Chemistry & STEM Measurement I

Measurement, Conversions & Calculations

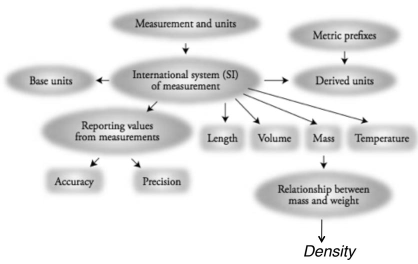
Dr. Ron Rusay

CHEM 108 Basic Measurements: for stuff that you can see or sense

- LENGTH, WIDTH, HEIGHT, (DIAMETER)
- TIME
- VOLUME (occupied space)
- TEMPERATURE
- MASS (weight)

- Qualitative vs. Quantitative
  - Eg. Qualitative: Old (sloth dung) vs. Young (you?)
  - Quantitative: 38,000 year old (dung) vs. a 20 year old (you?)

Units of Measure

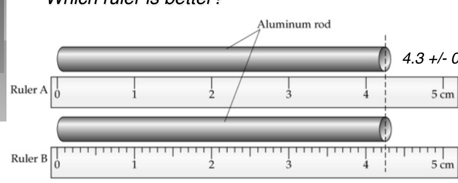


Units of Measure

Base Units	***U.S.***	***SI***	***Chemistry***
Mass (weight)	Pound (lb)	Kilogram (kg)	"Gram" (**g**, mg)
Volume	Gallon (gal)	Liter (L)	"Liter" (**mL**, L)
Temperature	Fahrenheit (^oF)	Kelvin (K)	K & Celsius (^oC)
Length	Mile (mi), Feet(ft), Inches (in)	Meter (m)	"Meter" (**cm**, mm, nm)
Time		Second (s)	Second (s)
			Mole (mol)

What is the length of the rod?

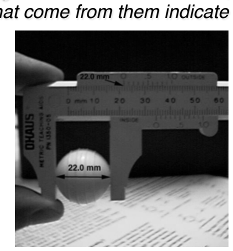
Different measurement tools give different numbers: Which ruler is better?



4.25 +/- 0.01 cm
or
4.25 +/- 0.05 cm

What is the diameter of a circle?

All measuring devices are not the same, and the values (numbers) that come from them indicate their limitations.

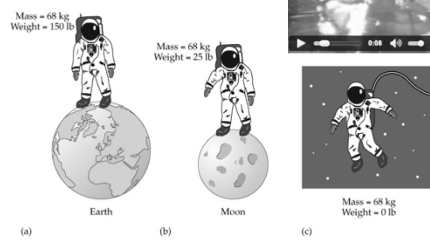


Is there a better instrument to use other than a ruler to measure the diameter of the sphere?

A caliper

Mass Determination
(Weighing Devices: Balances)

Mass vs. Weight
British vs. Metric



Dimensional Analysis
Conversion/Unit Factor Calculations

44.7 cm	?	? in
information given	× conversion factor(s) =	information sought

$$\text{given unit} \times \frac{\text{desired unit}}{\text{given unit}} = \text{desired unit}$$

$$\frac{2.54\ \text{cm}}{1\ \text{in.}} = 1 = \frac{1\ \text{in.}}{2.54\ \text{cm}}$$

$$44.7\ \text{cm} \times \frac{1\ \text{in.}}{2.54\ \text{cm}} = 17.6\ \text{in.}$$

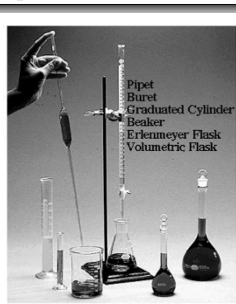
Dimensional Analysis
Conversion/Unit Factor Calculations

- *Qualitative Description: Are you heavy, slim, average? vs. Quantitative?.....The weight on your driver's license? birth certificate?*
- *Calculate your weight in kilograms. Scale Factor UNITS: 1 kg = 2.2 lb; 1 lb = 16 ounces (oz); 1 ounce (oz) = 0.0283495 kg*

___?___ lbs ___?___ ounces ⟶ ? kg

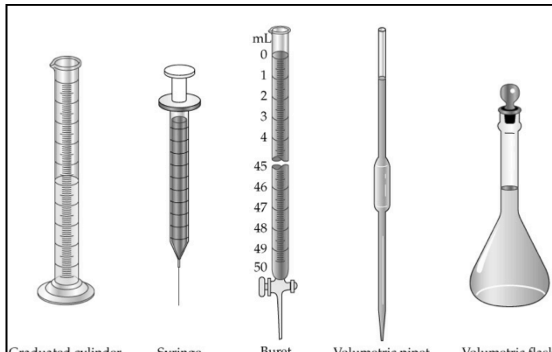
$$?\ \text{lbs} \times \frac{16\ \text{oz}}{1\ \text{lbs}} \times \frac{0.0283\ \text{kg}}{1\ \text{oz}} + ?\ \text{oz} \times \frac{0.0283\ \text{kg}}{1\ \text{oz}} = ?\ \text{kg}$$

Volume
(Liquid Measurement Tools)

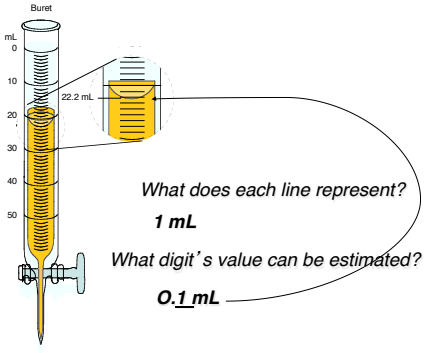


(CHEM 108) METRIC UNITS: milliliter

mL
m = milli
L = liter



Volume UNITS: milliliter / mL / m = milli L = liter

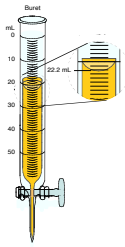


What does each line represent?

1 mL

What digit's value can be estimated?

O.1 mL



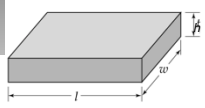
What can be estimated?

O.1 mL

22.2 mL

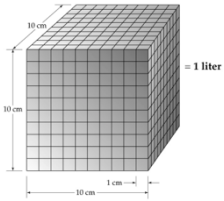
The tenths decimal (last) place is estimated & "significant"; Therefore, there are a total of 3 significant digits.)

Volumes of regular shapes

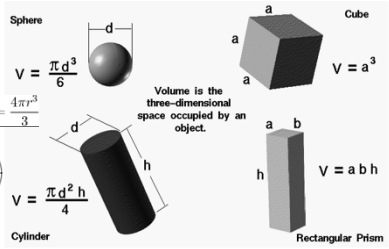


$V = l \times w \times h$

$V = s^3$



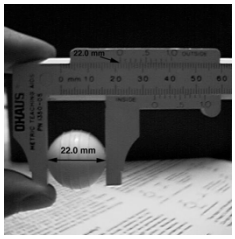
Volumes of regular shapes



$V = \pi r^2 h$

Euclid ~300 B.C.E.

What is the volume the sphere?

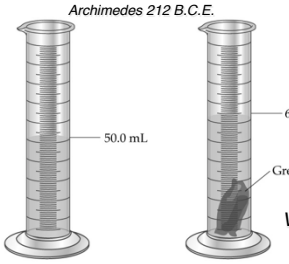


$$V = \frac{4\pi r^3}{3}$$

V = 4/3 x 3.14 x (11.0 mm)³
= 5,570 mm³

Volume of an object (any shape) by displacement

Archimedes 212 B.C.E.

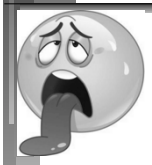


V = 60.5 mL – 50.0 ml
=10.5 mL
= 10.5 cm³

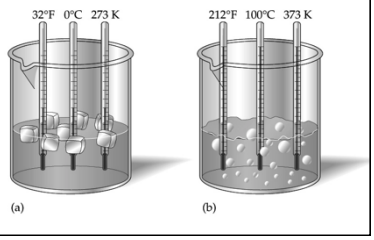
What is the volume of the jade?

UNITS: Celsius (°C) & Kelvin (K)

Temperature is NOT Energy



***"Temperature** (sometimes called thermodynamic **temperature**) is a measure of the average kinetic energy of the particles in a system. Adding heat to a system causes its **temperature** to rise."*

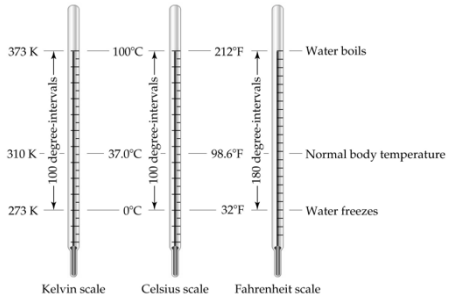


August. 15, 2015
+142°F Manama, Bahrain

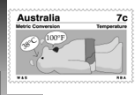
°C? = 61.7°C
K? = 61.7°C +273.15
= 334.85 K

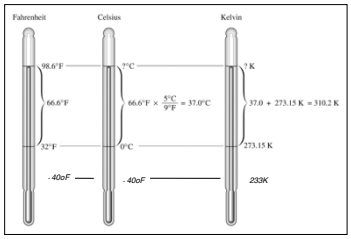
Temperature Scales

Relative to Water



"Normal" Body Temperature



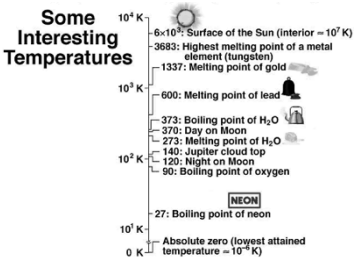


QUESTION

Dr. R. walks into class and claims, "It is very cold in here today. It feels like 242 K." If that were the temperature, would you agree that you would feel cold? What would that be in Celsius degrees?

A. I agree, that would be 31°C.
B. I agree, that would be – 31°C.
C. I do not agree, that would be 31°C.
D. I do not agree, that would be 515°C.

Temperature



QUESTION

Identify the best match between the dimension or quantity and the unit that is most likely to be measured in Chem 108 lab.

	Dimension or Quantity	*Unit*
A)	***Mass***	***Kilogram***
B)	***Length***	***Meter***
C)	***Volume***	***Milliliter***
D)	***Temperature***	***Fahrenheit***
E)	***Amount of substance***	***Megamole***

Commonly Used Prefixes in Chemistry

Metric Prefixes

Prefix	Symbol	Multiple/Fraction
giga-	G	$1{,}000{,}000{,}000 = 1 \times 10^{9}$
mega-	M	$1{,}000{,}000 = 1 \times 10^{6}$
kilo-	k	$1{,}000 = 1 \times 10^{3}$
Basic unit: meter, gram, liter, second		
deci-	d	$0.1 = 1 \times 10^{-1}$
centi-	c	$0.01 = 1 \times 10^{-2}$
milli-	m	$0.001 = 1 \times 10^{-3}$
micro-	μ*	$0.000\,001 = 1 \times 10^{-6}$
nano-	n	$0.000\,000\,001 = 1 \times 10^{-9}$

QUESTION

Select the correct relationship between these metric units of length or distance.

A) 1 km = 100 m ***B) 1 mm = 10 cm***

C) 1 nm = 10^{9} m ***D) 10^{3} mm = 1 m***

QUESTION

Coincidentally, a U.S. nickel has a mass of approximately 5 grams. If you had one dollar's worth of nickels in your jean's what would be the mass of the nickels in milligrams?

A. 100 milligrams
B. 50 milligrams
C. 1,000 milligrams
D. 100,000 milligrams

1000 milligrams (mg) = 1 gram (g)

Science, 317, 765-775, (2007)
"The Electron Stopwatch"

QUESTION

An array of multilayer mirrors compresses ultrabroadband laser pulses (orange beam). The attosecond x-ray pulses allow the real-time observation of atomic-scale electron motion. The previous spectroscopic method was on a femtosecond scale, which was too slow to capture the movement.

How many times faster is attosecond spectroscopy compared to femtosecond methods?

A. 10x B. 100x C. 1,000x D. 1,000,000x

Science, 317, 765-775, (2007)
"The Electron Stopwatch"

QUESTION

How many times faster is attosecond spectroscopy compared to femtosecond methods?

Table: SI prefixes

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

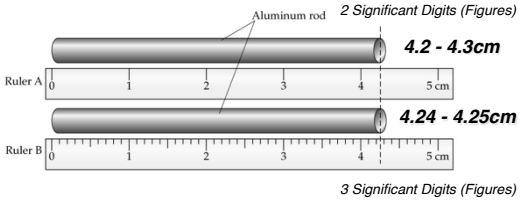
A. 10x B. 100x C. 1,000x D. 1,000,000x

Numbers

- ***Expressing a number correctly is determined by the method used in the measurement!***
- *How many numbers should I include?*
  Significant Digits (Figures)
  Consider: the exactness of the ***measured*** *value*
- *Short Hand expression translates the number to* ***Scientific Notation***

What is the length of the rod?

Different measurement tools give different numbers: Which ruler is better?



Reporting Numbers
Rules for Significant Digits (Figures)

- Nonzero integers always count as significant figures.
  - 3456 g has how many sig figs?
    - 4 sig figs.
  - Expressed in scientific notation?

3.456×10^{3} g

Reporting Numbers
Rules for Significant (Digits) Figures

- Exact numbers (unit, conversion or scale factors) can have an infinite number of significant figures.
  - 1 liter = 1,000. ml, exactly
  - 1 inch = 2.54 cm, exactly

Zeros

- Leading zeros do not count as significant figures.
  - 0.0486 mL has how many sig figs?
    - 3 sig figs.
  - Number expressed in scientific notation? 4.86×10^{-2} mL

Zeros

- Captive zeros always count as significant figures.
  - 16.<u>0</u>7 cm has how many sig figs?
    - 4 sig figs.
  - Number expressed in scientific notation? 1.607×10^{1} cm

Zeros

- Trailing zeros are significant only if the number contains a decimal point.
  - 9.300 kg has how many sig figs?
    - 4 sig figs.
  - Number expressed in scientific notation? 9.300 kg

QUESTION

In which of these measured values are the zeros not significant figures?

I) 0.0591 cm
II) 504 g
III) 2.70 m
IV) 5300 L

A) I and II ***B) II and III*** ***C) I and IV***

D) I, III, and IV ***E) II, III, and IV***

QUESTION

Which one of the following does NOT represent four significant digits?

A. 0.07100 mg
B. 0.7100 mg
C. 0.7010 mg
D. 0.0710 mg

Mathematics & Arithmetic

- *Relative to method(s) of measurement*
- *Short Hand expression: Scientific Notation*
- *Numbers : How many to include?*
  Quantitative vs. Qualitative
- *Addition/Subtraction.....*
- *Multiplication/Division.....*
- *What is "significant"?.....Rounding Off*
- *http://www.chemteam.info/SigFigs/SigFigsFable.html*

Computational Rules

- *Addition/Subtraction: Answer expressed to the least number of decimal places of the figures in the process*
- *Multiplication/Division: Answer expressed to the least number of significant figures*

Computational Rules

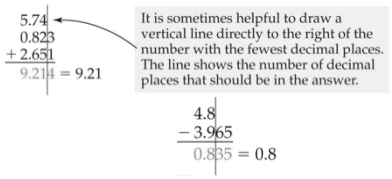
Rules for Rounding Off:

- When numbers are used in a calculation, the result is rounded to reflect the significant figures of the *data*.
- For calculations involving multiple steps, only the final answer is only rounded—*NO rounding between steps*.
  This prevents small rounding errors being magnified in the final answer.
- *Use only the last (or leftmost) digit being dropped to decide how to round—ignore all digits to the right of it.*
- *The last number to be reported remains the same if the neighboring digit to be dropped is 4 or less; rounded up if the neighboring digit is 5 or more.*

Computational Rules

Addition and Subtraction Rule:

In addition or subtraction, the reported result has the same number of decimal places as the number with the fewest decimal places.



Addition

- *Four students were each asked to measure different pieces of wire and provide a total length for the four pieces.*
- *Report the result correctly:*

	0.05	cm
	12.01	cm
	1.9	cm
+	2.386	cm
	~~16.346~~	cm

QUESTION

If you were unloading a 23.50 kg box of books from your car and a "friend" added two more 482 gram chemistry books, how much in kg using the rules for significant digits, would you be lifting?

A. 23.98 kg
B. 24.464 kg
C. 24.46 kg
D. 24.5 kg

Computational Rules

Multiplication and Division Rule:

The result of multiplication or division carries the same number of significant figures as the factor with the fewest significant figures.

$$5.02 \times 89.665 \times 0.10 = 45.0118 = 45$$
(3 sig. figures) (5 sig. figures) (2 sig. figures) (2 sig. figures)

$$5.892 \div 6.10 = 0.96590 = 0.966$$
(4 sig. figures) (3 sig. figures) (3 sig. figures)

Computational Rules

In calculations involving both multiplication/division and addition/subtraction, do any steps in parentheses first; determine the correct number of significant figures in the intermediate answer without rounding; then do the remaining steps.

3.489 cm × (5.67 cm – 2.3 cm) = ?

5.67 cm – 2.3 cm = 3.37 cm

Use the subtraction rule to determine that the intermediate answer has only one significant decimal place. Do not round; underline the least significant figure as a reminder.

3.489 cm × 3.37 cm = 11.758 cm^2= 12 cm^2

Use the multiplication rule to determine that the intermediate answer (11.758) rounds to two significant figures (12) because it is limited by the two significant figures in 3.37.

Mathematical Processes:

- *Provide correct answers assuming each value (unit omitted) is written with the correct number of significant figures:*

$$\frac{12.01 \times 1.90}{2.386} = \sout{9.56370}$$

$$\frac{12.01 \times 1.90}{2.386} + 0.05 = \sout{9.61370}$$

QUESTION

The average mass of a certain brand of vitamin C tablets is 253 mg. What is the mass of three such tablets rounded to the proper number of significant digits?

A. 0.760 grams
B. 0.759 grams
C. 0.7590 grams
D. 0.253 grams

Systematic Problem Solving

Dimensional/Unit Analysis: Conversions

Workshop

How many mL of milk are in a1/2 gallon carton?

0.50 gal → *? mL*

1 gal = 4 qt → *1 qt = 946 mL*

$$\frac{0.50\ \text{gal} \mid 4\ \text{qt} \mid 946\ \text{mL}}{\mid 1\ \text{gal} \mid 1\ \text{qt}} = ?\ \text{mL}$$

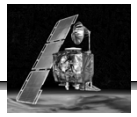
Complete the following

Units & Conversions

Number	*Scientific Notation*	*Named unit*
13,000,000,000 yrs.	*1.3 x 10^{10} yrs*	*? gigayears* / *13 Gyrs*
546 mL	*5.46 X 10^{2}* mL	*0.546 Liters* / *0.546 L*
0.845 kg	*8.45 x 10^{-1} kg*	*? grams* / *845 g*

QUESTION

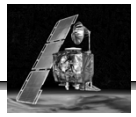
General Chemistry Level Challenge



In 1999, NASA lost the $125 million Mars Climate Orbiter, when it mistakenly was sent to come within 37 miles from Mars' surface, which took it far into the Martian atmosphere where friction caused it to burn and break apart. The failed plan had been to place it in an orbit 142 miles above Mars where the atmosphere is thinner.

QUESTION

General Chemistry Level Challenge



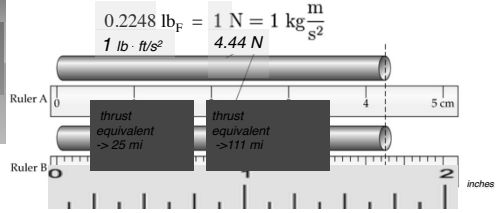
- *The problem was caused by a navigation error from different calculations & communications between two computer programs, one using English units for force (pounds of force), and the other using metric units (Newtons), which are numerically more than 4 times larger than the pound of force unit.*

Comparing Distances (length)

Different measurement units give different numbers:

$$0.2248\ \text{lb}_\text{F} = 1\ \text{N} = 1\ \text{kg}\frac{\text{m}}{\text{s}^2}$$

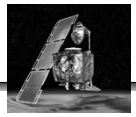
1 lb · ft/s² *4.44 N*



…..navigating thrust and distance for the Mars Climate Orbiter

QUESTION

General Chemistry Level Challenge



- *One NASA program specified navigation of the Climate Orbiter to a distance of 7.55 × 10^{5} ft from the surface, while the second program using this value as a unitless number calculated thrust in Newtons that took it to 5.95 × 10^{4} m*
- *What is the difference in kilometers between the two altitudes?*

Numbers & Measurement

Units & Conversions

Crash Course: Hank & John Green
Unit Conversion & Significant Figures:
https://www.youtube.com/watch?v=hQpQ0hxVNTg&list=PL8dPuuaLjXtPHzzYuWy6fYEaX9mQQ8oGr&index=2 11:23 min/sec

Calculations / Computations

Fastest computer (2001):12 TeraFLOPS/second)

TI-Graphing
6 Ghz
Cost ≈ $100
(2001 dollars)

Tera- = 10 [12] (trillion)

Cost = ~$ 30,000,000 (2001 dollars)

http://www.llnl.gov/asci-scrapbook/

World's fastest computers (2017)

https://www.youtube.com/watch?v=KEdsrT1mFAU

Peta- = 10 [15] (quadrillion); 1,000 trillion

Sunway TaihuLight (93 PetaFLOPS), China
Tianhe-2, aka Milky Way (33.9 PetaFLOPS), China
Estimated Costs: >$100 million (2016 dollars)

Floating Point Operations (FLOPS)

Equivalent to adding one plus one

- When told to begin, count 1+1.
- Keep repeating the counting of 1+1 and keep track of how many times that you have repeated 1+1.
- Stop when told to, note your total.

https://www.youtube.com/watch?v=DsXXjMhHMVg

Floating Point Operations

FLOPS

•There about 60 of us here. The estimated processing power/min for our group is:_____. The median for our group is:_____ (*Average vs. Median?*)

•This is equal to how many FLOPS (FLoating point OPerations/ sec.)? _____

•How many people would be needed to produce 1 petaFLOP (i.e. adding 1+1 one quadrillion [1 x 10^{15}] times)? _____

• In 2018, the estimated population of the U.S. is 327 million people, the world population estimated at 7.3 billion. How many of these respective U.S. populations and world populations are needed to do the work of the world's fastest computer (93 petaFLOPS) ?

•U.S. _____ World_____

(93 x 10^{15} FLOPs / 327 x 10^{6} persons) x 1 person / 1 FLOP = / 7.3 x 10^{9} persons

General Chemistry Level Challenge

Measurements: Scaling/ Problem Solving

Powers of Ten (Exponents: 10^{x})

- *Scaling: U.S. Population in 2003 vs. 2018*
  - *1 birth every 12 seconds (2003) vs. 8 seconds (2018)*
  - *1 death every 20 seconds (2003) vs. 10 seconds in (2018)*
  - *1 new immigrant every 21 s (2003) vs. 29 s (1/2018)*
- *Considering the data, what is the net effect on the U.S. population in 2018…. Is it growing or declining? ….. faster or slower than 2003? … by what percent vs. 2003?*
- *The U.S. census population was 321,442,019 on July 4, 2015. Calculate what it is today considering the data.*
- *KEY: How many seconds from July 4, 2015 to February 1, 2018?*