Chapter 1+2: Matter, Atoms, Ions, and Periodic Table

August 30, 2022

Chemistry Department, Cypress College

Class Announcements

- Delayed homework assignment 1
- File submissions - merge all into one file (preferred)
- Office Hour: M 11:30am - 12:30pm in Science, Engineering, and Mathematics (SEM) building in Room 150
- First canvas quiz this Friday at 11am due next Tues at 11:59pm

Lecture Weekly Agenda

- Cover Ch 1 - pg 1 – 55
- Go over Ch 2 - pg 56 – 88
- In-class Ch 1+2 worksheet

One More Time: Sig Figs

Perform the calculation and write the appropriate number of significant figures

$$\frac{1.0 \times 10^{-2}\text{g} - 1.2 \times 10^{-3}\text{g}}{1.579 \times 10^{-1}\text{cm}}$$

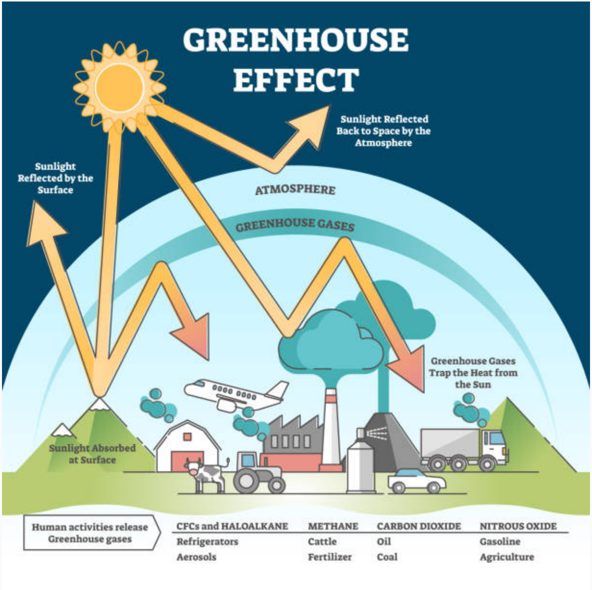
One More Time: Unit Conversion

Convert the following.

- 2.9 nm to dam
- 3 hHz to mHz

Outline

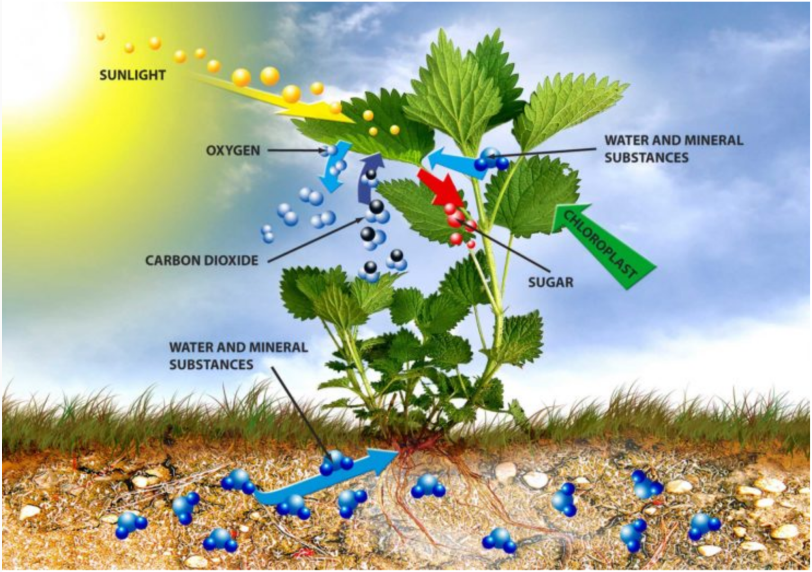
Chemistry Connection: Climate Change



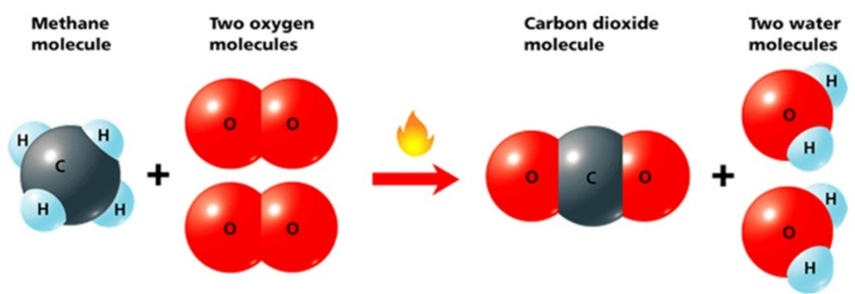
Conservation of Mass

Any system closed to all transfers of matter and energy, the mass of the system must remain constant over time

Photosynthesis: Converting H_2O and CO_2 into Sugar



Combustion Reaction



Classification: Composition of Matter

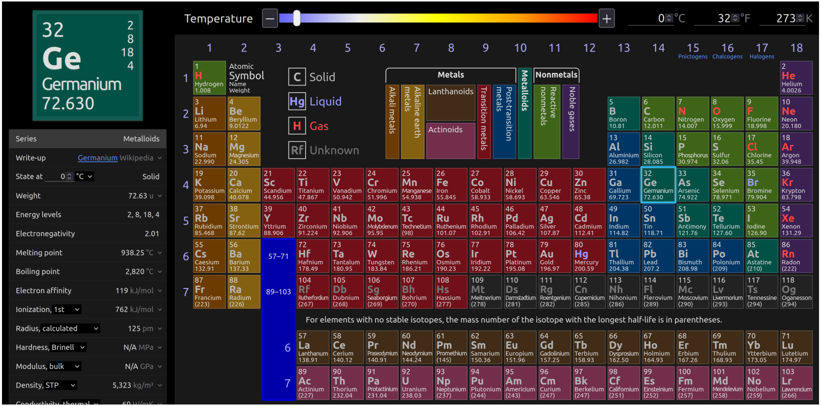
Pure substance - cannot be separated into components

Mixture - consists at least 2 pure substances mixed together

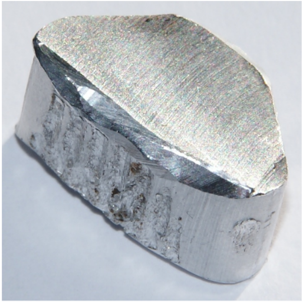
Classification: Composition of Matter

Pure substance - cannot be separated into components

Checkout the preiodic table (ptable)

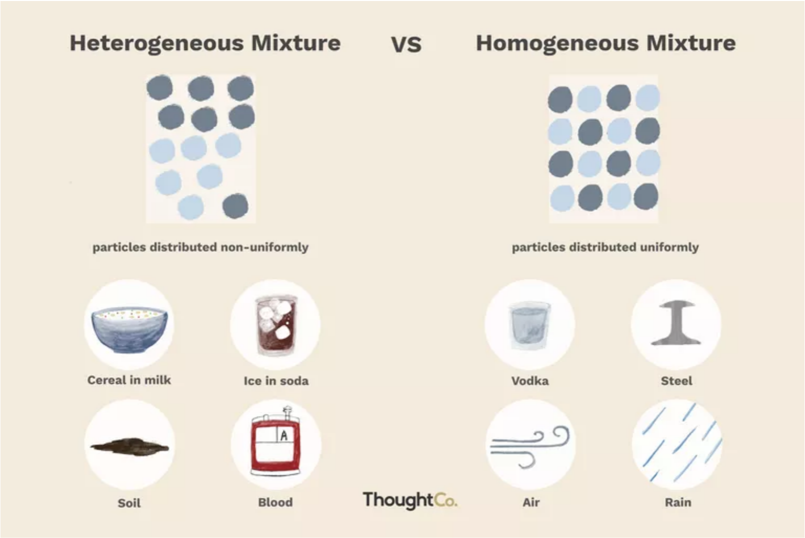


Examples of Pure Substances

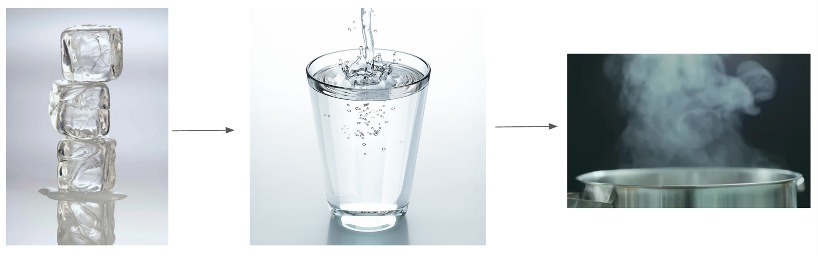


Is water a pure substance?

Types of Mixtures



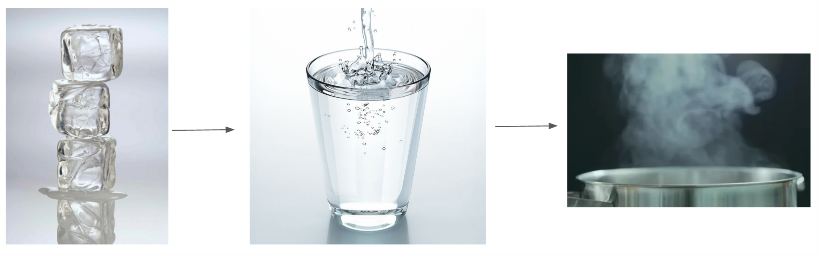
States of Matter: Water



- Solid has the smallest volume whereas gas occupies the largest space
- Water molecules have the most energy in which state?
- Notation for states - $H_2O(s)$, $H_2O(l)$, $H_2O(g)$
- **Aqueous state** - substance dissolved in water e.g. $NaCl(aq)$

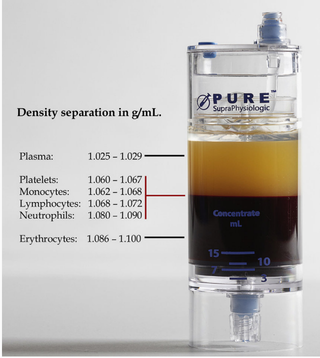
Physical Properties

A characteristic that can be observed or measured without changing the composition of a substance



Quantifying Physical Properties

- Mass - quantifies matter; measuring in grams
- Volume - amount of space occupied; measuring in L
- Density - ratio of mass and volume



- Temperature - quantifies the intensity of heat in a substance or object

Chemical Properties

A characteristic of a particular subtance that can be observed in a chemical reaction e.g. combustion

Practice: Classify the following as chemical or physical changes

1. Melting solid gold into liquid gold
2. Combining copper and tin to form bronze (an alloy)
3. Electrolysis of water (H_2O) into hydrogen (H_2) gas and oxygen (O_2) gas
4. Filtering algae from water

Potential vs Kinetic Energy

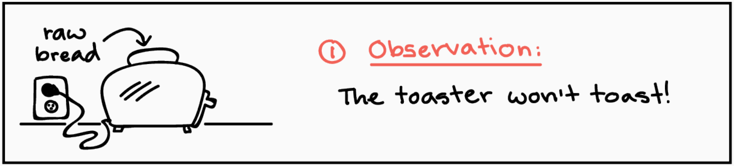
Potential Energy - Stored energy; elastic, chemical, and gravitational

Kinetic Energy - Involves motion

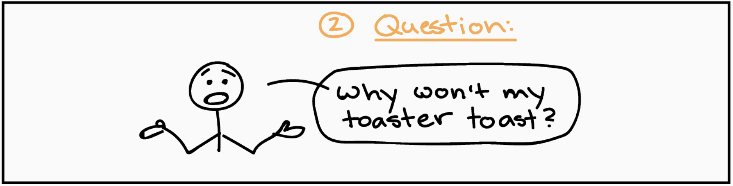
Research Uses Scientific Method

1. Gather observations
2. Ask a question. Propose a hypothesis which is a supposed explanation of a given phenomenon
3. Design and perform your experiment
4. If results support the hypothesis, then propose a theory, which explains the observation. If not, then revise the hypothesis.

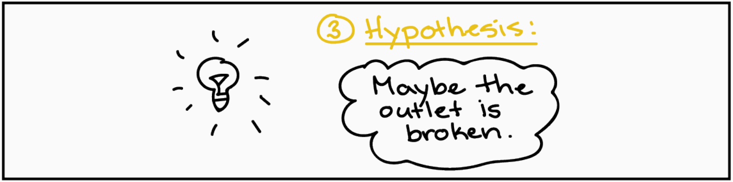
Everyday Life Example: Failure to Toast



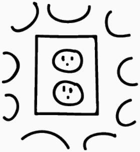
Hypothesis - Ask the Question



Propose Hypothesis



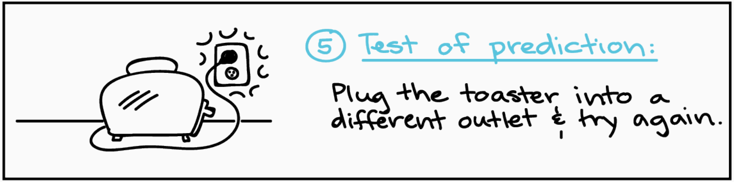
Make a Prediction



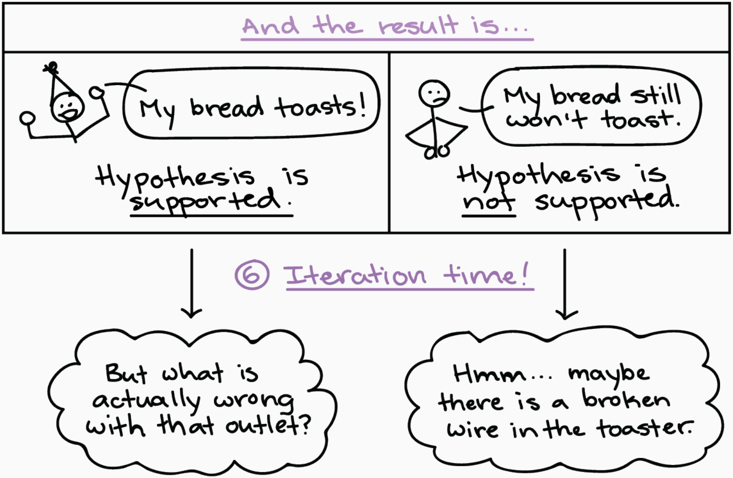
④ Prediction:

If I plug the toaster into a different outlet, then it will toast the bread.

Test the Prediction



Check the Results



Outline

Recall: Conservation of Mass

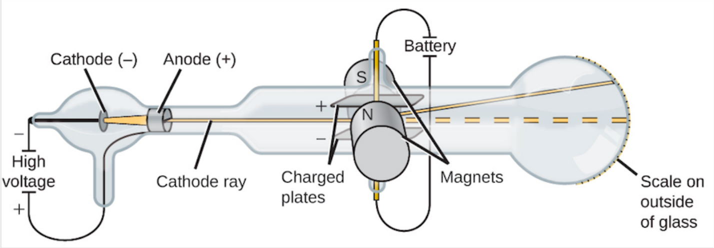
Any system closed to all transfers of matter and energy, the mass of the system must remain constant over time

Dalton's Atomic Theory

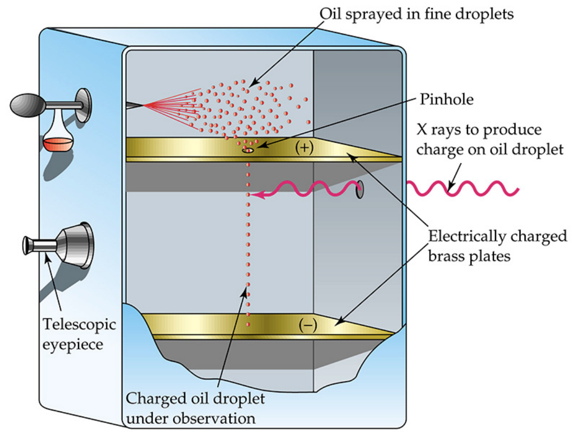
1. Elements consist of indivisible small particles (atoms)
2. All atoms of the same element are identical and different elements have different types of atom
3. Atoms can neither be created nor destroyed
4. Compounds are formed when atoms of different elements join in simple ratios

Existence of the Electron

- J.J. Thompson Cathode-ray experiment led to discovering of the electron

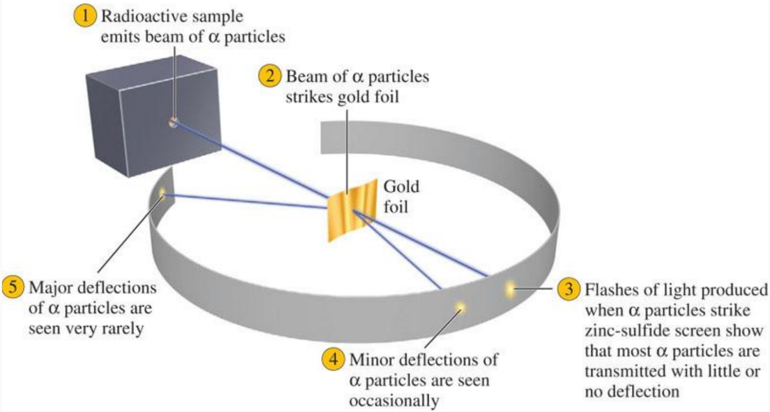


Millikan's Oil-Drop Experiment



- Experiment determined the charge of an electron to be -1.6022×10^{-19} Coulomb (C) and the mass to be 9.1094×10^{-28} g

J.J. Thompson's Plum Pudding Model



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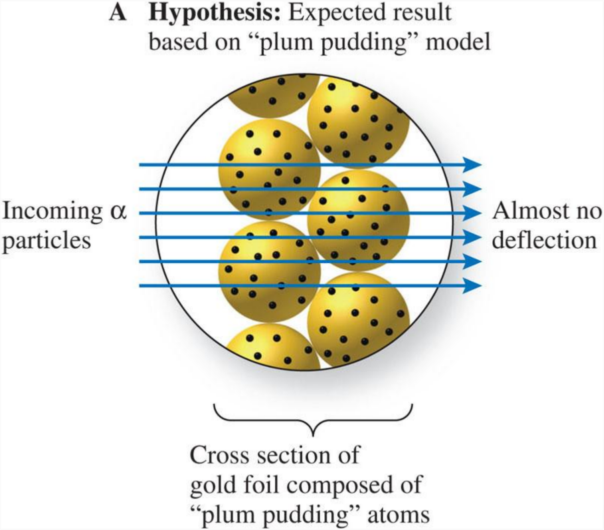

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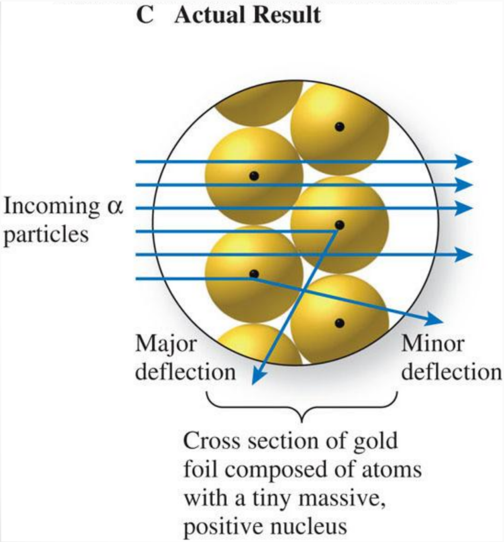


Existance of the Nucleus

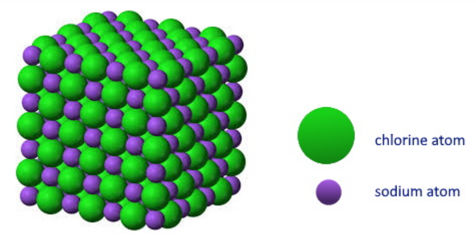
- Plum pudding model is not valid
- Nuclear model is developed where the diameter of the nucleus is $\sim 10^{-14}$ m and the diameter of the atom is $\sim 10^{-10}$ m
- **Question:** If an atom is made of mostly space, why can't we walk through anything?

What are atoms made of?

	Mass (g)	Atomic Units (Amu)	Charge (C)
Neutron	1.675×10^{-24}	1	0
Proton	1.675×10^{-24}	1	1.6022×10^{-19}
Electron	9.1094×10^{-28}	$1/1840$	-1.6022×10^{-19}

- 1 amu $= 1.6606 \times 10^{-24}$ g
- Protons and neutrons are located in the nucleus
- Electrons revolve around the nucleus (difference between core electrons and valence electrons)

What are ions?



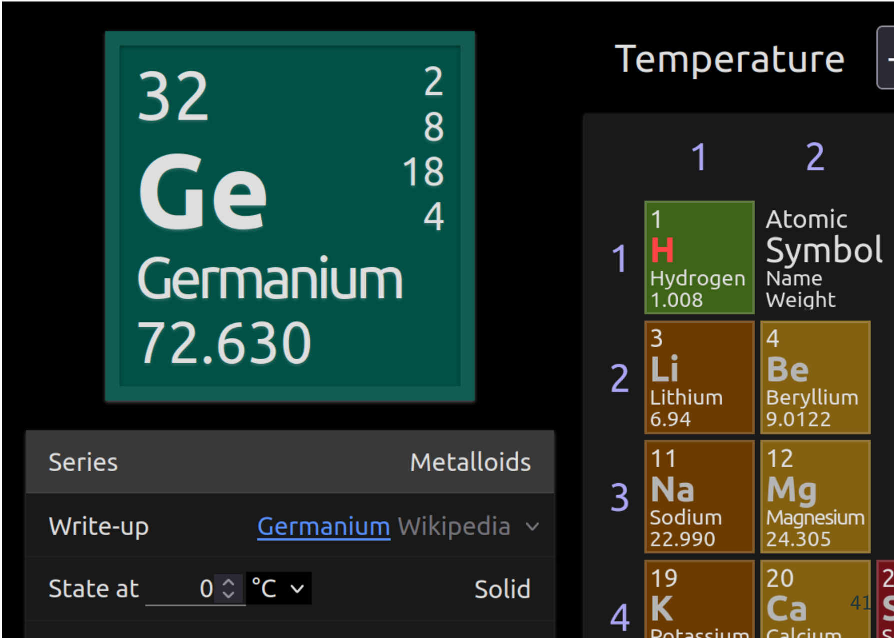
- When an atom loses (cation) or gains (anion) an electron

Defining Atomic Number and Mass

$$ {}^{A}_{Z}X^{C} \tag{1} $$

where A is the atomic mass, Z is the atomic number, X is atomic symbol, and C is the overall charge

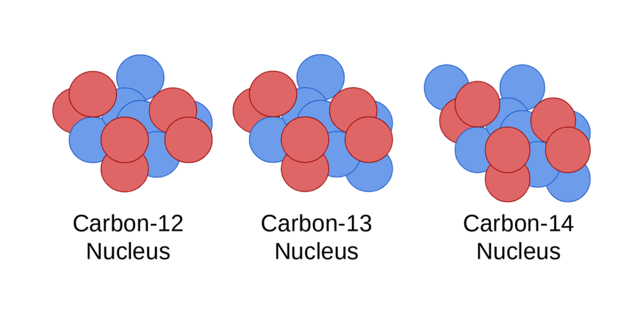
Reminder: Periodic Table



Practice: Write the Nuclear Symbol

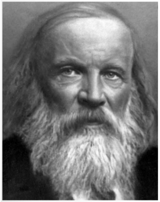
- Ge - atomic mass: 72
- He - atomic mass: 2
- Ge^{3+} - atomic mass: 72
- Br^{-} - atomic mass: 79
- S^{2-} - atomic mass: 32

Isotopes: Revisiting the Neutron



where red is the proton and blue is the neutron

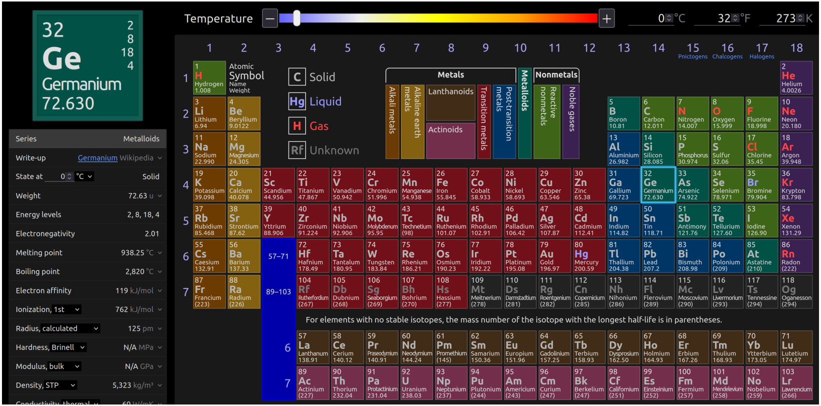
- Same number of protons (Z)
- Different number of neutrons leading to a different atomic mass (A)
- **Practice:** Write the Nuclear Symbol for C-12, C-13, and C-14



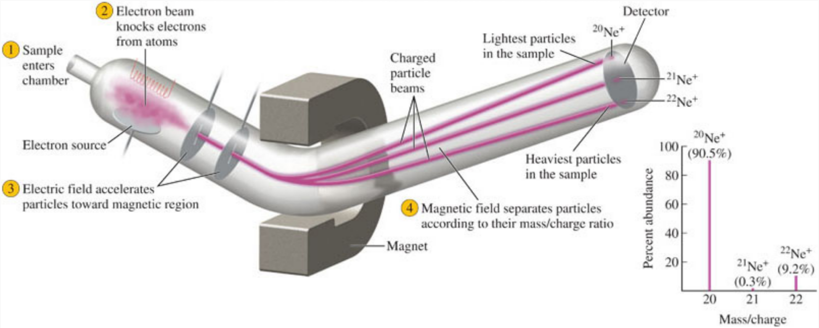
			Ti = 50	Zr = 90	? = 180
			V = 51	Nb = 94	Ta = 182
			Cr = 52	Mo = 96	W = 186
			Mn = 55	Rh = 104,4	Pt = 197,4
			Fe = 56	Ru = 104,4	Ir = 198
			Ni = Co = 59	Pd = 106,6	Os = 199
H = 1			Cu = 63,4	Ag = 108	Hg = 200
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,5	Br = 80	J = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Ti = 204
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,6	Th = 118?		

- Dmitrij Mendeleev Arranged base on atomic mass
- Grouped known elements into rows and columns

Modern Period Table



Mass Spectroscopy: Determining the Atomic Mass



- Ionizes the atom and electric field accelerates atoms
- Time of flight - heavier atoms will travel slower than lighter ones
- Weighter average of atomic masses

Relative Atomic Mass Formula

$$\text{Relative Atomic Mass} = (I_1 \times A_1) + (I_2 \times A_2) + \ldots \qquad (2)$$

where I is the mass of the isotope, and A is the relative abundance between 0 and 1

Calculating the Relative Atomic Masses

Magnesium is composed of three isotopes. Calculate the relative atomic mass of magnesium and compare to the periodic table.

Isotope	Mass (amu)	Natural Abundance (%)
^{24}Mg	23.985	78.99
^{25}Mg	24.986	10.00
^{26}Mg	25.983	11.01

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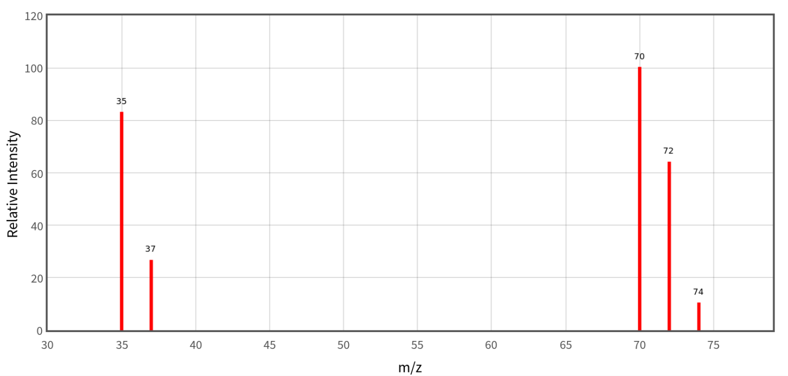
$$
\begin{array}{r}
23.985\text{amu} \times 0.7899 = 18.95\text{amu} \\
24,986\text{amu} \times 0.1000 = 2.499\text{amu} \\
25.983\text{amu} \times 0.1101 = 2.861\text{amu} \\
\hline
24.31\text{amu}
\end{array}
$$

Practice: Calculate the Atomic Mass

Boron has two naturally occuring isotopes. Determine the atomic mass of boron.

Isotope	Natural Abundance (%)
^{10}B	19.9
^{11}B	80.1

Practice: Calculate the Atomic Mass



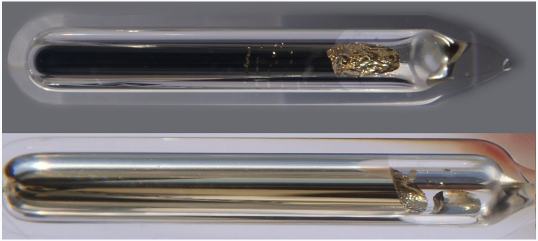
Determine atomic mass of Cl given the mass spectrum. Hint: Cl naturally exists as a diatomic e.g. Cl_2.

Conceptual Question

Naturally occurring gallium (ga) is made of two isotopes Ga-69 and Ga-71. Which of the following statements is true? Hint: Look at the periodic table.

1. Gallium's relative atomic mass is 70.00 amu
2. Both isotopes have the same mass: 69.72 amu
3. The isotopes are present in the same percentages
4. Ga-71 is present in the largest percent abundance
5. Ga-69 is present in the largest percent abundance

Alkali Metal



- Lower densities than other metals
- Extremely soft metals
- Highly reactive e.g. forming H_2 when in contact with water
- Prefer to lose an electron

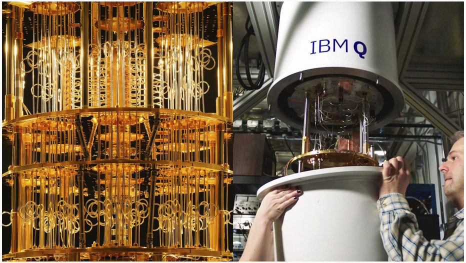
Alkaline Earth Metal

- Fairly reactive metals
- Can form solutions with a pH greater than 7 (more basic or alkaline)
- Calcium and magnesium important for life
- Prefer to lose 2 electrons

Transition Metals

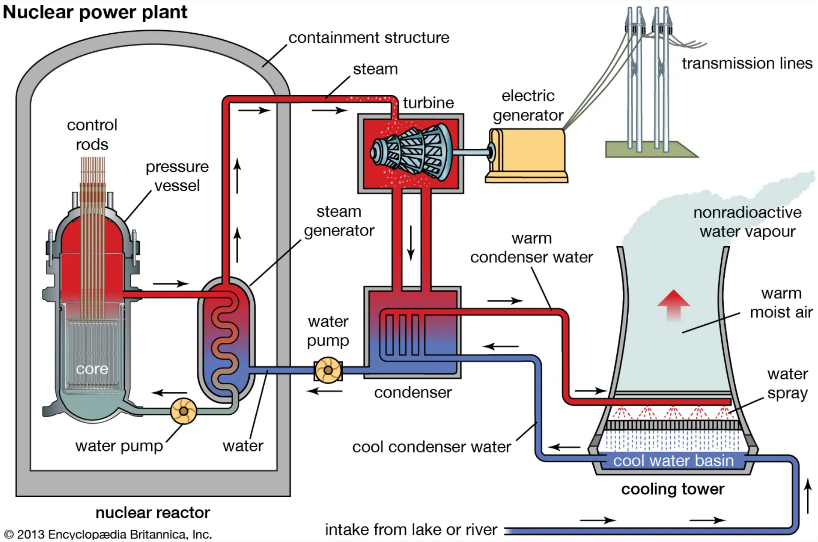
- Easily malleable and great conductors of heat and electricity
- High melting points except mercury (liquid at Room temperature)
- High densities
- Oxidation states (ability to lose electrons) can vary between 1+ to 6+

Actinides and Lanthanides



- Radioactive due to instability
- Silvery/silvery-white luster in metallic form
- Potential application to quantum computers and nuclear power
- Oxidation states can range from 2+ to 7+

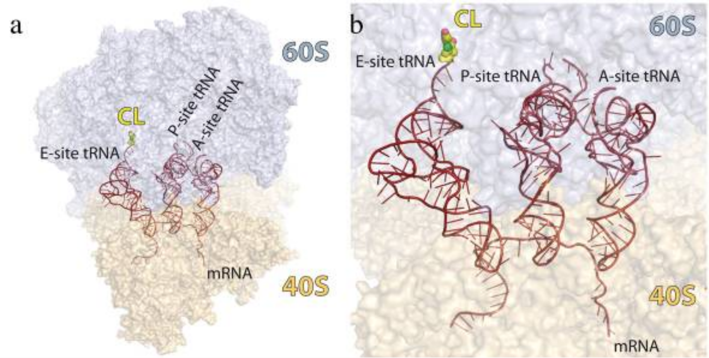
Nuclear Power Plants



Halogens

- Fairly toxic and form acids when combined with hydrogen
- Readily react with metals to form salts e.g. NaCl
- Important for drug development due to their “sticky” nature
- Prefers to gain an electron

My Research Project: Chlorolissoclimide



- Chlorolissoclimide is a potent cancer drug that is naturally found in sea squirts
- Reference - doi: 10.1038/nchem.2800

Noble Gases

- Colorless, odorless, tasteless, and non-flammable under standard conditions
- Extremely non-reactive and most stable elements
- Do not like to gain or lose electrons

Practice: Periodic Table

Group the elements into the following groups

- Br
- K
- Mg
- Al
- Mn
- Ar
- U

Practice

What is the charge of the ions for each of the following elements?

- Al
- P
- Br
- S