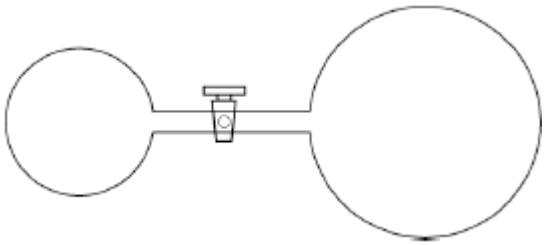
**UNIT 3ACHE** **NAME:**_____

**REACTIONS & STOICHIOMETRY:** **Answer all questions**

**Part A: Multiple Choice Questions. (10 marks)**

Q1. A 1 L vessel containing argon gas at a pressure of 100 kPa is attached via a tube and tap of negligible volume to a 2 L vessel containing neon gas at a pressure of 150 kPa.



The tap is opened and the gases allowed to mix, what is the final pressure in the vessels?

A 100 kPa
B. 133 kPa
C. 150 kPa
D. 250 kPa

Q2. 0.5755 g of a compound, containing sulfur and fluorine only, has a volume of 255.0 mL, at 288.0 K and 50.01 kPa. What is the molecular formula of this compound?

A. $SF_2$
B. $SF_4$
C. $SF_6$
D. $S_4F_{10}$

Q3. Which of the following groups of ions can coexist in significant quantities in aqueous solution **without** reacting with each other?

A. $HSO^{4-}$, $K^+$, $Na^+$, $HCO^{3-}$

B. $K^+$, $CO_3^{2-}$, $Cl^-$, $Al^{3+}$

C. $K^+$, $Ba^{2+}$, $NO_3^-$, $OH^-$

D. $Na^+$, $Ba^{2+}$, $H^+$, $SO_4^{2-}$

Q4. When 5.00 g of zinc is treated with 20.0 mL of a 1.00 mol $L^{-1}$ solution of hydrochloric acid until no further reaction occurs, the mass of zinc which remains unreacted is

A. 0.00 g
B. 0.65 g
C. 3.7 g
D. 4.35 g

Q5. The number of moles of chloride ions present in 100 mL of 0.1 mol $L^{-1}$ solution of calcium chloride ($CaCl_2$) is

A. 1.00 B. 0.02 C. 0.01 D. 0.001

Q6. Two moles of sulphur dioxide ($SO_2$) at 273 K and 101.3 kPa has

A. a mass of 128 grams B. a volume of 22.41 litres

C. $24 \times 10^{23}$ $SO_2$ molecules D. two $SO_2$ molecules.

Q7. The volume of carbon dioxide in litres measured at S.T.P. required to convert 7.0 g of calcium oxide to calcium carbonate is:

A. 2.8 L B. 2.6 L C. 2.2 L D. 1.6 L

Q8. Consider the following data:

| **Element** | **Atomic mass** |
|---|---|
| **A** | **12.01** |
| **B** | **35.5** |

A and B combine to form a new substance, X. If 4 moles of B atoms combine with 1 mole of A atoms to give 1 mole of X molecules, then the mass of 1 mole of X is

A. 47.5 g B. 74.0 g

C. 83.5 g D. 154.0 g

Q9. A gaseous mixture containing ethane ($C_2H_6$) and methane ($CH_4$) underwent complete combustion to produce 5.28 g of carbon dioxide and 3.78 g of water. What is the volume ratio of ethane to methane in the original mixture?

A. 4:1
B. 1:4
C. 2:1
D. 1:2

Q10. When 1.27 g samples of the following substances are all treated with excess dilute hydrochloric acid, all give off carbon dioxide. Which gives off the greatest mass of carbon dioxide?

A. lithium carbonate
B. sodium carbonate
C. magnesium carbonate
D. potassium carbonate

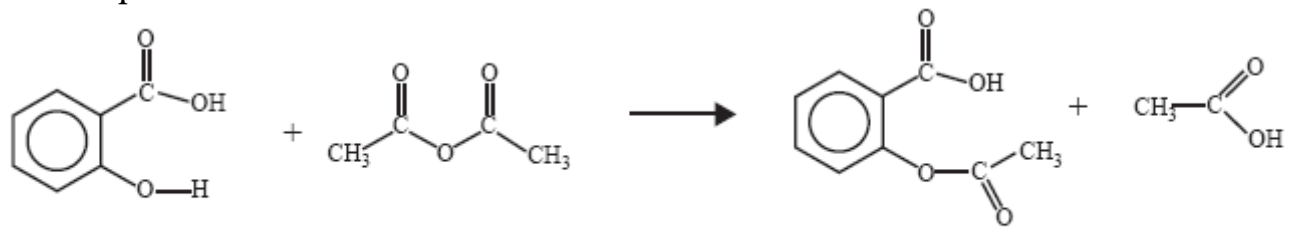
**END OF PART A**

## PART B: SHORT ANSWER QUESTIONS (15 marks)

The calculations are to be set out in detail. Marks will be allocated for correct equations and clear setting out, even if you cannot complete the problem. When questions are divided into sections, clearly distinguish each using (a), (b), and so on. Express your final numerical answers to three (3) significant figures where appropriate, and provide units where applicable. Information which may be necessary for solving the problems is located on the separate Chemistry Data Sheet. Show clear reasoning: if you don't, you will lose marks.

11. A sample of aspirin was prepared by reacting 2.20 g of salicylic acid with 4.20 mL of ethanoic anhydride in a conical flask. After heating for 20 minutes the reaction mixture was cooled and white crystals precipitated. The crystals were then collected, dried to constant mass and weighed.

The equation for the reaction is



salicylic acid (s) ethanoic anhydride (l) aspirin (s)

The following results were obtained.

| | |
|---|---|
| mass of salicylic acid | 2.20 g |
| volume ethanoic anhydride | 4.20 mL |
| mass product | 2.25 g |

Use the following data to answer the questions below.

| | **molar mass ($g\ mol^{-1}$)** | **Density ($g\ mL^{-1}$)** |
|---|---|---|
| aspirin | 180 | |
| ethanoic anhydride | 102 | 1.08 |
| salicylic acid | 138 | |

A. Calculate the initial amount, in moles, of salicylic acid used in this preparation.

_____

B. What initial amount, in moles, of ethanoic anhydride was used?

_____

_____

C. What is the maximum mass of aspirin that can theoretically be produced from these reagents?

_____

D. Determine the percentage yield in this preparation.

_____

(6 marks)

Q12. Sulfur dioxide gas is commonly used as a preservative in wine. An important source of $SO_2$ is solid sodium metabisulfite ($Na_2S_2O_5$). $Na_2S_2O_5$ reacts readily with acid as follows.

$$Na_2S_2O_{5(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)} + 2SO_{2(g)}$$

A. Calculate the volume, in litres, of $SO_2$ produced at 1.00 atm pressure and 15.0 $^0$C when 250 g of $Na_2S_2O_5$ reacts with excess acid.

(3 marks)

B. The concentration of an aqueous solution of $SO_2$ (solution A) is to be determined using its reaction with an aqueous solution of triiodide ions ($I_3^-$). The relevant half reactions are

$$SO_{2(aq)} + 2H_2O_{(l)} \rightarrow 4H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2e^-$$

$$I_3^-{}_{(aq)} + 2e^- \rightarrow 3I^-_{(aq)}$$

50.0 mL of a 0.0125 mol $L^{-1}$ solution of $I_3^-$ is added to 50.0 mL of solution A, providing excess of $I_3^-$. The final 100.0 mL solution is called solution B.
Write an overall balanced chemical equation for the reaction that occurs, identifying the substance that is the reductant.

Equation _____

Reductant _____

(2 marks)

C. Calculate the amount, in mol, of $I_3^-$ added to solution A.

(1 mark)

D. The excess $I_3^-$ remaining in the solution is determined by titration with a standard solution of sodium thiosulfate ($Na_2S_2O_3$). The equation for the reaction is

$$S_2O_3^{2-}{}_{(aq)} + I_3^-{}_{(aq)} + H_2O_{(l)} \rightarrow 3I^-_{(aq)} + S_2O_4^{2-}{}_{(aq)} + 2H^+_{(aq)}$$

14.70 mL of a 0.00850 mol $L^{-1}$ solution of $Na_2S_2O_3$ reacts exactly with all the $I_3^-$ remaining in solution B. Calculate the original concentration of $SO_2$ in solution A.

(3 marks)

**PART C: SHORT ANSWER QUESTIONS (15 marks)**

Q13. Basic copper(II) sulfate is used as a fungicide and has the formula $CuSO_4.3Cu(OH)_2.H_2O$. It can be produced using the following reaction:

$$4CuSO_4.5H_2O_{(s)} + 6NH_{3(aq)} \rightarrow CuSO_4.3Cu(OH)_2.H_2O_{(s)} + 3(NH_4)_2SO_{4(aq)} + 13H_2O$$

100.0 kg of copper(II) sulfate pentahydrate, with a purity of 95.5%, was added to 15.0 L of saturated ammonia solution, with a concentration of 0.880 g $mL^{-1}$.

A. Determine which reactant is the limiting reagent.
B. Calculate the mass of basic copper(II) sulfate that will be produced. Note that the relative formula mass of basic copper(II) sulfate is 470.32.
C. Calculate the number of moles of excess reactant remaining.

(8 marks)

Q14. An old drum has been found on a farm. The label has fallen off and for safe disposal its contents need to be analysed.

Elemental analysis shows the presence of carbon, hydrogen, phosphorus and oxygen. A 5.21 g sample of the pesticide produces 6.32 g of carbon dioxide and 3.23 of water when combusted completely in excess oxygen.

A second, 3.15 g sample of the pesticide is treated with excess nitric acid to convert all of the phosphorus to phosphate ions. The resulting solution is treated with excess calcium nitrate solution to produce 3.37 g of calcium phosphate.

A. Determine the empirical formula of the pesticide.

B. Mass spectral analysis shows the molar mass of the pesticide to be 290.18 g $mol^{-1}$. What is the pesticide's molecular formula. (7 marks)

**END OF TEST**

**UNIT3ACHE** **SOLUTIONS**

**REACTIONS AND STOICHIOMETRY:** **Answer all questions**

**PART A: MULTIPLE CHOICE QUESTIONS (10 marks)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1B | 2B | 3C | 4D | 5B | 6A | 7A | 8D | 9D | 10A |

**PART B: SHORT ANSWER QUESTIONS (15 marks)**

**11.**

**A.** n(salicylic acid) = 2.2/138 = 0.01594 mol

**B.** g(ethanoic anhydride) = 4.2 mL x 1.08 g $ml^{-1}$ = 4.536 g
n(ethanoic anhydride) = 4.536/102 = 0.04447 mol

**C.** salicylic acid is limiting
m(aspirin) = 0.01594 x 180 = 2.869 g

**D.** % Yield = Actual Yield/Theoretical Yield x 100% = 2.25/2.869 = 78.4%

**12.**

**A.** $n(Na_2S_2O_5)$ = 250 g/ 190.1 = 1.315 mol
$n(SO_2)$ = 2 x 1.315 mol = 2.63 mol
PV=nRT therefore V =nRT/P
V = [2.63 x 8.315 x (273.1 + 15)]/101.3 = 62.18 L or 62.2 L

**B.** $SO_2 + 2H_2O + I_3^- = 3I^- + SO_4^{2-} + 4H^+$
$SO_2$ is the reductant

**C.** $n(I_3^-) = cV = 0.0125 \times 0.05 = 6.25 \times 10^{-4}$ mol

**D.** $n(Na_2S_2O_3) = cV = 0.00850 \times 0.0147 = 1.2495 \times 10^{-4}$ mol
$n(I_3^-)_{inxs} = n(S_2O_3^{2-}) = 1.2495 \times 10^{-4}$ mol
$n(I_3^-)_{reacting} = n(I_3^-)_{initially} - n(I_3^-)_{inxs}$
$= 6.25 \times 10^{-4} - 1.2495 \times 10^{-4}$ mol
$= 5.0005 \times 10^{-4}$ mol
$n(SO_2) = n(I_3^-)_{reacting} = 5.0005 \times 10^{-4}$ mol
$c(SO_2)$ or $[SO_2] = n/V = 5.0005 \times 10^{-4}/0.05 = 0.0100$ $molL^{-1}$

**13.**

**A.** $m(CuSO_4.5H_2O)$ = 95.5 kg = $9.55 \times 10^4$ g
$n(CuSO_4.5H_2O) = 9.55 \times 10^4$ g/ 249.69 = 382.47 mol
n(basic copper(II) sulfate) = 1/4 x $n(CuSO_4.5H_2O)$ = 1/4 x 382.47
= 95.61 mol

$m(NH_3)$ = 0.88 x 1000 x 15 = 13200 g or $1.32 \times 10_4$ g
$n(NH_3) = 1.32 \times 10^4$ g/ 17.034 = 774.9 mol
n(basic copper(II) sulfate) = 1/6 x $n(NH_3)$ = 1/6 x 774.9
= 129.15 mol

Since 95.61 mol < 129.15 mol it follows that $CuSO_4.5H_2O$ is the limiting reagent

**B.** M(basic copper(II) sulfate) = 470.32
m(basic copper(II) sulfate) = n x M = 95.61 x 470.32 = 44967 g
= 45.0 kg or $4.50 \times 10_4$ g

**C.** $n(NH_3)_{inxs} = n(NH_3)_{initially} - n(NH_3)_{reacting}$
$n(NH_3)_{inxs} = 774.9 - (6/4 \times n(CuSO_4.5H_2O))$
$= 774.9 - 6/4 \times 382.47$
$= 774.9 - 573.7$
= 201.1 mol or 201 mol (3 sig. figs.)

**14.**

**Sample 1** [C, H, O, P] → $CO_2$ + $H_2O$
5.21 g 6.32 g 3.23 g

**Sample 2** [C, H, O, P] → $Ca_3(PO_4)_2$
3.15 g 3.37 g

m(C) in $CO_2$ = m($CO_2$) x m(C) in $CO_2$ = 6.32 x 12.01/(12.01 + 2(16))
= 6.32 x 12.01/44.01 = 1.7246 g

m(H) in $H_2O$ = m($H_2O$) x m(H) in $H_2O$ = 3.23 x 2(1.008)/(2(1.008) + 16)
= 3.23 x 2.016/18.016 = 0.3614 g

m(P) in $Ca_3(PO_4)_2$ = m($Ca_3(PO_4)_2$) x m(P) in $Ca_3(PO_4)_2$
= 3.37 x 2(30.97)/(3(40.08) + 2(30.97) + 12(16))
= 3.37 x 61.94/310.18 = 0.6729 g
%P in sample 2 = 0.6729/3.15 = 21.36%
m(P) in sample 1 = 5.21 x 21.36% = 1.113 g

m(O) in sample 1 = m[C, H, O, P] – m[C, H, P]
= 5.21 – [1.7246 + 0.3614 + 1.113]
= 5.21 – 3.199 = 2.011 g

| | C | H | O | P |
|---|---|---|---|---|
| m = | 1.7246 | 0.3614 | 2.011 | 1.113 |
| n = m/M | 1.7246/12.01 | 0.3614/1.008 | 2.011/16 | 1.113/30.97 |
| n = | 0.1436 | 0.3585 | 0.1256 | 0.03593 |
| ÷ 0.03593 | 3.99 | 9.97 | 3.49 | 1 |
| x 2 to get the smallest whole number ratio | | | | |
| Formula | 8 | 20 | 7 | 2 |

Empirical formula: $C_8H_{20}O_7P_2$

**B.** Empirical formula mass = 8(12.01) + 20(1.008) + 7(16) + 2(30.98)
= 290.18
Since empirical formula mass in grams = molar mass

Molecular formula = Empirical formula = $C_8H_{20}O_7P_2$