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CALCULATIONS FROM CHEMICAL EQUATIONS

From the previous lesson, do you remember what does a chemical reaction tells us?

Below is an example of an equation:

Methane + Oxygen → Carbon dioxide + Water

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Reactants

Products

1 molecule

2 molecules

1 molecule

2 molecules

1 mole

2 mole

1 mole

2 mole

Ratio of the moles of reactants and products

Reacting Masses

How to calculate reacting masses?

- ☑Mass of one substance must be given.
- ☑Balanced equation.
- ☑Ratio of moles from the equation.
- ☑No. of moles.

- **Example 1:**

Calculate the mass of *water* produced from the complete combustion of 0.25 mol of *methane*.

Solution:

Step 1: Balanced equation	**CH_4 (g) + 2O_2 (g) → CO_2(g) + 2H_2O(l)**
Step 2: Mole ratio	1 : 2
Step 3: Find no.of moles	No. of moles of CH_4 = 0.25 mol 0.25 mol : x x = (0.25 X 2) / 1 = 0.5 mol. ❖No. of moles of H_2O = 0.5 mol.
Step 4: Find mass	*Mass of H_2O:* No. of moles = $\frac{\text{Mass (g)}}{\text{Molar mass (g) or Mr}}$ Mass (g) = No.of moles X Molar mass or Mr =0.5 mol X 18 (g) = 9 g.

- **Example 2:**
- To obtain iron, iron(III) oxide reacts with carbon monoxide according to the equation:

$$Fe_2O_3\,(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$$

What mass of iron is produced from 40g of iron (II) oxide?

Solution:

Step 1: Balanced equation	**Fe_2O_3 (s) + 3CO(g) → 2Fe(l) + 3CO_2(g)**
Step 2: Mole ratio	1 : 2
Step 2.5*: Calculate no. of moles	Mass of Fe_2O_3 = 40g Molar mass = (2x56) + (3x16) = 160g No. of moles of Fe_2O_3 : $\frac{\text{Mass (g)}}{\text{Molar mass}}$ $\frac{40}{160}$ <u>=0.25 mol</u>
Step 3: Find no. of moles	1 : 2 0.25mol : x x = (0.25 x 2) / 1 = 0.50 mol ❖No. of moles of Fe = 0.50 mol.
Step 4: Find mass	<u>*Mass of Fe:*</u> No. of moles = $\frac{\text{Mass (g)}}{\text{Molar mass or Mr}}$ Mass (g) = No. of moles x Molar mass or Mr = 0.50 mol x 56g = 28 g.

How about calculating volumes of gases produced or used in reactions.

- Same procedure!

- Must be there:

☑ Mass /volume of one substance must be given.

☑ Balanced equation.

☑ Ratio of moles from the equation.

☑ No. of moles.

- Example 1:

Magnesium reacts with hydrochloric acid according to the equation:

$$Mg\ (s) + 2HCl\ (aq) \rightarrow McCl_2\ (aq) + H_2\ (g)$$

Calculate the **volume** of *hydrogen* gas, measured at room conditions, produced from the reaction of **14.6g** of *hydrochloric acid*.

- ***Solution:***

Step 1: Balanced equation	$\mathbf{Mg(s) + 2HCl(aq) \rightarrow McCl_2\,(aq) + H_2(g)}$
Step 2: Mole ratio	2 : 1
Step 2.5*: Calculate no. of moles	Mass of HCl = 14.6g Molar mass = 1 + 35.5 = 36.5g No. of moles of HCl : $\dfrac{\text{Mass (g)}}{\text{Molar mass}}$ $\dfrac{14.6}{36.5}$ <u>= 0.4 mol</u>
Step 3: Find no. of moles	2 : 1 0.4 mol : x x = (0.4 x 1) / 2 = 0.2 mol ❖No. of moles of H_2 = 0.2 mol.
Step 4: Find volume	<u>*Volume of H_2:*</u> No. of moles = $\dfrac{\text{Volume (dm}^3)}{\text{Molar volume (dm}^3)}$ Volume (dm^3) = No. of moles x Molar volume = 0.2 mol x $24dm^3$ = $4.8dm^3$.

Example 2:

Lead (IV) oxide, PbO_2, decomposes when heated strongly. The equation for the reaction is:

$$2PbO_2 (s) \rightarrow 2PbO (s) + O_2 (g)$$

Calculate the **mass** of *lead (IV) oxide* that decomposes to produce **1.2dm³** of *oxygen*, measured at room conditions.

Solution:

Step 1: Balanced equation	**$2PbO_2\ (s) \rightarrow 2PbO\ (s) + O_2\ (g)$**
Step 2: Mole ratio	2 : 1
Step 2.5*: Calculate no. of moles	Volume of O_2 = 1.2 dm^3 Molar volume = 24 dm^3 No. of moles of O_2 : $\dfrac{\text{Volume } (dm^3)}{\text{Molar volume } (dm^3)}$ $\dfrac{1.2}{24}$ <u>= 0.05 mol</u>
Step 3: Find no. of moles	2 : 1 x : 0.05 mol x = (0.05 x 2) / 1 = 0.10 mol ❖No. of moles of PbO_2 = 0.10 mol.
Step 4: Find mass	<u>*Mass of PbO2:*</u> Molar mass of PbO_2 = 207 + (2x16)= 239 No. of moles = $\dfrac{\text{Mass (g)}}{\text{Molar Mass (g) or Mr}}$ Mass (g) = No. of moles x Molar Mass or Mr = 0.10 mol x 239 = 23.9 g

Limiting reactants/reagents

- It is the chemical that is completely consumed in a reaction.
- The reaction stops as soon as the limiting reactant is totally consumed.
- The limiting reactant limits the amount of products formed.
- Check for limiting reactant when the quantities of **two** (or **more**) reactants are given.
- Calculation: Always involves **<u>no. of moles.</u>**

Example 1:

In the Haber process, ammonia is manufactured from nitrogen and hydrogen. A mixture of 5 moles of nitrogen and 10 moles of hydrogen were allowed to react according to the following equation:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Which substance is the limiting reagent?

- ***Solution:***

Mole ratio from equation:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

1 : 3

From the quantities given:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

5 : 10

No. of moles of NH_3 (Products):

Using mole ratio N_2 = $(5 \times 2) / 1 = 10$ mol.

Using mole ratio H_2 = $(10 \times 2) / 3 = 6.67$ mol.

- The lowest no. of moles produced is the limiting reactants.
- Excess of N_2, limiting reagent/reactant is H_2.