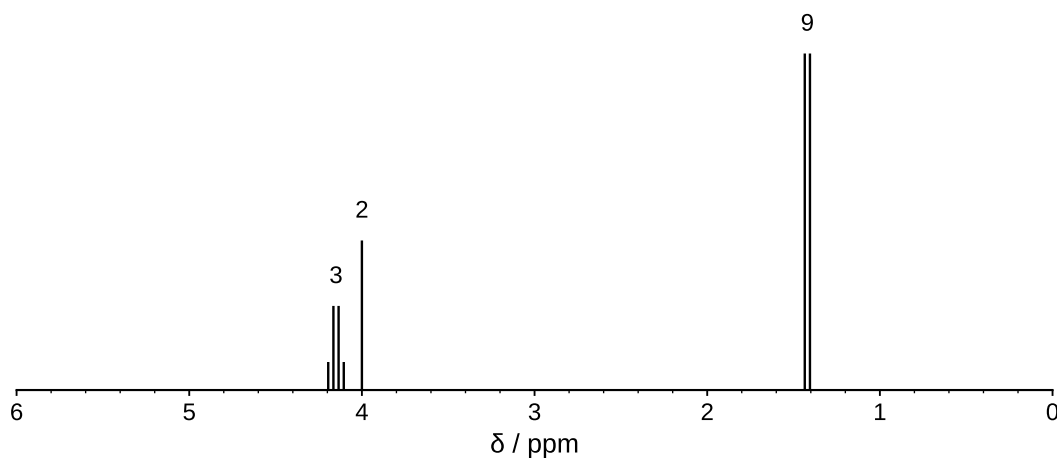


Fig. 20.2

- (c) Use Fig. 20.2 to determine the ratio of the two types of repeat unit in Z. Comment on whether your answer agrees with your answer to (b).

[3]

- (d) Explain why the bonds linking the repeat units in Z are broken down in the body, but those in poly(propene) are not.

[2]

Turn over



SECTION C: UNIFIED CHEMISTRY

Synoptic questions across all modules, with practical skills

- 21** A student determines the concentration of ethanoic acid in vinegar. The student dilutes 25.0 cm^3 of vinegar to 250.0 cm^3 with distilled water in a volumetric flask. The student titrates 25.0 cm^3 portions of the diluted vinegar with $0.100 \text{ mol dm}^{-3} \text{ NaOH(aq)}$, using phenolphthalein indicator. Table 21.1 shows the results.

Table 21.1

titration	rough	1	2	3
final burette reading / cm^3	23.60	23.65		23.30
initial burette reading / cm^3	0.00	0.50	23.65	0.15
titre / cm^3	23.60	23.15		23.15

Fig. 21.1 shows the burette at the end of titration 2.

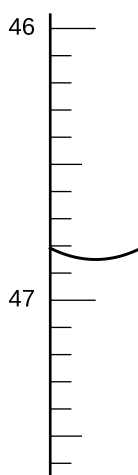


Fig. 21.1

- (a) Complete Table 21.1.

[2]

- (b) Calculate the mean titre, using concordant results only.

mean titre = ... cm^3 [1]

- (c) Write an equation for the reaction of ethanoic acid with sodium hydroxide.

.....
 [1]

Turn over



- (d) Calculate the concentration, in mol dm^{-3} , of ethanoic acid in the original vinegar.

concentration = ... mol dm^{-3} [3]

- (e) Calculate the concentration of ethanoic acid in the original vinegar in g dm^{-3} .

concentration = ... g dm^{-3} [1]

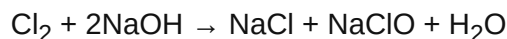
- (f) Each burette reading has an uncertainty of $\pm 0.05 \text{ cm}^3$.
Calculate the percentage uncertainty in the titre for titration 2.

percentage uncertainty = ... % [1]

Turn over



- 22 Household bleach is made by reacting chlorine with cold, dilute sodium hydroxide:



- (a) Use oxidation numbers to explain why this reaction is described as disproportionation.

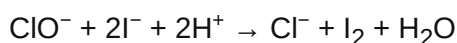
.....

.....

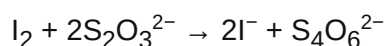
.....

..... [2]

A student determines the concentration of NaClO in a bleach. The student dilutes 10.0 cm³ of the bleach to 250.0 cm³ with distilled water. A 25.0 cm³ portion is added to an excess of acidified potassium iodide:



The iodine formed is titrated with 0.100 mol dm⁻³ sodium thiosulfate, using starch indicator. The mean titre is 13.60 cm³.



- (b) Calculate the concentration of NaClO in the bleach, in g dm⁻³.

concentration = ... g dm⁻³ [4]

- (c) Starch indicator is added near the end point.

- (i) State the colour change at the end point.

..... [1]

- (ii) Explain why the starch is not added at the start of the titration.

.....

..... [1]

Turn over



- (d) Bottles of bleach carry a warning not to mix bleach with acidic toilet cleaners that contain hydrochloric acid.

Write an ionic equation to explain this warning.

.....

.....

..... [2]

Turn over



23 Table 23.1 shows the boiling points of three compounds with similar relative molecular masses.

Table 23.1

compound	formula	M_r	boiling point / °C
propane	CH ₃ CH ₂ CH ₃	44.0	−42
methoxymethane	CH ₃ OCH ₃	46.0	−24
ethanol	CH ₃ CH ₂ OH	46.0	78

- (a) Explain the differences in the boiling points of the three compounds.

[4]

- (b) Draw a diagram to show a hydrogen bond between two ethanol molecules. Include relevant dipoles and lone pairs.

- (c) Predict the H-N-H bond angles in NH_3 and in NH_4^+ . Explain the difference.

[3]

Turn over



- (d) The C=O bonds in CO₂ are polar, but a CO₂ molecule is non-polar.

Explain why.

.....
..... [1]

- (e) Propan-1-ol, CH₃CH₂CH₂OH, boils at 97 °C.

Explain why its boiling point is higher than that of ethanol.

.....
.....
.....
..... [2]

Turn over



- 24** A student determines the relative molecular mass of a volatile liquid hydrocarbon, H, using the apparatus in Fig. 24.1. The gas syringe is kept at 100 °C. The student injects 0.200 g of H, which vaporises completely. The volume in the gas syringe increases by 71.4 cm³. The pressure is 101 kPa.

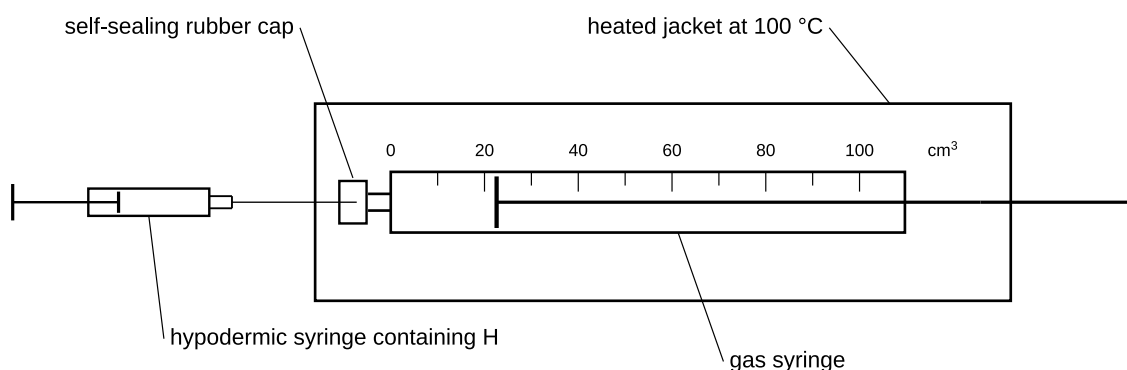


Fig. 24.1

- (a) Calculate the relative molecular mass of H.

$$M_r = \text{-----} \quad [3]$$

- (b) Complete combustion of 0.200 g of H forms 0.614 g of carbon dioxide and 0.293 g of water.

Use these data and your answer to (a) to determine the molecular formula of H.

[3]

Turn over



H is hexane. Table 24.1 shows some average bond enthalpies.

Table 24.1

bond	C-H	C-C	O=O	C=O	O-H
average bond enthalpy / kJ mol^{-1}	413	347	498	805	464

- (c) (i) Use Table 24.1 to calculate a value for the enthalpy change of combustion of hexane, C_6H_{14} .

$$\Delta_c H = \text{.....} \text{ kJ mol}^{-1} \quad [2]$$

- (ii) The data-book value of the standard enthalpy change of combustion of hexane is $-4163 \text{ kJ mol}^{-1}$.

Explain why your value in (c)(i) is different.

.....

.....

.....

..... [2]

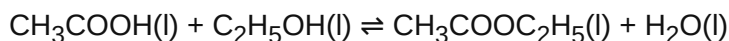
- (d) One structural isomer of hexane has only two peaks in its ^1H NMR spectrum. Draw the skeletal formula of this isomer.

[1]

Turn over



- 25 A student mixes 0.250 mol of ethanoic acid, 0.200 mol of ethanol and a small volume of concentrated sulfuric acid as a catalyst, in a sealed flask. The mixture is left at 25 °C until equilibrium is reached. The water in the catalyst can be ignored.



The student pours the equilibrium mixture into ice-cold distilled water and makes the volume up to 250.0 cm³. 25.0 cm³ portions are titrated quickly with 0.500 mol dm⁻³ NaOH(aq). The mean titre is 24.15 cm³.

In a separate experiment, the same volume of sulfuric acid, treated in the same way, requires 3.60 cm³ of the NaOH(aq) for each 25.0 cm³ portion.

- (a) Write an expression for K_c for this equilibrium.

.....

.....

..... [1]

- (b) Explain why the equilibrium mixture is poured into ice-cold water before it is titrated.

.....

..... [1]

- (c) Calculate K_c .

$$K_c = \text{.....} [5]$$

- (d) Explain why K_c can be calculated without knowing the volume of the equilibrium mixture.

.....

..... [1]

Turn over



- (e) The student predicts that using 0.400 mol of ethanol with 0.250 mol of ethanoic acid will double the equilibrium amount of ethyl ethanoate.
Evaluate this prediction. Use calculations.

.....

.....

.....

.....

.....

.....

.....

..... [3]

Turn over



26 Brass is an alloy of copper and zinc. A student determines the percentage by mass of copper in a sample of brass by colorimetry.

- 0.500 g of brass is dissolved in concentrated nitric acid in a fume cupboard, and the solution is made up to 100.0 cm³ with water.
- 10.0 cm³ of this solution is mixed with an excess of aqueous ammonia and made up to 50.0 cm³ with water. The copper is present as deep blue $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ ions.
- The absorbance of this solution is measured with a colorimeter.

Fig. 26.1 shows a calibration graph made using standard solutions of $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$.

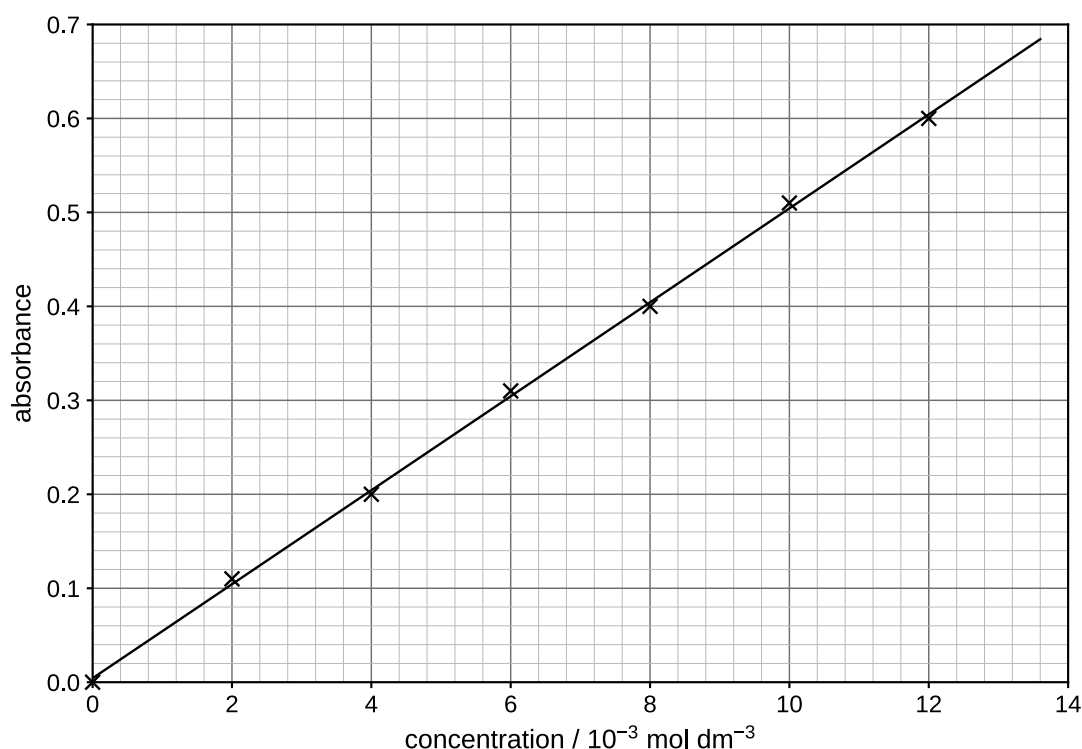


Fig. 26.1

(a) Copper reacts with concentrated nitric acid to form copper(II) nitrate, nitrogen dioxide and water.

Write an equation for this reaction. Use oxidation numbers to identify the element that is reduced.

[2]

(b) Write an equation for the formation of $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ from $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$.

[1]

Turn over

- (c) Explain why the zinc ions in the solution do not affect the absorbance.

.....
..... [1]

- (d) The colorimeter is fitted with an orange filter. Explain why.

.....
..... [1]

- (e) The absorbance of the brass solution is 0.47.
Use Fig. 26.1 to determine the percentage by mass of copper in the brass.

percentage of copper = ... % [4]

- (f) The standard solutions are made from $0.0500 \text{ mol dm}^{-3}$ copper(II) sulfate solution.
Describe how the student should prepare 100.0 cm^3 of the standard solution containing
 $6.0 \times 10^{-3} \text{ mol dm}^{-3} [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$. Include the volume of copper(II) sulfate solution
needed.

.....
.....
.....
.....
.....
..... [3]

Turn over



- 27 Fig. 27.1 shows a direct ethanol fuel cell with an acidic electrolyte. At the negative electrode, ethanol is oxidised to carbon dioxide. At the positive electrode, oxygen is reduced to water.

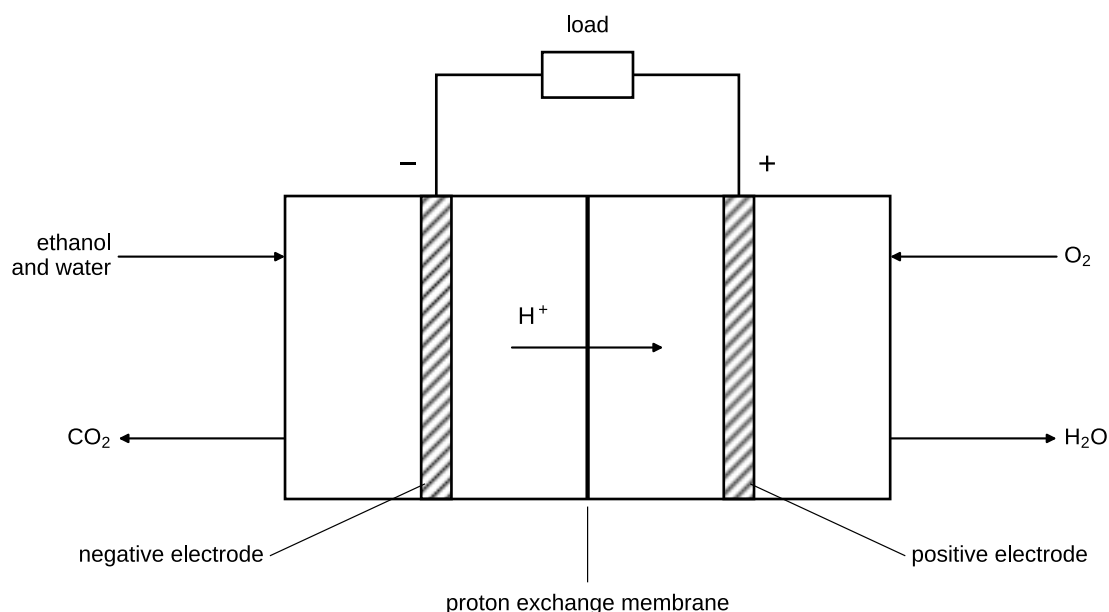


Fig. 27.1

The standard electrode potential of $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$ is +1.23 V. The standard electrode potential for the reduction of carbon dioxide to ethanol in acidic solution is +0.08 V.

- (a) Construct the half-equation for the oxidation of ethanol to carbon dioxide at the negative electrode.

..... [2]

- (b) Calculate the standard cell potential, and write the overall equation for the cell reaction.

..... [2]

- (c) In some fuel cells, ethanol is oxidised only to ethanoic acid. Construct the half-equation for this oxidation. Calculate the charge delivered per mole of ethanol as a percentage of the charge delivered when ethanol is oxidised to carbon dioxide.

..... [2]

Turn over

Data: $\Delta_c H(\text{ethanol}) = -1367 \text{ kJ mol}^{-1}$; $\Delta_c H(\text{hydrogen}) = -286 \text{ kJ mol}^{-1}$; density of ethanol = 0.789 g cm^{-3} .

- (d) A student claims that hydrogen is a better fuel than ethanol because it releases more energy.
Evaluate this claim. Calculate the energy released per gram and per dm^3 for each fuel, with hydrogen as a gas at RTP.

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

Turn over



- 28** Aspirin is made by reacting 2-hydroxybenzoic acid with ethanoic anhydride, as shown in Fig. 28.1.

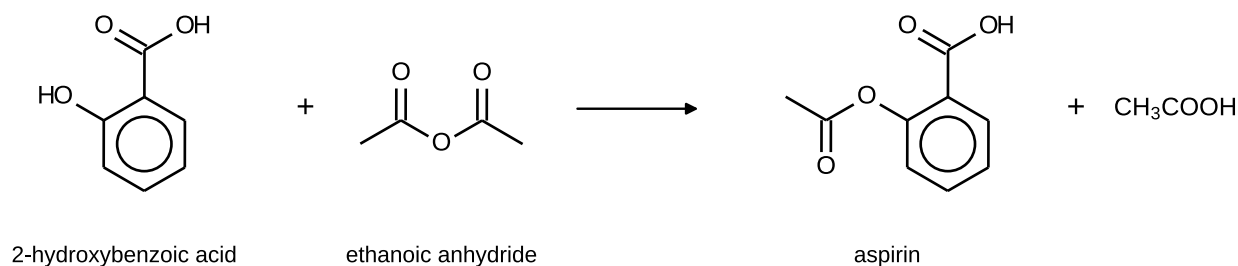


Fig. 28.1

A student makes aspirin from 2.00 g of 2-hydroxybenzoic acid and an excess of ethanoic anhydride. The crude product has a mass of 2.30 g.

To find the purity of the crude product, the student heats 0.600 g of it with 50.0 cm³ of 0.200 mol dm⁻³ NaOH(aq) until hydrolysis is complete. The mixture is cooled and made up to 250.0 cm³ with water. 25.0 cm³ portions are titrated with 0.0500 mol dm⁻³ HCl(aq). The mean titre is 7.75 cm³.

Under the conditions of this titration, phenol (aromatic –OH) groups do not react.

- (a) Determine the percentage purity of the crude aspirin. Assume that the impurities do not react with NaOH(aq).

percentage purity = ... % [5]

Turn over

- (b) Further tests show that the impurity is unreacted 2-hydroxybenzoic acid. Determine the true percentage purity of the crude aspirin.

true percentage purity = ... % [4]

- (c) Use your answer to (b) to calculate the percentage yield of pure aspirin.

percentage yield = ... % [3]

- (d) The crude product melts over the range 128 to 133 °C. Pure aspirin melts at 136 °C. Explain what this shows, and name a technique the student could use to purify the crude product.

.....
.....
..... [2]

Turn over



- 29 Methanol is manufactured from carbon monoxide and hydrogen:

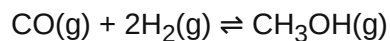


Table 29.1 shows some thermodynamic data.

Table 29.1

substance	CO(g)	H ₂ (g)	CH ₃ OH(g)
$\Delta_f H / \text{kJ mol}^{-1}$	-110.5	0	-201.0
$S / \text{J K}^{-1} \text{mol}^{-1}$	197.7	130.7	239.8

- (a) Calculate the temperature above which this reaction is not feasible.

temperature = ... K [4]

- (b) At 520 K and a total pressure of 8.00 MPa, an equilibrium mixture contains 0.250 mol of CO, 0.500 mol of H₂ and 0.750 mol of CH₃OH.

Calculate K_p at 520 K. Give its units.

K_p = ...
units = ... [4]

Turn over



(c)* The industrial process operates at about 520 K and 8 MPa, with a copper-based catalyst. Unreacted gases are recycled. Use your answers to (a) and (b), and your knowledge of rates and equilibria, to evaluate these conditions.

[6]

Additional answer space if required

Turn over



Turn over



Free on iPad

- 30** Compound X is a green crystalline salt. It contains potassium ions, iron ions, ethanedioate ions ($\text{C}_2\text{O}_4^{2-}$) and water of crystallisation only. A student carries out three analyses of X.

Water: heating 1.000 g of X until all the water of crystallisation is removed gives a loss in mass of 0.110 g.

Iron: X contains 11.4% iron by mass.

Ethanedioate: 0.982 g of X is dissolved in dilute sulfuric acid and made up to 100.0 cm^3 . 10.0 cm^3 portions are warmed to 60°C and titrated with $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4(\text{aq})$.

Manganate(VII) ions oxidise ethanedioate ions to carbon dioxide. The mean titre is 12.00 cm^3 .

- (a) (i) Calculate the percentage by mass of ethanedioate ions in X.

percentage of ethanedioate = ... % **[3]**

- (ii) Determine the formula of X.

formula = ... **[3]**

- (b) Deduce the oxidation number of iron in X.

..... **[1]**

Turn over



- (c) In X, the iron is present as the complex ion $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$. Each ethanedioate ion is a bidentate ligand.

Draw 3D diagrams of the two optical isomers of this complex ion. You may represent each ethanedioate ion as a curved line joining two O atoms.

[2]

- (d) In the titration, the first few drops of $\text{KMnO}_4(\text{aq})$ are decolourised slowly, even at 60°C , but later drops are decolourised almost at once. Suggest an explanation.

[2]

- (e) In sunlight, solutions of the complex ion slowly decompose. Iron(III) is reduced to iron(II), and some of the ethanedioate ions are oxidised to carbon dioxide. Construct an ionic equation for this reaction.

[2]

END OF QUESTION PAPER





Plumi

The iPad notebook for GCSE and A Level revision

Write your answers by hand. Each one is marked against that question's own mark scheme.

Stuck? The tutor nudges you with a hint before it gives anything away.

Practice adapts to you: the next question is chosen from what you have shown you can do.



Free on iPad · tryplumi.app

OCR-style practice written by Plumi. Not produced or endorsed by OCR.

