Chapter 4: Chemical Composition

Sept 14, 2022

Chemistry Department, Cypress College

Outline

Teaching Philosophy

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 therometer 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 Compsition

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

$$P_A = \frac{M_A}{M_{\text{Tot}}} \times 100\% \tag{1}$$

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

Magnetite, Fe_2O_4, is a mineral containing 72.4% iron. What mass of iron is present in an 837g sample of magnetite?

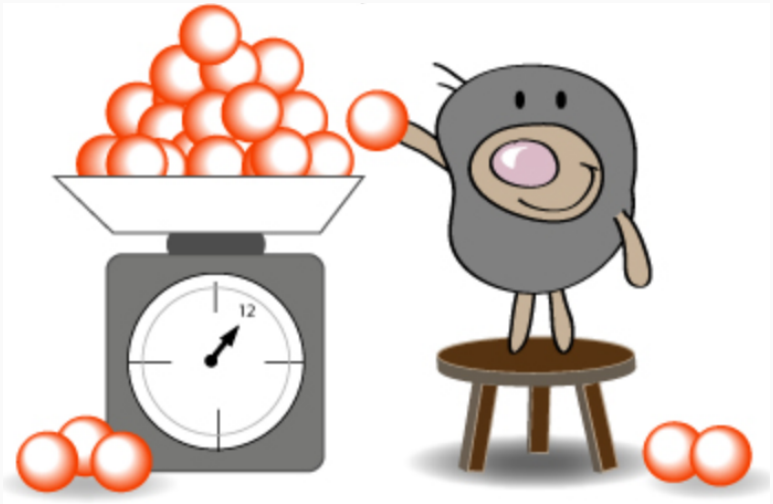
Example Problem: Percent Composition

Magnetite, Fe_2O_4, is a mineral containing 72.4% iron. What mass of iron is present in an 837g sample of magnetite?

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

Outline

The Mole Concept

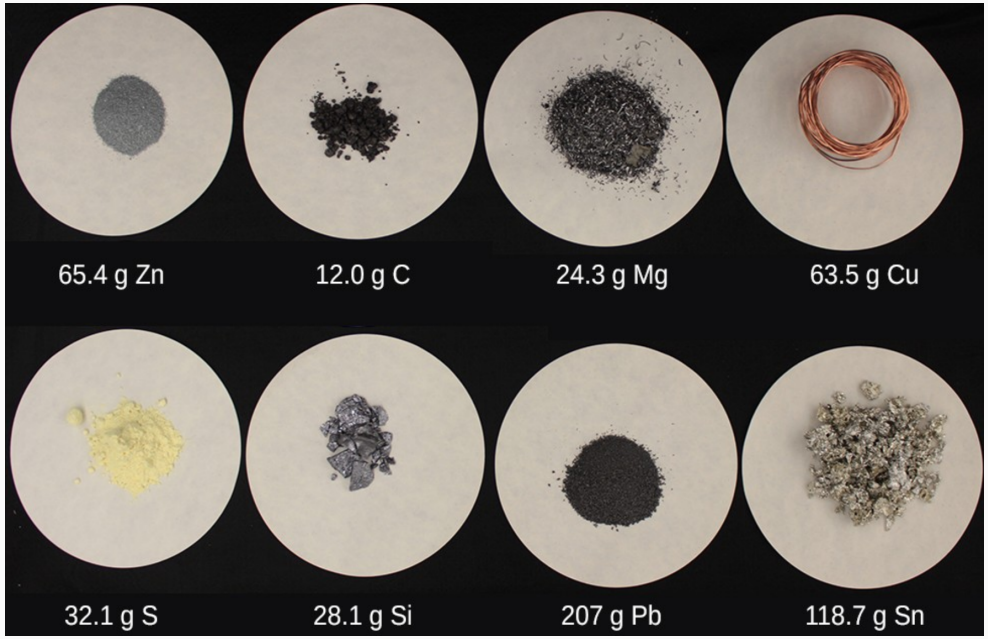


Q: What is a mole (mol)?

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

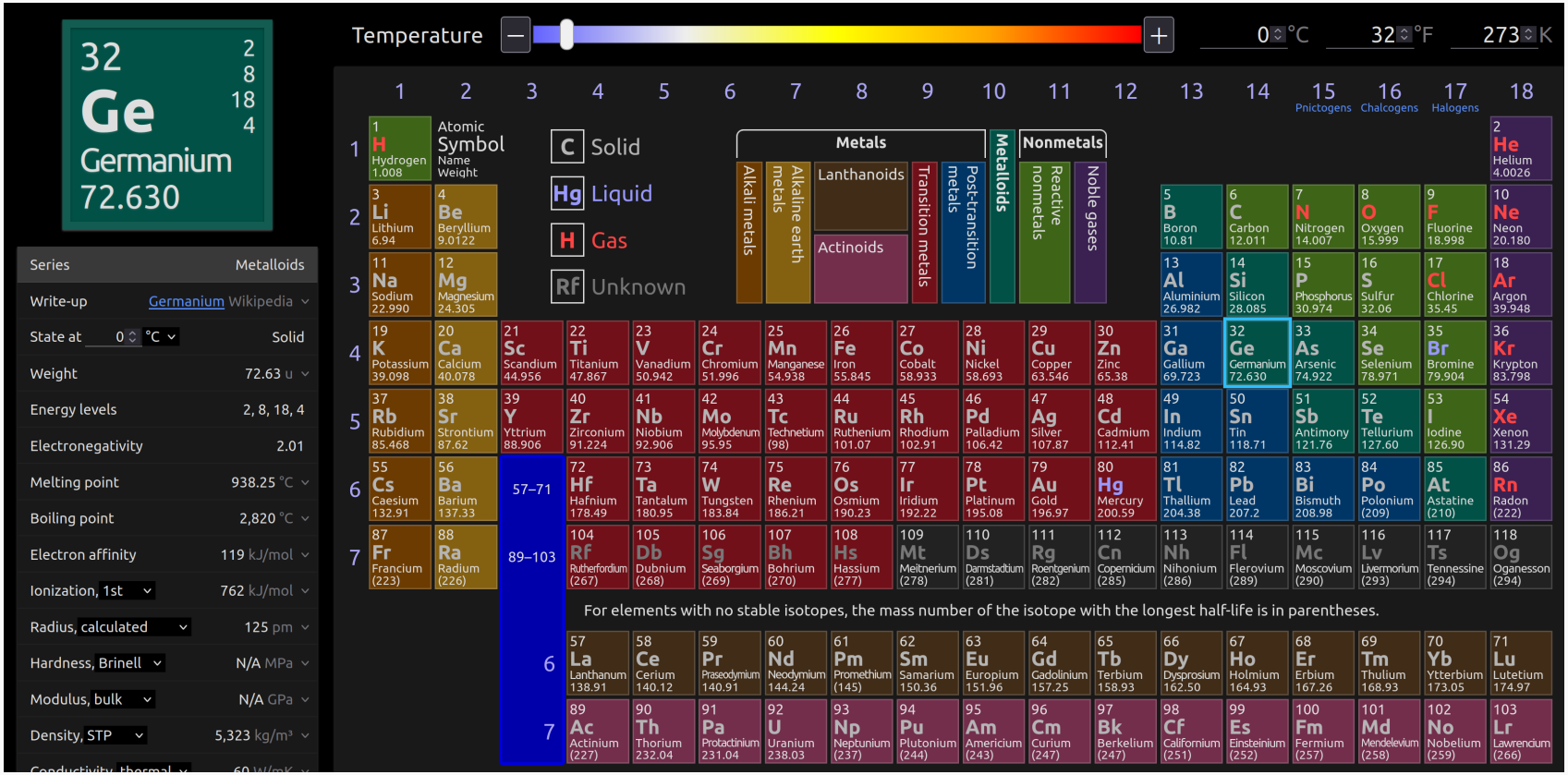
side note: Mole day is Oct. 23, between 6:02 a.m. and 6:02 p.m

Purpose of the Mole



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

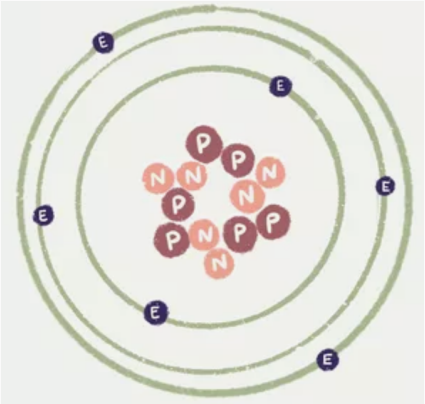
Reminder: Periodic Table



- 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

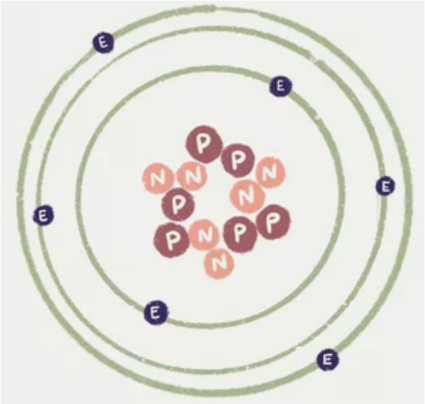


Molar Mass - mass of one mole of atoms or molecules

Example: Determine the molar mass of H_2O

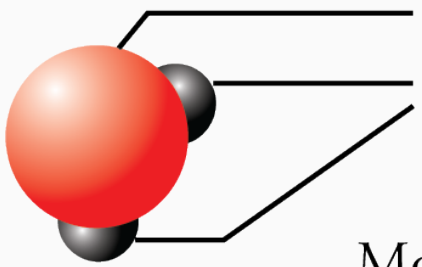
Relating amu to molar mass

Atomic Mass Unit - mass of one atom



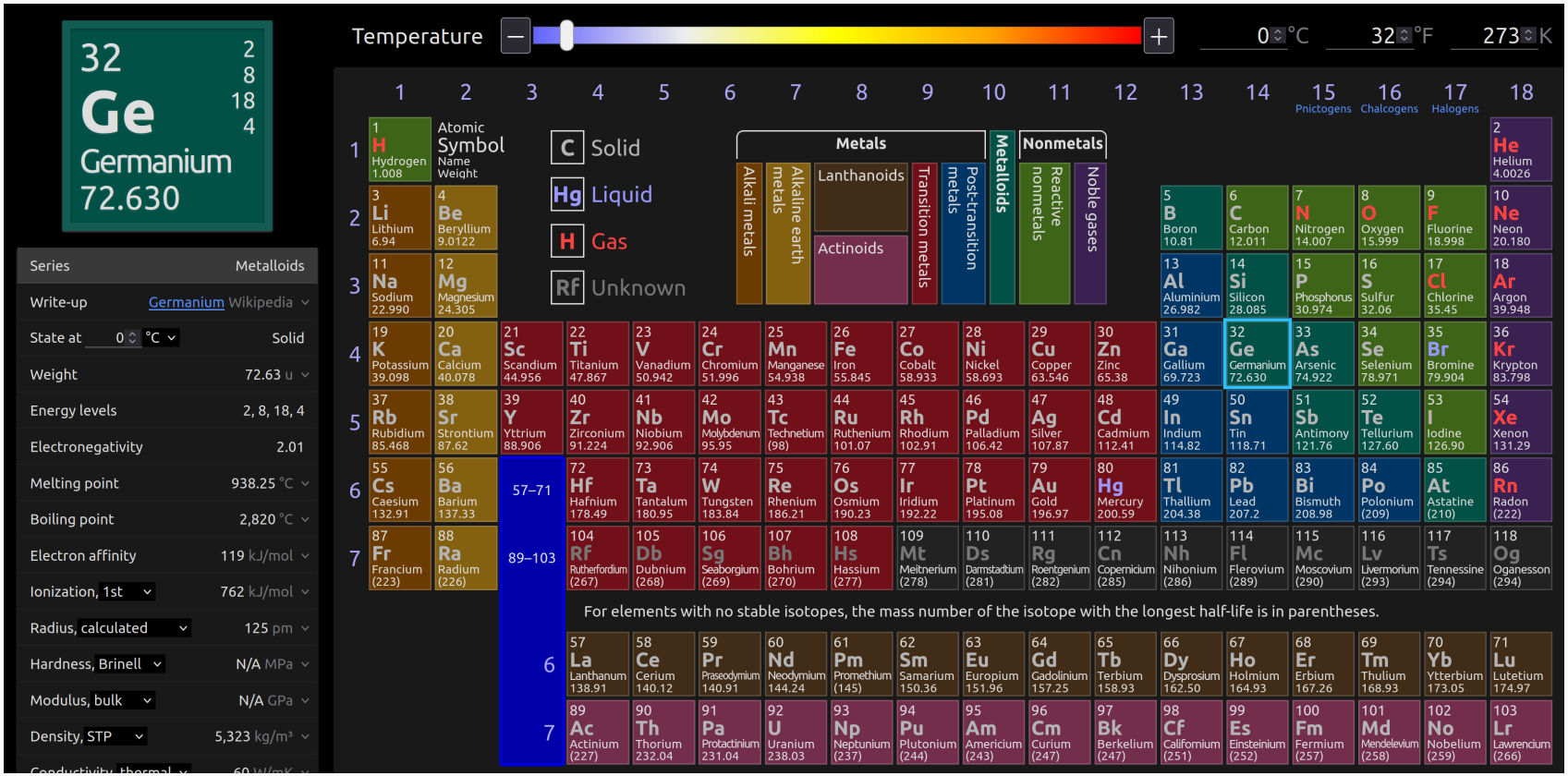
Molar Mass - mass of one mole of atoms or molecules

Example: Determine the molar mass of H_2O



Molar mass O:	15.9994 g/mol
Molar mass H:	1.00794 g/mol
	1.00794 g/mol
Molar mass H_2O:	18.0153 g/mol

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.

H_2O

$C_6H_{12}O_6$

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

H_2O - 2 mols H and 1 mol O

$C_6H_{12}O_6$

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

H_2O - 2 mols H and 1 mol O

$C_6H_{12}O_6$ - 6 mols C, 12 mols H, 6 mols O

Practice: Determine the molar masses

Example: Mole Connection to Chemical Rxn

$Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

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

Example: Mole Connection to Chemical Rxn

$Zn(s) + 2\ HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

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

1 mol Zn(s) and 2 mol HCl(aq) (reagents) produce 1 mol $ZnCl_2(aq)$ and 1 mol $H_2(g)$

Example: Combine Percent Composition and the Mole

Determine the mass percent of each element in $Al_2(SO_4)_3$.

$$\% \text{ mass of Al} =$$

Example: Combine Percent Composition and the Mole

Determine the mass percent of each element in $Al_2(SO_4)_3$.

$$\begin{aligned}\%\text{ mass of Al} &= \frac{n \times \text{molar mass Al}}{n \times \text{molar mass of } Al_2(SO_4)_3} \times 100\% \\ &= \frac{2 \times 26.98\text{g}}{342.14\text{g}} \\ &= 15.77\%\end{aligned}$$

Example: Combine Percent Composition and the Mole

Determine the mass percent of each element in $Al_2(SO_4)_3$.

$$\begin{aligned}
\%\text{ mass of Al} &= \frac{n \times \text{molar mass Al}}{n \times \text{molar mass of } Al_2(SO_4)_3} \times 100\% \\
&= \frac{2 \times 26.98\text{g}}{342.14\text{g}} \\
&= 15.77\%
\end{aligned}$$

$$\begin{aligned}
\%\text{ mass of S} &= \frac{n \times \text{molar mass S}}{n \times \text{molar mass of } Al_2(SO_4)_3} \times 100\% \\
&= \frac{3 \times 32.06\text{g}}{342.14\text{g}} \\
&= 28.11\%
\end{aligned}$$

$$\begin{aligned}
\%\text{ mass of O} &= \frac{n \times \text{molar mass O}}{n \times \text{molar mass of } Al_2(SO_4)_3} \times 100\% \\
&= \frac{12 \times 16.00\text{g}}{342.14\text{g}} \\
&= 56.12\%
\end{aligned}$$

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, $C_{12}H_{22}O_{11}$). 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 $C_{16}H_{25}NO_2$. 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.

- $H_2C_2O_4$
- $C_6H_3Cl_3$
- 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 multipled by that number

Practice: Determine Empirical Formula

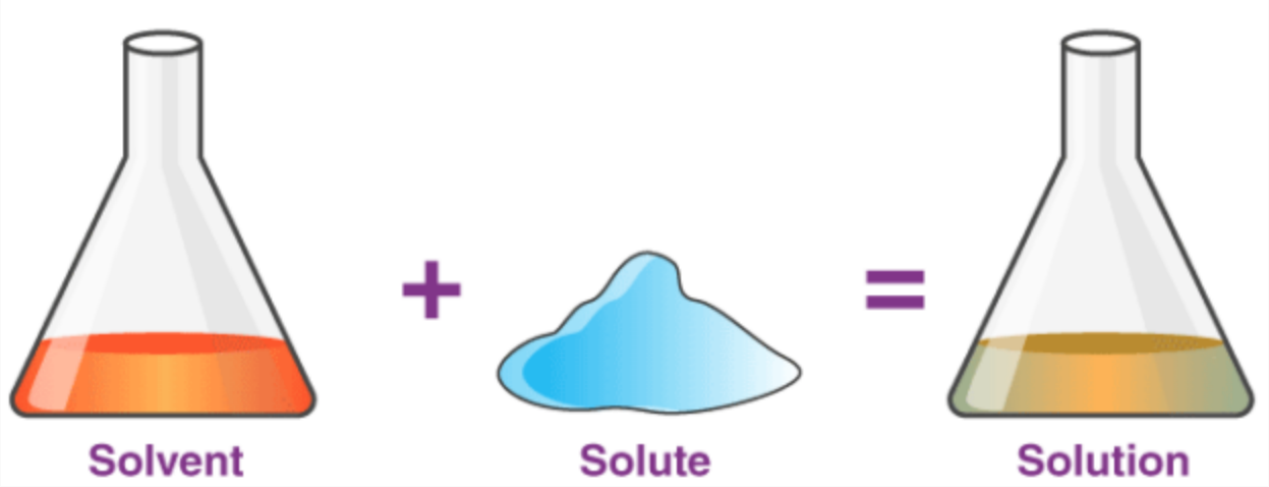
The copper mineral azurite has the deep-blue color azure. Azurite contains 55.31% copper, 6.97% carbon, 37.14% oxygen, and 0.58% hydrogen. Calculate the empirical formula of azurite.

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?

Outline

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

$$M = \frac{n_{\text{solute}}}{V} \tag{2}$$

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.

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.

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

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.

$$\begin{aligned} n_{\text{NaCl}} &= 17.0\text{g NaCl} \times \frac{1\text{mol NaCl}}{58.44\text{g NaCl}} \\ &= 0.2908967\text{mol NaCl} \\ V &= 150.0\text{mL} \times \frac{1\text{L}}{1000\text{mL}} \end{aligned}$$

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?

Determine what is given and the question is being asked.

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?

Determine what is given and the question is being asked.

$$M_1 V_1 = M_2 V_2$$

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?

Determine what is given and the question is being asked.

$$
\begin{aligned}
M_1 V_1 &= M_2 V_2 \\
M_2 &= \frac{M_1 V_1}{V_2} \\
&= \frac{2.25\text{M} \times 0.0852\text{L}}{0.2500\text{L}} = 0.767\text{M}
\end{aligned}
$$

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?

Determine what is given and the question is being asked.

$$
\begin{aligned}
M_1 V_1 &= M_2 V_2 \\
M_2 &= \frac{M_1 V_1}{V_2} \\
&= \frac{2.25\text{M} \times 0.0852\text{L}}{0.2500\text{L}} = 0.767\text{M}
\end{aligned}
$$

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 $H_2SO_4(aq)$ solution is diluted to a final volume of 500.00mL, what is the molarity of the diluted solution of $H_2SO_4(aq)$?

Determine what is given and the question is being asked.