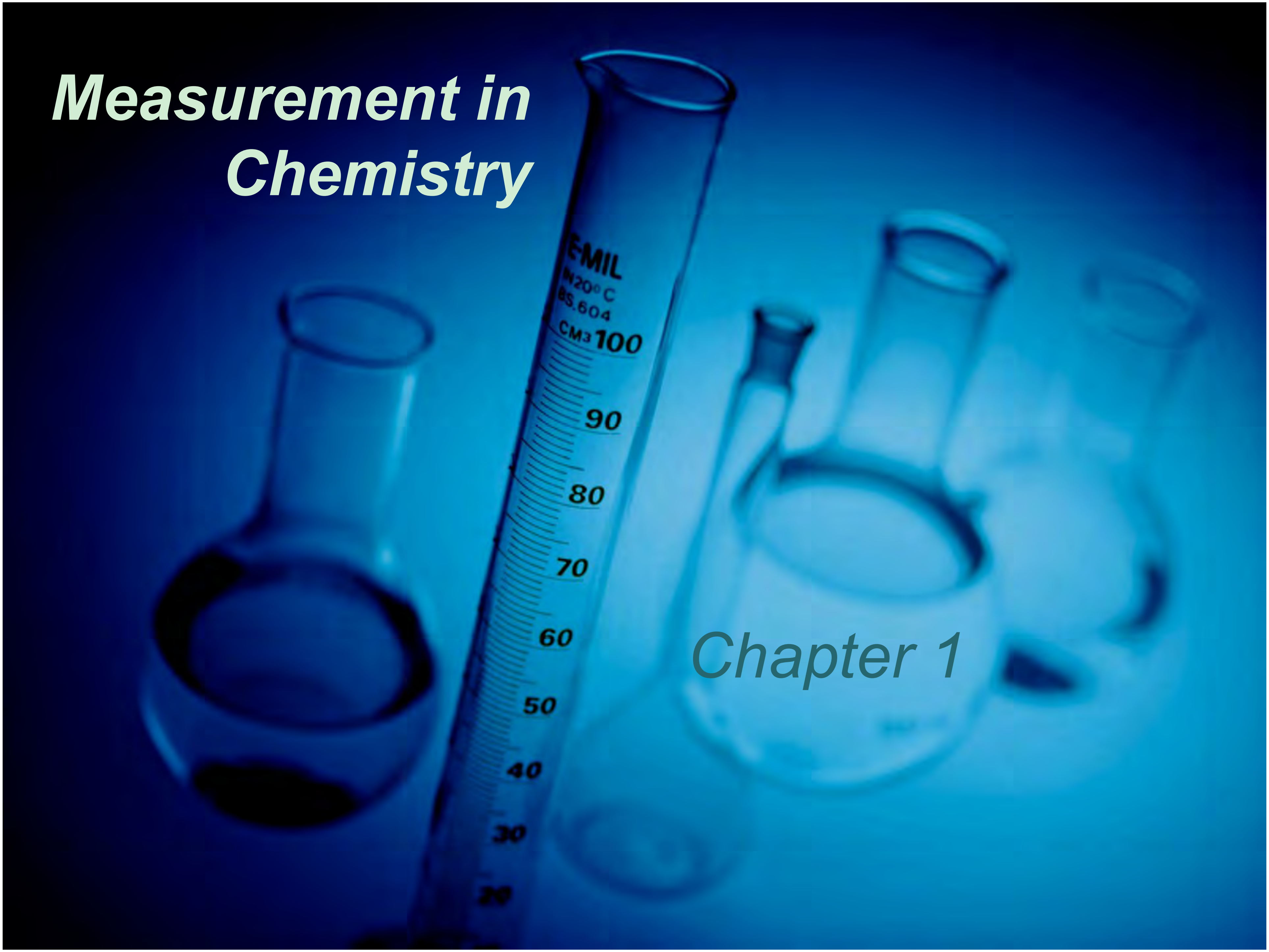
Measurement in Chemistry



Chapter 1

Measurement in Chemistry

- **Qualitative measurements** – Observations that describe a substance, mixture, reaction, or other process in **WORDS**.

- **Quantitative measurements** – Observations that describe a property with **NUMBERS** and **UNITS**.

UNITS and Quantitative measurements

- Numbers often make no sense if we do not have some sort of reference or standard to compare them to.
- ***Nearly all numbers MUST be followed by a unit label.***
- The unit indicates the standard against which the number is measured.

UNITS and Quantitative measurements

- The **metric system** is a system of measurement based on multiples of ten.
- In the metric system, a **prefix** may be added to the **base unit** to change the value of the unit by a factor of ten. The base unit is a reference to the standard.
- The **English system** of measurement is not based on powers of ten, and is therefore more difficult to use in calculations.
- Scientists almost exclusively work in the metric or **SI** system.

Base units: The *Système Internationale* (SI) base units are defined from some physically observable and reproducible quantity. The base units are:

Quantity	**Unit**	**Symbol**
Length	meter	m
Mass	kilogram (gram)	kg (g)
Time	second	S
Temperature	kelvin	K
Amount of a substance	mole	mol
Electric Current	ampere	A
Luminous Intensity	candela	cd

Metric Prefixes: The prefixes below change any of the base or derived metric units into a power of 10.

Prefix	Symbol	Multiple	Multiple
Tera-	T	10^{12}	1,000,000,000,000
Giga-	G	10^{9}	1,000,000,000
Mega-	M	10^{6}	1,000,000
kilo-	k	10^{3}	1,000
hecto-	h	10^{2}	100
deka-	dk	10^{1}	10
base unit		10^{0}	1
deci-	d	10^{-1}	0.1
centi-	c	10^{-2}	0.01
milli-	m	10^{-3}	0.001
micro-	μ	10^{-6}	0.000 001
nano-	n	10^{-9}	0.000 000 001
pico-	p	10^{-12}	0.000 000 000 001

TABLE 1.2 **The Prefixes Used in the SI System (Those most commonly encountered are shown in blue.)**

Prefix	Symbol	Meaning	Exponential Notation*
exa	E	1,000,000,000,000,000,000	10^{18}
peta	P	1,000,000,000,000,000	10^{15}
tera	T	1,000,000,000,000	10^{12}
giga	G	1,000,000,000	10^{9}
mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}
hecto	h	100	10^{2}
deka	da	10	10^{1}
—	—	1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}
femto	f	0.000000000000001	10^{-15}
atto	a	0.000000000000000001	10^{-18}

Simple Metric Conversions

- Converting from a larger prefix to a smaller one:
  - Move the decimal to the right:

    0.896 m → cm

    0 . 8 9 6 m → 8 9 . 6 cm

- Converting from a smaller prefix to a larger one:
  - Move the decimal to the left:

    750 mL → cL

    7 5 0 mL → 7 5 . 0 cL

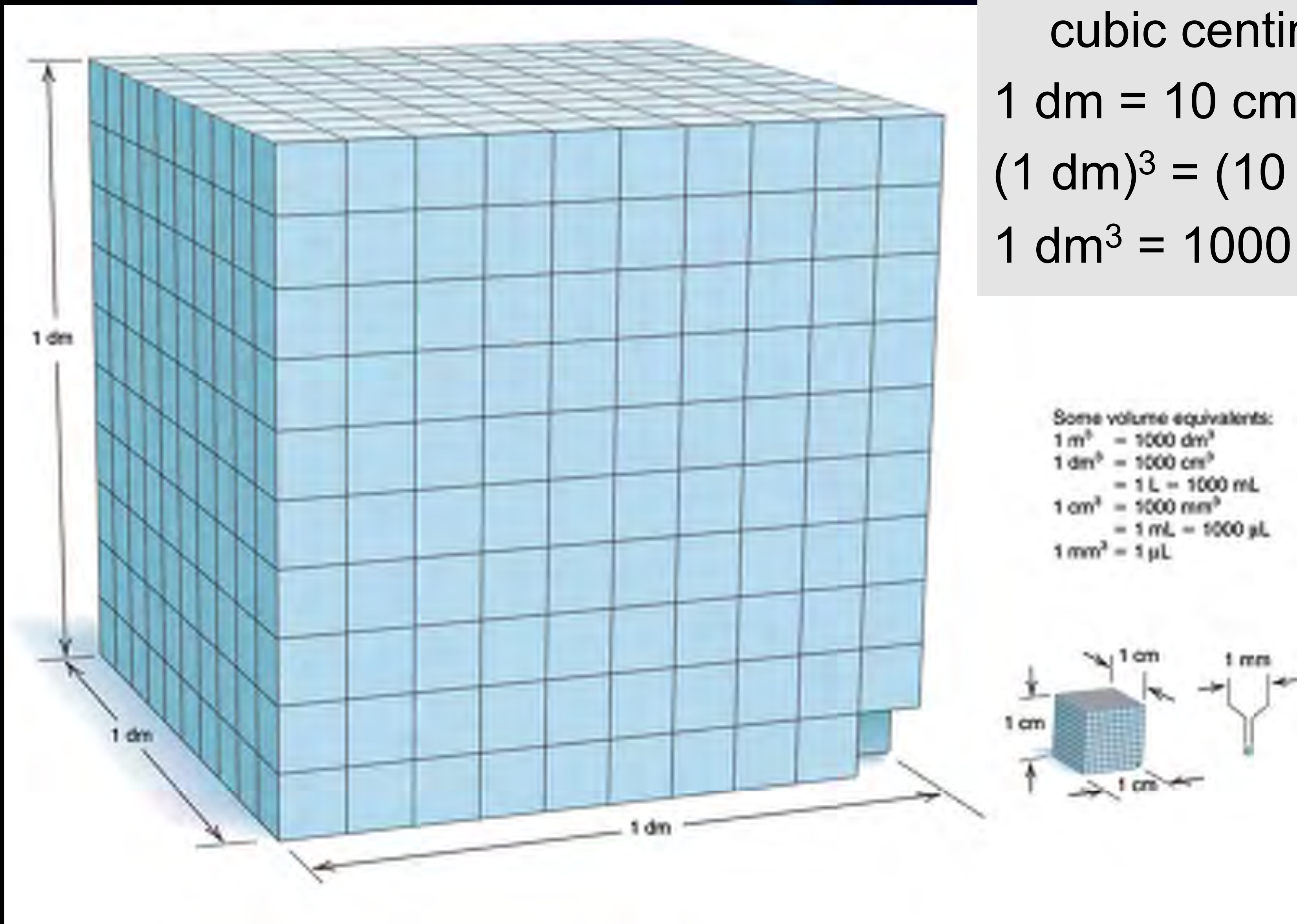
EXAMPLES:

1 kilometer (km)	=	1000 meters (m)		
1.0 mg	=	0.0010 g		
7.5 Ms	=	7,500,000 s		
55 cm	=	5.5 dm	=	0.55 m
450 nm	=	0.000 000 450 m		
0.0233 ps	**=**	**______________ μs**		
9.65×10^{8} cg	**=**	**______________ kg**		
7.87×10^{-7} dm	**=**	**______________ nm**		

SI derived units

- Derived units are mathematical combinations of the SI base units.
- **Volume** (space occupied by matter) is the most common derived unit that we will discuss in this course. The simplest formula for volume is for the volume of a box:
  - ***V = length x width x height***
    - Consider a box with:
      l = 5.0 cm, w = 3.0 cm, h = 7.0 cm
    - ***V*** *= 5.0* ***cm*** x *3.0* ***cm*** x *7.0* ***cm*** = *105* ***cm***^{3}
    - Just as the numbers are multiplied, so are the units.

Volume Conversion Factors



Cubic decimeters → cubic centimeters

1 dm = 10 cm

$(1\ dm)^3 = (10\ cm)^3$

$1\ dm^3 = 1000\ cm^3$

Volume units

The units that we commonly use to discuss volume is the Liter (L) and the milliliter (mL):

MEMORIZE these conversions:

1 Liter (L) = 1 cubic decimeter (dm^3)

1 milliliter (mL) = 1 cubic centimeter (cm^3)
= 0.001 L
= 1 cc

Common types of laboratory equipment used to measure liquid volume.

Relationships of selected U.S. and Metric Units

- In the U.S., many of the everyday measurements we use are based on the older English system.
- We primarily use the metric system for measurements in labs in the U.S. However it is still often necessary to make some conversions to the metric system.

Length	**Mass**	**Volume**
1 in = 2.54 cm	1 lb = 0.4536 kg	1 qt = 0.9464 L
1 yd = 0.9144 m	1 lb = 16 oz	4 qt = 1 gal
1 mi = 1.609 km	1 oz = 28.35 g	
1 mi = 5280 ft		

Dimensional Analysis & Simple Unit conversions:

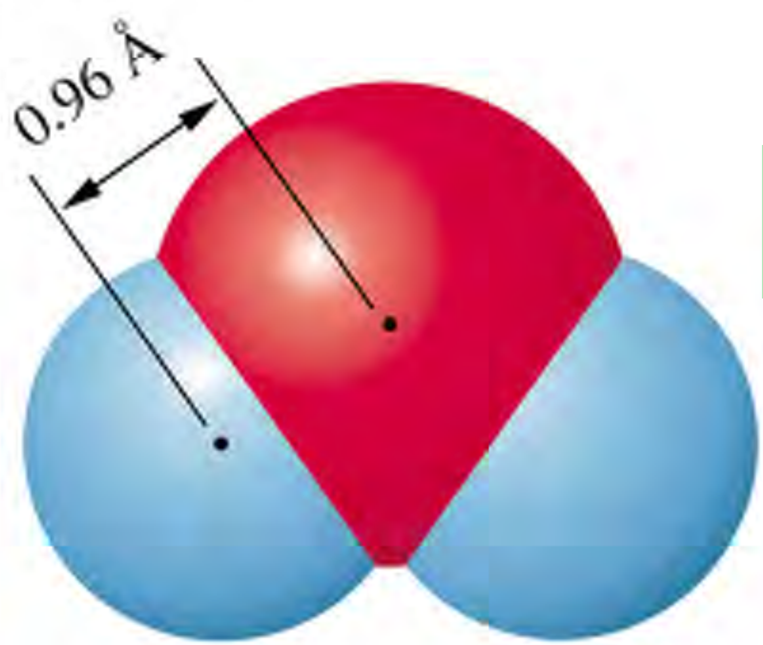
1) 4.5 L → cL

2) 758 nm → μm

3) 153. oz. → kg

Bond Length Conversion

Practice Problem 1.78 Water consists of molecules (groups of atoms). A water molecule has two hydrogen atoms, each connected to an oxygen atom. The distance between any one hydrogen atom and the oxygen atom is 0.96 Å. What is this distance in millimeters?



Conversion factor:
1 Å = 1 x 10^{-10} m

Compound Unit Conversion

- Convert: 65 mi/hr → m/s

Volume Conversion

- Convert: 1.2×10^5 cm^3 → m^3

Mass and Weight

- **Mass** is a measurement of how much matter is present.
- **Weight** is brought about by the force of gravity pulling one object toward another.
- Mass and weight are not the same things.
- Mass is independent of gravity.
- A classic **balance** functions by comparing the weight of some unknown mass to the weight of another object of known mass.
- With the same pull of gravity, two objects of the same mass will have the same weight.
- Mass is an ***extensive*** property of matter – it depends on the amount of matter present.

31.863 g
METTLER PJ300

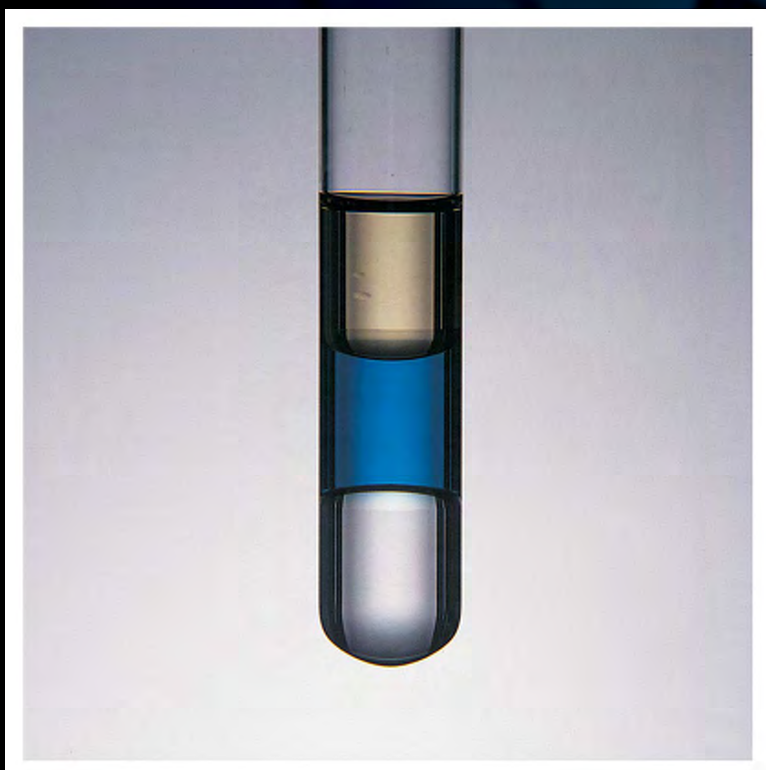
Density

- Density is a physical property of matter that describes the relationship between mass and volume of a substance.

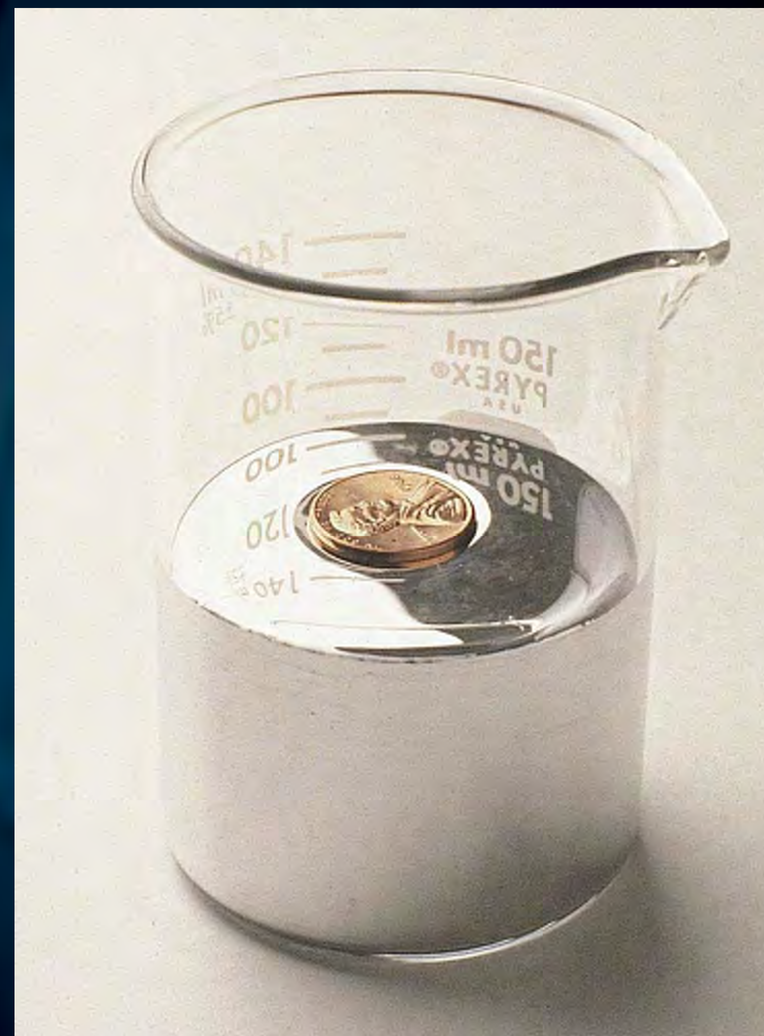
$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad D = \frac{m}{V}$$

- Density is an ***intensive*** property of matter - A substance will have a characteristic density that is independent of the amount of the substance present.
- In lay terms, we might say it describes how "heavy" a substance is (a misuse of the word).

The relative densities of methylene chloride, water (with dye added) and hexanes.



The relative densities of copper and mercury.



5-step Method for Problem-solving

1. Identify the **UNKNOWN** in the problem.

2. Identify the **GIVEN** quantities and useful information.

3. Choose the appropriate **formulas** & **conversion factors.**

4. **Plan the solution**.
   - Identify how you will use formulas & conversion factors.
   - Set up **dimensional analysis** tables.
   - Isolate unknown variables in formulas.

5. Substitute the givens (in formulas) and **SOLVE**.
   (Plug & Chug!)

Problem Solving Examples

1. Ethanol has a density of 0.789 g/cm^3.
   What is the volume of ethanol that must be measured to equal 30.3 g?

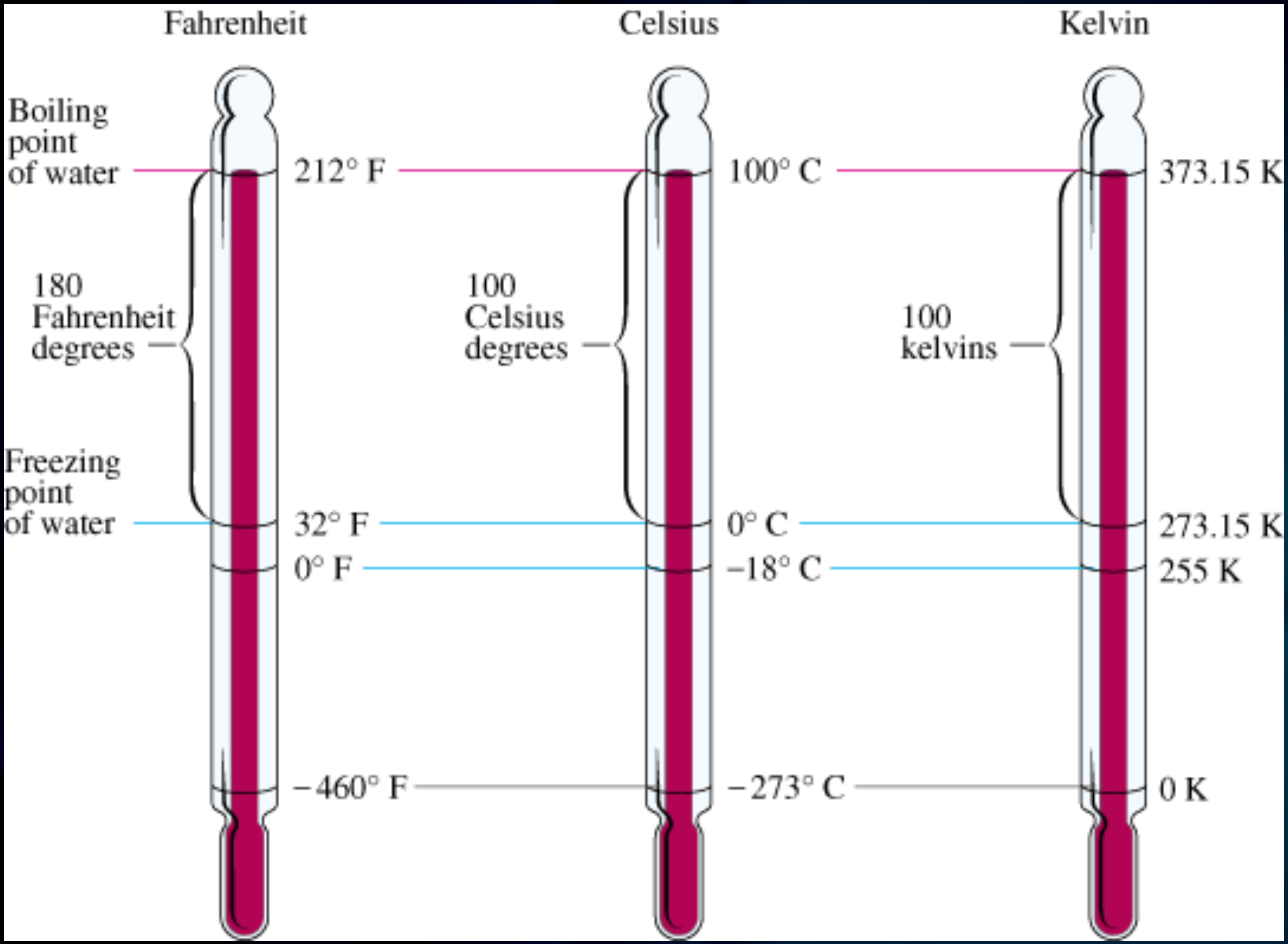
2. Convert the density of aluminum, 2.70 g/cm^3 *to* **oz. / in^3**

3. Aluminum has a density of 2.70 g/cm^3.
   What is the mass of aluminum in a sheet that is 2.00 **m** x 2.00 **m** x 1.50 ***mm***?

Temperature

- Temperature is the measure of the kinetic energy of particles.
- Temperature Scales:
  - ***Fahrenheit*** – system in common use in the US.
  - ***Celsius*** – system most commonly used in the laboratory and throughout the rest of the world. Has convenient reference points.
  - ***Kelvin*** – absolute temperature scale. Zero Kelvin is the theoretical temperature at which all molecular motion stops (or reaches its lowest possible quantum level). No negative temperatures.

Temperature Scales



Temperature Conversions

- °C = 5/9 (°F - 32)
- °F = 9/5 °C + 32
- **K = °C + 273.15** ***MEMORIZE***

EXAMPLES:

- Convert 10.0 °F to °C and to K.
- Convert 353 K to °C.