

# Chapter 4: Chemical Composition

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Sept 14, 2022

Chemistry Department, Cypress College

## Percent Composition

## The Mole Concept

### Determining Empirical and Molecular Formulas

## Molarity of Solution

### Chemical Composition: Solvent and Solute

### Concentrations and Dilutions

## Humanist-inspired pedagogy:

- Student-teacher relationship is central
  - Mutual respect and growth
  - “Unconditional positive regard”
  - Awareness of the other and their thoughts/emotions
  - Teacher is coach/supporter/mentor rather than supervisor/boss
- Focus on attitude and approach rather than content
- Learning to fail
- Collaboration rather than competition
- Explore and experience something new together, learn about chemistry and ourselves

# Making the Most of It

Questions to consider:

- Why am I taking this course?
- What would I like to achieve?
- What methods/tools/resources work for me?

Your feedback, questions, participation are vital:

- Attend lectures and discussions, if possible
- Give on-going feedback to instructors through facial expression, emojis, chat, email, during office hours etc.
- Fill out evaluations
- Own your education
- Be proactive, do not hesitate to speak up or get help

# Lecture and Lab Weekly Agenda

## Lab Section

- Experiment 2 - Measurements: Temp, Mass, Length, Volume, and Density
- Demonstration - weighing the scale
- Warning - Do not leave thermometer touching the bottom of beaker when heating the water

## Lecture Section

- Go over homework assignment 2; present your work for 1pt EC
- Review Ch 4 - Chemical Composition
- Homework and quiz 4 released Fri, Sept 23 at 3pm
- Homework due Fri, Sept 30 at 11:59pm
- Quiz 4 due Mon, Sept 26 at 11:59pm
- **Important Date:** Exam 1 - approx 1.5 hrs

# Outline

Percent Composition

The Mole Concept

Determining Empirical and Molecular Formulas

Molarity of Solution

Chemical Composition: Solvent and Solute

Concentrations and Dilutions

## Percent Composition

**Main Takeaway:** Convert the mass of each component to a percentage of the total mass

$$P_A = \frac{M_A}{M_{\text{Tot}}} \times 100\% \quad (1)$$

where  $M_{\text{Tot}}$  is the total mass,  $M_A$  is the mass and  $P_A$  is the percent composition for component  $A$

## Example Problem: Percent Composition

Magnetite,  $\text{Fe}_3\text{O}_4$ , is a mineral containing 72.4% iron. What mass of iron is present in an 837g sample of magnetite?



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$$(837\text{g magnetite}) \frac{72.4\text{g iron}}{100\text{g magnetite}} = 606\text{g iron}$$

# Outline

Percent Composition

The Mole Concept

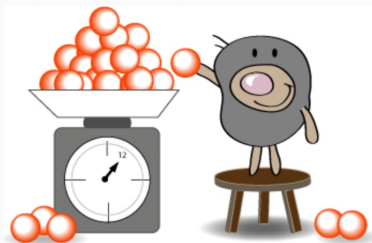
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# The Mole Concept

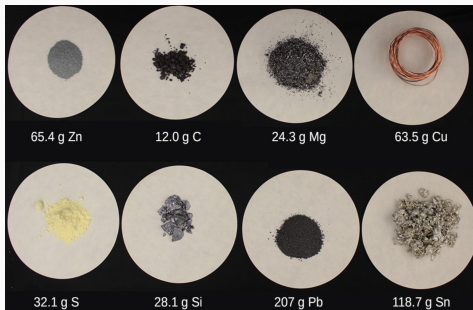


**Q:** What is a mole (mol)?

**A:** A mole is measurement of a substance and relates to Avogadro's number ( $6.022 \times 10^{23}$ )

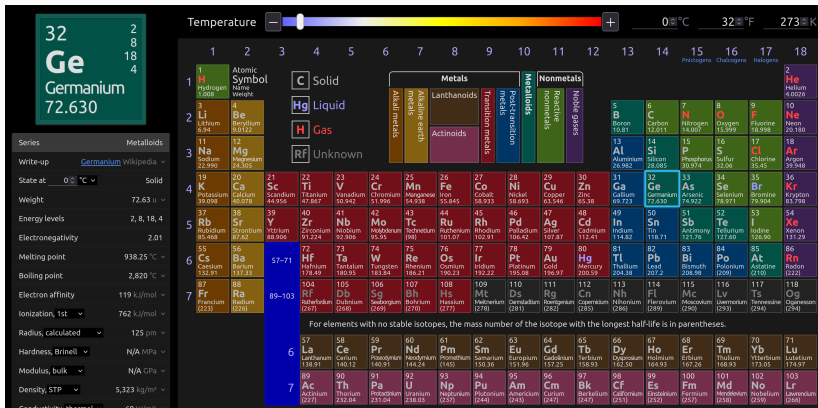
**side note:** Mole day is Oct. 23, between 6:02 a.m. and 6:02 p.m

# Purpose of the Mole



- Gives a consistent method to convert between atoms/molecules and grams
- Convenient way to perform calculations
- View the mole (mol) as a unit conversion type approach

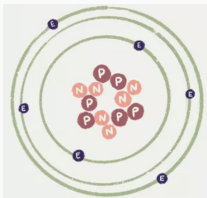
# Reminder: Periodic Table



- Organized based on atomic number, rel. atomic mass unit, and different categories of elements

# Relating amu to molar mass

**Atomic Mass Unit** - mass of one atom

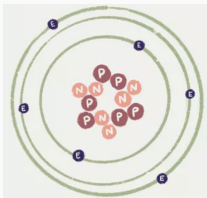


**Molar Mass** - mass of one mole of atoms or molecules

**Example:** Determine the molar mass of  $\text{H}_2\text{O}$

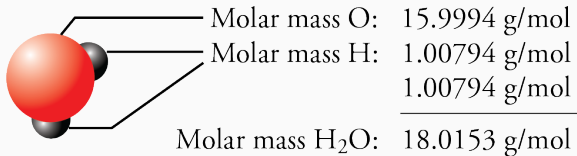
# Relating amu to molar mass

**Atomic Mass Unit** - mass of one atom

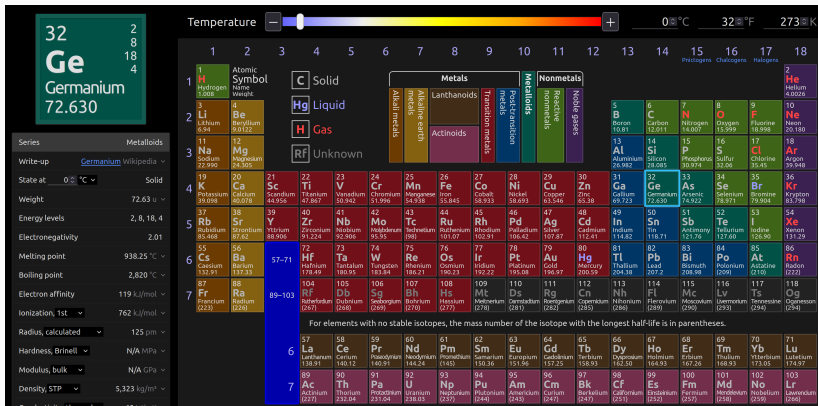


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# Periodic Table Revisited

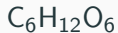


**Ge** - 72.630 amu for 1 atom and the molar mass is 72.630 g/mol

$$1 \text{ amu} = 1.66054 \times 10^{-24} \text{ g}$$



**Example: Determine the mol of each element within a compound.**



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$\text{H}_2\text{O}$  - 2 mols H and 1 mol O

$\text{C}_6\text{H}_{12}\text{O}_6$

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$\text{H}_2\text{O}$  - 2 mols H and 1 mol O

$\text{C}_6\text{H}_{12}\text{O}_6$  - 6 mols C, 12 mols H, 6 mols O

**Practice:** Determine the molar masses

## Example: Mole Connection to Chemical Rxn



**Q:** What are the mols of each reagent required to run this reaction? And how much mol of each product is produced?

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**Q:** What are the mols of each reagent required to run this reaction? And how much mol of each product is produced?

2 mol Zn(s) and 2 mol HCl(aq) (reagents) produce 1 mol ZnCl<sub>2</sub>(aq) and 1 mol H<sub>2</sub>(g)

## Example: Combine Percent Composition and the Mole

Determine the mass percent of each element in  $\text{Al}_2(\text{SO}_4)_3$ .

% mass of Al =

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$$\begin{aligned}\% \text{ mass of Al} &= \frac{n \times \text{molar mass Al}}{n \times \text{molar mass of Al}_2(\text{SO}_4)_3} \times 100\% \\ &= \frac{2 \times 26.98\text{g}}{342.14\text{g}} \\ &= 15.77\%\end{aligned}$$

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$$\begin{aligned}\% \text{ mass of S} &= \frac{n \times \text{molar mass S}}{n \times \text{molar mass of Al}_2(\text{SO}_4)_3} \times 100\% \\ &= \frac{3 \times 32.06\text{g}}{342.14\text{g}} \\ &= 28.11\%\end{aligned}$$

$$\begin{aligned}\% \text{ mass of O} &= \frac{n \times \text{molar mass O}}{n \times \text{molar mass of Al}_2(\text{SO}_4)_3} \times 100\% \\ &= \frac{12 \times 16.00\text{g}}{342.14\text{g}} \\ &= 56.12\%\end{aligned}$$



## Practice: Determine Mass from Moles

A friend heats water in a copper kettle and makes a cup of tea.  
The friend adds 0.0120 mol of table sugar (sucrose,  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ ).  
What mass of sugar has he added?

## Practice: Number of Molecules from Mass

A substance named Agorca M5640 is used for concentrating extracted copper ore. Its molecular formula is  $\text{C}_{16}\text{H}_{25}\text{NO}_2$ . If you have a 150.0 g sample of Agorca M5640, how many molecules do you have?

## Defn: Empirical and Molecular Formulas

**Empirical Formula** - the simplest ratios of atoms in a compound;  
lowest possible ratio

**Molecular Formula** - a factor of the empirical formula

## Empirical or Molecular Formula?

**Q:** Are the following empirical or molecular formula? If it is a molecular formula, then determine the empirical formula.

- $\text{H}_2\text{C}_2\text{O}_4$
- $\text{C}_6\text{H}_3\text{Cl}_3$
- $\text{CH}_2\text{O}$
- $\text{HgO}$

# Approach for Empirical/Molecular Problems

- Convert all elemental masses to mols
- Determine the lowest possible ratio
- Round to the nearest integer for each element and that number is the empirical formula
- For molecular formula, use the given experimental molar mass and divide by the molar mass of empirical formula. Multiply the empirical formula by that ratio.

## Practice: Empirical Formula from Percent Composition

Determine the empirical formula for the mineral chalcocite, which has the percent composition 79.8% Cu and 20.2% S.

## Empirical Formula when Ratio is Fractional

- If the fractional ratio of an element doesn't yield an integer, then multiply by a factor e.g.  $1/2$  multiply by 2,  $1/3$  multiply by 3, and  $1/4$  multiply by 4
- When multiplying to an integer, all elements must be multiplied by that number

## Practice: Determine Empirical Formula

The copper mineral azurite has the deep-blue color azure. Azurite contains 55.31% copper, 6.97% carbon, 37.14% oxygen, and 0.58% hydrogen. Calculate the empirical formula of azurite.



## Practice: Determine Molecular Formula

The empirical formula for an acid was determined to be  $\text{HCO}_2$ . If the molar mass of the acid is determined to be about  $90.0\text{g/mol}$ . What is the molecular formula for this acid?

Percent Composition

The Mole Concept

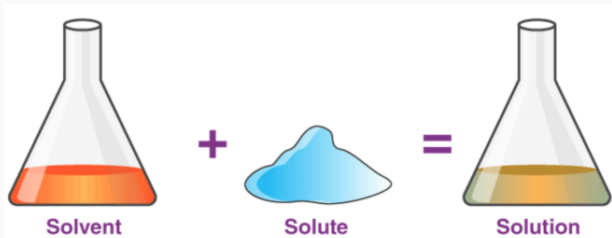
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## Defn: Solvent and Solute



**Solute** - a substance (solid, liquid, or gas) dissolved in a solvent

**Solvent** - the material (liquid or gas) that dissolves the solute

# Molarity - Concentration of Solution

## Definition of Molarity

$$M = \frac{n_{\text{solute}}}{V} \quad (2)$$

where  $M$  is molarity,  $n_{\text{solute}}$  is the mols of solute, and  $V$  is volume in L

**Q:** What is the units for molarity  $M$ ?

## Example: Preparing NaCl Solution

A solution is prepared from 17.0g of NaCl dissolved in sufficient water to give 150.0mL of solution. What is the molarity of the solution? (The molar mass of NaCl is 58.44 g/mol.)

**Determine** what is given and the question is being asked.

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$$\begin{aligned}n_{\text{NaCl}} &= 17.0\text{g NaCl} \times \frac{1\text{mol NaCl}}{58.44\text{g NaCl}} \\ &= 0.2908967\text{mol NaCl}\end{aligned}$$

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$$= 0.2908967\text{mol NaCl}$$

$$V = 150.0\text{mL} \times \frac{1\text{L}}{1000\text{mL}}$$

## Practice: Molarity

A solution of copper(II) acetate is used as a green dye for textiles. We want to prepare a  $0.150M$  solution of copper(II) acetate, starting with  $40.0g$  of the solute. What should be the total volume of the solution? (The molar mass of copper(II) acetate is  $181.6g/mol$ .)



# Diluting Solutions



Dilution is the process that makes a solution less concentrated.  
Example is lemonade tasting too sweet.

**Q:** For given concentrated solution at molarity  $M_1$  and a given volume  $V_1$ , does diluting the solution to a new concentration  $M_2$  and volume  $V_2$  change the amount of mols present?

## Deriving Dilution Formula

Since the moles before and after dilution are the same, we can derive a formula that determine volume required at the new concentration

$$n_1 = n_2$$

$$M_1 V_1 = M_2 V_2$$

## Example: Dilution

If 85.2mL of 2.25M copper(II) chloride solution is diluted to a final volume of 250.0mL, what is the molarity of the diluted solution?

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$$\begin{aligned}M_1 V_1 &= M_2 V_2 \\M_2 &= \frac{M_1 V_1}{V_2} \\&= \frac{2.25\text{M} \times 0.0852\text{L}}{0.2500\text{L}}\end{aligned}$$

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**Q:** Taking the same volume 85.2mL of 2.25M copper(II) chloride and diluting to a smaller final volume, how does this molarity compare to the one above?

## Practice: Dilution

If 42.8mL of 3.02M  $\text{H}_2\text{SO}_4(\text{aq})$  solution is diluted to a final volume of 500.00mL, what is the molarity of the diluted solution of  $\text{H}_2\text{SO}_4(\text{aq})$ ?

**Determine** what is given and the question is being asked.