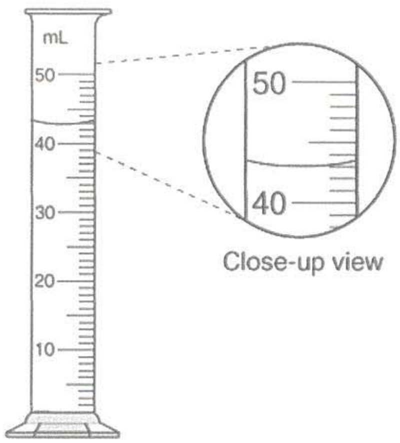
Jigsaw Station 2: Sig Fig Review!

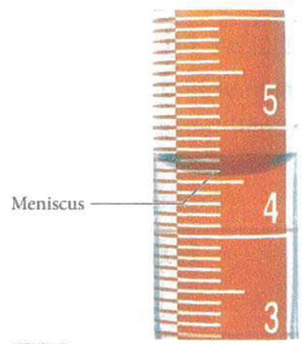
Significant Figures (otherwise and forever known as Sig figs) in a measurement consist of all the digits known with certainty plus one final digit, which is estimated.

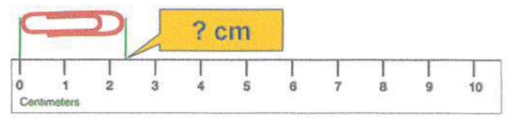
> **Rule of Thumb:** Always measure to the place value measured by the markings on your instrument (e.g. ruler, graduated cylinder) **PLUS ONE MORE.**

Let's Practice! Using correct significant figures, what is the measurement that is represented in each picture?

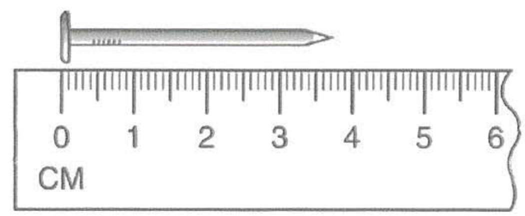


Graduated cylinder





3. Markings? ones place
Measurement? 2.3 cm



1. Markings? ones place
Measurement? 43.0 mL

2. Markings? tenths place
Measurement? 4.59 mL

4. Markings? tenths place
Measurement? 3.75 cm

Rules for Significant Figures

1. Non-zero digits and zeros between non-zero digits (sandwich) are always significant.
   Examples: 102 → 3 sig fig(s), 1.73005 → 6 sig fig(s)
2. Leading zeros are not significant. (left)
   Examples: 0.37 → 2 sig fig(s), 0.0001 → 1 sig fig(s)
3. (trailing zeros) Zeros to the right of all non-zero digits are only significant if a decimal point is shown.
   Examples: 100 → 1 sig fig(s), 100. → 3 sig fig(s), 0.0100 → 3 sig fig(s)
4. For values written in scientific notation, the digits in the coefficients are significant.
   Examples: 5×10^4 → 1 sig fig(s), 1.30×10^{-13} → 3 sig fig(s)
5. Counting numbers (one kitten, two kittens) and conversion factors (6.022×10^{23} atoms/1 mol) are considered exact value and have an infinite number of sig figs!
   Examples: 3 cats → ∞ sig fig(s), 1 student → ∞ sig fig(s)

Now You Try! Fun with Tasty Sig Figs.

Number	How many Sig Figs?	Number	How many Sig Figs?
3.0800 mL	5	55 puppies	∞
0.00418 g	3	1,800. m	4
0.00000040 L	2	1,800 m	2
3 people	∞	2.998 x 10^8 m/sec	∞ or 4 (↑ universal constant! ☺)

Rules for Sig Fig Calculations (Hint: *Alpha order!*)

1. **Adding/subtracting**: round to least precise place value (A → P) *Awesome People*
2. **Multiplying/dividing**: round to least precise total number (M → T) *Memorization Technique* ☺
3. Note: **do not round any of the numbers you are given until the very end** after you have plugged them into your equations in their full, precise glory!

Let's Try!

Example #1

  2.348
  0.07
+ 2.9975
= 5.4155 → **5.42**

Example #2

  5.9
− 0.261
= 5.639 → **5.6**

Example #3

  1,010
  2.9
− 0.76
= 1,006.34 → **1,010** ☺

Example #4: 1.052 (4) x 12.504 (5) x 0.53 (2) = 6.9717... = **7.0**

Example #5: 2.0035 (5) ÷ 3.20 (3) = 0.62609... = **0.626**

Example #6: 6.78 (3) x 5.903 (4) x (5.489 − 4.99) [0.499 (2)] = 19.97... = **20.**

More Tasty Calculations Practice!

	Calculator Answer	Rounded Answer (with Correct # of Sig Figs)
1. 170 + 3.5 − 28	138.5	140
2. 47.0 ÷ 2.2	21.36...	21
3. 691,300 ÷ (5.022 − 4.31) [0.712]	970,926.9	970,000
4. (0.054 + 1.33) × 5.4 [1.384]	7.4736	7.5

Jigsaw Station 3: Atomic Structure and Types of Matter

Coulomb's Law: fundamental relationship between electrostatic attraction and repulsion.

- It applies to charged particles, magnets, gravitation, etc.
- In chemistry, we are most interested in the energy of attraction or repulsion between Subatomic particles

p^+, n°, e^-

$$E \propto \frac{Q_1 Q_2}{r}$$

E= energy of attraction or repulsion between particles
Q_1 = charge of first particle
Q_2 = charge of second particle
r = distance between charged particles

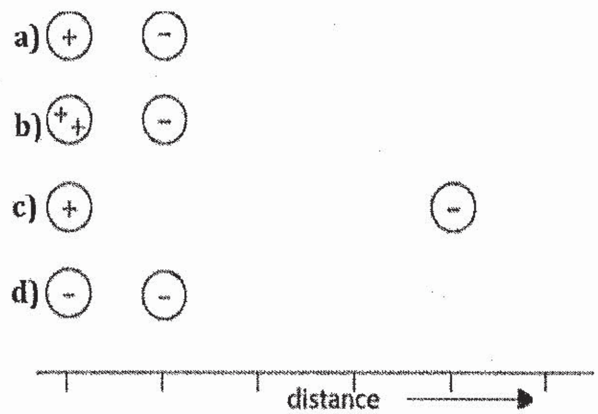
In short:

- Energy of attraction/repulsion ↑ as the magnitudes (sizes) of the charges ↑
- Energy of attraction/repulsion ↓ as the distance between the charges ↑

Thought question: Will an electron be more attracted to the nucleus of a hydrogen atom or a helium atom, and why?

Helium! He has 2 p^+ while H has only 1 p^+, and ↑ + charge means a negative e^- will be more attracted.

Examples:



1. Consider the particles in the diagram to the right.
   a. Compare the particles shown in (a) and (b). Which pair is more attracted to each other and why?

   (b), b/c ↑ + charge (and same − charge)

   b. Compare the particles shown in (a) and (c). Which pair is more attracted to each other and why?

   (a), b/c they're closer together

   c. Compare the particles shown in (a) and (d). Which pair is more attracted to each other and why?

   (a), b/c the particles in (d) repulse each other (like charges)

2. An electron would be most attracted to a nucleus containing which of the following?
   a. 7 protons, 5 neutrons
   (b.) 8 protons, 5 neutrons ← n° irrelevant
   c. 5 protons, 5 neutrons
   d. 7 protons, 8 neutrons

Atomic Theory

- Matter is anything that has mass and takes up space.
- All matter is made up of atoms.

Structure of the Atom

- The atom can be divided into two regions: the nucleus and the e^- cloud.
  1. The nucleus is a very small region near the center of an atom that is positively charged.
  2. The e^- cloud is a very large region that surrounds the nucleus and is negatively charged. It consists mostly of empty space.
- The atom is composed of three subatomic particles

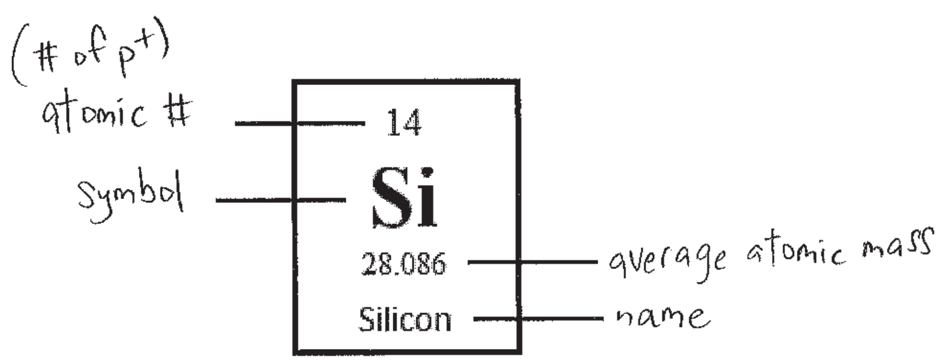
The Three Subatomic Particles

Particle	Symbol	Location	Charge	Mass (amu)
proton	p^+	nucleus	+1	1 amu
neutron	n^0	nucleus	Ø	1 amu
electron	e^-	e^- cloud	−1	~Ø

- The unit of mass for atomic particles is the atomic mass unit (amu)
  - 1 amu = one-twelfth the mass of a carbon atom containing six protons and six neutrons.

Understanding the Periodic Table

- **Atomic Number:** the **number** that tells you the identity of the element; number of protons
- **Average Atomic Mass:** average mass of all of the element's isotopes
  - To find the mass of a SPECIFIC (isotope) atom, you must add up the protons + neutrons
- **Symbol:** shortened element name; starts with a capital letter
- **Name:** the identity of an atom (not a proper noun = not capitalized in sentences! ☺)



Isotopes

- What are **isotopes?** Atoms of the Same element, but different mass
- This means the number of protons is the same, and the number of neutrons is different.

→Mass of an isotope = # protons + # neutrons ←

Two ways to write isotopes:

Type	**hyphen-notation**		**isotope notation/ nuclide symbol**	
Definition	name-mass		$^{\text{mass \#}}_{\text{atomic \#}}\text{Symbol}$	
Example	carbon-12	vs	$^{12}_{6}C$	
More examples	carbon-14		$^{14}_{6}C$	$^{235}_{92}U$
	uranium-235			

Examples: Consider the following sets of isotopes and then explain the similarities and differences between *each* set.

Set I

$^{12}_{6}C$ $^{13}_{6}C$

Similarities:

- Same # p^+, e^-
- same element

Differences:

- diff. # of n°
- different mass

Set II

$^{24}_{12}Mg$ ~~$^{26}_{12}Mg$~~ $^{24}_{11}Na$

Similarities:

- Same mass
- Same # particles in the nucleus ($p^+ + n^\circ$)

Differences:

- diff. # of p^+
- diff element

Practice: Complete the following table using your knowledge of atomic structure.

Element	Hyphen notation	Atomic Number	Number of Protons	Number of Neutrons	Number of Electrons	Mass Number
$^{1}_{1}H$	hydrogen-1	1	1	Ø	1	1
$^{35}_{17}Cl$	chlorine-35	17	17	18	17	35
$^{60}_{27}Co$	cobalt-60	27	27	33	27	

Types of Matter

Matter: anything that occupies space and has mass. We classify matter according to its **composition** (the basic components that make it up).

Matter

Can it be physically separated? NO! → Pure substances; YES! → Mixtures

Pure substances

- Same/fixed composition
- **Must be separated chemically** (bonds broken)
- Examples: O_2, Ti, H_2O

Mixtures

- Formed when two or more substances (s, l, g, aq) are **physically** combined
- All substances in mixture retain their own chemical properties
- Can be separated physical means, such as:

Pure substances

Separate into simpler substances? NO! → Elements; YES! → Compounds

Elements

- Cannot be broken down and still maintain identity
- One type of atom (basic building blocks)
- Found on the periodic table

Compounds

- Chemical combination of 2 or more elements in **fixed definite proportions**
- **Cannot** be separated by physical means
- Properties of compound are different than individual elements

Mixtures

Uniform throughout? NO! → Heterogeneous; YES! → Homogeneous

Heterogeneous

- Parts of the mixtures are NOT evenly distributed (poorly mixed)
  - Does not look the same throughout
- Examples:
  granite, chocolate chip cookies

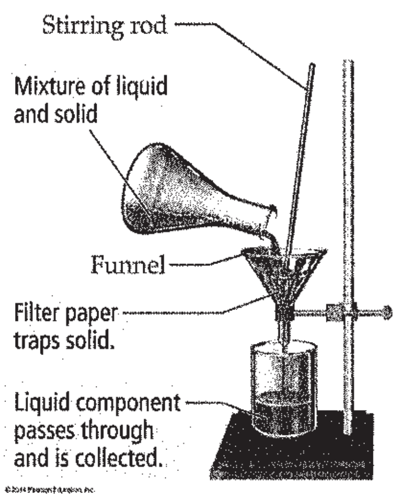
Homogeneous

- Parts of the mixtures are evenly distributed (evenly mixed)
- Is also called a Solution
  - Substance doing the dissolving is called the **solvent** (ex: H_2O in salt water)
  - The substance being dissolved is the **solute** (ex: salt in salt water)
- Examples:
  air, milk, alloys (steel, brass)

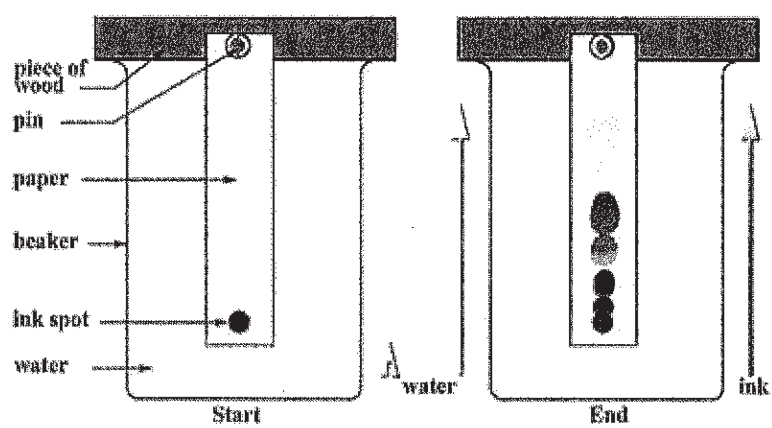
Methods for Separating a Mixture: Both heterogeneous and homogeneous mixtures can be separated by physical means into the component parts that make up the mixture.

1. A solid and liquid mixture can be separated by pouring the mixture through a filter paper designed to allow only the liquid to pass.
2. A homogeneous mixture of liquids can be separated using distillation, a process in which the mixture is heated and the more volatile (more easily vaporized) liquid is boiled off first. A condenser is then used to recollect the vaporized component.
3. Paper chromatography takes advantage of the fact that different components of a homogeneous mixture have different attractions to a solvent and paper.

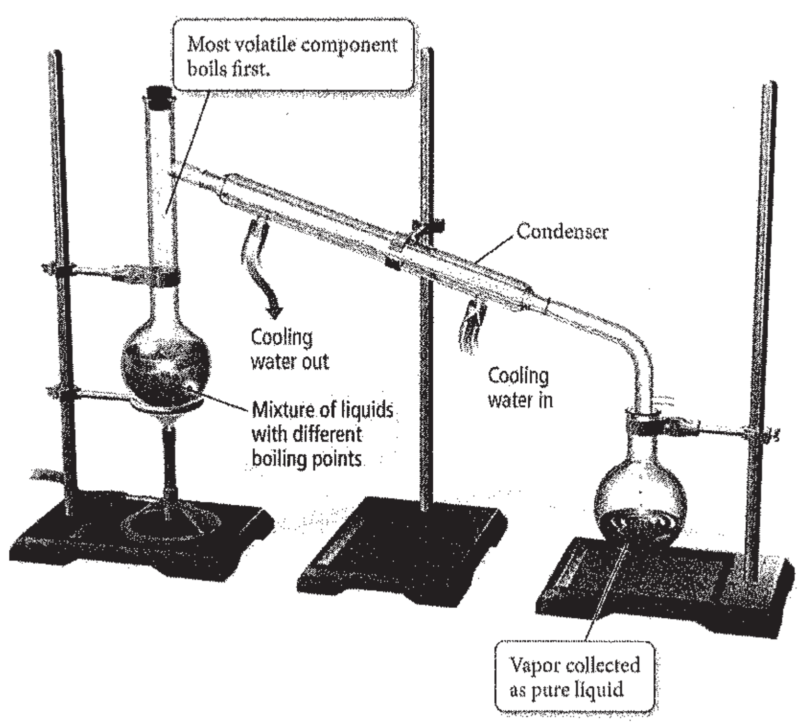
Filtration



Simple chromatography



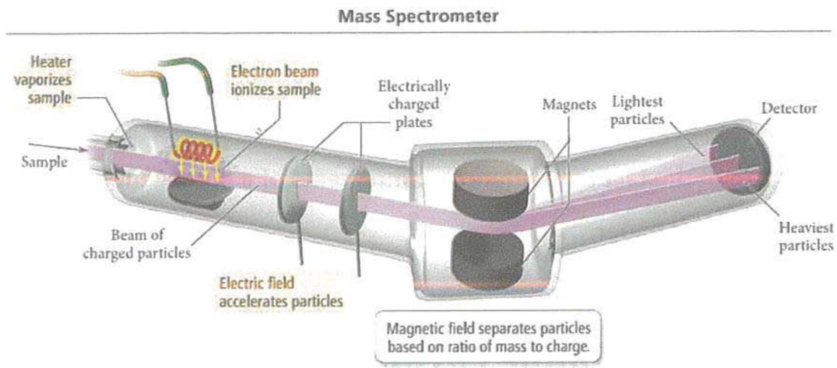
Distillation

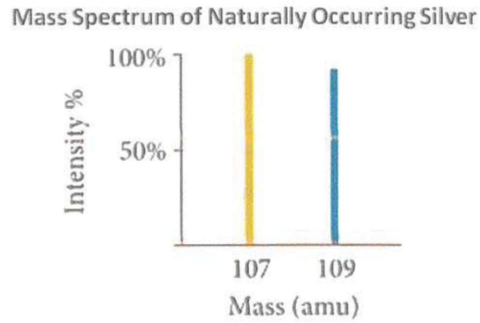


Jigsaw Station 4: Average Atomic Mass and Mass Spec

Mass Spectroscopy

The masses of elements and their percent abundances of isotopes of elements are measured using mass **spectrometry**: a technique that separates particles according to their mass, producing a mass Spectrum.





a. The position (location) of each peak on the x-axis indicates the mass of the isotope.

b. The intensity (indicated by the height of the peak) indicates the relative abundance (how common that isotope is in nature).

Average Atomic Mass: the weighted average mass of an element's isotopes and is the mass found on the periodic table.

not on F.C.! $$Average\ atomic\ mass = mass_1\left(\frac{\%\ Abundance}{100}\right) + mass_2\left(\frac{\%\ Abundance}{100}\right) + \cdots$$

- The average atomic mass will be between the mass of the largest and the mass of the smallest isotope.
- The average atomic mass will generally be closest to the most abundant isotope.
- Note: It is important to understand that the masses of a proton and neutron are ***approximately*** 1 amu, but the actual mass of each isotope is NOT a whole number (mmm, nuclear binding energy). When specific, non-whole number masses are provided for each isotope, use the specific masses!

Guided Practice: Delicious average atomic mass practice.

1. Silicon has three, stable, naturally occurring isotopes. These are silicon-28, silicon-29, and silicon-30. The relative abundance of each is 92.21%, 4.70%, and 3.09% respectively.
   a. ESTIMATE the value of the answer before you begin. Will the weighted average be closer to 28, 29, or 30? Why?

   The weighted average (i.e. average atomic mass) will be closest to 28, b/c silicon-28 has the largest % abundance.

   b. What is the average atomic mass of silicon?

   $aam = 28(0.9221) + 29(0.0470) + 30(0.0309)$

   $= 25.8188 + 1.363 + 0.927$

   $= 28.1088 = \boxed{28.11\ amu}$

2. Calculate the average atomic mass of magnesium using the following data for three, stable magnesium isotopes.

Isotope	mass (amu)	relative abundance
Mg-24	23.985	78.70%
Mg-25	24.986	10.13%
Mg-26	25.983	11.17%

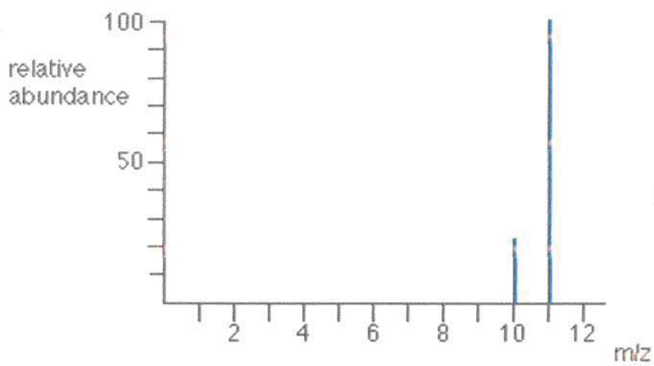
aam = 23.985(0.7870) + 24.986(0.1013) + 25.983(0.1117)
= 18.8762 + 2.5310818 + 2.9023
= 24.3095 = 24.31 amu

3. The average atomic mass of copper is 63.546 amu. Cu-63 has 69.17% abundance and 62.940 amu. What is the mass of the second isotope of copper?

100% − 69.17 = 30.83%

63.546 = 62.940(0.6917) + x(0.3083)
= 43.5356 + 0.3083x
20.0104 = 0.3083x ⇒ x = 20.0104 / 0.3083 = 64.91 amu

4. Given the mass spectrum and data for boron below, estimate the average atomic mass of boron.



Isotope	Peak Intensity
boron–10	23%
boron–11	100.%

aam = $10\left(\frac{23}{123}\right) + 11\left(\frac{100.}{123}\right)$
= 10(0.18699) + 11(0.81301)
= 1.8699 + 8.9431
= 10.813... = 10.8 amu

5. Europium has two stable isotopes: ^{151}Eu with a mass of 150.9196 amu and ^{153}Eu with a mass of 152.9209 amu. If elemental Europium is found to have a mass of 151.96 amu, calculate the percent of each of the two isotopes. (Hint: Use a system of equations. ☺)

151.96 = 150.9196(x) + 152.9209(y) and x + y = 100% ⇒ y = 100% − x = 1 − x
= 150.9196x + 152.9209(1−x)
= 150.9196x + 152.9209 − 152.9209x

−0.9609 = −2.0013x

x = −0.9609 / −2.0013 = 0.48 = 48%

⇒ % Ab(^{151}Eu) = 48%
% Ab(^{153}Eu) = 52%