STOICHIOMETRY
QUANTITATIVE RELATIONS IN CHEMICAL REACTIONS

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 x 10^{23} molecules	+	**3** x 6.023 x 10^{23} molecules	⟶	**2** x 6.023 x 10^{23} molecules

1 mole N_2 molecules + 3 moles H_2 molecules ⟶ 2 moles NH_3 molecules

THIS IS THE MOLE RATIO BETWEEN REACTANTS AND PRODUCTS

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 ?

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

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

Mole Ratio

Example 2:

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

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

$$\text{? moles } NH_3 = 32\ \cancel{\text{moles } H_2} \times \frac{\quad}{\quad} = \quad \text{moles } NH_3$$

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)

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

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

- 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:

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

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

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:

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

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

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

Example 2:

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

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

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).

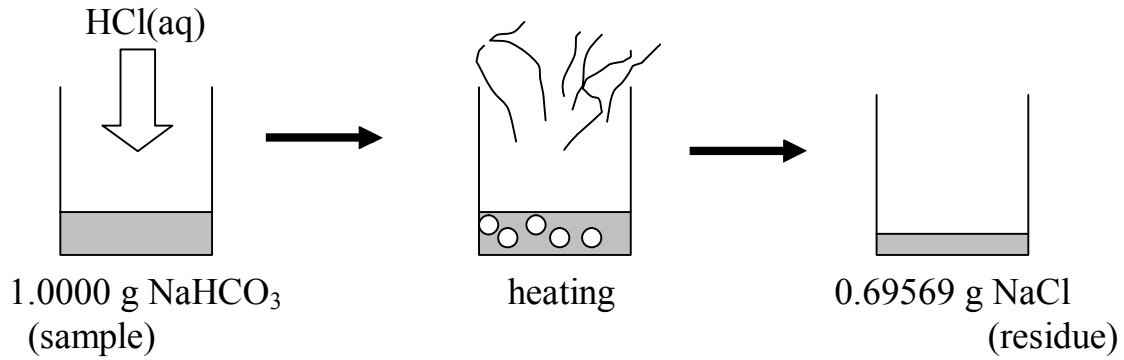
1. Write a balanced chemical equation for this reaction. Include state designations.

1 $NaHCO_3(s)$ + **1** $HCl(aq) \longrightarrow$ 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 $NaHCO_3$**

$$\text{? g NaCl} = 1.0000\text{ g } NaHCO_3 \times \frac{1\text{ mole } NaHCO_3}{84.007\text{ g } NaHCO_3} \times \frac{1\text{ mole NaCl}}{1\text{ mole } NaHCO_3} \times \frac{58.443\text{ g NaCl}}{1\text{ mole NaCl}} = 0.69569\text{ g NaCl}$$

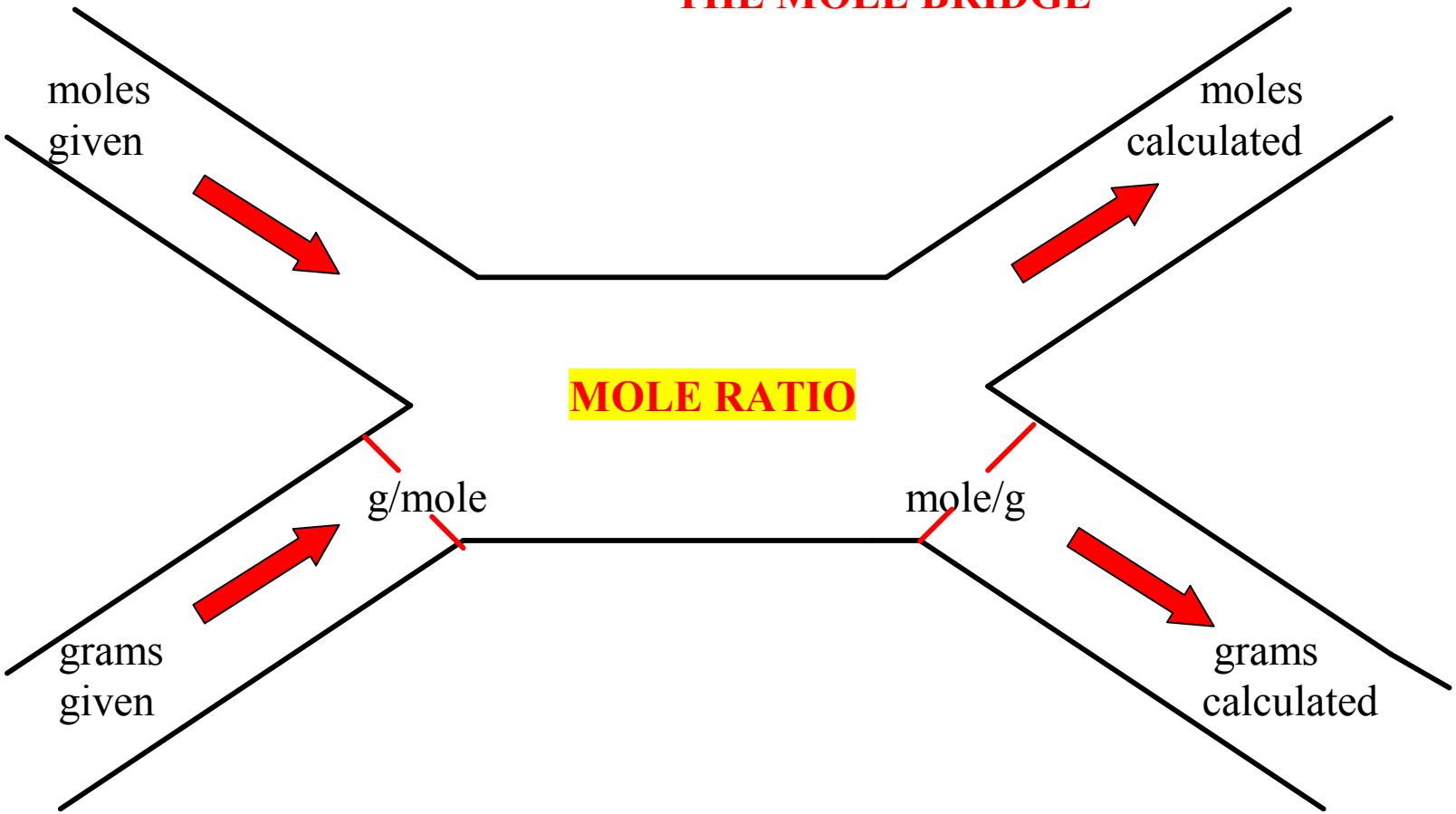
3. How much is the total mass of the gaseous products ($CO_2 + H_2O$) given off ?



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

SUMMARY OF STOICHIOMETRIC CALCULATIONS

THE MOLE BRIDGE



ALL STOICHIOMETRIC CALCULATIONS ARE BASED ON THE MOLE RATIO