An Introduction to the Chemistry of the Transition Elements

Question Paper 3

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 3

Time Allowed:	**59 minutes**
Score:	**/49**
Percentage:	**/100**

Grade Boundaries:

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

1 (a) (i) What is meant by the *density* of a substance?

.....

(ii) Use data from the *Data Booklet* to explain why the density of iron is greater than that of calcium.

.....

.....

.....

[3]

(b) In general, reactions of the compounds of transition elements can be classified under one or more of the following headings.

acid-base
ligand exchange
precipitation
redox

Choose the most suitable heading to describe each of the following reactions, by placing a tick (✓) in the appropriate column in the table below.
Only one tick should be placed against each reaction.

reaction	acid-base	ligand exchange	precipitation	redox
$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+} + 6H_2O$				
$[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 4H^+ + 6H_2O$				
$2FeCl_2 + Cl_2 \rightarrow 2FeCl_3$				
$[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$				
$2Fe(OH)_2 + ½O_2 + H_2O \rightarrow 2Fe(OH)_3$				
$CrO_3 + 2HCl \rightarrow CrO_2Cl_2 + H_2O$				
$Cr(H_2O)_3(OH)_3 + OH^- \rightarrow [Cr(H_2O)_2(OH)_4]^- + H_2O$				
$[Cr(OH)_4]^- + 1½H_2O_2 + OH^- \rightarrow CrO_4^{2-} + 4H_2O$				

[8]

(c) Alloys of aluminium, titanium and vanadium are used in aerospace and marine equipment, and in medicine.

When a powdered sample of one such alloy is heated with an excess of aqueous NaOH, only the aluminium reacts, according to the following equation.

$$2Al(s) + 2OH^-(aq) + 6H_2O(l) \rightarrow 2[Al(OH)_4]^-(aq) + 3H_2(g)$$

Reacting 100 g of alloy in this way produced 8.0 dm^3 of hydrogen, measured under room conditions.

Calculate the percentage by mass of aluminium in the alloy.

percentage = ... %
[3]

[Total: 14]

2 **(a)** **(i)** Suggest why transition elements show variable oxidation states in their compounds whereas s-block elements like calcium do not.

.....

.....

(ii) Calculate the oxidation number of the metal in each of the following ions.

VO_2^+ .....

CrF_6^{2-} .....

MnO_4^{2-} .....

[4]

(b) Explain why transition element complexes are often coloured whereas compounds of s-block elements such as calcium and sodium are not.

.....

.....

.....

.....

.....

.....

[4]

(c) SO_2 and MnO_4^- react together in acidic solution.

(i) Use the *Data Booklet* to construct a balanced equation for this reaction.

.....

(ii) Describe the colour change you would see when SO_2(aq) is added to a sample of acidified $KMnO_4$ until the SO_2 is in excess.

from ..... to .....

[3]

(d) Describe the observations you would make when NH_3(aq) is added gradually to a solution containing Cu^{2+} ions, until the NH_3 is in an excess.

.....

.....

.....

.....

[3]

[Total: 14]

3 Washing soda is hydrated sodium carbonate, $Na_2CO_3.xH_2O$.

A student wished to determine the value of x by carrying out a titration, with the following results.

> 5.13 g of washing soda crystals were dissolved in water and the solution was made up to 250 cm^3 in a standard volumetric flask.
>
> 25.0 cm^3 of this solution reacted exactly with 35.8 cm^3 of 0.100 mol dm^{-3} hydrochloric acid and carbon dioxide was produced.

(a) Write a balanced equation for the reaction between Na_2CO_3 and HCl.

.....

(ii) Calculate the amount, in moles, of HCl in the 35.8 cm^3 of solution used in the titration.

(iii) Use your answers to **(i)** and **(ii)** to calculate the amount, in moles, of Na_2CO_3 in the 25.0 cm^3 of solution used in the titration.

(iv) Use your answer to **(iii)** to calculate the amount, in moles, of Na_2CO_3 in the 250 cm^3 of solution in the standard volumetric flask.

(v) Hence calculate the mass of Na_2CO_3 present in 5.13 g of washing soda crystals.

[6]

(b) Use your calculations in **(a)** to determine the value of x in $Na_2CO_3.xH_2O$.

[2]

[Total: 8]

4 Zinc is an essential trace element which is necessary for the healthy growth of animals and plants. Zinc deficiency in humans can be easily treated by using zinc salts as dietary supplements.

(a) One salt which is used as a dietary supplement is a hydrated zinc sulfate, $ZnSO_4.xH_2O$, which is a colourless crystalline solid.

Crystals of zinc sulfate may be prepared in a school or college laboratory by reacting dilute sulfuric acid with a suitable compound of zinc.

Give the formulae of **two** simple compounds of zinc that could **each** react with dilute sulfuric acid to produce zinc sulfate.

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

(b) A simple experiment to determine the value of *x* in the formula $ZnSO_4.xH_2O$ is to heat it carefully to drive off the water.

$$ZnSO_4.xH_2O(s) \rightarrow ZnSO_4(s) + xH_2O(g)$$

A student placed a sample of the hydrated zinc sulfate in a weighed boiling tube and reweighed it. He then heated the tube for a short time, cooled it and reweighed it when cool. This process was repeated four times. The final results are shown below.

mass of empty tube / g	mass of tube + hydrated salt / g	mass of tube + salt after fourth heating / g
74.25	77.97	76.34

(i) Why was the boiling tube heated, cooled and reweighed four times?

.....

.....

(ii) Calculate the amount, **in moles**, of the anhydrous salt produced.

(iii) Calculate the amount, **in moles**, of water driven off by heating.

(iv) Use your results to **(ii)** and **(iii)** to calculate the value of x in $ZnSO_4.xH_2O$.

[7]

(c) For many people, an intake of approximately 15 mg per day of zinc will be sufficient to prevent deficiencies.

Zinc ethanoate crystals, $(CH_3CO_2)_2Zn.2H_2O$, may be used in this way.

(i) What mass of pure crystalline zinc ethanoate (M_r = 219.4) will need to be taken to obtain a dose of 15 mg of zinc?

(ii) If this dose is taken in solution as 5 cm^3 of aqueous zinc ethanoate, what would be the concentration of the solution used?
Give your answer in mol dm^{-3}.

[4]

[Total: 13]