**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.

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| **First Name** | **Surname** |
| **ANSWERS** |  |

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| **Teacher** |
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| **Mark / 39** | **Percentage** |
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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]

**CaCO3(s) + 2HCl(aq) → CaCl2(aq) + CO2(g) + H2O(l)**

**or: CaCO3(s) + 2H+(aq) → Ca2+(aq) + CO2(g) + H2O(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(CaCO3) = 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(CaCO3) = 2/1 = 2**

**AMR = n(HCl) / n(CaCO3) = 0.0400 / 0.031225 = 1.28 [1]**

**AMR < SR therefore HCl is the limiting reagent. [1]**

***Other methods OK. Need to show reasoning.***

**n(CaCO3 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(CO2­) = 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 = 0.489 L [1]**

1. When solid ammonium sulfite ((NH4)2SO3) is heated strongly it decomposes to form the gases ammonia (NH3), sulfur dioxide (SO2), and water.

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

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

**(NH4)2SO3(*s*) → 2NH3(*g*) + SO2(*g*) + H2O(*g*)**  [1]

1. Calculate the pressure inside the gas vessel when decomposition is complete.

[4 marks]

**n((NH4)2SO3) = 1.54 / 116.154 = 0.01326 mol [1]**

**n(gas)total = n(NH3) + n(SO2) + n(H2O) [1]**

**n(gas) = (0.01326)+( 0.01326)+(2 x 0.01326) = 0.05303 mol [1]**

**P(gas) = nRT / V**

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

1. The gaseous products are passed through limewater, (Ca(OH)2 (*aq*)). What mass of calcium sulfite (CaSO3) would precipitate?

[2 marks]

**SO2(g) + Ca(OH)2(aq) 🡪 CaSO3(s) + H2O(l) [1]**

**n(SO2) = n((NH4)2SO3) = n(CaSO3) = 0.01326 mol [or 1]**

**m(CaSO3) = 0.01326 x 120.15 = 1.59 g [1]**

1. 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 200oC and 150 kPa.

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

[8 marks]

**n(H in 10.15 g) = 2 x n(H2O) = 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 C2H3Cl [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 (C2H3Cl) = 62.49 g mol-1**

**125/ 62.49 = 2 [1]**

**∴ molecular Formula = 2 x Emp. Form. = C4H6Cl2 [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]**

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

Cu*w*Si*x*O*y*.*Z*H2O

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 SiO2 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(H2O) = 10.00 – 7.21 = 2.79 g [1]**

**%(H2O) = (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 H2O**

**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 CuSiO3.3H2O [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