OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

CHEMISTRY 2815/01

Trends and Patterns

Tuesday **28 JUNE 2005** Morning 1 hour

Candidates answer on the question paper.
Additional materials:
Data Sheet for Chemistry
Scientific calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- You may use the *Data Sheet for Chemistry*.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	16	
2	17	
3	12	
TOTAL	45	

This question paper consists of 8 printed pages.

Registered Charity Number: 1066969
[Turn over

2 The carbonates and nitrates of Group 2 elements decompose when heated.

(a) Calcium oxide is manufactured by the decomposition of calcium carbonate.

(i) Write the equation for this decomposition.

..... [1]

(ii) Explain why the decomposition temperature of calcium carbonate is much lower than that of barium carbonate.

.....

.....

..... [2]

(b) Barium nitrate decomposes when heated to make barium oxide, nitrogen dioxide and oxygen.

$$2Ba(NO_3)_2(s) \longrightarrow 2BaO(s) + 4NO_2(g) + O_2(g) \qquad \textbf{Equation 2.1}$$

(i) Use oxidation states to explain why this decomposition reaction involves both oxidation **and** reduction.

.....

.....

.....

..... [3]

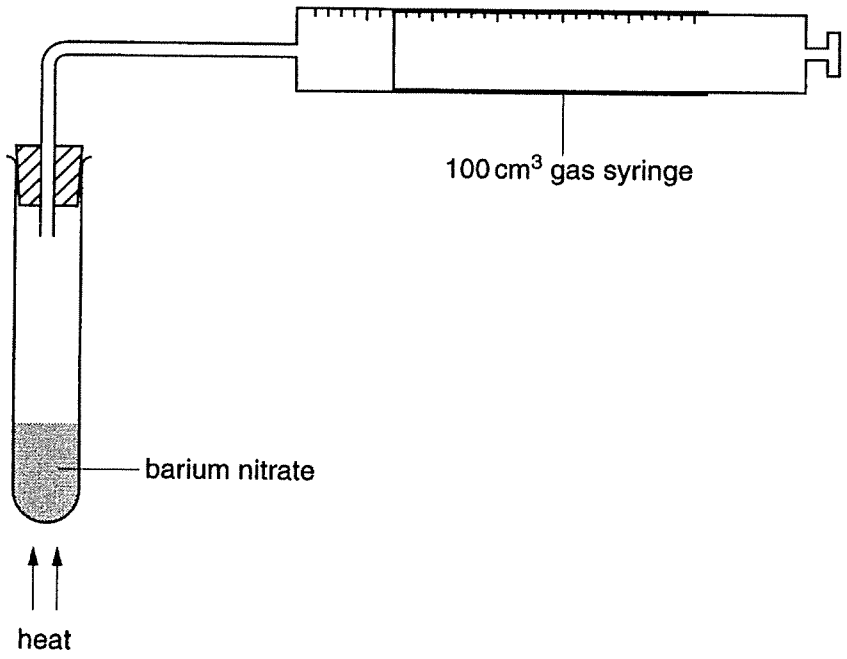
(ii) Calculate the enthalpy change of reaction, ΔH_r, in $kJ\,mol^{-1}$, for the thermal decomposition of barium nitrate using the enthalpy changes of formation, ΔH_f, given in the table.

compound	ΔH_f / $kJ\,mol^{-1}$
$Ba(NO_3)_2(s)$	–992
$BaO(s)$	–558
$NO_2(g)$	+33

answer ..... $kJ\,mol^{-1}$ [3]

(c) A student investigates the volume of gas formed when barium nitrate is heated.

The diagram shows the apparatus the student uses.



(i) A 1.31 g sample of barium nitrate is completely decomposed.

Use **Equation 2.1** to calculate the volume, in cm^3, of gas formed at room temperature and pressure.

1 mol of gas molecules occupies 24 000 cm^3 at room temperature and pressure.

answer ..... cm^3 [3]

(ii) Suggest **one** problem that the student may encounter when carrying out the investigation.

.....

..... [1]

(d) Barium nitrate has a higher decomposition temperature than calcium nitrate. One of the reasons for this is the difference between the lattice enthalpy of barium oxide and that of calcium oxide.

(i) Explain what is meant by the term *lattice enthalpy*.

.....

.....

..... [2]

(ii) Explain why the lattice enthalpy of barium oxide is much **less exothermic** than that of calcium oxide.

.....

.....

.....

..... [2]

[Total: 17]

For Examiner's Use

3 In this question, one mark is available for the quality of use and organisation of scientific terms.

Copper and iron are typical transition elements. One of the characteristic properties of a transition element is that it can form complex ions.

- Explain in terms of electronic configuration why copper is a transition element.
- Give an example of a complex ion that contains copper. Draw the three dimensional shape of the ion and describe the bonding within this complex ion.
- Transition elements show typical metallic properties. Describe **three other** typical properties of transition elements. Illustrate each property using copper or iron or their compounds.

[11]
QWC=[1]
=[12]

[Turn over

Answer **all** the questions.

1 Chlorine gas may be prepared in the laboratory by reacting hydrochloric acid with potassium manganate(VII). The following standard electrode potentials relate to this reaction.

$$\tfrac{1}{2}Cl_2 + e^- \rightleftharpoons Cl^- \qquad E^\ominus = +1.36\,V$$

$$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O \qquad E^\ominus = +1.52\,V$$

(a) Define the term *standard electrode potential.*

.....

.....

.....

..... [3]

(b) Determine the standard cell potential for a cell constructed from these two redox systems.

[1]

(c) Use the half-equations above to:

(i) construct an ionic equation for the reaction between hydrochloric acid and potassium manganate(VII);

.....

.....

..... [2]

(ii) determine the oxidation numbers of chlorine and manganese before and after the reaction has taken place;

.....

.....

..... [2]

(iii) state what is oxidised and what is reduced in this reaction.

.....

.....

..... [2]

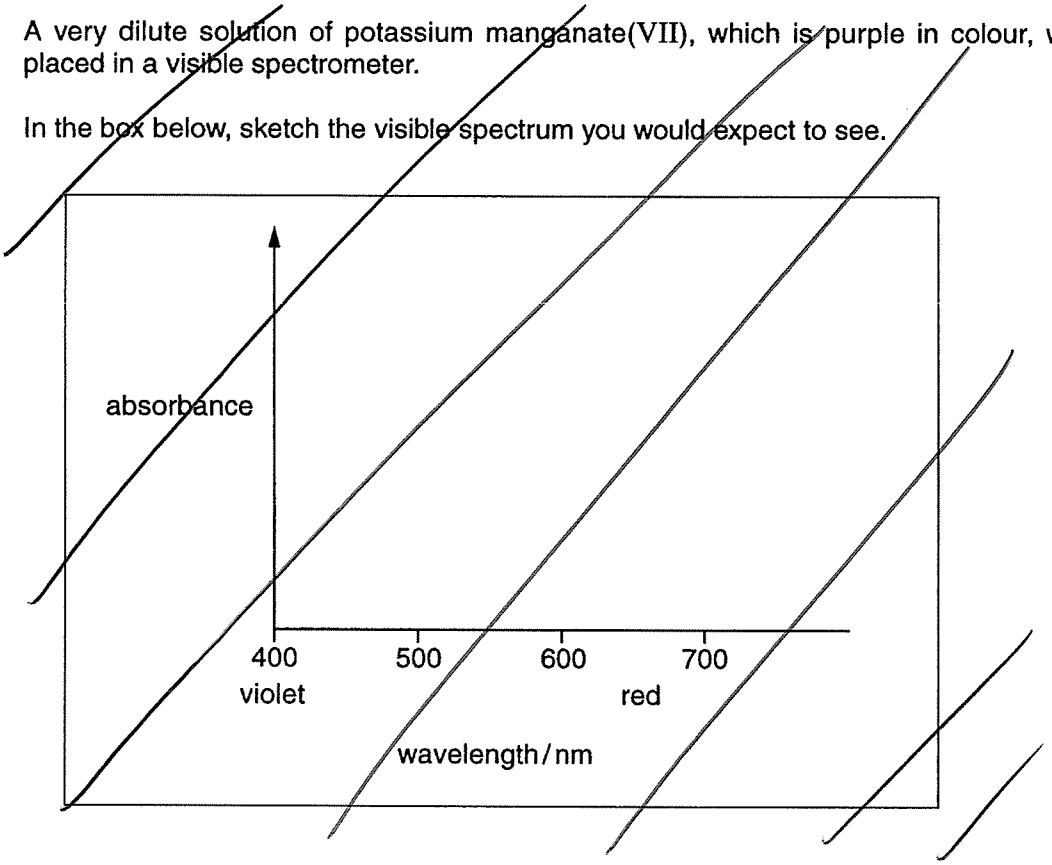
(d) If potassium manganate(VII) and very dilute hydrochloric acid are mixed, there is no visible reaction. Suggest why there is no visible reaction in this case.

.....

..... [1]

(e) A very dilute solution of potassium manganate(VII), which is purple in colour, was placed in a visible spectrometer.

In the box below, sketch the visible spectrum you would expect to see.



[1]

[Total: 12]

2 Brass is a widely used alloy of copper. It is possible to analyse a sample of brass by initially dissolving it in concentrated nitric acid.

(a) **(i)** What other metal is present in brass?

..... [1]

(ii) Give **one** common use for brass and state the property of brass which makes it ideal for that purpose.

.....

..... [1]

(b) During the analysis of brass, 1.65 g of the alloy was reacted with concentrated nitric acid. The resulting solution was neutralised, transferred to a volumetric flask and made up to 250 cm^3 using distilled water.

An excess of aqueous potassium iodide was added to a 25.0 cm^3 portion of the solution from the volumetric flask and the liberated iodine was titrated with 0.100 mol dm^{-3} sodium thiosulphate. 20.0 cm^3 of aqueous sodium thiosulphate were required to remove the iodine.

(i) What could be used to neutralise the excess nitric acid?

..... [1]

(ii) What indicator is used in the titration of iodine with sodium thiosulphate?

..... [1]

(iii) When is this indicator added to the titration mixture?

..... [1]

(c) The reactions taking place in this titration may be summarised as follows.

$$2Cu^{2+} + 4I^- \longrightarrow 2CuI + I_2$$

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

(i) Calculate the amount, in moles, of sodium thiosulphate in 20.0 cm^3 of solution.

answer ..... mol [1]

(ii) For every one mole of Cu^{2+} ions present in solution, deduce the amount, in moles, of $S_2O_3^{2-}$ ions needed for the titration.

answer ..... mol [1]

(iii) What is the amount, in moles, of Cu^{2+} ions present in 25.00 cm^3 of solution?

answer ..... mol [1]

(iv) Calculate the percentage by mass of copper in the sample of brass.

answer ..... % Cu [3]

[Total: 11]

3 The Co^{2+} ion can form complexes with two different co-ordination numbers.

(a) What is meant by the *co-ordination number* of a complex ion?

.....

..... [1]

(b) The following equilibrium is readily established.

$$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$$

(i) In the boxes below, draw the shape of each complex ion.

$[Co(H_2O)_6]^{2+}$	$[CoCl_4]^{2-}$

[2]

(ii) What colour change would you expect to see when an excess of Cl^- is added to $[Co(H_2O)_6]^{2+}$?

from ..... to ..... [2]

(iii) Describe how you would move the position of this equilibrium to the left.

..... [1]

(c) Cobalt also forms complex ions with an oxidation state of +3. The following standard electrode potentials refer to cobalt(III) complexes.

$$[Co(H_2O)_6]^{3+} + e^- \rightleftharpoons [Co(H_2O)_6]^{2+} \qquad E^{\ominus} = +1.82\,V$$

$$[Co(NH_3)_6]^{3+} + e^- \rightleftharpoons [Co(NH_3)_6]^{2+} \qquad E^{\ominus} = +0.11\,V$$

Which of the four complexes above is the strongest reducing agent? Explain your answer.

.....

.....

.....

..... [3]

(d) Why does ammonia form a more stable cobalt(III) complex than water?

.....

..... [1]

[Total: 10]

For Examiner's Use

4 In this question, one mark is available for the quality of use and organisation of scientific terms.

(a) Stereoisomerism is very common in transition metal complexes. Some complexes have found an important use in the treatment of cancer.

(i) Name a transition metal complex used in the treatment of cancer.

..... [1]

(ii) Describe how this complex helps in the treatment of cancer.

.....

.....

..... [2]

(b) Describe the types of stereoisomerism found in transition metal complexes.

Use suitable examples to illustrate your answer.

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[8]
QWC=[1]
=[9]

For Examiner's Use

Answer **all** the questions.

1 This question looks at **two** different experiments that investigate rates of reaction.

(a) The decomposition of dinitrogen pentoxide, N_2O_5, at 45 °C was investigated. The reaction that takes place is shown below.

$$2N_2O_5 \longrightarrow 4NO_2 + O_2$$

In an experiment, N_2O_5 with a concentration of 0.60 mol dm^{-3} was decomposed at 45 °C.

At this temperature, the reaction has a constant half-life of 1200 s.

(i) How can you tell that this reaction is first order with respect to N_2O_5?

.....

.....[1]

(ii) Write down an expression for the rate equation of this decomposition.

.....[1]

(iii) Complete the graph opposite to show how the $[N_2O_5]$ changes over the first 3600 s of the reaction. [2]

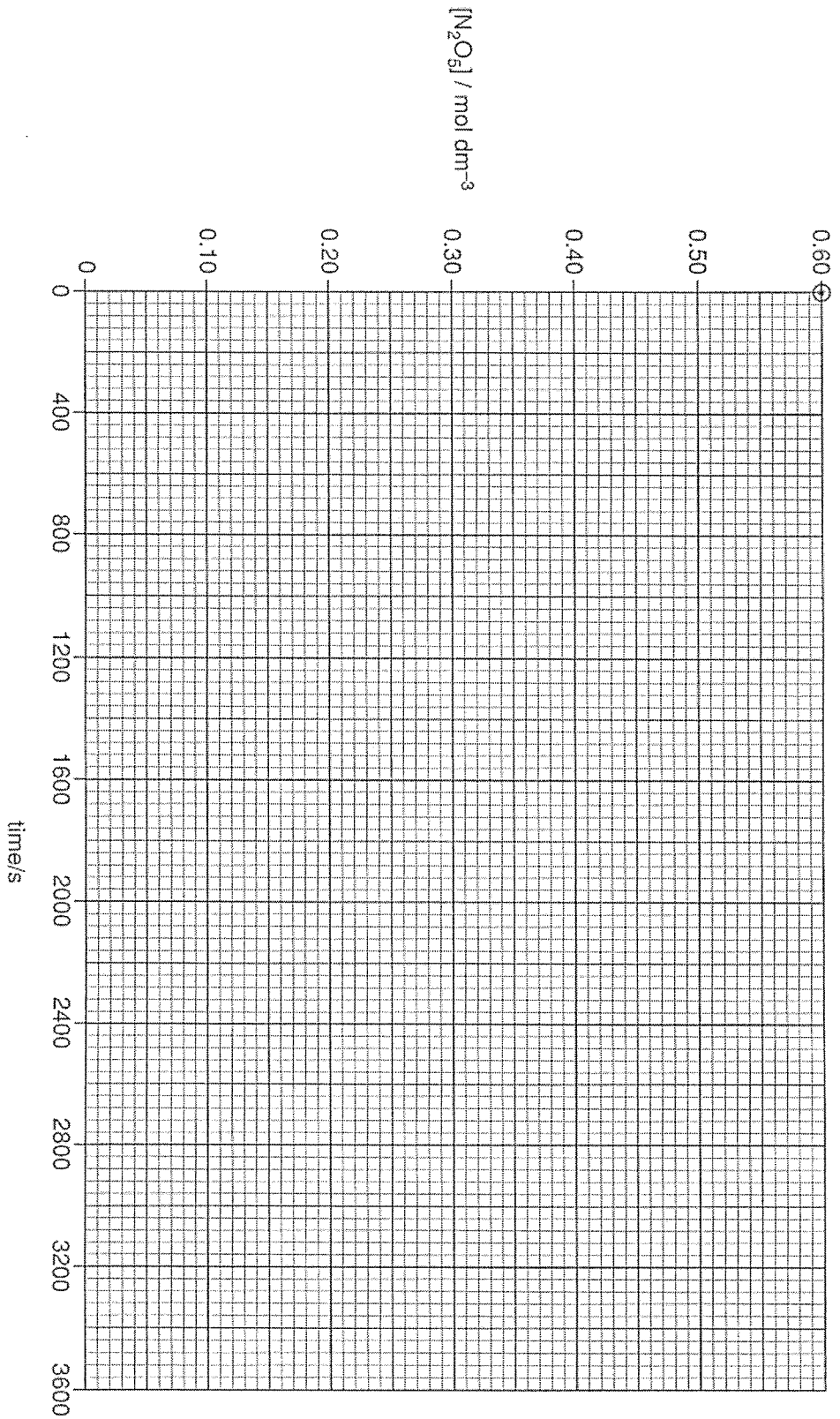
(iv) The rate of this reaction can be determined from this graph.

Show on the graph how the rate can be measured after 1200 s. [1]

(v) The rate can also be calculated from the rate equation. The rate constant for this reaction is $6.2 \times 10^{-4}\ s^{-1}$.

Calculate the initial rate of this reaction. State the units.

rate =..... units..... [2]


[N2O5] / mol dm−3
0
0.10
0.20
0.30
0.40
0.50
0.60
time/s
0
400
800
1200
1600
2000
2400
2800
3200
3600

For Examiner's Use

(b) A student investigated the hydration of 2-methylpropene, $(CH_3)_2C{=}CH_2$, with dilute aqueous acid to form 2-methylpropan-2-ol, $(CH_3)_3COH$.

The following mechanism has been proposed for this hydration.

step 1 $(CH_3)_2C{=}CH_2 + H^+(aq) \longrightarrow (CH_3)_3C^+$ rate determining step

step 2 $(CH_3)_3C^+ + H_2O \longrightarrow (CH_3)_3COH + H^+(aq)$

(i) Step 1 is the rate-determining step for this hydration.

What is meant by the term *rate-determining step*?

.....

.....[1]

(ii) Write a balanced equation for the overall hydration reaction.

.....[1]

(iii) Suggest the role of $H^+(aq)$ in this mechanism. Explain your reason.

.....

.....

.....[2]

(iv) Use the mechanism above to suggest the rate equation for this hydration.

.....[1]

[Total: 12]

[Turn over

2 Methanol, $CH_3OH(g)$, is manufactured from carbon monoxide and hydrogen in an equilibrium reaction.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\ kJ\ mol^{-1}$$

(a) In this question, one mark is available for the quality of use and organisation of scientific terms.

Explain the advantages and disadvantages of running this reaction

- at a high pressure,
- at a high temperature.

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.....[5]

Quality of Written Communication [1]

(b) This equilibrium reaction is normally carried out at 10 MPa pressure and 550 K, and starting with a 1 : 2 CO : H_2 mixture. At equilibrium, only 10% of the CO has reacted.

(i) Deduce the equilibrium amounts, mole fractions and partial pressures of CO, H_2 and CH_3OH present at equilibrium. Write your answers in the table below.

Assume that you have started with a mixture of 1.0 mol CO and 2.0 mol H_2.

	CO	H_2	CH_3OH
initial amount /mol	1.0	2.0	0.0
equilibrium amount /mol	0.9		
mole fraction at equilibrium			
partial pressure at equilibrium /MPa			

[4]

3 A student carried out an investigation with aqueous solutions of nitric acid, sodium hydroxide, ethanoic acid and water.

(a) Nitric acid, HNO_3, is a strong Brønsted-Lowry acid.

(i) Explain what is meant by a *strong acid* and a *Brønsted-Lowry acid*.

.....

.....

.....[2]

(ii) What is the conjugate base formed from HNO_3?

.....[1]

(b) The student diluted 0.015 mol dm^{-3} nitric acid with an equal volume of water and measured the pH of the diluted acid at 25 °C.

(i) Calculate the pH of 0.015 mol dm^{-3} nitric acid.

[2]

(ii) Calculate the pH of the diluted acid.

[1]

(c) The student measured the pH of a solution of sodium hydroxide as 13.54 at 25 °C.

$K_w = 1.0 \times 10^{-14}$ $mol^2 dm^{-6}$ at 25 °C.

(i) Write down an expression for the ionic product, K_w, for water.

.....[1]

(ii) Calculate the concentration, in mol dm^{-3}, of this solution of sodium hydroxide.

[2]

(d) The student prepared two solutions.

- Solution **A** was made by mixing together 25 cm^3 0.010 mol dm^{-3} aqueous sodium hydroxide with 50 cm^3 0.010 mol dm^{-3} ethanoic acid, CH_3COOH. Solution **A** is a buffer solution.

- Solution **B** was made by mixing together 25 cm^3 0.020 mol dm^{-3} aqueous sodium hydroxide with 50 cm^3 0.010 mol dm^{-3} ethanoic acid, CH_3COOH. Solution **B** is **not** a buffer solution.

(i) What is meant by a *buffer solution*?

.....

.....[1]

(ii) Explain why Solution **A** is a buffer solution whereas Solution **B** is **not**.

.....

.....

.....

.....

.....

.....

.....[4]

(e) The student measured the pH of water as 7.0 at 25 °C. The student then warmed the water to 40 °C and measured the pH as 6.7.

What do these results tell you about the tendency of water to ionise as it gets warmer? Explain your reasoning in terms of equilibrium.

.....

.....

.....

.....[2]

[Total: 16]

4 *In your answers to the questions that follow, show all of your working.*

At room temperature and pressure, r.t.p., 1 mol of gas molecules has a volume of 24 dm^3.

Whilst digging his garden, a chemistry student found what appeared to be a piece of bronze, possibly from the Bronze Age. The student knew that bronze was an alloy of copper with other metals including tin. He carried out three experiments on samples of the bronze.

(a) **Experiment 1**

He dissolved a small piece of the bronze, weighing 0.28 g, in concentrated (16 mol dm^{-3}) nitric acid, HNO_3. 5 cm^3 of a blue solution **C** containing Cu^{2+} ions was formed together with a brown gas with the molecular formula NO_2.

Equation **4.1** represents the equation for the reaction between copper and concentrated nitric acid.

$$Cu + 4H^+ + 2NO_3^- \longrightarrow Cu^{2+} + 2NO_2 + 2H_2O \qquad \text{equation 4.1}$$

The student analysed the blue colour from the Cu^{2+} ions in solution **C** using a colorimeter. He found out that the concentration of Cu^{2+} ions in solution **C** was 0.68 mol dm^{-3}.

The student concentrated the solution and obtained some blue crystals of a compound **A** with a percentage composition by mass of Cu, 26.29%; N, 11.60%; O, 59.63%; H, 2.48%. This composition included 3 waters of crystallisation.

- Calculate the percentage of copper in the bronze relic. [3]
- Calculate the empirical formula of **A**. [2]
- How would the formula of **A** normally be shown on a bottle of the chemical? [2]

(b) **Experiment 2**

The student dissolved another small piece of the bronze relic in dilute (8 mol dm^{-3}) nitric acid. A blue solution containing Cu^{2+} ions was again formed but this time a colourless gas was produced with the molecular formula NO.

Equation **4.2** represents the **unbalanced** equation for this second reaction.

$$Cu + H^+ + NO_3^- \longrightarrow Cu^{2+} + NO + H_2O \qquad \text{equation 4.2}$$

- By considering oxidation numbers, balance equation **4.2**. [3]

(c) **Experiment 3**

The student heated a third small piece of the bronze relic with concentrated sulphuric acid. The copper in the bronze relic reacted to produce a blue solution and 90 cm^3 of a gas **B**, measured at r.t.p.. The mass of the gas **B** collected was 0.24 g.

- Suggest a possible identity of gas **B**.
- Suggest a likely balanced equation for this reaction. [4]

[Total: 14]

END OF QUESTION PAPER