A-Level Chemistry

Empirical and Molecular Formula

Question Paper

Time available: 61 minutes
Marks available: 58 marks

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1. Compounds containing $Cu2^{+}$, OH^{-} and CO_3^{2-} ions are sometimes described as basic copper carbonates.

(a) Solid $Cu_2(OH)_2CO_3$ is added to an excess of dilute hydrochloric acid.
A solution of copper(II) chloride is formed, together with two other products.

(i) Write an equation for the reaction.

_____

(2)

(ii) Suggest **one** observation that could be made during the reaction.

_____

_____

(1)

(b) A 5.000 g sample of a different basic copper carbonate contains 0.348 g of carbon, 0.029 g of hydrogen and 1.858 g of oxygen.

(i) State what is meant by the term empirical formula.

_____

_____

(1)

(ii) Calculate the empirical formula of this basic copper carbonate.
Show your working.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

2. A sample of hydrated nickel sulfate ($NiSO_4.xH_2O$) with a mass of 2.287 g was heated to remove all water of crystallisation. The solid remaining had a mass of 1.344 g.

(a) Calculate the value of the integer x.
Show your working.

(4)

(b) Suggest how a student doing this experiment could check that all the water had been removed.

(2)

(Total 6 marks)

3. This question is about citric acid, a hydrated tricarboxylic acid. Its formula can be represented as $H_3Y.xH_2O$

(a) A 1.50 g sample of $H_3Y.xH_2O$ contains 0.913 g of oxygen by mass.
The sample burns completely in air to form 1.89 g of CO_2 and 0.643 g of H_2O

Show that the empirical formula of citric acid is $C_3H_5O_4$

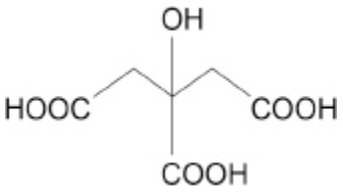
(5)

(b) A 3.00 g sample of $H_3Y.xH_2O$ (M_r = 210.0) is heated to constant mass. The anhydrous H_3Y that remains has a mass of 2.74 g

Show, using these data, that the value of x = 1

(2)

The figure shows the structure of H_3Y



(c) Complete this IUPAC name for H_3Y

_____ propane-1, 2, 3-tricarboxylic acid

(1)

(d) State the number of peaks you would expect in the ^{13}C NMR spectrum for H_3Y

_____

(1)

(Total 9 marks)

4. Glucose can decompose in the presence of microorganisms to form a range of products. One of these is a carboxylic acid (M_r = 88.0) containing 40.9% carbon and 4.5% hydrogen by mass.

(a) Deduce the empirical and molecular formulas of the carboxylic acid formed.

Empirical formula = _____ Molecular formula = _____

(4)

(b) Ethanol is formed by the fermentation of glucose.
A student carried out this fermentation reaction in a beaker using an aqueous solution of glucose at a temperature of 25 °C in the presence of yeast.

Write an equation for the reaction occurring during fermentation.

_____

(1)

(c) In industry, this fermentation reaction is carried out at 35 °C rather than 25 °C.

Suggest **one** advantage and **one** disadvantage for industry of carrying out the fermentation at this higher temperature.

Advantage _____

_____

Disadvantage _____

_____

(2)

(d) The method used by the student in part (b) would result in the ethanol being contaminated by ethanoic acid.

How does this contamination occur?

_____

_____

(1)

(e) Give **two** differences between the infrared spectrum of a carboxylic acid and that of an alcohol other than in their fingerprint regions.
Use **Table A** on the Data Sheet.

Difference 1 _____

_____

Difference 2 _____

_____

(2)

(Total 10 marks)

5. (a) Calcium phosphate reacts with aqueous nitric acid to produce phosphoric acid and calcium nitrate as shown in the equation.

$$Ca_3(PO_4)_2 + 6HNO_3 \longrightarrow 2H_3PO_4 + 3Ca(NO_3)_2$$

(i) A 7.26 g sample of calcium phosphate reacted completely when added to an excess of aqueous nitric acid to form 38.0 cm^3 of solution.

Calculate the concentration, in mol dm^{-3}, of phosphoric acid in this solution.
Give your answer to 3 significant figures.

(5)

(ii) Calculate the percentage atom economy for the formation of calcium nitrate in this reaction.
Give your answer to 1 decimal place.

(2)

(b) Write an equation to show the reaction between calcium hydroxide and phosphoric acid to produce calcium phosphate and water.

(1)

(c) Calcium dihydrogenphosphate can be represented by the formula $Ca(H_2PO_4)_x$ where x is an integer.
A 9.76 g sample of calcium dihydrogenphosphate contains 0.17 g of hydrogen, 2.59 g of phosphorus and 5.33 g of oxygen.

Calculate the empirical formula and hence the value of x.
Show your working.

(4)

(Total 12 marks)

6. Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

(a) People who have a zinc deficiency can take hydrated zinc sulfate ($ZnSO_4.xH_2O$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer x in $ZnSO_4.xH_2O$
Show your working.

(3)

(b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

A 0.0830 mol sample of pure zinc oxide was added to 100 cm^3 of 1.20 mol dm^{-3} hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

(4)

(c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

(4)

(d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

(3)

(Total 14 marks)