The McGraw-Hill Companies

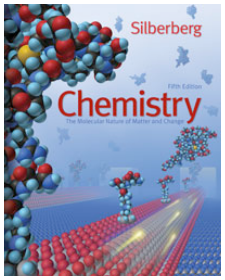
Unit I - Lecture 2

Chemistry

The Molecular Nature of Matter and Change

Fifth Edition

Martin S. Silberberg



Chapter 1 : Keys to the Study of Chemistry

1.4 Chemical Problem Solving

1.5 Measurement in Scientific Study

1.6 Uncertainty in Measurement: Significant Figures

A Systematic Approach to Solving Chemistry Problems

- State Problem
  - Clarify the known and unknown.
- Plan
  - Suggest steps from known to unknown.
  - Prepare a visual summary of steps.
- Solution
- Check
- Comment
- Follow-up Problem

Sample Problem 1.3 Converting Units of Length

PROBLEM: To wire your stereo equipment, you need 325 centimeters (cm) of speaker wire that sells for \$0.15/ft. What is the price of the wire?

PLAN: Known - length (in cm) of wire and cost per length (\$/ft)
We have to convert cm to inches and inches to feet followed by finding the cost for the length in ft.

length (cm) of wire
↓ 2.54 cm = 1 in
length (in) of wire
↓ 12 in = 1 ft
length (ft) of wire
↓ 1 ft = \$0.15
Price (\$) of wire

SOLUTION:

Length (in) = length (cm) x conversion factor

$= 325\ \text{cm} \times \frac{\text{in}}{2.54\ \text{cm}} = 128\ \text{in}$

Length (ft) = length (in) x conversion factor

$= 128\ \text{in} \times \frac{\text{ft}}{12\ \text{in}} = 10.7\ \text{ft}$

Price (\$) = length (ft) x conversion factor

$= 10.7\ \text{ft} \times \frac{\$0.15}{\text{ft}} = \$1.60$

Table 1. 2 SI Base Units

Physical Quantity (Dimension)	*Unit Name*	*Unit Abbreviation*
mass	kilogram	kg
length	meter	m
time	second	s
temperature	kelvin	K
electric current	ampere	A
amount of substance	mole	mol
luminous intensity	candela	cd

Table 1.3 Common Decimal Prefixes Used with SI Units

Prefix	*Prefix Symbol*	*Word*	*Conventional Notation*	*Exponential Notation*
tera	T	trillion	1,000,000,000,000	$1\text{x}10^{12}$
giga	G	billion	1,000,000,000	$1\text{x}10^{9}$
mega	M	million	1,000,000	$1\text{x}10^{6}$
kilo	k	thousand	1,000	$1\text{x}10^{3}$
hecto	h	hundred	100	$1\text{x}10^{2}$
deka	da	ten	10	$1\text{x}10^{1}$
-----	----	one	1	$1\text{x}10^{0}$
deci	d	tenth	0.1	$1\text{x}10^{-1}$
centi	c	hundredth	0.01	$1\text{x}10^{-2}$
milli	m	thousandth	0.001	$1\text{x}10^{-3}$
micro	µ	millionth	0.000001	$1\text{x}10^{-6}$
nano	n	billionth	0.000000001	$1\text{x}10^{-9}$
pico	p	trillionth	0.000000000001	$1\text{x}10^{-12}$
femto	f	quadrillionth	0.000000000000001	$1\text{x}10^{-15}$

Table 1.4 Common SI-English Equivalent Quantities

Quantity	SI to English Equivalent	English to SI Equivalent
Length	1 km = 0.6214 mile 1 m = 1.094 yard 1 m = 39.37 inches 1 cm = 0.3937 inch	1 mi = 1.609 km 1 yd = 0.9144 m 1 ft = 0.3048 m 1 in = 2.54 cm
Volume	1 cubic meter (m^3) = 35.31 ft^3 1 dm^3 = 0.2642 gal 1 dm^3 = 1.057 qt 1 cm^3 = 0.03381 fluid ounce	1 ft^3 = 0.02832 m^3 1 gal = 3.785 dm^3 1 qt = 0.9464 dm^3 1 qt = 946.4 cm^3 1 fluid ounce = 29.57 cm^3
Mass	1 kg = 2.205 lb 1 g = 0.03527 ounce (oz)	1 lb = 0.4536 kg 1 oz = 28.35 g

Sample Problem 1.4 **Converting Units of Volume**

PROBLEM: When a small piece of galena, an ore of lead, is submerged in the water of a graduated cylinder that originally reads 19.9 mL, the volume increases to 24.5 mL. What is the volume of the piece of galena in cm^3 and in L?

PLAN: The volume of galena is equal to the change in the water volume before and after submerging the solid.

volume (mL) before and after addition
↓ subtract
volume (mL) of galena
1 mL = 1 cm^3 ↓ ↓ 1 mL = 10^{-3} L
volume (cm^3) of galena | volume (L) of galena

SOLUTION: (24.5 - 19.9) mL = volume of galena = 4.6 mL

$4.6\ \text{mL} \times \frac{1\ cm^3}{\text{mL}} = 4.6\ cm^3$ $\qquad 4.6\ \text{mL} \times \frac{10^{-3}\ L}{\text{mL}} = 4.6\times10^{-3}\ L$

Sample Problem 1.5 **Converting Units of Mass**

PROBLEM: What is the total mass (in kg) of a cable made of six strands of optical fiber, each long enough to link New York and Paris (8.84×10^3 km)? One strand of optical fiber used to traverse the ocean floor weighs 1.19 x 10-3 lbs/m.

PLAN: The sequence of steps may vary but essentially you have to find the length of the entire cable and convert it to mass.

length (km) of fiber
↓ 1 km = 10^3 m
length (m) of fiber
↓ 1 m = 1.19×10^{-3} lb
mass (lb) of fiber
↓ 6 fibers = 1 cable
mass (lb) of cable
↓ 2.205 lb = 1 kg
mass (kg) of cable

SOLUTION:

$8.84 \times 10^3\ \text{km} \times \frac{10^3\ m}{\text{km}} = 8.84 \times 10^6\ m$

$8.84 \times 10^6\ \text{m} \times \frac{1.19 \times 10^{-3}\ lbs}{m} = 1.05 \times 10^4\ lb$

$1.05 \times 10^4\ lb \times \frac{6\ fibers}{cable} = \frac{6.30 \times 10^4\ lb}{cable}$

$\frac{6.30 \times 10^4\ lb}{cable} \times \frac{1 kg}{2.205\ lb} = \frac{2.86 \times 10^4\ kg}{cable}$

Some interesting quantities.

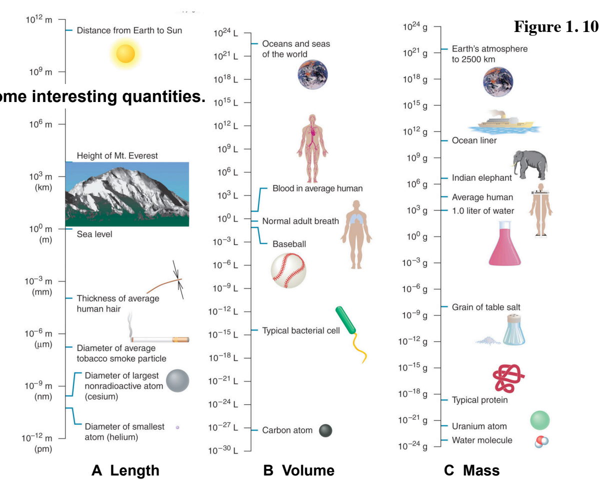


Figure 1. 10

Table 1.5	**Densities of Some Common Substances***	
Substance	***Physical State***	***Density (g/cm³)***
Hydrogen	**Gas**	**0.0000899**
Oxygen	**Gas**	**0.00133**
Grain alcohol	**Liquid**	**0. 789**
Water	**Liquid**	**0.998**
Table salt	**Solid**	**2.16**
Aluminum	**Solid**	**2.70**
Lead	**Solid**	**11.3**
Gold	**Solid**	**19.3**

At room temperature(20°C) and normal atmospheric pressure(1atm).

Sample Problem 1.6 **Calculating Density from Mass and Length**

PROBLEM: If a rectangular slab of Lithium (Li) weighs 1.49×10^3 mg and has sides that measure 20.9 mm by 11.1 mm by 11.9 mm, what is the density of Li in g/cm^3 ?

PLAN: Density is expressed in g/cm^3 so we need the mass in grams and the volume in cm^3.

mass (mg) of Li
↓ 10^3 mg = 1 g
mass (g) of Li

lengths (mm) of sides
↓ 10 mm = 1 cm
lengths (cm) of sides
↓ multiply lengths
volume (cm^3)
↓ divide mass by volume
density (g/cm^3) of Li

SOLUTION:

$1.49\times10^3\ mg \times \frac{1\ g}{1000\ mg} = 1.49\ g$

$20.9\ mm \times \frac{1\ cm}{10\ mm} = 2.09\ cm$

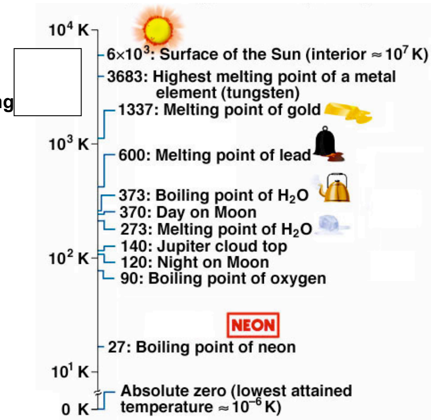
Similarly the other sides will be 1.11 cm and 1.19 cm, respectively.

$2.09 \times 1.11 \times 1.19 = 2.76\ cm^3$

$\text{density of Li} = \frac{1.49\ g}{2.76\ cm^3} = 0.540\ g/cm^3$

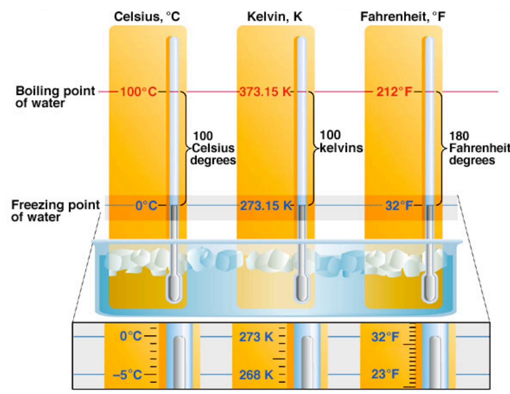
Figure 1.11

Some interesting temperatures.



13

Figure 1.12 **The freezing and boiling points of water.**



14

Temperature Scales and Interconversions

Kelvin (K) - The "Absolute temperature scale" begins at absolute zero and only has positive values.

Celsius (°C) - The temperature scale used by science, formally called centigrade, most commonly used scale around the world; water freezes at 0°C, and boils at 100°C.

Fahrenheit (°F) - Commonly used scale in the U.S. for our weather reports; water freezes at 32°F and boils at 212°F.

T (in K) = T (in °C) + 273.15
T (in °C) = T (in K) - 273.15

T (in °F) = 9/5 T (in °C) + 32
T (in °C) = [T (in °F) - 32] 5/9

15

Sample Problem 1.7 **Converting Units of Temperature**

PROBLEM: A child has a body temperature of 38.7˚C.

(a) If normal body temperature is 98.6˚F, does the child have a fever?

(b) What is the child's temperature in kelvins?

PLAN: We have to convert ˚C to ˚F to find out if the child has a fever and we use the ˚C to Kelvin relationship to find the temperature in Kelvin.

SOLUTION:

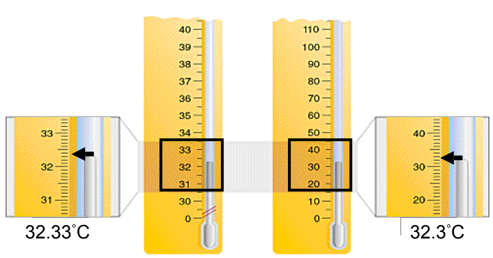
(a) Converting from ˚C to ˚F $\frac{9}{5}$ (38.7˚C) + 32 = 101.7˚F

(b) Converting from ˚C to K 38.7˚C + 273.15 = 311.8K

16

Figure 1.14A

The number of significant figures in a measurement depends upon the measuring device.



17

Rules for Determining Which Digits are Significant

All digits are significant *except zeros that are used only to position the decimal point.*

- Make sure that the measured quantity has a decimal point.
- Start at the left, move right until you reach the first nonzero digit.
- Count that digit and every digit to it's right as significant.

Zeros that end a number and lie either after or before the decimal point are significant; thus 1.030 ml has four significant figures, and 5300. L has four significant figures also.

Numbers such as 5300 L are assumed to only have 2 significant figures. A terminal decimal point is often used to clarify the situation, but scientific notation is the best!

18

Sample Problem 1.8 Determining the Number of Significant Figures

PROBLEM: For each of the following quantities, underline the zeros that are significant figures (sf), and determine the number of significant figures in each quantity. For **(d)** to **(f),** express each in exponential notation first.

(a) 0.0030 L **(b)** 0.1044 g **(c)** 53,069 mL

(d) 0.00004715 m **(e)** 57,600. s **(f)** 0.0000007160 cm^3

PLAN: Determine the number of sf by counting digits and paying attention to the placement of zeros.

SOLUTION:

(a) 0.0030 L 2sf **(b)** 0.1044 g 4sf **(c)** 53,069 mL 5sf

(d) 0.00004715 m 4sf
4.715×10^{-5} m

(e) 57,600. s 5sf
5.7600×10^{4} s

(f) 0.0000007160 cm^3 4sf
7.160×10^{-7} cm^3

Rules for Significant Figures in Calculations

1. *For multiplication and division*. The answer contains the same number of significant figures as there are in the measurement with the fewest significant figures.

Multiply the following numbers:

9.2 cm x 6.8 cm x 0.3744 cm = 23.4225 cm^3 = 23 cm^3

Rules for Significant Figures in Calculations

2. *For addition and subtraction*. The answer has the *same number of decimal places as there are in the measurement with the fewest decimal places.*

Example: adding two volumes

83.5 mL
\+ 23.28 mL
106.78 mL = **106.8** mL

Example: subtracting two volumes

865.9 mL
\- 2.8121 mL
863.0879 mL = **863.1** mL

Rules for Rounding Off Numbers

1. If the digit removed is *more than 5,* the preceding number increases by 1.
5.379 rounds to 5.38 if three significant figures are retained and to 5.4 if two significant figures are retained.

2. If the digit removed is *less than 5,* the preceding number is unchanged.
0.2413 rounds to 0.241 if three significant figures are retained and to 0.24 if two significant figures are retained.

3. If the digit removed *is 5,* the preceding number increases by 1 if it is odd and remains unchanged if it is even.
17.75 rounds to 17.8, but 17.65 rounds to 17.6.
If the 5 is followed only by zeros, rule 3 is followed; if the 5 is followed by nonzeros, rule 1 is followed:
17.6500 rounds to 17.6, but 17.6513 rounds to 17.7

4. Be sure to carry two or more additional significant figures through a multistep calculation and round off only the *final* answer only.

Issues Concerning Significant Figures

Figure 1.15

Electronic Calculators

be sure to correlate with the problem

FIX function on some calculators

Choice of Measuring Device

graduated cylinder < buret ≤ pipet

Exact Numbers

numbers with no uncertainty

60 min = 1 hr

1000 mg = 1 g

These have as many significant digits as the calculation requires.

Sample Problem 1.8 Significant Figures and Rounding

PROBLEM: Perform the following calculations and round the answer to the correct number of significant figures:

(a) $$\frac{16.3521\ cm^2 - 1.448\ cm^2}{7.085\ cm}$$

(b) $$\frac{4.80\times10^4\ mg \left(\frac{1\ g}{1000\ mg}\right)}{11.55\ cm^3}$$

PLAN: In (a) we subtract before we divide; for (b) we are using an exact number.

SOLUTION:

(a) $$\frac{16.3521\ cm^2 - 1.448\ cm^2}{7.085\ cm} = \frac{14.904\ cm^2}{7.085\ cm} = 2.104\ cm$$

(b) $$\frac{4.80\times10^4\ mg \left(\frac{1\ g}{1000\ mg}\right)}{11.55\ cm^3} = \frac{48.0\ g}{11.55\ cm^3} = 4.16\ g/cm^3$$

Precision and Accuracy
Errors in Scientific Measurements

Precision -
Refers to *reproducibility* or how close the measurements are to each other.

Accuracy -
Refers to how close a measurement is to the real value.

Systematic error -
Values that are either all higher or all lower than the actual value.

Random Error -
In the absence of systematic error, some values that are higher and some that are lower than the actual value.

Precision and accuracy in the laboratory.

Figure 1.16

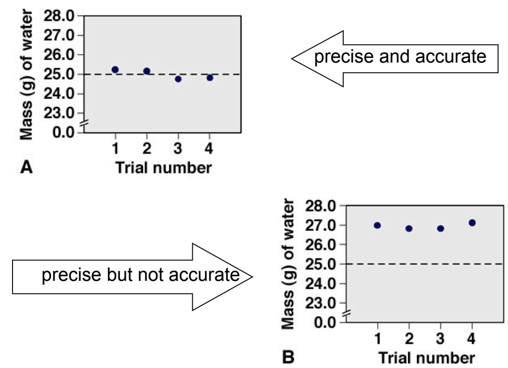


Figure 1.16
continued

Precision and accuracy in the laboratory.