Mole Ratios

How can the coefficients in a chemical equation be interpreted?

Why?

A balanced chemical equation can tell us the number of reactant and product particles (ions, atoms, molecules or formula units) that are necessary to conserve mass during a chemical reaction. Typically when we balance the chemical equation we think in terms of individual particles. However, in real life the reaction represented by an equation occurs an unimaginable number of times. Short of writing very large numbers (10^{23} or larger) in front of each chemical in the equation, how can we interpret chemical equations so that they more realistically represent what is happening in real life? In this activity you will explore the different ways a chemical reaction can be interpreted.

Model 1 – A Chemical Reaction

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

1. Consider the reaction in Model 1.
   a. What are the coefficients for each of the following substances in the reaction?

   N_2 H_2 NH_3

   b. Draw particle models below to illustrate the reaction in Model 1.

2. Consider each situation below as it relates to the reaction in Model 1.
   a. Calculate the amount of reactants consumed and products made.
   b. Record the ratio of N_2 to H_2 to NH_3. Reduce the ratio to the lowest whole numbers possible.

	N_2 Consumed	**H_2 Consumed**	**NH_3 Produced**	**Ratio N_2:H_2:NH_3 (reduced)**
For a single reaction, how many molecules of each substance would be consumed or produced?				
If the reaction occurred one hundred times, how many molecules would be consumed or produced?				
If the reaction occurred 538 times, how many molecules would be consumed or produced?				

3. Refer to the data table in Question 2.

   a. How do the reduced ratios in the last column compare to the coefficients in the reaction shown in Model 1?

   b. Use mathematical concepts to explain how your answer in part *a* is possible.

4. Even 538 is a small number of molecules to use in a reaction. Typically chemists use much larger numbers of molecules. (Recall that one mole is equal to 6.02 x 10^{23} particles.) Consider each situation below as it relates to the reaction in Model 1: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$.

   a. Calculate the amount of reactants consumed and products made.

   b. Record the ratio of N_2 to H_2 to NH_3. Reduce the ratio to the lowest whole number possible.

	N_2 Consumed	**H_2 Consumed**	**NH_3 Produced**	**Ratio N_2:H_2:NH_3**
If the reaction occurred 6.02 × 10^{23} times, how many molecules would be consumed or produced?				
How many ***moles*** of each substance would be consumed or produced in the previous situation?				

5. Refer to the data table in Question 4.

   a. How do the reduced ratios in the last column compare to the coefficients in the reaction in Model 1?

   b. Use mathematical concepts to explain how your answer in part *a* is possible.

6. The ratio obtained from the coefficients in a balanced chemical equation is called the **mole ratio**.

   a. What is the mole ratio for the reaction in Model 1?

   b. Explain why this ratio is called the mole ratio?

7. Use the mole ratio from the balanced chemical equation in Model 1, $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, to solve the following problems. *Hint:* Set up proportions.

   a. How many moles of nitrogen would be needed to make 10.0 moles of ammonia?

   b. How many moles of ammonia could be made by completely reacting 9.00 moles of hydrogen?

   c. How many moles of hydrogen would be needed to react completely with 7.41 moles of nitrogen?

8. Consider this situation as it relates to the reaction in Model 1, $N_2(g) + 3H_2(g) \rightarrow 2\ NH_3(g)$.

   a. Calculate the amounts of reactants consumed and the amount of product made.

   b. Record the mass ratio of N_2 to H_2 to NH_3. Reduce the ratio to the lowest whole numbers possible.

	N_2 Consumed	**H_2 Consumed**	**NH_3 Produced**	**Mass Ratio N_2:H_2:NH_3**
How many grams of each substance would be consumed or produced in the situation in Question 4?				

9. Refer to the data table in Question 8.

   a. Can the mole ratio from a balanced chemical equation be interpreted as a ratio of masses?

   b. Use mathematical concepts to explain how your answer in part *a* is possible.

10. As a group, develop a plan to solve the following problem. Remember that the mole ratio cannot be used directly in this situation. *Note:* You do not need to do the actual calculation here.

    "What mass of nitrogen is needed to produce 30.0 g of ammonia?"

Model 2 – Proposed Calculations for Mass of NH_3 to Mass of N_2

Toby's Method

$$\frac{x \text{ grams}}{30.0 \text{ g}} = \frac{1 \text{ mole } N_2}{2 \text{ moles } NH_3} \rightarrow x = _____ \text{ g } N_2$$

Rachel's Method

$$30.0 \text{ g } NH_3 \times \frac{1 \text{ mole } NH_3}{17.0 \text{ g } NH_3} = _____ \text{ moles } NH_3$$

$$\frac{x \text{ mole } N_2}{_____ \text{ mole } NH_3} = \frac{1 \text{ mole } N_2}{2 \text{ moles } NH_3} \rightarrow x = _____ \text{ moles } N_2$$

$$_____ \text{ mole } N_2 \times \frac{28.0 \text{ g } N_2}{1 \text{ mole } N_2} = _____ \text{ g } N_2$$

Jerry's Method

$$30.0 \text{ g } NH_3 \times \frac{1 \text{ mole } NH_3}{17.0 \text{ g } NH_3} \times \frac{1 \text{ mole } N_2}{2 \text{ moles } NH_3} \times \frac{28.0 \text{ g } N_2}{1 \text{ mole } N_2} = _____ \text{ g } N_2$$

11. Model 2 shows three proposed calculations to solve the problem in Question 10. Complete the calculations in Model 2 by filling in the underlined values.
12. Which method does not use the mole ratio in an appropriate manner? Explain.

13. Two of the methods in Model 2 give the same answer. Show that they are mathematically equivalent methods.

14. Use either Rachel or Jerry's method from Model 2 to calculate the mass of hydrogen needed to make 30.0 g of ammonia. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

Extension Questions

15. One mole of any gas will occupy 22.4 L of volume at standard temperature and pressure (STP).

    Consider this situation as it relates to the reaction in Model 1: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

    a. Calculate the volumes of reactants consumed and the volume of product made.

    b. Record the ratio of N_2 to H_2 to NH_3. Reduce the ratio to the lowest whole numbers possible.

	N_2 Consumed	**H_2 Consumed**	**NH_3 Produced**	**Volume Ratio N_2:H_2:NH_3**
How many liters of each substance would be consumed or produced if the reaction occurred 6.02×10^{23} times at STP?				

16. Refer to the data table in Question 15.

    a. Can the mole ratio from a balanced chemical equation be interpreted as a ratio of volumes for gases?

    b. Use mathematical concepts to explain how your answer in part *a* is possible.

17. Explain why the ratio of volumes is NOT followed in the following reactions.

$2H_2(g)$	+	$O_2(g)$	→	$2H_2O(l)$		$NH_3(g)$	+	$HCl(g)$	→	$NH_4Cl(s)$
44.8 L		22.4 L		0.036 L		22.4 L		22.4 L		0.035 L

18. Which of the following quantities are **conserved** (total amount in reactants = total amount in products) in a chemical reaction? Find an example or counter example from this activity to support your answer for each.

    a. Molecules

    b. Moles

    c. Mass

    d. Volume

    e. Atoms of an element