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What happened to Avogadro when he got bit by  $6.02 \times 10^{23}$  mosquitoes?

He got Mol-aria

## POGIL- Stoichiometry

### How do chemists use balanced chemical equations?

#### Why?

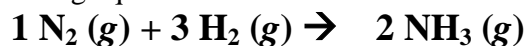
Chemists use balanced chemical equations as a basis to calculate how much reactant is needed or product is formed in a reaction. This is called **Stoichiometry- (stoi-key-ah-meh-tree)** Another way of looking at it is using the mole ratio from the balanced equation and information about one compound in the reaction to determine information about another compound in the equation. A **mole ratio** is a conversion factor derived from the coefficients of a balanced chemical equation interpreted in terms of moles. In chemical calculations, mole ratios are used to convert between moles one thing and moles of another.

**Purpose:** In this activity we will address the question: *How do I convert between different chemical species in a given reaction?*

### MODEL 1: Mole-to-Mole Stoichiometry (1-step)

#### Example: mole-to-mole

**Question:** Given the following equation:



How many moles of  $\text{H}_2$  are needed to produce 34.8 moles of  $\text{NH}_3$ ?

**Answer:**

$$\frac{34.8 \text{ mol NH}_3}{1} \times \frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3} = 52.2 \text{ mol H}_2$$

Mole ratio

**OR**

$$34.8 \text{ mol NH}_3 \times \frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3} = 52.2 \text{ mol H}_2$$

Mole ratio

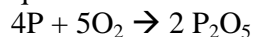
#### Key Questions:

1. What was the given in the example above?
2. Where did the  $\frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3}$  come from?
3. Double check to see if 52.2 moles of  $\text{H}_2$  is the correct answer. SHOW the math below.

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**You Try...**

4. Given the following chemical equation



- (a) How many **moles of P<sub>2</sub>O<sub>5</sub>** are formed from **3.4 moles of O<sub>2</sub>**? SHOW the math below
- (b) How many **moles of P** are needed to react with **30.1 moles of O<sub>2</sub>**? SHOW the math below.

5. Aluminum reacts with copper(II) chloride to make aluminum chloride and copper

(a) Write the balanced equation

(b) Given 6 **moles** of CuCl<sub>2</sub>, how many **moles** of AlCl<sub>3</sub> were made? SHOW the math below

(c) If 4.5 **moles** of AlCl<sub>3</sub> were made, how many **moles** of CuCl<sub>2</sub> were used? SHOW the math below

6. Methane (CH<sub>4</sub>) and sulfur (S<sub>8</sub>) react to produce carbon disulfide and hydrogen sulfide, a liquid often used in the production of cellophane

(a) Write the balanced equation

(b) Calculate the **moles** of CS<sub>2</sub> produced when 1.50 **mol** of S<sub>8</sub> are used. SHOW the math below

(c) How many **moles** of H<sub>2</sub>S are produced? SHOW the math below

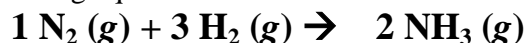
7. Summarize model 1 in 2-3 sentences:



## MODEL 2: Mole ↔ Mass Stoichiometry (2-step)

### Example: Starting with the mole

**Question:** Given the following equation:



How many **grams of H<sub>2</sub>** are needed to produce **34.8 moles of NH<sub>3</sub>**?

Molar Mass H<sub>2</sub>  
(2 x 1.01 g/mol) = 2.02 g/mol

**Answer:**

	Mole ratio	Molar Mass	
	}	}	
34.8 mol NH <sub>3</sub>			= 105 g H <sub>2</sub>
	3 mol H <sub>2</sub>	2.02 g H <sub>2</sub>	
	2 mol NH <sub>3</sub>	1 mol H <sub>2</sub>	

**Key Questions:**

8. What was the given in the example above?
9. Where did the  $\frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3}$  come from?
10. Where did the,  $\frac{2.0 \text{ g H}_2}{1 \text{ mol H}_2}$  come from?
11. Look at the periodic table, how much does one mole of a Hydrogen atom weigh? Why is the molar mass of hydrogen (H<sub>2</sub>) 2.02 g/mol in the example 1 above?
12. Double check to see if 105 g H<sub>2</sub> is the correct answer. SHOW the math below.

**You Try...**

13. Given the following chemical equation
 
$$4 \text{ P} + 5 \text{ O}_2 \rightarrow 2 \text{ P}_2\text{O}_5$$
  - (a) What is the molar mass of P<sub>2</sub>O<sub>5</sub>? (use your periodic table). SHOW the math below
  - (b) How many grams of P<sub>2</sub>O<sub>5</sub> are formed from 3.4 moles of O<sub>2</sub>? SHOW the math below

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14. Acetylene gas (C<sub>2</sub>H<sub>2</sub>) and calcium hydroxide are produced by adding water to calcium carbide(CaC<sub>2</sub>)

(a) Write the balanced equation

(b) What is the molar mass of acetylene, C<sub>2</sub>H<sub>2</sub>? **show your math below.**

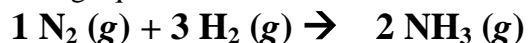
(c) How many **grams** of acetylene, C<sub>2</sub>H<sub>2</sub>, are produced by adding 3 **moles** of CaC<sub>2</sub>? **show your math below.**

(d) What is the molar mass of CaC<sub>2</sub>? **show your math below.**

(e) How many **grams** of CaC<sub>2</sub> are needed to react completely with 490.0 **moles** H<sub>2</sub>O? **show your math below.**

### Example: starting with the mass

**Question:** Given the following equation:



How many **moles of H<sub>2</sub>** are needed to produce **34.8 grams** of NH<sub>3</sub>?

Molar Mass NH<sub>3</sub>

$$14.01 \text{ g/mol} + (3 \times 1.01 \text{ g/mol}) = 17.04 \text{ g/mol}$$

**Answer:**

	Molar Mass	Mole ratio	
34.8 g NH <sub>3</sub>	1 mol NH <sub>3</sub>	3 mol H <sub>2</sub>	= 3.06 mol H <sub>2</sub>
	17.04 g NH <sub>3</sub>	2 mol NH <sub>3</sub>	

### Key Questions:

15. What was the given in the example above?

16. Look at the periodic table, how much does Hydrogen weigh? Nitrogen weigh?

17. Where did the  $\frac{1 \text{ mol NH}_3}{17 \text{ g NH}_3}$ , come from?

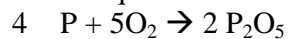
18. Where did the,  $\frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3}$  come from?

19. Double check to see if 3.06 mol H<sub>2</sub> is the correct answer. **SHOW** the math below.

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**You Try...**

20. Given the following chemical equation



- (a) What is the molar mass of  $\text{O}_2$ ? **show your math below.**
- (b) How many **moles of  $\text{P}_2\text{O}_5$**  are formed from **3.4 grams of  $\text{O}_2$** ? SHOW the math below

21. Titanium is a transition metal used in many alloys because it is extremely strong and light weight. Titanium tetrachloride is extracted from titanium(IV) oxide, using chlorine and coke (carbon). Carbon dioxide is also released.

- (a) Write the balanced equation
- (b) Calculate the molar mass of  $\text{TiO}_2$ . **show your math below.**
- (c) How many moles of  $\text{Cl}_2$  gas are needed to react with 1.25 grams of  $\text{TiO}_2$ ? **show your math below.**
- (d) How many moles of C are needed to react with 1.25 grams of  $\text{TiO}_2$ ? **show your math below.**

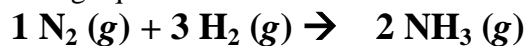
22. Summarize model 2 in 3-4 sentences.



## MODEL 3: Mass ↔ Mass Stoichiometry (3-step)

### Example

**Question:** Given the following equation:



How many **grams of H<sub>2</sub>** are needed to produce **34.8 grams of NH<sub>3</sub>**?

Molar Mass H<sub>2</sub>

$$(2 \times 1.01 \text{ g/mol}) = 2.02 \text{ g/mol}$$

Molar Mass NH<sub>3</sub>

$$14.01 \text{ g/mol} + (3 \times 1.01 \text{ g/mol}) = 17.04 \text{ g/mol}$$

**Answer:**

	Molar Mass	Mole ratio	Molar Mass	
	}	}	}	
34.8 g NH <sub>3</sub>				= 6.19 g H <sub>2</sub>
	1 mol NH <sub>3</sub>	3 mol H <sub>2</sub>	2.02 g H <sub>2</sub>	
	17.04 g NH <sub>3</sub>	2 mol NH <sub>3</sub>	1 mol H <sub>2</sub>	

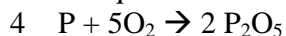
**Key Questions:**

23. What was the given in the example above?
  
24. What are the 3-steps to solving the mass-to-mass problem above? (Note: these are always the same three steps!)
  
25. Where did the  $\frac{3 \text{ mol H}_2}{2 \text{ mol NH}_3}$  come from?
  
26. Where did the,  $\frac{2.0 \text{ g H}_2}{1 \text{ mol H}_2}$  come from?
  
27. Where did the  $\frac{1 \text{ mol NH}_3}{17 \text{ g NH}_3}$  come from?
  
28. Double check to see if 6.19 g H<sub>2</sub> is the correct answer. SHOW the math below.

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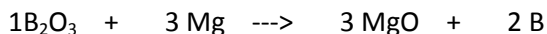
**You Try...**

29. Given the following chemical equation



- (a) What is the molar mass of  $\text{P}_2\text{O}_5$ ? (use your periodic table)-**show your math below.**
- (b) What is the molar mass of  $\text{O}_2$ ? (use your periodic table)- **show your math below.**
- (c) How many **grams of  $\text{P}_2\text{O}_5$**  are formed from **3.4 grams of  $\text{O}_2$** ? SHOW the math below

30. Use the following balanced equation:



- (a) Calculate the molar mass of  $\text{B}_2\text{O}_3$ .
- (b) How many **grams of B** can be obtained from **234 grams** of  $\text{B}_2\text{O}_3$ ?
- (c) How many **grams of magnesium** are required to produce **40.0 grams of boron**?

31. One the reactions used to inflate automobile air bags involves sodium azide ( $\text{NaN}_3$ ):



Balance and determine (calculate) the mass of  $\text{N}_2$ , produced from the decomposition of 100.0 g  $\text{NaN}_3$ . **SHOW ALL WORK** including how you get the molar masses.



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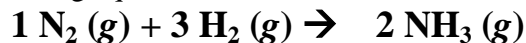
## Model 4: Volume Conversions

1 mole of any gas at STP\* = 22.4 L of that gas

\*STP = standard temperature and pressure, or 0°C and 1 atmosphere

### Example

**Question:** Given the following equation:



How many **L of N<sub>2</sub>** are needed to produce **38.2 g of NH<sub>3</sub>**?

Molar Mass NH<sub>3</sub>

$$14.01 \text{ g/mol} + (3 \times 1.01 \text{ g/mol}) = 17.04 \text{ g/mol}$$

	Molar Mass	Mole Ratio	Molar Volume	
	}	}	}	
38.2 g NH <sub>3</sub>	1 mol NH <sub>3</sub>	1 mol N <sub>2</sub>	22.4 L N <sub>2</sub>	= 25.1 L N <sub>2</sub>
	17.04 g NH <sub>3</sub>	2 mol NH <sub>3</sub>	1 mol N <sub>2</sub>	

32. What was the given in the example equation above?

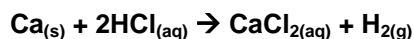
33. Where did the  $\frac{22.4 \text{ L N}_2}{1 \text{ mol N}_2}$ , come from?

34. Where did the,  $\frac{1 \text{ mol N}_2}{2 \text{ mol NH}_3}$  come from?

35. Where did the  $\frac{1 \text{ mol NH}_3}{17 \text{ g NH}_3}$  come from?

36. Double check to see if 25.1 L N<sub>2</sub> is the correct answer. SHOW the math below.

37. Given the following equation, how many L of H<sub>2</sub> gas are produced from 3.5 g HCl at STP?



38. Look at the purpose of the POGIL on the front page and answer the question.



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### Conversion Factors

You just learned four conversion factors during this POGIL. (Molar Mass, Mole Ratio, Molar Volume, and Avagadro's Number). Match each of these with the questions below, describing how to determine the value or writing the value if it is constant. Include units.

39. What conversion factor is used to convert between atoms/formula units/molecules and moles? What is the value of this conversion factor?
  
  
  
  
  
  
  
  
  
  
40. What conversion factor is used to convert between mass and moles? How can this be calculated?
  
  
  
  
  
  
  
  
  
  
41. What is the only conversion factor that can be used to convert between two substances in a reaction? This is used to convert between moles of one substance to moles of another substance. How can this be determined?
  
  
  
  
  
  
  
  
  
  
42. What conversion factor is used to convert between moles and volume when at STP? What is the value of this conversion factor?