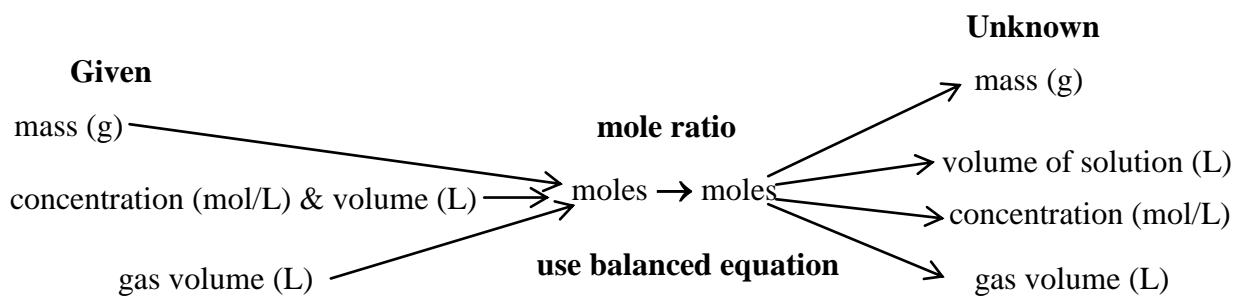


Chemistry 20

Lesson 21 – Stoichiometry II

I. Solution stoichiometry

Solution stoichiometry is essentially no different than gravimetric stoichiometry. The basic process of converting to moles, using the mole ratio, and then calculating the unknown is essentially the same.

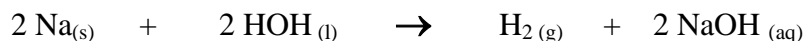


Example 1

What mass of sodium is required to react with water to form 400 mL of a 0.10 mol/L solution of sodium hydroxide?

Step 1 – read the question

Step 2 – write the balanced equation



$$m_{\text{Na}} = ?$$

$$c_{\text{NaOH}} = 0.10 \text{ mol/L}$$

$$v_{\text{NaOH}} = 0.400 \text{ L}$$

$$n_{\text{NaOH}} = c_{\text{NaOH}} \times v_{\text{NaOH}}$$

$$n_{\text{NaOH}} = 0.10 \text{ mol/L} (0.400 \text{ L})$$

$$n_{\text{NaOH}} = 0.040 \text{ mol}$$

Step 3 – list given and unknown quantities

Step 4 - convert to moles

Step 6 – calculate mass

$$m_{\text{Na}} = n_{\text{Na}} M_{\text{Na}}$$

$$m_{\text{Na}} = 0.040 \text{ mol} (22.99 \text{ g/mol})$$

$$m_{\text{Na}} = \mathbf{0.92 \text{ g}}$$

$$\frac{n_{\text{Na}}}{2} = \frac{n_{\text{NaOH}}}{2}$$

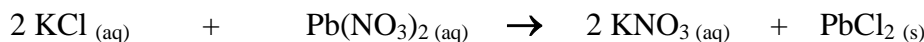
$$\frac{n_{\text{Na}}}{2} = \frac{0.040 \text{ mol}}{2}$$

$$n_{\text{Na}} = 0.040 \text{ mol}$$

Step 5 - set up mole ratio

Example 2

If 52.5 mL of a 1.25 mol/L solution of potassium chloride is required to completely react with 25.0 mL of a lead (II) nitrate solution, what is the concentration of the lead (II) nitrate solution?



$$c_{\text{Pb}(\text{NO}_3)_2} = 0.0525 \text{L}(\text{KCl}) \times \frac{1.25 \text{mol}(\text{KCl})}{1 \text{L}(\text{KCl})} \times \frac{1 \text{mol}(\text{Pb}(\text{NO}_3)_2)}{2 \text{mol}(\text{KCl})} \times \frac{1}{0.0250 \text{L}(\text{Pb}(\text{NO}_3)_2)} = \mathbf{1.31 \text{mol/L}}$$

II. Percent Error and Percent Yield

A particular type of chemical reaction involves the mixing of two solutions whereon a solid forms. The solid that forms is called the **precipitate** and this type of reaction is called a **precipitate reaction**. To determine if the product of a reaction is a solid or not, we use the solubility table that we learned about in Lesson 17. For example, when solutions of silver nitrate and sodium iodide are combined, a double replacement reaction occurs.



When we use the solubility table we find that NaNO_3 is soluble and AgI is not soluble in water. Therefore we write the chemical reaction as



and silver iodide is the precipitate.

Note: From now on you will be required to provide all states of matter in all chemical equations.

When we perform a stoichiometric calculation for a precipitate reaction, our calculation predicts the **theoretical yield** of the reaction. In other words, the calculation predicts the mass of precipitate what should occur. However, were we to actually perform the experiment and measure the actual **experimental yield**, one may find it to be different from the theoretical yield. In order to communicate this difference, a **percent error** calculation is used:

$$\% \text{error} = \frac{\text{experimental yield} - \text{theoretical yield}}{\text{theoretical yield}} \times 100 \%$$

For example, if the predicted amount of precipitate was calculated to be 15.0 g and the actual amount obtained in an experiment was 14.2 g, the % error would be:

$$\% \text{error} = \frac{\text{experimental yield} - \text{theoretical yield}}{\text{theoretical yield}} \times 100 \%$$

$$\% \text{error} = \frac{14.2 \text{g} - 15.0 \text{g}}{15.0 \text{g}} \times 100 \%$$

$$\% \text{error} = -5.3 \%$$

Note that a **negative** % error indicates that the experimental yield was **less** than the theoretical yield, and a **positive** % error indicates that the experimental yield was **greater** than the theoretical yield.

In most experiments, a percent error calculation is a measure of accuracy. In some experiments in which a product is collected and measured, a **percent yield** calculation is used instead of percent error. Using the example above, the percent yield would be:

$$\% \text{ yield} = \frac{\text{experimental yield}}{\text{theoretical yield}} \times 100 \%$$

$$\% \text{ yield} = \frac{14.2\text{g}}{15.0\text{g}} \times 100\%$$

$$\% \text{ yield} = 94.7 \%$$

Example 3

25.0 mL of a 0.963 mol/L solution of silver nitrate is added to a concentrated solution of sodium iodide. If 5.24 g of precipitate is recovered, what is the percent yield and the percent error?



$$m_{\text{AgI}} = 0.0250\text{L}(\text{AgNO}_3) \times \frac{0.963 \text{ mol}(\text{AgNO}_3)}{1\text{L}(\text{AgNO}_3)} \times \frac{1\text{mol}(\text{AgI})}{1\text{mol}(\text{AgNO}_3)} \times \frac{234.77\text{g}(\text{AgI})}{1\text{mol}(\text{AgI})} = \mathbf{5.65\text{g}}$$

The theoretical yield is 5.65 g.

$$\% \text{ yield} = \frac{\text{experimental yield}}{\text{theoretical yield}} \times 100 \%$$

$$\% \text{ yield} = \frac{5.24\text{g}}{5.65\text{g}} \times 100\%$$

$$\% \text{ yield} = \mathbf{92.7\%}$$

$$\% \text{ error} = \frac{\text{experimental yield} - \text{theoretical yield}}{\text{theoretical yield}} \times 100 \%$$

$$\% \text{ error} = \frac{5.24\text{g} - 5.65\text{g}}{5.65\text{g}} \times 100\%$$

$$\% \text{ error} = \mathbf{-7.29\%}$$

III. Assignment

1. What mass of copper is required to react completely with 250 mL of 0.100 mol/L silver nitrate solution?
2. A piece of aluminum is placed in a beaker containing 500 mL of sulfuric acid ($\text{H}_2\text{SO}_{4(aq)}$) solution. Using the data table below, calculate the concentration of the acid:
initial mass of aluminum 15.14 g
final mass of aluminum 9.74 g
3. A 200 g bar of magnesium metal is placed in 2.40 L of 6.00 mol/L hydrochloric acid ($\text{HCl}_{(aq)}$) solution. What is the final mass of the magnesium bar?
4. Chlorine gas is bubbled through 120 mL of 0.300 mol/L sodium bromide solution until the reaction is completed. How many moles of chlorine reacted?
5. 50.0 mL of a 0.670 mol/L ammonium hydroxide solution reacts with sufficient iron (III) chloride. If 1.135 g of precipitate is collected, what is the percent error?
6. 55.6 mg of gas is collected when 46.1 mL of 1.35 mol/L hydrobromic acid ($\text{HBr}_{(aq)}$) reacts with magnesium. What is the percent error?
7. A student poured 20.0 mL of a 1.75 mol/L solution of sodium sulfate into a sufficiently concentrated solution of barium hydroxide. If 6.17 g of precipitate is recovered, what is the percent yield?
8. What volume of 3.00 mol/L nitric acid ($\text{HNO}_{3(aq)}$) is required to neutralize 60.0 mL of 0.10 mol/L sodium hydroxide solution?
9. 25.0 mL of a 0.045 mol/L solution of barium hydroxide is added to a concentrated solution of aluminum sulfate. If 0.31 g of precipitate was actually recovered, what is the percent error?
10. A student obtained the following data from a reaction between $\text{Pb}(\text{NO}_3)_2(aq)$ and rubidium bromide:

mass of filter paper:	0.21 g
mass of paper & product:	6.83 g

What was the mass of rubidium bromide used?

11. A somewhat crazed and delinquent Chemistry 20 student decided to go on a chemical mixing rampage. The first solution contained 17.86 g of magnesium nitrate. The second solution contained 0.035 mol of Na_2SO_4 . She poured the two solutions into a sufficiently concentrated solution of barium hydroxide. What mass(es) of precipitate(s) form?