Surname	Centre Number	Candidate Number
Other Names		2

GCE A LEVEL

A410U10-1

S19-A410U10-1

TUESDAY, 4 JUNE 2019 – AFTERNOON

CHEMISTRY – A level component 1
Physical and Inorganic Chemistry

2 hours 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 8.**	**15**	
Section B	**9.**	**22**	
	10.	**17**	
	11.	**15**	
	12.	**16**	
	13.	**23**	
	14.	**12**	
	Total	**120**	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:
- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions in the spaces provided.
Section B Answer **all** questions in the spaces provided.

Candidates are advised to allocate their time appropriately between **Section A (15 marks)** and **Section B (105 marks)**.

INFORMATION FOR CANDIDATES

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

The maximum mark for this paper is 120.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q.9***(a)*(iii) and **Q.11***(b)*(ii).

If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

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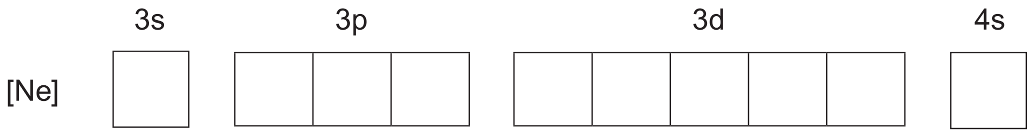
SECTION A

Answer **all** *questions in the spaces provided.*

1. Complete the diagram below, using arrows to represent electrons, to show the electron arrangement for an atom of cobalt. [1]



2. Complete the definition below.

Relative atomic mass is the average mass of an atom of an element compared to

.... [1]

3. Draw a dot-and-cross diagram to show the bonding of the compound magnesium fluoride. [2]

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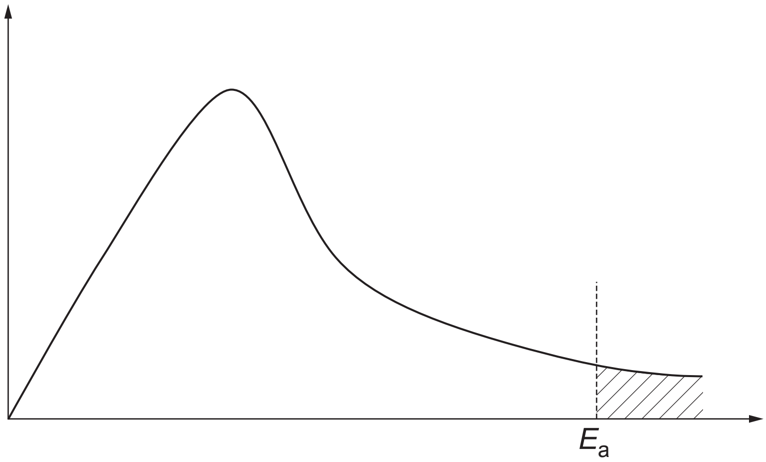
4. *(a)* The graph below shows the energy distribution of particles at a temperature of 298 K.

Sketch the distribution at a higher temperature on the same axes. [1]

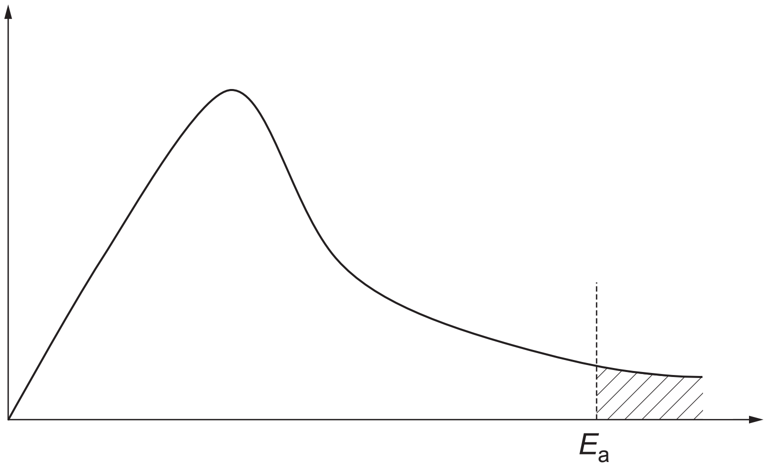
Fraction of molecules with energy E



Energy E

(b) Use the diagram below to show how a catalyst can affect the number of particles with sufficient energy to react. [1]

Fraction of molecules with energy E



Energy E

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5. Both iodine and diamond contain covalent bonding. Explain why their melting temperatures are very different. [2]

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6. When blue crystals of $CuSO_4.5H_2O$ are heated they form a white solid. Upon addition of water they return to their original blue colour.

Explain these observations. [2]

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7. A sample of the element boron contains 22.10 % boron-10 and 77.90 % boron-11.

Calculate the relative atomic mass of this sample, giving your answer to **four** significant figures. [2]

A_r = ...

Examiner only

8. Potassium manganate(VII) can be used to oxidise Fe^{2+} ions to Fe^{3+} ions in a redox titration. The following reaction occurs.

$$MnO_4^- + 5Fe^{2+} + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

In an experiment 25.00 cm^3 portions of Fe^{2+}(aq) were titrated against a standard acidified potassium manganate(VII) solution of concentration 0.0200 mol dm^{-3}.

The results were as follows.

	Titration 1	Titration 2	Titration 3	Titration 4
Volume of acidified potassium manganate(VII) solution added / cm^3	27.20	27.10	27.30	26.80

(a) Calculate the mean volume of acidified potassium manganate(VII) solution added. [1]

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Mean volume = ... cm^3

(b) Calculate the number of moles of Fe^{2+} present in each 25.00 cm^3 portion. [2]

Number of moles = ... mol

15

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SECTION B

Answer **all** *questions in the spaces provided.*

9. Many common acids donate one hydrogen ion during chemical reactions, however others can donate two or more hydrogen ions.

(a) Hydrochloric acid, HCl, and ethanoic acid, CH_3COOH, are examples of monobasic acids – these are acids that can donate only one hydrogen ion in chemical reactions.

Hydrochloric acid is a strong acid and ethanoic acid is a weak acid.

(i) Define pH. [1]

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(ii) Write an expression for the acid dissociation constant, K_a, for ethanoic acid. [1]

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(iii) A student makes the following statements:

- when the concentration of any monobasic acid is doubled, the concentration of H^+ ions is also doubled; this applies to both strong acids and weak acids
- each time the concentration of an acid is doubled, the pH value increases by 0.3

Is the student correct? Explain your answer.

You should refer to both statements and the difference(s) between strong acids and weak acids in your answer. [6 QER]

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(b) Sulfuric acid is a dibasic acid as it can donate up to two hydrogen ions during chemical reactions.

When a small amount of sodium hydroxide is present the following reaction can occur.

$$H_2SO_4(aq) + NaOH(aq) \longrightarrow NaHSO_4(aq) + H_2O(l)$$

When more sodium hydroxide is present the following reaction can occur.

$$NaHSO_4(aq) + NaOH(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l)$$

(i) The soluble salt $NaHSO_4$ can be prepared as a white solid using the first reaction above. Briefly outline how this preparation would be undertaken.

A detailed experimental procedure is not required. [4]

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(ii) The $NaHSO_4$ formed in this preparation is hydrated and has the formula $NaHSO_4.xH_2O$.

In an experiment a sample of $NaHSO_4.xH_2O$ was heated to constant mass. The sample lost 37.5% of its mass.

Calculate the value of x in the formula $NaHSO_4.xH_2O$. [3]

x = ...

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(iii) $NaHSO_4$ can also be formed by reaction of concentrated sulfuric acid with sodium halides such as sodium chloride, sodium bromide or sodium iodide.

When concentrated sulfuric acid is added to **one** of these halides several changes are observed, including a smell of rotten eggs.

Identify the halide used and explain why the smell is observed with this halide but not with the others. [2]

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(c) Many reactions of acids produce hydrogen gas. When an electrical discharge is passed through this gas certain frequencies of energy are emitted.

(i) Explain why this energy is emitted. [2]

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(ii) The first ionisation energy of hydrogen is 1316 $kJ\,mol^{-1}$.

Calculate the wavelength of the convergence limit of the Lyman series for hydrogen in nm. [3]

Wavelength = ... nm

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10. The green mineral atacamite contains three different ions, $M_a(OH)_bX_c$. It is insoluble in water but can form a solution when added to acid.

A student planned to analyse a sample of atacamite using the following method.

STEP 1: Add 1.00 g of atacamite to 150 cm^3 of strong acid of concentration 0.100 mol dm^{-3}, and then make this up to exactly 250 cm^3 with more of the same acid.

STEP 2: Take exactly 25.0 cm^3 of the solution from step 1 and add excess silver nitrate solution. If any precipitate forms, filter it off and dry completely. Record its colour and the mass formed.

STEP 3: Take exactly 25.0 cm^3 of the solution from step 1 and add excess barium chloride solution. If any precipitate forms, filter it off and dry completely. Record its colour and the mass formed.

STEP 4: Take exactly 25.0 cm^3 of the solution from step 1 and add excess sodium hydroxide solution. If any precipitate forms, filter it off and dry completely. Record its colour and the mass formed.

STEP 5: To find the amount of acid remaining in the solution, use a pH probe to find the precise pH of the solution prepared in step 1.

(a) The student had to select an appropriate strong acid from the common laboratory reagents.

Suggest an appropriate acid to use. Explain your choice. [2]

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(b) In step 2 a white precipitate of mass 0.0672 g was produced.

State which ion this step identifies and calculate the number of moles of this ion present in the original 250 cm^3 of solution. [3]

Ion ....

Number of moles = ... mol *(c)* After completing step 2, the student decides that he does not need to carry out step 3.

Is he correct? Give a reason for your answer. [2]

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(d) A pale blue precipitate is formed in step 4.

(i) Give the **formula** of the **ion** identified from this observation. [1]

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(ii) When the student heats the precipitate to ensure it is dry, a colour change is seen with some of the solid turning black but most of it remaining blue. He did not record a mass for the sample.

Suggest why he would not have been able to use the mass of the solid to calculate the number of moles of the ion in the original compound. [1]

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Examiner only

(e) In step 5, the pH of a $25.0\,cm^3$ portion of the remaining solution was found to be 1.36.

(i) Calculate the number of moles of acid remaining in $25.0\,cm^3$ of the solution. [2]

Number of moles = ... mol

(ii) Calculate the number of moles of hydroxide ion present in the original 1.00 g of atacamite. [3]

Number of moles = ... mol

(f) Deduce the formula of atacamite. [3]

Formula of atacamite ....

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Examiner only

11. *(a)* Selenium is an element in the p-block of the Periodic Table.

What information regarding the electronic structure of the selenium atom can be deduced from this statement? [1]

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(b) The illustration below gives some information about the elements surrounding selenium in the Periodic Table.

	S **Sulfur** electronegativity = 2.58 boiling temperature = 445 first ionisation energy = 1000 standard electrode potential for S(+6) → S(+4) = +0.16 V	
As **Arsenic** electronegativity = 2.18 boiling temperature = 603 first ionisation energy = 947	**Se** **Selenium** electronegativity = ? boiling temperature = 685 first ionisation energy = ? standard electrode potential for Se(+6) → Se(+4) = ?	**Br** **Bromine** electronegativity = 2.96 boiling temperature = 60
	Te **Tellurium** electronegativity = 2.10 boiling temperature = 990 standard electrode potential for Te(+6) → Te(+4) = +1.18 V	

All ionisation energies are given in kJ mol^{-1} and all temperatures in °C

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(i) Both sulfur and selenium have molecules containing rings of eight atoms.

Explain the difference in their boiling temperatures. [2]

(ii) Suggest values for the missing properties of selenium. Use the ideas you have studied to explain the values you have chosen. [6 QER]

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(c) One radioactive isotope of selenium is selenium-75. It can be used as a medical tracer to identify cartilaginous tumours.

(i) The half-life of selenium-75 is 120 days. Samples are provided that have eight times higher concentration of selenium-75 atoms than the minimum needed for use as a tracer.

Find the maximum time a sample can be stored before the concentration of selenium-75 becomes too low to use. [2]

Time = ... days

(ii) Selenium-75 does not emit alpha particles when it decays.

Explain why this is important for its use as a medical tracer. [2]

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(d) Selenium dioxide, SeO_2, is a foul smelling solid, with a smell resembling rotting horseradish. It can be used to oxidise alkenes.

$$SeO_2 + C_3H_6 + H_2O \longrightarrow H_2SeO_2 + C_3H_6O$$

In an oxidation experiment, 2.70 g of C_3H_6 produced a yield of 62 % of C_3H_6O.

Calculate the mass of C_3H_6O formed. [2]

Mass = ... g

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Examiner only

12. Chlorine is one of the most widely used elements, and compounds containing chlorine atoms have a huge range of uses in the home and in industry.

(a) Give **one** large scale use of the **element** chlorine. [1]

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(b) Chlorine reacts with hot concentrated sodium hydroxide solution to form two chlorine-containing products. Write the equation for this reaction. [1]

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(c) Chlorine can be used to produce bromine from the bromide ions present in seawater. An excess of chlorine is usually used in this process.

In one experiment, a volume of 2.00 dm^3 of chlorine gas was bubbled into seawater at 298 K under 1 atm pressure. A mass of 9.4 g of bromine was produced.

Calculate the percentage of chlorine that remains unreacted at the end of the experiment, giving your answer to an **appropriate** number of significant figures. [3]

Percentage of chlorine unreacted = ... %

Examiner only

(d) Chlorine-containing compounds can be studied using mass spectrometry.

(i) Explain how ions are formed and separated in the mass spectrometer. [2]

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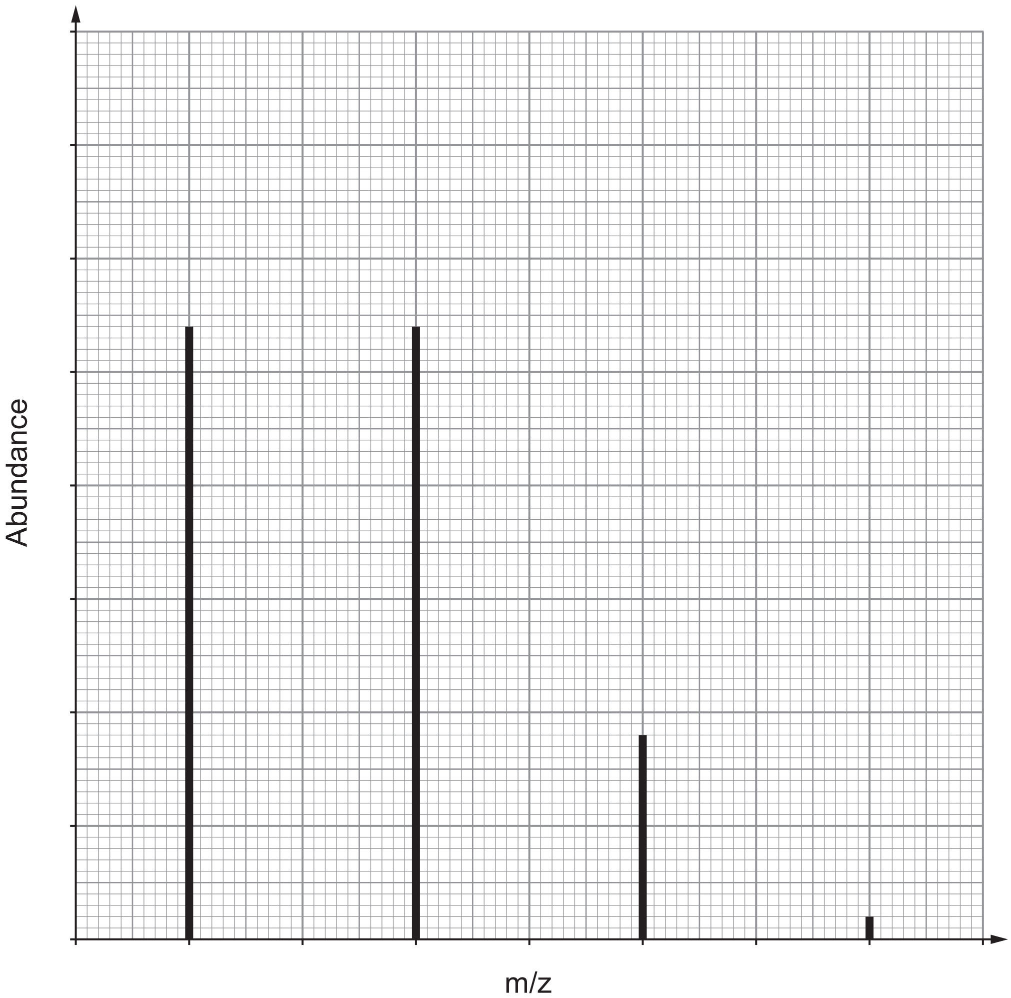
(ii) The diagram below shows **part** of the mass spectrum of a chlorine-containing compound. There are no other significant peaks near this group of peaks and adjacent peaks are two atomic mass units apart.



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I. State how many chlorine atoms are present in these ions, giving a reason for your answer. [2]

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II. The height of the first peak is 54 and the height of the final peak is 2.

Explain the ratio of these peak heights. [2]

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(e) Chlorine can form many compounds of general formula AB_3, for example $AlCl_3$ and ClF_3.

(i) Draw the shape of the $AlCl_3$ molecule, giving its bond angle(s). [1]

(ii) Explain why the molecule $AlCl_3$ often forms dimers. [2]

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(iii) Use the principles of valence shell electron pair repulsion theory to explain why the shape of ClF_3 is not the same as that of BF_3.

You do not need to identify the shape of the ClF_3 molecule. [2]

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13. Ammonia, NH_3, and hydrazine, NH_2NH_2, are both compounds containing only nitrogen and hydrogen.

(a) The production of ammonia in the Haber process uses nitrogen and hydrogen gases as starting materials, a pressure of 200 atm and a temperature of 400 °C. The reaction occurring is shown below.

$$N_2(g) \; + \; 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -94\,\text{kJ mol}^{-1}$$

(i) Explain fully why a pressure of 200 atm is used for this reaction. [3]

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(ii) The enthalpy change value given above is not the standard enthalpy change of formation for ammonia. Give **one** reason why this is not the standard enthalpy change of formation. [1]

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(iii) Write an expression for the equilibrium constant, K_c, for this reaction. [1]

(iv) State the effect (if any) of increasing temperature on the value of K_c. Give a reason for your answer. [2]

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(v) A mixture of nitrogen and hydrogen has an initial concentration of 0.020 mol dm^{-3} of each gas. The mixture is allowed to come to equilibrium in a fixed volume.

In the equilibrium mixture 20 % of the nitrogen gas had been converted into ammonia. Calculate the value of K_c under these conditions. [3]

K_c = ...

(b) The standard enthalpy change of formation for ammonia is −46 kJ mol^{-1} and for hydrazine it is +51 kJ mol^{-1}.

(i) State what information these values provide about the stability of these molecules. [1]

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(ii) One method of producing hydrazine is to oxidise ammonia using an appropriate oxidising agent, such as hydrogen peroxide.

$$2NH_3(g) + H_2O_2(l) \longrightarrow NH_2NH_2(l) + 2H_2O(l) \qquad \Delta H^\theta = -241\ kJ\ mol^{-1}$$

Substance	Standard enthalpy change of formation, $\Delta_f H^\theta$ / kJ mol^{-1}	Standard entropy, S^θ / J K^{-1} mol^{-1}
$NH_3(g)$	−46	193
$NH_2NH_2(l)$	+51	122
$H_2O_2(l)$		102
$H_2O(l)$	−286	70

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I. Calculate the standard enthalpy change of formation of hydrogen peroxide, H_2O_2. [2]

$\Delta_f H^\theta$ = ... $kJ\,mol^{-1}$

II. Calculate the temperature at which the value of ΔG^θ is equal to zero. [3]

T = ... K

III. A student states that the temperature calculated in part II is the minimum temperature required for the reaction to occur. Is the student correct? Give a reason for your answer. [2]

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(iii) An alternative route for producing hydrazine starts with the molecule urea, which is produced in biological systems.

$$(NH_2)_2CO + NaOCl + 2NaOH \longrightarrow N_2H_4 + H_2O + NaCl + Na_2CO_3$$

Give **one** disadvantage of this route over the production of hydrazine from ammonia. [1]

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Examiner only

(iv) Hydrazine can undergo both oxidation and reduction reactions. Electrochemical potentials for both processes are included in the table below.

	Standard electrode potential, E^{θ} / V
$Co^{3+}(aq) + e^- \rightleftharpoons Co^{2+}(aq)$	+1.82
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$N_2H_4(aq) + 4H_2O(l) + 2e^- \rightleftharpoons 2NH_4^+(aq) + 4OH^-(aq)$	+0.11
$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	–0.26
$Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq)$	–0.42
$N_2(g) + 4H_2O(l) + 4e^- \rightleftharpoons N_2H_4(aq) + 4OH^-(aq)$	–1.15

I. Suggest whether addition of sodium hydroxide to a hydrazine solution will favour its use as a reducing agent. Give a reason for your answer. [2]

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II. Identify which of these four M^{3+} ions (if any) can be reduced by hydrazine under standard conditions. Give a reason for your answer. [2]

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Turn over for Q.14

14. It is possible to study the concentration dependence of rate by finding how the rate of a reaction changes over time. This is because the concentrations of the reactants change over time.

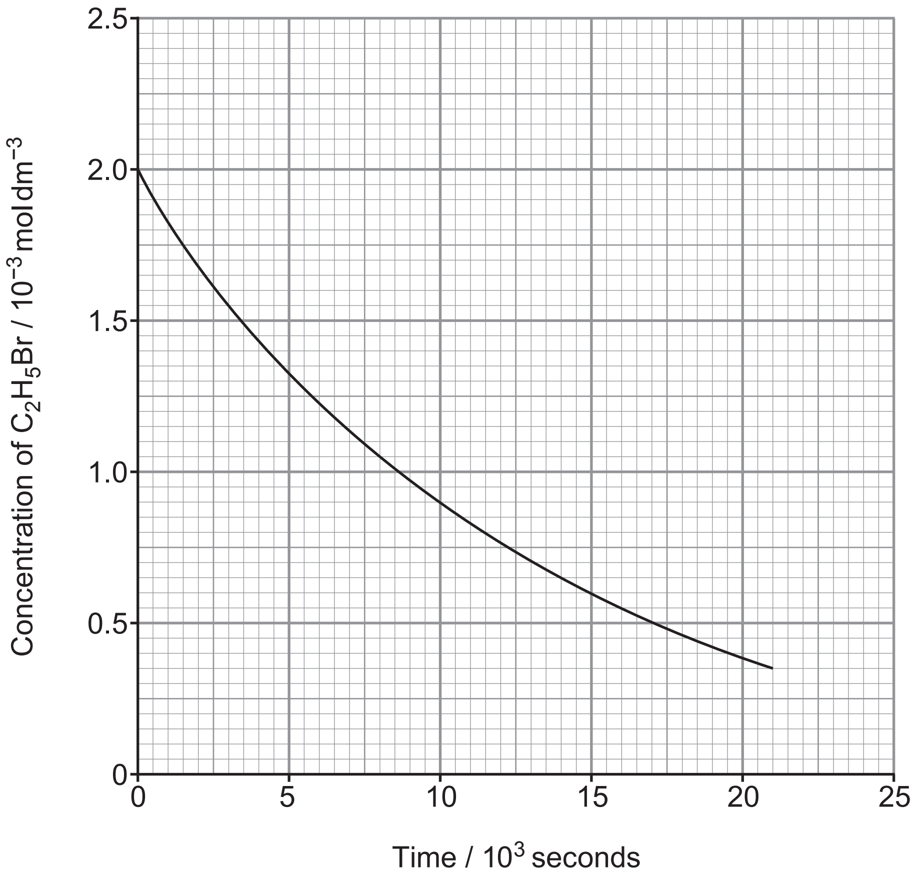
The reaction below occurs in non-aqueous solution in the presence of a small amount of water.

$$C_2H_5Br + OH^- + H_2O \longrightarrow C_2H_5OH + Br^- + H_2O$$

Three students carried out experiments to find how the concentration of each reactant affects the rate. Each one changed the concentration of a different reactant. They used the initial concentrations shown below and an automated sampling device to take measurements every 10 minutes for 6 hours.

	Initial concentration of each reactant / mol dm^{-3}		
	$[C_2H_5Br]$	$[OH^-]$	$[H_2O]$
George's experiment: Finding the effect of $[C_2H_5Br]$ on rate	2.00×10^{-3}	2.00	2.00
Hannah's experiment: Finding the effect of $[H_2O]$ on rate	2.00	2.00	2.00×10^{-3}
Jamal's experiment: Finding the effect of $[OH^-]$ on rate	2.00	2.00×10^{-3}	2.00

(a) The results obtained in George's experiment are shown on the graph below.



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(i) Calculate the initial rate for the reaction, stating its unit. [3]

Initial rate = ...

Unit ....

(ii) Use the graph to show that the reaction is first order with respect to C_2H_5Br. [2]

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(b) Suggest why this method uses much lower concentrations of the reactants being studied than those of the other reactants involved. [1]

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Examiner only

(c) Hannah finds that the concentration of water does not change during her experiment.

(i) Give a reason why the concentration of water does not change. [1]

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(ii) The order of the reaction with respect to water is zero. Suggest how Hannah could confirm this. [1]

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(d) Jamal carried out his experiment at a slightly different temperature from George.

He found that the reaction is first order with respect to hydroxide ions. The final rate equation is therefore as follows.

$$\text{rate} = k[C_2H_5Br][OH^-]$$

The value of the rate constant is 4.07×10^{-5}.

(i) Give the unit of the rate constant. [1]

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(ii) The activation energy for this reaction is $89.5\,kJ\,mol^{-1}$ and its frequency factor, *A*, has a value of 4.30×10^{11}.

Calculate the temperature used for Jamal's experiment.

You **must** show your working. [3]

Temperature = ... K

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