Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A410U10-1

O20-A410U10-1

TUESDAY, 6 OCTOBER 2020 – 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 6.**	**15**	
Section B	**7.**	**11**	
	8.	**13**	
	9.	**20**	
	10.	**11**	
	11.	**24**	
	12.	**13**	
	13.	**13**	
	Total	**120**	

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.10***(c)*(ii) and **Q.11***(c)*.

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.

SECTION A

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

1. *(a)* Draw a dot and cross diagram for the molecule BF_3. [1]

(b) Use valence shell electron pair repulsion theory to explain why BF_3 has a trigonal planar structure. [1]

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2. Give the formulae of the **four** sulfur-containing products of the reaction of sodium iodide, NaI, with concentrated sulfuric acid. [2]

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3. A radioactive sample of sodium-24 decays with a half-life of 15 hours to produce magnesium-24.

(a) Identify the type of radioactive decay occurring. [1]

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(b) A sample of 0.276 g of ^{24}Na decays for 45 hours. Calculate the mass of magnesium-24 produced in this time. [2]

Mass = ... g

4. Addition of excess potassium iodide to 25.0 cm^3 of aqueous copper(II) sulfate produces a brown solution of iodine and a white solid.

(a) Give the **formula** of the white solid. [1]

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(b) The iodine is titrated using sodium thiosulfate solution of concentration 0.200 mol dm^{-3}.

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

The experiment is repeated and the results are shown below.

	Titration 1	Titration 2	Titration 3	Titration 4	Mean titre
Volume of sodium thiosulfate solution / cm^3	24.40	23.90	23.80	23.85	23.85

(i) Suggest why the value from titration 1 is not used in calculating the mean titre. [1]

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(ii) Calculate the number of moles of iodine produced from each 25.0 cm^3 of aqueous copper(II) sulfate solution. [1]

Moles of iodine = ... mol

5. The boiling temperatures of three compounds are shown below.

Compound	ammonia, NH_3	phosphine, PH_3	arsine, AsH_3
Boiling temperature / °C	–33	–88	–63

(a) Explain why the boiling temperature of ammonia is much higher than that of phosphine and arsine. [2]

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(b) Give a reason why the boiling temperature of arsine is higher than that of phosphine. [1]

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6. Iron metal reacts with chlorine to form iron(III) chloride and it reacts with iodine to form iron(II) iodide. Use the standard electrode potentials below to explain this difference. [2]

	Standard electrode potential, E^{θ} / V
$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54

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SECTION B

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

7. Carboxylic acids are weak acids. The table below gives the K_a values for some carboxylic acids.

Acid	K_a / mol dm^{-3}
ethanoic acid, CH_3COOH	1.74×10^{-5}
chloroethanoic acid, $ClCH_2COOH$	1.43×10^{-3}
dichloroethanoic acid, $Cl_2CHCOOH$	5.13×10^{-2}
trichloroethanoic acid, Cl_3CCOOH	2.24×10^{-1}

(a) Describe how the replacement of hydrogen atoms by chlorine atoms affects the strength of the acid. [1]

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(b) Find the pH of a solution of chloroethanoic acid of concentration 0.200 mol dm^{-3}. [2]

pH = ...

(c) The soluble salt sodium ethanoate can be produced from ethanoic acid. A student suggests the following method:

- Measure 25 cm^3 of a solution of ethanoic acid of concentration 0.200 mol dm^{-3} in a measuring cylinder.
- Transfer to a conical flask and add a few drops of methyl orange indicator. This is selected because it changes colour in a pH range of 3.1-4.4.
- Add sodium hydroxide solution of concentration 2.00 mol dm^{-3} from a burette until the indicator changes colour.
- Record the volume of sodium hydroxide required.
- Measure another 25 cm^3 of the ethanoic acid solution.
- Add the same volume of sodium hydroxide as in the first experiment, this time without an indicator.
- Transfer the solution to an evaporating basin and evaporate most of the water.
- Leave the hot solution to cool and allow crystals to form. Filter these away from the solution.

(i) The teacher tells the student that their proposed method would form 0.68 g of sodium ethanoate trihydrate ($CH_3COONa.3H_2O$) and that the solubility of this compound is 2.42 mol dm^{-3} at 20 °C.

Find the minimum volume of water needed to dissolve the mass of sodium ethanoate trihydrate formed at 20 °C and hence suggest why the final step in the method may not be successful. [3]

Miniumum volume = ... cm^3

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(ii) Suggest **three** changes that should be made to this method, giving reasons for each. [5]

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8. Magnesium and sodium lie adjacent to each other in the Periodic Table.

(a) The melting temperature of sodium is 98 °C and magnesium has a melting temperature of 639 °C.

Explain why magnesium has a much higher melting temperature than sodium. [2]

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(b) Sodium and magnesium both conduct electricity. State which of these two metals you would expect to be the better conductor of electricity. Give a reason for your answer. [1]

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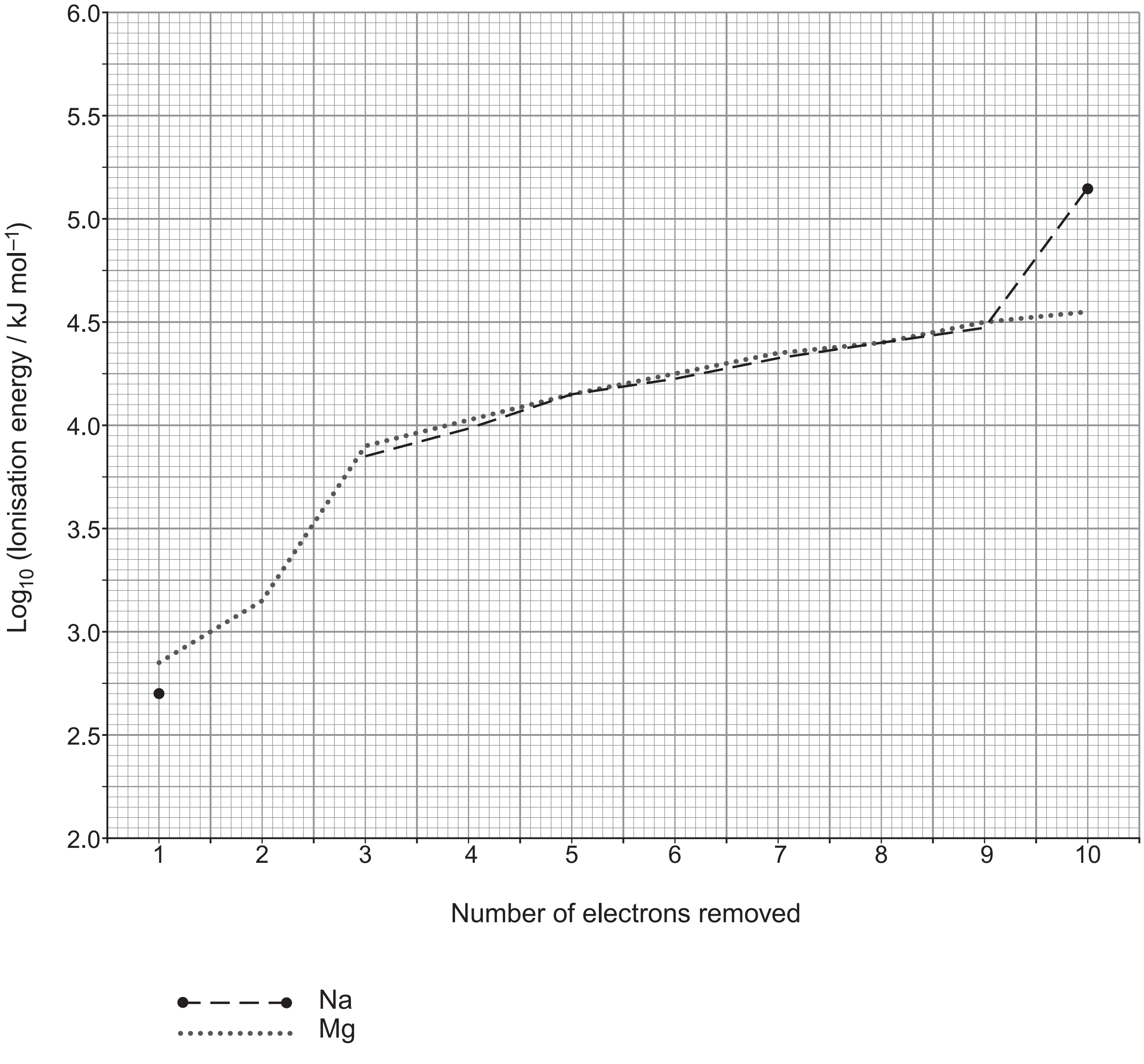
(c) The graph below shows the first ten log molar ionisation energies of sodium and magnesium.



(i) Give the equation for the **third** ionisation energy of magnesium. [1]

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(ii) Explain why the tenth ionisation energy of sodium is much larger than the tenth ionisation energy of magnesium. [2]

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(iii) The plot for the log of the second ionisation energy of sodium is missing from the graph. Estimate its value and hence calculate an approximate second ionisation energy. [2]

Second ionisation energy = ... kJ mol^{-1}

(d) (i) Heating magnesium carbonate causes the compound to decompose forming magnesium oxide and carbon dioxide. The equation for this process is:

$$MgCO_3(s) \longrightarrow MgO(s) + CO_2(g)$$

	Standard enthalpy change of formation, $\Delta_f H^\theta$ / kJ mol^{-1}	Standard entropy, S^θ / J mol^{-1} K^{-1}
$MgCO_3(s)$	–1113	66
$MgO(s)$	–602	27
$CO_2(g)$	–394	214

Calculate the minimum temperature required, in °C, for the thermal decomposition to occur. [4]

Minimum temperature = ... °C

(ii) The element calcium lies below magnesium in Group 2. Suggest a value for the minimum temperature required for the thermal decomposition of $CaCO_3$. Give a reason for your answer. [1]

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Turn over.

9. Organometallic compounds contain metal atoms bonded directly to the carbon atom of an organic group. One example is methyllithium (CH_3Li).

(a) The electronegativity values of the elements present in methyllithium are given below.

Element	H	Li	C
Electronegativity	2.20	0.98	2.55

(i) State what is meant by the term *electronegativity*. [1]

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(ii) State which type of bond will form between lithium and carbon. Give a reason for your answer. [1]

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(b) Methyllithium is synthesised by treating bromomethane with a suspension of metallic lithium in a non-aqueous solvent. This forms a solution of methyllithium in the non-aqueous solvent.

$$CH_3Br \ + \ 2Li \longrightarrow CH_3Li \ + \ LiBr$$

(i) Calculate the atom economy for this method of producing methyllithium. [2]

Atom economy = ... %

(ii) An alternative method of synthesising methyllithium is by using chloromethane as a source of the methyl group. Use the information given below to suggest which method is better for the production of methyllithium.

You should include **two** advantages and **one** disadvantage for your chosen method. [4]

	CH_3Cl	CH_3Br	CH_3Li	LiCl	LiBr
M_r	50.5	94.9	21.9	42.4	86.8
Melting temperature / °C	–97	–94			
Boiling temperature / °C	–24	+4			
Solubility in solvent used	very soluble	very soluble	soluble	insoluble	partly soluble
Relative cost per gram	1.5	1.0			

Atom economy for production of methyllithium from chloromethane = 34.0 %

(c) Methyllithium is a very strong base.

State what is meant by the term *strong base*. [1]

(d) When methyllithium is added to water the reaction below occurs.

$$CH_3Li(sol) \quad + \quad H_2O(l) \longrightarrow LiOH(aq) \quad + \quad CH_4(g)$$

When 10.00 cm^3 of a non-aqueous solution of methyllithium is added to 250.0 cm^3 of water a total volume of 391.8 cm^3 of methane is produced at a temperature of 298 K and a pressure of 1 atm. The pH of the aqueous layer formed is 12.8.

You may assume that LiOH is totally insoluble in the non-aqueous solvent.

(i) Use the volume of gas produced to calculate the concentration of the initial methyllithium solution. Give your answer to an **appropriate** number of significant figures.

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

Concentration = ... mol dm^{-3}

(ii) Use the pH to calculate the concentration of the initial methyllithium solution.

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

Concentration = ... mol dm^{-3}

(iii) State which of these two methods gives the more accurate value. Give a reason for your answer. [2]

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(iv) The reaction between methyllithium and water is exothermic. The enthalpy change of the reaction is –198 kJ mol^{-1}.

Calculate the expected temperature rise when 0.010 mol of pure methyllithium is added to 250.0 cm^3 of water. [3]

Temperature rise = ... °C

20

10. Copper and cobalt are both considered to be transition elements whilst zinc is not.

(a) Give a reason why zinc is not considered to be a transition element. [1]

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(b) Transition elements are able to form complex ions and these ions are usually coloured.

Give the colour of the $[Co(H_2O)_6]^{2+}$ ion. [1]

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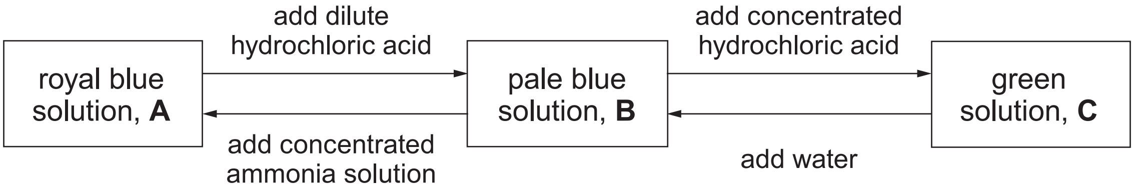
(c) When an aqueous solution containing Cu^{2+} ions is treated with a concentrated aqueous solution of ammonia a pale blue precipitate forms. This dissolves when more ammonia is added to form a royal blue solution, labelled **A** in the scheme below.

(i) Identify the pale blue precipitate. [1]

(ii) Some of the colour changes observed when other solutions are added to solution **A** are given in the following scheme.


add dilute hydrochloric acid
add concentrated hydrochloric acid
royal blue solution, **A**
pale blue solution, **B**
green solution, **C**
add concentrated ammonia solution
add water

Identify the species causing these colours and use Le Chatelier's principle to explain the changes that occur. Your answer should include appropriate equations. [6 QER] *(d)* Give another typical property of transition elements and use it to show that copper is a typical transition element but zinc is not. [2]

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11. Fuel cells are an electrochemical method of obtaining energy from fuels.

(a) Give **one** advantage and **one** disadvantage of the use of fuel cells. [2]

Advantage ....

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Disadvantage ....

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(b) Hydrogen gas is a common fuel used in fuel cells. Hydrogen can be produced in the electrolysis of sodium chloride solution. The reaction occurring is shown below.

$$2NaCl(aq) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g) + Cl_2(g)$$

(i) Electrolysis was undertaken on 250 cm^3 of a solution of sodium chloride of concentration 5.00 mol dm^{-3} until 2856 cm^3 of hydrogen gas was produced at a temperature of 320 K and a pressure of 1.14×10^5 Pa.

Calculate the concentration of the sodium hydroxide present at the end of the process. [4]

Concentration = ... mol dm^{-3}

(ii) The chlorine gas produced in the reaction was stored under a pressure of 5.05×10^5 Pa at a temperature of 283 K.

Calculate the volume of the chlorine gas under these conditions. [2]

Volume = ... cm^3

(iii) At the end of the electrolysis process the solution contained a base and a salt. A student suggests that this could therefore be used as a buffer. Is the student correct? Explain your answer. [3]

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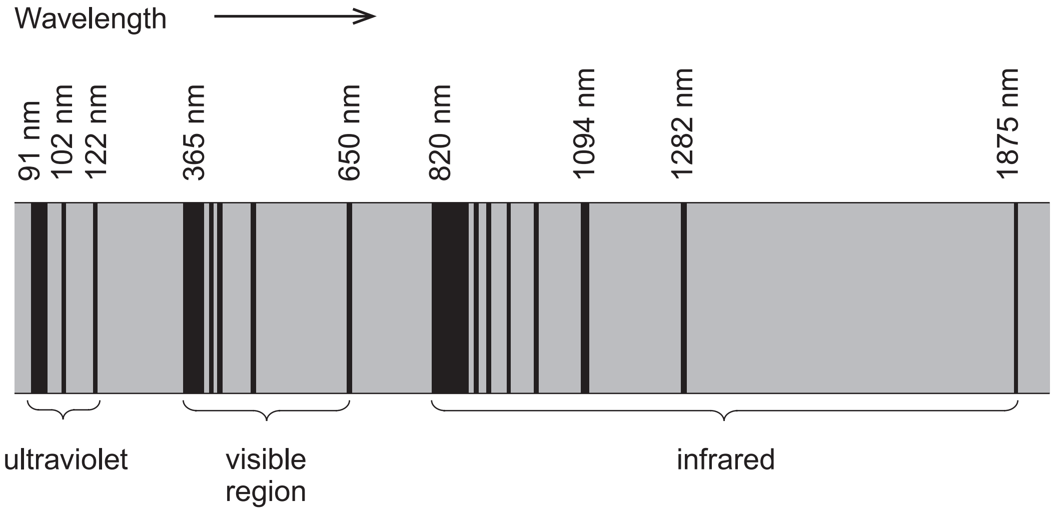
(c) When an electrical discharge is passed through hydrogen gas, the atoms emit light and other frequencies of electromagnetic radiation. These form the emission spectrum shown below.



Explain why this pattern of sharp lines forms and how it can be used to find the ionisation energy of hydrogen. You should also calculate the ionisation energy of hydrogen in kJ mol^{-1}. [6 QER]

Ionisation energy = ... kJ mol^{-1}

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(d) Another fuel that can be used in fuel cells is methanol. The equation for the combustion of gaseous methanol at a temperature of 120°C is given below.

$$2CH_3OH(g) \quad + \quad 3O_2(g) \quad \longrightarrow \quad 2CO_2(g) \quad + \quad 4H_2O(g) \qquad \Delta H = -1286\,\text{kJ}\,\text{mol}^{-1}$$

(i) Calculate the bond energy of the C—O bond in methanol. [3]

Bond	Bond energy / $\text{kJ}\,\text{mol}^{-1}$
C—H	414
O═O	498
O—H	464
C═O	803

Bond energy = ... $\text{kJ}\,\text{mol}^{-1}$

(ii) Give a reason why the value calculated in part (i) may not precisely match the actual energy of this C—O bond. [1]

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(iii) The standard enthalpy change of combustion of methanol has a value of $-715\,\text{kJ mol}^{-1}$. Give reasons why this value is very different from the value associated with the equation. [3]

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12. The oxidation of carbon monoxide to carbon dioxide in the presence of suitable catalysts is an important method of removing this toxic gas from gas mixtures produced during incomplete combustion.

$$2CO + O_2 \longrightarrow 2CO_2$$

Some catalysts for this reaction are produced by soaking aluminium oxide pellets in a solution of a transition metal chloride followed by drying. Two suitable transition metal chlorides are palladium chloride and ruthenium chloride.

(a) These catalysts are examples of heterogeneous catalysts.

(i) State what is meant by *heterogeneous* in this context. [1]

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(ii) Give another example of a heterogeneous catalyst, clearly identifying the reaction that it catalyses. [1]

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(b) Some information regarding these catalysed reactions is given below.

	Activation energy / kJ mol^{-1}	Frequency factor, *A* / mol dm^{-3} s^{-1}
palladium catalyst	61.7	6.1×10^{9}
ruthenium catalyst	79.4	14.1×10^{9}

(i) At a temperature of 600 K, the value of the rate constant for the reaction catalysed by palladium is 2.58×10^{4}.

I. Give the unit for this rate constant. [1]

....

II. Find the value of the rate constant for the ruthenium catalyst under the same conditions and hence identify which of these two catalysts is the more effective. [4]

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(ii) Under certain conditions the oxidation of carbon monoxide can occur without a catalyst. The rate equation for this process is

$$\text{rate} = k[CO][O_2]$$

Suggest a two-step mechanism for the uncatalysed oxidation of carbon monoxide. Label the rate determining step clearly. [3]

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(c) Carbon monoxide is classed as a reducing agent.

(i) State what is meant by a *reducing agent*. [1]

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(ii) Explain why carbon monoxide is a reducing agent whilst the corresponding oxide of lead, PbO, is not. [2]

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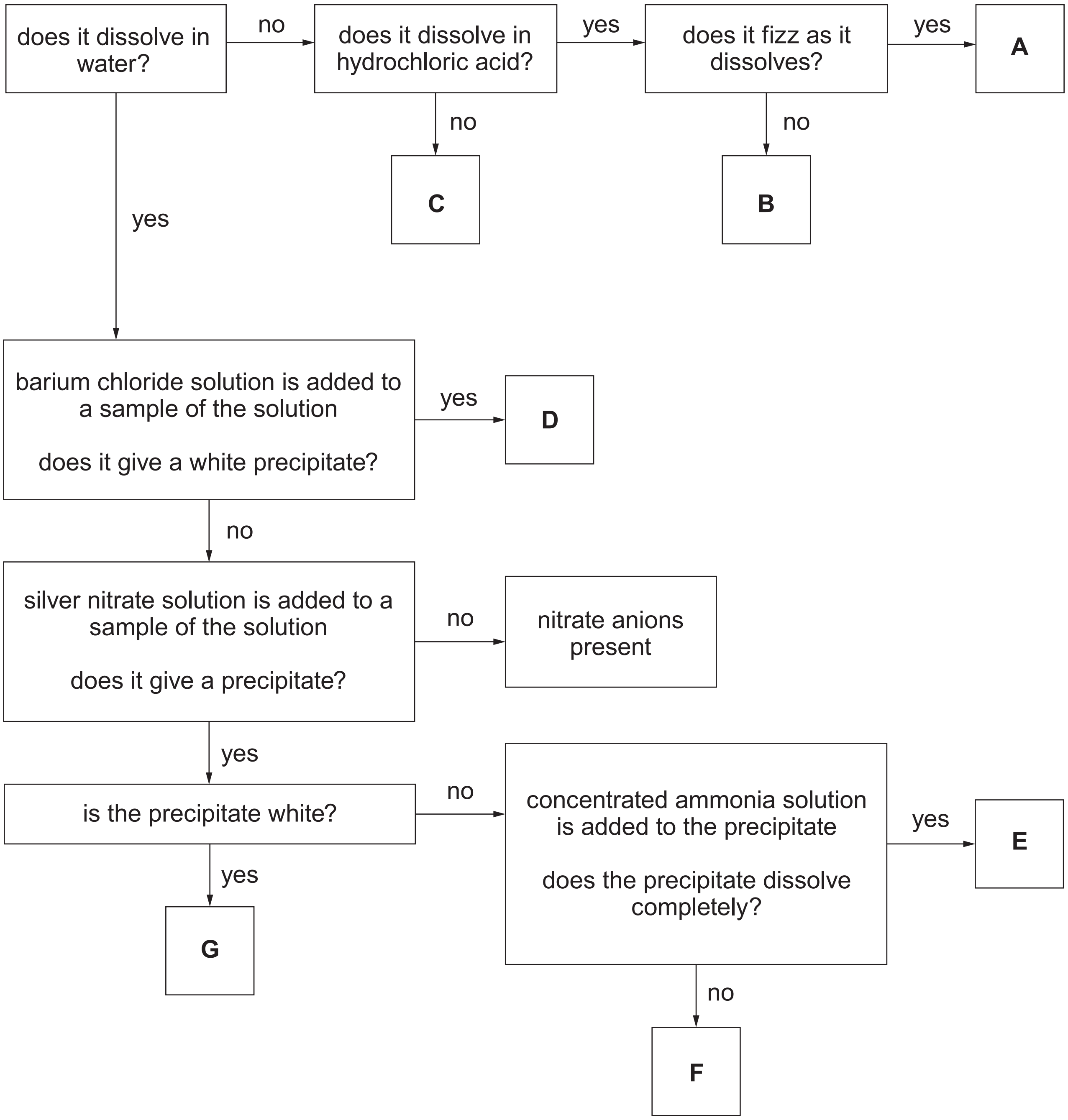
FOR QUESTION 13

13. A student is given several magnesium compounds containing common anions and designs the scheme below to identify the anion present in each compound.


does it dissolve in water?
no
does it dissolve in hydrochloric acid?
yes
does it fizz as it dissolves?
yes
A
no
C
no
B
yes
barium chloride solution is added to a sample of the solution
does it give a white precipitate?
yes
D
no
silver nitrate solution is added to a sample of the solution
does it give a precipitate?
no
nitrate anions present
yes
is the precipitate white?
no
concentrated ammonia solution is added to the precipitate
does the precipitate dissolve completely?
yes
E
yes
G
no
F

(a) The student labels seven possible results as **A-G**. He is able to suggest likely identities for anions that would give six of these results, and his teacher said that none of the common anions that he had studied would give the seventh result.

Suggest possible anions for six of the seven results below. Write '**UNKNOWN**' for the result that would not correspond to a common anion. [4]

A ....

B ....

C ....

D ....

E ....

F ....

G ....

(b) The planned method would not be suitable for identifying **all** these anions in **sodium** compounds. Explain why the method would not be suitable and suggest how it could be modified to make it suitable. [3]

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(c) Concentrated aqueous ammonia solution at 298 K contains 31.0 % ammonia by mass. The density of this solution is 0.900 $\mathrm{g\,cm^{-3}}$.

Calculate the concentration of this solution in $\mathrm{mol\,dm^{-3}}$. [3]

Concentration = ... $\mathrm{mol\,dm^{-3}}$

(d) The student is provided with a solution containing chloride as the only anion. He is told that the solution also contains sodium ions, magnesium ions, or a mixture of both sodium and magnesium ions.

He proposes using a flame test to identify the cation(s) present in the mixture.

State the observations expected for each possibility and explain whether this method would be appropriate. [3]

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