Ch 1. The Chemical World

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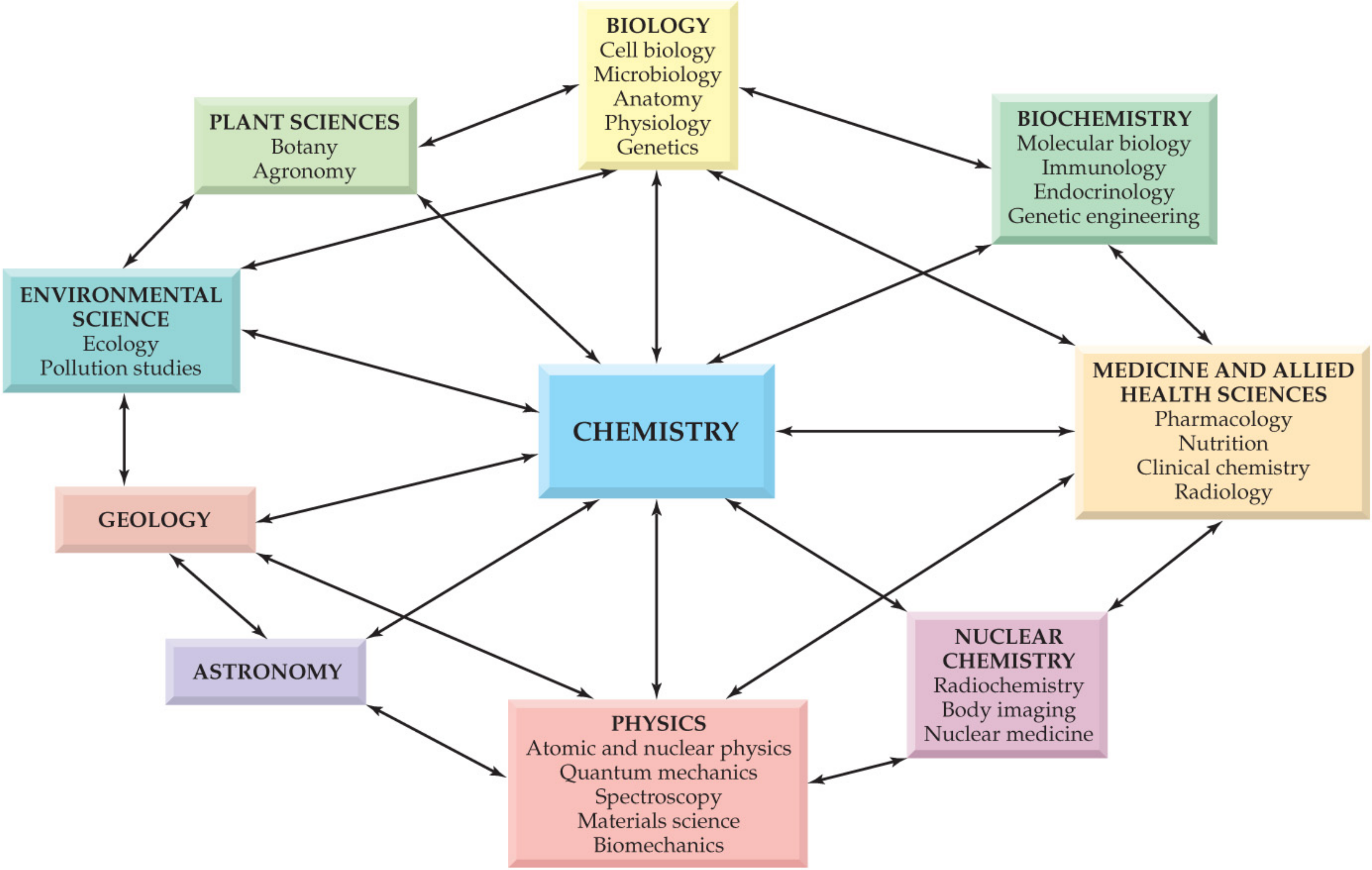
What is Chemistry?

CHEMISTRY:

the science that deals with matter and the changes that matter undergoes

- Matter: anything that has mass and volume

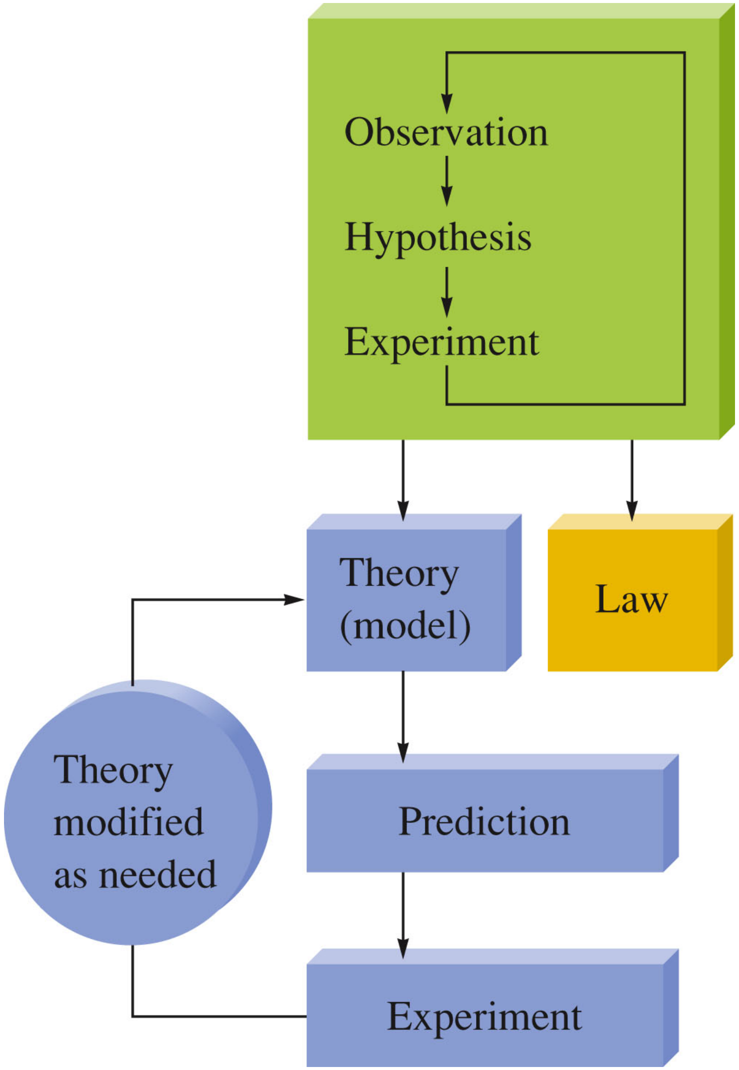
Chemistry: The Central Science



Goals of This Course

- Provide a solid foundation in chemistry for further study.
- Help you learn to solve problems more critically and analytically.
- Help you become more aware of our world and make informed choices in your life (health, products you use, environment, etc.)

The Scientific Method



- **Hypothesis**: a tentative explanation of observations
- **Natural Law**: Summary of observations, tells what happens.
- **Theory**: A model, an attempt to explain why it happens.

Question

Classify each statement as an observation, a law, or theory.

a) The star closest to Earth is moving away from Earth at a high speed. Obervation

b) A body in motion stays in motions unless acted upon by a force. Law

c) The universe began as a cosmic explosion called the Big Bang. Theory

d) A stone dropped from an altitude of 450 m falls to the ground in 9.6 s. Obervation

Ch 2. Measurement and Problem Solving

Measurement

Measurement: a <u>quantitative</u> observation

- A measurement always consists of a number and a unit (scale or standard).

<u>1</u> <u>centimeter</u>

number

unit

Scientific Notation (= Exponential Notation)

- A method for making very large or very small numbers more compact and easier to write.

- Scientific notation is expressed as:

$$\underline{32{,}000} = 3.2 \times 10{,}000 = \boxed{\underline{3.2} \quad \underline{\times} \quad \underline{10^4}}$$

$1 \leq$ Number < 10

Appropriate power of 10

Know how to enter scientific notation in your calculator!

Power of 10

- 10^x
- Exponent tells how many times 10 is multiplied.

Power of 10	Multiplication Form	Number
10^1	10	10
10^2	10 x 10	100
10^3	10 x 10 x 10	1000
10^4	10 x 10 x 10 x 10	10000
10^{-1}	1/10	1/10 or 0.1
10^{-2}	1/(10 x 10)	1/100 or 0.01
10^{-3}	1/(10 x 10 x 10)	1/1000 or 0.001
10^{-4}	1/(10 x 10 x 10 x 10)	1/10,000 or 0.00001

Q: What is 10^0?

Writing Numbers in Scientific Notation

$\mathbf{10}^{(+/-)x}$

When you write a number in scientific notation:

- x (value of exponent): Comes from number of places decimal is moved.
- **+** or – (sign of exponent): Comes from direction decimal is moved

Writing Numbers in Scientific Notation

From Conventional Notation to Scientific Notation

- If you moved decimal to the left to get number between 1 and 10, use 10^{+x}.

$$93{,}000{,}000 = 9.3 \times 10^{7}$$

7 6 5 4 3 2 1

- If you moved decimal to the right to get number between 1 and 10, use 10^{-x} .

$$0.000167 = 1.67 \times 10^{-4}$$

1 2 3 4

Ex probs

Units

Two *Commonly* Used Systems of Units

1. English system (U.S.)
2. Metric System (rest of the world)

Scientific System of Units

International System (SI)

The Fundamental SI Units

Physical Quantity	*Name of Unit*	*Abbreviation*
Mass	kilogram	kg
Length	meter	m
Time	second	s
Temperature	kelvin	K
Electric current	ampere	A
Amount of substance	mole	mol

Measurement of Length

Length

– Fundamental SI unit of length: meter (m)

Unit	Symbol	Meter Equiv.	Power of 10	Used to measure
kilometer	km	1000 m	10^{3} m	NY to SF
meter	m	1 m		Sprint distance
decimeter	dm	0.1 m	10^{-1} m	
centimeter	cm	0.01 m	10^{-2} m	pencil
millimeter	mm	0.001 m	10^{-3} m	dime thickness
micrometer	µm	0.00001 m	10^{-6} m	cell
nanometer	nm	0.000000001 m	10^{-9} m	DNA diameter

Prefixes Multipliers in SI System

Prefix multipliers can be used to change the size of units.

TABLE 1.6 Some Prefixes for Multiples of Metric and SI Units

Prefix	Symbol	Base Unit Multiplied By*	Example
mega	M	1,000,000 = 10^6	1 megameter (Mm) = 10^6 m
kilo	k	1000 = 10^3	1 kilogram (kg) = 10^3 g
hecto	h	100 = 10^2	1 hectogram (hg) = 100 g
deka	da	10 = 10^1	1 dekaliter (daL) = 10 L
deci	d	0.1 = 10^{-1}	1 deciliter (dL) = 0.1 L
centi	c	0.01 = 10^{-2}	1 centimeter (cm) = 0.01 m
milli	m	0.001 = 10^{-3}	1 milligram (mg) = 0.001 g
micro	μ	0.000 001 = 10^{-6}	1 micrometer (μm) = 10^{-6} m
nano	n	0.000 000 001 = 10^{-9}	1 nanogram (ng) = 10^{-9} g
pico	p	0.000 000 000 001 = 10^{-12}	1 picogram (pg) = 10^{-12} g
femto	f	0.000 000 000 000 001 = 10^{-15}	1 femtogram (fg) = 10^{-15} g

**The scientific notation method of writing large and small numbers (for example, 10^6 for 1,000,000) is explained in Section 1.10.*

Memorize

kilo, centi, milli, micro, nano

Examples

1 km = 1000 m

1 cm = 1 x 10^{-2} m

1 mm = 1 x 10^{-3} m

1 µm = 1 x 10^{-6} m

1 nm = 1 x 10^{-9} m

Measurement of Mass

Mass

- Quantity of matter in an object
- Fundamental SI unit of mass: kilogram (kg)
- Mass ≠ Weight (=mass x g)

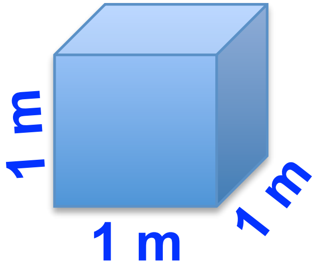
Unit	Symbol	Gram Equiv.	Used to measure
kilogram	kg	1000 g	Human mass
gram	g	1 g	Paper clip, dollar bill
milligram	mg	0.001g = 10^{-3}g	Mosquito

Measurement of Volume (Derived Unit)

Volume

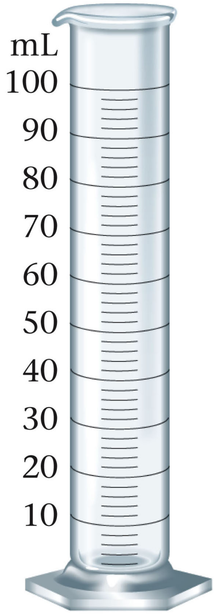
– the amount of 3D space occupied by a substance

– SI unit for volume: cubic meter (m^3)



Volume = L (m) x W (m) x H (m)

= m^3



– Commonly used volume units in chemistry:

liter (L) = 1 dm^3

milliliter (mL) = 1 cm^3 (cc) Memorize

Relationship: 1L = 1000 mL

Measurement of Temperature

Temperature: a measure of the energy due to motion (average kinetic energy)

Three Units of Temperature

- Kelvin (K) – SI unit; "absolute temperature"
- Celsius (°C) – metric system
- Fahrenheit (°F) – English system

Temperature Conversion Formulas

Kelvin <–> Celsius

K = °C + 273.15 Memorize

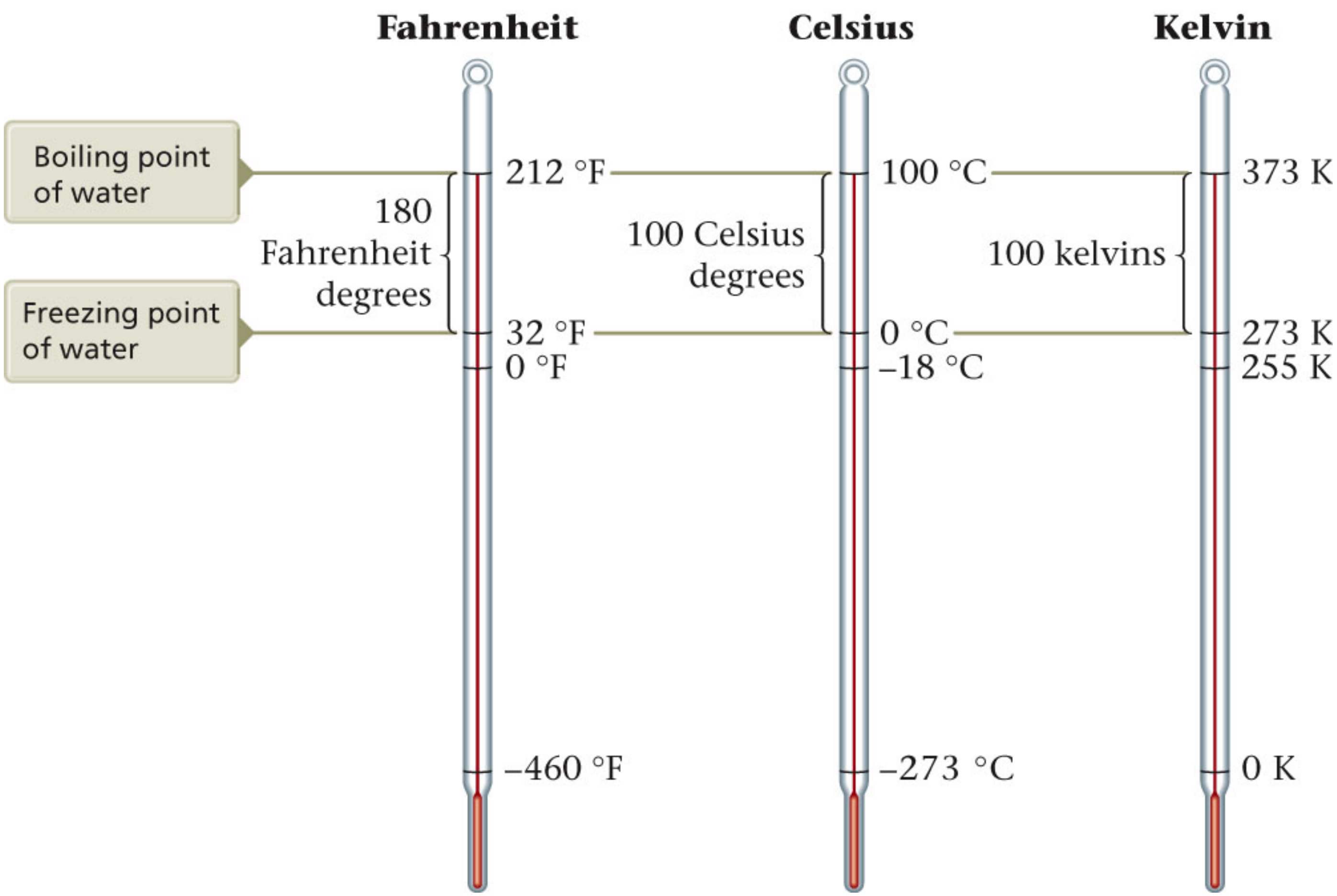
°C = K – 273.15

Celsius <–> Fahrenheit

$$°C = \frac{(°F - 32)}{1.8}$$

°F = (1.8 x °C) + 32

Three Temperature Scales

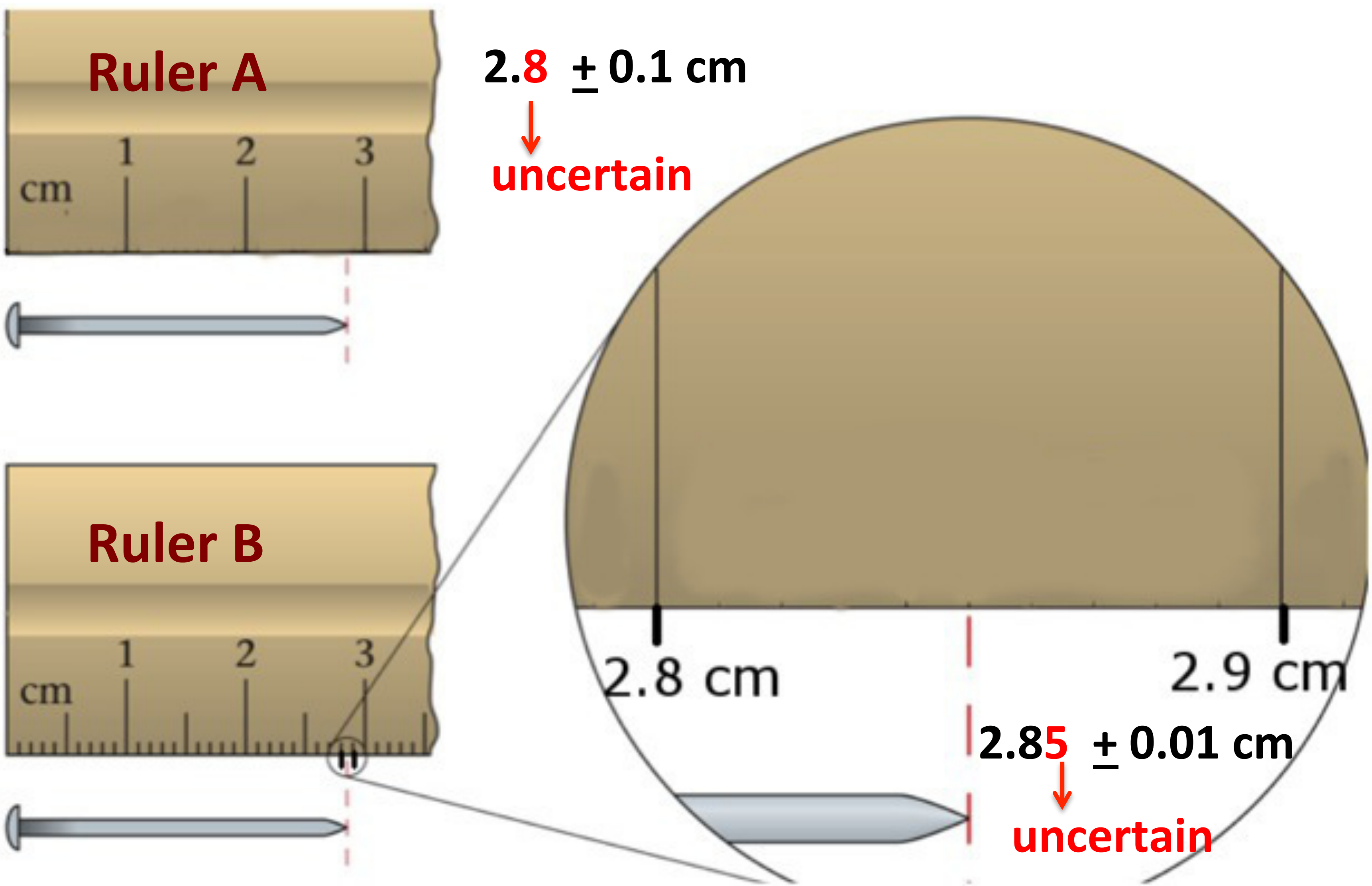


Know freezing point, boiling point of water!
Note size of each temperature unit.

Uncertainty in Measurements

- A measurement always has some degree of uncertainty.
- Uncertainty arises partly because every measurement includes some estimation.

Uncertainty from Limits of a Measuring Device



Significant Figures in Measurements

- Significant Figures: All the certain digits plus the first uncertain (estimated) digit of a measurement
- The certainty of a measurement is indicated by its number of significant figures → More significant figures, more certain the measurement.
- When reporting a measurement, report it with the correct number of significant figures: all certain digits + first uncertain digit

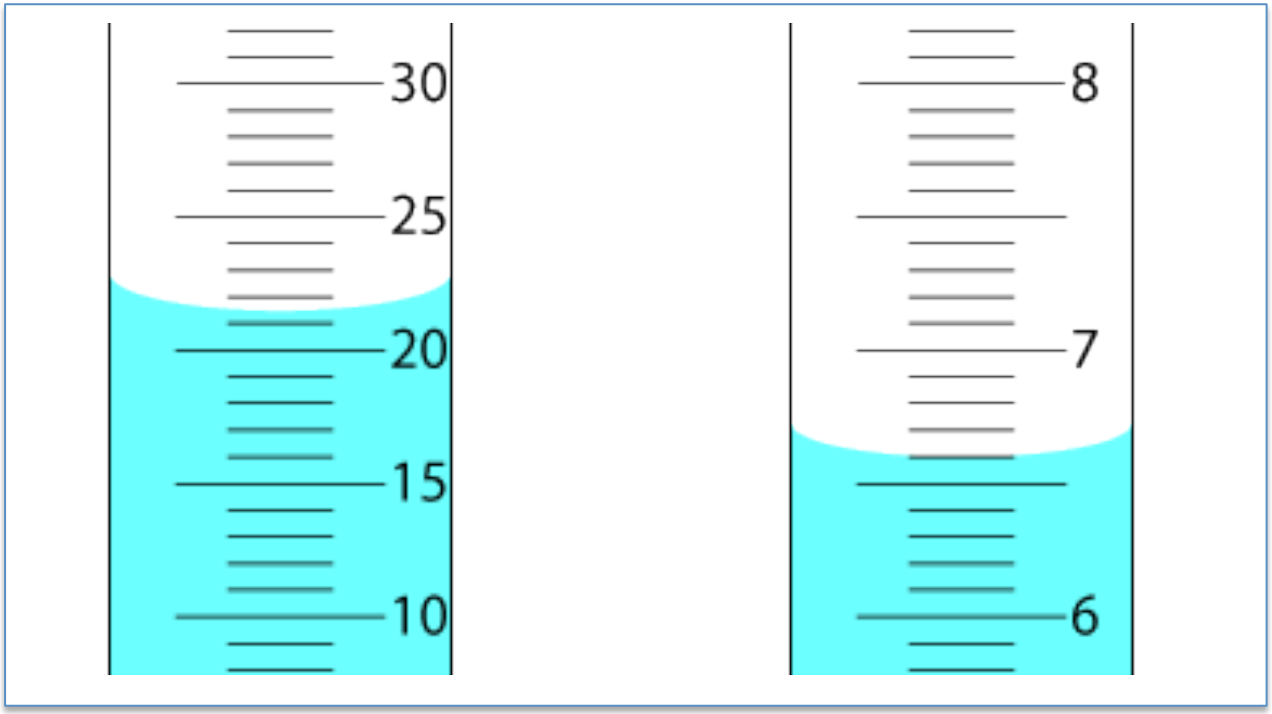
Getting the Estimated Digit

- (In general) Visually divide the increment of the smallest marking into 10 equal quantities, then estimate the digit.

- The above method is equivalent to estimating one decimal place beyond the decimal place marked on the measuring device.

Q: Reporting Measurements to Correct Sig Figs

What are the volumes in these graduated cylinders, to the correct number of sig figs?



(meniscus)

A 21.3 mL

B 6.60 mL

Significant Figures in Results of Calculations

- You may need to do mathematical operations (calculations) with your measurements.
- The number of significant figures in the final result of your calculation is limited by your least certain measurement.
- The final result of the calculation must be rounded off to have the correct number of significant figures.

Significant Figures in Calculation Results

To report the result of a calculation to correct number of sig figs, you need to:

1. Know how to identify and count sig figs in a number.
2. Know how to determine how many sig figs should be in the result of a calculation.
3. Know how to round off numbers.

Rules for Identifying/Counting Significant Figures

1. Nonzero Integers

   Nonzero integers always count as significant figures.

   - 3456 has 4 sig figs (significant figures).

2. Zeros: Three classes of zeros

a. Zeros that come before all the nonzero digits (leading zeros) do NOT count as significant figures.

   - 0.048 has 2 sig figs.
   - 0.00009 has 1 sig fig.

Rules for Identifying/Counting Significant Figures (cont'd)

b. Zeros between nonzero digits (captive zeros) always count as significant figures.
   - 16.07 has 4 sig figs.
   - 100.39 has 5 sig figs.

c. Zeros at the right end of the number (trailing zeros) are significant only if the number contains a decimal point.
   - 9.300 has 4 sig figs.
   - 150 has 2 sig figs. (ambiguous)
   - 150. has 3 sig fig.
   - 1.50 x 10^2 has 3 sig figs.

Rules for Identifying/Counting Significant Figures (cont'd)

3. Exact numbers have an infinite number of significant figures.

- Counted number: 9 pencils (9 has infinite number of sig figs)
- Defined quantities: 1 inch = 2.54 cm exactly (Both 1 and 2.54 have infinite number of sig figs.); 1 m = 100 cm
- Whole numbers that are part of an equation: 2 in "$C = 2\pi r$"

Ex probs

Rules for Rounding Off

1. If the digit to be removed is less than 5, the preceding digit stays the same.
   - Round to 2 sig figs: 5.64 rounds to 5.6

2. If the digit to be removed is equal to or greater than 5, the preceding digit is increased by 1.
   - Round to 2 sig fis: 5.68 rounds to 5.7
   - Round to 2 sig figs: 3.861 rounds to 3.9

Significant Figures in Calculation Results

There are different rules for determining the number of significant figures that should be in a calculation result depending on the operation type!!

Operation Types

1. Multiplication/division
2. Addition/subtraction

Rules for Determining Sig Figs in Calculation Results

1. For Multiplication or Division

The result has same number of sig figs as the measurement with the smallest number of sig figs.

1.342 × 5.5 = 7.381 → 7.4

4 sig figs — 2 sig figs (limiting)

Round off to 2 sig figs

Rules for Determining Sig Figs in Calculation Results

2. For Addition or Subtraction

The result has same number of decimal places (digits after the decimal) as the measurement with the smallest number of decimal places.

12.11	(2 decimal places)	
18.0	(1 decimal place)	→ limiting
+ 1.013	(3 decimal places)	
31.123	Round off to 1 decimal place	→ 31.1

The number of sig figs is 3.

Ex probs

Significant Figures in Multistep Calculations

- For a series of operations involving only one operation type, round off the result only at the end of the series of operations.
    1. Carry the extra digits through to the final result on your calculator.
    2. Round off to correct number of sig figs only on your final answer.

Ex probs

Significant Figures in Multistep Calculations

- For a series of operations involving both operation types, round off the result for each type of operation, in the order you do the operations.
    1. Round off at the end of every series of operation of the same type.
    2. Remember the order of operations: Do operations in the parentheses first!

Ex probs

Unit Conversion

You need to convert units in problems like:

- 3 cups → ? pints
- 250 pesos → ? dollars
- 3125 km → ? miles

How to Convert Units (Dimensional Analysis)

- Problem: A nail is 4.85 cm long. How long is it in inches?

  4.85 cm → ? Inches

1. Start with the equivalence statement relating the two units.

   2.54 cm = 1 inch (same quantity, two different units)

How to Convert Units (cont'd)

2. Turn the equivalence statement into a conversion factor (a ratio relating the two units that is effectively equal to 1)

$$\frac{2.54\ \text{cm}}{1\ \text{in}} \quad \text{or} \quad \frac{1\ \text{in}}{2.54\ \text{cm}} \quad (= 1)$$

How to Convert Units (cont'd)

3. Multiply the correct conversion factor to quantity that needs to be converted, to give desired units. (Which conversion factor?)

Problem: 4.85 cm → ? in

$$4.85\ \text{cm} \times \left(\frac{1\ \text{in}}{2.54\ \text{cm}}\right) = 1.91\ \text{in}$$

$$4.85\ \text{cm} \times \left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right) = ✖$$

Some Metric-English System Equivalents

TABLE 2.3 Some Common Units and Their Equivalents

Length	
1 kilometer (km)	= 0.6214 mile (mi)
1 meter (m)	= 39.37 inches (in.)
	= 1.094 yards (yd)
1 foot (ft)	= 30.48 centimeters (cm)
1 inch (in.)	= 2.54 centimeters (cm) (exact)
Mass	
1 kilogram (kg)	= 2.205 pounds (lb)
1 pound (lb)	= 453.59 grams (g)
1 ounce (oz)	= 28.35 grams (g)
Volume	
1 liter (L)	= 1000 milliliters (mL)
	= 1000 cubic centimeters (cm^3)
1 liter (L)	= 1.057 quarts (qt)
1 U.S. gallon (gal)	= 3.785 liters (L)

Ex probs

Density

Density

Density

- Density: Amount of matter present in a given volume of a substance

- Expressed as:

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad \left[\ \frac{g}{mL} \quad \text{or} \quad \frac{g}{cm^3}\ \right]$$

Density

Density is an intensive property.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

- Intensive property: Independent of amount of substance
- Extensive property: Dependent on amount of substance

Q: What about mass and volume?

Densities of Common Substances

Density is an "identification tag" for a substance!

Table 2.8 Densities of Various Common Substances at 20 °C

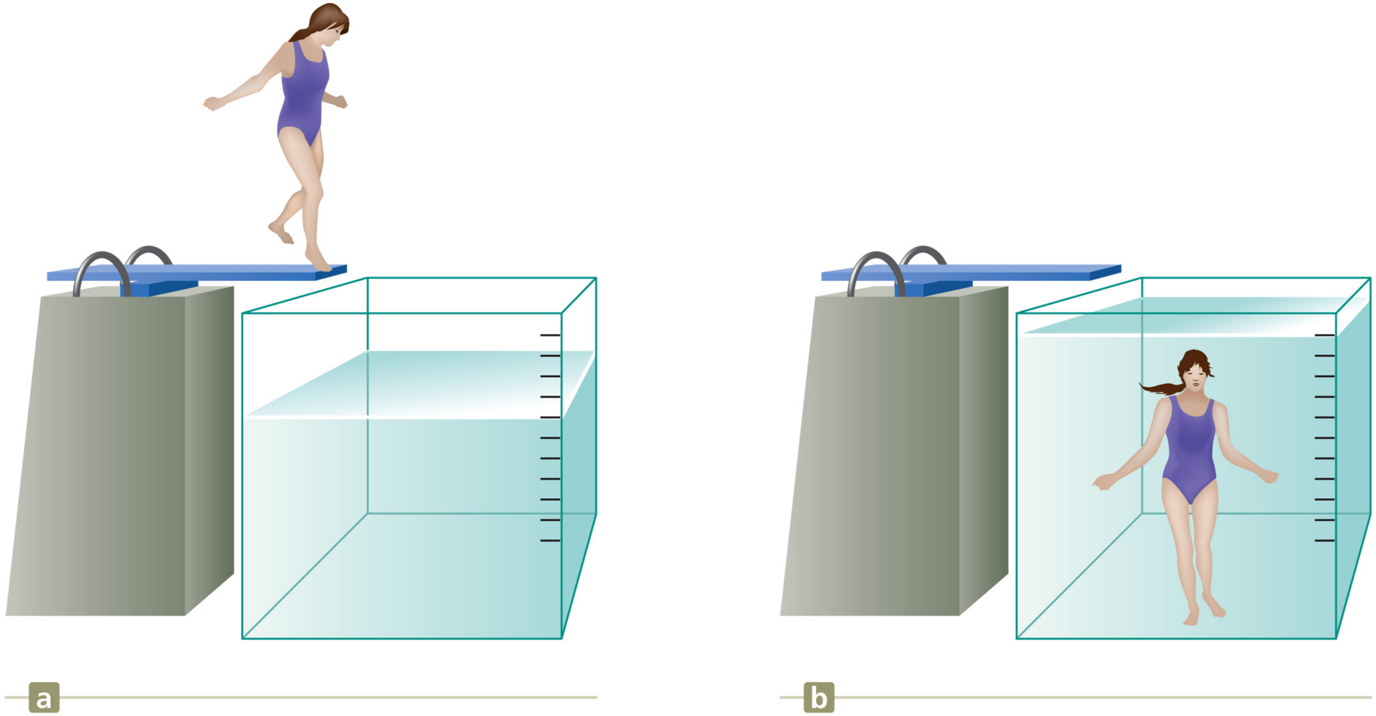
Substance	Physical State	Density (g/cm^3)
oxygen	gas	0.00133*
hydrogen	gas	0.000084*
ethanol	liquid	0.785
benzene	liquid	0.880
water	liquid	1.000
magnesium	solid	1.74
salt (sodium chloride)	solid	2.16
aluminum	solid	2.70
iron	solid	7.87
copper	solid	8.96
silver	solid	10.5
lead	solid	11.34
mercury	liquid	13.6
gold	solid	19.32

*At 1 atmosphere pressure

*At typical temperatures, density of water is very close to 1 g/mL.

Measuring Density (mass/volume)

- Mass: Measure with a balance
- Volume: Measure with water displacement



Tank of water

Person submerged in the tank, raising the level of the water

Ex probs