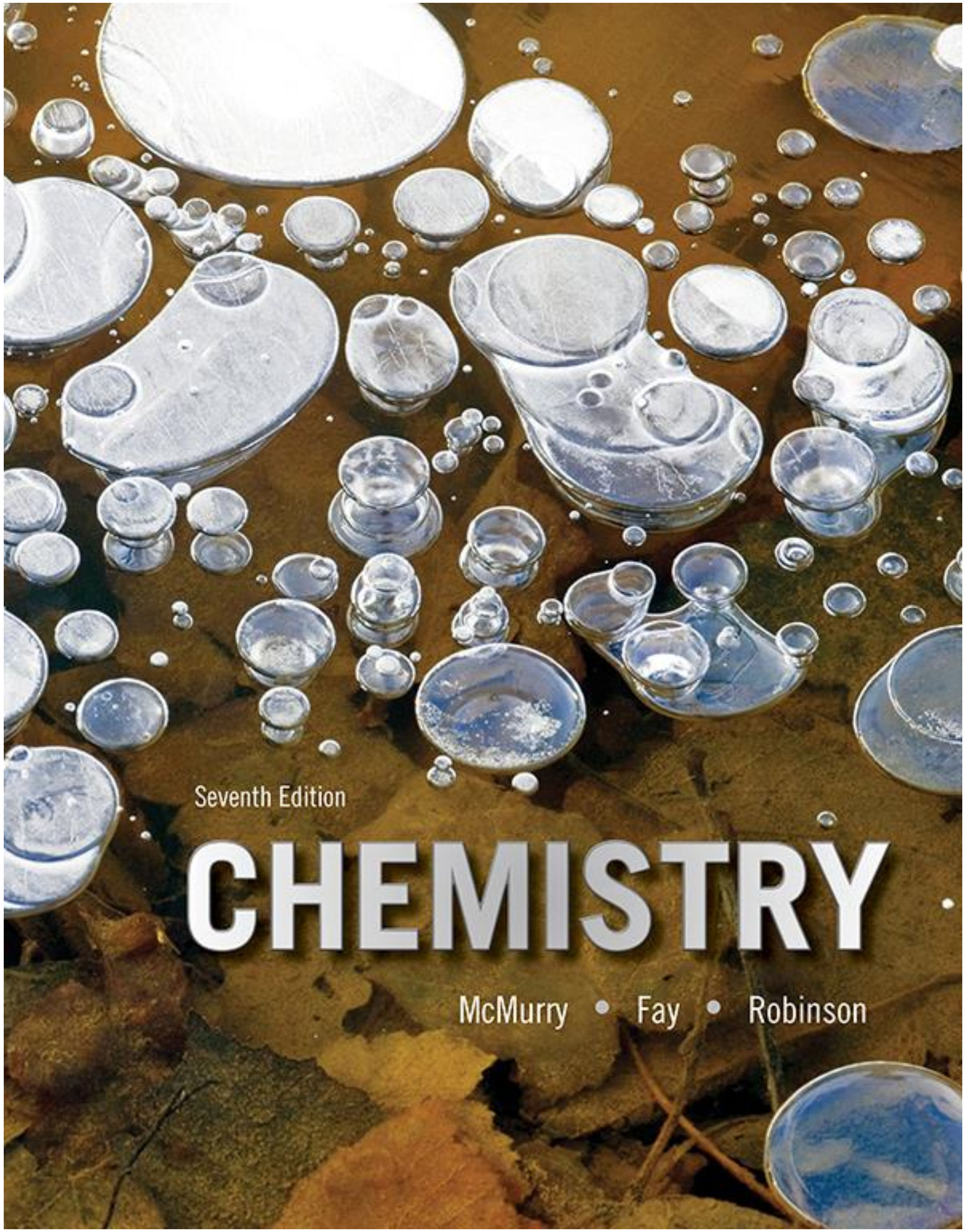

Lecture Presentation

Chapter 1

Chemical Tools: Experimentation and Measurement

John E. McMurry
Robert C. Fay

Instructor's Resource Materials (Download only) for *Chemistry,* 7e
John E. McMurry, Robert C. Fay, Jill Robinson

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The Scientific Method: Improved Pharmaceutical Insulin

- Comparing insulin profiles
  - Natural insulin release
  - Injected insulin
  - An early spike means potential for low blood sugar later.
- Humalog®, designed to mimic the body's natural release profile

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The Scientific Method

- Observations
  - Recording qualitative or quantitative data
- Hypothesis
  - Explanation of observations
- Experiments
  - Change one variable at a time
  - Test hypothesis
- Theory
  - Explains experiment
  - Predicts further outcome

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Experimentation and Measurement

Système Internationale d'Unités

TABLE 1.1 The Seven Fundamental SI Units of Measure

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

All other units are derived from these fundamental units.

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TABLE 1.2 Some Prefixes for Multiples of SI Units. The most commonly used prefixes are shown in red.

Factor	Prefix	Symbol	Example
1,000,000,000,000 = 10^{12}	tera	T	1 teragram (Tg) = 10^{12} g
1,000,000,000 = 10^{9}	**giga**	**G**	1 gigameter (Gm) = 10^{9} m
1,000,000 = 10^{6}	**mega**	**M**	1 megameter (Mm) = 10^{6} m
1000 = 10^{3}	**kilo**	**k**	1 kilogram (kg) = 10^{3} g
100 = 10^{2}	hecto	h	1 hectogram (hg) = 100 g
10 = 10^{1}	deka	da	1 dekagram (dag) = 10 g
0.1 = 10^{-1}	**deci**	**d**	1 decimeter (dm) = 0.1 m
0.01 = 10^{-2}	**centi**	**c**	1 centimeter (cm) = 0.01 m
0.001 = 10^{-3}	**milli**	**m**	1 milligram (mg) = 0.001 g
*0.000 001 = 10^{-6}	micro	μ	1 micrometer (μm) = 10^{-6} m
*0.000 000 001 = 10^{-9}	nano	n	1 nanosecond (ns) = 10^{-9} s
*0.000 000 000 001 = 10^{-12}	pico	p	1 picosecond (ps) = 10^{-12} s
*0.000 000 000 000 001 = 10^{-15}	femto	f	1 femtomole (fmol) = 10^{-15} mol

*For very small numbers, it is becoming common in scientific work to leave a thin space every three digits to the right of the decimal point, analogous to the comma placed every three digits to the left of the decimal point in large numbers.

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Mass and Its Measurement

Mass: Amount of matter in an object

Weight: Measures the force with which gravity pulls on an object

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Length and Its Measurement

Meter

- **1790**: One ten-millionth of the distance from the equator to the North Pole along a meridian running through Paris, France
- **1889**: Distance between two thin lines on a bar of platinum-iridium alloy stored near Paris, France
- **1983**: The distance light travels in a vacuum in 1/299,792,458 of a second

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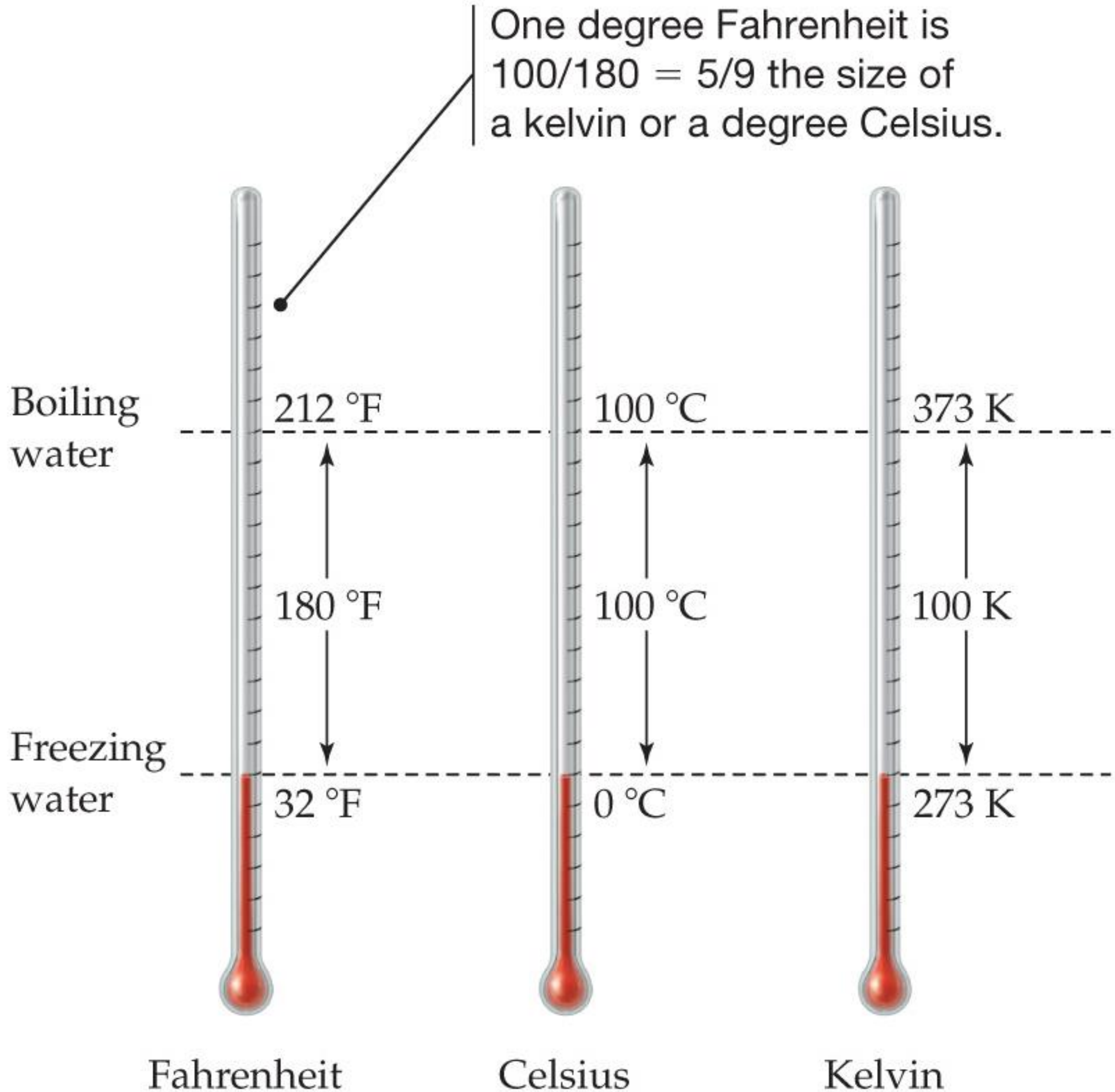

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Temperature and Its Measurement

$$°F = \left(\frac{9\ °F}{5\ °C}\right)°C + 32\ °F$$

$$°C = \left(\frac{5\ °C}{9\ °F}\right)(°F - 32\ °F)$$

$$K = °C + 273.15$$

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Derived Units: Volume and Its Measurement

TABLE 1.3 Some Derived Quantities

Quantity	Definition	Derived Unit (Name)
Area	Length times length	m^2
Volume	Area times length	m^3
Density	Mass per unit volume	kg/m^3
Speed	Distance per unit time	m/s
Acceleration	Change in speed per unit time	m/s^2
Force	Mass times acceleration	$(kg \cdot m)/s^2$ (newton, N)
Pressure	Force per unit area	$kg/(m \cdot s^2)$ (pascal, Pa)
Energy	Force times distance	$(kg \cdot m^2)/s^2$ (joule, J)

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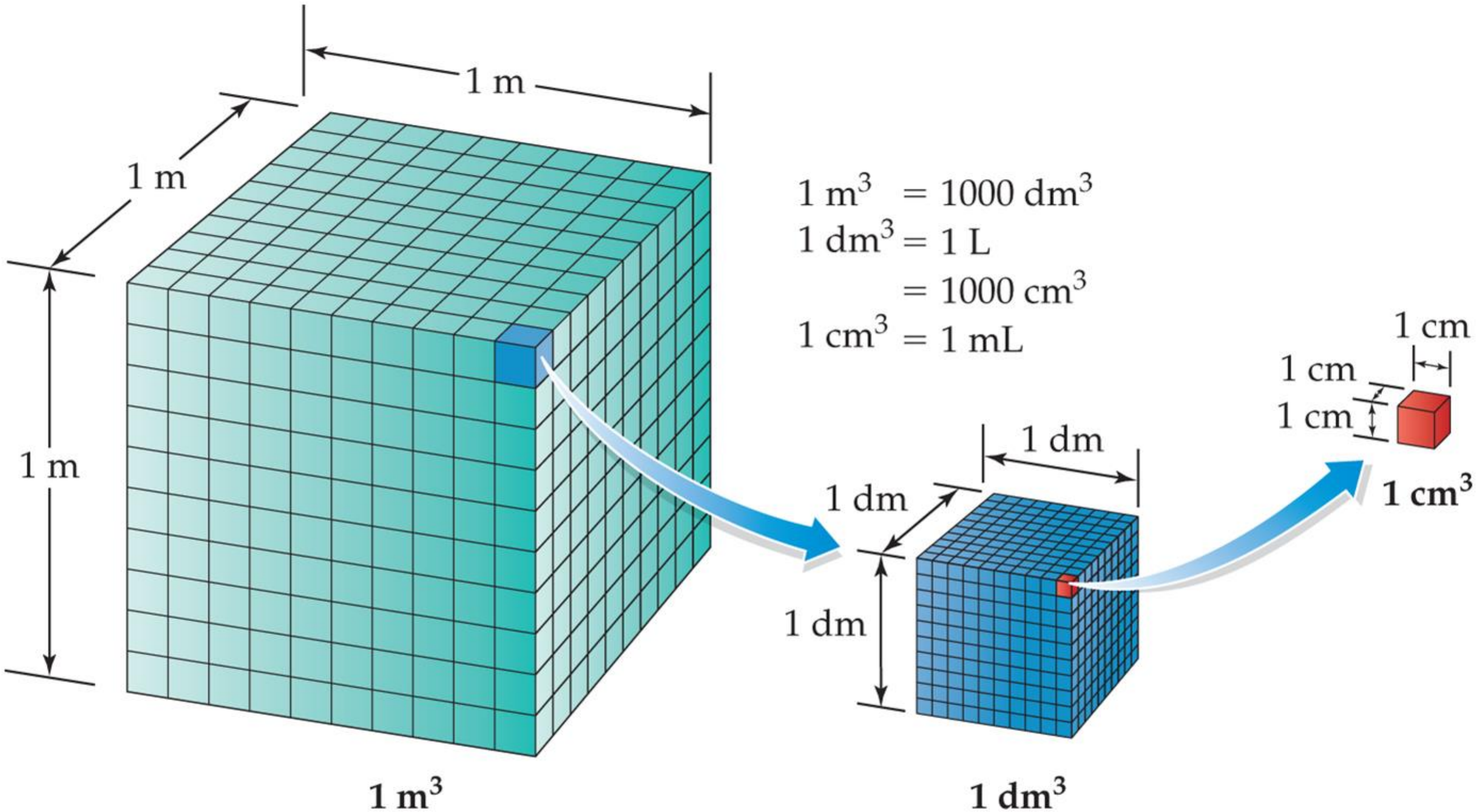

Each **cubic meter** contains 1000 **cubic decimeters** (liters).

Each **cubic decimeter** contains 1000 **cubic centimeters** (milliliters).

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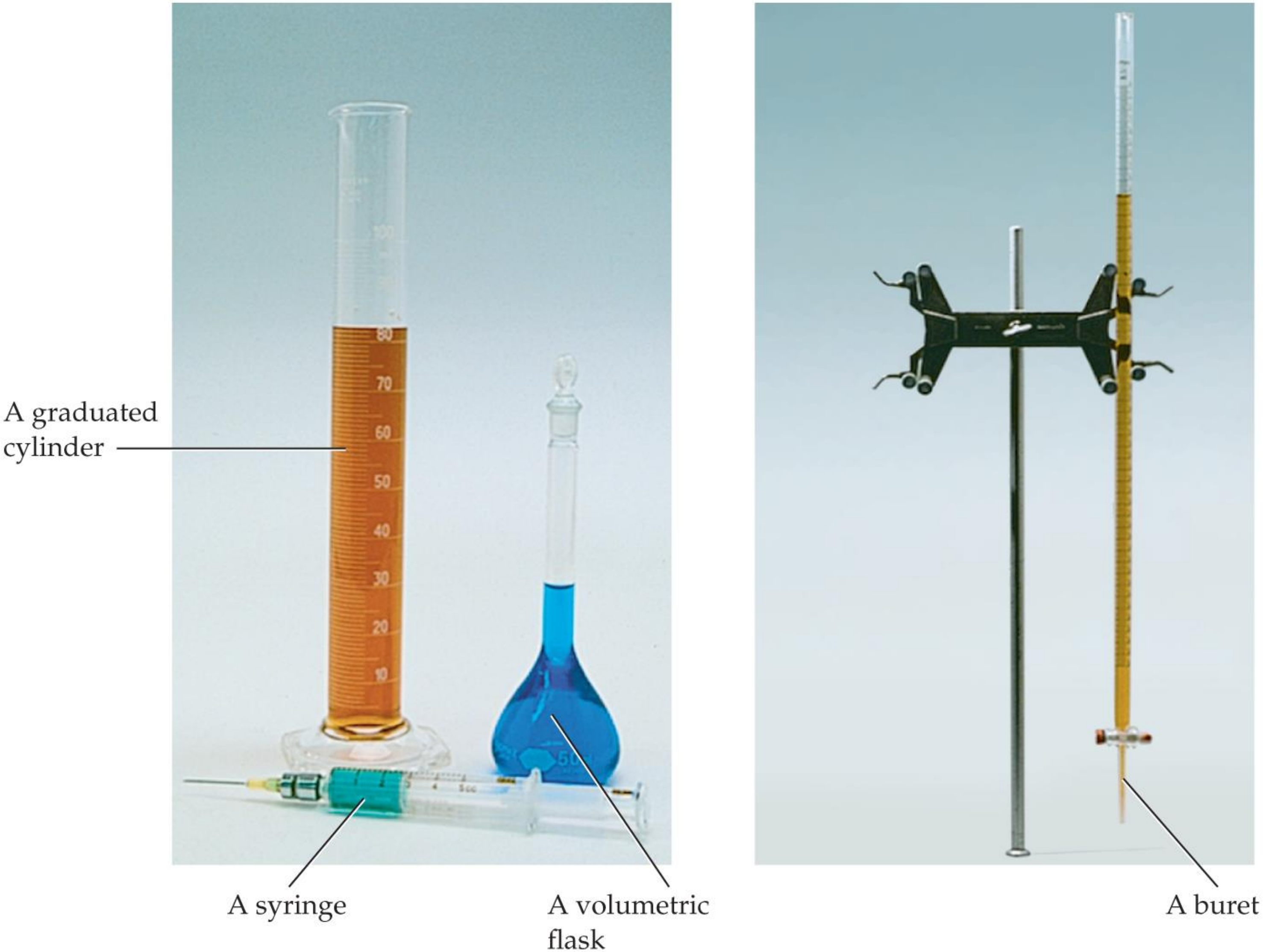
Derived Units: Volume and Its Measurement



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Derived Units: Density and Its Measurement

TABLE 1.4 Densities of Some Common Materials

Substance	Density (g/cm^3)
Ice (0 °C)	0.917
Water (3.98 °C)	1.0000
Gold	19.31
Helium (25 °C)	0.000 164
Air (25 °C)	0.001 185
Human fat	0.94
Human muscle	1.06
Cork	0.22–0.26
Balsa wood	0.12
Earth	5.54

Typical volume units:
- Solids: cm^3
- Liquids: mL
- Gases: L

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

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Accuracy, Precision, and Significant Figures in Measurement

Accuracy: How close to the true value a given measurement is

Precision: How well a number of independent measurements agree with each other

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Accuracy, Precision, and Significant Figures in Measurement

Mass of a Tennis Ball
(True mass = 54.441 778 g)

Measurement #	Bathroom Scale	Lab Balance	Analytical Balance
1	0.1 kg	54.4 g	54.4418 g
2	0.0 kg	54.5 g	54.4417 g
3	0.1 kg	54.3 g	54.4418 g
(average)	(0.07 kg)	(54.4 g)	(54.4418 g)

good accuracy
good precision

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Accuracy, Precision, and Significant Figures in Measurement

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(average)	(0.07 kg)	(54.4 g)	(54.4418 g)

good accuracy
poor precision

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Accuracy, Precision, and Significant Figures in Measurement

Mass of a Tennis Ball
(True mass = 54.441 778 g)

Measurement #	Bathroom Scale	Lab Balance	Analytical Balance
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3	0.1 kg	54.3 g	54.4418 g
(average)	(0.07 kg)	(54.4 g)	(54.4418 g)

poor accuracy
poor precision

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Accuracy, Precision, and Significant Figures in Measurement

Significant Figures: The total number of digits recorded for a measurement

Generally, the last digit in a reported measurement is uncertain (estimated).

Exact numbers and relationships (7 days in a week, 30 students in a class, etc.) effectively have an infinite number of significant figures.

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Accuracy, Precision, and Significant Figures in Measurement

Rules for Counting Significant Figures (Left-to-Right):

1. Zeros in the middle of a number are like any other digit; they are always significant.

4.803 cm Four SFs

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Accuracy, Precision, and Significant Figures in Measurement

Rules for Counting Significant Figures (Left-to-Right):

1. Zeros in the middle of a number are like any other digit; they are always significant.

2. Zeros at the beginning of a number are not significant (placeholders).

0.006 61 g Three SFs (or 6.61×10^{-3} g)

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Accuracy, Precision, and Significant Figures in Measurement

Rules for Counting Significant Figures (Left-to-Right):

1. Zeros in the middle of a number are like any other digit; they are always significant.

2. Zeros at the beginning of a number are not significant (placeholders).

3. Zeros at the end of a number and after the decimal point are always significant.

55.220 K Five SFs

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Accuracy, Precision, and Significant Figures in Measurement

Rules for Counting Significant Figures (Left-to-Right):

1. Zeros in the middle of a number are like any other digit; they are always significant.
2. Zeros at the beginning of a number are not significant (placeholders).
3. Zeros at the end of a number and after the decimal point are always significant.
4. Zeros at the end of a number and before the decimal point may or may not be significant.

34,200 m ? SFs

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Rounding Numbers

Math Rules for Keeping Track of Significant Figures:

- **Multiplication or Division**: The answer can't have more significant figures than any of the original numbers.

Three SFs ← 278 mi

Four SFs ← 11.70 gal

$$\frac{278\ \text{mi}}{11.70\ \text{gal}} = 23.760\,684\ \text{mi/gal}$$

$$= 23.8\ \text{mi/gal}$$

↓

Three SFs

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Rounding Numbers

Math Rules for Keeping Track of Significant Figures:

- **Multiplication or Division**: The answer can't have more significant figures than any of the original numbers.

- **Addition or Subtraction**: The answer can't have more digits to the right of the decimal point than any of the original numbers.

$$
\begin{array}{rl}
3.18 & \rightarrow \text{Two decimal places} \\
+\ 0.01\,315 & \rightarrow \text{Five decimal places} \\
3.19\,315 & \\
3.19 & \rightarrow \text{Two decimal places}
\end{array}
$$

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Rounding Numbers

Rules for Rounding off Numbers:

1. If the first digit you remove is less than 5, round down by dropping it and all following numbers.

5.664 525 = 5.66

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Rounding Numbers

Rules for Rounding off Numbers:

1. If the first digit you remove is less than 5, round down by dropping it and all following numbers.

2. If the first digit you remove is 6 or greater, round up by adding 1 to the digit on the left.

5.664 525 = 5.7

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Rounding Numbers

Rules for Rounding off Numbers:

1. If the first digit you remove is less than 5, round down by dropping it and all following numbers.

2. If the first digit you remove is 6 or greater, round up by adding 1 to the digit on the left.

3. If the first digit you remove is 5 and there are more nonzero digits following, round up.

5.664 525 = 5.665

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Rounding Numbers

Rules for Rounding off Numbers:

1. If the first digit you remove is less than 5, round down by dropping it and all following numbers.

2. If the first digit you remove is 6 or greater, round up by adding 1 to the digit on the left.

3. If the first digit you remove is 5 and there are more nonzero digits following, round up.

4. If the digit you remove is a 5 with nothing following, round down.

5.664 525 = 5.664 52

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Calculations: Converting from One Unit to Another

Dimensional Analysis: A method that uses a conversion factor to convert a quantity expressed in one unit to an equivalent quantity in a different unit

Conversion Factor: Expresses the relationship between two different units

Original quantity × **Conversion factor** = **Equivalent quantity**

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Calculations: Converting from One Unit to Another

Relationship: 1 m = 39.37 in.

Conversion Factor: $\frac{1\ \text{m}}{39.37\ \text{in.}}$ or $\frac{39.37\ \text{in.}}{1\ \text{m}}$

Converts in. to m	Converts m to in.

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Calculations: Converting from One Unit to Another

$$69.5\ \cancel{\text{in.}} \times \frac{1\ \text{m}}{39.37\ \cancel{\text{in.}}} = 1.77\ \text{m}$$

Starting quantity

Conversion factor

Equivalent quantity

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