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| Description: Vertical full colour positive | Safety Bay Senior High School | | | | | |
| **CHEMISTRY UNIT 3 & 4** | | | | | | |
| **Practical:** | | | | | | |
| **Calculations using second-hand experimental data** | | | | | | |
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| **NAME:** | | | **ANSWERS** | | | |
|  | | |  | | | |
| **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 | 51 | |  |
|  | | |  | | **Total** | \_\_\_\_\_\_ / 51 |

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. (450x 10-2 mol L-1 ) | 1 |

1. **(12 marks)**

A sample of an unknown α-amino acid underwent analysis to determine its molecular structure. The amino acid was known to contain only the elements carbon, hydrogen, oxygen and nitrogen.

A 0.7529 g sample was burnt in pure oxygen and this produced 1.116 g of carbon dioxide and 0.5329 g of water vapour. A separate 1.650 g sample was treated to convert all the nitrogen present to nitrogen dioxide and at 138 kPa and 82 °C, 396 mL of NO2 was formed.

* 1. Determine the empirical formula of the amino acid. (10 marks)
  2. Determine the molecular formula of alanine if the known molecular weight is 89.1 g mol-1. (2 marks)

**OR**

|  |  |
| --- | --- |
| **m(C) = 12.01 / (44.01) x 1.116**  **= 0.304548 g**  **% C = 0.304548 / 0.752 x 100**  **= 40.44999**  **m(H) = 2 x 1.008 / 18.016 x 0.5329**  **= 0.0596318 g**  **% H = 0.0596318 / 0.752 x 100**  **= 7.92028**  **n(N) = n(NO2)**  **= PV/RT**  **= (138 x 0.396) / (8.314 x 355)**  **= 0.0185155**  **m(N) = nM**  **= 0.0185155 x 14.01**  **= 0.259402**  **% N = 0.259402 / 1.650 x 100**  **= 15.72136**  **% O = 100 - 40.44999 - 7.92028 -**  **15.72136**  **= 35.9837** | **n(C) = n(CO2)**  **= m/M**  **= 1.116 / 44.01**  **= 0.02535787**  **m(C) = nM**  **= 0.02535787 x 12.01**  **= 0.304548 g**  **n(H) = 2 x n(H2O)**  **= 2 x (0.5329 / 18.016)**  **= 0.0591585**  **m(H) = 0.0591585 x 1.008**  **= 0.0596318 g**  **n(N) = n(NO2)**  **= PV/RT**  **= (138 x 0.396) / (8.314 x 355)**  **= 0.0185155**  **scaling n(N) to match first sample size**  **n(N) = 0.0185155 / 1.65 x 0.7529**  **= 0.00844868**  **m(N) = 0.00844868 x 14.01**  **= 0.118366 g**  **m(O) = 0.7529 - 0.304548 - 0.0596318 -**  **0.118366**  **= 0.270354 g** |

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| --- | --- | --- | --- | --- |
|  | **C** | **H** | **O** | **N** |
| **ratio** | **3** | **7** | **2** | **1** |

**Therefore EF is C3H7O2N**

(b) Determine the molecular formula of alanine if the known molecular weight is 89.1 g mol-1.

1. marks)

**M(EF) = 89.096 g mol-1**

**M / M(EF) = 89.1 / 89.096**

**= 1**

**Therefore MF is also C3H7O2N**

1. **(14 marks)**

Chromium, the sixth most abundant transition metal in the Earth’s crust was discovered in 1797. It was named after the Latin *chroma* meaning ‘colour’. Chromium metal is extracted in large part from an ore containing chromite, FeCr2O4, via a multistep process. It is estimated that 70% of the world’s chromite reserves are located in South Africa, with additional deposits in India, Kazakhstan and Zimbabwe.

One process used to extract chromium metal from the chromite ore is shown below.

In the first step, the aerial oxidation of chromite (FeCr2O4) takes place in molten alkali, producing sodium chromate (Na2CrO4).

Step 1: 4 FeCr2O4 + 8 Na2CO3 + 7 O2 → 8 Na2CrO4 + 2 Fe2O3 + 8 CO2

In the second step, the sodium chromate is converted to sodium dichromate (Na2Cr2O7) by an acid.

Step 2: 2 Na2CrO4 + H2SO4 → Na2Cr2O7 + Na2SO4 + H2O

In the third step, the sodium dichromate is reduced to chromium (III) oxide (Cr2O3) with carbon.

Step 3: Na2Cr2O7 + 2 C → Cr2O3 + Na2CO3 + CO

The fourth step involves converting the chromium (III) oxide to the final pure chromium via an aluminothermic reaction.

Step 4: Cr2O3 + 2 Aℓ → 2 Cr + Aℓ2O3

A 4.11 tonne sample of chromite ore, known to be 58.2% pure, was reacted with 482 kL of oxygen gas at a pressure of 209 kPa and temperature of 356 °C (in the presence of excess sodium carbonate).

(a) Calculate the limiting reagent. (5 marks)

**m(FeCr2O4) = 58.2 / 100 x 4.11 = 2.39202 t = 2 392 020 g**

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|  | **FeCr2O4** | **O2** |
| **n(present)** | **n = m/M**  **= 2 392 020 / 223.85**  **= 10 685.81639 mol** | **n = PV / RT**  **= (209 x 482 000) / (8.314 x 629)**  **= 19 263.3874** |
| **n(required)** | **n = 19 263.3874 / 7 x 4**  **= 11007.6499 mol** | **n = 10 685.81639 / 4 x 7**  **= 18 700.17868** |

**Therefore FeCr2O4 is LR**

**OR**

**Stoichiometric ratio O2 / FeCr2O4 = 7 / 4 = 1.75**

**Actual ratio O2 / FeCr2O4 = 19 263.3874 / 10 685.81639 = 1.803**

**Therefore FeCr2O4 is LR**

(b) Calculate the mass of excess reagent. (3 marks)

**n(xs O2) = 19 263.3874 - 18 700.17868**

**= 563.209 mol**

**m(xs O2) = nM**

**= 563.209 x 32**

**= 18 022.68 g**

**= 1.80 x 104 g OR 18.0 kg**

(c) Calculate the mass of chromium (III) oxide produced if the combined yield of the first three steps is 73.4%. (3 marks)

**n(Cr2O3) = n(FeCr­2O4) x 73.4/100**

**= 10 685.81639 x 73.4/100**

**= 7 843.389 mol**

**m(Cr2O3) = nM**

**= 7 843.389 x 152**

**= 1 192 195.128 g**

**= 1.19 x 106 g OR 1.19 t**

The factory owner wishes to obtain 0.75 tonne of pure chromium from this sample of ore.

(d) What would the minimum possible yield of the fourth step need to be, to ensure this target is reached. (3 marks)

**n(Cr2O3 produced) = 7 843.389 mol**

**n(Cr theoretical) = n(Cr2O3) x 2**

**= 7 843.389 x 2**

**= 15 686.778 mol**

**m(Cr theoretical) = nM**

**= 15 686.778 x 52**

**= 815712 g**

**= 0.8157 t**

**% yield = actual / theoretical x 100**

**= 0.75 / 0.8157 x 100**

**= 91.9 %**

**OR**

**n(Cr needed) = m/M**

**= 750 000 / 52**

**= 14 423.077 mol**

**n(Cr2O3 needed) = n(Cr) / 2**

**= 14 423.077 /2**

**= 7 211.538**

**% yield = needed / available x 100**

**= 7 211.538 / 7 843.389 x 100**

**= 91.9 %**

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 mol | 1 |
| (d) | n(S) / n(Ni) = 2 | 1 |
| Empirical formula is NiS2 | 1 |