Stoichiometric Relationships

Introduction to the Particulate Nature of Matter and Chemical Change

The Mole Concept

Reacting Masses and Volumes

Ms. Thompson - SL Chemistry
Wooster High School

Topic 1.2
The Mole Concept

- The mole is a fixed number of particles and refers to the amount, n, of substance.
- Masses of atoms are compared on a scale relative to ^{12}C and are expressed as relative atomic mass (A_r) and relative formula/molecular mass (M_r).
- Molar mass (M) has the units g mol^{-1}.
- The empirical formula and molecular formula of a compound give the simplest ratio and the actual number of atoms present in a molecule respectively.

The Mole Concept

SI: the international system of measurement

Property	Unit	Symbol
mass	kilogram	kg
temperature	kelvin	K
time	second	s
amount	mole	mol
electric current	ampère	A
luminosity	candela	cd
length	metre	m

The International Bureau of Weights and Measures (BIPM) monitors the correct use of SI units and ensures consistency regardless of where they being used.

Know these!

The Mole Concept

Avogadro's Constant (N_A)

6.02×10^{23} mol^{-1}

Molar volume of an ideal gas at 273K and 100kPa

2.27×10^{-2} m^3 mol^{-1}

($=22.7$ dm^3 mol^{-1})

Negative indices and units

*An **index** or **power** is a mathematical notation that shows that a quantity or physical unit is repeatedly multiplied by itself: $m \times m = m^2$*

*A **negative index** shows a reciprocal*

$1/x = x^{-1}$ $dm^{-3} = 1/dm$

Useful Prefixes

Prefix	Abbreviation	Scale
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
standard	-	1
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}

The Mole Concept

Amount of substance: The mole

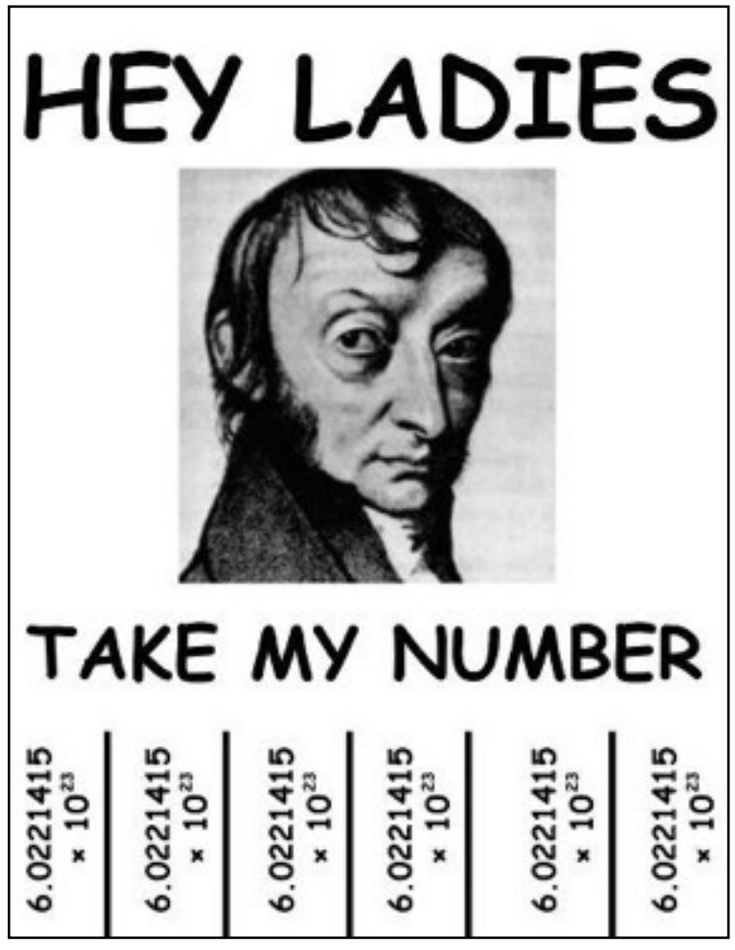
- The ability to measure precise amounts of reacting substances is of crucial importance.

- All chemical substances are made up of elements and their constituent atoms which vary in their number of protons, neutrons, and electrons

The Mole Concept

Amount of substance: The mole

- Had to determine a way to measure equal amounts of different elements regardless of how big their atoms are which tells us how much reacting quantities we have



- The **mole** is an SI unit, symbol **mol**, defined as a fixed amount, *n*, of a substance.
  - This is known as **Avogadro's constant** = 6.02×10^{23} mol^{-1}

The Mole Concept

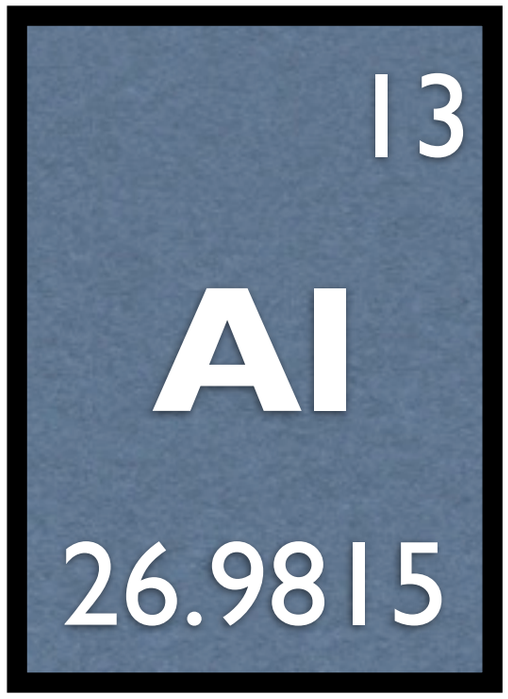
Relative atomic mass, relative formula mass, and molar mass

- **Isotopes** are atoms of the same element that have the same number of protons in nucleus but different numbers of neutrons.
- **Relative abundance** is how much of that element occurs and influences the atomic mass of the atom.
- **Relative atomic mass (A_r)** is the average of the different isotopes and their masses.
- **Relative molecular mass (M_r)** is determined by combining the **A_r** values of the individual atoms or ions.
- **Molar Mass** mass of one mole of a substance in grams per mole (g mol^{-1})

Practice Problem

... I Do ...

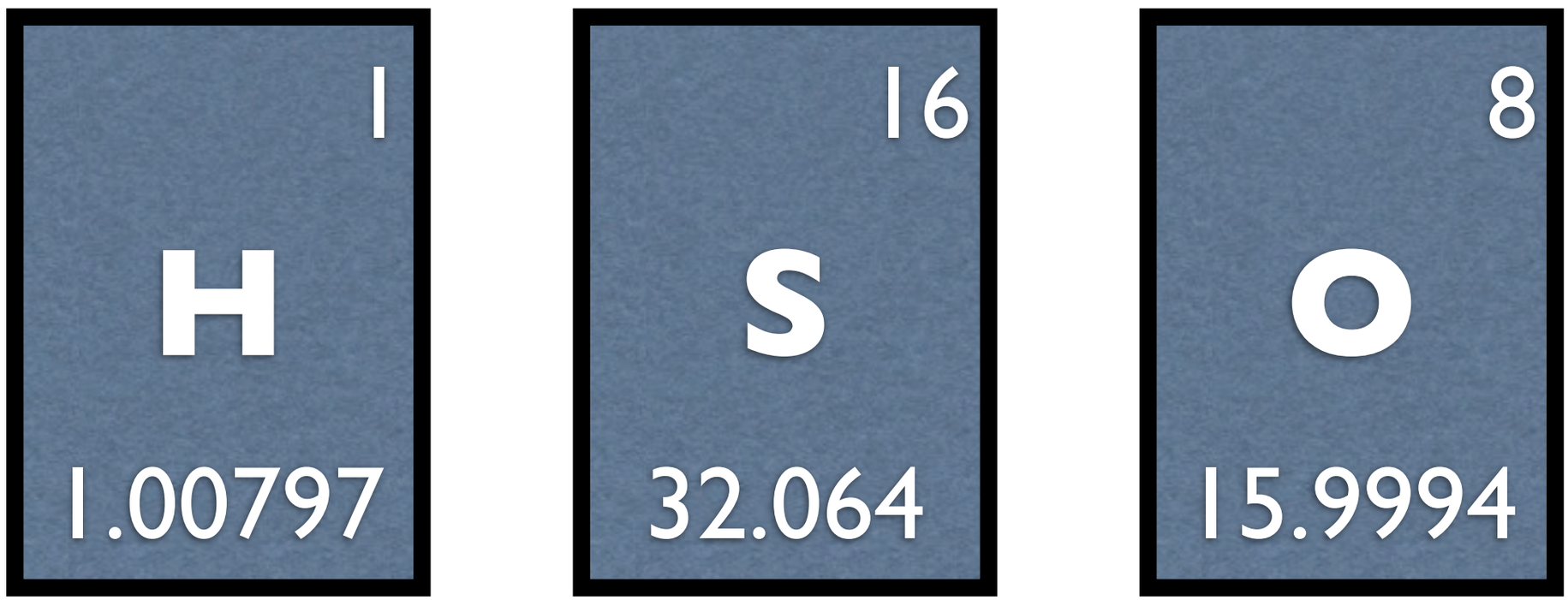
State the relative atomic mass A_r of aluminum.



Practice Problem

... We Do ...

Calculate the molar mass (M_r) of sulfuric acid H_2SO_4.



Practice Problem

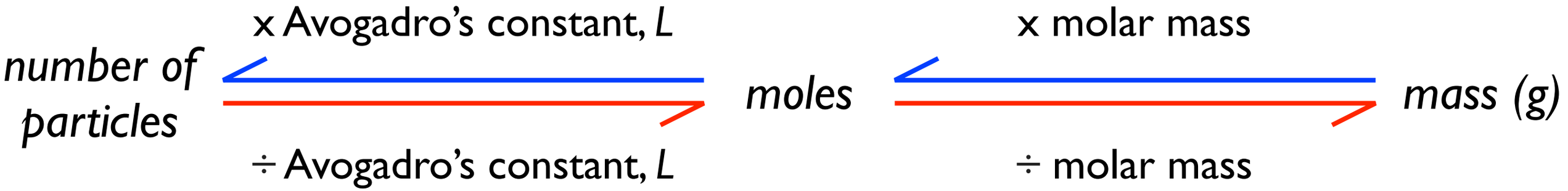
... You Do ...

Calculate M_r of copper (II) sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$.

29	16	1	8
Cu	**S**	**H**	**O**
63.546	32.064	1.00797	15.9994

The Mole Concept

Mole Calculations



Practice Problem

... I Do ...

Calculate the amount (in mol) of carbon dioxide, $n(CO_2)$ in a sample of 1.50×10^{23} molecules.

number of particles → *moles*

÷ Avogadro's constant, *L*

Practice Problem

... I Do ...

Calculate the amount (in mol) in 8.80g of carbon dioxide, CO_2.

moles ← *mass (g)*

÷ molar mass

Classwork

Work with a partner, or alone, in answering the following questions. SHOW ALL WORK and UNITS

1. <u>Calculate</u> the molar mass of the following substances and ions:

- $Mg(NO_3)_2$
- Na_2CO_3
- $[Al(H_2O)_6]^{3+}$
- $MgSO_4 \cdot 7H_2O$

2. <u>Calculate</u> the amount (in mol) in the following masses:

- 25.0g calcium carbonate
- 279.94g of iron (III) sulfate

3. <u>Calculate</u> the mass (in grams) in each of the following:

- 0.150 mol of sulfur dioxide
- 0.710 mol of calcium phosphate, $Ca_3(PO_4)_2$

4. <u>Calculate</u> the number of particles present in the following:

- 2.00 mol of vanadium, V
- 72.99 mol of sodium chlorate (VII), $NaClO_4$

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The Mole Concept

Experimental empirical and molecular formula determination

- **Empirical** describes information that is derived through observation and/or investigation.
- **Qualitative analysis** focuses on determining which elements are present in a compound. It could also verify the purity of the substance.
- **Quantitative analysis** enables chemists to determine the relative masses of elements which allows them to work out their exact composition.
- The **molecular formula** is the actual number of atoms or amount (in mol) of elements in one structural unit or one mole of the compound.
- The **empirical formula** of a compound is the simplest whole-number ratio of atoms or amount (in mol) of each element present in a compound.

Substance	*Molecular Formula*	*Empirical Formula*
Hydrogen Peroxide	H_2O_2	*HO*

Classwork

Work with a partner and identify the substances molecular formula and empirical formula

Substance	Molecular Formula	Empirical Formula
ethane		
water		
butanoic acid		
glucose		
naphthalene		
benzene		

The Mole Concept

Experimental empirical and molecular formula determination

- To determine the empirical formula of a compound from experimental data:
  - Assume any percentages are masses, in grams
  - Convert all masses to moles (divide by molar mass)
  - Divide by the smallest number of moles - is all are whole numbers (within 0.1), the numbers are the subscripts
  - If not, make whole numbers by multiplying all moles by given integer (.5x2, .33 or .67 by 3, .25 or .75 by 4 etc.)
  - Now the numbers are the subscripts.
  - Hydrates are compounds with water molecules incorporated into their structure. Their formulas are determined using % (compound) **and** % (water) to determine ratio of waster molecules per formula unit of the compound (example: $CuSO_4 \cdot 5H_2O$

The Mole Concept

Percentage composition by mass

You can use your understanding of how to calculate the molar mass of a compound to calculate the percentage by mass of elements in a compound

1. Calculate the percentage by mass of sulfur in sulfuric acid, H_2SO_4.
2. Determine the empirical formula of an organic compound that contains 75% carbon and 25% hydrogen by mass.

$$\text{relative amount of substance} = \frac{\%\ \text{composition}}{\text{molar mass}}$$

$$\text{determine ratio} = \frac{\text{relative amount}}{\text{smallest quotient from r.a. calculation}}$$

$$\text{molecular formula} = \frac{\text{molar mass}}{\text{empirical formula mass}}$$

Then, multiply molecular formula by number from above calculation

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