STOICHIOMETRY
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Stoichiometry: calculations of the quantities of reactants and products involved in a chemical reaction.

Based on:
1. Balanced chemical equation (mole ratio)
2. Relationship between mass and moles
3. Proportional thinking

Consider the industrial process by which NH_3 is obtained:

1 $N_2(g)$	+	**3** $H_2(g)$	→	**2** $NH_3(g)$
1 molecule		**3** molecules		**2** molecules
100 molecules		**300** molecules		**200** molecules
1 million molecules		**3** million molecules		**2** million molecules
1 x 6.023×10^{23} molecules	+	**3** x 6.023×10^{23} molecules	→	**2** x 6.023×10^{23} molecules

1 mole N_2 molec ules + 3 moles H_2 molec ules 2 moles NH_3 molec ules

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Note: The mole ratio is given by the coefficients of the balanced chemical equation.

Example 1:

How many moles of nitrogen will react with 2.4 moles of hydrogen ?

$$\mathbf{1}N_2(g) + \mathbf{3}\ H_2(g) \longrightarrow \mathbf{2}\ NH_3(g)$$

$$?\ \text{moles } N_2 = 2.4\ \text{moles}H_2 \times \frac{\textbf{1 mole } N_2}{\textbf{3 moles } H_2} = 0.80\ \text{moles } N_2$$

Mole Ratio

Example 2:

How many moles of NH_3 can be produced from 32 moles of hydrogen ? (Assume there is plenty nitrogen available)

$$\mathbf{1}N_2(g) + \mathbf{3}\ H_2(g) \longrightarrow \mathbf{2}\ NH_3(g)$$

$$?\ \text{moles } NH_3 = 32\ \text{moles}H_2 \ \frac{\qquad}{\qquad} = \qquad \text{moles } NH_3$$

Example 3:

Butane, C_4H_{10}, burns with the oxygen in air to give carbon dioxide and water. How many moles of carbon dioxide are produced from 0.15 moles C_4H_{10}

(Assume sufficient amount of oxygen is available)

$$\mathbf{2}\ C_4H_{10}(g) + \mathbf{13}\ O_2(g) \longrightarrow \mathbf{8}CO_2(g) + \mathbf{10}\ H_2O(g)$$

$$?\ \text{moles } CO_2 = 0.15\ \text{mole}C_4H_{10} \times \frac{\qquad}{\qquad} = \qquad \text{mole } CO_2$$

- Quantities of reactants and products may also be expressed in grams.
- The reasoning is similar, but the conversion from the given quantity to the quantity we are looking for should be done through the mole ratio.

Mass ⟶ Moles

Consider the following balanced equation:

$$6\,ClO_2(g) + 3\,H_2O(l) \longrightarrow 5\,HClO_3(aq) + 1\,HCl(aq)$$

How many **moles of $HClO_3$** are produced from **14.3 g of ClO_2** ? (Assume excess amount of water)

$$?\ \text{mole } HClO_3 = 14.3\ \text{g } ClO \times \frac{1\ \text{mole } ClO_2}{67.45\ \text{g } ClO_2} \times \frac{5\ \text{mole } HClO_3}{6\ \text{mole } ClO_2} = 0.177\ \text{mole } HClO_3$$

Example 1:

How many moles of water are required to produce 30.0 g of $HClO_3$?

Moles ⟶ Mass

Acetylene gas, C_2H_2, is produced in a reaction between calcium carbide, CaC_2, and water, according to the following equation:

$$1\ CaC_2(s) + 2\ H_2O(l) \longrightarrow 1\ C_2H_2(g) + 1\ Ca(OH)_2(aq)$$

How many **grams of C_2H_2** can be obtained from **0.500 mole CaC_2** ? (Assume an excess of water)

$$? \text{ g } C_2H_2 = 0.500\ \cancel{\text{mole } CaC_2} \times \frac{1\ \cancel{\text{mole}C_2H_2}}{1\ \cancel{\text{mole}CaC_2}} \times \frac{26.04 \text{ g } C_2H_2}{1\ \cancel{\text{mole}C_2H_2}} = 13.0 \text{ g } C_2H_2$$

Example 2:

How many grams of iron are required to produce 3.90 mol of Fe_2O_3 as shown below:

$$4\ Fe(s) + 3\ O_2\ (g) \longrightarrow 2\ Fe_2O_3\ (s)$$

Mass → Mass

A sample of solid sodium hydrogen carbonate is reacted with excess hydrochloric acid and produces a white solid residue (sodium chloride) and two gaseous products (carbon dioxide and water vapor).

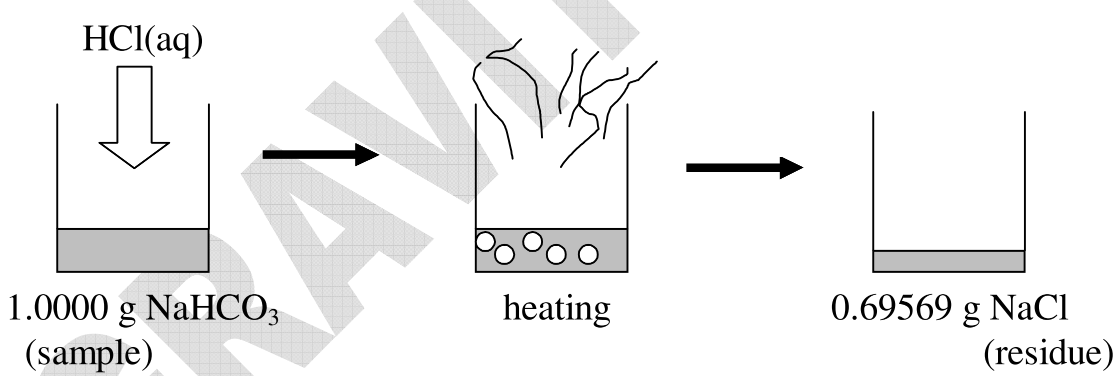
1. Write a balanced chemical equation for this reaction. Include state designations.

$$1\ NaHCO_3(s) + 1\ HCl(aq) \rightarrow 1\ NaCl(s) + 1\ CO_2(g) + 1\ H_2O(g)$$ BALANCED

2. Calculate the **mass of solid residue (NaCl)** obtained from **1.0000 g $NaHCO_3$**

$$\textbf{? g NaCl} = \textbf{1.0000 g } \mathbf{NaHCO_3} \times \frac{1 \text{ mole } NaHCO_3}{84.007 \text{ g } NaHCO_3} \times \frac{1 \text{ mole NaCl}}{1 \text{ mole } NaHCO_3} \times \frac{58.443 \text{ g NaCl}}{1 \text{ mole NaCl}} = \textbf{0. 69569 g NaCl}$$

3. How much is the total mass of the gaseous products (**$CO_2 + H_2O$**) given off ?



Mass of **($CO_2 + H_2O$)** given off = 1.0000 g $NaHCO_3$ - 0.69569 g NaCl = **0.3043 g**

SUMMARYOFSTOICHIOMETRICCALCULATIONS

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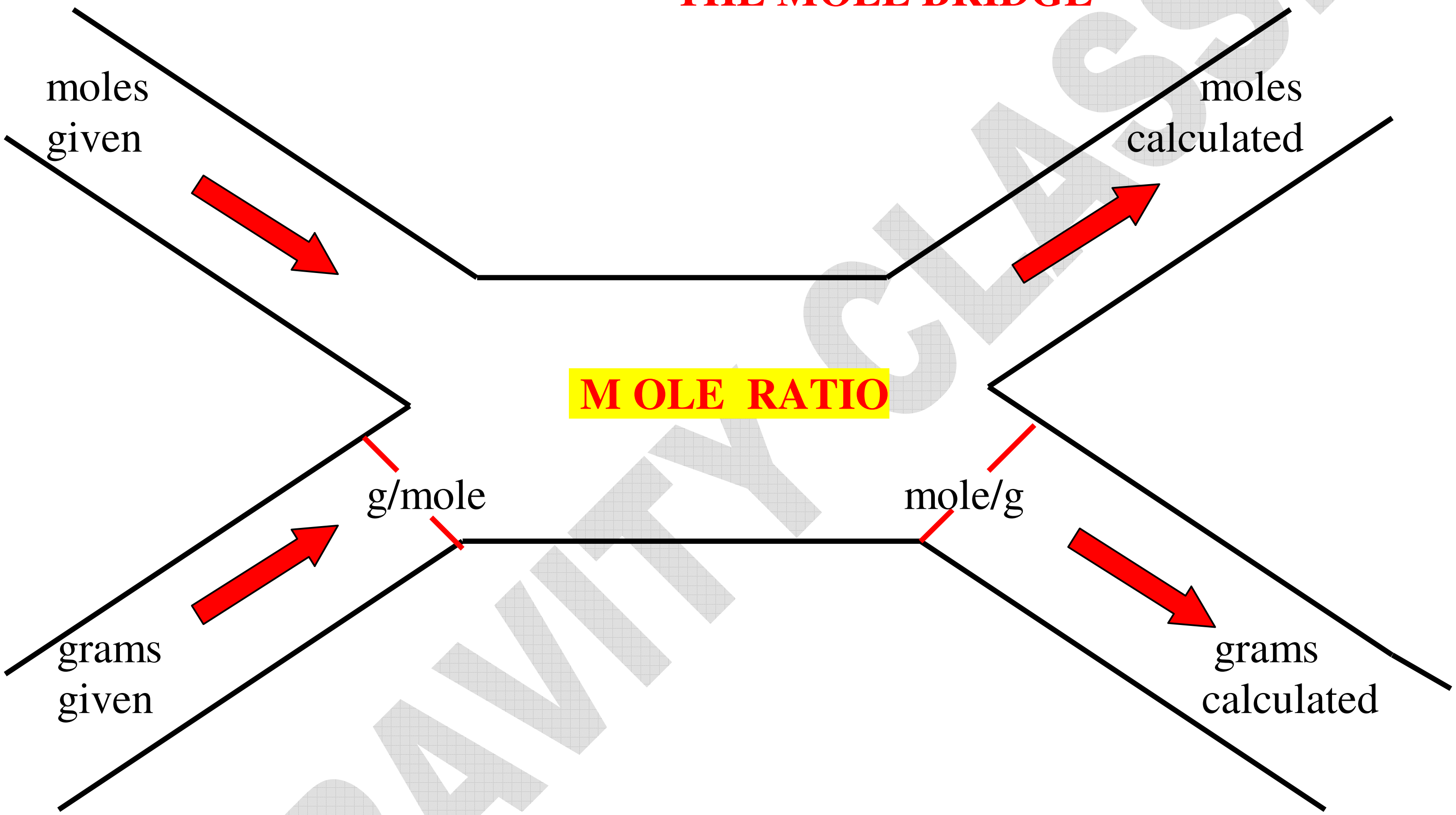

ALL STOICHIOMETRIC CALCULATIONS ARE BASED ON THE MOLE RATIO