Teaching and Learning Center
UNIVERSITY OF WASHINGTON TACOMA

CHEMISTRY I (TESC 141) STUDY GUIDE

MOLES/ STOICHIOMETRY

Mole- a unit of measurement that expresses the amount of atoms, molecules or some other unit. The number of items in one mole is commonly referred to **Avogadro's number** which equals 6.022×10^{23}. Example: One mole of carbon equals 6.022×10^{23} atoms or particles of carbon.

Molar Mass- the mass of one mole of a substance (usually reported in grams per mole). Example: one mole of H_2O is 18.0 g/mol.

Stoichiometry- the quantitative relationship between the reactants and products in a chemical reaction. Example:

2 $Ca_3(PO_4)_2$ + $6SiO_2$ + 10C → **1**P_4 + $6CaSiO_3$ + 10CO

From the above equation, we can determine that for every two moles of $Ca_3(PO_4)_2$ that react, one mole of P_4 will be produced. Therefore, the **molar ratio** between $Ca_3(PO_4)_2$ and P_4 is **2:1.**

We can use molar ratios to calculate how much product is formed from a particular amount of reactant:

If 16.58 g of $Ca_3(PO_4)_2$ reacts, how much CO will form?

$$16.58\ g\ of\ Ca_3PO_4 \times \frac{1\ mol\ of\ Ca_3PO_4}{310.18\ g\ Ca_3PO_4} \times \frac{10\ mol\ of\ CO}{2\ mol\ of\ Ca_3PO_4} \times \frac{28.0\ g\ of\ CO}{1\ mol\ of\ CO} = 7.48\ g\ of\ CO$$

mass of reactant x 1/molar mass of reactant x molar ratio x molar mass of product = mass of product

Limiting reactant- the reactant that gets completely consumed or 'used up' in a reaction. Other reactants that do not get 'used up' are said to be 'in excess'.

Example: If 12.25 g of NaOH is combined with 10.62 g of H_3PO_4 in the following reaction, which reactant is limiting?

3NaOH + H_3PO_4 → Na_3PO_4 + $3H_2O$

Step 1. Convert each reactant into moles by dividing grams by the molar mass of the reactant:

$$\frac{12.25\ g\ of\ NaOH}{40.0\frac{g}{mol}\ NaOH} = 0.306\ moles\ of\ NaOH$$

$$\frac{10.62\ g\ of\ H_3PO_4}{98.0\frac{g}{mol}H_3PO_4} = 0.108\ moles\ of\ H_3PO_4$$

Step 2. We can't determine limiting reactant based solely on the amount of moles of each reactant. We must look at molar ratios between each reactant and a product to determine the limiting reactant (Here we will use H_2O, though you can also use Na_3PO_4):

0.306 moles of NaOH x $\frac{3\ mol\ of\ H_2O}{3\ mol\ of\ NaOH}$ = 0.306 moles of H_2O

0.108 moles of H_3PO_4 x $\frac{3\ mol\ of\ H_2O}{1\ mol\ of\ H_3PO_4}$ = 0.324 moles of H_2O

NaOH is the limiting reactant because the amount given (12.25 g), produces only 0.306 moles of H_2O; while the given amount of H_3PO_4 (10.62 g) produces 0.324 moles of H_2O.

Note: You can recognize a limiting reactant problem by the fact that more than one reagent amount is given in the problem (i.e 22 g of $CuCl_2$ is combined with 4.5 moles of KOH. How much product is formed?)

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IDEAL GAS LAWS

Gases are fluid and compressible which allows them to assume the volume and shape of the container. Due to the compressibility of gas, changes in pressure (P), volume (V), temperature (T), and number of moles (n) can be calculated using different gas laws.

Boyle's Law- relates pressure to volume when temperature is held constant. The volume of a gas increases when pressure decreases (and vice versa):

$$P_1V_1 = P_2V_2$$

Charles's Law- relates volume of gas to temperature when pressure is held constant. The volume of a gas increases directly with an increase in temperature (in Kelvin):

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Avogadro's Law- relates the number of moles of gas present with volume when both temperature and pressure are held constant. The volume of gas increases when number of moles of gas increases:

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Ideal Gas Law- the above laws are combined to create the Ideal Gas Law:

$$PV = nRT$$

Where R is the gas constant and equals 0.08206 atm *L/ mol*K.

The ideal gas law can be modified to calculate mass (m) in grams, molar mass (*M)* in g/mol, or density *d* in g/mL:

$$PVM = mRT$$

$$PM = dRT$$

EQUILIBRIUM

When a chemical reaction has reached **equilibrium**, the concentrations of both products and reactants no longer change because the rate of the forward reaction equals the rate of the reverse reaction.

For the general chemistry equation:

$aA + bB \rightarrow cC + dD$

the equilibrium constant expression is:

$$K_c = \frac{[C]^c[D]^d}{[A]^a\,[B]^b}$$

Where the uppercase letters in brackets represent concentrations of the reactants and products while the lowercase letters represent the coefficients in the balanced equation.

When the reaction has not reached equilibrium yet, we calculate the **reaction quotient *(Q)*,** using the same equations as above. Instead of calculating a K we calculate Q. Once we calculate Q, we can compare it to K to determine the direction of the reaction:

If $Q < K$, the reaction goes towards products (to the right)

If $Q > K$, the reaction goes towards reactants (to the left)

If $Q=K$, the reaction is at equilibrium