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| https://upload.wikimedia.org/wikipedia/en/3/33/BSHS_Logo.jpg | Bunbury Senior High School | | | | | |
| **CHEMISTRY UNIT 3 & 4** | | | | | | |
| **Practical:** | | | | | | |
| **Calculations using second-hand experimental data** | | | | | | |
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| **NAME:** | | |  | | | |
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| **Time allowed for this paper** | | | | | | |
| Reading time: | | 5 minutes | | | | |
| Working time: | | 50 minutes | | | | |
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| **Structure of this paper:** | | | | | | |
| Section | | | Number of questions | Marks available | | Marks achieved |
| Calculation questions | | | 5 | 50 | |  |
|  | | |  | | **Total** | \_\_\_\_\_\_ / 50 |

1. **(8 marks)**

As part of a practical test, a student needed to determine the concentration of sulfuric acid in a sample of acid from a car battery. They performed the experiment in the following way:

**Step 1:** The concentration of sodium hydroxide was determined by titration against 0.105 mol L-1 hydrochloric acid, using phenolphthalein as the indicator. 20.00 mL of hydrochloric acid required 22.34 mL of sodium hydroxide solution to reach the end point.

**Step 2:** 5.00 mL of battery acid was diluted to 500.0 mL in a volumetric flask

**Step 3:** The diluted battery acid was titrated with the sodium hydroxide solution which was standardised in Step 1. 19.15 mL of the standard sodium hydroxide solution was required to react completely with 20.00 mL of the diluted battery acid using phenolphthalein as the indicator.

* 1. Using the information in Step 1, calculate the concentration of sodium hydroxide solution. (3 marks)
  2. Using the information in Step 3, calculate the concentration of the diluted battery acid. (3 marks)
  3. Using the information in Step 2, calculate the concentration of the battery acid.   
     Give your answer to three significant figures. (2 marks)

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| **Part** | **Answer** | **Marks** |
| (a) | n(HCℓ) = c x V = 0.105 x 0.020 = 0.0021 mol | 1 |
| n(NaOH) = n(HCℓ) = 0.0021 mol | 1 |
| c(NaOH) = n / V = 0.0021 / 0.02234 = 0.0940 mol L-1 | 1 |
| (b) | n(NaOH) = c x V = 0.0940 x 0.01915 = 0.00180 mol | 1 |
| n(H2SO4) = ½ x n(NaOH) = 9.00 x 10-4 mol | 1 |
| c(H2SO4 dilute) = n / V = 9.00 x 10-4 / 0.020 = 0.0450 mol L-1 | 1 |
| (c) | c(H2SO4 original) = c(H2SO4 dilute) x 500/5 = 4.50 mol L-1 | 1 |
| Three significant figures. | 1 |

1. **(16 marks)**

A herbicide which contains only carbon, hydrogen, nitrogen and chlorine was analysed to determine its empirical formula. A combustion analysis of 0.6678 g of the compound produced 1.09 g of carbon dioxide and 0.390 g of water.

A separate 0.3320 g sample of the compound was reacted with silver nitrate, producing 0.221 g of silver chloride precipitate.

* 1. Determine the empirical formula of the compound. (11 marks)
  2. 7.35 g of the compound was vapourised and was found to occupy 0.956 L at 150 °C and   
     125.4 kPa. Determine the molecular formula of the compound. (5 marks)

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| **Part** | **Answer** | **Marks** |
| (a) | n(CO2) = m / M = 1.09 / 44.01 = 0.0248 mol  n(C) = n(CO2) = 0.0248 mol | 1 |
| m(C) = n x 12.01 = 0.297 g | 1 |
| n(H2O) = m / M = 0.390 / 18.016 = 0.0216 mol  n(H) = 2 x n(H2O) = 0.0433 mol | 1 |
| m(H) = n x 1.008 = 0.0436 g | 1 |
| *Adjusting for sample size…*  m(AgCℓ) = 0.221 x 0.6678/0.3320 = 0.445 g | 1 |
| n(AgCℓ) = 0.445 / 143.35 = 0.00310 mol  n(Cℓ) = n(AgCℓ) = 0.00310 mol | 1 |
| m(Cℓ) = n x 35.45 = 0.110 g | 1 |
| m(N) = m(sample) – m(C) – m(H) – m(Cℓ) = 0.2172 g | 1 |
| n(N) = m / M = 0.2172 / 14.01 = 0.0155 mol | 1 |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | C | H | N | Cℓ | | n | 0.0248 | 0.0443 | 0.0155 | 0.00310 | | Divide by 0.00310 | 8.0 | 14.0 | 5.0 | 1.0 | | 1 |
| Empirical formula is C8H14N5Cℓ | 1 |
| (b) | T = 423.15 K | 1 |
| n = PV/RT = 0.03408 mol | 1 |
| M = m / n = 7.35 / 0.03408 = 216 g mol-1 | 1 |
| Empirical formula… M(C8H14N5Cℓ) = 216 g mol-1 | 1 |
| ∴ molecular formula = empirical formula = C8H14N5Cℓ | 1 |

1. **(9 marks)**

When concentrated nitric acid is added to copper, nitrogen dioxide gas is produced. This reaction can be represented by the following equation:

Cu + 4 HNO3 → Cu(NO3)2 + 2 NO2 + 2 H2O

If 4.56 g of copper is added to 25.0 mL of 5.55 mol L-1 solution of nitric acid:

* 1. Identify the limiting reagent (show all working). (4 marks)
  2. Calculate the volume of NO2 formed at 28 °C and 0.983 atm (3 marks)
  3. Calculate the moles of excess (unused) reactant left over at the end of the reaction. (2 marks)

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| **Part** | **Answer** | **Marks** |
| (a) | Cu + 4 HNO3 → Cu(NO3)2 + 2 NO2 + 2 H2O | 1 |
| (b) | n(Cu) = m / M = 4.56 / 63.55 = 0.0718 mol | 1 |
| n(HNO3) = c x V = 5.55 x 0.025 = 0.139 mol | 1 |
| n(HNO3 needed) = 4 x n(Cu) = 0.287 mol | 1 |
| n(HNO3 present) < n(HNO3 needed), ∴ HNO3 is limiting reagent | 1 |
| (c) | n(NO2) = 1/2 x n(HNO3) = 0.0694 mol | 1 |
| T = 301.15 K, P = 99.6 kPa | 1 |
| V = nRT / P = 1.74 L | 1 |
| (d) | n(Cu used) = 1/4 x n(HNO3) = 0.03469 mol | 1 |
| n(Cu remaining) = n(Cu initial) – n(Cu used) = 0.0371 mol | 1 |

1. **(8 marks)**

The equations for the production of sulfuric acid in the Contact Process are given as follows:

Step 1 S + O2 → SO2

Step 2 2 SO2 + O2 → 2 SO3

Step 3 SO3 + H2SO4 → H2S2O7

Step 4 H2S2O7 + H2O → 2 H2SO4

Steps 1, 3 and 4 are 100% efficient. Step 2 is 95% efficient.

* 1. Calculate the volume of SO2 produced at 101.3 kPa and 600 °C from burning 1.00 tonne of sulfur.  
     (1 tonne = 1000 kg) (3 marks)
  2. Calculate the mass of sulfur trioxide (SO3) produced from burning 1.00 tonne of sulfur. (2 marks)
  3. Calculate the volume of sulfuric acid produced from burning 1.00 tonne of sulfur if the concentration of sulfuric acid produced in Step 4 is 8.50 mol L-1. (3 marks)

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| **Part** | **Answer** | **Marks** |
| (a) | n(S) = m / M = 1,000,000 / 32.07 = 31,182 mol | 1 |
| n(SO2) = n(S) = 31,182 mol | 1 |
| V = nRT/P = 31182 x 8.314 x (600+273.15) / 101.3 = 2.23 x 106 L | 1 |
| (b) | n(SO3) = 0.95 x n(SO2) = 29,623 mol | 1 |
| m(SO3) = n x M = 29623 x 80.07 = 2.37 x 106 g | 1 |
| (c) | n(H2S2O7) = n(SO3) = 29,623 mol | 1 |
| n(H2SO4) = 2 x n(H2S2O7) = 59,245 mol | 1 |
| V = n / c = 59,245 / 8.50 = 6970 L = 6.97 x 103 L | 1 |

1. **(9 marks)**

A sample of ore was known to contain the elements nickel and sulfur. No other elements were present.

An industrial chemist was tasked with determining the empirical formula of the ore. The chemist roasted 500 kg of the ore in air, which released the sulfur in the formed of sulfur dioxide (SO2). The sulfur dioxide was trapped in a hydrogen peroxide “scrubbing” solution. The scrubbing process converted the sulfur dioxide into sulfate ions.

SO2(aq) + H2O2(aq) → 2 H+(aq) + SO42-(aq)

A 2.50 mL aliquot of the 10,000 L scrubbing solution was then taken. Barium nitrate was adding to the aliquot of the scrubbing solution, producing 0.480 g of barium sulfate (BaSO4) precipitate.

Given that the ore contains only nickel and sulfur, deduce the masses of sulfur and nickel in the 500 kg sample of ore and hence find its empirical formula.

* 1. Using the mass of barium sulfate produced from the 2.50 mL aliquot of the scrubbing solution, calculate the moles of SO42- in the original 10,000 L scrubbing solution. (3 marks)
  2. Calculate the moles of sulfur in the original 500 kg sample of ore. (1 marks)
  3. Calculate the moles of nickel in the original 500 kg sample of ore. (3 marks)
  4. Determine the empirical formula of the ore. (2 marks)

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| **Part** | **Answer** | **Marks** |
| (a) | n(BaSO4) = m / M = 0.480 / 233.37 = 0.002057 mol | 1 |
| n(SO42- in aliquot) = n(BaSO4) = 0.002057 mol | 1 |
| n(SO42- original) = n(SO42- aliquot) x 10,000/0.0025 = 8.23 x 103 mol | 1 |
| (b) | n(S) = n(SO42-) = 8.23 x 103 mol | 1 |
| (c) | m(S) = n x M = 8.23 x 103 x 32.07 = 2.64 x 105 g | 1 |
| m(Ni) = m(ore) – m(s) = 5.00 x 105 – 2.64 x 105 = 2.36 x 105 g | 1 |
| n(Ni) = m / M = 2.36 x 105 / 58.69 = 4.02 x 103 g | 1 |
| (d) | n(S) / n(Ni) = 2 | 1 |
| Empirical formula is NiS2 | 1 |