Chemistry Fundamentals

Lecture 15: The Mole Concept

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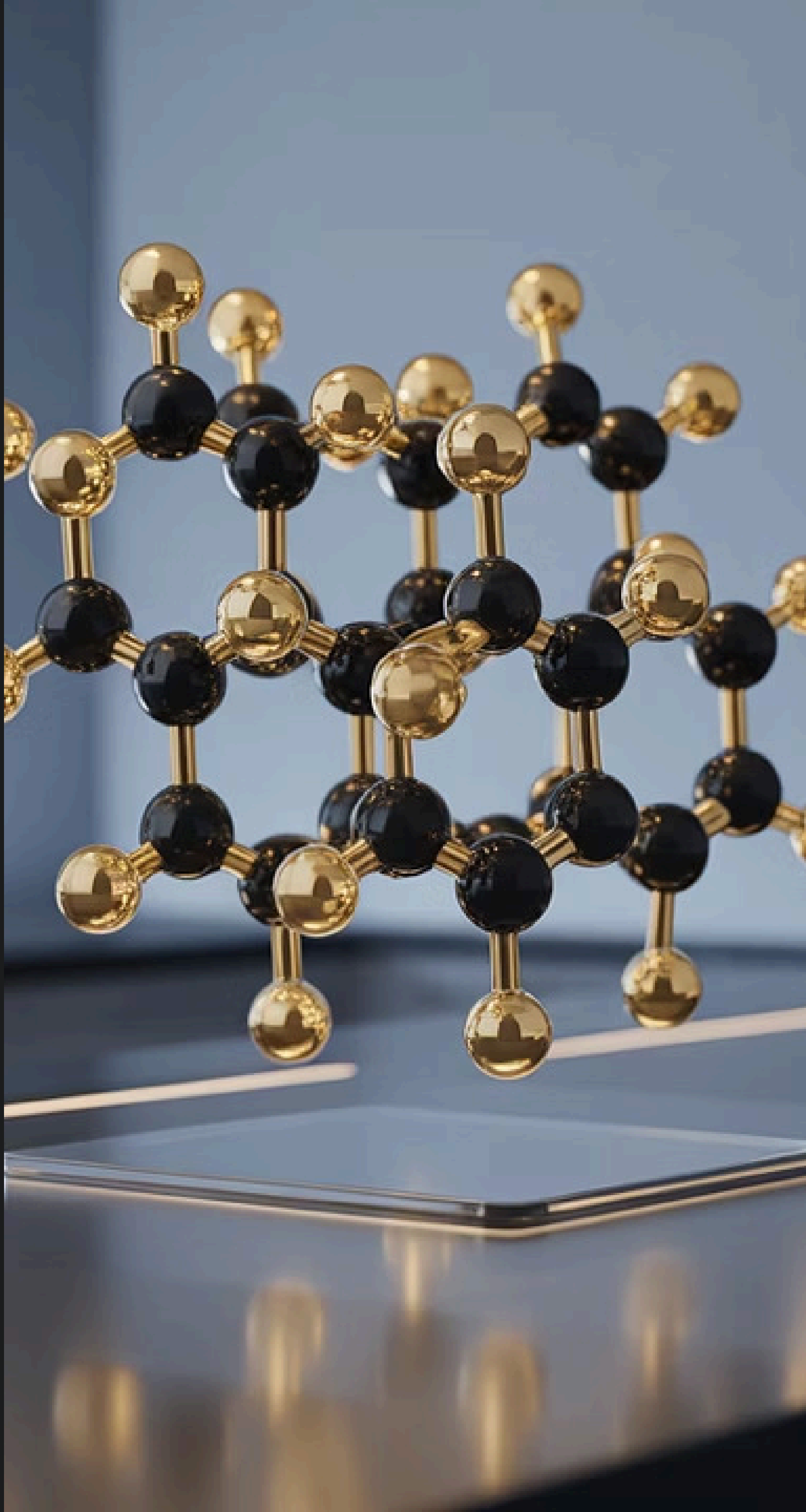
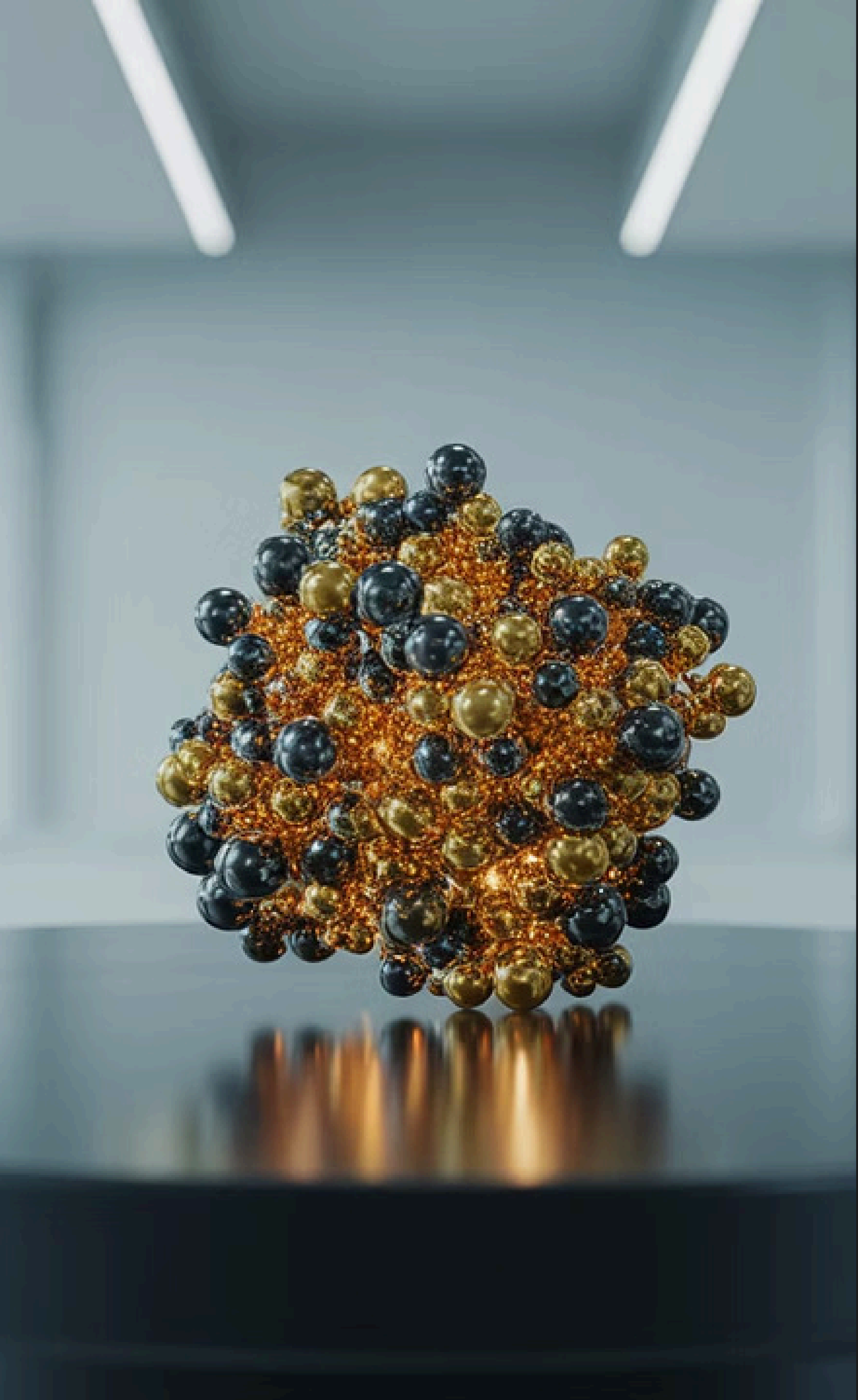




Introduction to the Mole - Why We Need It

The Scale Problem

Atoms are incredibly small - a single carbon atom has a mass of 1.99×10^{-23} g

The Solution

The mole - a counting unit like "dozen" but for atoms and molecules

One mole = 6.022×10^{23} particles (Avogadro's number)

Real-World Analogy

If you had a mole of pennies, you could give every person on Earth about 8×10^{13} dollars

Why This Matters: Allows us to count atoms by weighing them, making chemistry calculations practical

Avogadro's Number - The Bridge Between Worlds

Historical Context & Value

- Named after Amedeo Avogadro (1776-1856), though he never calculated this number
- Precise Value: $6.02214076 \times 10^{23}$ particles per mole (2019 SI definition)
- Originally measured through X-ray crystallography and oil drop experiments

Magnitude Understanding

- 1 mole of rice grains would cover Earth's surface 75 miles deep
- 1 mole of seconds equals 1.9×10^{16} years (older than the universe)
- Links atomic mass units to grams - 1 mole of carbon-12 atoms = exactly 12 grams

Memory Aid: "A mole is a lot" - remember the enormity of 6.02×10^{23}

Molar Mass - Converting Between Moles and Mass

Definition: Mass of one mole of substance, expressed in grams per mole (g/mol)

1

For Elements

Molar mass = atomic mass from periodic table

- Carbon: 12.01 g/mol
- Hydrogen: 1.008 g/mol
- Oxygen: 15.999 g/mol

2

For Compounds

Sum of atomic masses × number of atoms

Worked Example - H_2O:

- H: 2 atoms × 1.008 g/mol = 2.016 g/mol
- O: 1 atom × 15.999 g/mol = 15.999 g/mol
- Total: 18.015 g/mol

Common Mistake: Forgetting to multiply by number of atoms in formula

Practical Significance: Allows conversion between laboratory measurements and molecular quantities

Mole Calculations - Mass to Moles and Back

Basic Conversion Formula: moles = mass (g) ÷ molar mass (g/mol)

Step 1

Identify given information and desired unit

Step 2

Find molar mass from periodic table

Step 3

Set up conversion factor

Step 4

Calculate with proper significant figures

Example 1: Mass to Moles

How many moles in 45.0 g of water?

- Given: 45.0 g H_2O
- Molar mass H_2O = 18.015 g/mol
- moles = 45.0 g ÷ 18.015 g/mol = 2.50 mol

Example 2: Moles to Mass

What mass is 0.750 mol of NaCl?

- Molar mass NaCl = 22.99 + 35.45 = 58.44 g/mol
- mass = 0.750 mol × 58.44 g/mol = 43.8 g

Units Check: Always verify units cancel properly

Counting Particles - From Moles to Atoms/Molecules

The Fundamental Relationship: 1 mole = 6.022×10^{23} particles

Conversion Factor: particles = moles × 6.022×10^{23}

Types of Particles

- Atoms (for elements)
- Molecules (for covalent compounds)
- Formula units (for ionic compounds)

Worked Example

How many water molecules in 2.50 mol H_2O?

particles = 2.50 mol × 6.022×10^{23} molecules/mol

particles = 1.51×10^{24} molecules

Multi-Step Problem: Atoms in 45.0 g H_2O

1. 45.0 g ÷ 18.015 g/mol = 2.50 mol
2. 2.50 mol × 6.022×10^{23} molecules/mol = 1.51×10^{24} molecules
3. Each molecule has 3 atoms, so $1.51 \times 10^{24} \times 3 = 4.53 \times 10^{24}$ atoms

Molar Volume of Gases - STP Conditions

Key Concepts

- Standard Temperature and Pressure (STP): 0°C (273.15 K) and 1 atm pressure
- Avogadro's Law: Equal volumes of gases at same T and P contain equal numbers of molecules
- Molar Volume at STP: 22.4 L/mol for any gas

Important Note: This relationship only applies to gases, not liquids or solids

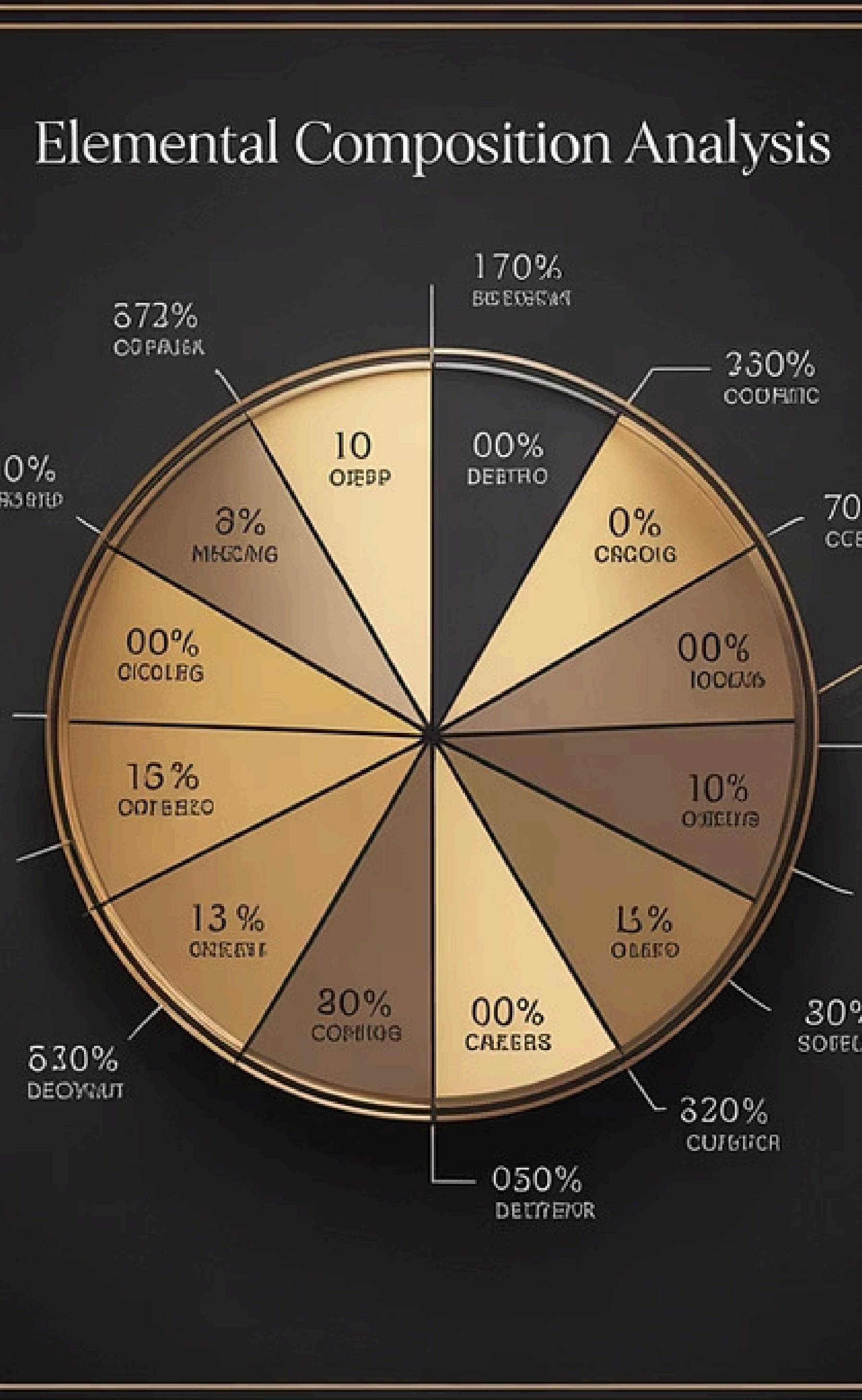
Practical Applications

- Calculating gas volumes in reactions
- Determining gas densities
- Converting between gas volume and moles

Example Problem: Volume of 3.50 mol CO_2 at STP

Volume = 3.50 mol × 22.4 L/mol = 78.4 L

Real-World Connection: A mole of any gas at room conditions occupies about 24.5 L



Percent Composition from Molar Mass

Definition: Mass percent of each element in a compound

Formula: % element = (mass of element in formula/molar mass of compound) × 100%

Worked Example - H_2O

- Molar mass H_2O = 18.015 g/mol
- % H = (2.016 g/18.015 g) × 100% = 11.19%
- % O = (15.999 g/18.015 g) × 100% = 88.81%
- Check: 11.19% + 88.81% = 100.00% ✓

Complex Example - $Ca(NO_3)_2$

- Molar mass = 40.08 + 2(14.01) + 6(15.999) = 164.10 g/mol
- % Ca = (40.08/164.10) × 100% = 24.42%
- % N = (28.02/164.10) × 100% = 17.07%
- % O = (95.994/164.10) × 100% = 58.50%

Applications: Quality control, fertilizer analysis, nutritional labeling

Problem-Solving Summary and Common Mistakes

1

Mass (g)

Use molar mass (g/mol)

2

Moles (mol)

Use Avogadro's number (6.022×10^{23})

3

Particles

For gases, use molar volume at STP (22.4 L/mol)

Common Mistakes to Avoid

- Forgetting to multiply by number of atoms in formula when calculating molar mass
- Using wrong number of significant figures
- Confusing molecules with atoms in particle calculations
- Applying molar volume to liquids or solids

Step 1

Identify what you have and what you need

Step 2

Choose appropriate conversion factor

Step 3

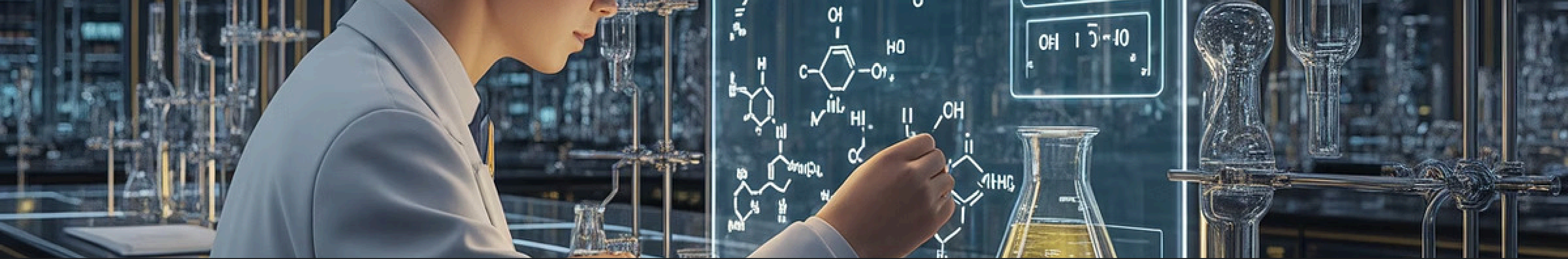
Set up dimensional analysis

Step 4

Calculate with proper significant figures

Step 5

Check if answer makes sense



Next Lecture:

Chemical Formulas and Nomenclature

Master these conversions - they're fundamental to all chemistry calculations:

- Mass ↔️ Moles
- Moles ↔️ Particles
- Volume (for gases) ↔️ Moles

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