

**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.

<b>First Name</b>	<b>Surname</b>
<b>ANSWERS</b>	

<b>Teacher</b>

<b>Mark / 39</b>	<b>Percentage</b>

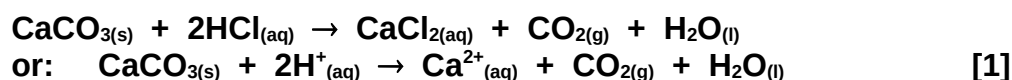
Equipment allowed: Pens, pencils, erasers, whiteout, rulers and non-programmable calculators permitted by the Schools Curriculum and Standards Authority.

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<sup>-1</sup> HCl<sub>(aq)</sub>

- (a) Write an equation for the reaction occurring.

[1 mark]



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

[5 marks]

$$\begin{aligned} n(\text{CaCO}_3) &= m/M = 3.125 / 100.09 = 0.031225 \text{ mol} \\ n(\text{HCl}) &= cV = 0.0200 \times 2.00 = 0.0400 \text{ mol} \end{aligned}$$

[1]

$$\begin{aligned} \text{SR} &= n(\text{HCl}) / n(\text{CaCO}_3) = 2/1 = 2 \\ \text{AMR} &= n(\text{HCl}) / n(\text{CaCO}_3) = 0.0400 / 0.031225 = 1.28 \end{aligned}$$

$$\text{AMR} < \text{SR} \text{ therefore HCl is the limiting reagent.} \quad [1]$$

*Other methods OK. Need to show reasoning.*

$$n(\text{CaCO}_3 \text{ remaining}) = 0.031225 - 0.0200 = 0.01123 \text{ mol}$$

[1]

- (c) What would be the volume of carbon dioxide produced at 25 °C and 1.00 atm?

[2 marks]

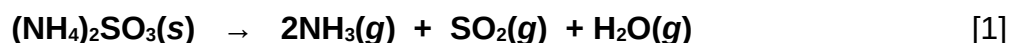
$$n(\text{CO}_2) = \frac{1}{2} \times n(\text{HCl}) = \frac{1}{2} \times 0.040 = 0.0200 \text{ mol} \quad [1]$$

$$\begin{aligned} \text{PV} &= nRT \\ V &= nRT / P = 0.0200 \times 0.082 \times 298 / 1 = \underline{0.489 \text{ L}} \end{aligned} \quad [1]$$

2. When solid ammonium sulfite ((NH<sub>4</sub>)<sub>2</sub>SO<sub>3</sub>) is heated strongly it decomposes to form the gases ammonia (NH<sub>3</sub>), sulfur dioxide (SO<sub>2</sub>), and water.

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

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



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

[4 marks]

$$n(\text{(NH}_4\text{)}_2\text{SO}_3) = 1.54 / 116.154 = 0.01326 \text{ mol} \quad [1]$$

$$n(\text{gas})_{\text{total}} = n(\text{NH}_3) + n(\text{SO}_2) + n(\text{H}_2\text{O}) \quad [1]$$

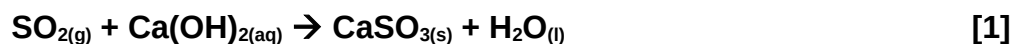
$$n(\text{gas}) = (0.01326) + (0.01326) + (2 \times 0.01326) = 0.05303 \text{ mol} \quad [1]$$

$$P(\text{gas}) = nRT / V$$

$$= 0.05303 \times 8.314 \times (302+273) / 1.85 = 137 \text{ kPa} \quad [1]$$

- (c) The gaseous products are passed through limewater, (Ca(OH)<sub>2</sub> (aq)). What mass of calcium sulfite (CaSO<sub>3</sub>) would precipitate?

[2 marks]



$$n(\text{SO}_2) = n(\text{(NH}_4\text{)}_2\text{SO}_3) = n(\text{CaSO}_3) = 0.01326 \text{ mol} \quad [\text{or } 1]$$

$$m(\text{CaSO}_3) = 0.01326 \times 120.15 = 1.59 \text{ g} \quad [1]$$

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°C and 150 kPa.

- (a) Calculate the empirical formula of X.

[8 marks]

$$n(\text{H in 10.15 g}) = 2 \times n(\text{H}_2\text{O}) = 2 \times 4.40 / 18.016 = 0.4885 \text{ mol} \quad [1]$$

$$m(\text{H in 10.15 g}) = 1.008 \times 0.4885 = 0.4924 \text{ g}$$

$$\% \text{ comp (H)} = (0.4924 / 10.15) \times 100 = 4.8513 \% \quad [1]$$

$$n(\text{Cl in 5.48 g}) = n(\text{AgCl}) = 12.54 / 143.35 = 0.08748 \text{ mol}$$

$$m(\text{Cl in 5.48 g}) = 0.08748 \times 35.45 = 3.1011 \text{ g}$$

$$\% \text{ comp (Cl)} = (3.1011 / 5.48) \times 100 = 56.5894 \% \quad [1]$$

$$\% \text{ comp (C)} = 100\% - (56.5894\% + 4.8513\%) = 38.5593 \% \quad [1]$$

	<u>C</u>	<u>H</u>	<u>Cl</u>	
$n = m/M =$	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 <u>C<sub>2</sub>H<sub>3</sub>Cl</u>			[1]

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

[4 marks]

$$\begin{aligned} PV = nRT \quad n &= PV / RT \\ n &= (150 \times 1.05) / (8.314 \times 473) \\ &= 4.00 \times 10^{-2} \text{ mol} \quad [1] \\ M = m / n &= 5.00 / 4.00 \times 10^{-2} = 125 \text{ g mol}^{-1} \quad [1] \end{aligned}$$

$$\begin{aligned} M(\text{C}_2\text{H}_3\text{Cl}) &= 62.49 \text{ g mol}^{-1} \\ 125 / 62.49 &= 2 \quad [1] \end{aligned}$$

$$\therefore \text{molecular Formula} = 2 \times \text{Emp. Form.} = \text{C}_4\text{H}_6\text{Cl}_2 \quad [1]$$

(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:



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  $\text{SiO}_2$  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 <sub>2</sub> O)	= 10.00 – 7.21	= 2.79 g	[1]		
%(H <sub>2</sub> O)	= (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%)	= <u>24.81 %</u>	[1]		
M	(63.55)	(28.09)	(16.00)	(18.016)	
	<u>Cu</u>	<u>Si</u>	<u>O</u>	<u>H<sub>2</sub>O</u>	
	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 <sub>3</sub> .3H <sub>2</sub> O	[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