

*Chemistry 3A*

# Introductory General Chemistry

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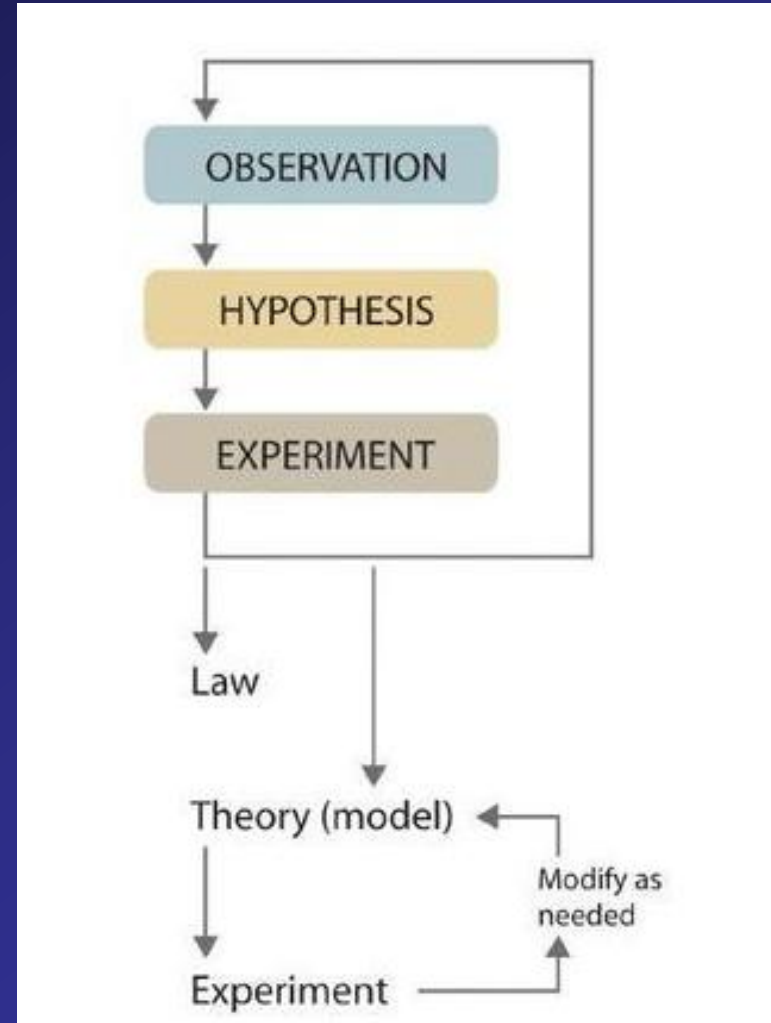
# Concepts

- Scientific Method
- Atomic Theory
- Subatomic Structure: protons, electrons, neutrons
- Atomic Properties
- Patterns of matter: Periodic Table
- Electric properties of atoms: ions
- Neutrons and isotopes
- Atomic mass: weight average of atoms

# Scientific Method

# Terms You Should Know

- *Observation*
- *Hypothesis*
- *Experiment*
- *Theory* (or model)
- *Law*



# Scientific Method

## Observations

- Qualitative

properties or occurrences in ways that do not rely on numbers

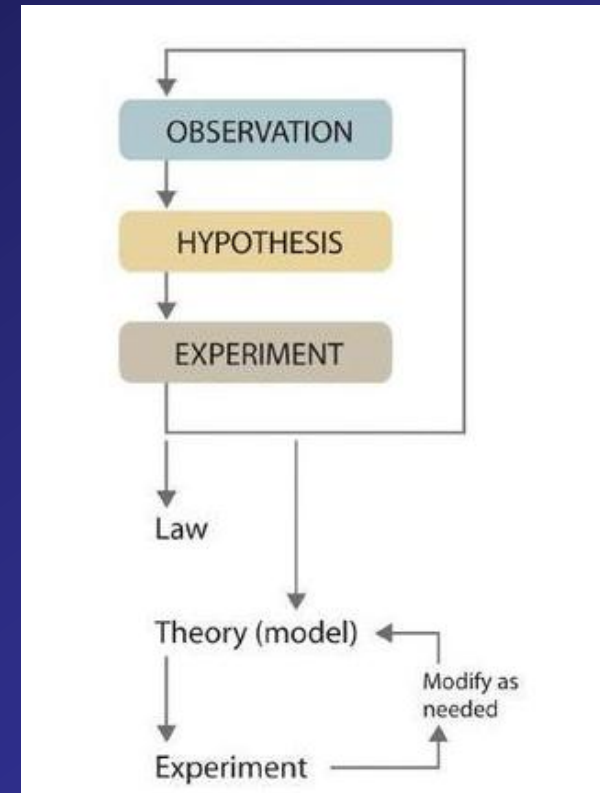
- table salt is crystalline solid
- dilute nitric acid used to dissolve penny forms blue solution and brown gas
- air temperature is cooler in winter season

- Quantitative

numerical measurements

***data has number with units!***

- melting point of crystalline sulfur → 115.21°C
- 35.9 g sodium chloride (NaCl) will dissolve in 100 g water at 20 °C
- Iridium in sediments from 66 million years ago were 20-160 times higher than normal

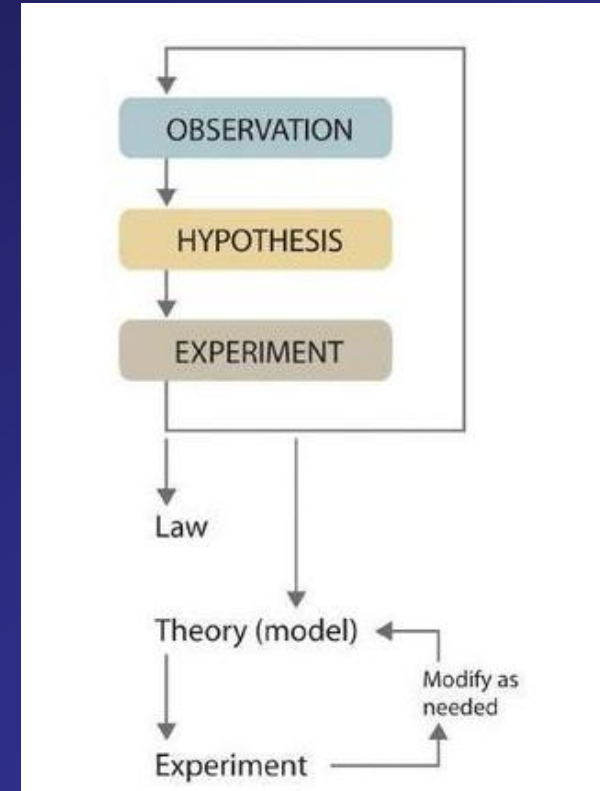


# Scientific Method

## Hypothesis

- A tentative explanation to account for (set of related) observations
- Two hypotheses to account why sun rises in east and sets in the west
  1. Sun revolves around the Earth  
*geocentric hypothesis for observation*
  2. Earth rotates on an axis, exposing only one side to sun  
*heliocentric hypothesis for observation*

Iridium levels observation brought **hypothesis** that dinosaur extinction event by large extraterrestrial object hitting Earth

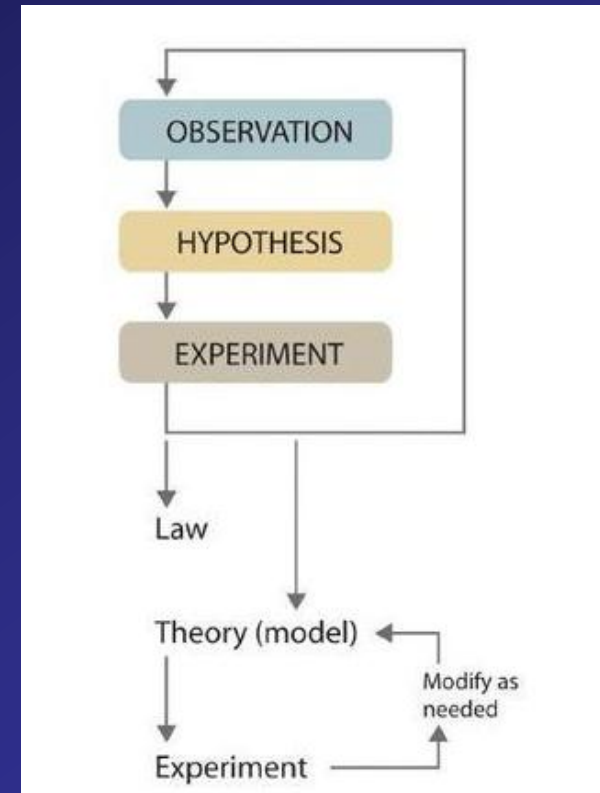


# Scientific Method

## Experiment

- Systematic **observations** or **measurements**, preferably made under controlled conditions—that is, under conditions in which a **single variable** changes
- These are designed to test **validity** of a **hypothesis** (more experiments test additional hypotheses)
- Experimental results should show if hypothesis is correct or sound or needing to be modified or revised

A wrong hypothesis does not mean there are problems with scientific method or with “doing science”. It means an educated guess was made, was not true in whole or in part, and a new guess is needed



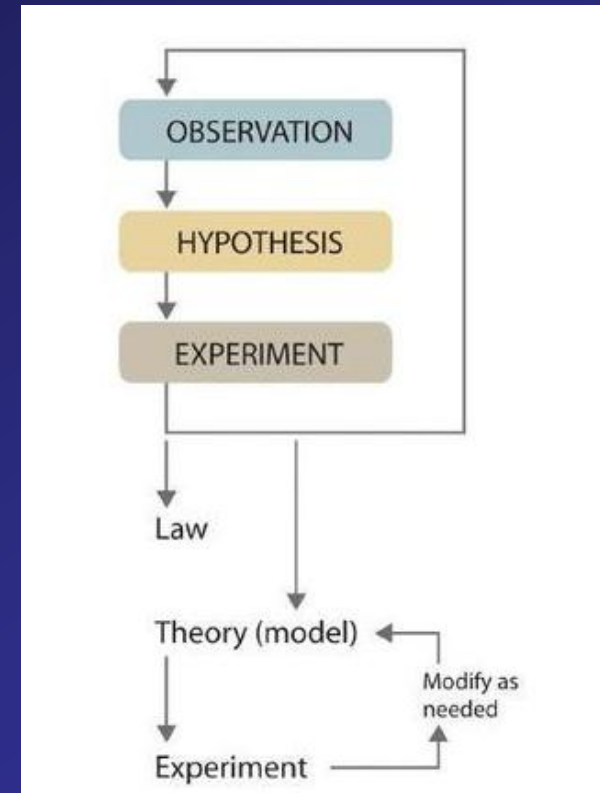
# Scientific Method

**$n = 3$ , not  $n = 1$**

Experimental results should be reproducible, that is repeated experiments

$n$  refers to the number of times an experiment under identical conditions is to be done to get results which should be reproduced to prove the reliability, dependability, precision, accuracy of observations

It is generally accepted an experiment should be done 3 times ( $n = 3$ ) to show results are reproducible. It is never acceptable to do an experiment only once ( $n = 1$ )





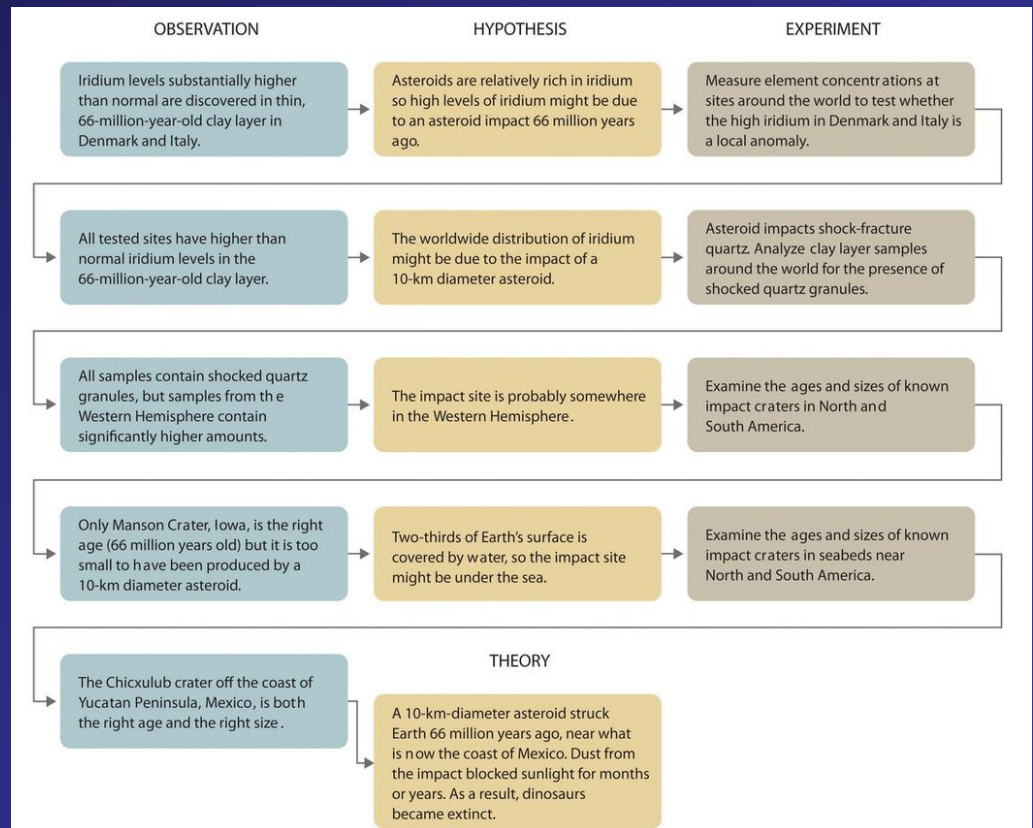
# Scientific Method

## *Asteroid Theory and Dinosaur Extinction*

### Development of a Theory

Observation → Hypothesis → Experiment

repeated cycles





# Atomic Theory

- A couple of millennia\* ago, Greek philosophers talked about matter as made of atoms  
Tiny, indivisible, solid objects
  - But it was only a couple of centuries ago (1800s) that **experimental science** really propelled humanity forward
  - English chemist John Dalton (researcher, professor)
    - Studied combustion: carbon reacting with oxygen  
*Elements were already known for millennia*
    - Knew water had elements hydrogen and oxygen
    - Proposed a theory based on experimental results that “the known elements are actually composed of **atoms**”
- \*Science is also about history, a history showing learning through trial-and-error & progression of thought and knowledge

# Dalton's Atomic Theory

## 1. All matter made of indivisible atoms

- Atoms are smallest units of matter
- Atoms cannot be created, divided, or destroyed (later revised with the discovery of subatomic particles)

## 2. All atoms of a given element are identical

- Atoms of the same element have same mass and properties
- later revised—atoms of the same element can have different masses known as isotopes

## 3. Compounds are formed by a combination of atoms of different elements

A given compound always contains the same kinds and ratios of atoms

## 4. Chemical reactions involve the rearrangement of atoms

Atoms are neither created nor destroyed in a chemical reaction—only rearranged

Atoms are about  $5.4 \times 10^{-10}$  m in diameter  
= 0.54 nanometer (nm) or 5.4 angstrom (Å)

# Subatomic Structure

Chemists see the atom structure having the important properties of **mass** and **(electric) charge**

- Electrons
  - mass =  $9.109 \times 10^{-31}$  kg,  $5.486 \times 10^{-4}$  amu
  - charge = -1
- Protons
  - mass =  $1.673 \times 10^{-27}$  kg, 1.007 amu, 1836 times electron mass
  - charge = +1
- Neutrons
  - mass =  $1.675 \times 10^{-27}$  kg, 1.009 amu, 1.001 times proton mass
  - charge = 0

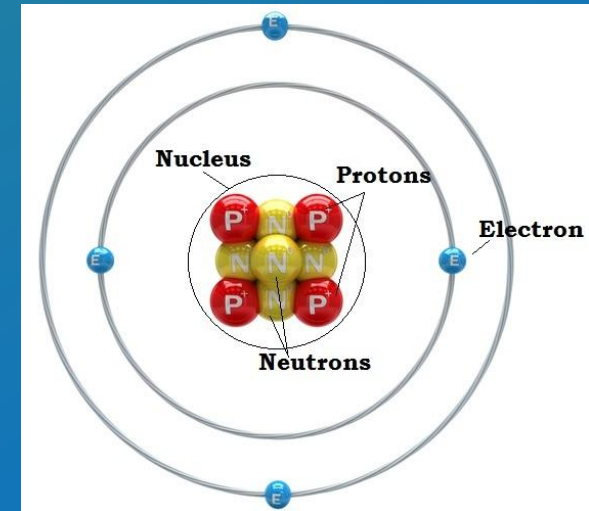
Table 2.3.1: Properties of Subatomic Particles

Particle	Symbol	Mass (amu)	Relative Mass (proton = 1)	Relative Charge	Location
proton	$p^+$	1	1	+1	inside the nucleus
electron	$e^-$	$5.45 \times 10^{-4}$	0.00055	-1	outside the nucleus
neutron	$n^0$	1	1	0	inside the nucleus

# Nucleus & Orbitals

- Protons and neutrons organized in the nucleus
- Electrons spatially located outside of the nucleus
- Electrons "orbit" the nucleus in **orbitals** but not like planets revolving around the sun
- Their position/location is determined by probabilities calculated by complex mathematical expressions
- Each orbital pairs two electrons of opposite spin

Yes, electrons have a spin just as the Earth rotates on an axis, and this spin generates a magnetic field



# Atomic Mass Units (amu)

Table 2.3.1: Properties of Subatomic Particles

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electron	e <sup>-</sup>	$5.45 \times 10^{-4}$	0.00055	-1	outside the nucleus
neutron	n <sup>0</sup>	1	1	0	inside the nucleus

- Definition of “amu” is 1/12<sup>th</sup> of mass of carbon-12 atom (has 6 protons, 6 neutrons, 6 electrons)
- This is not equal to mass of one proton, which is actually equal to 1.007276 amu
- This is only of importance to physicists and is explained by the “mass deficit” which is the energy to that holds a nucleus together

# Atomic Properties

- Atomic Number (the **Z** value)
  - *essentially defines the element*  
makes hydrogen, oxygen, carbon, chlorine, etc. what it is
  - = number of protons (in atom's nucleus)
- Mass Number (the **A** value)
  - = sum of count of protons and neutrons in atom's nucleus
  - Indicate the **isotope** form of element's atoms

Table 2.4.1: Atoms of the First Six Elements

Name	Protons	Neutrons	Electrons	Atomic Number (Z)	Mass Number (A)
Hydrogen	1	0	1	1	1
Helium	2	2	2	2	4
Lithium	3	4	3	3	7
Beryllium	4	5	4	4	9
Boron	5	6	5	5	11
Carbon	6	6	6	6	12

# Atomic Properties

## *Names and Symbols*

- Elements have names and 1- or 2-character symbols that represent the element
- Atoms are the physical part of the element
- Learn the names and symbols of common elements

Table 2.4.2: Symbols and Latin Names for Elements		
Chemical Symbol	Name	Latin Name
Na	Sodium	Natrium
K	Potassium	Kalium
Fe	Iron	Ferrum
Cu	Copper	Cuprum
Ag	Silver	Argentum
Sn	Tin	Stannum
Sb	Antimony	Stibium
Au	Gold	Aurum
Pb	Lead	Plumbum



# Isotopes

Elements can have different mass number (A) values. Chemistry is same though.

- Hydrogen = 1 proton (99.9885%)
- Deuterium ("hydrogen-2") = 1 proton + 1 neutron (0.0115%)
- Tritium ("hydrogen-3") = 1 proton + 2 neutrons (1 in  $10^{18}$ )  
*radioactive (beta emitter)*
- Carbon-12 = 6 protons + 6 neutrons (98.93%)
- Carbon-13 = 6 protons + 7 neutrons (1.07%)
- Carbon-14 = 6 protons + 8 neutrons (trace)

Isotopic abundance values in parentheses

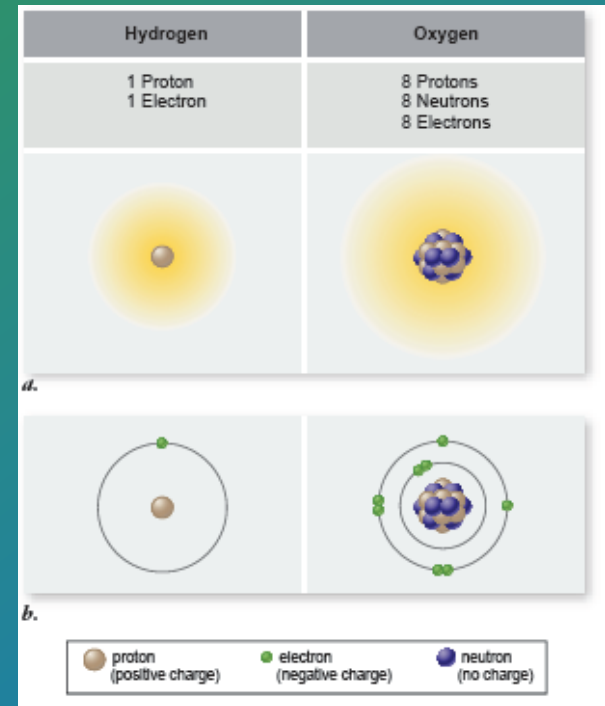
# Elements

- Elements all have the same number of protons
- But elements can have different number of neutrons
- An element with different numbers of neutrons is an **isotope** of the element
- When referring to an isotope of an element, use this



Where

- $X$  is element symbol (e. g., hydrogen = H)
- $Z$  is **atomic number**, = # protons ( $Z = 1$  for H)
- $A$  is **mass number**, = #protons + #neutrons



# Patterns of Matter: Periodic Table

- Observations
  - chlorine, bromine, iodine react with sodium
  - lithium, sodium, potassium react with other elements in similar ways
- Organizing elements with these properties by Mendeleev (also Meyer)

- **Symbols**  
Element name (optional)
- **Atomic Number**
- **Atomic Weight**  
***Not the mass number!***

1 H Hydrogen Nonmetal	<div><div>1</div><div>H</div><div>Hydrogen</div><div>Nonmetal</div></div> <div><div>Atomic Number</div><div>Symbol</div><div>Name</div><div>Chemical Group Block</div></div>																2 He Helium Noble Gas																				
3 Li Lithium Alkali Metal	4 Be Beryllium Alkaline Earth Metal																	5 B Boron Metalloid	6 C Carbon Nonmetal	7 N Nitrogen Nonmetal	8 O Oxygen Nonmetal	9 F Fluorine Halogen	10 Ne Neon Noble Gas														
11 Na Sodium Alkali Metal	12 Mg Magnesium Alkaline Earth Metal																	13 Al Aluminum Post-Transition Metal	14 Si Silicon Metalloid	15 P Phosphorus Nonmetal	16 S Sulfur Nonmetal	17 Cl Chlorine Halogen	18 Ar Argon Noble Gas														
19 K Potassium Alkali Metal	20 Ca Calcium Alkaline Earth Metal	21 Sc Scandium Transition Metal	22 Ti Titanium Transition Metal	23 V Vanadium Transition Metal	24 Cr Chromium Transition Metal	25 Mn Manganese Transition Metal	26 Fe Iron Transition Metal	27 Co Cobalt Transition Metal	28 Ni Nickel Transition Metal	29 Cu Copper Transition Metal	30 Zn Zinc Transition Metal	31 Ga Gallium Post-Transition Metal	32 Ge Germanium Metalloid	33 As Arsenic Metalloid	34 Se Selenium Nonmetal	35 Br Bromine Halogen	36 Kr Krypton Noble Gas	37 Rb Rubidium Alkali Metal	38 Sr Strontium Alkaline Earth Metal	39 Y Yttrium Transition Metal	40 Zr Zirconium Transition Metal	41 Nb Niobium Transition Metal	42 Mo Molybdenum Transition Metal	43 Tc Technetium Transition Metal	44 Ru Ruthenium Transition Metal	45 Rh Rhodium Transition Metal	46 Pd Palladium Transition Metal	47 Ag Silver Transition Metal	48 Cd Cadmium Transition Metal	49 In Indium Post-Transition Metal	50 Sn Tin Post-Transition Metal	51 Sb Antimony Metalloid	52 Te Tellurium Metalloid	53 I Iodine Halogen	54 Xe Xenon Noble Gas		
55 Cs Cesium Alkali Metal	56 Ba Barium Alkaline Earth Metal	*	72 Hf Hafnium Transition Metal	73 Ta Tantalum Transition Metal	74 W Tungsten Transition Metal	75 Re Rhenium Transition Metal	76 Os Osmium Transition Metal	77 Ir Iridium Transition Metal	78 Pt Platinum Transition Metal	79 Au Gold Transition Metal	80 Hg Mercury Transition Metal	81 Tl Thallium Post-Transition Metal	82 Pb Lead Post-Transition Metal	83 Bi Bismuth Post-Transition Metal	84 Po Polonium Metalloid	85 At Astatine Halogen	86 Rn Radon Noble Gas	87 Fr Francium Alkali Metal	88 Ra Radium Alkaline Earth Metal	**	104 Rf Rutherfordium Transition Metal	105 Db Dubnium Transition Metal	106 Sg Seaborgium Transition Metal	107 Bh Bohrium Transition Metal	108 Hs Hassium Transition Metal	109 Mt Meitnerium Transition Metal	110 Ds Darmstadtium Transition Metal	111 Rg Roentgenium Transition Metal	112 Cn Copernicium Transition Metal	113 Nh Nihonium Post-Transition Metal	114 Fl Flerovium Post-Transition Metal	115 Mc Moscovium Post-Transition Metal	116 Lv Livermorium Post-Transition Metal	117 Ts Tennessine Halogen	118 Og Oganesson Noble Gas		
		*	57 La Lanthanum Lanthanide	58 Ce Cerium Lanthanide	59 Pr Praseodymium Lanthanide	60 Nd Neodymium Lanthanide	61 Pm Promethium Lanthanide	62 Sm Samarium Lanthanide	63 Eu Europium Lanthanide	64 Gd Gadolinium Lanthanide	65 Tb Terbium Lanthanide	66 Dy Dysprosium Lanthanide	67 Ho Holmium Lanthanide	68 Er Erbium Lanthanide	69 Tm Thulium Lanthanide	70 Yb Ytterbium Lanthanide	71 Lu Lutetium Lanthanide																				
		**	89 Ac Actinium Actinide	90 Th Thorium Actinide	91 Pa Protactinium Actinide	92 U Uranium Actinide	93 Np Neptunium Actinide	94 Pu Plutonium Actinide	95 Am Americium Actinide	96 Cm Curium Actinide	97 Bk Berkelium Actinide	98 Cf Californium Actinide	99 Es Einsteinium Actinide	100 Fm Fermium Actinide	101 Md Mendelevium Actinide	102 No Nobelium Actinide	103 Lr Lawrencium Actinide																				

# Features of Periodic Table

- **Periods**

- The rows of the table
- Number of elements in period not always same!
  - Pattern: 2, 8, 8, 18, 18, 32, 32 for the seven periods
  - Physical reason for this important in chemistry
  - Special periods: inner transition metals, lanthanides, actinides

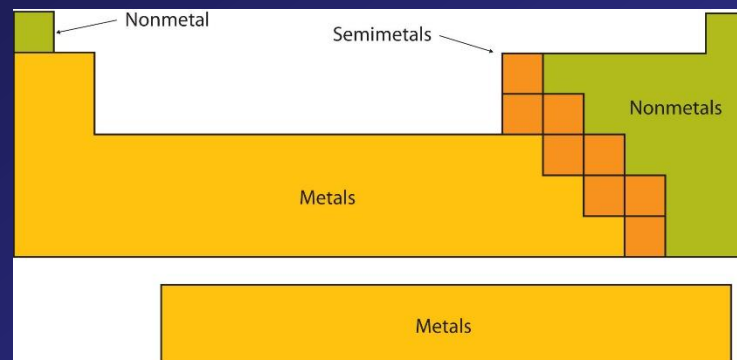
- **Groups (“Families”)**

- The columns of the table
- Usually have similar chemistry (chemical properties)

# Patterns of Matter: Periodic Table

## *Classes of elements*

- Metals
  - “shiny”, “silvery in color” (but varies)
  - usually electrical and heat conductors
  - malleable (hammer into sheets)
  - ductile (pulled into wires)
- Nonmetals
  - not shiny, brittle in solid form
  - poor electrical and heat conductors
- “Metalloids” (Semimetals)
  - between metal and nonmetal: B, Si, Ge, As, Sb, Te
  - metallic luster, solid at room temperature
  - brittle (not malleable)
  - semiconductors: useful when “doped” with impurities
- 3/4ths of elements are metals



# Periodic Table of Elements

Biologists should know what elements are  
(1) metals and (2) nonmetals generally

Diagram illustrating the Periodic Table of Elements, showing the arrangement of elements by groups and periods. The table is color-coded to distinguish between Metals (yellow), Metalloids (purple), and Nonmetals (blue).

**Main groups:** 1A, 2A, 3A, 4A, 5A, 6A, 7A, 8A.

**Transition metal groups:** 3B, 4B, 5B, 6B, 7B, 8B, 9B, 10B, 11B, 12B.

**Periods:** 1 through 7.

**Lanthanides and Actinides:** These series are shown below the main table, separated by a zigzag line. Lanthanides are numbered 58 to 71, and Actinides are numbered 90 to 118.

Period	1A	2A	3B	4B	5B	6B	7B	8B	9B	10B	11B	12B	13	14	15	16	17	18
1	1 H 1.00794	2 He 4.00260											13 B 10.81	14 C 12.011	15 N 14.0067	16 O 15.9994	17 F 18.9984	18 Ne 20.1797
2	3 Li 6.941	4 Be 9.01218											13 B 10.81	14 C 12.011	15 N 14.0067	16 O 15.9994	17 F 18.9984	18 Ne 20.1797
3	11 Na 22.98977	12 Mg 24.305	3	4	5	6	7	8	9	10	11	12	13 Al 26.98154	14 Si 28.0855	15 P 30.9738	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
4	19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
5	37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.9055	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.41	49 In 114.82	50 Sn 118.710	51 Sb 121.757	52 Te 127.60	53 I 126.9045	54 Xe 131.29
6	55 Cs 132.9054	56 Ba 137.33	57 *La 138.9055	58 Ce 140.9077	59 Pr 140.9077	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.965	64 Gd 157.25	65 Tb 158.9254	66 Dy 162.50	67 Ho 164.9304	68 Er 167.26	69 Tm 168.9342	70 Yb 173.04	71 Lu 174.967	
7	87 Fr (223)	88 Ra (226)	89 †Ac (227)	90 Th 232.0381	91 Pa 231.0399	92 U 238.0289	93 Np 237.048	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)	

**Legend:**

- Metals (Yellow)
- Metalloids (Purple)
- Nonmetals (Blue)

## The periodic table of the elements.

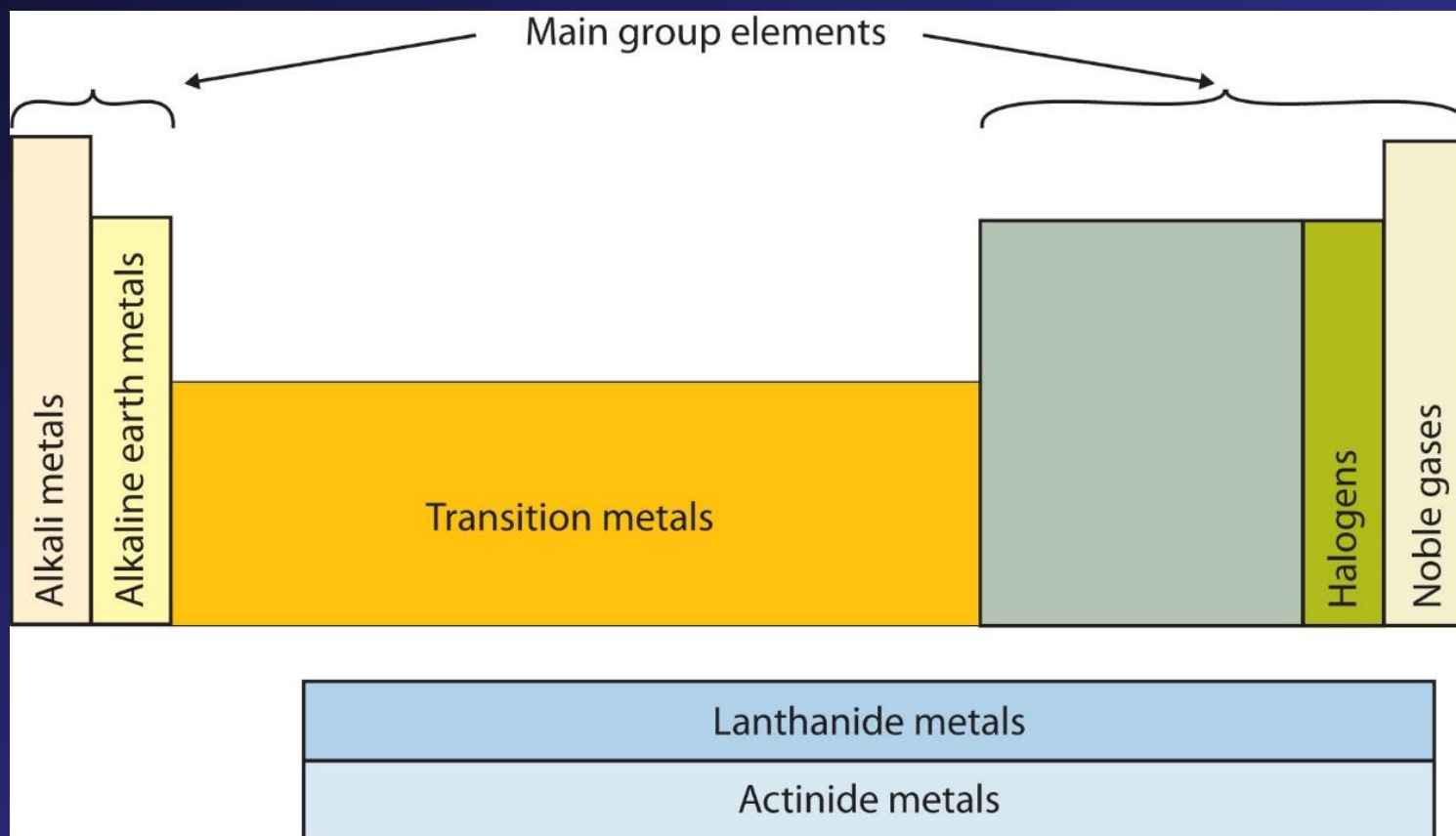
Each element is identified by a one- or two-letter symbol and is characterized by an *atomic number*. The table begins with hydrogen (H, atomic number 1) in the upper left-hand corner and continues to the yet unnamed element with atomic number 118. The 14 elements following lanthanum (La, atomic number 57) and the 14 elements following actinium (Ac, atomic number 89) are pulled out and shown below the others.

Elements are organized into 18 vertical columns, or *groups*, and 7 horizontal rows, or *periods*. The two groups on the left and the six on the right are the *main groups*; the ten in the middle are the *transition metal groups*. The 14 elements following lanthanum are the *lanthanides*, and the 14 elements following actinium are the *actinides*; together these are known as the *inner transition metals*. Two systems for numbering the groups are explained in the text. Those elements (except hydrogen) on the left-hand side of the zigzag line running from boron (B) to astatine (At) are *metals*, those elements to the right of the line are *nonmetals*, and most elements abutting the line are *metalloids*.



# Special Groups of Elements

Some groups of elements should be noted since their chemistry is commonly observed





# Special Groups of Elements

## **Alkali Metals**

Sodium:

- table salt
- cellular function

Potassium:

- cellular function (like sodium)

Lithium:

- used in “grease” lubricants
- batteries
- drugs to control neurological conditions affecting behavior (bipolar “disorder”)

The image shows a standard periodic table of elements. An arrow points to the first column, which contains the alkali metals. To the right of the main table, a vertical strip highlights the elements of this group in red boxes, showing their atomic numbers, symbols, and names.

Atomic Number	Symbol	Name
3	Li	Lithium
11	Na	Sodium
19	K	Potassium
37	Rb	Rubidium
55	Cs	Caesium
87	Fr	Francium

# Special Groups of Elements

## ***Alkaline Earth Metals***

Magnesium:

- also important in cellular function
- Forms important minerals

Calcium:

- Like magnesium, necessary for cell/tissue function
- Limestone is calcium carbonate

Others are rare and **Ra** is radioactive

A standard periodic table of elements. An arrow points to the second column, which contains the alkaline earth metals: Be, Mg, Ca, Sr, Ba, and Ra. The elements are color-coded by groups: Group 1 (red), Group 2 (orange), Groups 3-10 (various blues and greys), Groups 11-18 (various greens and yellows).

4	9.012	Be	Beryllium
12	24.304	Mg	Magnesium
20	40.078	Ca	Calcium
38	87.62	Sr	Strontium
56	137.327	Ba	Barium
88	(226)	Ra	Radium

# Special Groups of Elements

## *Halogens*

Term “halogen” → salt-forming

React with metals to form salts

A periodic table of elements with the halogen group highlighted in green. An arrow points to the halogen group, which includes Fluorine (F), Chlorine (Cl), Bromine (Br), and Iodine (I).

Fluorine:

- the fluoride in toothpaste
- non-stick Teflon

Chlorine:

- essential for cellular function
- a component of plastics (chlorides of carbon polymers)

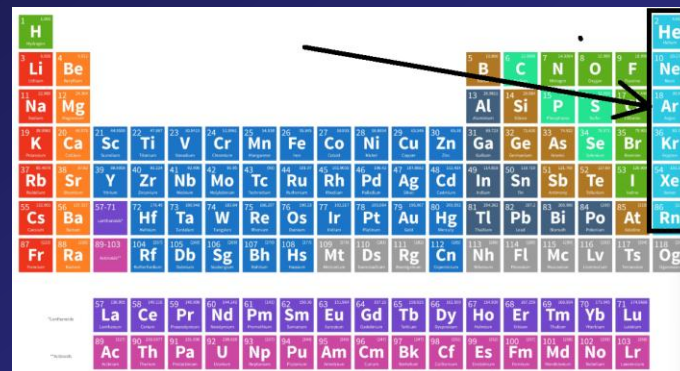
9	18.998	<b>F</b>	Fluorine
17	35.446	<b>Cl</b>	Chlorine
35	79.901	<b>Br</b>	Bromine
53	126.904	<b>I</b>	Iodine

# Special Groups of Elements

## *Noble Gases*

Also called “inert gases” and “rare gases”

Basically once thought to be chemically **unreactive**



A periodic table of elements with noble gases (He, Ne, Ar, Kr, Xe, Rn) highlighted in yellow. An arrow points from the text 'Noble Gases' to this group.

Usually exist as single atoms, explains why gases  
Neon used to make red lighting

But some form interesting compounds with nonmetals

- Xenon hexafluoroplatinate ( $\text{XePtF}_6$ ): first compound with noble gas ever produced
- Xenon difluoride ( $\text{XeF}_2$ ): powerful fluorinating and oxidizing agent used in microprocessor production
- Krypton difluoride ( $\text{KrF}_2$ ): used to make  $\text{KrF}$  excimer lasers for photolithography ( $\text{ArF}$  also used in this way)



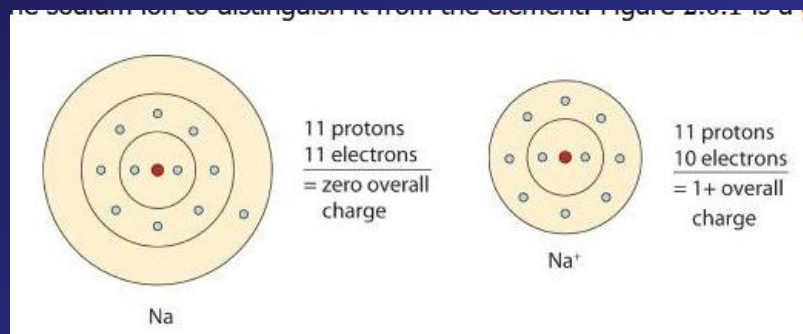
A vertical strip showing the noble gas elements with their atomic numbers and names:

2	4.0026	He	Helium
10	20.1797	Ne	Neon
18	39.948	Ar	Argon
36	83.798	Kr	Krypton
54	131.293	Xe	Xenon
86	(222)	Rn	Radon

# Electric properties of atoms: Ions

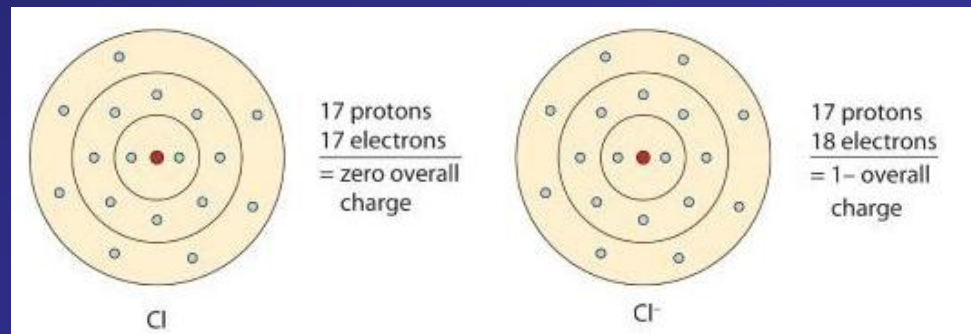
- Ions
  - Neutral atom/particle: zero charge, plus=minus
  - Ions: positively or negatively charged atoms/particles
- Cations – is a **POSITIVELY** charged ion

Lose an electron



- Anions – is a **NEGATIVELY** charged ion

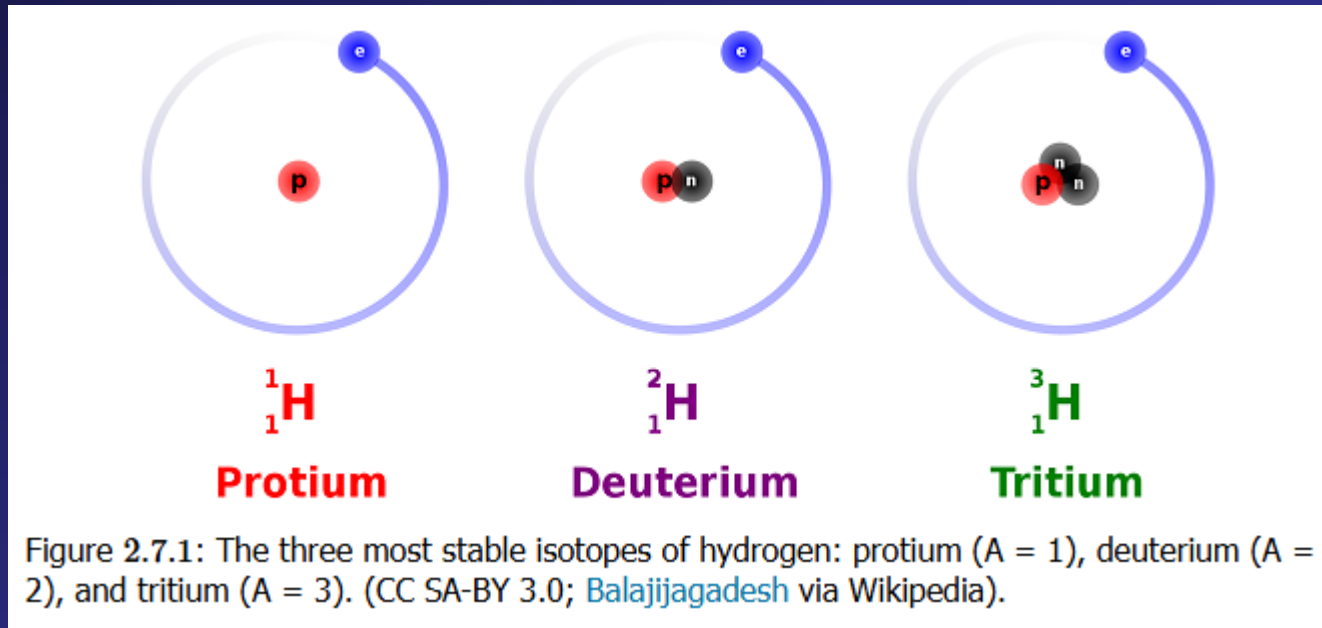
Gain an electron





# Isotopes

- **Isotopes** are forms of an atom with the same **proton** number (**Z**) but different **mass number** (**A**)
- That is, they are forms of an element with different numbers of **neutrons** in the atom



# Isotopes

- Lithium has only one atomic number ( $Z = 3$ )

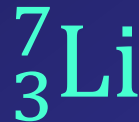
This is the number of protons an element's atoms has

- Lithium can have two mass numbers

- 3 neutrons:  $A = 6$  ( = 3 protons + 3 neutrons)



- 4 neutrons:  $A = 7$  ( = 3 protons + 4 neutrons)



Why not  $\text{Li}$  with 2 or 5 neutrons? Because we only report on what exists naturally



# Representing Isotopes

Isotopes can be written in two ways

## *Nuclear Symbol*



But the atomic number subscript (Z) is unnecessary if the element symbol indicates it



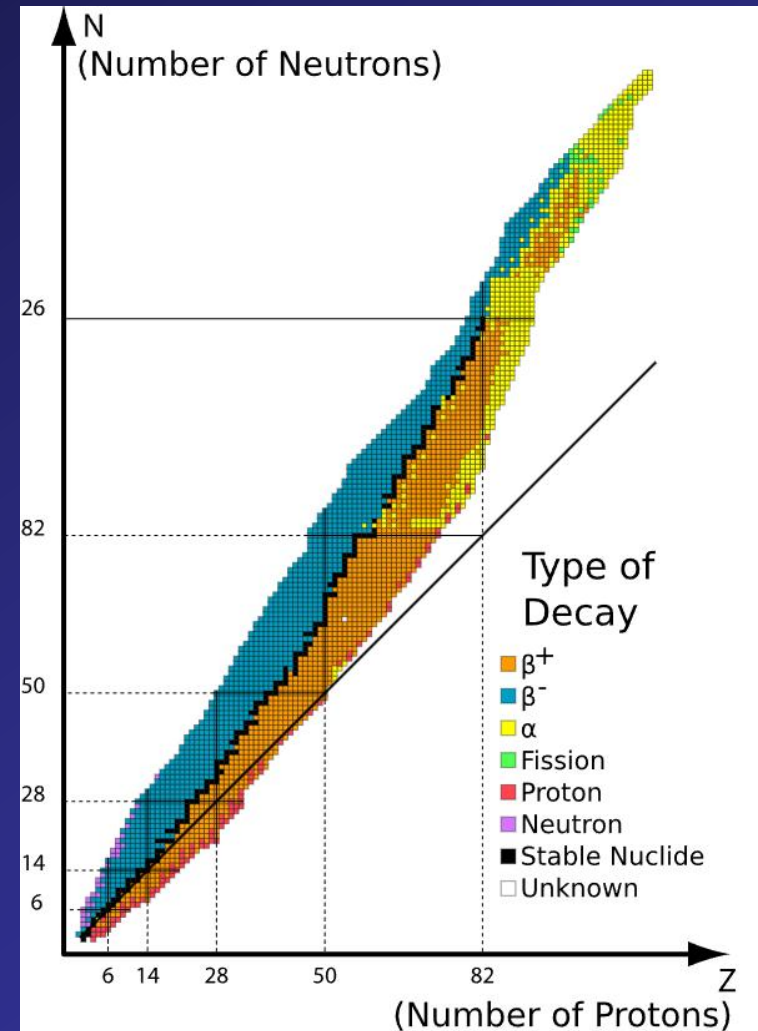
Or as the "<element-name>-<mass-number>"

Carbon-12, Carbon-13, Carbon-14

# Isotope Stability

- The stability of the atomic nucleus (of elements) depends on a ratio of neutrons to protons
- Carbon has two stable isotopes,  $^{12}\text{C}$  and  $^{13}\text{C}$ . But  $^{14}\text{C}$  is unstable and radioactive
- The trend at right shows that nuclei will have more and more neutrons than protons in the nucleus as the  $Z$  gets larger!

That is  $\frac{\text{neutrons}}{\text{protons}} > 1$



# Atomic Mass (Atomic Weight)

- Book defines **atomic mass** as the “weighted average mass of atoms in a naturally occurring sample of the element”
- Its **units** are **atomic mass units (amu)**
- **Relative abundance**: **fraction** of element which is a given **isotope** (fraction might be as a percentage)
- Note that all the relative abundances should add up to 1 (100%)

$$\sum (\text{relative abundance of isotope})_i \times (\text{isotope mass})_i$$

What book calls “atomic mass” most properly call “atomic weight”. Atomic mass refers to an isotope’s actual mass (in amu)

# Atomic Weight Calculation

## *Hydrogen Atomic Weight Calculation*

- Protium ( $^1\text{H}$ )
  - Abundance:  $\sim 99.985\%$
  - Atomic Mass: 1.0078 amu
- Deuterium ( $^2\text{H}$  or D)
  - Abundance:  $\sim 0.015\%$
  - Atomic Mass: 2.0141 amu
- Tritium ( $^3\text{H}$  or T)
  - Abundance: trace
  - Atomic Mass: 3.0160 amu

$$0.99985 \times 1.0078 + 0.00015 \times 2.0141 = 1.0079 \text{ amu}$$

# Atomic Weight Calculation

## *Carbon Atomic Weight Calculation*

- Carbon-12 ( $^{12}\text{C}$ )
  - Abundance:  $\sim 98.93\%$
  - Atomic Mass: 12.0000 amu
- Carbon-13 ( $^{13}\text{C}$ )
  - Abundance:  $\sim 1.07\%$
  - Atomic Mass: 13.0034 amu
- Carbon-14 ( $^{14}\text{C}$ )
  - Abundance: trace
  - Atomic Mass: 14.0032 amu

$$0.9893 \times 12.0000 + 0.0107 \times 13.0034 = 12.0107 \text{ amu}$$

# Atomic Weight Calculation

## *Boron Atomic Weight Calculation*

- Boron-10 ( $^{10}\text{B}$ )
  - Abundance:  $\sim 19.9\%$
  - Atomic Mass: 10.0129 amu
- Boron-11 ( $^{11}\text{B}$ )
  - Abundance:  $\sim 80.1\%$
  - Atomic Mass: 11.0093 amu

$$0.199 \times 10.0129 + 0.801 \times 11.0093 = 10.811 \text{ amu}$$

# Atomic Weight Calculation

## *Neon Atomic Weight Calculation*

- Neon-20 ( $^{20}\text{Ne}$ )
  - Abundance:  $\sim 90.48\%$
  - Atomic Mass: 19.9924 amu
- Neon-21 ( $^{21}\text{Ne}$ )
  - Abundance:  $\sim 0.27\%$
  - Atomic Mass: 20.9938 amu
- Neon-22 ( $^{22}\text{Ne}$ )
  - Abundance:  $\sim 9.25\%$
  - Atomic Mass: 21.9914 amu

$$0.9048 \times 19.9924 + 0.0027 \times 20.9938 + 0.0925 \times 21.9914 = 20.180 \text{ amu}$$