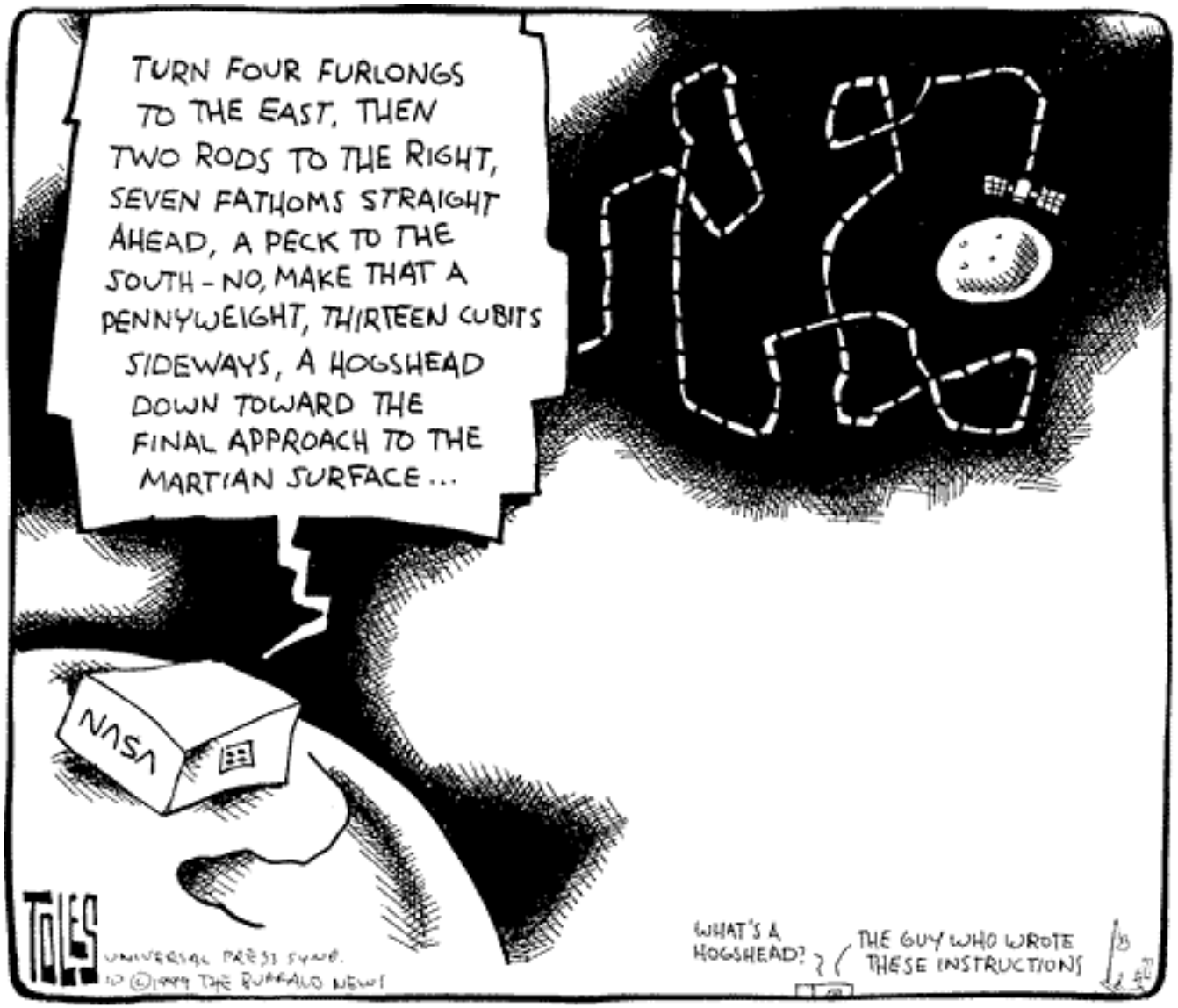
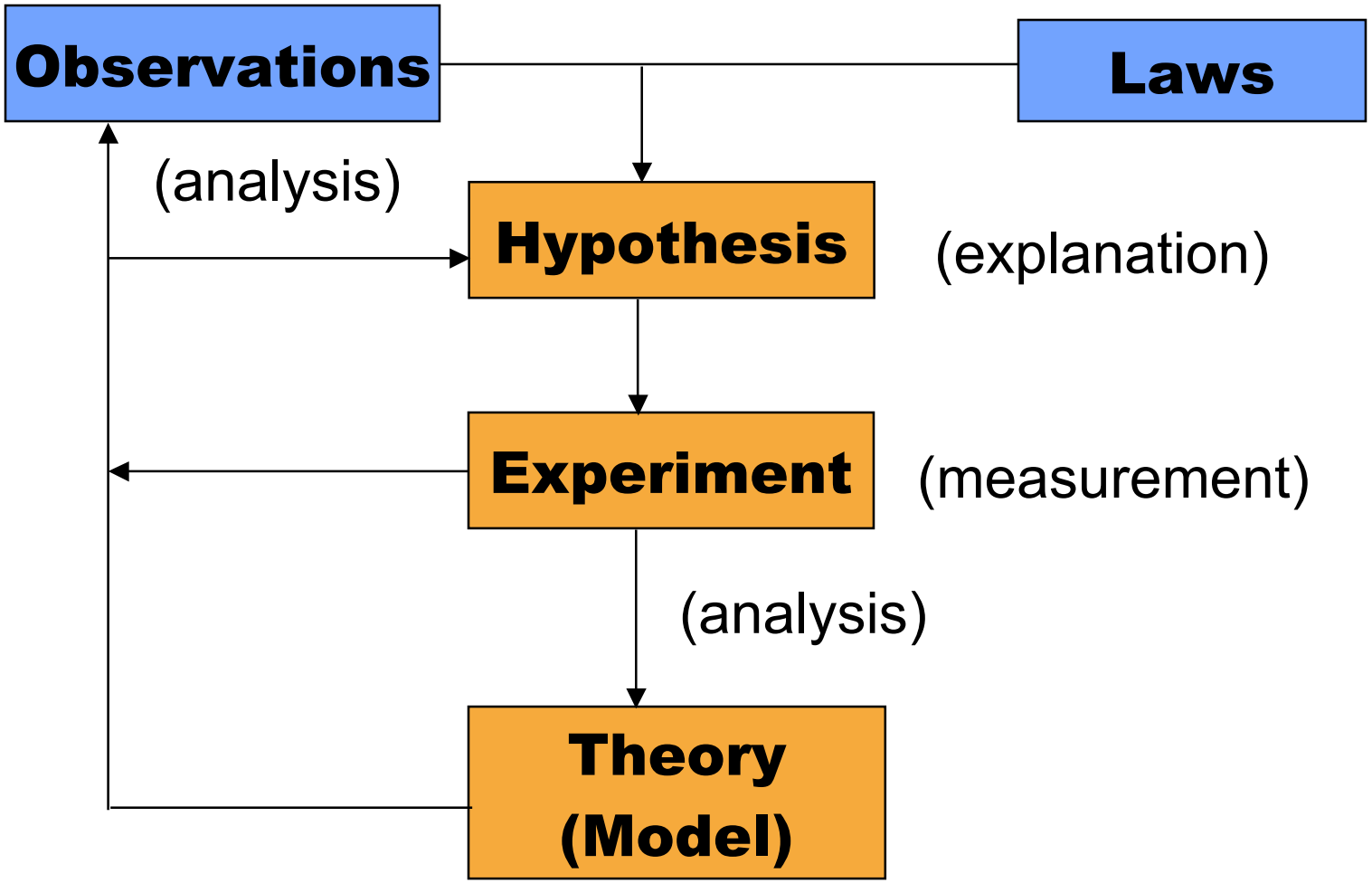
Standards for Measurement

Preparation for College Chemistry
Columbia University
Department of Chemistry


TURN FOUR FURLONGS TO THE EAST, THEN TWO RODS TO THE RIGHT, SEVEN FATHOMS STRAIGHT AHEAD, A PECK TO THE SOUTH - NO, MAKE THAT A PENNYWEIGHT, THIRTEEN CUBITS SIDEWAYS, A HOGSHEAD DOWN TOWARD THE FINAL APPROACH TO THE MARTIAN SURFACE...
NASA
TOLES
UNIVERSAL PRESS SYND.
(C)1999 THE BUFFALO NEWS
WHAT'S A HOGSHEAD?
THE GUY WHO WROTE THESE INSTRUCTIONS

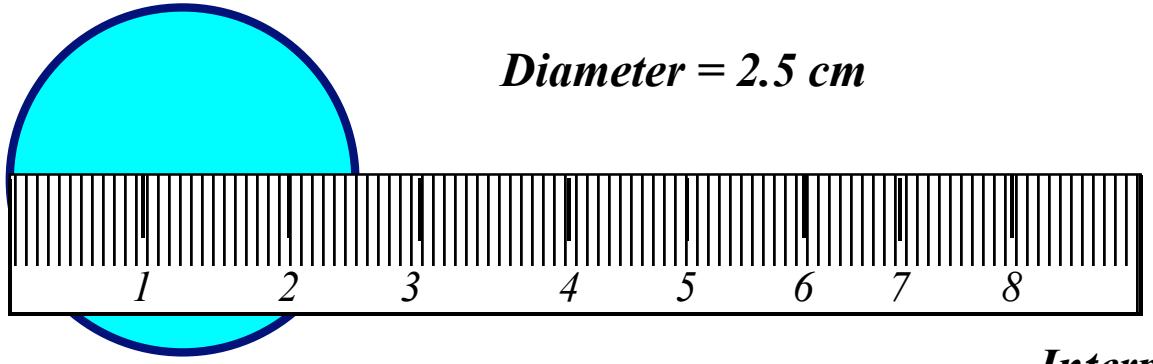
10/4/99

The Scientific Method



Measurement and Interpretations

Direct Measurement



Diameter = 2.5 cm

Interpretation Step

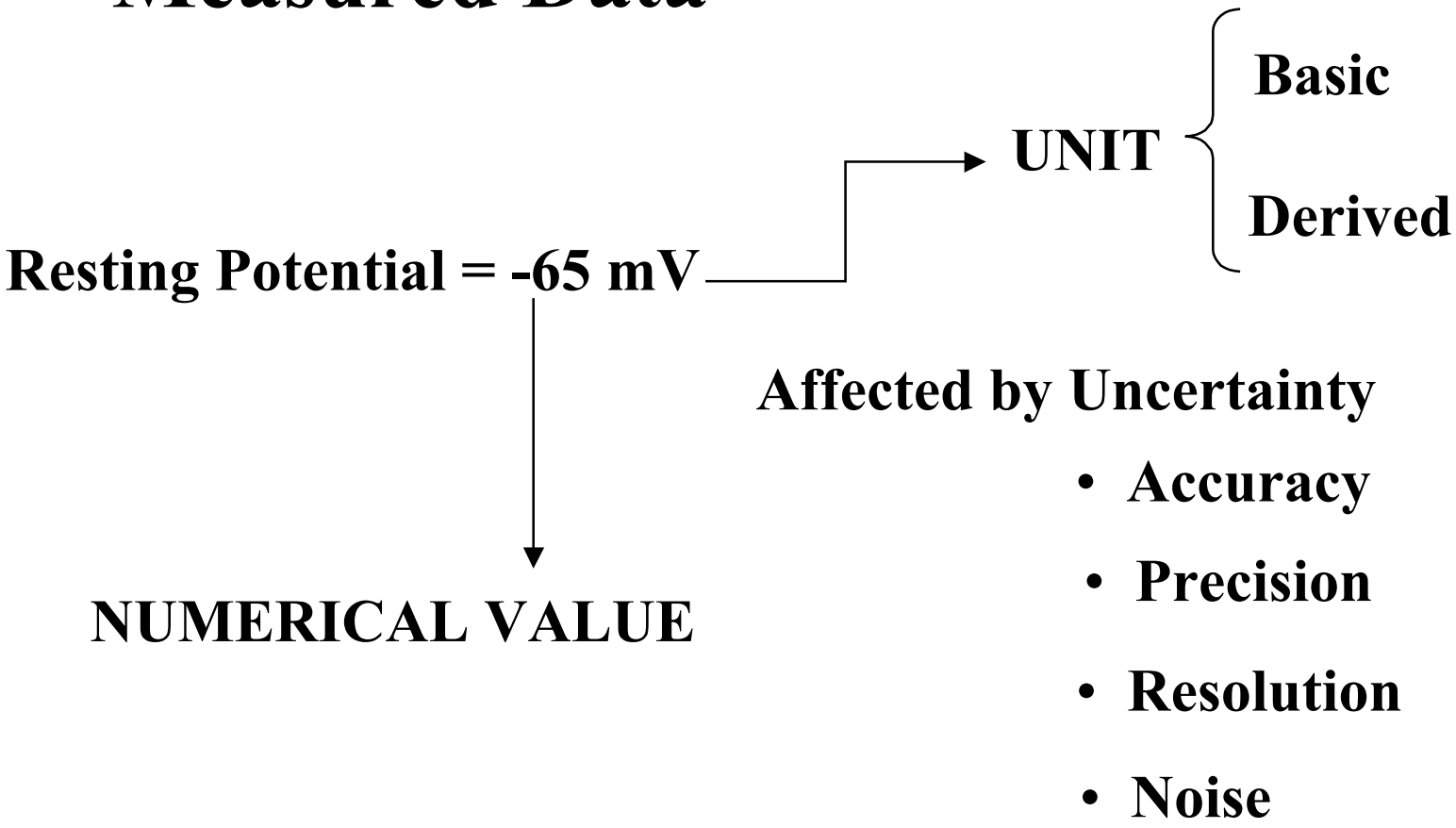
Radius = Diameter/2 ***Area = π x r^2 = 8.04 cm^2***

Art of Scientific Measurement:

- ***Recognize what can be measured directly.***
- ***Devise a way to obtain the desired information from measurement data.***

Experimentation

Measured Data



Significant Figures (Sig. Figs.)

The mass of an object weighed on a triple beam balance (precision ± 0.1g) is found to be 23.6 g.

This quantity contains 3 significant figures, i.e., three experimentally meaningful digits.

If the same measurement is made with an analytical balance (precision ± 0.0001g) , the mass might be 23.5820 g (6 sig. fig.)

Evaluating Zero

Zero is SIGNIFICANT when:

Is between nonzero digits: 61.09 has four sig Figs.

Appears at the end of a number that includes a decimal point 0.500 has three sig. Figs.; 1000. has four sig. Figs.

Zero is NON SIGNIFICANT when:

Appears before the first nonzero digit. 0.0025 has two sig. Figs. Leading Zeros are non significant

Appears at the end of a number without a decimal point. 1,000 has one sig. Fig.; 590 has two sig. Figs.

Exact Numbers

Defined numbers, like 12 inches in a foot, 60 minutes in an hour, 1,000mL in one liter.

Numbers that occur in counting operations.

Exact numbers have an infinite number of sig. figs.

Exact numbers do not limit the number of sig. figs. in a calculation.

Scientific Notation

Number written as a factor between 1 and 10 multiplied by 10 raised to a power.

$$0.0468 = 4.68 \times 10^{-2}$$

$$0.00003 = 3.0 \times 10^{-5} \quad \text{(two digits)}$$

$$\text{or } 3 \times 10^{-5} \quad \text{(one digit)}$$

Useful to unequivocally designate the significant figures.

$$1200 = 1.200 \times 10^{3} \quad \text{(four digits)}$$

$$6,600,000 = 6.6 \times 10^{6} \quad \text{(two digits)}$$

Multiplication or Division

The answer must contain as many significant figures as in the least precise quantity (measurement with least precision).

What is the density of a piece of metal weighing 36.123 g with a volume of 13.4 mL?

Drop these three digits

$$d = \frac{mass}{volume} = \frac{36.123g}{13.4mL} = 2.69\overbrace{575}g/mL$$

Round off to 7

ANSWER: $2.70g/mL$

Addition or Subtraction

Keep only as many digits after the decimal point as there are in the least precise quantity

Ex. Add 1.223 g of sugar to 154.5 g of coffee:

Total mass = 1.2 g + 154.5 g = 155.7 g

Addition or Subtraction

Note that the rule for addition and subtraction does not relate to significant figures.

The number of significant figures often decreases upon subtraction.

Mass beaker + sample =	52.169 g	(5 sig. figs.)
- Mass empty beaker =	52.120 g	(5 sig. figs.)
Mass sample =	0.049 g	(2 sig figs)

SI Units Prefixes (Multiples)

Prefix	Symbol	Value	Power
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}

SI Units Prefixes (Submultiples)

Prefix	Symbol	Value	Power
atto	a	0.000000000000000001	10^{-18}
femto	f	0.000000000000001	10^{-15}
pico	p	0.000000000001	10^{-12}
nano	n	0.000000001	10^{-9}
micro	μ	0.000001	10^{-6}
milli	m	0.001	10^{-3}
centi	c	0.01	10^{-2}
deci	d	0.1	10^{-1}

Système International (SI)
The Metric System

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

Based on seven DIMENSIONALLY INDEPENDENT quantities

Length

Base unit is the meter (m)

1790s: 10-millionth of the distance from the equator to the North Pole along a meridian.

1889: Distance between two engraved lines on a Platinum-Iridium alloy bar maintained at 0°C in Sevres-France.

1960-1983: 1,650,763.73 wavelengths of the orange-red emision of ^{18}Kr at standard conditions

Since 1983: 1/299,792,458 of the distance traveled by light in 1 second through vacuum.

Length

Engineering dimensions

1 km = 10^{3} m

1 cm = 10^{-2} m

1 mm = 10^{-3} m

1 μm = 10^{-6} m

1 in = 2.54cm

1 mile = 1.61km

Atomic dimensions

1 nm = 10^{-9} m

1 Å = 10^{-10} m

Mass Base unit is the kilogram (kg)

International prototype: a platinum-iridium cylinder maintained in Sevres-France.

$$1\ kg = 10^{3}\ g;\ \ 1\ mg = 10^{-3}\ g$$

A mass of 1 kg has a terrestrial weight of 9.8 newtons (2.2 lbs)

Depending on the precision required and the amount of material, different balances are used:

- The Quadruple Beam Balance (± 10 mg)
- The Top Loading Balance (± 1 mg).
- The Analytical Balance (± 0.1 mg).

Comparison of Temperature Scales

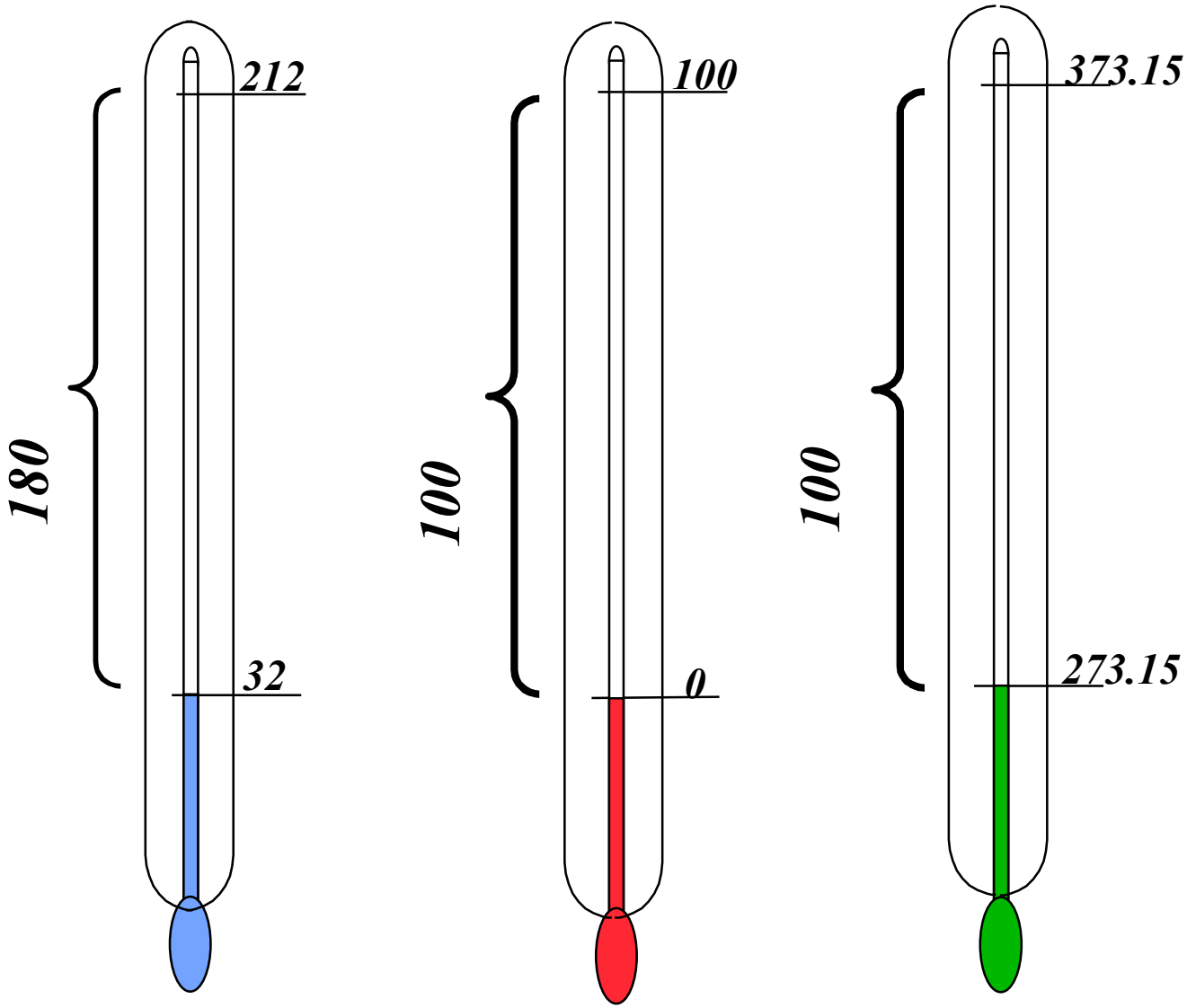
$°F = (1.8 \times °C) + 32$ — *Fahrenheit*

$°C = (°F - 32) / 1.8$ — *Celsius*

$K = °C + 273.15$ — *Kelvin*

Boiling point of water

Freezing point of water



Temperature Conversion

$$\mathbf{K = °C + 273.15}$$

$$\mathbf{°F = (1.8 \times °C) + 32}$$

$$\mathbf{°C = (°F - 32) / 1.8}$$

Ex. 2.20 Convert 110°F to °C and K

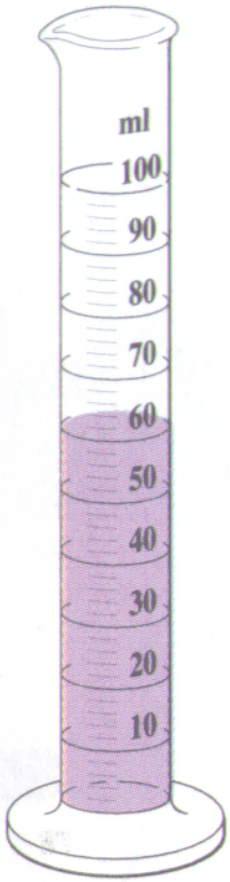
$$°C = (68° - 32°) / 1.8 = 20°C$$

$$K = 20 + 273 = 293\ K$$

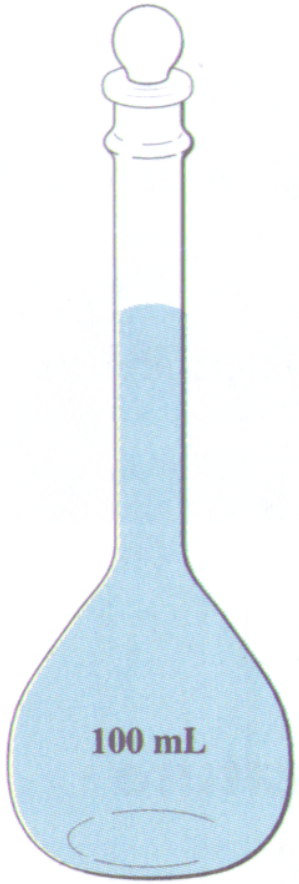
Derived Units

Physical quantity	Name	Symbol	Definition
Frequency	Hertz	Hz	s^{-1}
Force	newton	N	$m.kg.s^{-2}$
Pressure, stress	pascal	Pa	$N.m^{-2} = m^{-1}.kg.s^{-2}$
Energy work, heat	joule	J	$N.m = m^{2}.kg.s^{-2}$
Electric charge	coulomb	C	A.s
Electromotive Force	volt	V	$J.C^{-1} = m^{2}.kg.s^{-3}.A^{-1}$
Electric Resistance	ohm	Ω	$V.A^{-1} = m^{2}.kg.s^{-3}.A^{-2}$

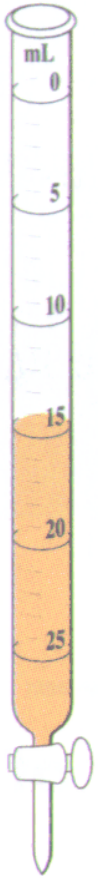
Measurement of Volume



Graduated cylinder

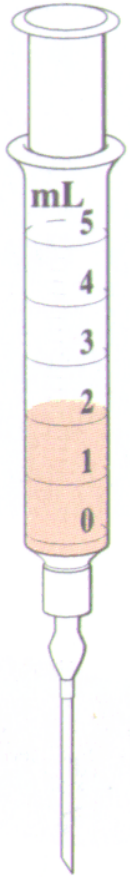


Volumetric flask



Buret

Pipet



Syringe

Conversion Factors

$$1\ in = 2{,}54cm \Rightarrow \underbrace{\frac{2.54cm}{1\ in} \text{ or } \frac{1\ in}{2.54cm}}$$

Two conversion factors

$$\cancel{Unit\ given} \Rightarrow \frac{Unit\ needed}{\cancel{Unit\ given}} = Unit\ needed$$

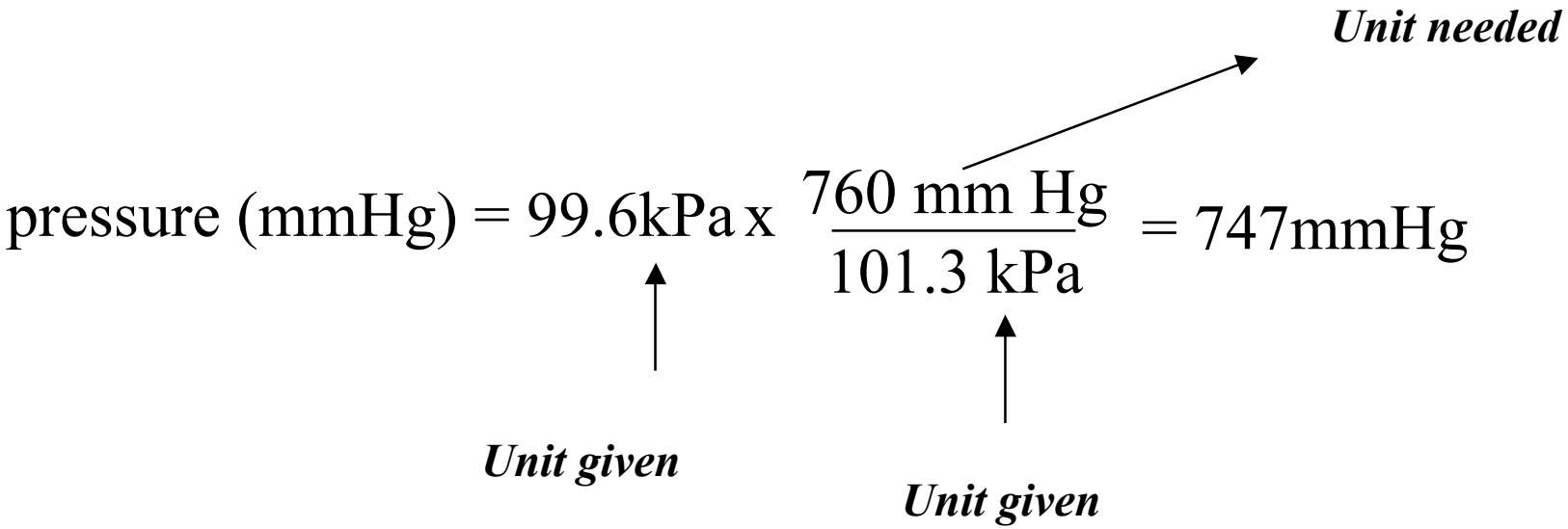
Dimensional Analysis

- ***Read Problem. What needs to be solved for? Write it down***
- ***Tabulate data given. Label all factors with proper units***
- ***Determine principles involved and unit relationships***
- ***Set up the problem deciding for the proper conversion factor***
- ***Perform mathematical operations***
- ***Check if the answer is reasonable***

Simple, One Step Conversions

CBS News reported the barometric pressure to be 99.6 kPa. Express this in mm Hg.

Conversion factor : 101.3 kPa = 760 mm Hg



Simple, One Step Conversions

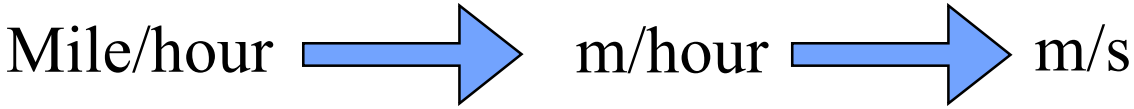
A rainbow trout is measured to be 16.2 in. long. What is the length in cm?

$$\textit{length in cm} = 16.2\ \textit{in} \times \frac{2.54\ \text{cm}}{1\ \text{in}} = 41.1\ \text{cm}$$

Note the cancellation of units. To convert from centimeters to inches, the conversion factor would be 1 in / 2.54 cm.

Multiple Conversion Factors

A baseball is thrown at 89.6 miles per hour. What is the speed in meters per second?



$$1 \text{ mile} = 1.609 \text{ km} = 1.609 \times 10^{-3} \text{ m}; \quad 1 \text{ h} = 3600 \text{ s}$$

$$\text{speed} = 89.6 \frac{\text{miles}}{\text{hour}} \times \frac{1.609 \times 10^{-3} \text{m}}{1 \text{ mile}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 40.0 \text{ m / s}$$

Three sig. figs.

Units raised to a Power

The conversion factor must also be raised to that power.

A circle has an area of 28 in^2. Calculate area in cm^2.

$$in^2 \longrightarrow cm^2$$

$$(1\ in)^2 = (2.54\ cm)^2$$

$$\text{Area} = 28\ in^2 \times \frac{(2.54\ cm)^2}{(1\ in)^2} = \frac{6.45\ cm^2}{1\ in^2} = 1.8 \times 10^2\ cm^2$$

↓

Two sig. figs.

Density: Conversion factor
mass ⟷ volume

An empty flask weighs 22.138 g. You pipet 5.00 mL of octane into the flask. The total mass is 25.598 g. What is the density?

Octane amount in g:

$$\begin{array}{r} 25.598 \\ -22.138 \\ \hline 3.460\text{g} \end{array}$$

$$d = \frac{3.460\text{g}}{5.00\ \text{mL}} = 0.692\text{g / mL}$$

What is the volume occupied by ten grams of octane?

$$V = 10.00\text{g} \times \frac{1\ \text{mL}}{0.692\text{g}} = 14.5\ \text{mL}$$

Solubility

Expressed as grams of solute per 100 g of solvent in the CRC (Chemical Rubber Company) Chemistry and Physics Handbook.

For lead nitrate in aqueous solution:

Solubility (g/100g water)	T (°C)
50	10
140	100

Solubility

How much water is required to dissolve 80 g of lead nitrate at 100°C?

$$\text{Mass water} = 80\text{g lead nitrate} \times \frac{100\text{g water}}{140\text{g lead nitrate}} = 57\text{g water}$$

Conversion factor
(from table)

Cool the solution to 10°C. How much lead nitrate remains in solution?

$$\text{Mass of lead nitrate} = 57\text{g water} \times \frac{50\text{g lead nitrate}}{100\text{g water}} = 28\text{g lead nitrate}$$

28g lead nitrate remain in solution

80g lead nitrate were initially in solution

80g – 28g = 52g lead nitrate crystallizes out of solution