ST. JOSEPH'S INSTITUTION
PRELIMINARY EXAMINATION 2024
(YEAR 4)

CANDIDATE NAME			
CLASS		INDEX NUMBER	

CHEMISTRY	**6092/02**
Paper 2	**14 August 2024**
Candidates answer on the Question Paper. No Additional Materials are required.	**1 hour 45 minutes** **(11:50 – 13:35)**

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black fluid ink pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions. Write your answers in the spaces provided.

Section B
Answer **one** question. Write your answers in the spaces provided.

The number of marks is given in brackets [ ] at the end of each question or part question.

The use of an approved scientific calculator is expected, where appropriate.

A copy of the Periodic Table is printed on **page 2**.

For Examiner's Use	
Section A	**/ 70**
Section B	**/ 10**
Total	**/ 80**

The Periodic Table of Elements

Key

proton (atomic) number atomic symbol name relative atomic mass

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	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 lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	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 –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}

Section A

Answer **all** questions.

1 Select elements from the list to answer the following questions.

You may use each element once, more than once or not at all.

argon	**iodine**	**neon**
chlorine	**iron**	**sodium**
hydrogen	**lithium**	**zinc**

(a) Which element shows both metallic and non-metallic character?

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

(b) Which element, other than iron, is used in the manufacture of steel?

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

(c) Which element gives a reddish-brown solution when added to aqueous potassium bromide?

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

(d) Which **two** elements react together most vigorously?

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

(e) **(i)** Which elements, when separately added to aqueous copper(II) nitrate, will cause a gas to be formed?

……………………………………………………………………………………..[1]

(ii) For **one** of the elements in **(e)(i)**, write a chemical equation for the formation of the gas.

……………………………………………………………………………………..[1]

[Total: 6]

2 **(a)** A reaction in which the same element is both oxidised and reduced is called a *disproportionation* reaction.

The reaction between chlorine and hydroxide ions is shown below.

$$3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$$

Use oxidation states to explain why this reaction is a *disproportionation* reaction.

....

....

....

....[2]

(b) 1.0 g samples of two oxochlorides, Si_2OCl_6 and $Si_3O_2Cl_8$, are separately reacted with excess water, during which all the chlorine atoms are converted into chloride ions.

The chloride ions are precipitated out using excess aqueous silver nitrate, and the precipitates are dried and weighed.

By calculating the amount, in moles, of chloride ions formed when each oxochloride is reacted with excess water, deduce which of the two oxochlorides would form the larger mass of precipitate.

[3]

[Total: 5]

3 Table 3.1 shows vehicle emissions from cars with different types of engines.

Table 3.1

engine type	carbon dioxide / arbitrary units	carbon monoxide / arbitrary units
electric	10	22
hybrid (electric and petrol)	50	176
diesel	160	408
petrol	120	221

(a) Using the information provided, determine which engine type causes most harm to the environment.

....

....[1]

(b) **(i)** Describe how carbon monoxide is formed in car engines.

....

....[1]

(ii) Cars are fitted with catalytic convertors.

Explain how catalytic convertors remove harmful pollutants like carbon monoxide.

Include relevant equations to support your answer.

....

....

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....

....[3]

(c) Governments are increasingly encouraging the use of electric vehicles to reduce carbon dioxide emissions.

Explain why reducing carbon dioxide emissions is of global importance.

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....[2]

[Total: 7]

4 The alcohols are a homologous series.

Table 4.1 shows some data about the enthalpy change when 1 mol of each alcohol is completely combusted.

Table 4.1

name of alcohol	formula	enthalpy change of combustion / kJ/mol
methanol	CH_3OH	-715
ethanol	CH_3CH_2OH	-1371
propan-1-ol	$CH_3CH_2CH_2OH$	
butan-1-ol	$CH_3CH_2CH_2CH_2OH$	-2673

(a) Ethanol can be made from either ethene or glucose.

(i) The reaction for the formation of ethanol from ethene is shown below.

$$C_2H_4 + H_2O \rightarrow CH_3CH_2OH$$

State the conditions under which this reaction takes place.

....[1]

(ii) Explain why ethanol made from ethene is a non-renewable fuel but that made from glucose is a renewable fuel.

....

....

....[1]

(b) The enthalpy change when 4.0 g of propan-1-ol is burnt is -134 kJ.

Calculate the enthalpy change of combustion of propan-1-ol in kJ/mol.

Show your working.

[1]

(c) The enthalpy change of combustion becomes more negative from methanol to butan-1-ol.

Use ideas about breaking and forming bonds to explain why.

……………………………………………………………………………………………

……………………………………………………………………………………………

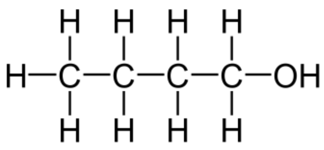
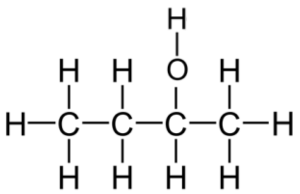
……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………[2]

Table 4.2 shows some information about three isomers, butan-1-ol, butan-2-ol and diethylether.

Table 4.2

	butan-1-ol	butan-2-ol	diethylether
structural formula			
enthalpy change of combustion / kJ/mol	-2673		-2732

(d) **(i)** State the molecular formula of diethylether.

…………………………………………………………………………………[1]

(ii) Molecules of diethylether are symmetrical and contain a C–O–C functional group.

Draw the full structural formula of diethylether.

[1]

(e) The same products are formed when each of the three isomers in Table 4.2 are completely combusted.

However, the enthalpy change of combustion of butan-1-ol (-2673 kJ/mol) is less negative than that of diethylether (-2732 kJ/mol).

(i) Suggest a reason why the enthalpy changes of combustion for butan-1-ol and diethylether are different.

………………………………………………………………………………………

………………………………………………………………………………………[1]

(ii) Hence, suggest a value for the enthalpy change of combustion of butan-2-ol.

………………………………………………………………………………………[1]

[Total: 9]

5 A student carried out some experiments using the metals iron, manganese and chromium.

He added the metals into dilute sulfuric acid. He also heated the metals in air.

Table 5.1 shows his observations.

Table 5.1

metal	reaction with dilute sulfuric acid	reaction with air
iron	metal dissolves slowly with effervescence pale green solution formed	burns in air to form dark brown iron(III) oxide
manganese	metal dissolves quickly with effervescence pale pink solution of manganese(II) sulfate formed	burns in air with an intense white light to form a red solid, manganese(II,III) oxide, which consists of MnO and Mn_2O_3
chromium	metal dissolves with effervescence violet solution of chromium(III) sulfate formed	burns in air to form green chromium(III) oxide

(a) Arrange the three metals in increasing order of reactivity.

....[1]

(b) Using information from Table 5.1, identify **two** properties of the metals which show that they are transition elements, and explain your answer.

....

....

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....

....

....[3]

(c) Write an ionic equation, with state symbols, for the reaction between manganese and sulfuric acid.

[2]

(d) In another set of experiments, the student separately added strips of metal into two salt solutions, as shown in Fig. 5.1.

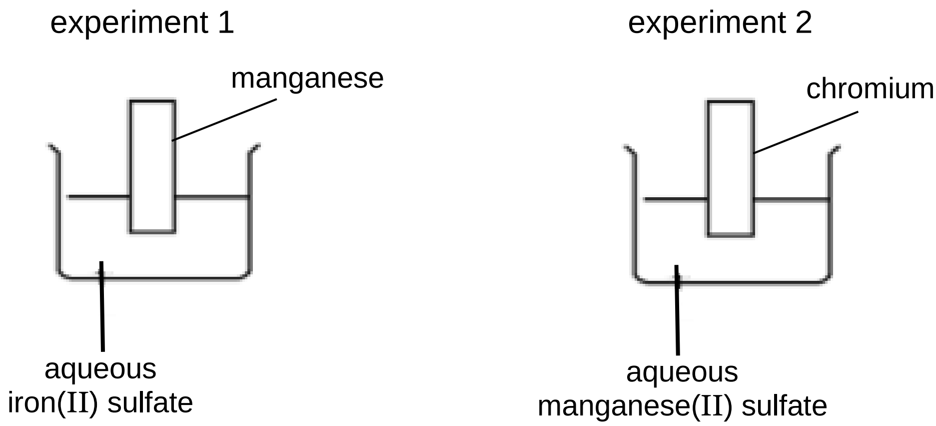

Fig. 5.1

Complete Table 5.2 by describing the observations you would expect to see.

Table 5.2

experiment	observations
1	
2	

[2]

(e) The carbonates of metals such as iron and mercury decompose upon heating.

The equation for the decomposition of mercury(II) carbonate is shown below.

$$2HgCO_3 \rightarrow 2Hg + 2CO_2 + O_2$$

Deduce the position of mercury relative to iron in the reactivity series.

Explain your answer.

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....

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....[2]

[Total: 10]

6 Fig. 6.1 shows how ethene gas can be converted into ester **B** over multiple steps.

The names of the organic products formed at the end of each step are provided.

The **[O]** represents an oxygen atom from an oxidising agent.

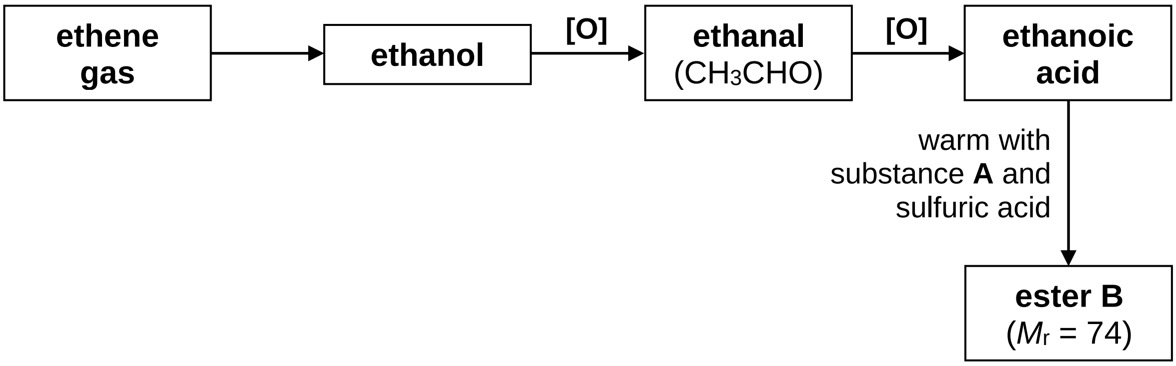

Fig. 6.1

(a) Table 6.1 shows some information about tests for ethene gas, ethanol and ethanoic acid.

Complete Table 6.1 with the relevant test and result expected.

Table 6.1

substance	test	result
ethene gas		changes from reddish-brown to colourless
ethanol	add acidified aqueous potassium manganate(VII)	changes from purple to colourless
ethanoic acid	add Universal Indicator solution to aqueous ethanoic acid	

[2]

(b) Polymerising ethene gas using heat and pressure forms poly(ethene). On average, each single poly(ethene) molecule formed contains 6000 carbon atoms.

(i) Calculate the average mass, in g, of a single poly(ethene) molecule.

[2]

(ii) Recycling plastics like poly(ethene) comes with economic and environmental issues.

Outline these issues.

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……………………………………………………………………………………………[2]

(c) Ethanal, CH_3CHO, is a member of the aldehyde homologous series.

Draw a ‘dot-and-cross’ diagram to show the bonding in ethanal.

Show outer electrons only.

[2]

(d) Ethanoic acid reacts with substance **A** to form ester **B**, which has a relative molecular mass of 74.

(i) Draw the full structural formula of ester **B**.

[1]

(ii) Hence, name substance **A**.

……………………………………………………………………………………………[1]

(e) Another carboxylic acid, compound **C**, contains 62.1% carbon and 10.3% hydrogen by mass.

Deduce the empirical formula of compound **C**, and thus its molecular formula.

Show your working.

[3]

[Total: 13]

7 Different applications of chromatography

Chromatographic techniques have a wide range of applications, such as in the analysis of water samples, and in synthesising organic compounds.

Ion chromatography in analysis of a water sample

Ion chromatography is a technique able to detect ions even at low concentrations. It is often used to identify ions present in water samples from reservoirs. However, non-ionic species cannot be detected or separated using ion chromatography.

In ion chromatography, a sample is passed through a chromatography column. Different ions travel through the column at different speeds. A detector is attached to the end of the column. The results are electronically printed out on a graph.

The retention time is the time it takes each ion to travel through the column. Ions can be identified by their retention times, which mainly depend on the ion's relative mass, and the magnitude of its ionic charge.

The concentration of ions is measured in parts per million (ppm), where 1 ppm is equivalent to 1 mg of ions dissolved in 1000 cm^3 of water. [1 mg = 10^{-3} g]

Fig. 7.1 and Fig. 7.2 show the ion chromatograms of positive and negative ions respectively in a 250 cm^3 water sample from a reservoir.

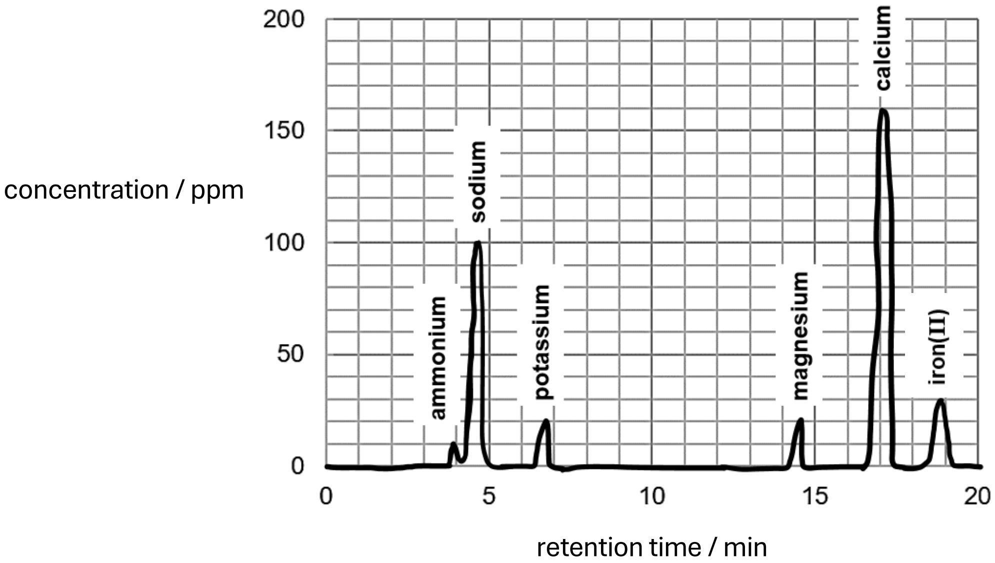

Fig. 7.1

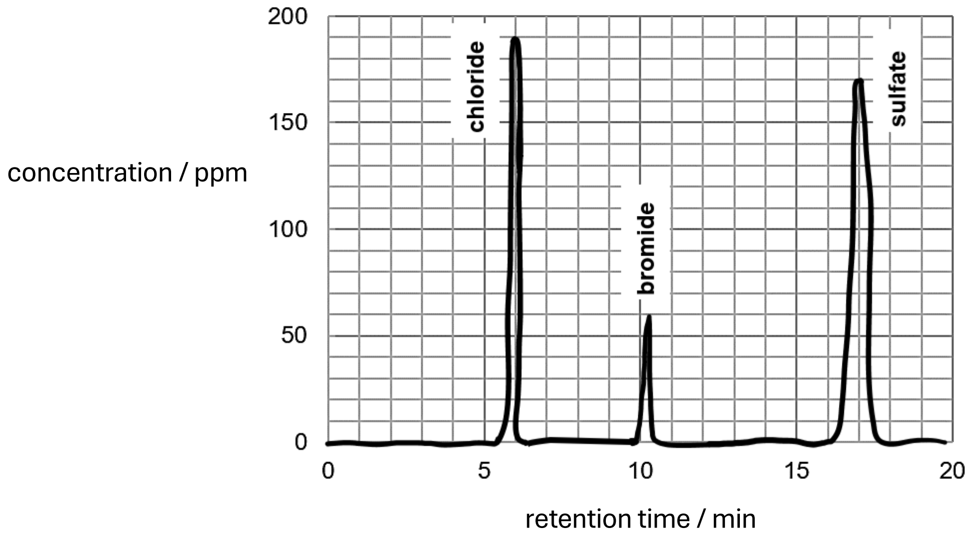

Fig. 7.2

Thin-layer chromatography and column chromatography in synthesis of aspirin

In **thin-layer chromatography (TLC)**, a small amount of sample is spotted on a thin plate which is then placed in a solvent. When the solvent rises up the plate, the components of the mixture separate into different spots.

TLC can be used to track the progress of reactions, such as that between salicylic acid and ethanoic anhydride to form aspirin and a known by-product **BP** (Fig. 7.3).

$$\underset{\text{salicylic acid}}{HOOC–C_6H_4–OH} + \underset{\text{excess ethanoic anhydride}}{H_3C–\overset{\overset{\large O}{||}}{C}–O–\overset{\overset{\large O}{||}}{C}–CH_3} \rightarrow \underset{\text{aspirin}}{HOOC–C_6H_4–OCOCH_3} + \underset{\text{one by-product molecule}}{\mathbf{BP}}$$

Fig. 7.3

A student reacts a fixed mass of salicylic acid with excess ethanoic anhydride. He removed small samples of liquid from the reaction mixture **M** every five minutes, starting from time t = 0 min when both reactants were first mixed together.

He did TLC experiments using reaction mixture **M** every five minutes (Fig. 7.4), and compared it against pure samples of salicylic acid reactant (**R1**), ethanoic anhydride reactant (**R2**), aspirin product (**P**), and the known by-product (**BP**). This allowed him to track how the composition of reaction mixture **M** varied over time.

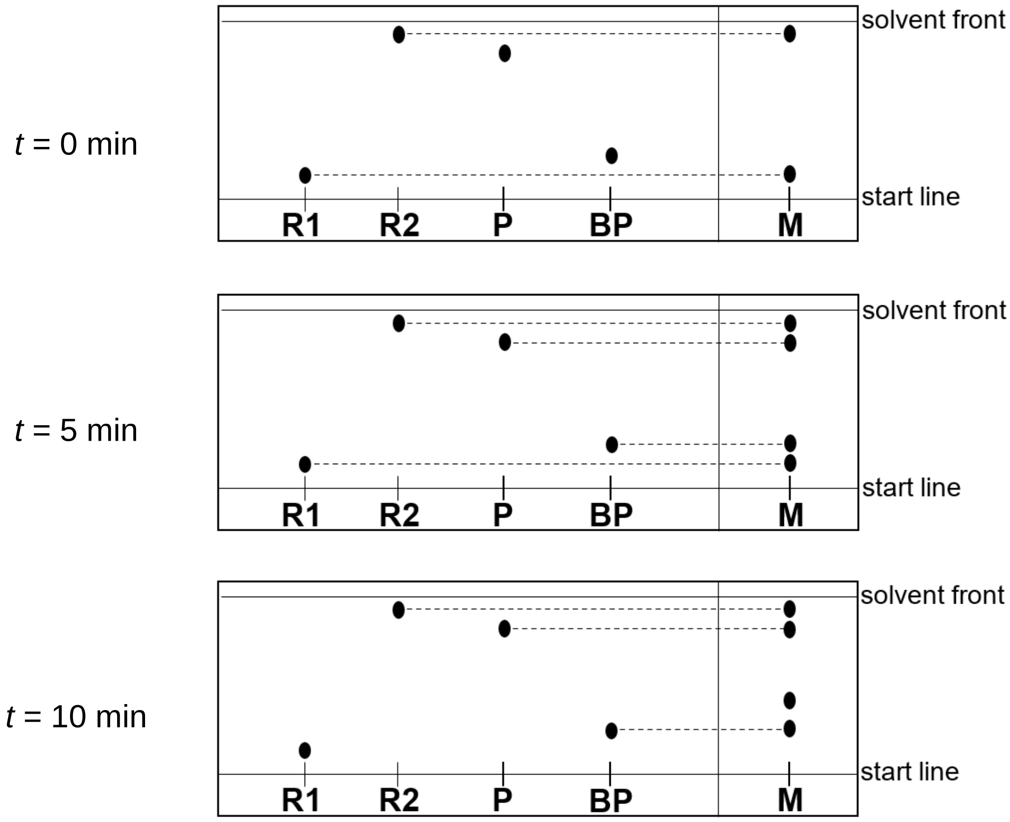

Fig. 7.4

After analysing the TLC at t = 10 min, the student decided that the reaction was complete. He then purified the reaction mixture using **column chromatography**, which is often used in the large-scale purification and collection of many different compounds.

To obtain pure aspirin, the student dissolved the reaction mixture at t = 10 min in ethanol solvent, and added it at the top of the column (Fig. 7.5). The compound most soluble in ethanol reached the bottom of the column most quickly and was collected first, followed by the other compounds of lower solubility.

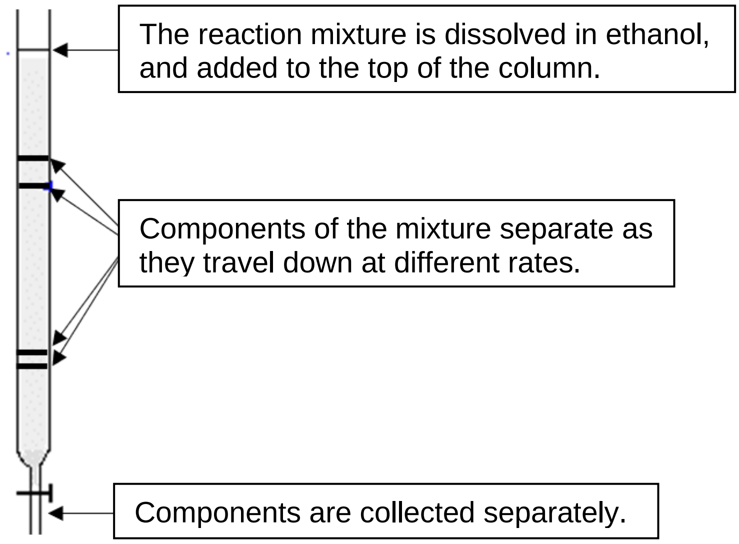

Fig. 7.5

(a) Using the results in Fig. 7.1, calculate the amount of sodium ions in the 250 cm^3 water sample collected from the reservoir.

[2]

(b) **(i)** While analysing the chromatogram in Fig. 7.1, a student claimed, "an ion's retention time is affected both by its ionic charge and its relative mass.'

Based on the information in Fig. 7.1, do you agree with the student's claim?

Explain your reasoning.

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…………………………………………………………………………………………

…………………………………………………………………………………………[2]

(ii) Predict the retention time of nitrate ions in Fig. 7.2 if nitrate ions were present in the water sample.

Explain your reasoning.

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…………………………………………………………………………………………

…………………………………………………………………………………………[2]

(c) Using Fig. 7.3, write the structural formula of the known by-product in the synthesis of aspirin.

…………………………………………………………………………………………[1]

(d) **(i)** Using Fig. 7.4, state the composition of the reaction mixture at t = 10 min in the synthesis of aspirin.

……………………………………………………………………………………………

…………………………………………………………………………………………[1]

(ii) Explain why the student decided that the reaction was complete after t = 10 min.

……………………………………………………………………………………………

…………………………………………………………………………………………[1]

(e) After the column chromatography experiment, the student found that his aspirin product contained ethanoic anhydride as an impurity.

Using Fig. 7.4, suggest why this impurity was found in the aspirin product.

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…………………………………………………………………………………………[1]

(f) State two differences between ion chromatography and column chromatography.

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…………………………………………………………………………………………[2]

[Total: 12]

8 A hot sample of aqueous cobalt(II) nitrate, a pale red solution, is electrolysed using the set-up shown in Fig. 8.1.

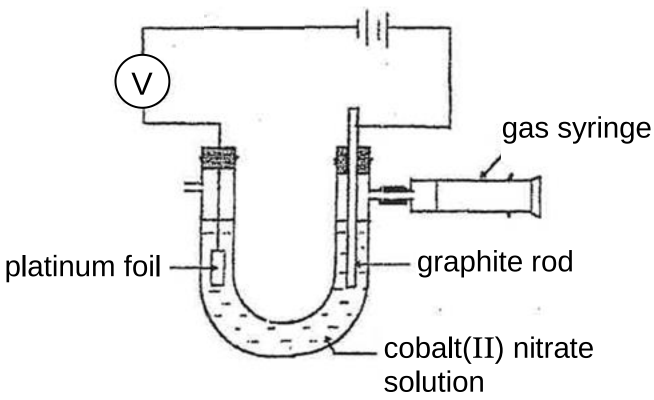

Fig. 8.1

During the electrolysis of hot aqueous cobalt(II) nitrate, grey cobalt solid is formed on the platinum foil, and gas bubbles are seen around the graphite rod.

(a) **(i)** Write an ionic half-equation for the reaction at the graphite rod.

[1]

(ii) When a sample of gas from the gas syringe is bubbled through limewater, a white precipitate is formed.

Suggest why a white precipitate is formed.

....

....[1]

(b) Describe the change that would be observed in the electrolyte after some time.

Explain your answer.

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....[2]

(c) Predict how the pH of the electrolyte may change during the electrolysis experiment.

Explain your answer.

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

(d) Another experiment is carried out to produce grey cobalt solid from aqueous cobalt(II) nitrate, as shown in Fig. 8.2.

A known mass of aqueous cobalt(II) nitrate is first poured into a beaker, before a zinc rod is placed into it.

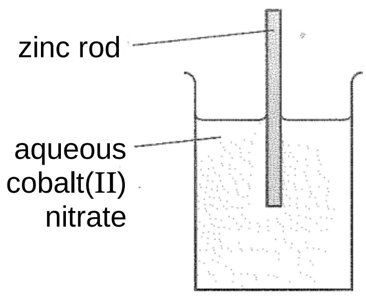

Fig. 8.2

After the experiment, the zinc rod is removed from the set-up, before the mass of solution is measured.

Predict how the mass of the solution is expected to change during this experiment. Explain your answer.

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

[Total: 8]

Section B

Answer **one** question from this section.

9 There are several different types of nylon, which is used to make strong, waterproof ropes.

(a) One type of nylon is nylon-5,10, which is made by reacting two monomers (Fig. 9.1) together.

$$H_2N{-}(CH_2)_5{-}NH_2 \quad + \quad HO{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}(CH_2)_8{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}OH$$

Fig. 9.1

(i) Draw the repeating unit of nylon-5,10.

[1]

(ii) During the manufacturing process, the chain length of the nylon is controlled so that the nylon polymer molecules have an average relative molecular mass in the range 11000 to 20000.

What is the range of the average number of repeating units in the nylon-5,10 polymer molecules?

Show your working.

[2]

(b) Another type of nylon, nylon-6, was later invented using a single monomer.

Fig. 9.2 shows the repeating unit of nylon-6.

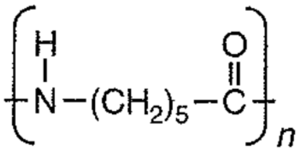

Fig. 9.2

Draw the structural formula of the monomer used to form nylon-6.

[1]

(c) By comparing the structures of the monomers used in nylon-5,10 and nylon-6, explain why nylon-6 can be formed using a single monomer.

....

....

....[1]

(d) Table 9.1 shows some differences between the properties of nylon-6, hydrogen chloride, and graphite.

Table 9.1

	nylon-6	hydrogen chloride	graphite
melting point / °C	220	-114	3650
electrical conductivity	poor	good in aqueous state, but poor in gaseous state	good

Using ideas about structure and bonding, explain:

- why the melting points of the three substances differ from each other,
- the electrical conductivity of graphite, and aqueous hydrogen chloride.

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....[5]

[Total: 10]

10 A student investigated the rate of reaction when dilute acid reacts with excess solid calcium carbonate.

He measured the time taken to collect 10 cm^3 of gas at room temperature and pressure. He also measured the total volume of gas at the end of the experiment at room temperature and pressure.

He carried out four experiments using different acids.

In all four experiments, he used the same concentration and volume of acid.

In one of the experiments (experiment 4), he used oxalic acid, a dibasic organic acid with the formula $(COOH)_2$.

Table 10.1 shows some of his experimental results.

Table 10.1

experiment	acid	time taken to collect 10 cm^3 of gas / s	total volume of gas / cm^3
1	nitric	7	150
2	hydrochloric	15	
3	ethanoic	1500	
4	oxalic		

(a) The student carried out experiment 2 using acid at a lower temperature, and the other three experiments using acid at room temperature.

Explain, in terms of collisions between reacting particles, why a lower temperature affects the rate of reaction.

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....[2]

(b) Write the chemical equation for the reaction in experiment 3.

[1]

(c) Some of the student's experimental results are missing from Table 10.1.

Fill in the blanks in Table 10.1 by predicting the results the student should obtain.

Explain how you arrived at your answer.

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....[4]

(d) Using solid calcium carbonate and chemicals commonly found in a school laboratory, describe how you would prepare a pure, dry sample of calcium sulfate.

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....[3]

[Total: 10]

END OF PAPER