

### Part A: Knowledge & Understanding

1. Multiple choice (10 marks): Please answer all questions on your scantron card in pencil.

2. Explain how the Avogadro constant, average atomic mass, and molar mass are related. (3 marks K)

Avogadro's constant is the number of particles in one mole. It is essentially a definition of a mole. Average atomic mass is the number of grams per mole of an element, molar mass is equivalent to atomic mass but also covers compounds. If someone were to find the number of particles in 1g of  $H_2O$  they would have to add up the average atomic masses to create a molar mass and multiply by  $N_A$ .

### Part B: Thinking and Investigation & Communication

3. What mass of pure silver is contained in  $2.00 \times 10^2 \text{ g}$  of silver nitrate,  $AgNO_3(s)$ ? (3 marks T, 1 mark C)

$$\begin{aligned} & 200g \text{ } AgNO_3 \\ & = \frac{200g}{(107.87 + 14 + 3 \times 16) \text{ g/mol}} \\ & = 1.18 \text{ mol } AgNO_3 \times 1 \\ & = 1.18 \text{ mol } Ag \times 107.87 \text{ g/mol} = 127.39 \text{ g } Ag \end{aligned}$$

So there is 127g of silver in silver nitrate

4. A class of compounds called sodium metaphosphates were used as additives to detergents to improve cleaning ability. One of them has a molar mass of 612g/mol. Analysis shows the composition to be 22.5% Na, 30.4% P, and 47.1% O.

a) Determine the empirical formula of the compound. (3 marks T, 1 mark C)

$$\begin{aligned} & \begin{array}{ccc} 22.5\% \text{ Na} & 30.4\% \text{ P} & 47.1\% \text{ O} \\ \hline 1 & 1.35 & 2.09 \\ \hline \times 3 & \times 3 & \times \\ \hline = 3 & 4 & 6 \\ \hline = Na_3 P_4 O_6 \end{array} \end{aligned}$$

b) Determine the molecular formula of this compound. (2 marks T, 1 mark C)

$$\begin{aligned} MM &= (22.99 \times 3 + 4 \times 30.97 + 6 \times 16.00) \\ &= 288.85 \text{ g/mol} \end{aligned}$$

$$\text{Multiplier} = \frac{612 \text{ g/mol}}{288.85 \text{ g/mol}} = 2.12 \times = 2 \times$$



4T + 1SC

$$25.8\% = \frac{16 \text{ g/mol} \times 100}{2x + 16 \text{ g/mol}}$$

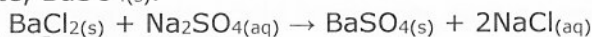
$$\frac{16}{0.258} = 2x + 16$$

$$62 = 2x + 16$$

$$x = \frac{62 - 16}{2}$$

$$= 23 \text{ g/mol}$$

6. An impure sample of barium chloride,  $\text{BaCl}_2$ , with a mass of 4.36 g, is added to an aqueous solution of sodium sulfate,  $\text{Na}_2\text{SO}_4$ . This results in the formation of a precipitate of barium sulfate,  $\text{BaSO}_4$ .



After the reaction is complete, the solid barium sulfate,  $\text{BaSO}_4$ , is filtered and dried. Its mass is found to be 2.62 g. Calculate what mass of barium chloride was contained in the original (impure) sample? (4 marks T, 1 mark C)

4-36

$$\frac{2.62 \text{ g}}{233.4 \text{ g/mol}}$$

$\text{BaSO}_4$

$$= 0.0112 \text{ mol BaSO}_4$$

1:1

$$= 0.0112 \text{ mol BaCl}_2$$

$$\times 208.23 \text{ g/mol}$$

$$= 2.33 \text{ g of BaCl}_2 \checkmark$$

$$4.36 \text{ g of impure BaCl}_2 - 2.33 \text{ g theoretical amount}$$

$$= 1.87 \text{ g BaCl}_2 \times$$

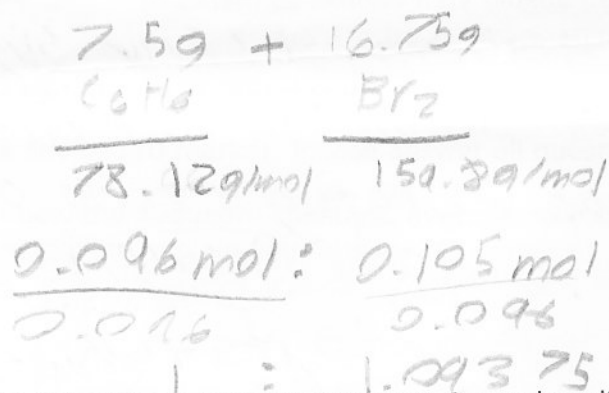
3T + 1C

30 There was 1.87 g  $\text{BaCl}_2$  out of the impure substance.

6T + 1.5C

7. 7.50 g of benzene,  $C_6H_6$  reacts with 16.75  $Br_2$  to form bromobenzene,  $C_6H_5Br$ . ( $C_6H_6(g) + Br_2(g) \rightarrow C_6H_5Br(g) + HBr(g)$ )

a) What is the limiting reactant? (3 marks T, 1 mark C)



So There is an excess of Bromine  
So the limiting reactant is benzene

3T+1C

b) What mass of bromobenzene, is produced? (2 marks T, 1 mark C)

0.096 mol of each substance reactant is used

0.096 mol of bromobenzene

$$0.096 mol \times 157.01g/mol = 15.1g$$

So The mass

of bromobenzene is 15.1g ✓

c) What is the mass of the unused excess reactant? (2 marks T, 1 mark C)

$$\Delta_{\text{excess}} = 0.105 mol - 0.096 mol = 0.009 mol Br_2$$

$$0.009 mol \cdot 159.8g/mol = 1.4g$$

So There is 1.4g of excess Bromine

8. The following reaction proceeds with a 92.4% yield.  $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

How many grams of calcium oxide can the chemist expect to obtain if 12.4 g of calcium carbonate is heated? (3 marks T, 1 mark C)

$$\begin{array}{r} 12.4g \\ CaCO_3 \\ \hline 100.09g/mol \\ = 0.1239 mol CaCO_3 \\ \times 92.4\% \\ = 0.1145 mol CaCO_3 \times 1 \\ 1:1 \end{array}$$

$$= 0.1145 mol CaO$$

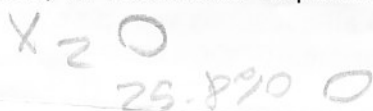
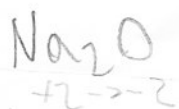
$$= 5.104g/mol CaO$$

So The chemist can expect

6.41g of CaO with a 92.4% yield ✓

3T+1C

5. A compound contains an unknown element X. This element forms an oxide with chemical formula  $X_2O$ . Experimental tests show that  $X_2O$  contains 25.8 % oxygen, by mass. What is the identity of element X? Explain. (3 marks T, 1 mark C)



$25.8\% = \frac{16 \text{ g/mol}}{2x + 16 \text{ g/mol}} \times 100$

$\frac{16}{0.258} = 2x + 16$

$62 = 2x + 16$

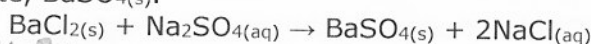
$x = \frac{62 - 16}{2}$

$= 23 \text{ g/mol}$   
which is 23 g/mol

So the identity of the substance is sodium, this is solved with basic math if oxygen is 25.8% then the formula is  $25.8\% = \frac{16 \text{ g/mol}}{2x + 16 \text{ g/mol}}$  If you solve for X, X = the molar mass of substance

3T+1C

6. An impure sample of barium chloride,  $BaCl_2$ , with a mass of 4.36 g, is added to an aqueous solution of sodium sulfate,  $Na_2SO_4$ . This results in the formation of a precipitate of barium sulfate,  $BaSO_4$ .



After the reaction is complete, the solid barium sulfate,  $BaSO_4$ , is filtered and dried. Its mass is found to be 2.62 g. Calculate what mass of barium chloride was contained in the original (impure) sample? (4 marks T, 1 mark C)

4.36

$\frac{2.62 \text{ g}}{233.4 \text{ g/mol}} BaSO_4$

$= 0.0112 \text{ mol } BaSO_4$

1:1

$= 0.0112 \text{ mol } BaCl_2$   
 $\times 208.23 \text{ g/mol}$

$= 2.33 \text{ g of } BaCl_2$

$4.36 \text{ g of impure } BaCl_2 - 2.33 \text{ g theoretical amount}$

$= 1.87 \text{ g } BaCl_2$

3T+1/2C

So there was 1.87 g  $BaCl_2$  out of the impure substance.

7. 7.50 g of benzene,  $C_6H_6$  reacts with 16.75  $Br_2$  to form bromobenzene,  $C_6H_5Br$ . ( $C_6H_6(g) + Br_2(g) \rightarrow C_6H_5Br(g) + HBr(g)$ )

a) What is the limiting reactant? (3 marks T, 1 mark C)

$$\begin{array}{r} 7.5g \\ C_6H_6 \\ \hline 78.12g/mol \\ 0.096 mol \end{array} \quad \begin{array}{r} 16.75g \\ Br_2 \\ \hline 159.8g/mol \\ 0.105 mol \end{array}$$

$$\frac{0.096 mol}{0.096} : \frac{0.105 mol}{0.096}$$

$$1 : 1.09375$$

∴ There is an excess of Bromine  
∴ the limiting reactant is benzene

3T+1C

b) What mass of bromobenzene, is produced? (2 marks T, 1 mark C)

0.096 mol of each ~~substance~~ reactant is used

0.096 mol of bromobenzene

0.096 mol  $\times$  157.01 g/mol = 15.1 g

∴ The mass of bromobenzene is 15.1 g ✓

2T+1C

c) What is the mass of the unused excess reactant? (2 marks T, 1 mark C)

$\Delta_{\text{excess}} = 0.105 mol - 0.096 mol = 0.009 mol Br_2$

$0.009 mol \cdot 159.8 g/mol = 1.4 g$

∴ There is 1.4 g of excess Bromine

2T+1C

8. The following reaction proceeds with a 92.4% yield.  $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

How many grams of calcium oxide can the chemist expect to obtain if 12.4 g of calcium carbonate is heated? (3 marks T, 1 mark C)

$$\begin{array}{r} 12.4g \\ CaCO_3 \\ \hline 100.09g/mol \\ 0.1239 mol \\ \times 92.4\% \\ 0.1145 mol \\ CaCO_3 \times 1 \\ 1:1 \\ 0.1145 mol \\ CaO \\ \times 56.04g/mol \\ CaO \end{array}$$

∴ The chemist can expect 6.41 g of CaO with a 92.4% yield ✓

3T+1C

10T+3.5C

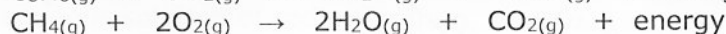
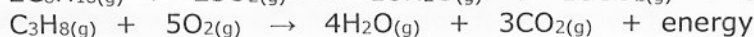
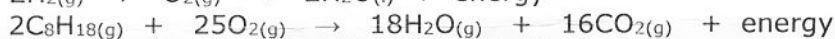
### Part C: Application

9. Gold can be extracted from ore containing gold(III) sulfide by passing hydrogen gas through the ore:  $\text{Au}_2\text{S}_3(\text{s}) + 3\text{H}_2(\text{g}) \rightarrow 3\text{H}_2\text{S}(\text{g}) + 2\text{Au}(\text{s})$   
Based on the chemical equation, which reagent should be the limiting reagent in order for this process to be most profitable? Justify your choice. (3 marks A)

For this reaction gold(III) sulfide should be the limiting reagent, hydrogen is extremely abundant and cheap so having excess of it is not a problem however gold(III) sulfide is expensive so it should be used up to its fullest in the reaction.

3A

10. There are a number of fossil fuels that are burned for energy consumption. Hydrogen has also been proposed as a fuel for automobiles and, unlike fossil fuels, it produces only water. For the reactions listed below:



Explain which of the above fuels would be cleaner burning and more environmentally friendly. (3 marks A)

The synthesis of hydrogen and oxygen to create only water is the most efficient. All the other fuels reactions form carbon dioxide, a harmful greenhouse gas while this reaction forms water.

Not only this but it uses simple abundant reactants like hydrogen and oxygen while the others require hydrocarbons which can be damaging to the environment when harvested/mined. Finally water is easy to dispose of.

11. Imagine that you are a lawyer. You are representing a client charged with possession of a controlled substance. The prosecutor introduces, as a forensic evidence, the empirical formula of the substance that was found in your client's possession. How would you deal with the evidence as a lawyer for defence? Support your answer with examples. (3 marks A)

I would argue that the prosecutor is misleading the jury, an empirical formula does not fully represent the properties of a compound, the molecular formula must be shown.

2A

Not only this but just showing a formula is misleading sodium and chlorine are both very dangerous but when combined it makes simple table salt. Methane ( $\text{CH}_4$ ) is a highly dangerous.

and can cause