Chemistry Fundamentals

Lecture5:
Density

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Density - Mass Packed into Space

Fundamental Definition

Density is the amount of mass contained in a given volume of substance.

Formula: D = m/V

- D: Density (g/cm^3, g/mL, kg/L)
- m: Mass (g, kg)
- V: Volume (cm^3, mL, L)

Physical Meaning

- High density: Atoms/molecules packed tightly together
- Low density: Atoms/molecules spread farther apart
- Intensive property: Doesn't depend on amount of substance
- Characteristic property: Each pure substance has unique density

Atomic Structure Factors

- Atomic mass: Heavier atoms generally create denser substances
- Atomic packing: How efficiently atoms fit together
- Crystal structure: Arrangement of atoms in solids

Temperature Effects

- Generally: Density decreases as temperature increases
- Thermal expansion: Substances expand when heated
- Water exception: Ice is less dense than liquid water

The Density Equation and Its Applications

Basic Equation and Rearrangements

Basic Equation: D = m/V

Rearranged Forms:

- To find mass: m = D × V
- To find volume: V = m/D

Units and Conversions

- g/cm³ = g/mL (1 cm³ = 1 mL)
- Water standard: 1.00 g/mL at 4°C
- kg/L: Often used for larger quantities
- Conversion: 1 g/cm³ = 1000 kg/m³

Identify what you're given

Mass, volume, or density

Choose correct form of equation

D = m/V, m = D × V, or V = m/D

Substitute values with units

Make sure units are compatible

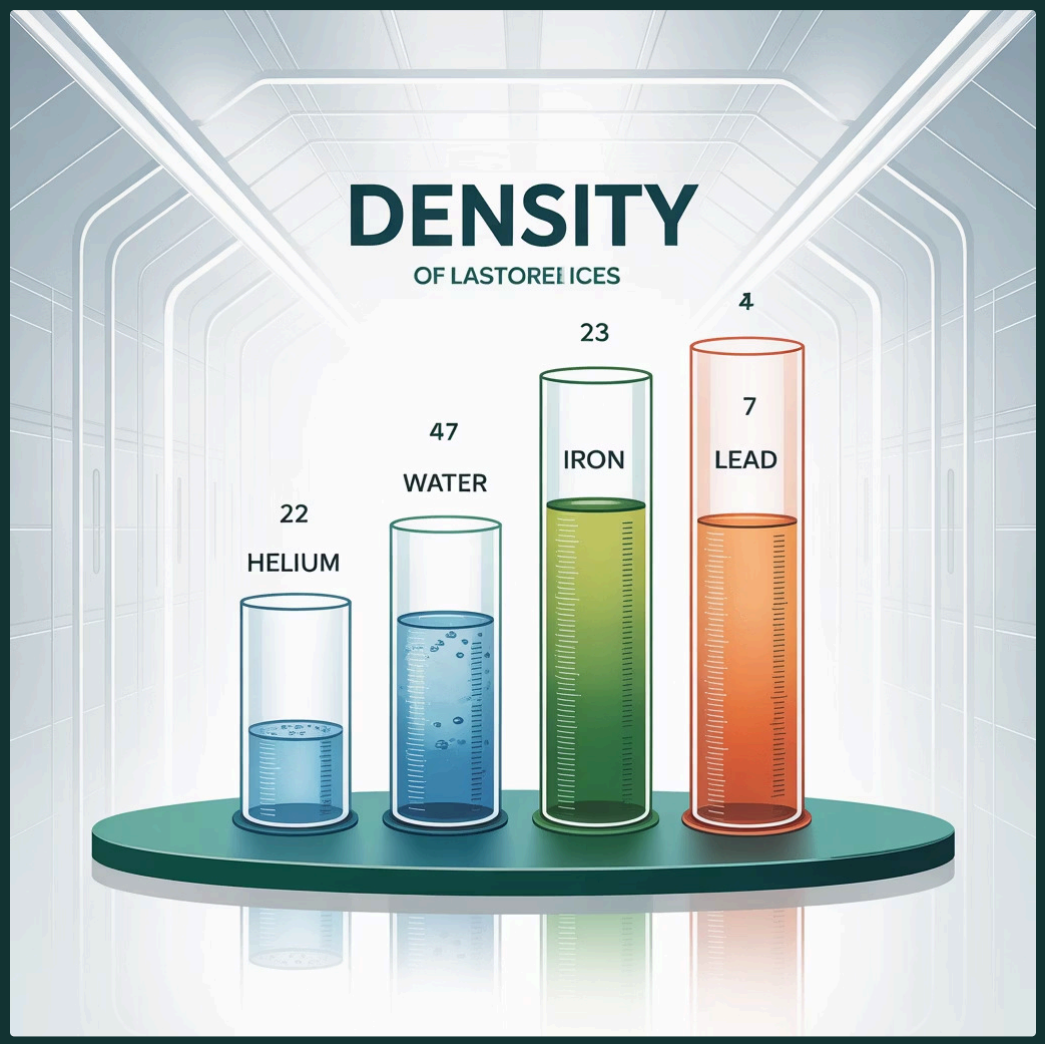
Calculate and check units

Follow significant figure rules

Verify answer makes sense

Compare to known substances

Density Values - A Reference Guide



Gases (very low density)

- Air: 0.0012 g/cm³
- Helium: 0.00018 g/cm³
- Carbon dioxide: 0.00198 g/cm³

Liquids (moderate density)

- Water: 1.00 g/cm³ (reference standard)
- Ethanol: 0.789 g/cm³
- Olive oil: 0.92 g/cm³
- Mercury: 13.6 g/cm³ (liquid metal)

Solids (generally high density)

- Ice: 0.92 g/cm³ (less dense than water!)
- Wood (oak): ~0.75 g/cm³
- Aluminum: 2.70 g/cm³
- Iron: 7.87 g/cm³
- Gold: 19.3 g/cm³
- Osmium: 22.6 g/cm³ (densest element)

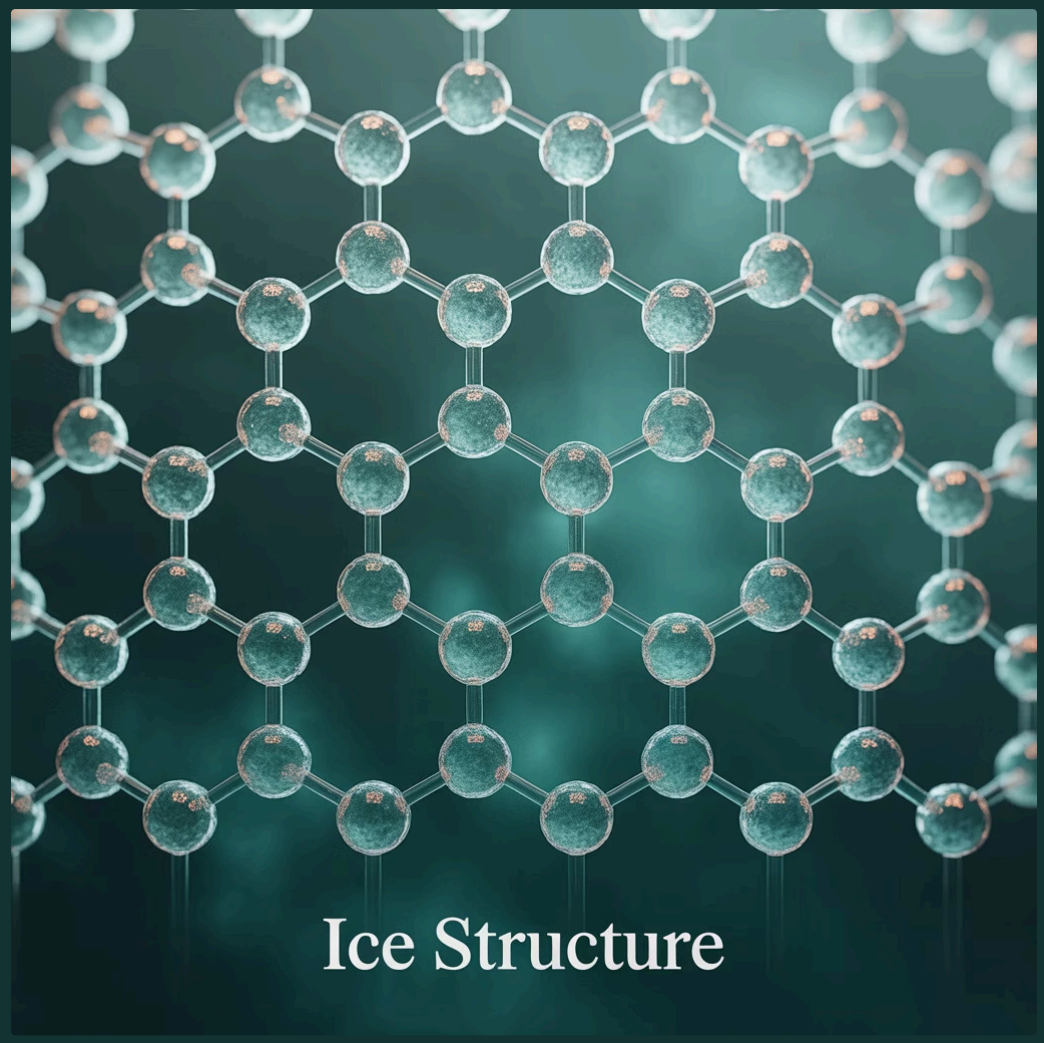
Why Ice Floats - A Molecular Explanation

The Density Anomaly

- Ice density: 0.92 g/cm^3
- Water density: 1.00 g/cm^3
- Result: Ice floats because it's less dense than liquid water

Molecular Explanation

- Liquid water: H_2O molecules randomly arranged, pack closely
- Ice formation: Molecules form rigid hexagonal crystal structure
- Hydrogen bonding: Forces specific geometric arrangement
- Less efficient packing: Crystal structure has more empty space



Biological and Environmental Importance

- Aquatic life: Fish survive under ice layer in winter
- Weathering: Ice formation in rock cracks breaks rocks apart
- Ocean currents: Ice formation affects ocean circulation
- Climate: Ice caps and glaciers float, affecting global climate

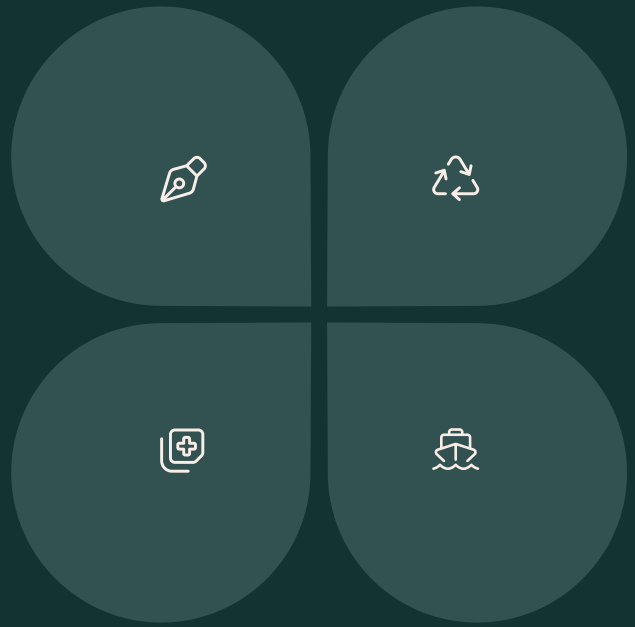
Density Applications in Real World

Material Identification

- Forensic science: Identifying unknown substances
- Quality control: Detecting impurities
- Archaeology: Dating and identifying ancient materials

Medical Applications

- Bone density: Measuring bone health
- Body composition: Determining muscle vs. fat ratio
- Medical imaging: Contrast agents with different densities



Separation Techniques

- Oil spills: Oil floats on water (0.8-0.9 g/cm^3)
- Cream separation: Cream rises to top of milk
- Mining: Dense ores settle while lighter materials float

Engineering Applications

- Ship design: Hull shape for proper buoyancy
- Airplane design: Light materials for reduced weight
- Construction: Concrete density affects building strength

Density Calculations - Worked Examples

1

Basic Density Calculation

A 50.0 g sample of metal has a volume of 25.0 mL. Calculate the density.

Solution:

D = m/V = 50.0 g / 25.0 mL = 2.00 g/mL

Analysis: This density suggests aluminum (2.70 g/cm³) with impurities.

2

Finding Volume from Density

Gold has a density of 19.3 g/cm³. What volume does 100.0 g of gold occupy?

Solution:

V = m/D = 100.0 g / 19.3 g/cm³ = 5.18 cm³

Visualization: About the size of a small cube, 1.7 cm on each side.

3

Multi-step Problem

A rectangular block measures 5.0 cm × 3.0 cm × 2.0 cm and has a mass of 81.0 g. What is its density, and what material might it be?

Solution:

V = 5.0 cm × 3.0 cm × 2.0 cm = 30.0 cm³

D = 81.0 g / 30.0 cm³ = 2.7 g/cm³

Identification: This density matches aluminum (2.70 g/cm³).

Practice Problems and Problem-Solving Strategies

Problem 1: Calculate Density

A sample of liquid has a mass of 85.0 g and occupies 34.0 mL. Calculate its density.

Solution: D = 85.0 g / 34.0 mL = 2.50 g/mL

Problem 2: Find Volume

A piece of aluminum (density 2.70 g/cm^3) has a mass of 54.0 g. Find its volume.

Solution: V = 54.0 g / 2.70 g/cm^3 = 20.0 cm^3

Problem 3: Floating or Sinking?

Will a substance with density 0.75 g/mL float on water? Explain your reasoning.

Solution: Yes, it will float because 0.75 g/mL < 1.00 g/mL (water's density).

Problem 4: Multi-step Calculation

A cube of unknown material has sides of 2.5 cm and a mass of 39.1 g. Identify the material.

Solution: V = (2.5 cm)^3 = 15.625 cm^3

D = 39.1 g / 15.625 cm^3 = 2.50 g/cm^3

This is close to aluminum (2.70 g/cm^3), possibly an aluminum alloy.

Common Mistakes to Avoid

- Unit confusion: Make sure mass and volume units are compatible
- Forgetting to convert: Sometimes units need conversion before calculation
- Ignoring significant figures: Results should reflect measurement precision
- Not checking reasonableness: Unrealistic answers often indicate errors

Next Lecture:

Atomic Structure:
Number & Mass

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