An Introduction to the Chemistry of the Transition Elements

Question Paper 1

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	An Introduction to the Chemistry of the Transition Elements
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 1

Time Allowed: **66 minutes**

Score: **/55**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1 The commonest form of iron(II) sulfate is the heptahydrate, $FeSO_4.7H_2O$. On heating at 90 °C this loses **some** of its water of crystallisation to form a different hydrated form of iron(II) sulfate, $FeSO_4.xH_2O$.

3.40 g of $FeSO_4.xH_2O$ was dissolved in water to form 250 cm^3 of solution.

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.0200 mol dm^{-3} potassium manganate(VII).

In this titration 20.0 cm^3 of this potassium manganate(VII) solution was required to react fully with the Fe^{2+} ions present in the sample.

(a) The MnO_4^- ions in the potassium manganate(VII) *oxidise* the Fe^{2+} ions in the acidified solution.

(i) Explain, in terms of electron transfer, the meaning of the term *oxidise* in the sentence above.

....

.... [1]

(ii) Complete and balance the ionic equation for the reaction between the manganate(VII) ions and the iron(II) ions.

$MnO_4^-(aq)$ + $5Fe^{2+}(aq)$ + ...$H^+(aq)$ → ....(aq) + $5Fe^{3+}(aq)$ + ...$H_2O(l)$

[3]

(b) Calculate the number of moles of manganate(VII) used in the titration.

[1]

(ii) Use the equation in **(a)(ii)** and your answer to **(b)(i)** to calculate the number of moles of Fe^{2+} present in the 25.0 cm^3 sample of solution used.

[1]

(iii) Calculate the number of moles of $FeSO_4.xH_2O$ in 3.40 g of the compound.

[1]

(iv) Calculate the relative formula mass of $FeSO_4.xH_2O$.

[1]

(v) The relative formula mass of anhydrous iron(II) sulfate, $FeSO_4$, is 151.8.

Calculate the value of *x* in $FeSO_4.xH_2O$.

[1]

[Total: 9]

2 A 6.30 g sample of hydrated ethanedioic acid, $H_2C_2O_4.xH_2O$, was dissolved in water and the solution made up to 250 cm^3.

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.100 mol dm^{-3} potassium manganate(VII) solution. 20.0 cm^3 of this potassium manganate(VII) solution was required to react fully with the ethanedioate ions, $C_2O_4^{2-}$, present in the sample.

(a) The MnO_4^- ions in the potassium manganate(VII) *oxidise* the ethanedioate ions.

(i) Explain, in terms of electron transfer, the meaning of the term *oxidise* in the sentence above.

....

.... [1]

(ii) Complete and balance the ionic equation for the reaction between the manganate(VII) ions and the ethanedioate ions.

$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) +$ ....$H^+(aq) \rightarrow$ ....$(aq) + 10CO_2(aq) +$ ....$H_2O(l)$

[3]

(b) Calculate the number of moles of manganate(VII) used in the titration.

[1]

(ii) Use the equation in **(a)(ii)** and your answer to **(b)(i)** to calculate the number of moles of $C_2O_4^{2-}$ present in the 25.0 cm^3 sample of solution used.

[1]

(iii) Calculate the number of moles of $H_2C_2O_4.xH_2O$ in 6.30 g of the compound.

[1]

(iv) Calculate the relative formula mass of $H_2C_2O_4.xH_2O$.

[1]

(v) The relative formula mass of anhydrous ethanedioic acid, $H_2C_2O_4$, is 90.

Calculate the value of x in $H_2C_2O_4.xH_2O$.

[1]

[Total: 9]

3 A sample of a hydrated double salt, $Cu(NH_4)_x(SO_4)_2.6H_2O$, was boiled with an excess of sodium hydroxide. Ammonia was given off.

The ammonia produced was absorbed in 40.0 cm^3 of 0.400 mol dm^{-3} hydrochloric acid. The resulting solution required 25 cm^3 of 0.12 mol dm^{-3} sodium hydroxide to neutralise the excess acid.

(a) Write the ionic equation for the reaction between ammonium ions and hydroxide ions.

.... [1]

(b) **(i)** Calculate the amount, in moles, of hydrochloric acid in 40.0 cm^3 of 0.400 mol dm^{-3} solution.

[1]

(ii) Calculate the amount, in moles, of sodium hydroxide needed to neutralise the excess acid. This will be equal to the amount of hydrochloric acid left in excess.

[1]

(iii) Calculate the amount, in moles, of hydrochloric acid that reacted with ammonia.

[1]

(iv) Calculate the amount, in moles, of ammonium ions in the sample of the double salt.

[1]

(v) The sample contained 0.413 g of copper. Use this information and your answer to **(iv)** to calculate the value of *x* in $Cu(NH_4)_x(SO_4)_2.6H_2O$.

[2]

(vi) Calculate the M_r of $Cu(NH_4)_x(SO_4)_2.6H_2O$.

[1]

[Total: 8]

4 The ions of transition elements form *complexes* by reacting with *ligands*.

(a) State what is meant by the terms:

complex, ...

....

ligand. ....

....

(ii) Two of the complexes formed by copper are $[Cu(H_2O)_6]^{2+}$ and $CuCl_4^{2-}$.
Draw three-dimensional diagrams of their structures in the boxes and name their shapes.

$[Cu(H_2O)_6]^{2+}$	$CuCl_4^{2-}$
shape:	shape: ....

(iii) Platinum forms square-planar complexes, in which all four ligands lie in the same plane as the Pt atom.
There are two isomeric complexes with the formula $Pt(NH_3)_2Cl_2$.
Suggest the structures of the two isomers, and, by comparison with a similar type of isomerism in organic chemistry, suggest the type of isomerism shown here.

Structures of isomers:

isomer 1	isomer 2

Type of isomerism: ....

[7]

(b) Copper forms two series of compounds, one containing copper(II) ions and the other containing copper(I) ions.

(i) Complete the electronic structures of these ions.

Cu(II) [Ar] ....

Cu(I) [Ar] ....

(ii) Use these electronic structures to explain why

copper(II) salts are usually coloured,

....

....

....

....

copper(I) salts are usually white or colourless.

....

....

[5]

(c) Copper(I) oxide and copper(II) oxide can both be used in the ceramic industry to give blue, green or red tints to glasses, glazes and enamels.

The table lists the $\Delta H_f^\ominus$ values for some compounds.

compound	$\Delta H_f^\ominus$ / kJ mol^{-1}
$Cu_2O(s)$	–168.6
$CuO(s)$	–157.3
$Cu(NO_3)_2(s)$	–302.9
$NO_2(g)$	+33.2

(i) Copper(II) oxide can be produced in a pure form by heating copper(II) nitrate. Use suitable $\Delta H_f^\ominus$ values from the table to calculate the $\Delta H^\ominus$ for this reaction.

$$Cu(NO_3)_2(s) \rightarrow CuO(s) + 2NO_2(g) + \tfrac{1}{2}O_2(g)$$

$\Delta H^\ominus$ = ... kJ mol^{-1}

(ii) Copper(I) oxide can be produced from copper(II) oxide.

- Use suitable $\Delta H_f^\ominus$ values from the table to calculate $\Delta H^\ominus$ for the reaction.

$$2CuO(s) \rightleftharpoons Cu_2O(s) + \tfrac{1}{2}O_2(g)$$

$\Delta H^\ominus$ = ... kJ mol^{-1}

- Hence suggest whether a low or a high temperature of oxidation would favour the production of copper(I) oxide. Explain your reasoning.

....

....

[4]

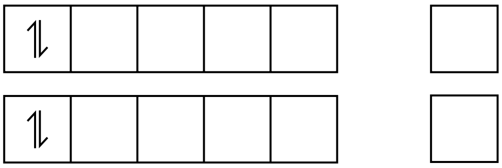
[Total: 16]

5 (a) Complete the electron configurations for Ni and Ni^{2+}.

3d 4s

Ni [Ar]

Ni^{2+} [Ar]



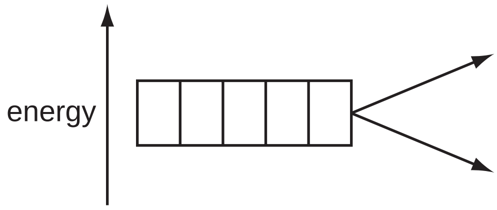
[2]

(b) The presence of electrons in d orbitals is responsible for the colours of transition element compounds.

(i) The d orbitals in an isolated transition metal atom or ion are all at the same energy level. What term is used to describe orbitals that are at the same energy level?

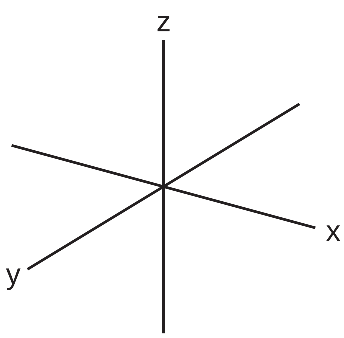
....

(ii) Complete the diagram to show the splitting of the d orbital energy levels in an octahedral complex ion.

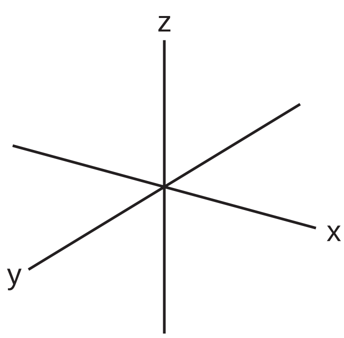


(iii) On the axes below, sketch the shapes of one d orbital from the lower energy level and one d orbital from the higher energy level.

lower energy level



higher energy level



[4]

(c) The octahedral complex $[Ni(H_2O)_6]^{2+}$ is green. Explain the origin of the colour of this complex.

....

....

....

....

.... [3]

(d) When NH_3(aq) is added to the green solution containing $[Ni(H_2O)_6]^{2+}$, a grey-green precipitate, **A**, is formed. This precipitate dissolves in an excess of NH_3(aq) to give a blue-violet solution, **B**. Suggest formulae for **A** and **B** and write equations for the two reactions producing **A** and **B**.

....

....

....

.... [4]

[Total: 13]