Australian Islamic College 2018

ATAR Chemistry Units 3 and 4

Task 13 (Weighting: 3%)

Empirical Formula and Stoichiometry Test

Test Time: 45 minutes

Please do not turn this page until instructed to do so.

First Name	Surname
ANSWERS	

Teacher

Mark / 39	Percentage

Equipment allowed: Pens, pencils, erasers, whiteout, rulers and non-programmable calculators permitted by the Schools Curriculum and Standards Authority.

1. Carbon dioxide is prepared by reacting hydrochloric acid with marble chips (calcium carbonate).

If 3.125 g of marble chips were mixed with 20.0 mL of 2.00 mol L^{-1} $HCl_{(aq)}$

(a) Write an equation for the reaction occurring.

[1 mark]

$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$
or: $CaCO_{3(s)} + 2H^+_{(aq)} \rightarrow Ca^{2+}_{(aq)} + CO_{2(g)} + H_2O_{(l)}$ [1]

(b) Determine the limiting reagent and calculate the number of moles of the excess reagent remaining after the reaction is completed.

[5 marks]

$n(CaCO_3)$ = m/M = 3.125 / 100.09 = 0.031225 mol [1]
n(HCl) = cV = 0.0200 x 2.00 = 0.0400 mol
[1]

SR = $n(HCl) / n(CaCO_3)$ = 2/1 = 2
AMR = $n(HCl) / n(CaCO_3)$ = 0.0400 / 0.031225 = 1.28 [1]

AMR < SR therefore HCl is the limiting reagent. [1]
Other methods OK. Need to show reasoning.

$n(CaCO_{3\ remaining})$ = 0.031225 – 0.0200 = 0.01123 mol

[1]

(c) What would be the volume of carbon dioxide produced at 25 ^oC and 1.00 atm?

[2 marks]

$n(CO_2)$ = ½ x n(HCl) = ½ x 0.040 = 0.0200 mol [1]

PV = nRT
V = nRT / P = 0.0200 x 0.082 x 298 / 1 <u>= 0.489 L</u> [1]

2. When solid ammonium sulfite ($(NH_4)_2SO_3$) is heated strongly it decomposes to form the gases ammonia (NH_3), sulfur dioxide (SO_2), and water.

   A 1.54 g sample of ammonium sulfite decomposed at 302 ^oC in a sealed gas vessel of volume 1.850 L.

   (a) Write a balanced chemical equation for the reaction. [1 mark]

   $(NH_4)_2SO_3(s) \rightarrow 2NH_3(g) + SO_2(g) + H_2O(g)$ [1]

   (b) Calculate the pressure inside the gas vessel when decomposition is complete.

   [4 marks]

   $n((NH_4)_2SO_3) = 1.54 / 116.154 = 0.01326$ mol **[1]**

   $n(gas)_{total} = n(NH_3) + n(SO_2) + n(H_2O)$ **[1]**

   $n(gas) = (0.01326)+(0.01326)+(2 \times 0.01326) = 0.05303$ mol **[1]**

   $P(gas) = nRT / V$

   $= 0.05303 \times 8.314 \times (302+273) / 1.85 = 137$ kPa **[1]**

   (c) The gaseous products are passed through limewater, ($Ca(OH)_2$ (*aq*)). What mass of calcium sulfite ($CaSO_3$) would precipitate?

   [2 marks]

   $SO_{2(g)} + Ca(OH)_{2(aq)} \rightarrow CaSO_{3(s)} + H_2O_{(l)}$ **[1]**

   $n(SO_2) = n((NH_4)_2SO_3) = n(CaSO_3) = 0.01326$ mol **[or 1]**

   $m(CaSO_3) = 0.01326 \times 120.15 = 1.59$ g **[1]**

3. An unknown organic compound X, which was known to contain hydrogen, carbon and chlorine was analysed to find its formula. A 10.15g sample was combusted in air and produced 4.40g of water.

   A separate 5.48g of **X** underwent a substitution reaction to convert the chlorine atoms to chloride ions. On addition of excess silver nitrate solution to the resulting solution, 12.54g of silver chloride was precipitated.

   A third 5.00g sample of X was vapourised and found to occupy 1.05 L at 200^{o}C and 150 kPa.

   (a) Calculate the empirical formula of **X**.

   [8 marks]

n(H in 10.15 g) = 2 x n(H_2O) = 2 x 4.40 / 18.016 = 0.4885 mol **[1]**
m(H in 10.15 g) = 1.008 x 0.4885 = 0.4924 g
% comp (H) = (0.4924 / 10.15) x 100 = 4.8513 % **[1]**
n(Cl in 5.48 g) = n(AgCl) = 12.54 / 143.35 = 0.08748 mol
m(Cl in 5.48 g) = 0.08748 x 35.45 = 3.1011 g
% comp (Cl) = (3.1011 / 5.48) x 100 = 56.5894 % **[1]**
% comp (C) = 100% – (56.5894% + 4.8513%) = 38.5593 % **[1]**

	C		**H**		**Cl**	
n = m/M =	**38.5 / 12.01**		**4.90 / 1.008**		**56.6 / 35.45**	
n =	**3.21**		**4.86**		**1.597**	**[1]**
mole ratio =	**3.21/1.597**		**4.86/1.597**		**1.597/1.597**	**[1]**
	2.01	**:**	**3.04**	**:**	**1**	**[1]**

Empirical Formula is C_2H_3Cl **[1]**

   (b) Calculate the molar mass of **X**, and hence work out the molecular formula.

   [4 marks]

PV = nRT **n = PV / RT**
n = (150 x 1.05) / (8.314 x 473)
= 4.00 x 10^{-2} mol **[1]**
M = m / n = 5.00 / 4.00 x 10^{-2} = 125 g mol^{-1} **[1]**

M (C_2H_3Cl) = 62.49 g mol^{-1}
125/ 62.49 = 2 **[1]**
∴ molecular Formula = 2 x Emp. Form. = $C_4H_6Cl_2$ **[1]**

(c) Draw and name a possible structure for **X** that would react readily with aqueous bromine but would not form geometric *(cis/trans)* isomers

[2 marks]

many possibilities, such as:

1,1-dichlorobut-1-ene **1,1-dichloro-2-methylprop-1-ene**
2,4-dichlorobut-1-ene **4,4-dichlorobut-1-ene** **[1]**

Drawing **[1]**

4. The blue-green pigment Chrysocolla, is a hydrated salt that contains copper, silicon and oxygen:

$$Cu_wSi_xO_y.ZH_2O$$

A 10.00 g sample was carefully heated to remove water and the resulting solid had a mass of 7.21g.

To calculate the amount of silicon present, this 7.21g was roasted at high temperature in the presence of oxygen and 3.10g of SiO_2 was produced.

In a separate analysis, it was found that the original hydrated salt was found to contain 32.8% copper.

(a) Determine the empirical formula of Chrysocolla by calculating the values of *w, x, y and Z.*

[9 marks]

$m(H_2O)$ = 10.00 – 7.21 = 2.79 g [1]
$\%(H_2O)$ = (2.79 / 10.00) x 100 = 27.9% [1]
m(Si) = (28.09 / 60.09) x 3.10 = 1.449 g [1]
%(Si) = (1.449 / 10.00) x 100 = 14.49% [1]
%(Cu) = 32.8%
%(O) = 100% – (27.9% + 14.49% + 32.8%) = 24.81 % [1]

M	***(63.55)***	***(28.09)***	***(16.00)***	***(18.016)***	
	Cu	**Si**	**O**	**H_2O**	
	32.8 %	**14.49 %**	**24.81 %**	**27.9 %**	
n = m/M =	**32.8 / 63.55**	**14.49 / 28.09**	**24.81 / 16.00**	**27.9 / 18.016**	**[1]**
n =	**0.516**	**0.516**	**1.55**	**1.55**	
mole ratio =	**0.516/0.516**	**0.516/0.516**	**1.55/0.516**	**1.55/0.516**	**[1]**
	1	**1**	**3**	**3**	**[1]**
	w	**x**	**y**	**Z**	

Empirical Formula is $CuSiO_3.3H_2O$ [1]

(b) Based on the colour of the pigment, state the oxidation number of the copper, and calculate the oxidation state of silicon in the compound.

[1 mark]

Copper = +2 Silicon = +4

[1 mark; ½ each]

Spare paper