

Chapter 4: Chemical Composition

Sept 14, 2022

Chemistry Department, Cypress College

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

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_{Tot} is the total mass, M_A is the mass and P_A is the percent composition for component A

Example Problem: Percent Composition

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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

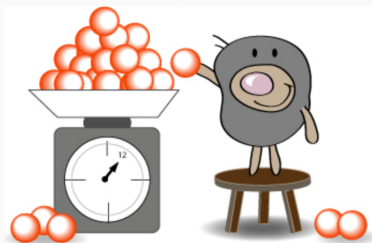
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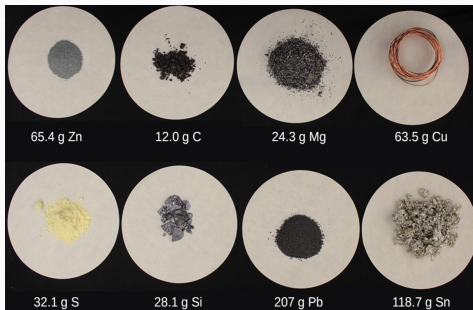


Q: What is a mole (mol)?

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

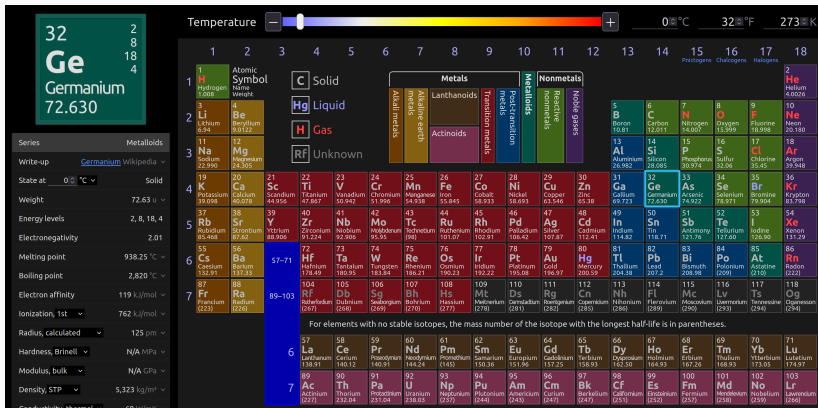
side note: Mole day is Oct. 23, between 6:02 a.m. and 6:02 p.m

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

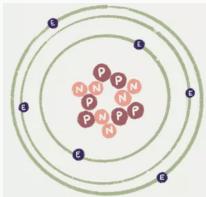
Reminder: Periodic Table



- 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

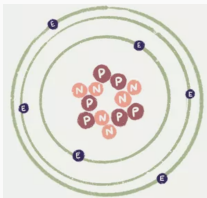


Molar Mass - mass of one mole of atoms or molecules

Example: Determine the molar mass of H_2O

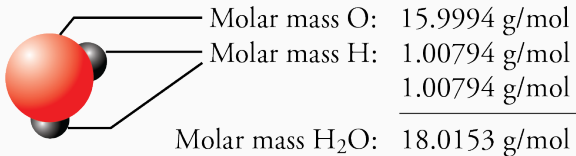
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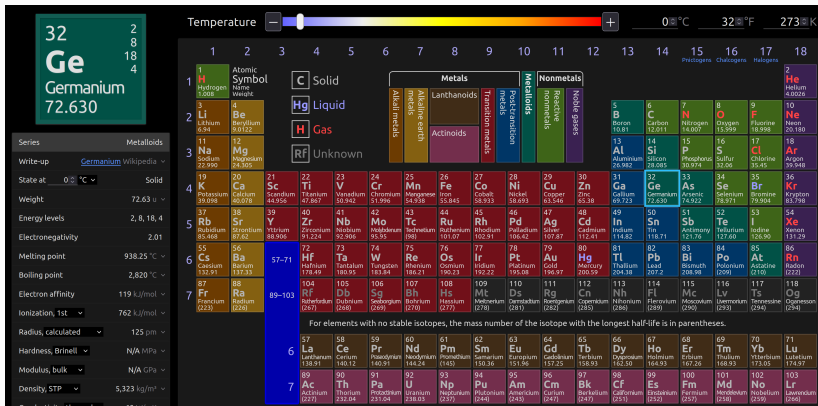


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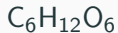
Periodic Table Revisited



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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H_2O - 2 mols H and 1 mol O

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$\text{C}_6\text{H}_{12}\text{O}_6$ - 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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2 mol Zn(s) and 2 mol HCl(aq) (reagents) produce 1 mol ZnCl₂(aq) and 1 mol H₂(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.

- $\text{H}_2\text{C}_2\text{O}_4$
- $\text{C}_6\text{H}_3\text{Cl}_3$
- CH_2O
- 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 HCO_2 . If the molar mass of the acid is determined to be about 90.0g/mol . What is the molecular formula for this acid?

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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_{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.