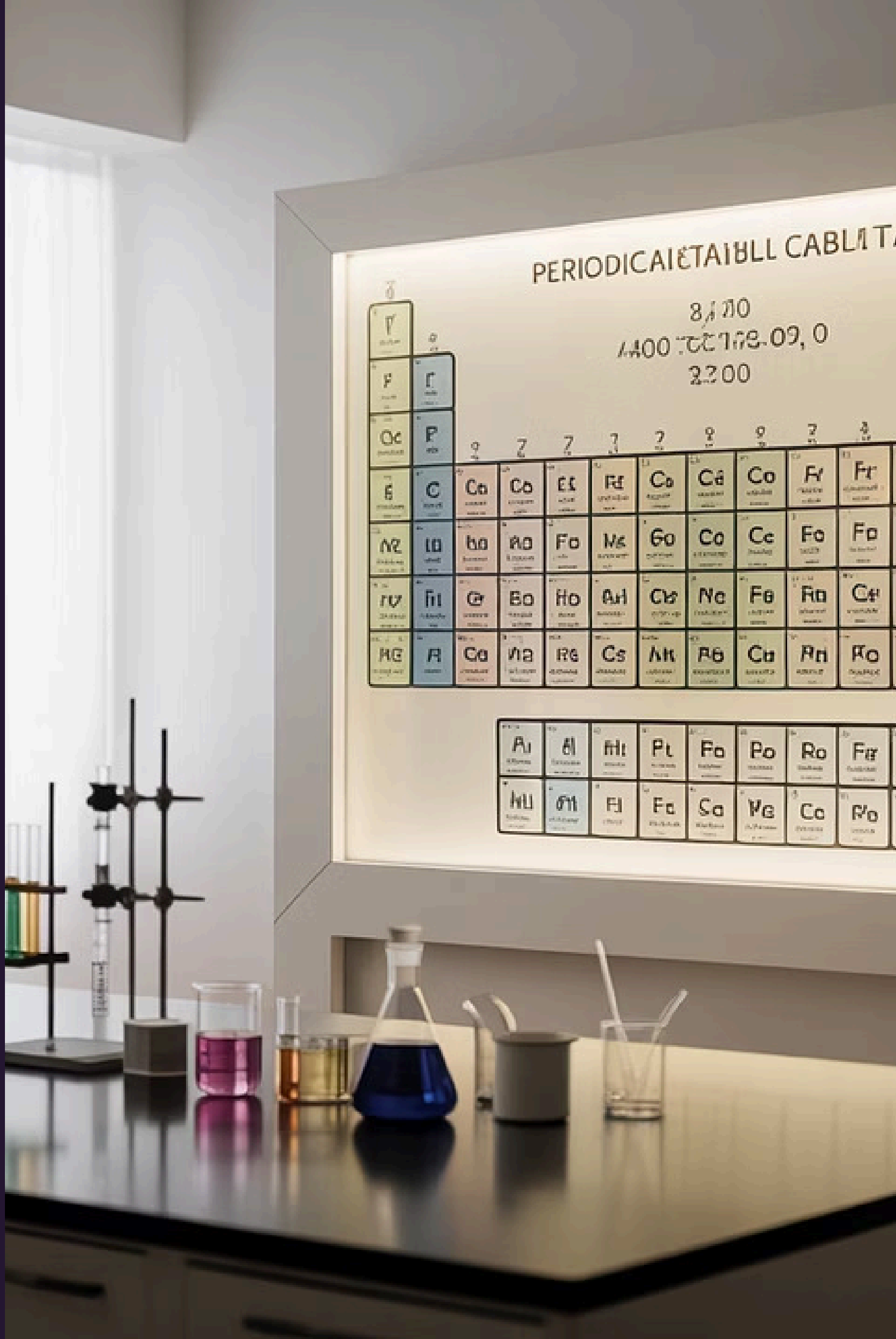
Chemistry Fundamentals

Lecture 8: Atomic Mass of Elements



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From Individual Isotopes to Elemental Atomic Mass

Fundamental Concept

Elements exist as isotope mixtures in nature

Atomic Mass Definition

Weighted average of all naturally occurring isotopes, accounting for their relative abundance

Measurement Units

Atomic mass units (amu) or unified atomic mass units (u), known to 6-9 significant figures

Periodic table values represent these weighted averages, essential for stoichiometric calculations. The concept evolved from Dalton's whole number hypothesis to today's precise measurements.

The Weighted Average Calculation Method

Mathematical Formula: Atomic mass = Σ(isotope mass × fractional abundance)

Step 1

Convert percentages to decimal fractions

Step 2

Multiply each isotope mass by its fractional abundance

Step 3

Sum all products

Step 4

Apply significant figure rules

Example: Magnesium Isotopes

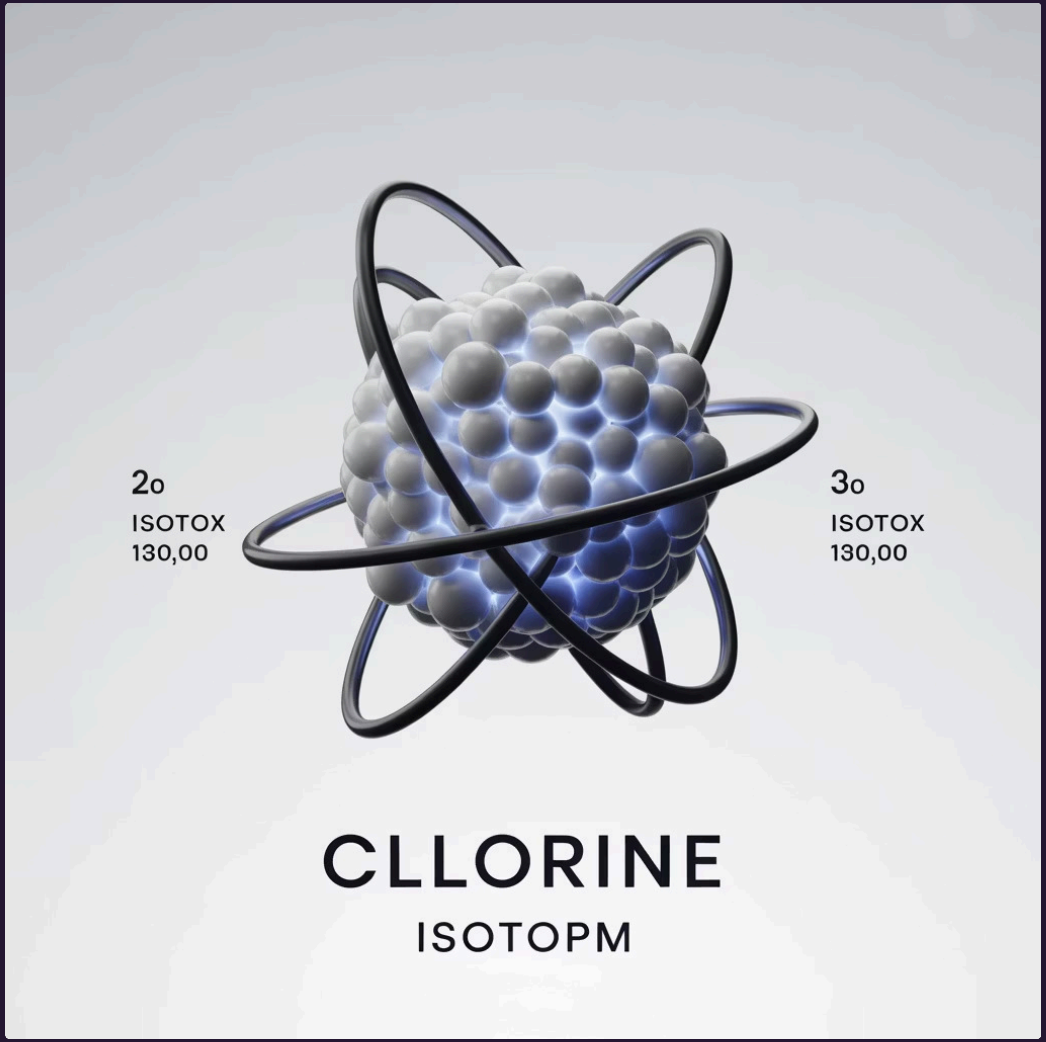
^{24}Mg: 23.985 amu (78.99%)

^{25}Mg: 24.986 amu (10.00%)

^{26}Mg: 25.983 amu (11.01%)

Calculation: (23.985 × 0.7899) + (24.986 × 0.1000) + (25.983 × 0.1101) = 24.31 amu

Chlorine - A Detailed Example



Natural Isotopes of Chlorine

Isotope	Exact Mass	Abundance
^{35}Cl	34.969 amu	75.77%
^{37}Cl	36.966 amu	24.23%

Calculation: $(34.969 \times 0.7577) + (36.966 \times 0.2423) = 35.45$ amu

Periodic Table Check: Listed value is 35.45 amu ✓

Copper Isotopes - Another Practice Example

1

Copper-63 (^{63}Cu)

- Exact mass: 62.930 amu
- Natural abundance: 69.17%

2

Copper-65 (^{65}Cu)

- Exact mass: 64.928 amu
- Natural abundance: 30.83%

Calculation: (62.930 × 0.6917) + (64.928 × 0.3083) = 63.55 amu

Observation: The average is closer to the more abundant isotope mass

Verification: Periodic table lists Cu as 63.55 amu

Pattern Recognition: Atomic mass is always between the lightest and heaviest isotope masses

Reverse Calculations - Finding Unknown Abundance

When given atomic mass and isotope masses, we can find unknown abundances using algebraic equations.

Example: Silicon Isotopes

- ^{28}Si: 27.977 amu
- ^{29}Si: 28.976 amu
- Average atomic mass: 28.085 amu

Setup

Let x = fraction of ^{28}Si, then (1-x) = fraction of ^{29}Si

Equation

$27.977x + 28.976(1-x) = 28.085$

Solution

x = 0.893 (89.3% ^{28}Si, 10.7% ^{29}Si)

Verification

$(27.977 \times 0.893) + (28.976 \times 0.107) = 28.085$ ✓

Mass Spectrometry and Isotope Determination

Mass spectrometry separates and measures isotopes by mass-to-charge ratio, producing a spectrum where peak heights are proportional to isotope abundance.

Example: Bromine Spectrum

- Peak at m/z 79: Height 51 (^{79}Br)
- Peak at m/z 81: Height 49 (^{81}Br)
- Abundance ratio: 51:49 ≈ 50.5%:49.5%

High-resolution instruments can distinguish isotopes differing by as little as 0.001 amu.

Applications include elemental analysis, isotope ratio studies, and forensic science. One limitation is that ionization may not represent natural abundance exactly.

Factors Affecting Atomic Mass Values

Isotope Stability

Radioactive isotopes decay over time, changing abundance ratios

Geological Variation

Isotope ratios vary slightly by location on Earth

Artificial Isotopes

Human-made isotopes not included in standard values

Measurement Precision

Improved techniques lead to more accurate values

Example: Lead isotopes (^{206}Pb, ^{207}Pb, ^{208}Pb) abundances vary in different ore deposits, with a standard atomic mass of 207.2 amu (average of common samples).

The International Union of Pure and Applied Chemistry (IUPAC) maintains official values, which are periodically updated as measurement technology improves.

Practical Applications and Calculations

Atomic masses form the foundation for stoichiometry and are essential for mole calculations. The sum of atomic masses in a compound gives its molecular mass.

Example: Water (H_2O) Molecular Mass

- H: 1.008 amu × 2 = 2.016 amu
- O: 15.999 amu × 1 = 15.999 amu
- Total: 18.015 amu

Laboratory Applications

- Quantitative analysis
- Reaction yield calculations
- Precision measurements

Industrial Applications

- Quality control
- Material specifications
- Manufacturing standards

Next Lecture:

Periodic Table Overview

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