Chemistry Fundamentals

LECTURE 3:
Units in Chemistry & Significant Figures

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The Critical Importance of Units in Science

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Historical Disasters

- NASA Mars Climate Orbiter (1999): $125 million spacecraft lost due to metric/imperial confusion
- Gimli Glider (1983): Air Canada flight ran out of fuel due to pound/kilogram confusion
- Medical errors: Wrong dosages due to unit confusion can be fatal

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Benefits of Units

- Universal communication among scientists worldwide
- Error prevention through dimensional analysis
- Precision in measurements
- Reproducibility of experiments

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Chemistry Applications

- Concentration calculations: Molarity, molality, percent composition
- Stoichiometry: Converting between grams, moles, molecules
- Gas laws: Pressure, volume, temperature relationships
- Energy calculations: Heat, work, enthalpy changes

The International System of Units (SI)

SI Units were developed to standardize measurements globally, ensure scientific precision, and enable international cooperation.

Quantity	Unit	Symbol	Definition
Length	meter	m	Distance light travels in vacuum in 1/299,792,458 second
Mass	kilogram	kg	Mass of international prototype kilogram
Time	second	s	9,192,631,770 periods of cesium-133 radiation
Electric current	ampere	A	Current producing specific magnetic force
Temperature	kelvin	K	1/273.16 of thermodynamic temperature of water triple point
Amount of substance	mole	mol	Number of atoms in 0.012 kg of carbon-12
Luminous intensity	candela	cd	Luminous intensity of specific light source

Derived Units Common in Chemistry:

Volume (m^3, L, mL), Density (kg/m^3, g/cm^3), Pressure (Pa, atm), Energy (J, cal)

Metric Prefixes - Powers of Ten Made Simple

Understanding the Pattern:

- Each prefix represents a power of 10
- Larger prefixes: kilo (10^3), mega (10^6), giga (10^9)
- Smaller prefixes: milli (10^{-3}), micro (10^{-6}), nano (10^{-9})

Real-World Context:

- Nanoscale: Size of atoms and molecules
- Microscale: Size of cells and bacteria
- Milliscale: Size of insects and small components
- Centiscale: Size of everyday objects
- Kiloscale: Size of large objects and distances

Prefix	Symbol	Factor	Example
giga-	G	10^9	1 gigabyte = 10^9 bytes
mega-	M	10^6	1 megawatt = 10^6 watts
kilo-	k	10^3	1 kilogram = 10^3 grams
base unit	-	10^0	1 meter, 1 gram
centi-	c	10^{-2}	1 centimeter = 10^{-2} meters
milli-	m	10^{-3}	1 milliliter = 10^{-3} liters
micro-	μ	10^{-6}	1 micrometer = 10^{-6} meters
nano-	n	10^{-9}	1 nanometer = 10^{-9} meters

Scientific Notation - Handling Extreme Numbers

Why Scientific Notation is Essential:

- Very large numbers: Avogadro's number = 602,200,000,000,000,000,000,000
- Very small numbers: Mass of electron = 0.000000000000000000000000000000911 kg
- Calculation efficiency: Easier to multiply and divide
- Significant figures: Clearly shows precision of measurements

Standard Form: $M \times 10^n$

- M (mantissa): Number between 1 and 10
- n (exponent): Integer showing how many places decimal point moved

Step-by-Step Process:

1. Identify the first non-zero digit
2. Place decimal point after this digit
3. Count places moved: Right = negative exponent, Left = positive exponent
4. Write in $M \times 10^n$ form

Examples with Explanation:

- 1,500,000: Move decimal 6 places left → 1.5×10^6
- 0.00025: Move decimal 4 places right → 2.5×10^{-4}
- 345.67: Move decimal 2 places left → 3.4567×10^2

Calculator Usage: Use EE or EXP button to enter "$\times$ 10" part

Significant Figures - Precision in Measurements

Significant figures represent the precision of a measurement and include all certain digits plus one uncertain digit.

Rule 1: All non-zero digits are significant

- 123.45 has 5 significant figures
- 7.89 has 3 significant figures

Rule 2: Zeros between non-zero digits are significant

- 1002 has 4 significant figures
- 50.03 has 4 significant figures

Rule 3: Leading zeros are NOT significant

- 0.00123 has 3 significant figures (1, 2, 3)
- 0.0500 has 3 significant figures (5, 0, 0)

Rule 4: Trailing zeros are significant only if decimal point is present

- 1200 has 2 significant figures
- 1200. has 4 significant figures
- 1200.0 has 5 significant figures

Why This Matters: Measurement uncertainty, instrument precision, calculation rules

Common Mistakes: Exact numbers have infinite significant figures (12 inches = 1 foot), conversion factors are usually considered exact (1000 mL = 1 L)

Dimensional Analysis - The Problem-Solving Tool

Dimensional analysis (factor-label method) uses conversion factors to change units while keeping the quantity's value unchanged.

Conversion Factor Setup:

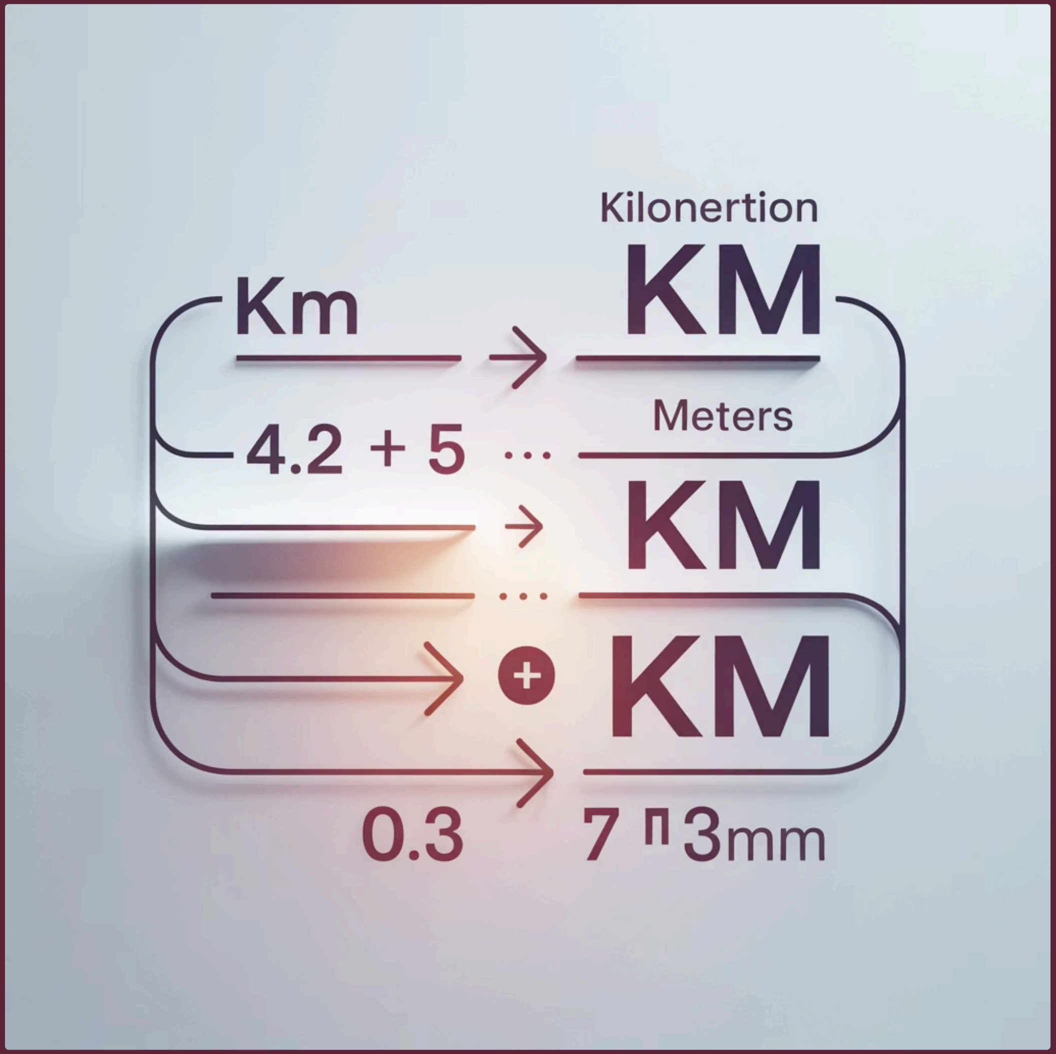
- Always equal to 1: (1000 mL)/(1 L) = 1
- Can be flipped: (1 L)/(1000 mL) = 1
- Choose orientation to cancel unwanted units

Step-by-Step Process:

1. Identify given quantity and desired units
2. Write conversion factor(s)
3. Set up so units cancel
4. Calculate numerical answer
5. Check units and reasonableness

Example Problem: Convert 2.5 km to meters

2.5 km × (1000 m/1 km) = 2500 m



Complex Conversion: Convert 65 miles/hour to meters/second

65 miles/hour × (1.609 km/1 mile) × (1000 m/1 km) × (1 hour/3600 s) = 29.1 m/s

Problem-Solving Strategy: Start with what you know, write out all conversion factors, check unit cancellation, verify answer makes sense

Practice Problems with Solutions

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Scientific Notation

Express in scientific notation:

a) 45,600,000 = 4.56×10^7 (moved decimal 7 places left)

b) 0.000789 = 7.89×10^{-4} (moved decimal 4 places right)

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Significant Figures

How many significant figures?

a) 0.0506 = 3 significant figures (5, 0, 6)

b) 2000.0 = 5 significant figures (decimal point makes trailing zeros significant)

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Unit Conversion

Convert 3.5 hours to seconds:

3.5 hours × (60 minutes/1 hour) × (60 seconds/1 minute) = 12,600 seconds

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Density Calculation

A sample has mass 2.34 g and volume 0.892 mL. Calculate density with correct significant figures:

Density = mass/volume = 2.34 g / 0.892 mL = 2.62 g/mL

(Answer limited to 3 significant figures by the volume measurement)

Next Lecture:

Temperature

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