Stoichiometry Tutorial

“If you know the number of moles of a substance, the balanced chemical equation allows you to determine the number of moles of all the other substances in the reaction.”

1. Balance the following Reaction:

\[ \underline{1} \text{N}_2(g) + \underline{3} \text{H}_2(g) \rightarrow \underline{2} \text{NH}_3(g) \]

2. Write a complete sentence explaining this reaction in terms of moles.
   One mole of nitrogen will react completely with 3 moles of hydrogen to produce two moles of ammonia.

3. Mole – Mole Calculations
   The coefficients from the balanced equation can be used to write conversion factors.
   
   \[
   \text{ex:} \quad \frac{3 \text{ mol H}_2}{1 \text{ mol N}_2} \quad \frac{2 \text{ mol NH}_3}{3 \text{ mol H}_2} \quad \frac{1 \text{ mol N}_2}{2 \text{ mol NH}_3}
   \]

   Write the three other mole ratios:

   \[
   \frac{1 \text{ mol N}_2}{3 \text{ mol H}_2} \quad \frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3} \quad \frac{2 \text{ mol NH}_3}{1 \text{ mol N}_2}
   \]

   Note that they are simply the reciprocals of the first three

4. This equation shows the formation of aluminum oxide.
   \[ 4 \text{ Al (s)} + 3 \text{ O}_2(g) \rightarrow 2 \text{ Al}_2\text{O}_3(s) \]
   Write the six mole ratios that can be derived from this equation.

   \[
   \frac{4 \text{ mol Al}}{3 \text{ mol O}_2} \quad \frac{4 \text{ mol Al}}{2 \text{ mol Al}_2\text{O}_3} \quad \frac{3 \text{ mol O}_2}{2 \text{ mol Al}_2\text{O}_3} \quad \text{also...} \quad \frac{2 \text{ mol A}}{1 \text{ mol Al}_2\text{O}_3} \quad \frac{1 \text{ mol Al}_2\text{O}_3}{2 \text{ mol Al}}
   \]

   \[
   \frac{3 \text{ mol O}_2}{4 \text{ mol Al}} \quad \frac{2 \text{ mol Al}_2\text{O}_3}{4 \text{ mol Al}} \quad \frac{2 \text{ mol Al}_2\text{O}_3}{3 \text{ mol O}_2}
   \]

5. How many moles of aluminum are needed to form 3.7 moles of Al₂O₃?
   
   \[
   3.7 \text{ mol Al}_2\text{O}_3 \times \frac{4 \text{ mol Al}}{2 \text{ mol Al}_2\text{O}_3} = 7.4 \text{ mol Al}
   \]
   Done using the mole ratio’s as conversion factors with dimensional analysis.

   Can also be done by setting up a proportion…

   \[
   \frac{3.7 \text{ mol Al}_2\text{O}_3}{X \text{ mol Al}} = \frac{2 \text{ mol Al}_2\text{O}_3}{4 \text{ mol Al}} \quad \text{simply solve for} \ X.
   \]
6. **Mass – Mass Calculations**

   Given a mass of one substance, a mole ratio can be used to calculate the mass of another substance in the chemical reaction.

   **Steps:**
   1. **Convert the mass given to moles.**
   2. **The mole ratio from the balanced equation can be used to calculate the number of moles of the unknown.**
   3. **Finally, convert the new number of moles back to grams of the new substance.**

   Ex: Calculate the number of grams of NH₃ produced by the reaction of 5.40 grams of hydrogen with an excess of nitrogen.

   \[
   \text{1 N}_2 (g) + 3 \text{ H}_2 (g) \rightarrow 2 \text{ NH}_3 (g)
   \]

   First, map out the problem:
   - First, convert the mass of hydrogen into moles by dividing by the molar mass of H₂.
   - Second, convert the moles of hydrogen to moles of ammonia using the mole ratio.
   - Third, convert the new moles of ammonia into mass by multiplying by the molar mass NH₃.

   Then, calculate each of the steps:

   **Step 1.** \( 5.40 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.0 \text{ g H}_2} = 2.7 \text{ mol H}_2 \)

   **Step 2.** \( 2.7 \text{ mol H}_2 \times \frac{2 \text{ mol NH}_3}{1 \text{ mol H}_2} = 5.4 \text{ mol NH}_3 \)

   **Step 3.** \( 5.4 \text{ mol NH}_3 \times \frac{17.0 \text{ g NH}_3}{1 \text{ mol NH}_3} = 91.8 \text{ g NH}_3 \)

   Once you are familiar with the steps of stoichiometry, you can combine the steps into one calculation to save time:

7. **Practice:** \( \text{CaC}_2 (s) + 2 \text{ H}_2\text{O} (l) \rightarrow \text{C}_2\text{H}_2 (g) + \text{Ca(OH)}_2 (aq) \)

   A. how many grams of acetylene (C₂H₂) are produced by adding water to 5.00 g CaC₂?

   Convert mass CaC₂ to moles CaC₂ to moles of C₂H₂ to mass of C₂H₂ (answer is 2.03 g C₂H₂)

   B. Determine how many grams of CaC₂ are needed to react completely with 49.0 g H₂O?

   Convert mass H₂O to moles H₂O to moles of CaC₂ to mass of CaC₂ (answer is 87.1 g CaC₂)

   Answers were calculated using the steps outlined above. Molar masses were rounded to 2 decimal places. Answers reported to 3 sig figs.)