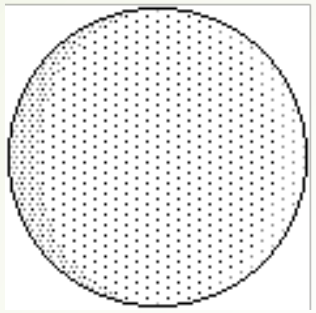
Atoms and Energy

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
- Atomics Number and Atomic Mass
- Isotopes
- Trends in Periodic Table

Models of the Atom



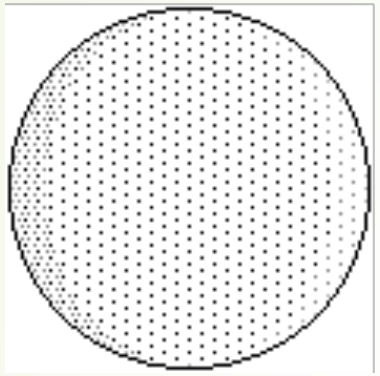
Greeks (500 BC) and Dalton (1803)

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.

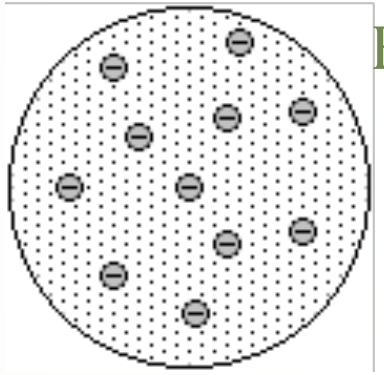
Dalton used the results of **experiments** in chemistry to revive this idea in the form of a theory that explained a huge number of experiments. Compounds were made by combining **atoms** of different **elements** in particular ratios.

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

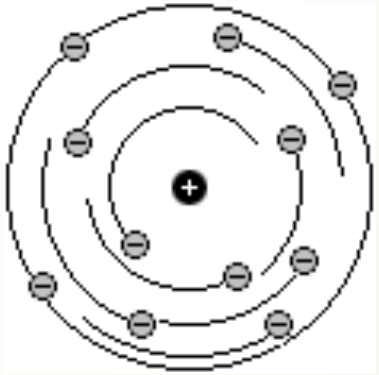
History of Early Atomic Models



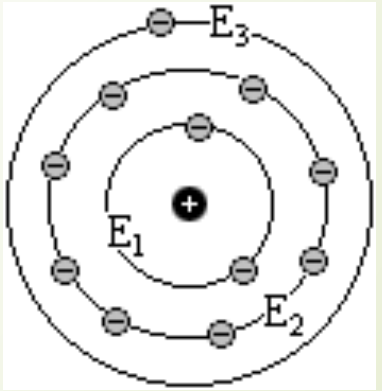
Solid sphere: Dalton (1803)



Electron discovered (1897)



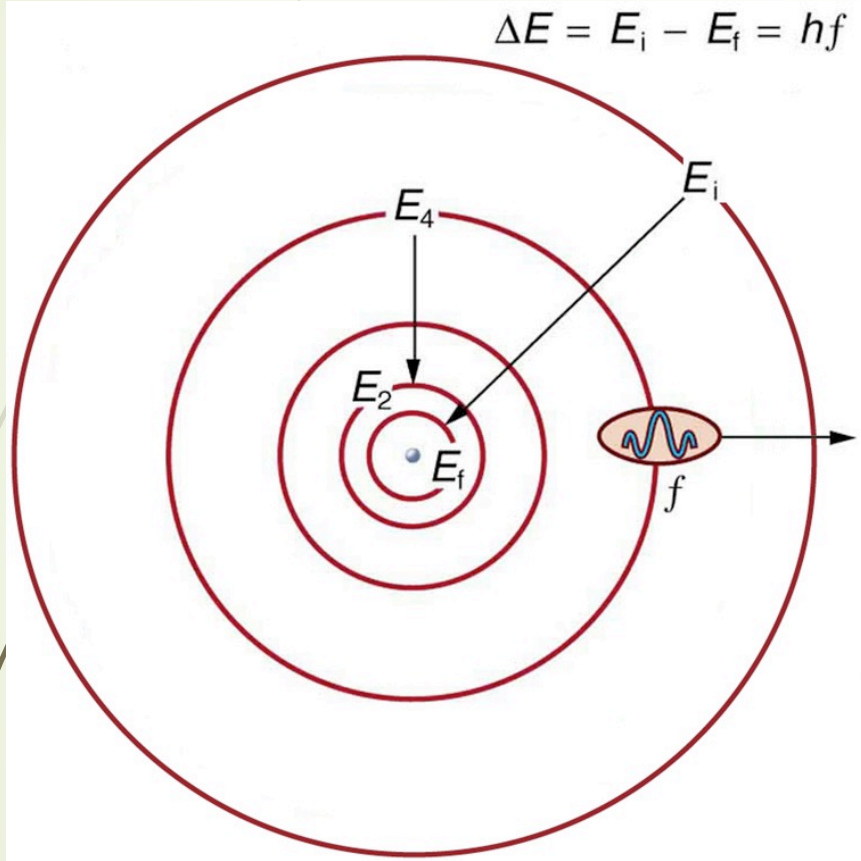
Rutherford experiment (1911)

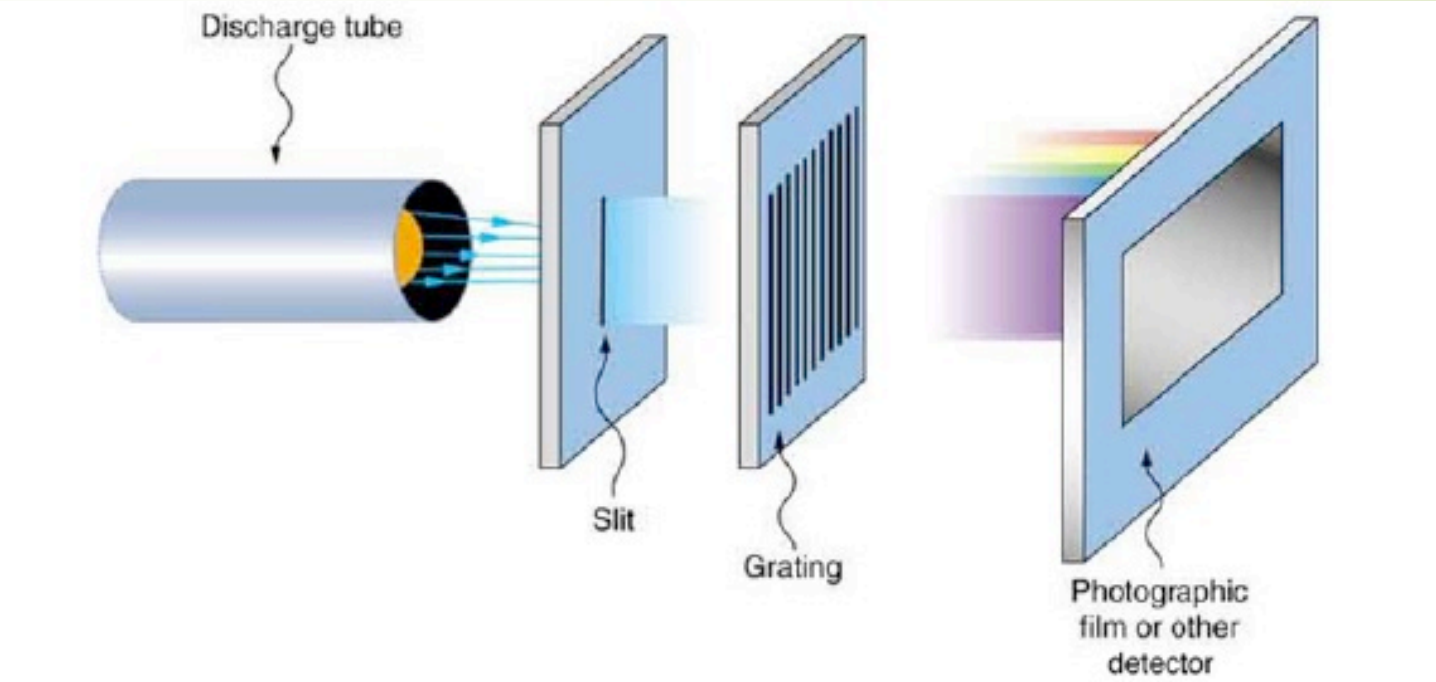


Electrons in specific energy levels: Bohr (1913)

Light emission spectra from atoms

explained by the Bohr model "jumps"

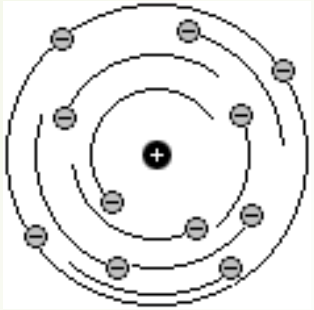




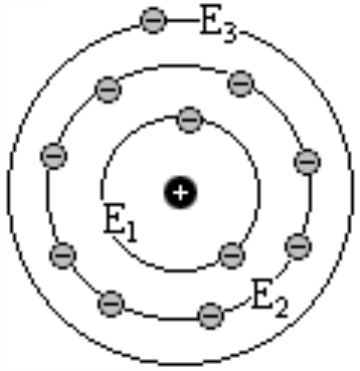
Emission line spectrum for Hydrogen

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

Development of "Modern" Models



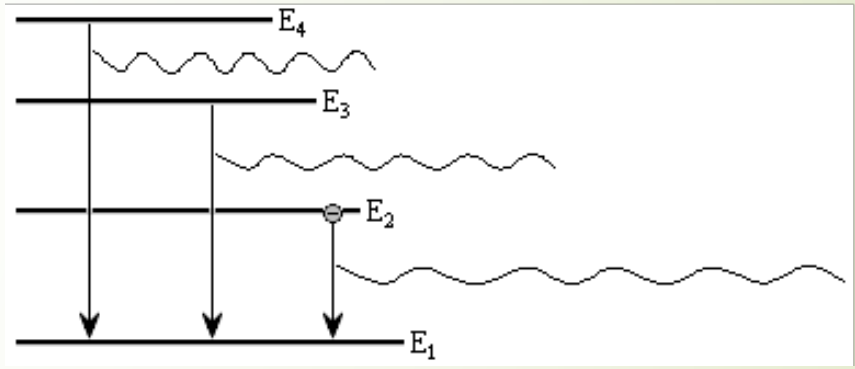
Rutherford (1911)



Bohr (1913)

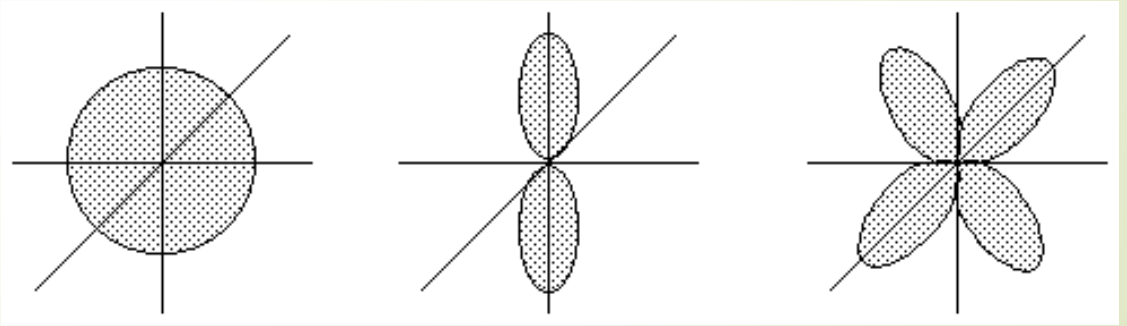
$$\Delta E = hf = E_i - E_f$$

$$E_n = -\frac{Z^2}{n^2}E_0$$

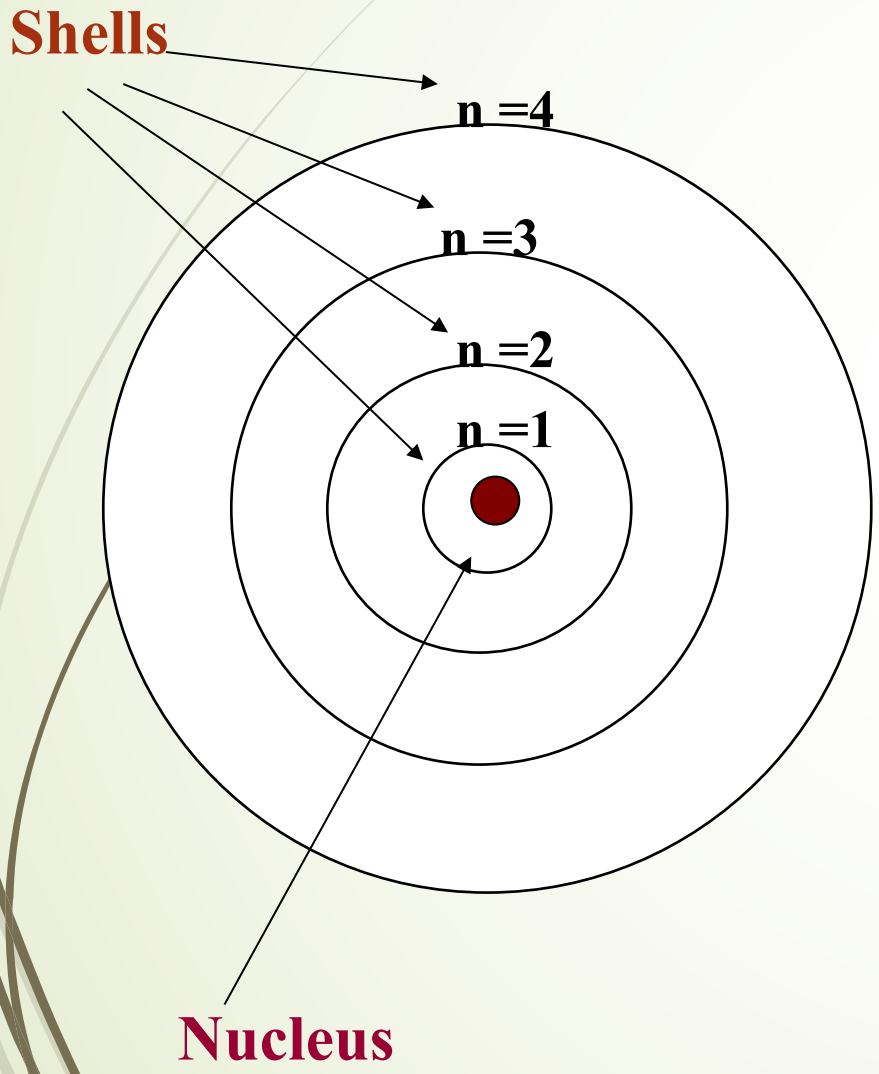


Quantum Mechanics:

Same energy levels but matter wave probabilities (1925)



Atomic Structure

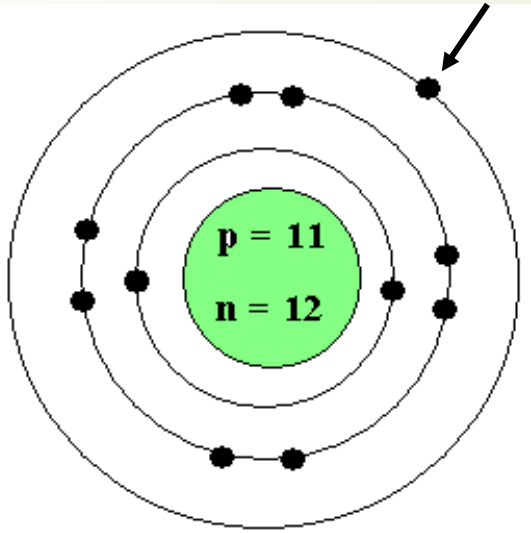


Outermost electron - Valence electron

Na atom

$^{23}_{11}Na$

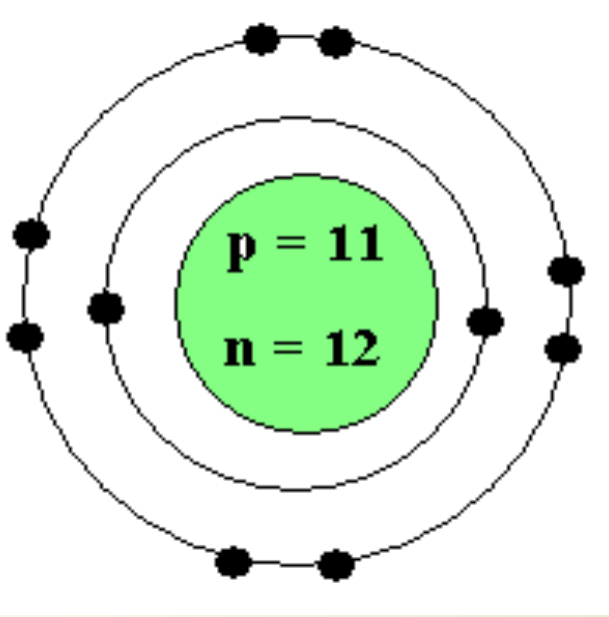
11 electrons



Na ion

$^{23}_{11}Na^{+1}$

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

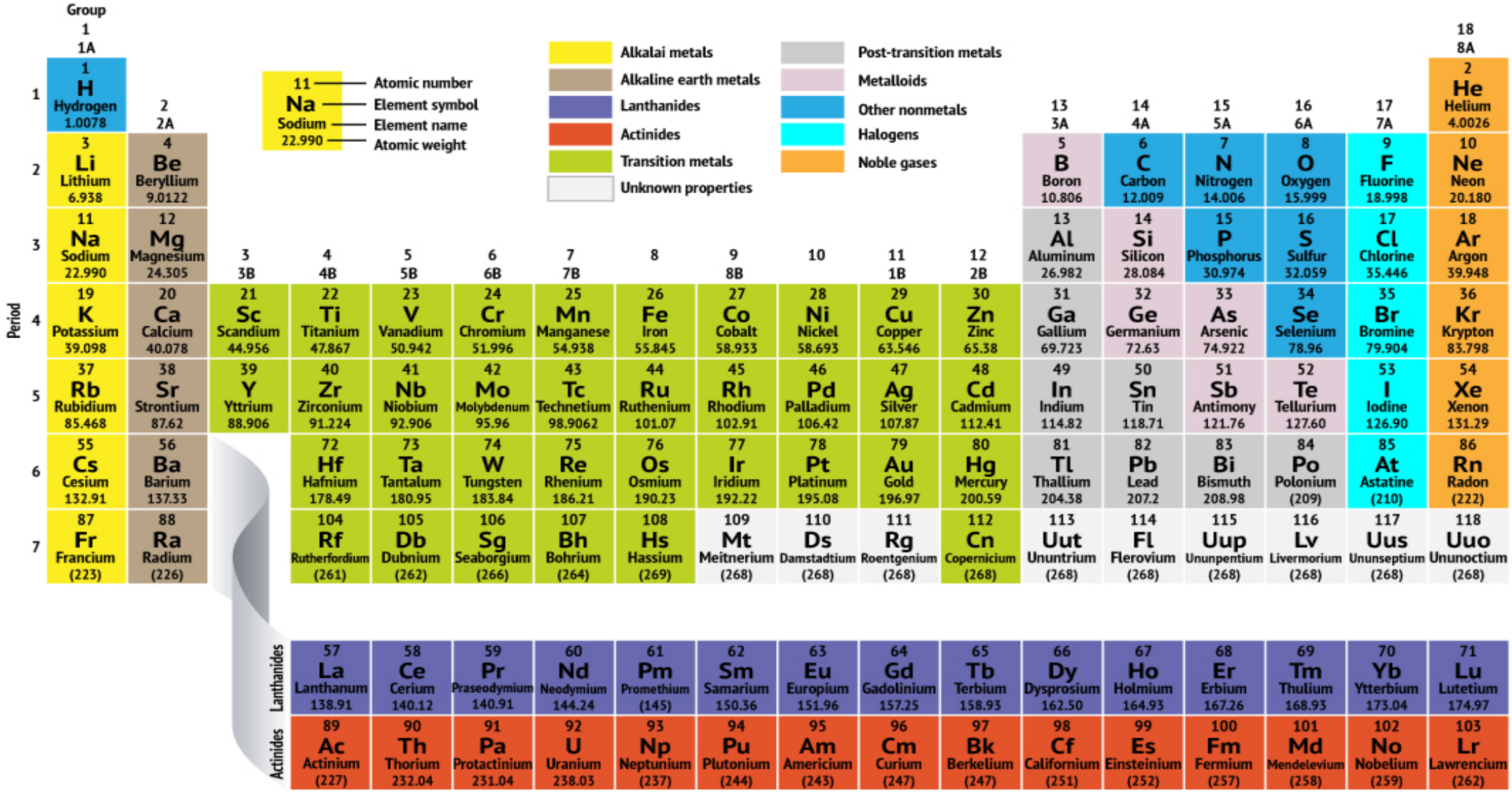
Electrons fill distinct energy “shells” and each row corresponds to the filling of a shell.

	1A	2A	3B	4B	5B	6B	7B	8B		1B	2B	3A	4A	5A	6A	7A	8A
1	H																He
2	Li	Be										B	C	N	O	F	Ne
3	Na	Mg										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



SOURCES: National Institute of Standards and Technology, International Union of Pure and Applied Chemistry

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**.

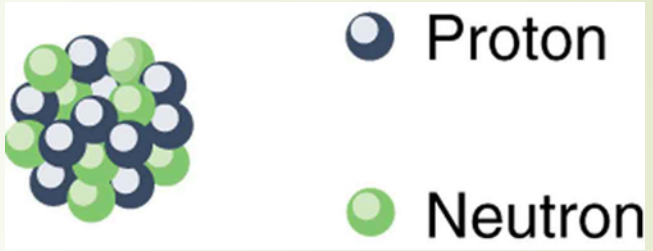
Atomic Mass

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.

$${}^{A}_{Z}\mathrm{X}_{N} \text{ or simply } {}^{A}\mathrm{X},$$

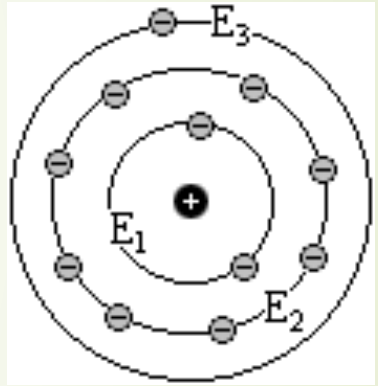
Atomic Nucleus

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	${}_{1}^{1}\mathrm{p}$	+1	1.00728 ~ 1
Neutron	${}_{0}^{1}\mathrm{n}$	0	1.00866 ~ 1
Electron	${}_{-1}^{0}\mathrm{e}$	−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

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

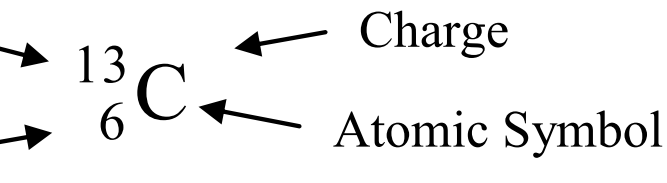
where, $r_0 = 1.2\ fm$. Nuclear volumes are proportional to mass number, *A*.

Atomic Symbols

$${}^{A}_{Z}\mathrm{X}_{N} \text{ or simply } {}^{A}\mathrm{X},$$

protons + # neutrons = Mass Number

protons = Atomic Number



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***

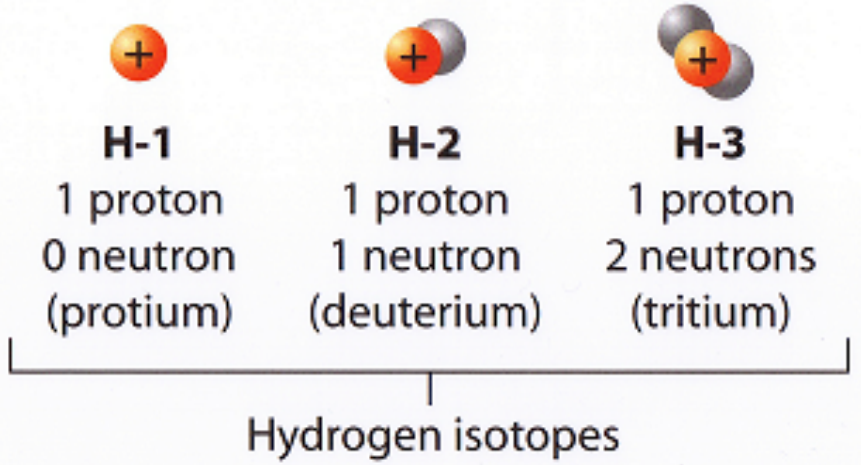
Mass number (protons+ neutrons)

Atomic number (protons)

$$^{1}_{1}H$$

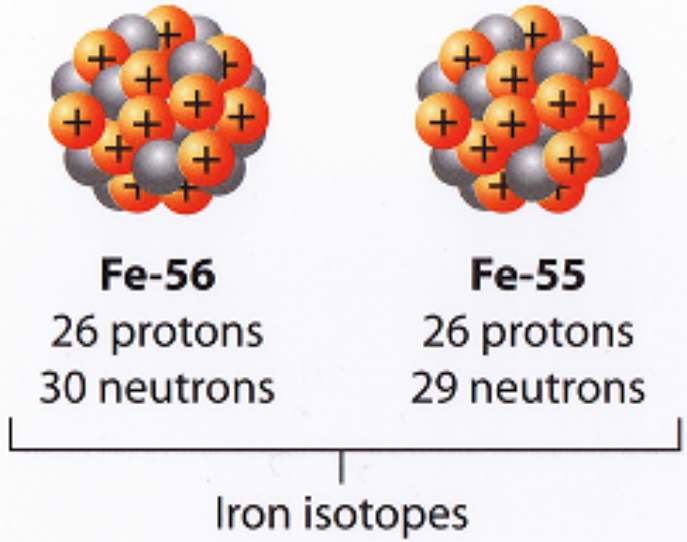
Atomic symbol Protium (normal hydrogen)

Hydrogen has three isotopes



Two isotopes of Iron

(26 protons + 29neutrons) $^{55}_{26}Fe$ **(26 protons + 30neutrons)** $^{56}_{26}Fe$

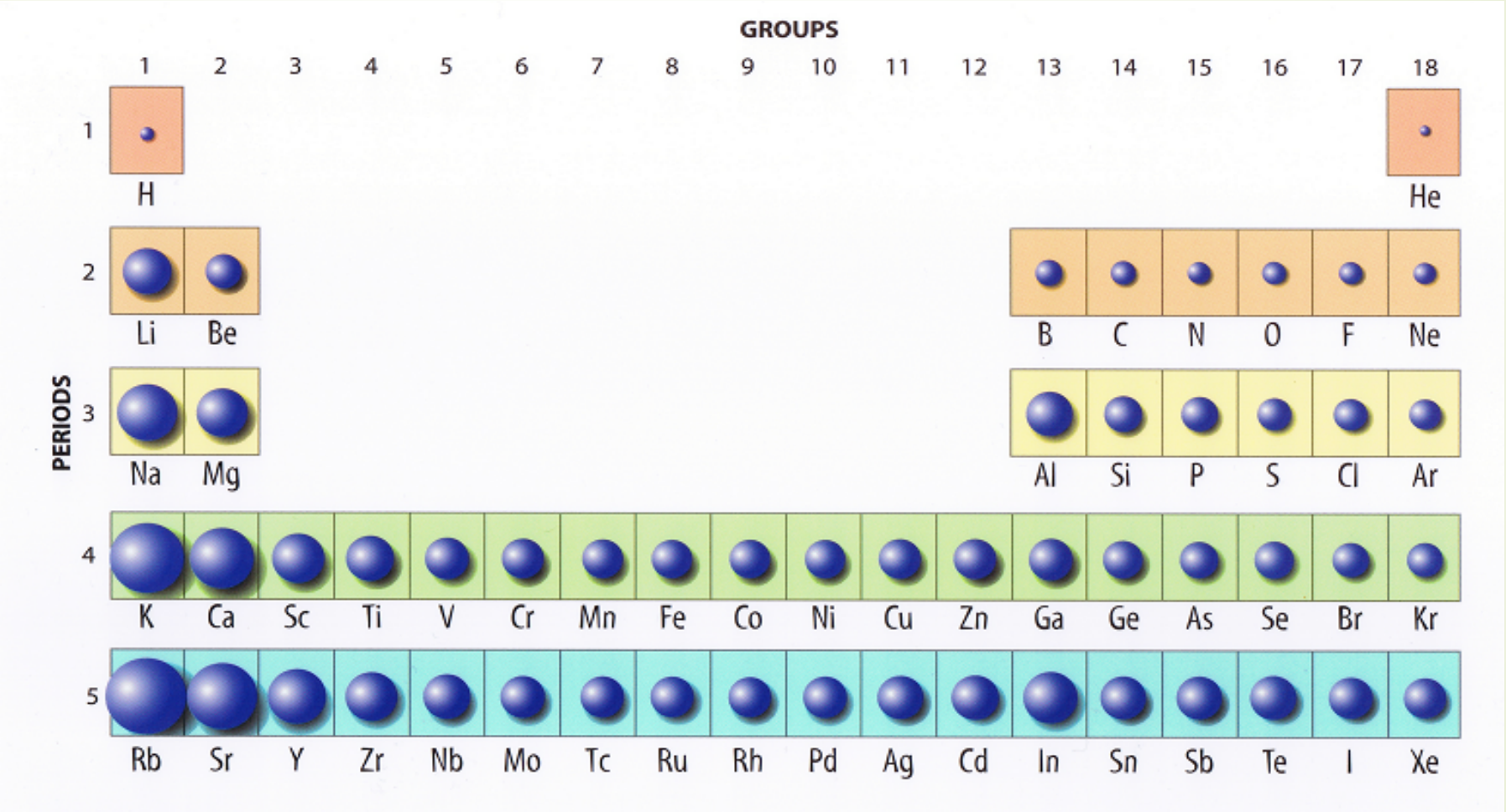


Examples

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

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