Mole Ratios and Conservation of Mass

How can 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.

      $N_2(g)$ + $3H_2(g)$? $2NH_3(g)$

2. Consider each situation below as it relates to the reaction in Model 1.
   a. Calculate the amount of ***molecules*** 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**
For a single reaction, how many ***molecules*** of each substance would be consumed or produced?				
If the reaction occurred a dozen times, how many ***molecules*** would be consumed or produced?				
If the reaction occurred 500 times, how many ***molecules*** would be consumed or produced?				

3. Refer to the data table in Question 2. How do the reduced ratios in the last column compare to the coefficients in the reaction shown in Model 1?

4. Even 500 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: $N_2(g) + 3H_2(g)$? $2NH_3(g)$.
   a. Calculate the ***molecules*** and ***moles*** 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 above*?				



5. Refer to the data table in Question 4. How do the reduced ratios in the last column compare to those in the reaction in Model 1?

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 ***masses*** of reactants consumed and the ***masses*** of products 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	Ratio N_2:H_2:NH_3
How many ***grams*** of each substance would be consumed or produced if the reaction was completed using 1 mole N_2, 3 moles H_2, and produced 2 mole NH_3 as 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. One mole of any gas will occupy 22.4L: of volume at standard temperature and pressure. 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 ***volumes*** of reactants consumed and the ***volumes*** 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**	**Ratio N_2:H_2:NH_3**
How many ***liters*** of each substance would be consumed or produced if the reaction was completed using 1 mole N_2, 3 moles H_2, and produced 2 mole NH_3 as in question 4?				

11. Refer to the data table in Question 10.
    a. Can the mole ratio from a balanced chemical equation be interpreted as a ratio of volume for gases at STP?

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

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

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ $\quad\quad$ $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

44.8 L 22.4 L 0.036 L $\quad\quad$ 22.4 L 22.4 L 0.035 L



13. Consider this situation as it relates to the reaction in Model 1, $N_2(g) + 3H_2(g) \rightarrow 2\ NH_3(g)$.
    a. Count the number of ***atoms*** of reactants consumed and the ***atoms*** 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**	**Ratio N_2:H_2:NH_3**
How many atoms of each substance would be consumed or produced if the reaction was completed using 1 molecule N_2, 3 molecules H_2, and produced 2 molecules NH_3 as in question 4?				

14. Refer to the data table in Question 13. Can the mole ratio from a balanced chemical equation be interpreted as a ratio of atoms for gases at STP?



15. Summarize your findings:
    a. What can coefficients represent in a balanced equation?Provide an example from the activity.
        i. molecules that reacted?
        ii. atoms that reacted?
        iii. grams that reacted?
        iv. liters that reacted?
        v. moles that reacted?

16. Refer to the data table in question 8. The masses of reactants and products are conserved. Using your masses from the data table in question 8, explain what masses are conserved might mean.

17. Refer to the data table in question 13. The number of atoms of reactants and products are conserved. Using your number of atoms from the data table in question 14, explain what conserved might mean.

Model 2 – Proposed Calculations

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

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

18. Model 2 shows three proposed calculations to determine how many grams of N_2 are required to produce 30.0g of NH_3. Complete the calculations in Model 2 by filling in the underlined values.
19. Which method does not use the mole ratio in an appropriate manner? Explain.

20. Use either correct method from Model 2 to calculate the mass of **hydrogen** needed to make 15.0 g of ammonia.