Chapter 1

Measurement, and Problem Solving

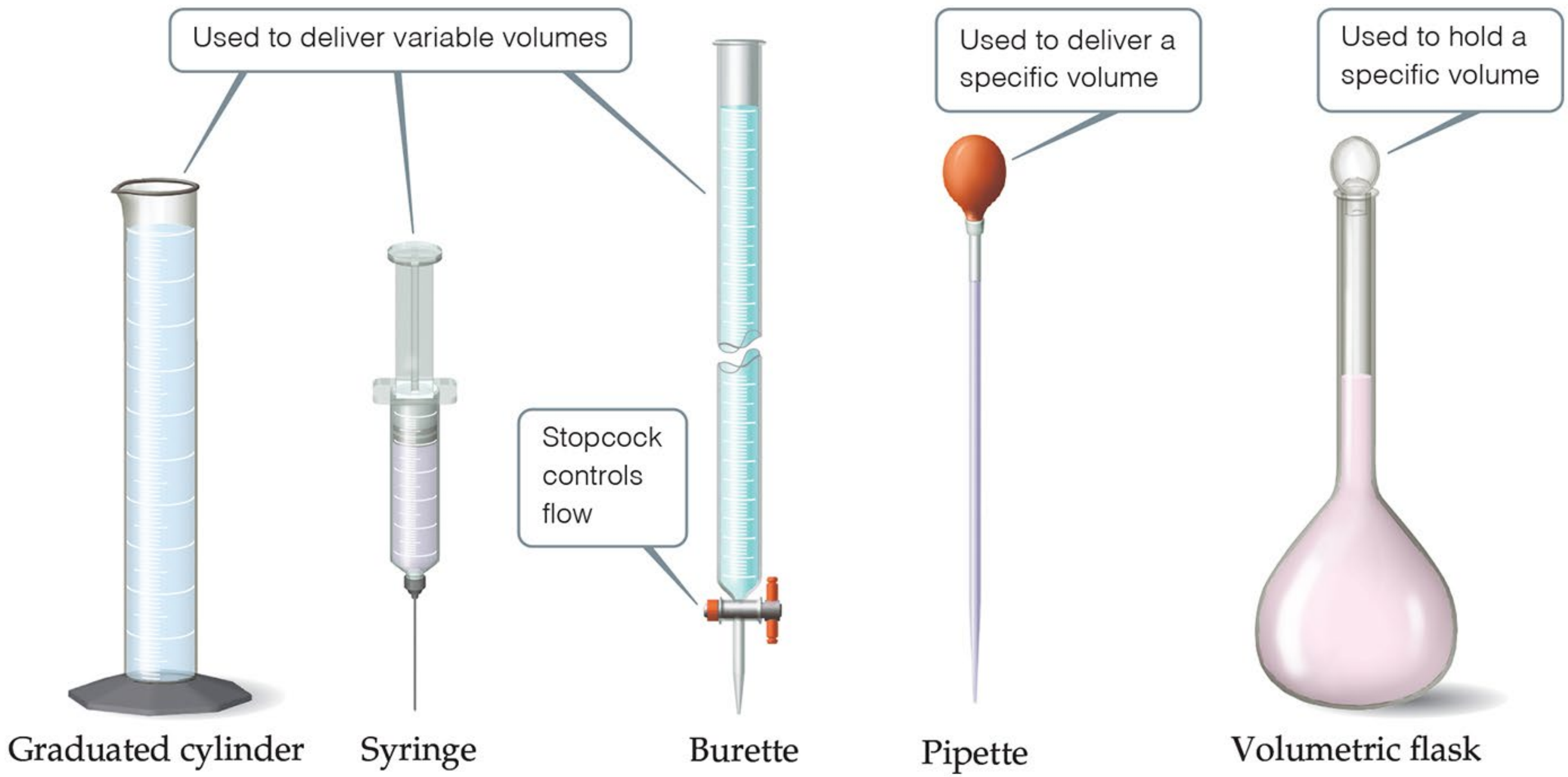
DIMENSIONAL ANALYSIS

Unit Conversions

Common SI Prefixes:

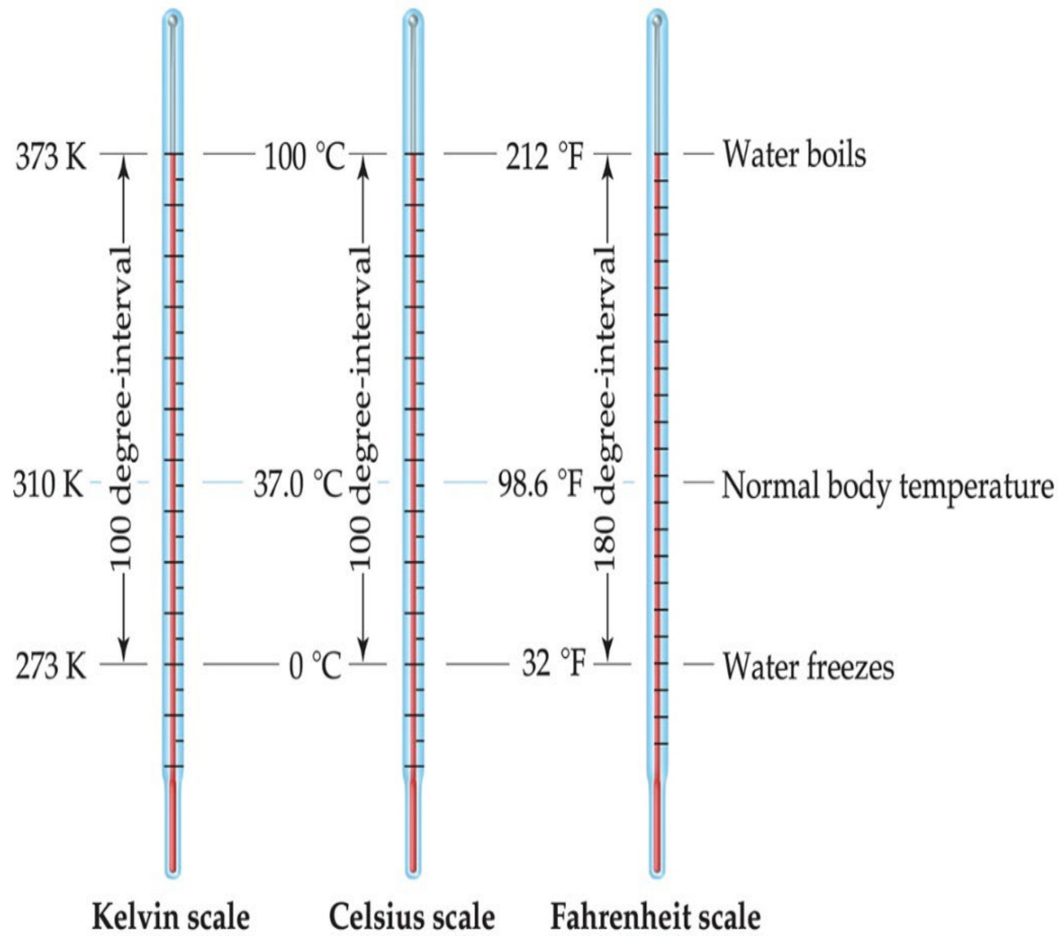
Factor	Prefix	Abbreviation
10^{6}	Mega	M
10^{3}	Kilo	k
10^{2}	Hecto	h
10^{1}	Deka	da
10^{-1}	Deci	d
10^{-2}	Centi	c
10^{-3}	Milli	m
10^{-6}	Micro	μ
10^{-9}	Nano	n
10^{-12}	Pico	p

Glassware for Measuring Volume



Temperature

- In general usage, **temperature** is considered the “hotness and coldness” of an object that determines the direction of heat flow.
- Heat flows spontaneously from an object with a higher temperature to an object with a lower temperature.



$T(K) = T(°C) + 273.15$ **$T(°F) = 1.8T(°C) + 32$**

$K = {}^{o}C + 273.15$

GROUP LECTURE QUIZ #2B

1. The melting point (freezing point) of mercury is -35^{o}C. What is the melting point temperature, in degrees Fahrenheit?

$$T(°F) = 1.8T(°C) + 32$$
$$= 1.8\,(-35) + 32 = -31F^{o}$$

2. Normal body temperature is 98.6^{o}F. What is this in Kelvin?

MEASUREMENTS LECTURE - METRIC

1. a) How many μm^3 are there in 1.25 mm^3? Express your answer in scientific notation.

$$1.25\ mm^3\left({}^{1m}/_{1000m}\right)^3\left({}^{10^6\ \mu m}/_{1m}\right)^3 = 1.25\ x10^9\ \mu m^3$$

b) How many liters is this?

$$1.25\ mm^3\left({}^{1m}/_{1000m}\right)^3\left({}^{100\ cm}/_{1m}\right)^3\ \left({}^{1mL}/_{1cm3}\right)\ \left({}^{1L}/_{1000mL}\right)$$

$$= 1.25\ x\ 10^{-6}\ L$$

LECTURE PROBLEMS- METRIC

1. The mass of a young student is found to be 67 kg. How many grams does this mass correspond to?

$$67\text{ kg}\left(\frac{1000\text{g}}{1\text{ kg}}\right) = 67000\text{ g} \quad \text{or} \quad 6.7 \times 10^4\text{ g}$$

2. How many liters is equivalent to 38.0 cubic meters?

$$38.0\text{ m}^3\left(\frac{100\text{ cm}}{1\text{ m}}\right)^3\left(\frac{1\text{ mL}}{1\text{cm}^3}\right)\left(\frac{1\text{ L}}{1000\text{ mL}}\right) = 3.80 \times 10^4\text{ L}$$

MEASUREMENTS

Since two different measuring systems exist, a scientist must be able to convert from one system to the other.

CONVERSIONS

Length:	1 in = 2.54 cm	1 mi = 1.61 km
Mass:	1 lb = 454 g	1 kg = 2.2 lb
Volume:	1 qt = 946 mL	1 L = 1.057 qt
	4 qt = 1 gal	1 mL = 1 cm^3
Temperature:	$°F = (1.8\ °C) + 32$	
	$°C = \dfrac{(°F - 32)}{1.8}$	$K = °C + 273.15$

MEASUREMENTS LECTURE - CONVERSIONS

1. In most countries, meat is sold in the market by the kilogram. Suppose the price of a certain cut of beef is 1600 pesos/kg, and the exchange rate is 124 pesos to the U.S. dollar. What is the cost of the meat in dollars per pound (lb)? ***(Note: 1 kg = 2.20 lb)***

KNOWN INFO:

1600 P/kg

124 P/$

1kg/2.20 lb

Cost? $/lb

1600P/kg (1$/124P) (1kg/2.20 lb) = $5.87/lb

or

$$\frac{1600\text{P}}{1\text{kg}} \times \frac{1\$}{124\text{P}} \times \frac{1\text{kg}}{2.20\text{ lb}} = \mathbf{\$5.87/lb}$$

MEASUREMENTS
In-Person LECTURE - CONVERSIONS

1. You are in Paris and would like to buy some peaches for lunch. The sign at the fruit stand indicates that peaches cost 2.45 euros/kg. If 1 euro is equivalent to $1.32, calculate the cost of one pound of peaches in dollars.

MEASUREMENT 101

2) Mercury poisoning is a debilitating disease that is often fatal. In the human body, mercury reacts with essential enzymes leading to irreversible inactivity of these enzymes. If the concentration of mercury, [Hg], in a polluted lake is 0.4 mg Hg/mL, what is the total mass, in grams, of mercury in the lake? The surface of the lake is 100 mi^2 and it has a depth of 20 ft.

HOME PRACTICE PROBLEMS

1. Convert 15.0 J to kcal 0.00359 kcal

2. Convert 15.0 mg to pounds 3.30×10^{-5} lb

3. Convert 15.0 ft^3 to cL 4.25×10^4 cL

4. How many liters of gasoline will be used to drive 725 miles in a car that averages 27.8 miles per gallon?

   98.7 L

5. Diamonds crystallize directly from rock melts rich in magnesium and saturated carbon dioxide gas that has been subjected to high pressures and temperatures exceeding 1677 K. Calculate this temperature in Fahrenheit.

   2559 ^{o}F

6. D.J. promised to bake 25 dozen cookies and deliver them to a bake sale. If each cookie weighs 3.5 ounces, how many kilograms will 25 dozen cookies weigh?

   30. kg

LEARNING EXCEL

- EXPERIMENT 1 IS LEARNING TO (1) MAKE CORRECT GRAPHS (2) LEARN EXCEL AND (3) READ/USE GRAPHED INFORMATION
- FIRST STEP IS COMPLETING THE DSM on GRAPHING in MASTERING CHEMISTRY & COMING TO LAB.

Chapter 1

Density

INTRODUCTION TO DENSITY

- Density is the measurement of the mass of an object per unit volume of that object.

$$d = m / V$$

- Density is usually measured in g/mL or g/cm^3 for solids or liquids.

- Volume may be measured in the lab using a graduated cylinder or calculated using:

  Volume = length x width x height if a box or

  $V = \pi r^2 h$ if a cylinder.

- Remember **1 mL = 1 cm^3** & $d_{(H_2O)} = 1\,{}^{g}/_{mL}$ at 4^{o}C

Two beakers are filled with different substances. One beaker is filled to the 100-mL mark with sugar (mass = 180.0g) and the other beaker is filled to the 100-mL mark with water (mass = 100.0 g). Next you pour the contents of both beakers into a single larger beaker and stir until all of the sugar dissolves.

1) **What is true about the mass of the final solution? Rationalize your answer**
   a) It is much greater than 280.0 g
   b) It is some what greater than 280.0 g
   c) It is exactly 280.0 g
   d) It is some what less than 280.0 g
   e) It is much less than 280.0 g

2) **What is true about the volume of the solution? Explain**
   a) It is much greater than 280.0 g
   b) It is some what greater than 280.0 g
   c) It is exactly 280.0 g
   d) It is some what less than 280.0 g
   e) It is much less than 280.0 g

A

GROUP QUIZ #3A on DENSITY

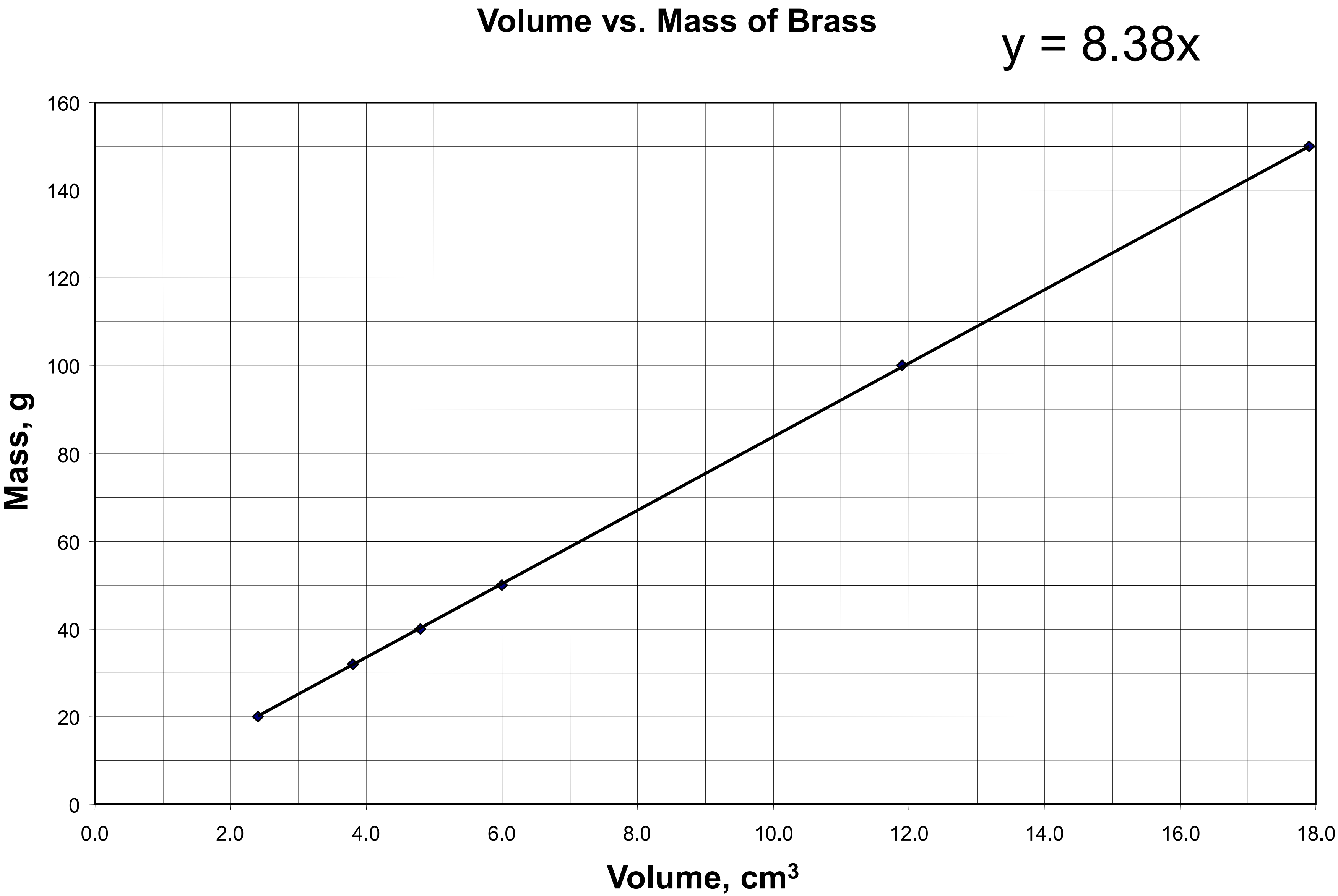
D1. For each of the following cases, state whether the density of the object increases (I), decreases (D), or remains the same (R).

a)_____________ A sample of chlorine gas is compressed.

b)___________ A lead weight is carried from sea level to the top of a high mountain.

c)____________ A sample of liquid water is frozen.

D2. Calculate the density of a box that is 750 mm long by 55 cm wide by 9 in high and weighs 24.33g. Will it sink or float in water? Justify your answer mathematically.


Volume vs. Mass of Brass
y = 8.38x
Mass, g
160
140
120
100
80
60
40
20
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Volume, cm³

DENSITY DETERMINATION

1. A student makes the following measurements in Lab then using excel, plots the data. DENSITY DETERMINATION

trials	Volume of unknown	Mass of unknwon
1	3.75 mL	8.1334 g
2	11.25 mL	24.4082 g
3	33.75 mL	73.2016 g

a) describe the axis's the student needs to create.

b) if the trend line in excel comes out as y = 2.1696x + 0.122, give the density of the object and comment on this data.

Relationship between measurements & graphing

2) A column of liquid unknown is found to expand linearly upon heating. If the column rises 5.25 cm for every 10.0 ^{o}F rise in temperature

a) Create an equation describing this trend.
b) If the initial temperature of the liquid was 98.6 ^{o}F, what will be its final temperature in ^{o}C if the liquid expands by 18.5 cm?

Density Problems

1) A 25.000 g insoluble solid sample is placed in a graduated cylinder and then the cylinder is filled full to the 50-mark with benzene. The mass of benzene and solid was 58.8054 g. If the density of benzene is 0.880 g/mL what is the density of the solid?

A

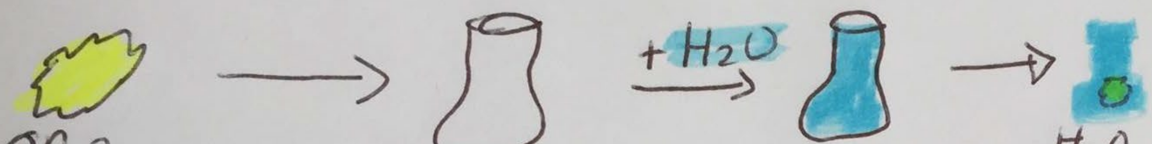
2) A cylindrical glass tube 15.00 cm in length is filled with Hg. The mass of Hg needed to fill the tube is 110.5025 g. Calculate the inner diameter, in cm, of the tube.

A

DENSITY DETERMINATION 3

3. What volume of acetone has the same mass as 10.0 mL of mercury? Take the densities of acetone and mercury to be 0.792 g/cm^3 and 13.56 g/cm^3, respectively.

DENSITY DETERMINATION



$d_{H_2O} = 0.997$ g/mL

$d_{ORE} = ?$

ORE 70.7g

flask $V_f = 53.2$ mL

H_2O + ORE 109.3g

① Set up the problem with visuals

② find correlations like H_2O + ore MASS and ore MASS

$$109.3\text{g} - 70.7\text{g} = 38.6\text{g mass of } H_2O$$

(* Keep excess digits)

③ $d_{H_2O} = \dfrac{m_{H_2O}}{V_{H_2O}}$ $\therefore$ $V_{H_2O} = \dfrac{m_{H_2O}}{d_{H_2O}} = \dfrac{38.6\text{g}}{0.997\text{g/mL}} = 38.716\text{mL } H_2O$

④ The flask has total volume of 53.2 mL but only 38.7 mL was water SO the ore is the rest of the volume.

$$53.2\text{mL} - 38.7\text{mL} = 14.484\text{ mL ore volume}$$

⑤ $d_{ORE} = \dfrac{m_{ore}}{V_{ore}} = \dfrac{70.7\text{g}}{14.484\text{mL}} = \boxed{4.88\text{ g/mL}}$ 3 sig fig

DENSITY in-class QUIZ #3B

1) A 15.00 g insoluble unknown solid was placed in a graduated cylinder then the cylinder was filled to the 50.00-mL mark with ethanol. The mass of the ethanol and solid combined was 51.78 g. In a separate graduated cylinder, 15.00 mL of ethanol was weighted. The mass of the graduated cylinder and ethanol was 109.7325 g and the mass of the graduated cylinder dry was 97.8975 g. Calculate the density of the unknown solid.

2) Sterling silver is an alloy (solid solution) of silver and copper. If a sterling silver necklace has a mass of 105.00 g and volume of 10.12 mL, calculate the mass percent of copper in the necklace.

PRACTICE PROBLEMS

A study of gemstones and dimensional analysis:

The basic unit for gemstones is the carat. One carat is equal to 200 milligrams. A well-cut diamond of one carat measures 0.25 inches exactly in diameter. Right click for answers

______ 1. The Star of India sapphire (Al_2O_3, corundum) weighs 563 carats. What is the weight of the gemstone in milligrams?

______ 2. The world's largest uncut diamond (C, an allotrope of carbon) was the Cullinan Diamond. It was discovered 1/25/1905 in Transvaal, South Africa. It weighed 3,106 carats. Calculate this weight in grams.

______ 3. The Cullinan Diamond was cut into nine major stones and 96 smaller brilliants. The total weight of the cut stones was 1063 carats, only 35% of the original weight! What weight (in kilograms) of the Cullinan Diamond was not turned into gemstones?

______ 4. Emerald is a variety of green beryl ($Be_3Al_2Si_6O_{18}$) that is colored by a trace of chromium, which replaces aluminum in the beryl structure. The largest cut emerald was found in Carnaiba, Brazil Aug. 1974. It weighs 86,136 carats. Assuming the diamond carat to size relationship stands for emeralds, calculate the approximate diameter of this stone in meters.

______ 5. The largest cut diamond, the Star of Africa, is a pear-shaped diamond weighing 530.2 carats. It is 2.12 in long, 4.4 cm wide, and 250 mm thick at its deepest point. What is the minimum volume (in liters) of a box that could be used to hide this diamond.

Home PRACTICE PROBLEMS

A study of gemstones and dimensional analysis:

The basic unit for gemstones is the carat. One carat is equal to 200 milligrams. A well-cut diamond of one carat measures 0.25 inches exactly in diameter. Right click for answers

1.13×10^5 mg 1. **The Star of India sapphire (Al_2O_3, corundum) weighs 563 carats. What is the weight of the gemstone in milligrams?**

621.2 g 2. **The world's largest uncut diamond (C, an allotrope of carbon) was the Cullinan Diamond. It was discovered 1/25/1905 in Transvaal, South Africa. It weighed 3,106 carats. Calculate this weight in grams.**

0.3948 kg 3. **The Cullinan Diamond was cut into nine major stones and 96 smaller brilliants. The total weight of the cut stones was 1063 carats, only 35% of the original weight! What weight (in kilograms) of the Cullinan Diamond was not turned into gemstones?**

0.54696 m 4. **Emerald is a variety of green beryl ($Be_3Al_2Si_6O_{18}$) that is colored by a trace of chromium, which replaces aluminum in the beryl structure. The largest cut emerald was found in Carnaiba, Brazil Aug. 1974. It weighs 86,136 carats. Assuming the diamond carat to size relationship stands for emeralds, calculate the approximate diameter of this stone in meters.**

0.59 L 5. **The largest cut diamond, the Star of Africa, is a pear-shaped diamond weighing 530.2 carats. It is 2.12 in long, 4.4 cm wide, and 250 mm thick at its deepest point. What is the minimum volume (in liters) of a box that could be used to hide this diamond.**

Chapter 1

Precision and Accuracy

Uncertainty in Measured Numbers

- uncertainty comes from limitations of the instruments used for comparison, the experimental design, the experimenter, and nature's random behavior
- to understand how reliable a measurement is we need to understand the limitations of the measurement
- **accuracy** is an indication of how close a measurement comes to the **actual** value of the quantity
- **precision** is an indication of how reproducible a measurement is

Precision

- imprecision in measurements is caused by **random errors**
  - ✓errors that result from random fluctuations
  - ✓no specific cause, therefore cannot be corrected
- we determine the precision of a set of measurements by evaluating how far they are from the actual value and each other
- even though every measurement has some random error, with enough measurements these errors should average out

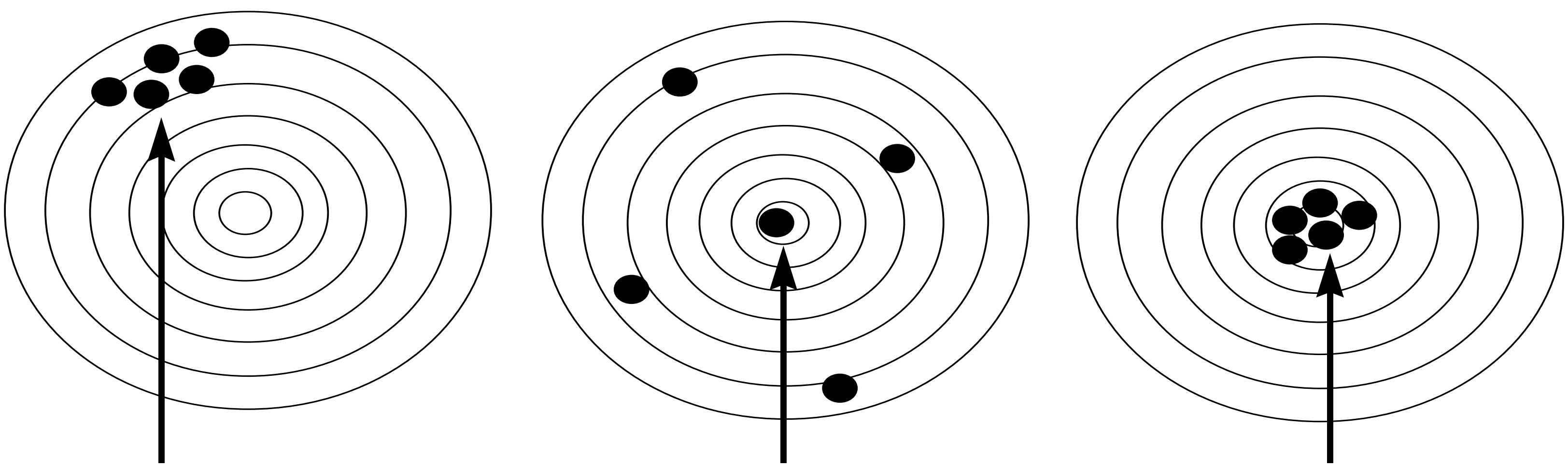
Accuracy

- inaccuracy in measurement caused by **systematic errors**
  - ✓errors caused by limitations in the instruments or techniques or experimental design
  - ✓can be reduced by using more accurate instruments, or better technique or experimental design
- we determine the accuracy of a measurement by evaluating how far it is from the actual value
- systematic errors do not average out with repeated measurements because they consistently cause the measurement to be either too high or too low

PRECISION AND ACCURACY

1. Precision – refers to the degree of reproducibility of a measured quantity.

2. Accuracy – refers to how close a measured value is to the accepted or true value.



Precise (not accurate) Accurate (not precise) Both Precise/Accurate

APPLICATION OF PRECISION & ACCURACY QUIZ #3C

1. An instructor gives a sample of powered metal to each of four students (W, X, Y, & Z), and they weigh the samples on different balances. Their results for three trials are as follows. The true value is 8.720 g.

Student	Trial 1	Trial 2	Trial 3	Average
W	8.72 g	8.7810g	8.6 g	________
X	8.50 g	8.48 g	8.511 g	________
Y	8.56 g	8.7770 g	8.830 g	________
Z	8.4100 g	8.720 g	8.550 g	________

a) Calculate the average mass for each data set with the correct significant figures.
b) Which student was the most accurate in weighing? ________
c) Which student was the most precise? ________
d) Which student had the best combination for accuracy and precision? ________

answer

Measurements in lab

The directions read: weight a clean dry empty 100-mL graduated cylinder then fill with dry sand up to the 10.0 mL mark. Use a 10-mL Mohr pipet to transfer 10.00 mL of methanol into the graduated cylinder. Mix thoroughly until no bubbles emerge. Re-weight the cylinder.

A

The following data was collected in lab:

$m_{cyl+wet\ sand} = 45.2613\ g$

$m_{cyl\ +\ dry\ sand} = 37.3488\ g$

$m_{cyl} = 22.8317\ g$

$V_{dry\ sand} = 10.0\ mL$

$V_{sand+methanol} = 17.6\ mL$

$V_{methanol} = 10.00\ mL$

Determine (a) the density of the dry sand, (b) density of methanol, and (c) density of wet sand, and (d) does the bubbling that occurred when methanol was added to the sand, indicate a chemical reaction between sand and methanol? Explain.

STANDARD DEVIATION

The **standard deviation** of a series of measurements which includes at least 6 independent trials may be defined as follows. If we let $\mathbf{x}_m$ be a measured value, **N** be the number of measurements, <**x**> be the average or **mean** of all the measurements, then **d** is the **deviation** of a value from the average:

$$\mathbf{d} = \mathbf{x}_m - \langle \mathbf{x} \rangle$$

and the standard deviation, **s**, is defined by:

$$s = \sqrt{\frac{\sum d^2}{(N - 1)}}$$

where $\Sigma \mathbf{d}^2$ means "sum of all the values of $\mathbf{d}^2$."

The **value of the measurement** should include some indication of the precision of the measurement. The standard deviation is used for this purpose if a large number of measurements of the same quantity is subject to random errors only. We can understand the meaning of **s** if we plot on the y-axis the number of times a given value of $\mathbf{x}_m$ is obtained, against the values, $\mathbf{x}_m$, on the x-axis. The "normal distribution curve" is bell-shaped, with the most frequent value being the average value, <**x**>.

STANDARD DEVIATION

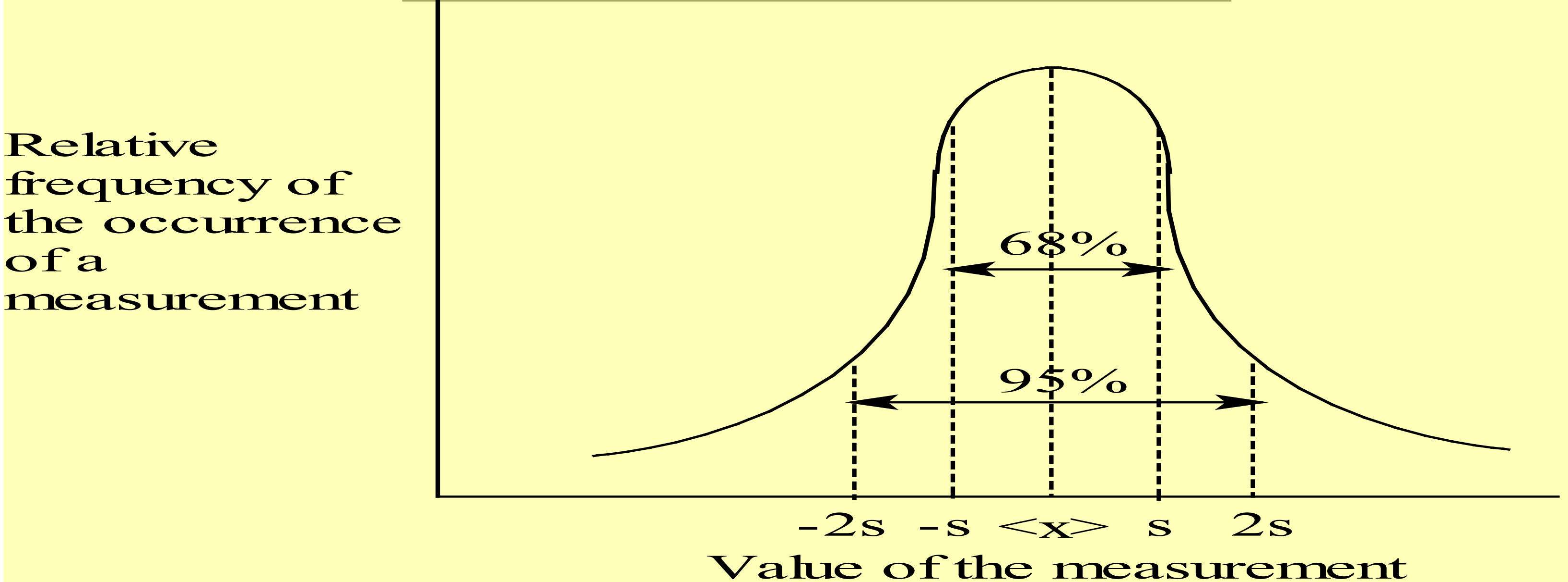


Figure 3: Distribution of Values of a Measurement

Most of the measurements give values near <**x**>. In fact, 68% of the measurements fall within the standard deviation **s** of <**x**> (see graph). 95% of the measured values are found within 2**s** of <**x**>. We call the value of 2**s** the uncertainty of the measurement, **u**. Then, if we report our value of the measurement as <**x**>± **u**, we are saying that <**x**> is the most probable value and 95% of the measured values fall within this <u>range</u>. The next example shows how the standard deviation can be used to evaluate the data.

STANDARD DEVIATION

Example 1. Weight of a test tube on 10 different balances

trial	weight	d =X_m - <X>	d^2
1	24.29	0.00	0.0000
2	24.26	-0.03	0.0009
3	24.17	-0.12	0.0144
4	24.31	0.02	0.0004
5	24.28	-0.01	0.0001
6	24.19	-0.10	0.0100
7	24.33	0.04	0.0016
8	24.50	0.21	0.0441
9	24.30	0.01	0.0001
10	24.23	-0.06	0.0036

$$< x > = 242.86/10 = 24.29 \text{ g and s} = \sqrt{(0.0752 / 9)} = 0.0917,$$

$$\text{range} = < x > \pm 2s = 24.29 \pm 0.18\, g$$

or, the test tube weighs between 24.11 and 24.47 g, with 95% certainty.

STANDARD DEVIATION ACTIVITY

Weight of a test tube on 10 different balances

trial	weight	d =X_m - <X>	d^2
1	24.29	0.00	0.0000
2	24.26	-0.03	0.0009
3	24.17	-0.12	0.0144
4	24.31	0.02	0.0004
5	24.28	-0.01	0.0001
6	24.19	-0.10	0.0100
7	24.33	0.04	0.0016
8	24.50	0.21	0.0441
9	24.30	0.01	0.0001
10	24.23	-0.06	0.0036

ACTIVITY: If each of the values of x_m are checked against the range, note that the weight from balance 8 is outside the range; it should be discarded as unreliable therefore, Using excel, recalculate <x>, d, d^2 and s. Email your excel file to me.