RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY — 2815/01

Trends and Patterns

Tuesday **24 JUNE 2003** 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	18	
2	15	
3	12	
TOTAL	**45**	

This question paper consists of 10 printed pages and 2 blank pages.

BLANK PAGE

Answer **all** the questions.

1 Calcium carbonate thermally decomposes into calcium oxide and carbon dioxide as shown in the equation.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

(a) Show that the thermal decomposition of calcium carbonate is **not** a redox reaction. Use oxidation states in your answer.

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.... [2]

(b) Magnesium carbonate also thermally decomposes. Describe and explain the difference in the ease of thermal decomposition between magnesium carbonate and calcium carbonate. Use ideas about charge density and polarisation in your answer.

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....[3]

(c) Calculate the enthalpy change of reaction, ΔH_r, for the thermal decomposition of calcium carbonate using the enthalpy changes of formation given in the table.

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
$CaCO_3(s)$	–1207
$CaO(s)$	–635
$CO_2(g)$	–393

answer .... kJ mol^{-1} [2]

(d) The lattice enthalpy of magnesium oxide is –3916 kJ mol^{-1}.

Explain, with the aid of a suitable equation, what is meant by the statement the 'lattice enthalpy of magnesium oxide is –3916 kJ mol^{-1}'.

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.... [3]

(e) The table below shows the enthalpy changes needed to calculate the lattice enthalpy of magnesium oxide.

process	equation	enthalpy change / kJ mol^{-1}
first ionisation energy of magnesium	$Mg(g) \rightarrow Mg^+(g) + e^-$	+735
second ionisation energy of magnesium	$Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$	+1445
first electron affinity of oxygen	$O(g) + e^- \rightarrow O^-(g)$	–141
second electron affinity of oxygen	$O^-(g) + e^- \rightarrow O^{2-}(g)$	+878
enthalpy change of formation for magnesium oxide	$Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$	–602
enthalpy change of atomisation for magnesium	$Mg(s) \rightarrow Mg(g)$	+150
....	$\frac{1}{2}O_2(g) \rightarrow O(g)$	+247

(i) Complete the table by writing in the missing process. [1]

(ii) Explain why the second ionisation energy of magnesium is **more endothermic** than the first ionisation energy.

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....[2]

(iii) Draw a labelled Born-Haber cycle using the information in the table. Show, by calculation, that the lattice enthalpy of magnesium oxide is –3916 kJ mol^{-1}.

[4]

(f) State **one** use for magnesium oxide that relies on its high lattice enthalpy.

.... [1]

[Total: 18]

For Examiner's Use

2 Aqueous copper(II) sulphate reacts with an excess of aqueous ammonia to give a dark blue solution. The solution contains the octahedral complex ion, $[Cu(NH_3)_x(H_2O)_y]^{2+}$.

The formula of this complex ion can be determined using colorimetry.

- A student makes up six different mixtures of 1.00 mol dm^{-3} aqueous ammonia and 0.500 mol dm^{-3} aqueous copper(II) sulphate and water.
- She filters the mixtures to remove any precipitate that forms.
- The filtrate is a dark blue solution that contains the complex ion, $[Cu(NH_3)_x(H_2O)_y]^{2+}$.
- The student places the blue solution into a colorimeter and measures the absorbance of the solution.

The table below shows the relative absorbance of each mixture.

mixture	one	two	three	four	five	six
volume of 0.500 mol dm^{-3} $CuSO_4(aq)$ / cm^3	5.00	5.00	5.00	5.00	5.00	5.00
volume of 1.00 mol dm^{-3} $NH_3(aq)$ / cm^3	3.00	6.00	9.00	11.00	15.00	18.00
volume of $H_2O(l)$ / cm^3	17.00	14.00	11.00	9.00	5.00	2.00
relative absorbance	0.29	0.57	0.86	0.95	0.94	0.95

(a) Copper is a transition element. One typical property of a transition element is that it forms coloured complex ions.

State **two** other typical properties of a transition element.

1. ....

2. .... [2]

(b) The precipitate formed when the student makes some of the mixtures is copper(II) hydroxide.

(i) Write an ionic equation to show the formation of copper(II) hydroxide from its ions.

.... [1]

(ii) If this precipitate is **not** removed, an inaccurate absorbance reading is obtained. Suggest why.

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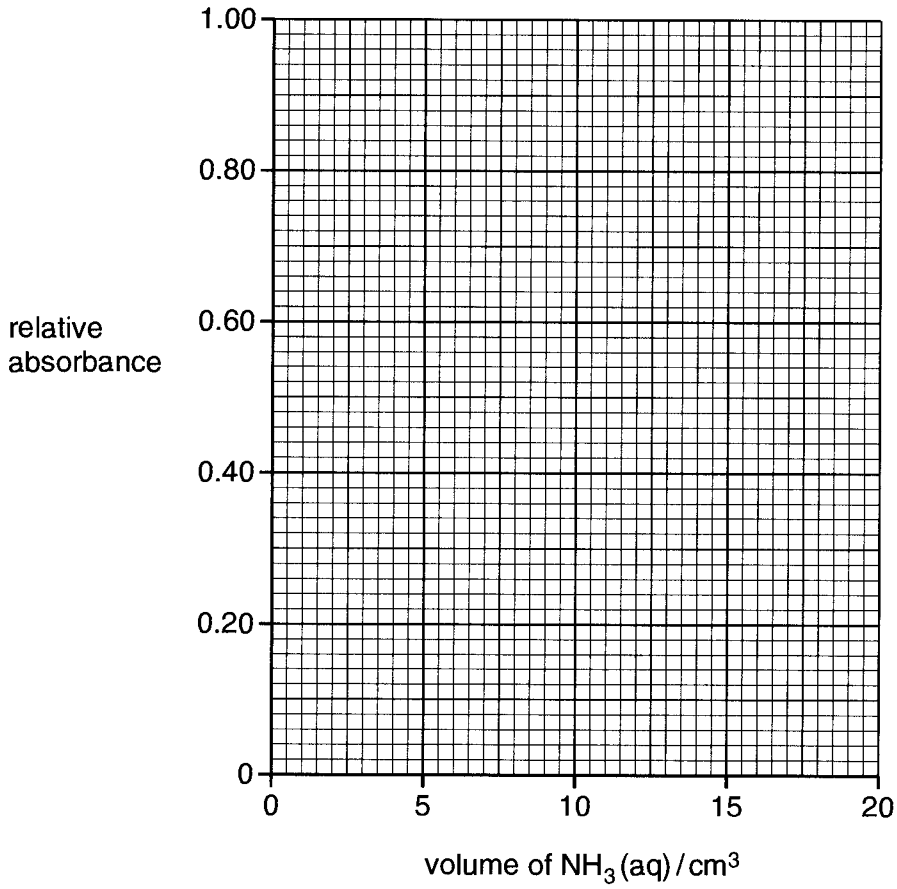
.... [1]

(c) Draw a graph of the relative absorbance against the volume of aqueous ammonia using the grid below.



[2]

(d) **(i)** How many moles of copper(II) sulphate are there in 5.00 cm^3 of a 0.500 mol dm^{-3} solution?

answer .... mol [1]

(ii) Use the graph to estimate the **smallest** volume of 1.00 mol dm^{-3} aqueous ammonia that gives the maximum relative absorbance.

answer .... cm^3 [1]

(iii) How many moles of ammonia are there in the volume in **(ii)**?

answer .... mol [1]

(iv) Deduce the values **x** and **y** in the formula of the octahedral complex ion, $[Cu(NH_3)_x(H_2O)_y]^{2+}$.

....

....[1]

For Examiner's Use

(e) In the octahedral complex, $[Cu(NH_3)_x(H_2O)_y]^{2+}$, ammonia is a ligand.

(i) Explain why ammonia can behave as a ligand.

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.... [1]

(ii) The bond angle around the nitrogen atom in an ammonia molecule is 107° but it is 109.5° in the octahedral complex. Explain why the bond angles differ.

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.... [2]

(f) Aqueous copper(II) ions react with concentrated hydrochloric acid to give a yellow solution of $[CuCl_4]^{2-}$(aq). This reaction is an example of ligand substitution.

(i) Write an equation to show the formation of $[CuCl_4]^{2-}$(aq).

[1]

(ii) Draw the shape of the $[CuCl_4]^{2-}$ ion.

[1]

[Total: 15]

For Examiner's Use

3 In this question, one mark is available for the quality of written communication.

We use our understanding of structure and bonding to explain physical and chemical properties of substances. Discuss this statement using examples taken from the oxides of the elements from Period 3 such as MgO, Al_2O_3 and SO_2.

Refer in your answer to
- physical properties such as electrical conductivity and melting point,
- chemical properties such as reaction with water.

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2815/01 Trends and Patterns

June 2003

Mark Scheme

The following annotations may be used when marking:

X	=	incorrect response (errors may also be underlined)
^	=	omission mark
bod	=	benefit of the doubt (where professional judgement has been used)
ecf	=	error carried forward (in consequential marking)
con	=	contradiction (in cases where candidates contradict themselves in the same response)
sf	=	error in the number of significant figures

Abbreviations, annotations and conventions used in the Mark Scheme:

/	=	alternative and acceptable answers for the same marking point
;	=	separates marking points
NOT	=	answers not worthy of credit
( )	=	words which are not essential to gain credit
___ (underlining)	=	key words which must be used
ecf	=	allow error carried forward in consequential marking
AW	=	alternative wording
ora	=	or reverse argument

Question		Expected answers	Marks
1 (a)		Correct oxidation states for **each** atom i.e. Ca = +2, C = +4 and O = -2 (1); Oxidation numbers do not change during the reaction / no electron transfer during reaction (1)	2
(b)		$MgCO_3$ decomposition easier than $CaCO_3$ / higher decomposition temperature with $CaCO_3$ / ora (1); Mg^{2+} higher charge density than Ca^{2+} / both have the same charge but Mg^{2+} has a smaller ionic radius (1); So Mg^{2+} will polarise CO_3^{2-} more than Ca^{2+} can / more distortion of the CO_3^{2-} electron cloud by Mg^{2+} (1)	3
(c)		$\Delta H =$ +1207 +(-635) + (-393) / correct energy cycle drawn / ΔH_fproduct – ΔH_f reactants (1); $\Delta H =$ +179 (kJ mol^{-1})(1)	2
(d)		Mg^{2+} + O^{2-} → MgO (1); (3916 kJ of) energy is released (1); when one mole of **solid** magnesium oxide is made from its constituent **gaseous** ions (1)	3
(e)	(i)	Enthalpy change of atomisation (of oxygen) (1)	1
	(ii)	**Any two from** Mg^{+} has one more proton than electrons / same number of protons but one fewer electron (1); Electron is lost from a particle that carries an overall positive charge (rather than being neutral) (1); So (outer) electron more firmly attracted to the nucleus (1)	2
	(iii)	Correct energy level diagram labelled with correct formulae / correct cycle labelled with correct formulae (1); **Any two from** Correct state symbols (1); Correct energy values shown in the Born-Haber cycle (1) Correct labels for the enthalpy changes (1) **And** Lattice enthalpy = -735 +(-1445) + (-150) + (-878) + 141 + (-247) + (-602) (1)	4
(f)		Furnace lining / aw (1)	1
			Total = 18

Question			Expected answers	Marks
2	(a)		Have variable oxidation states / aw (1); (Elements or compounds are) often catalysts (1)	2
	(b)	(i)	$Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s)$ / $[Cu(H_2O)_6]^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s) + 6H_2O(l)$ / $[Cu(H_2O)_6]^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(H_2O)_4(s) + 2H_2O(l)$	1
	(b)	(ii)	Colorimeter needs a clear solution / precipitate will interfere with the passage of light / precipitate may absorb light / colorimeter has been set up to measure the concentration of just the complex ion (1)	1
	(c)		Points plotted correctly (1); Two **straight** lines of best fit that intersect (1)	2
	(d)	(i)	0.0025 (1)	1
		(ii)	10 (cm^3)	1
		(iii)	Answer to part (ii) x 10^{-3} / 0.010 (1)	1
		(iv)	x = 4 and y = 2 (1)	1
	(e)	(i)	Has a lone pair / it is an electron pair donor (1)	1
		(ii)	Lone pair in the ammonia ligand is more like a bond (pair) / ammonia ligand has four bond (pairs) (1); So equal repulsion between all four electron pairs or bonds with the ligand / extra repulsion due to presence of lone-pair in ammonia / aw (1)	2
	(f)	(i)	$[Cu(H_2O)_6]^{2+} + 4Cl^{-} \rightarrow [CuCl_4]^{2-} + 6H_2O$ / $[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 6H_2O + 4H^{+}$ / $Cu^{2+} + 4HCl \rightarrow CuCl_4^{2-} + 4H^{+}$	1
		(ii)	Tetrahedral shape with either wedges or correct bond angles / square planar shape (1)	1
				Total = 15

Question	Expected answers	Marks
3	**Any eleven from** **Sodium oxide / magnesium oxide** Magnesium oxide has a (giant) ionic structure (1); (so it has a) high melting point (1); (because there is a) strong interaction between the positive ions and the negative ions / because there is a strong electrostatic attraction between ions (1); **Aluminium oxide** Aluminium oxide has ionic bonding with a high degree of covalent character / polar covalent bonding / intermediate bonding (1); It has a giant structure (1); (So it has a) high melting point (1); **Sodium oxide / magnesium oxide / aluminium oxide** Do not conduct electricity as a solid since its ions are not free to move (1); But will conduct electricity as a molten liquid because the ions are free to move (1); **Silicon dioxide** Giant molecular / giant covalent (1); High melting point (1); (because) it has many strong covalent bonds / aw (1); Does not conduct electricity (1) (because there are) no free electrons / all electrons localised in covalent bonds (1); **Sulphur dioxide / sulphur trioxide** Sulphur dioxide has a simple molecular structure / simple covalent (1); (so it has a) low melting point (1); (because) molecules are held together by weak intermolecular forces / van der Waals forces (1); Sulphur dioxide does not conduct electricity (1); (because there are) no free electrons / all electrons localised in covalent bonds (1);	12

Question	Expected answers	Marks
3	**Reaction with water** Magnesium oxide is basic / magnesium oxide reacts with water to form an alkaline solution / magnesium oxide is slightly soluble in water giving a basic solution (1); (because) oxide ions react with water to give hydroxide ions / O^{2-} + H_2O → $2OH^-$ / MgO + H_2O → $Mg(OH)_2$(1); Aluminium oxide is amphoteric / aluminium oxide does not react / does not dissolve in water (1); (because the) lattice enthalpy is too high /aw (1); Silicon dioxide does not dissolve in water (1); Silicon dioxide is an acidic oxide (1); Sulphur dioxide is an acidic oxide / sulphur dioxide reacts with water to form an acidic solution (1); SO_2 + H_2O → H_2SO_3 (1); (Since) covalent oxides are acidic oxides (1) **And** QWC – award one mark if the question has been addressed with no significant omissions and the candidate has illustrated answers with correct and appropriate scientific terms (1)	
		Total = 12