UNIT 5: The Mole

Lesson 1 : Using the "Mole" to count particles of a substance

Essential Question: What is a mole and how is that similar to a dozen? How is factor-label (dimensional analysis) related to the mole concept?

Questions/ Vocab, etc.	Notes:

What is a mole?

- ✔ It is a counting unit.
- ✔ Abbreviated "mol"
- ✔ We use it just like we use a dozen which = 12 and a ream = 500
- ✔ Because atoms & molecules are extremely small, we use the mole to count particles

1 mol of a substance = 6.022 x 10^{23} representative particles = (Avogadro's Number)

REMEMBER, matter is broken down into either SUBSTANCES or MIXTURES

Substances are broken down into either ELEMENTS or COMPOUNDS

TYPE OF SUBSTANCE	Representative Particle
Element (Cu)	
Ionic Compound ($CuCl_2$)	
Covalent Compound (CO)	
Diatomic Element (Cl_2)	

Mole Conversions with Avogadro's Number

Steps to Solving Mole Conversions

1. Underline the known, given amount/unit and circle the unknown desired unit.
2. Draw a t-chart & place the given amount/unit on the top,left of the t-chart.
3. Set up the conversion factor in the next section: put the given unit in the denominator and the desired unit in the numerator.
4. Match the numbers in the conversion factor to their respective units.
5. Cancel out any units that are identical on top and bottom. Do the math
6. Don't forget units and round your answer to the hundredth's place if possible

Particles to Moles

Use the conversion factor to convert from moles to atoms, or molecules, or formula units or vice versa

$$1\ mol = 6.022 \times 10^{23}\ particles$$

Examples

1. Convert 15.0 moles of copper into atoms

2. Convert 3.8×10^{14} molecules of CO to moles?

Calculating Molar Mass

Molar Mass

→ Defined as the mass of 1 mole of an atom or molecule or formula unit

→ Also known as molecular weight, molecular mass, formula weight & formula mass

Molar Mass for Elements

The average atomic mass = molar mass of 1 mole of an element

Average atomic mass can be found on the periodic table

Element	Mass
1 mole of carbon atoms C	g/mol
1 mole of oxygen atoms O_2	g/mol
1 mole of hydrogen atoms H_2	g/mol

Calculating the Molar Mass of a Compound

→ The molar mass for a molecule or formula unit = the sum of the atomic masses of all of the atoms in the compound

→ To find the molar mass

1. Count the number of each type of atom
2. Find the atomic mass of each atom on the periodic table.
3. Multiply the number of atoms by the atomic mass for each atom
4. Add all the masses up

Example

1. Find the molar mass of $CaBr_2$

Example

→ If you see a parentheses, be sure to distribute the subscript on the outside of the parentheses to the subscript (# of atoms) inside the parentheses

2. Find the molar mass for $Sr(NO_3)_2$

Molar Mass Conversions

Using Molar Mass in Conversions

→ When converting between moles and grams, molar mass is needed

1mole of a substance = molar mass of the substance in grams

Examples

1. How many grams are in 1.25 mol H_2O?

2. How many moles are in 25 g of NaCl?

Molar Volume

- The **molar volume** of a gas is measured at STP (standard temperature and pressure) **1 mole of any gas = 22.4 L**
- The molar volume at STP has about the same volume as 3 basketballs can be used to form 2 conversion factors:

$$\frac{22.4\ \text{L}}{1\ \text{mole}} \quad \text{and} \quad \frac{1\ \text{mole}}{22.4\ \text{L}}$$

Examples

1. An experiment requires 0.0580 moles of NO. What volume in liters would you need at STP?

2. Suppose you need 4.22 g of Cl_2. If at STP, what volume in liters would you use?

Lesson 2 : MultiStep Conversions and Percent Composition Calculations

Essential Question: What are the different conversions can we make between common units of a particular substance by using the mole concept?

Questions/ Vocab, etc.	Notes
	• Sometimes the use of more than 1 conversion factor is needed to solve the problem • If either the known or unknown units do not contain "mol", then your calculation will be more than 1 step. • Your 1st step is to go to moles! 1. How many formula units are in 25.5 g of NaCl? 2. How many molecules are in 78.0 g CCl_4?

Percent Composition

→ Defined as the percent by mass of each element in a compound.

Steps to Finding Percent Composition

1. Add up the mass of each element within the compound to get the mass of the compound (molar mass)
2. Divide each element's mass by the molar mass of the compound
3. Multiply by 100

$$\text{Percent Composition} = \frac{\text{mass of element}}{\text{mass of compound}} \times 100$$

Examples:

1.Calculate the % composition of each element in calcium carbonate, $CaCO_3$

Lesson 3 : Calculating Empirical and Molecular Formulas

Essential Question: What is the difference between Molecular and Empirical formulas? How can the empirical formula of any compound be obtained from experimental mass data (is there a trick to remembering this?) How can the molecular formula of a compound be determined?

Questions/ Vocab, etc.	Notes

Empirical Formula

- A chemical formula showing the _____ whole number ratio of moles of elements (subscripts)
- May or may not be the same as the ACTUAL molecular formula
- Hydrogen Peroxide has a molecular formula (ACTUAL) of _____ but an empirical formula of _____

HOW TO CALCULATE an empirical formula from % composition

Remember the Rhyme:
Percent to Mass
Mass to Mole
Divide by Small
Multiply till Whole!

1. Assume 100 grams of sample. Switch % sign to grams.
2. Convert mass of each element to moles of each element
3. Divide all elements' mole amount by the smallest mole amount in the entire problem. The answer is the subscript of the element within the compound.
4. ***Optional***: If mole ratio is not within .1 of a whole number, multiply every mole amount by the smallest whole number to make it either a whole number or to within .1 of a whole number
5. Common Endings: [1/5 = .20 X5 | 1/2= 0.50 X 2 | 1/3≈ 0.33 x 3 | 2/3≈ 0.67 x 3 | 3/4= 0.75 x 4]

Examples:

What is the empirical formula for 40.05% S and 59.95%O?

What is the empirical formula for 43.64% P and 56.36% O?

Molecular Formula

- Is the _____, true formula of the compound.
- They are usually multiples of their empirical formula
- N_2O_4 is the molecular formula; the empirical formula is _____
- Notice that the molecular formula is 2 times larger than the empirical formula

Examples:

Name	Molecular Formula	Empirical Formula
Formaldehyde	CH_2O	CH_2O
Acetic Acid	$C_2H_4O_2$	CH_2O
Glucose	$C_6H_{12}O_6$	CH_2O

HOW TO CALCULATE the Molecular Formula

1. You need to find the empirical formula and calculate its molar mass. Call this empirical formula mass (EFM)!
2. Find the mass of the actual formula, which will most likely be given to you in the problem in grams. Call this molecular formula mass (MFM)!
3. Divide the MFM by the EFM to get a factor.
4. Multiply the factor by the empirical formula to get the MOLECULAR FORMULA

Factor x (Empirical Formula) = Molecular Formula

Example:

What is the molecular formula of a compound whose empirical formula is CH_4N and its molecular formula mass is 60.12 g/mol.

	Example: An unknown compound is composed of 58.8% carbon and 9.8% hydrogen and 31.4% oxygen. The molecular formula mass is 204 g. Determine the molecular formula for the compound.

Lesson 4 : What is Stoichiometry and the key to your success: The MOLE RATIO

Essential Question: How does the mole enable us to accurately predict the amount of product that can be formed in a chemical reaction?

Questions/ Vocab, etc.	Notes
	Stoichiometry refers to the calculations of chemical quantities from balanced chemical equations. **What do coefficients mean?** → The _____of the balanced equation tell how many moles or particles of each substance is used in the reaction. → A Mole ratio is a _____ that relates 2 substances in moles. You must use a balanced chemical equation to create it. Example: What are all the possible mole ratios of: $2\ H_2 + O_2 \rightarrow 2\ H_2O$ List them here: **How to solve Stoichiometry Calculations** ALMOST ALL STOICHIOMETRIC PROBLEMS CAN BE SOLVED IN 4 SIMPLE STEPS 1. Do you have a balanced equation? If not, balance it. 2. Are you in MOLES? *Yes, move to step 3.* *No, convert the units of the given substance to moles of that given substance.* *Most likely will need 1 mol = molar mass (g)* 3. Using the mole ratio, calculate the moles of the given substance to the moles of the substance you want 4. Possible Next Steps: Convert the moles of new substance to its desired units. *Most likely will need 1 mol = molar mass (g)* USE THE MOLE MAP TO HELP GUIDE YOU THROUGH THE STEPS OF THE CALCULATION

Mole and Mole : 1 step Problem USE ONLY THE MOLE RATIO

1. If 4.2 moles of H_2 reacts completely with O_2, how many moles of O_2 are needed?

$$2\ H_2 + O_2 \rightarrow 2\ H_2O$$

- Sometimes the use of more than 1 conversion factor is needed to solve the problem
- The mol-mol ratio will always be used as one of your steps!
- Calculating an amount of a product is the same as calculating a theoretical yield

2 steps: grams of A to moles of A ; moles of A to moles of B

3 steps: grams of A to moles of A; moles of A to moles of B; moles of B to grams of B

Moles and Mass : 2 step Problem

We can't measure moles in the lab. We can only measure grams.

Molar Mass (grams) = 1 mole of a compound

Mole-Mass (2 step problem)

1. How many grams of AgCl (theoretical yield) will be precipitated if 0.45 mole $AgNO_3$ is reacted as follows: HINT: 2 steps $2\ AgNO_3 + CaCl_2 \rightarrow 2\ AgCl + Ca(NO_3)_2$

2. Given the BALANCED EQUATION: $N_2 + 3H_2 \rightarrow 2NH_3$
   How many moles of ammonia, NH_3 (theoretical yield) are produced from 4.42 g of hydrogen gas, H_2? HINT: 2 steps

Mass to Mass : 3 step Problem

We can't measure moles in the lab. We can only measure grams.

Molar Mass (grams) = 1 mole of a compound

Mass-Mass (3 step problem)

1. How many grams of $Ba(OH)_2$ (theoretical yield) are precipitated from 14.5 g of NaOH in the following reaction: $2\ NaOH + BaCl_2 \rightarrow 2\ NaCl + Ba(OH)_2$

HINT: 3 steps

Keeping all these MOLE equalities straight!

To Go Between…	*Use the Equality…*
Particles and Moles	1 mole = 6.022×10^{23} atoms, molecules or FU
Grams and Moles	1 mole = molar mass (grams)
2 different chemicals in a reaction	Coefficient ratio (mole ratio) from balanced equation

Lesson 5 : Percent Yield

Essential Question: How efficient is the reaction you performed in producing a desired product?

Questions/ Vocab, etc.	Notes

Percent Yield: A ratio that calculates how efficient a chemical reaction is

- The higher the % yield, the higher the efficiency, the better the reaction
- A "Yield" is a product
- "Actual Yield" (A): the actual amount of product produced in the lab
- "Theoretical Yield" (T) : the amount of product you should produce if nothing went wrong; use the balanced chemical equation to calculate it
- A "Percent Yield": ratio of the actual yield compared to the theoretical yield

$$\% \text{ Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100$$

Let's Practice: **Let's take this one in steps**

1a. 4.20 moles of H_2 reacts completely with O_2, how many grams of H_2O are produced? (otherwise known as the Theoretical Yield)?

$2H_2 + O_2 \rightarrow 2\,H_2O$

Theoretical yield of water = _____ g

1b. What is the percent yield if 60.0 grams of H_2O are actually produced?

2.You have precipitated 8.50 g of $Ba(OH)_2$. If you started with 4.57 grams NaOH, what is the percent yield?

$2\,NaOH + BaCl_2 \rightarrow Ba(OH)_2 + 2\,NaCl$

Hint: Identify the actual yield.
Calculate the theoretical yield of $Ba(OH)_2$ using the reactant amount