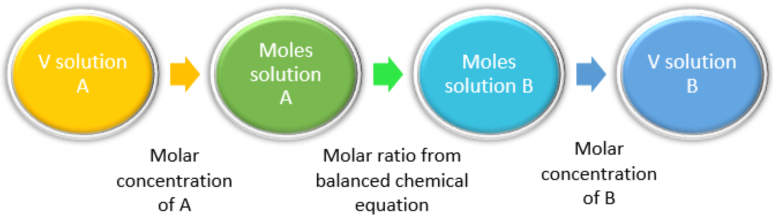
13.8: SOLUTION STOICHIOMETRY

LEARNING OBJECTIVES

- Determine amounts of reactants or products in aqueous solutions.

As we learned previously, double replacement reactions involve the reaction between ionic compounds in solution and, in the course of the reaction, the ions in the two reacting compounds are "switched" (they *replace* each other). Because these reactions occur in aqueous solution, we can use the concept of molarity to directly calculate the number of moles of reactants or products that will be formed, and therefore their amounts (i.e. volume of solutions or mass of precipitates).



As an example, lead (II) nitrate and sodium chloride react to form sodium nitrate and the *insoluble* compound, lead (II) chloride.

$$Pb(NO_3)_2(aq) + 2\,NaCl(aq) \rightarrow PbCl_2(s) + 2\,NaNO_3(aq) \tag{13.8.1}$$

In the reaction shown above, if we mixed 0.123 L of a 1.00 M solution of NaCl with 1.50 M solution of $Pb(NO_3)_2$, we could calculate the volume of $Pb(NO_3)_2$ solution needed to completely precipitate the Pb^{2+} ions.

The molar concentration can also be expressed as the following:

$$1.00\,M\,\text{NaCl} = \frac{1.00\,mol\ \text{NaCl}}{1\,L\ \text{NaCl solution}}$$

and

$$1.50\,M\,Pb(NO_3)_2 = \frac{1.50\,mol\ Pb(NO_3)_2}{1\,L\ Pb(NO_3)_2\text{solution}}$$

First, we must examine the reaction stoichiometry in the balanced reaction (Equation 13.8.1). In this reaction, one mole of $Pb(NO_3)_2$ reacts with two moles of NaCl to give one mole of $PbCl_2$ precipitate. Thus, the concept map utilizing the stoichiometric ratios is:

so the volume of lead (II) nitrate that reacted is calculated as:

$$0.123\,L\ \text{NaCl solution} \times \frac{1.00\,mol\ \text{NaCl}}{1\,L\ \text{NaCl solution}} \times \frac{1\,mol\ Pb(NO_3)_2}{2\,mol\ \text{NaCl}} \times \frac{1\,L\ Pb(NO_3)_2\ \text{solution}}{1.5\,mol\ Pb(NO_3)_2} = 0.041\ Pb(NO_3)_2\ L\ \text{solution}$$

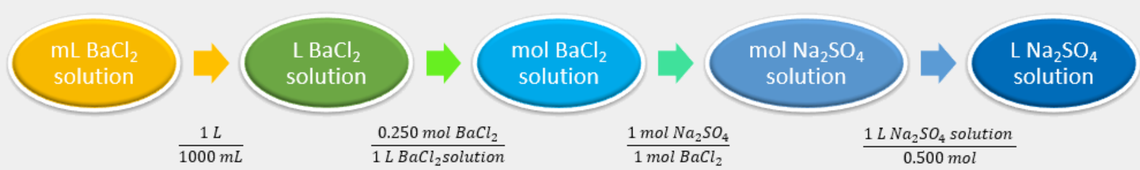
This volume makes intuitive sense for two reasons: (1) the number of moles of $Pb(NO_3)_2$ required is half of the number of moles of NaCl, based off of the stoichiometry in the balanced reaction (Equation 13.8.1); (2) the concentration of $Pb(NO_3)_2$ solution is 50% greater than the NaCl solution, so less volume is needed.

EXAMPLE 13.8.1

What volume (in L) of 0.500 M sodium sulfate will react with 275 mL of 0.250 M barium chloride to completely precipitate all Ba^{2+} in the solution?

Solution

Solutions to Example 13.8.1

Steps for Problem Solving	Example 13.8.1
Identify the "given" information and what the problem is asking you to "find."	Given: 275 mL $BaCl_2$ 0.250 M $BaCl_2$ or $\frac{0.250\ mol BaCl_2}{1\ L\ BaCl_2\ solution}$ 0.500 M Na_2SO_4 or $\frac{0.500\ mol Na_2SO_4}{1\ L\ Na_2SO_4\ solution}$ Find: Volume Na_2SO_4 solution.
Set up and balance the chemical equation.	$Na_2SO_4(aq) + BaCl_2(aq) \longrightarrow BaSO_4(s) + \underline{2}NaCl(aq)$ An insoluble product is formed after the reaction.
List other known quantities.	1 mol of Na_2SO_4 to 1 mol $BaCl_2$ 1000 mL = 1 L
Prepare a concept map and use the proper conversion factor.	
Cancel units and calculate.	$275\ \cancel{mL\ BaCl_2\ solution} \times \frac{1\ \cancel{L}}{1000\ \cancel{mL}} \times \frac{0.250\ \cancel{mol\ BaCl_2}}{1\ \cancel{L\ BaCl_2\ solution}} \times \frac{1\ \cancel{mol\ Na_2SO_4}}{1\ \cancel{mol\ BaCl_2}} \times \frac{1\ L\ Na_2SO_4\ solution}{0.500\ \cancel{mol Na_2SO_4}}$ = 0.1375 L sodium sulfate
Think about your result.	The lesser amount (almost half) of sodium sulfate is to be expected as it is more concentrated than barium chloride. Also, the units are correct.

? EXERCISE 13.8.1

What volume of 0.250 M lithium hydroxide will completely react with 0.500 L of 0.250 M of sulfuric acid solution?

Answer

0.250 L LiOH solution