

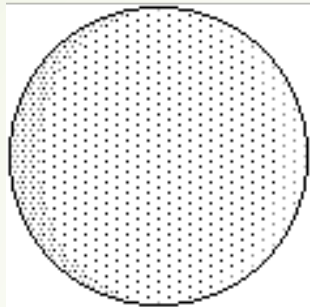
Atoms and Energy

Objective: Learning about atomic models, atomic structure and energy level of electrons. Also, explore the structure and the trends of periodic table.

Key concepts:

- ❖ Atomic Model
- ❖ Emission Spectrum and energy levels
- ❖ Periodic table
- ❖ Atomic Number and Atomic Mass
- ❖ Isotopes
- ❖ Trends in Periodic Table

Models of the Atom



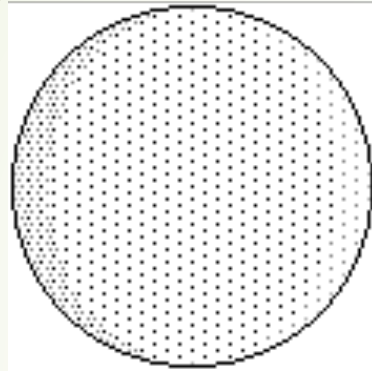
Greeks (500 BC) and Dalton (1803)

The idea that matter was made of atoms had been rejected by most Greek philosophers in favor of the idea that matter was continuous, like water, rather than particles, like sand.

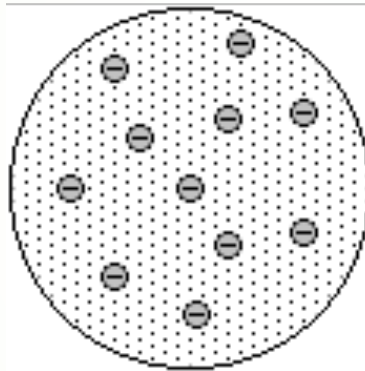
Dalton used the results of **experiments** in chemistry to revive this idea in the form of a theory that explained a huge number of experiments. Compounds were made by combining **atoms** of different **elements** in particular ratios.

Atoms of different elements have unique sizes, weights, and other properties.

History of Early Atomic Models

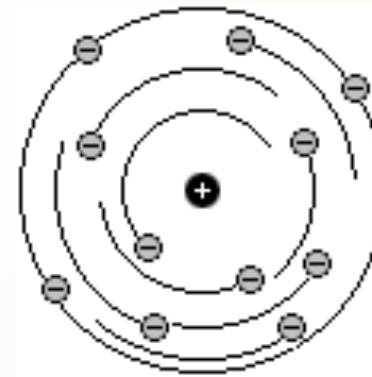


Solid sphere: Dalton (1803)

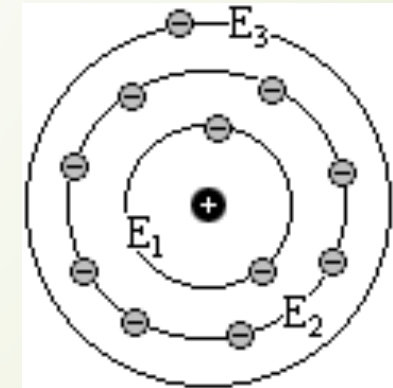


Electron discovered (1897)

Rutherford experiment (1911)

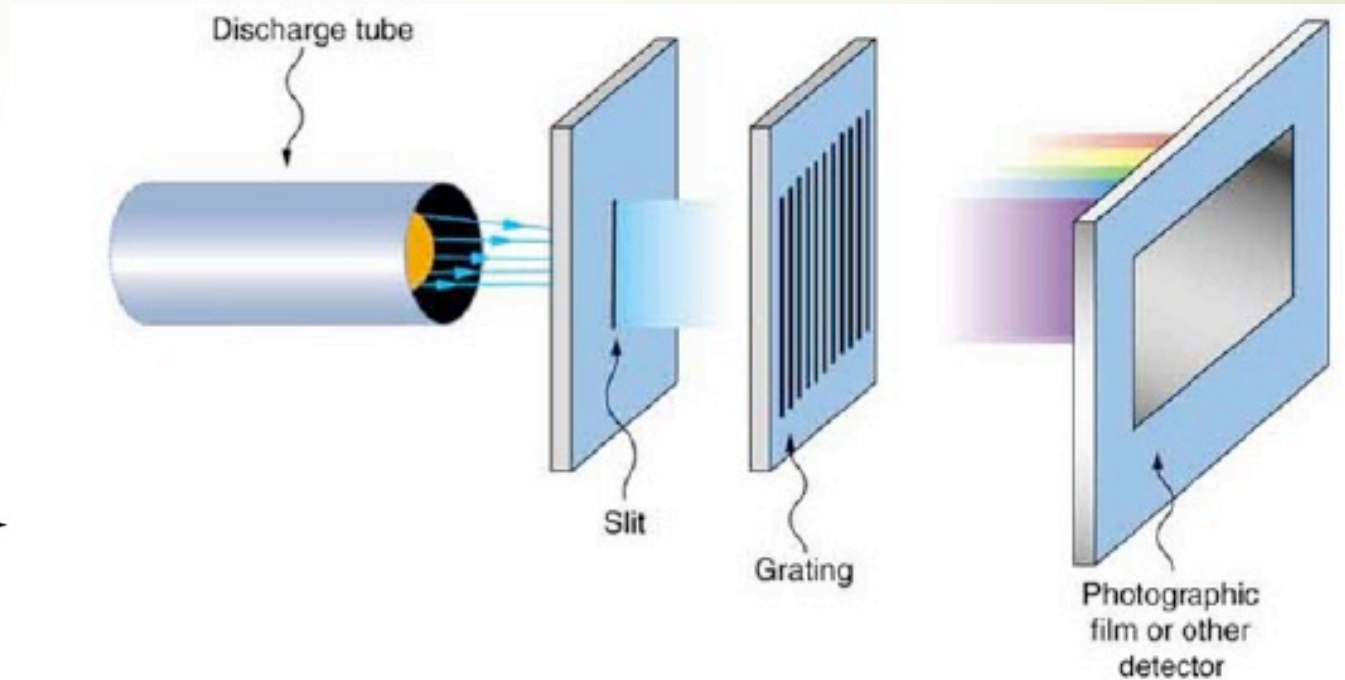
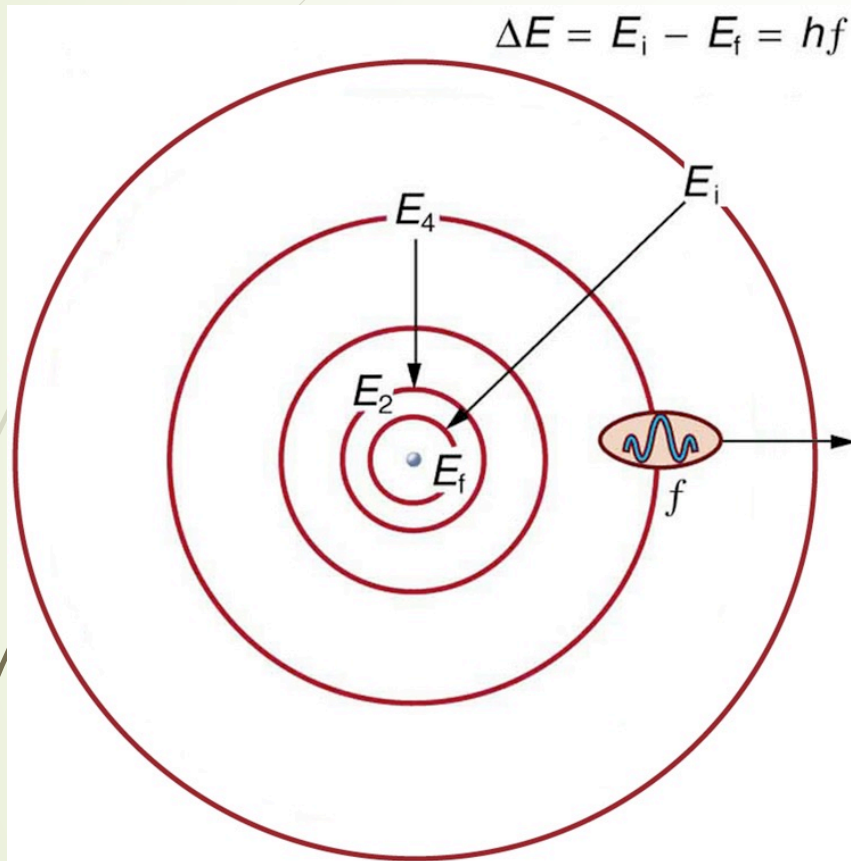


Electrons in specific energy levels: Bohr (1913)



Light emission spectra from atoms

explained by the Bohr model “jumps”

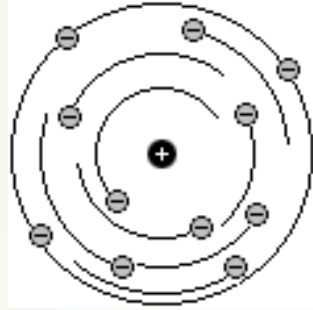


Emission line spectrum for Hydrogen

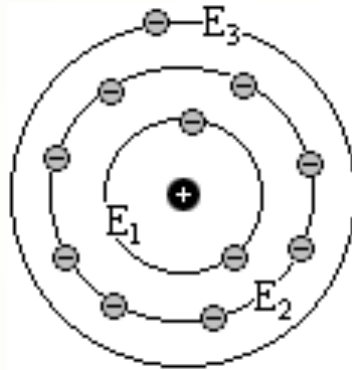


but also explained by Quantum Mechanics “transitions” between distinct energy levels unique to each element.

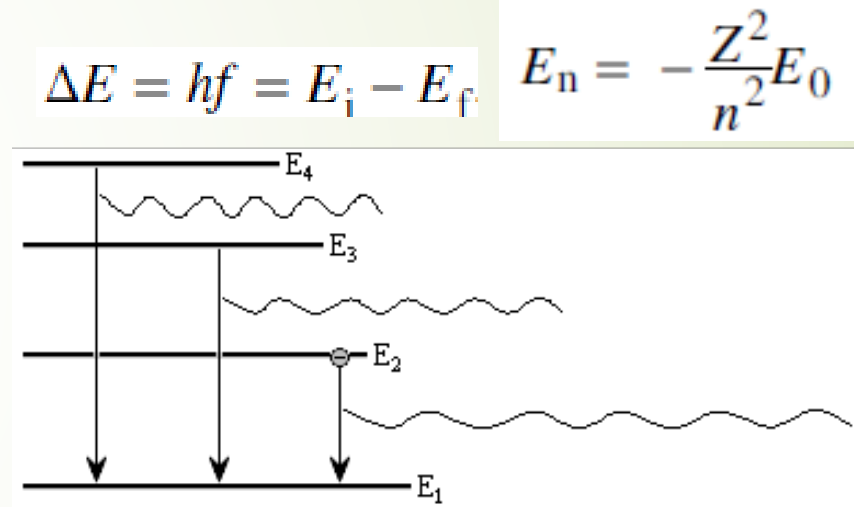
Development of “Modern” Models



Rutherford (1911)

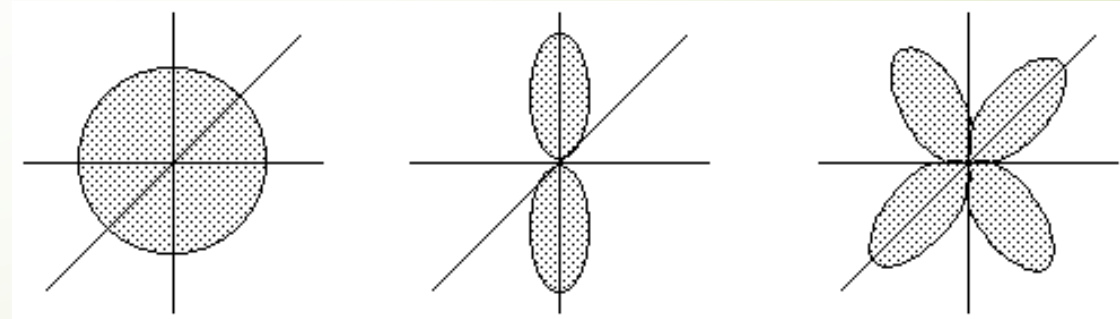


Bohr (1913)



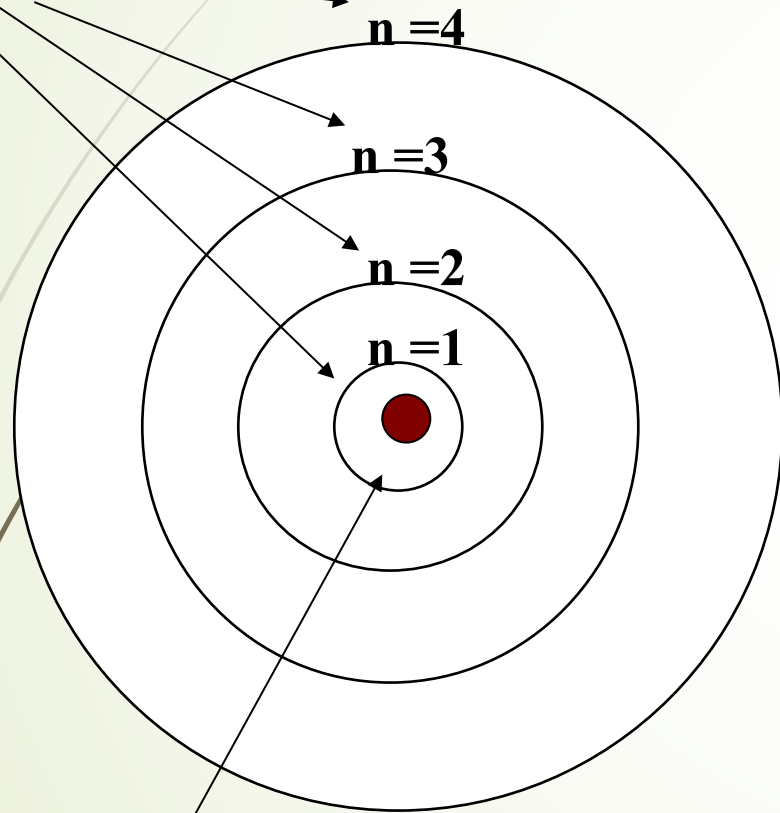
Quantum Mechanics:

Same energy levels but **matter wave probabilities** (1925)



Atomic Structure

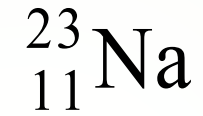
Shells



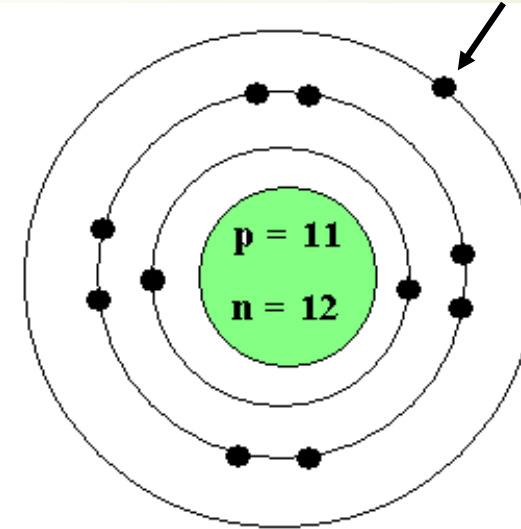
Nucleus

Outermost electron - Valence electron

Na atom



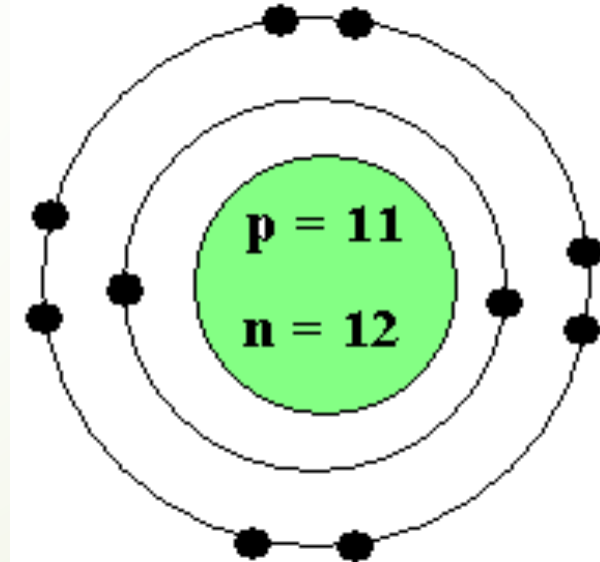
11 electrons



Na ion



10 electrons



Structure of the Periodic Table

The original arrangement of the Periodic Table came from organizing elements by their properties, which repeated in a regular pattern with a particular period (frequency).

Elements in the **same column** (group or family) have very **similar chemical properties** (see the next slide).

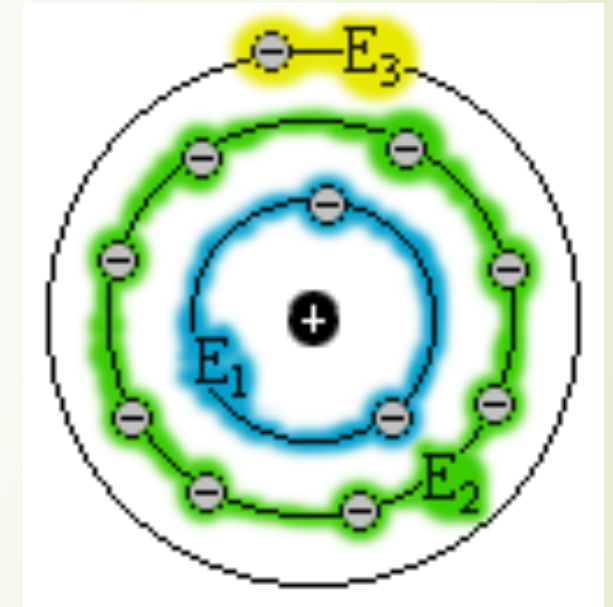
Elements in the same row show a smooth trend in properties as you move from one side to the other.

We now understand this to be a result of **the organization of electron energy levels** given by quantum mechanics.

Structure of the Periodic Table

Electrons fill distinct energy “shells” and each row corresponds to the filling of a shell.

	1A	2A											3A	4A	5A	6A	7A	8A	
1	H																		He
2	Li	Be											B	C	N	O	F		Ne
3	Na	Mg	3B	4B	5B	6B	7B	8B	1B	2B			Al	Si	P	S	Cl		Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br		Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I		Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At		Rn
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	113	114	115	116	117		118
			↑																
6	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu					
7	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr					



All of chemistry can be understood starting from this basic concept of atomic physics.

Periodic Table of the Elements

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	8A
1	1 H Hydrogen 1.0078																	2 He Helium 4.0026
2	3 Li Lithium 6.938	4 Be Beryllium 9.0122											5 B Boron 10.806	6 C Carbon 12.009	7 N Nitrogen 14.006	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
3	11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.084	15 P Phosphorus 30.974	16 S Sulfur 32.059	17 Cl Chlorine 35.446	18 Ar Argon 39.948
4	19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.63	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.96	43 Tc Technetium 98.9062	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
6	55 Cs Cesium 132.91	56 Ba Barium 137.33		72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)		104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (268)	111 Rg Roentgenium (268)	112 Cn Copernicium (268)	113 Uut Ununtrium (268)	114 Fl Flerovium (268)	115 Uup Ununpentium (268)	116 Lv Livermorium (268)	117 Uus Ununseptium (268)	118 Uuo Ununoctium (268)
			Lanthanides	57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
			Actinides	89 Ac Actinium (227)	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

11 — Atomic number
Na — Element symbol
 Sodium — Element name
 22.990 — Atomic weight

- Alkali metals
- Alkaline earth metals
- Lanthanides
- Actinides
- Transition metals
- Unknown properties
- Post-transition metals
- Metalloids
- Other nonmetals
- Halogens
- Noble gases

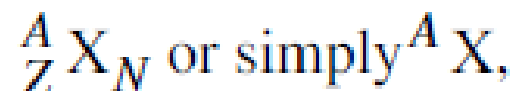
Atomic Number

The number at the top of each box in the full periodic table is the **atomic number**. It is equal to the number of **positively charged protons** in the nucleus, which defines the **element**.

The element symbol and the atomic number tell us the same thing, and also tell us the **number of negative electrons**.

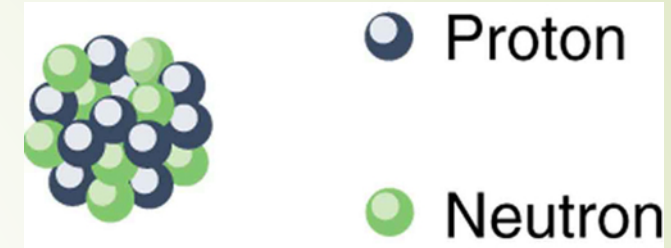
Atomic Mass

Part of the mass of one atom of an element comes from the protons. The rest comes from **neutrons**, neutral particles that are also found in the nucleus of the atom. The average mass found of an element found in nature is at the bottom of each element's box in the periodic table.



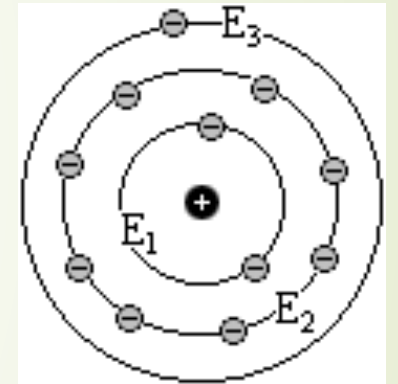
Atomic Nucleus

The protons and neutrons are in the **nucleus**, while the electrons "orbit" the nucleus.



Protons, Neutrons, and Electrons are inside the atom.

Name	Symbol	Charge (e)	Mass (amu)
Proton	${}^1_1\text{p}$	+1	1.00728 ~ 1
Neutron	${}^1_0\text{n}$	0	1.00866 ~ 1
Electron	${}^0_{-1}\text{e}$	-1	0.00055 ~ 0

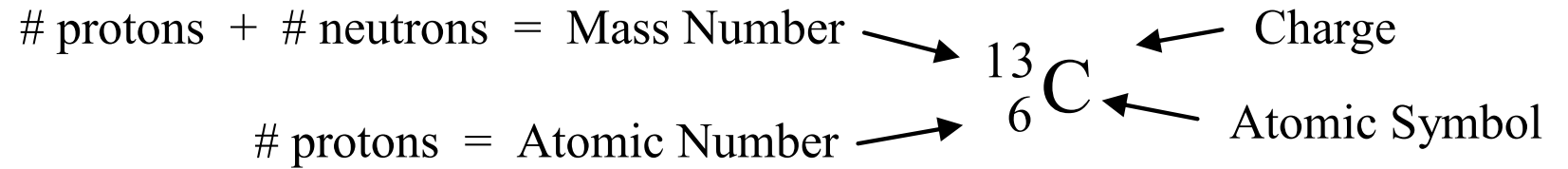
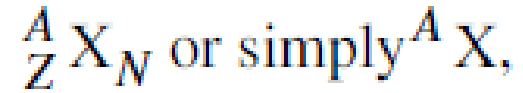


The electrons are very light, so almost all of the mass is at the center of the atom in what is called the “**nucleus**”. The radius of a nucleus, r , is approximately

$$r = r_0 A^{1/3},$$

where, $r_0 = 1.2 \text{ fm}$. Nuclear volumes are proportional to mass number, A .

Atomic Symbols



Changing the number of neutrons changes the mass of an atom but not change which element it is.

We use a special place-holder notation to keep track of different **isotopes** (atoms of the **same element** that have **different masses** because they have more or fewer neutrons) and whether that atom has a **charge** because the number of electrons it has is more or less than the number of protons.

Isotopes

Atoms with varying number of neutrons but with same number of protons are called *isotopes*

Hydrogen has three isotopes

Mass number
(protons+ neutrons)



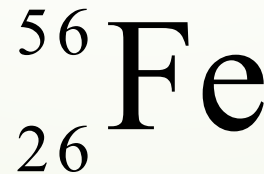
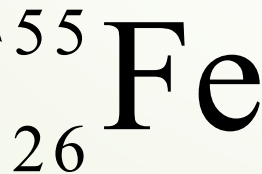
Atomic symbol
Protium (normal hydrogen)

Atomic number
(protons)

1

Two isotopes of Iron

(26 protons + 29neutrons) (26 protons + 30neutrons)



H-1

1 proton
0 neutron
(protium)



H-2

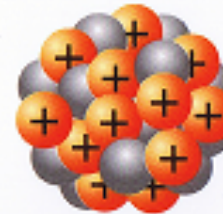
1 proton
1 neutron
(deuterium)



H-3

1 proton
2 neutrons
(tritium)

Hydrogen isotopes



Fe-56

26 protons
30 neutrons



Fe-55

26 protons
29 neutrons

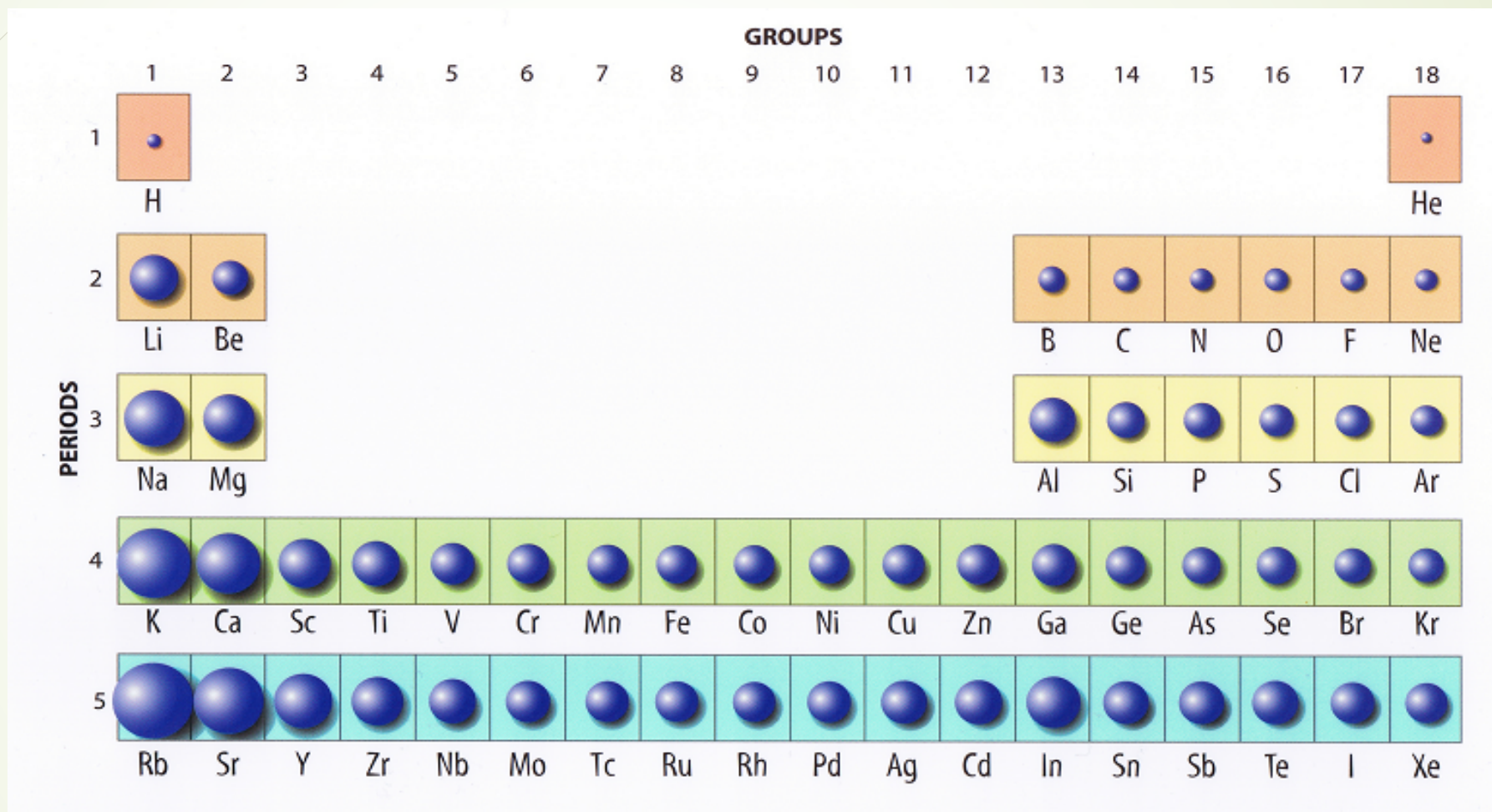
Iron isotopes

Examples

SYMBOL	Atomic Number	Mass Number	PROTON Number	NEUTRON Number	Charge	ELECTRON Number
${}^{208}_{82}\text{Pb}$	82	208	82	126	0	82
${}^{206}_{82}\text{Pb}^{+4}$	82	206	82	124	+ 4	78
${}^{35}_{17}\text{Cl}^{-1}$					- 1	
${}^{197}_{79}\text{Au}$						

Trends in Periodic Table

Trend is repeated with each period.



The size of atoms becomes smaller from left to right. *Hint: Coulomb Force and no. of electron shells!*

Trends in Periodic Table



Nonmetals



Metals



Metalloids

	1 IA																			18 VIIIA	
1	1 H 1.00794																				2 He 4.0026
2	3 Li 6.941	4 Be 9.0122																			
3	11 Na 22.9898	12 Mg 24.305																			
			3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB									
4	19 K 39.0983	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80			
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc [98]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29			
6	55 Cs 132.905	56 Ba 137.327	57 La* 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]			
7	87 Fr [223]	88 Ra [226]	89 Ac** [227]	104 Rf [261]	105 Db [262]	106 Sg [263]	107 Bh [264]	108 Hs [265]	109 Mt [268]												

*Lanthanides

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
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**Actinides

90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237]	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]
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