

Candidate Name

Candidate Number

Centre Name

Centre Number

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**Paper 1: Chemistry**

For Examination December 2023

(2 hours)

It is necessary to respond on the answer sheets provided alongside this question paper. Additionally, you must have a soft pencil (preferably of type B or HB), a clean eraser and a dark blue or black pen.

**INSTRUCTIONS:**

- You must write your name, candidate number, centre name and centre number on the answer sheets in the designated spaces.
- Attempt all the questions from using a dark blue or black pen.
- It is important to follow the instructions provided on the answer sheets.
- Do not use correction fluid.
- Avoid writing on any bar codes.

**INFORMATION:**

The number of marks assigned for every question or its parts is indicated within brackets [ ]

## The Periodic Table of Elements

|                        |                         | Group                                                                                                                                                                                                                                                                   |                         |                       |                          |                         |                          |                        |                          |                       |                        |                          |                         |                         |                          |                        |                       |                         |                        |                        |                     |                      |                      |                        |                       |                      |
|------------------------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------|--------------------------|-------------------------|--------------------------|------------------------|--------------------------|-----------------------|------------------------|--------------------------|-------------------------|-------------------------|--------------------------|------------------------|-----------------------|-------------------------|------------------------|------------------------|---------------------|----------------------|----------------------|------------------------|-----------------------|----------------------|
| 1                      | 2                       |                                                                                                                                                                                                                                                                         |                         |                       |                          |                         |                          |                        |                          |                       |                        | 13                       | 14                      | 15                      | 16                       | 17                     | 18                    |                         |                        |                        |                     |                      |                      |                        |                       |                      |
|                        |                         | <div style="border: 1px solid black; padding: 5px; display: inline-block;"> <b>Key</b><br/>                     atomic number<br/>                     name<br/>                     atomic symbol<br/>                     relative atomic mass                 </div> |                         |                       |                          |                         |                          |                        |                          |                       |                        |                          |                         |                         |                          |                        |                       |                         |                        |                        |                     |                      |                      |                        |                       |                      |
|                        |                         | <div style="border: 1px solid black; padding: 5px; display: inline-block;"> <sup>1</sup>H<br/>                     hydrogen<br/>                     1.0                 </div>                                                                                         |                         |                       |                          |                         |                          |                        |                          |                       |                        |                          |                         |                         |                          |                        |                       |                         |                        |                        |                     |                      |                      |                        |                       |                      |
|                        |                         | <div style="border: 1px solid black; padding: 5px; display: inline-block;"> <sup>2</sup>He<br/>                     helium<br/>                     4.0                 </div>                                                                                          |                         |                       |                          |                         |                          |                        |                          |                       |                        |                          |                         |                         |                          |                        |                       |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| 3                      | 4                       |                                                                                                                                                                                                                                                                         |                         |                       |                          |                         |                          |                        |                          |                       |                        | 5                        | 6                       | 7                       | 8                        | 9                      | 10                    | 11                      | 12                     | 13                     | 14                  | 15                   | 16                   | 17                     | 18                    |                      |
| Li<br>lithium<br>6.9   | Be<br>beryllium<br>9.0  |                                                                                                                                                                                                                                                                         |                         |                       |                          |                         |                          |                        |                          |                       |                        | B<br>boron<br>10.8       | C<br>carbon<br>12.0     | N<br>nitrogen<br>14.0   | O<br>oxygen<br>16.0      | F<br>fluorine<br>19.0  | Ne<br>neon<br>20.2    |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| 11                     | 12                      |                                                                                                                                                                                                                                                                         |                         |                       |                          |                         |                          |                        |                          |                       |                        | 13                       | 14                      | 15                      | 16                       | 17                     | 18                    |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| Na<br>sodium<br>23.0   | Mg<br>magnesium<br>24.3 |                                                                                                                                                                                                                                                                         |                         |                       |                          |                         |                          |                        |                          |                       |                        | Al<br>aluminium<br>27.0  | Si<br>silicon<br>28.1   | P<br>phosphorus<br>31.0 | S<br>sulfur<br>32.1      | Cl<br>chlorine<br>35.5 | Ar<br>argon<br>39.9   |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| 19                     | 20                      | 21                                                                                                                                                                                                                                                                      | 22                      | 23                    | 24                       | 25                      | 26                       | 27                     | 28                       | 29                    | 30                     | 31                       | 32                      | 33                      | 34                       | 35                     | 36                    |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| K<br>potassium<br>39.1 | Ca<br>calcium<br>40.1   | Sc<br>scandium<br>45.0                                                                                                                                                                                                                                                  | Ti<br>titanium<br>47.9  | V<br>vanadium<br>50.9 | Cr<br>chromium<br>52.0   | Mn<br>manganese<br>54.9 | Fe<br>iron<br>55.8       | Co<br>cobalt<br>58.9   | Ni<br>nickel<br>58.7     | Cu<br>copper<br>63.5  | Zn<br>zinc<br>65.4     | Ga<br>gallium<br>69.7    | Ge<br>germanium<br>72.6 | As<br>arsenic<br>74.9   | Se<br>selenium<br>79.0   | Br<br>bromine<br>79.9  | Kr<br>krypton<br>83.8 |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| 37                     | 38                      | 39                                                                                                                                                                                                                                                                      | 40                      | 41                    | 42                       | 43                      | 44                       | 45                     | 46                       | 47                    | 48                     | 49                       | 50                      | 51                      | 52                       | 53                     | 54                    |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| Rb<br>rubidium<br>85.5 | Sr<br>strontium<br>87.6 | Y<br>yttrium<br>88.9                                                                                                                                                                                                                                                    | Zr<br>zirconium<br>91.2 | Nb<br>niobium<br>92.9 | Mo<br>molybdenum<br>95.9 | Tc<br>technetium<br>—   | Ru<br>ruthenium<br>101.1 | Rh<br>rhodium<br>102.9 | Pd<br>palladium<br>106.4 | Ag<br>silver<br>107.9 | Cd<br>cadmium<br>112.4 | In<br>indium<br>114.8    | Sn<br>tin<br>118.7      | Sb<br>antimony<br>121.8 | Te<br>tellurium<br>127.6 | I<br>iodine<br>126.9   | Xe<br>xenon<br>131.3  |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| 55                     | 56                      | 57–71<br>lanthanoids                                                                                                                                                                                                                                                    |                         |                       |                          |                         |                          |                        |                          |                       |                        | 81                       | 82                      | 83                      | 84                       | 85                     | 86                    |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| Cs<br>caesium<br>132.9 | Ba<br>barium<br>137.3   |                                                                                                                                                                                                                                                                         |                         |                       |                          |                         |                          |                        |                          |                       |                        | Tl<br>thallium<br>204.4  | Pb<br>lead<br>207.2     | Bi<br>bismuth<br>209.0  | Po<br>polonium<br>—      | At<br>astatine<br>—    | Rn<br>radon<br>—      |                         |                        |                        |                     |                      |                      |                        |                       |                      |
| 87                     | 88                      | 89–103<br>actinoids                                                                                                                                                                                                                                                     |                         |                       |                          |                         |                          |                        |                          |                       |                        | 104                      | 105                     | 106                     | 107                      | 108                    | 109                   | 110                     | 111                    | 112                    | 113                 | 114                  | 115                  | 116                    | 117                   | 118                  |
| Fr<br>francium<br>—    | Ra<br>radium<br>—       |                                                                                                                                                                                                                                                                         |                         |                       |                          |                         |                          |                        |                          |                       |                        | Rf<br>rutherfordium<br>— | Db<br>dubnium<br>—      | Sg<br>seaborgium<br>—   | Bh<br>bohrium<br>—       | Hs<br>hassium<br>—     | Mt<br>meitnerium<br>— | Ds<br>darmstadtium<br>— | Rg<br>roentgenium<br>— | Cn<br>copernicium<br>— | Nh<br>nihonium<br>— | Fl<br>flerovium<br>— | Mc<br>moscovium<br>— | Lv<br>livermorium<br>— | Ts<br>tennessine<br>— | Og<br>oganesson<br>— |

| lanthanoids                 |                           |
|-----------------------------|---------------------------|
| 57                          | 58                        |
| La<br>lanthanum<br>138.9    | Ce<br>cerium<br>140.1     |
| 59                          | 60                        |
| Pr<br>praseodymium<br>140.9 | Nd<br>neodymium<br>144.4  |
| 61                          | 62                        |
| Pm<br>promethium<br>—       | Sm<br>samarium<br>150.4   |
| 63                          | 64                        |
| Eu<br>europium<br>152.0     | Gd<br>gadolinium<br>157.3 |
| 65                          | 66                        |
| Tb<br>terbium<br>158.9      | Dy<br>dysprosium<br>162.5 |
| 67                          | 68                        |
| Ho<br>holmium<br>164.9      | Er<br>erbium<br>167.3     |
| 69                          | 70                        |
| Tm<br>thulium<br>168.9      | Yb<br>ytterbium<br>173.1  |
| 71                          | 71                        |
| Lu<br>lutetium<br>175.0     | Lr<br>lawrencium<br>—     |

| actinoids                   |                        |
|-----------------------------|------------------------|
| 89                          | 90                     |
| Ac<br>actinium<br>—         | Th<br>thorium<br>232.0 |
| 91                          | 92                     |
| Pa<br>protactinium<br>231.0 | U<br>uranium<br>238.0  |

Instructions: Answer **all** the questions in the space provided.

### Question 1

Gallium is a metal in Group 13 of the Periodic Table.

(a) There are two stable isotopes of gallium,  $^{69}\text{Ga}$  and  $^{71}\text{Ga}$ .

State, with reference to subatomic particles, how the isotopes  $^{69}\text{Ga}$  and  $^{71}\text{Ga}$  differ from each other.

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

State what further information is needed to calculate the relative atomic mass of gallium.

..... [1]

(b) Gallium and its compounds show similar properties to aluminium and its compounds. Gallium reacts with excess chlorine to form gallium trichloride.

At 500 °C, gallium trichloride is a gas.

Suggest the type of attraction that exists at 500 °C

- between atoms within a gallium trichloride molecule

.....

- between gallium trichloride molecules.

.....

[2]

(ii) When gallium trichloride is cooled a solid,  $\text{Ga}_2\text{Cl}_6$ , forms.

Suggest the name of the attraction formed between two gallium trichloride molecules to form  $\text{Ga}_2\text{Cl}_6$ .

..... [1]

(c) Gallium metal reacts rapidly when exposed to air. A white solid layer is formed on its surface.

(i) Suggest an equation to describe the reaction occurring when gallium metal is exposed to air.

..... [2]

- (ii) The table gives the formula of each gallium-containing product formed when gallium oxide reacts separately with hot aqueous hydrochloric acid and hot aqueous sodium hydroxide.

|                               | formula of gallium-containing product |
|-------------------------------|---------------------------------------|
| hot aqueous hydrochloric acid | $\text{GaCl}_3$                       |
| hot aqueous sodium hydroxide  | $\text{NaGa}(\text{OH})_4$            |

Give the name of the type of behaviour shown by gallium oxide in these reactions.

..... [1]

[Total: 8]

## Question 2

(a) The equation shown in (a)(i) describes the reaction which occurs when aqueous potassium iodide is added to aqueous copper(II) sulfate. A white precipitate of copper(I) iodide forms in a brown solution of iodine and potassium sulfate.

Balance the equation and include state symbols.



[2]

The table gives the oxidation numbers of iodine in the different species in the equation.

| iodine-containing species | oxidation number of iodine |
|---------------------------|----------------------------|
| KI                        | -1                         |
| CuI                       | -1                         |
| $\text{I}_2$              | 0                          |

(ii) Deduce the oxidation number of copper in  $\text{CuSO}_4$  and  $\text{CuI}$ .

- oxidation number of copper in  $\text{CuSO}_4$  .....
- oxidation number of copper in  $\text{CuI}$  .....

[1]

(b) Describe the type of reaction shown by the equation in (a)(i). Explain your answer in terms of electron transfer.

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

(iii) In the reaction described in (a)(i), a student uses 17.43 g of  $\text{CuSO}_4 \cdot y\text{H}_2\text{O}$ . By further titration of the reaction products the student concludes that the total amount of  $\text{CuSO}_4$  in the sample is 0.0982 mol.

Use the *periodic table* to complete the table to calculate the value of  $y$ , where  $y$  is an integer. Show your working.

|                                                                                           |                                |
|-------------------------------------------------------------------------------------------|--------------------------------|
| mass of<br>0.0982 mol $\text{CuSO}_4$                                                     | ..... g                        |
| amount of $\text{H}_2\text{O}$ in<br>17.43 g of $\text{CuSO}_4 \cdot y\text{H}_2\text{O}$ | ..... mol $\text{H}_2\text{O}$ |
| value of $y$                                                                              | $y = \dots\dots\dots$          |

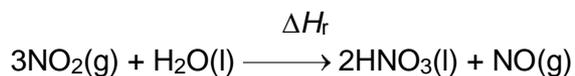
[4]

[Total: 9]

### Question 3

Nitric acid,  $\text{HNO}_3$ , can be made by reacting nitrogen dioxide with water.

The enthalpy change for the reaction can be measured indirectly using a Hess' cycle.



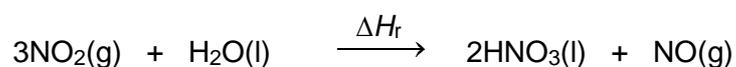
(a) Explain what is meant by the term *enthalpy change of formation*.

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

(b) Complete the Hess' cycle using the values given in the table and hence calculate the enthalpy change,  $\Delta H_r$ , for this reaction.

Show your working.

| substance                      | $\Delta H_f / \text{kJ mol}^{-1}$ |
|--------------------------------|-----------------------------------|
| $\text{NO}_2(\text{g})$        | 34.0                              |
| $\text{H}_2\text{O}(\text{l})$ | -286                              |
| $\text{HNO}_3(\text{l})$       | -173                              |
| $\text{NO}(\text{g})$          | 91.1                              |



$\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1}$   
[3]

(c) Nitrogen and oxygen do not react at normal atmospheric temperatures.

Explain why.

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

Nitrogen oxides can be formed naturally in the Earth's atmosphere from nitrogen and oxygen in the air.

(d) State **one** way that nitrogen oxides are produced naturally.

..... [1]

(e) Nitrogen dioxide, NO<sub>2</sub>, acts as a homogeneous catalyst in the oxidation of atmospheric sulfur dioxide.

(i) Explain why NO<sub>2</sub> is described as a homogeneous catalyst.

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

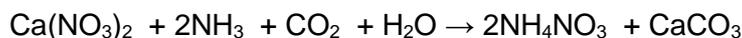
(ii) Write equations which describe the two reactions occurring when NO<sub>2</sub> acts as a catalyst in the formation of sulfur trioxide from sulfur dioxide.

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

[Total: 13]

#### Question 4

Calcium nitrate, Ca(NO<sub>3</sub>)<sub>2</sub>, reacts with ammonia, carbon dioxide and water to form a mixture of ammonium nitrate and calcium carbonate.



(a) Explain why ammonia is described as a Brønsted-Lowry base in this reaction.

..... [1]

The product mixture can then be added to soil.

(b) State **two** reasons why this mixture of products is added to some soils.

1 .....  
2 ..... [2]

(c) Complete the table to name the shape and give the bond angle of each species.

|                  | name of shape | bond angle / ° |
|------------------|---------------|----------------|
| CO <sub>2</sub>  |               |                |
| H <sub>2</sub> O |               |                |
| NH <sub>3</sub>  |               |                |

[3]

**Total: [6 marks]**

### Question 5

(a) Below is a list of species which can react with organic compounds.



i) From the list, identify a species which can react with ethane.  
..... [1]

ii) From the list, identify **two** species which can attack the  $\pi$  bond in ethene.  
..... [1]

iii) From the list, identify a species which can be used to distinguish between solutions of propanoic acid and propan-1-ol. Describe any relevant observations.  
.....  
.....  
..... [2]

(iv)  $\text{Cl(g)}$  can be made from  $\text{Cl}_2(\text{g})$ .

Describe the conditions required for this process.  
..... [1]

(v) Name this process.

..... [1]

(b) But-1-ene reacts with steam in the presence of concentrated phosphoric acid to form two isomers of molecular formula  $\text{C}_4\text{H}_{10}\text{O}$ .

Each reaction occurs via a different intermediate ion.

(i) Draw the structure of both intermediate ions.

(ii) Circle the more stable intermediate ion drawn in (d)(i). Explain your answer.

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

[Total: 10]

### Question 6

Nitrogen, N<sub>2</sub>, is the most abundant gas in the Earth's atmosphere and is very unreactive.

(i) State why N<sub>2</sub> is very unreactive.

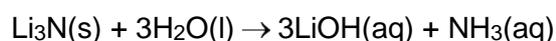
..... [1]

(ii) Magnesium and lithium both form nitrides with N<sub>2</sub>. These compounds both contain the N<sub>3</sub><sup>-</sup> ion.

a. Write an equation for the reaction of magnesium with N<sub>2</sub> to form magnesium nitride.

..... [1]

b. Solid lithium nitride, Li<sub>3</sub>N, reacts with water according to the following equation.



State **one** observation you would make during this reaction.

..... [1]

(iii) State the industrial importance of ammonia.

..... [1]

(iv) One method of producing NH<sub>3</sub> is by heating ammonium chloride, NH<sub>4</sub>Cl, with CaO.



Explain why the reaction of NH<sub>4</sub>Cl with CaO produces ammonia.

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

(v) Three oxides of nitrogen, NO, NO<sub>2</sub> and N<sub>2</sub>O, can be formed under different conditions.

Complete the table to give the oxidation numbers of nitrogen in NO and NO<sub>2</sub>.

|                       |    |                 |
|-----------------------|----|-----------------|
| compound              | NO | NO <sub>2</sub> |
| oxidation number of N |    |                 |

[1]

(vi) NO<sub>2</sub> can be formed by different chemical reactions.

Write equations for the formation of NO<sub>2</sub> by:

(iii) the reaction of N<sub>2</sub> with O<sub>2</sub>

.....

(d) the thermal decomposition of magnesium nitrate.

.....

[2]

[Total: 9 marks]

### Question 7

The elements in Group 17 of the Periodic Table are called the halogens. They form stable compounds with both metals and non-metals.

The table gives some data about F<sub>2</sub>, HCl and CaF<sub>2</sub>.

|                       |                |      |                  |
|-----------------------|----------------|------|------------------|
|                       | F <sub>2</sub> | HCl  | CaF <sub>2</sub> |
| boiling point / K     | 85             | 188  | 2773             |
| relative formula mass | 38.0           | 36.5 | 78.1             |

(a) (i) State what is meant by the term *relative formula mass*.

.....

.....

..... [2]

(ii) F<sub>2</sub> and HCl are both covalent molecules.

Suggest why the boiling point of HCl is higher than that of F<sub>2</sub>.

.....

.....

..... [2]

(iii) Explain why  $\text{CaF}_2$  has a very high boiling point.

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

(iv)  $\text{CaF}_2(\text{aq})$  can be made by the reaction of calcium carbonate with hydrofluoric acid,  $\text{HF}(\text{aq})$ .

Write an equation for this reaction. Include state symbols.

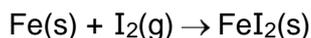
..... [2]

**(b) (i)** Complete the electronic configuration of a chloride ion.

$1s^2$  ..... [1]

(ii) When  $\text{Cl}_2$  is passed over hot iron,  $\text{FeCl}_3$  is formed.

However, when  $\text{I}_2(\text{g})$  is passed over hot iron, the following reaction occurs.



State what you would observe during the reaction between Fe and  $\text{I}_2$ . Explain why  $\text{FeI}_2(\text{s})$  is formed rather than  $\text{FeI}_3(\text{s})$ .

observation .....

.....

explanation .....

.....

..... [2]

**(iii)**  $\text{FeI}_2$  is soluble in water.

A student carries out a chemical test to confirm that a solution of  $\text{FeI}_2$  contains aqueous iodide ions,  $\text{I}^-(\text{aq})$ . The student adds a single reagent and a precipitate forms.

Identify the reagent the student uses. State the colour of the precipitate that forms.

reagent .....

colour of precipitate .....

[2]

(c) Compounds containing  $\text{I}^-$  are often contaminated by bromide ions,  $\text{Br}^-$ .

Identify a further reagent that the student could use to show that the precipitate formed in **(iii)** contained iodide ions.

..... [1]

(d) HOF is the only known molecule that contains only the elements hydrogen, oxygen and fluorine.

i) Draw a 'dot-and-cross' diagram to represent the bonding in a molecule of HOF. Show the outer shell electrons only.

[2]

ii) HOF can be made by the reaction of  $F_2$  with ice at  $-40\text{ }^\circ\text{C}$ . The reaction is similar to the reaction of  $Cl_2$  with cold water.

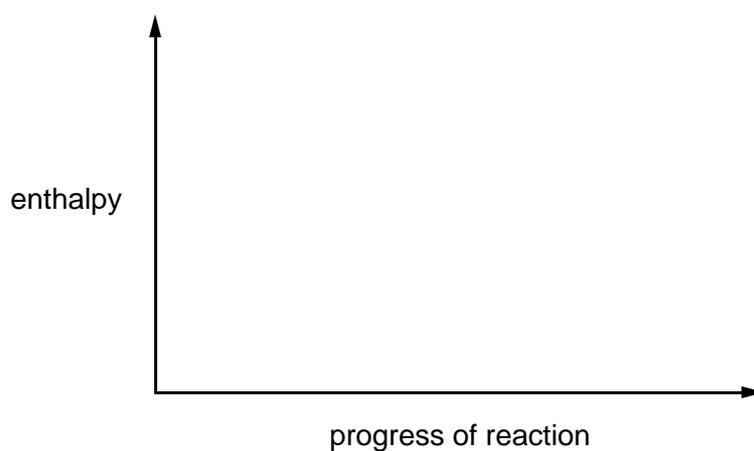
Suggest an equation for the reaction of  $F_2$  with ice.

..... [1]

iii) HOF is an unstable compound and decomposes to form HF and  $O_2$ .



Draw a fully labelled reaction pathway diagram on the axes provided to show the decomposition of HOF into HF and  $O_2$ .



[2]

- (e) Pure HF is a colourless liquid at 273 K. The liquid contains HF molecules that have strong hydrogen bonds between them.

Draw a fully labelled diagram to suggest how a hydrogen bond can form between two HF molecules.

[3]

- (f) Interhalogen compounds, such as  $\text{BrCl}$  or  $\text{IF}_5$ , contain two or more different halogen atoms that are covalently bonded.

**D** is an interhalogen compound that contains only chlorine and fluorine.

At 0 °C and 101 325 Pa, 1 dm<sup>3</sup> of **D** has a mass of 4.13 g.

- i) Use the general gas equation to calculate the relative molecular mass,  $M_r$ , of **D**.

$M_r = \dots\dots\dots$   
[3]

- (ii) Use your answer to (i) to determine the molecular formula of **D**.

If you were unable to calculate the  $M_r$  in (i), assume that the  $M_r$  is 130.5. This is **not** the correct value.

molecular formula of **D** =  $\dots\dots\dots$   
[1]

[Total: 25]

**Question 8**

**(a)** Explain what is meant by the term *relative isotopic mass*.

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

**(b)** A sample of copper contains two isotopes,  $^{63}\text{Cu}$  and  $^{65}\text{Cu}$ . The relative atomic mass of the copper in this sample is 63.55.

Calculate the percentage abundance of each of these isotopes. Show your working.

percentage abundance of  $^{63}\text{Cu}$  = ..... %

percentage abundance of  $^{65}\text{Cu}$  = ..... %  
[2]

**(c) (i)** Name the type of bonding within a sample of solid copper.

..... [1]

**(ii)** Draw a labelled diagram to show the bonding within a sample of solid copper.

[2]

**(iii)** State the electronic configuration of a copper atom.

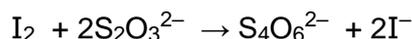
$1s^2$  ..... [1]

- (d) A student is provided with a sample of hydrated copper(II) sulfate,  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ , and is asked to determine the value of  $x$ .  
The student dissolves a sample of the hydrated copper(II) sulfate in water and adds it to an excess of aqueous potassium iodide to make a total volume of  $250.0 \text{ cm}^3$  of solution.



The amount of iodine produced during this reaction is found by titrating a sample of this solution with sodium thiosulfate solution.

$25.0 \text{ cm}^3$  of the iodine-containing solution requires  $20.0 \text{ cm}^3$  of  $0.10 \text{ mol dm}^{-3}$  sodium thiosulfate solution.



- (i) Calculate the amount, in mol, of copper(II) sulfate present in the original sample of hydrated copper(II) sulfate.

Show your working.

amount of copper(II) sulfate = ..... mol [2]

- (iv) A total of  $7.98 \text{ g}$  of  $\text{CuSO}_4$  is present in  $10.68 \text{ g}$  of  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ .

Complete each row of the table to calculate the value of  $x$ , where  $x$  is an integer.

[ $M_r$ :  $\text{CuSO}_4, 159.6$ ]

|                                                                                                     |                       |
|-----------------------------------------------------------------------------------------------------|-----------------------|
| amount of $\text{CuSO}_4$ in<br>$10.68 \text{ g}$ of $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$      | ..... mol             |
| amount of $\text{H}_2\text{O}$ in<br>$10.68 \text{ g}$ of $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ | ..... mol             |
| value of $x$                                                                                        | $x = \dots\dots\dots$ |

[3]

[Total: 13]

### Question 9

A sample of barium is heated in oxygen.

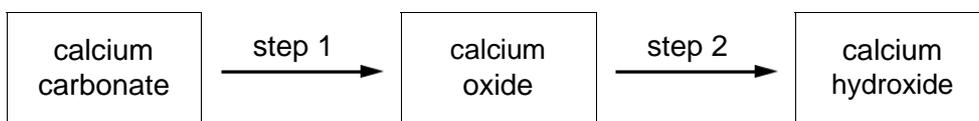
- (a) Describe **two** observations for this reaction.

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

- (b) Write an equation for this reaction. Include state symbols.

..... [1]

- (c) Calcium carbonate can be converted into calcium hydroxide in a two-step process.



- (i) Describe how the two-step process is carried out to convert calcium carbonate into calcium hydroxide. Include relevant equations.

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

- (ii) Name the type of reaction occurring when calcium carbonate is converted into calcium oxide.

..... [1]

- (iii) State **one** common use for both calcium carbonate and calcium hydroxide.

..... [1]

**(d)** Gallium is a silver-grey solid. Aluminium and gallium share many similar chemical properties.

i) Construct an equation for the reaction of gallium when heated in oxygen to form gallium oxide,  $\text{Ga}_2\text{O}_3$ .

..... [1]

ii) Deduce the oxidation number of gallium in  $\text{Ga}_2\text{O}_3$ .

..... [1]

**(e)** Complete the table by predicting the formula of each gallium-containing product formed when gallium oxide reacts separately with hot aqueous hydrochloric acid and with hot concentrated sodium hydroxide.

| reagents and conditions                                   | formula of gallium-containing product |
|-----------------------------------------------------------|---------------------------------------|
| gallium oxide + hot $\text{HCl}(\text{aq})$               |                                       |
| gallium oxide + hot concentrated $\text{NaOH}(\text{aq})$ |                                       |

[2]

[Total: 12]

Question 10

(a) The rate of chemical reactions is affected by changes in temperature and pressure.

(i) Draw a curve on the axes to show the Boltzmann distribution of energy of particles in a sample of gaseous krypton atoms at a given temperature.

Label the curve **T1** and label the axes.



[2]

]

(ii) On the diagram in (a)(i), draw a second curve to show the distribution of energies of the krypton atoms at a higher temperature.

Label the second curve **T2**.

[1]

[1]

The Boltzmann distribution assumes that the particles behave as an ideal gas.

(a) State **two** assumptions of the kinetic theory as applied to an ideal gas.

- 1  
.....  
.....
- 2  
.....  
.....

[  
2  
]

[2]

[Total: 5]

**End of Paper**