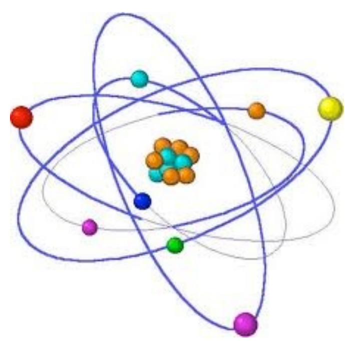
Ch03

Atomic Structure

Going inside the atom.

The discovery of subatomic particles and the structure atoms.



version 1.5

Ch03

Atomic Structure

- Faraday—Wandering Atoms
  - Electrical Charge
- JJ Thomson—Subatomic Particles
  - Electrical Charge
    - Ions, Cathode Rays, Millikan's Oil Drop
  - The Electron
  - Atomic Theory 3.0 — Plum Pudding
- Radioactive Matter
- Rutherford—the Nuclear Age
  - Radiation, Gold Foil, the Nucleus
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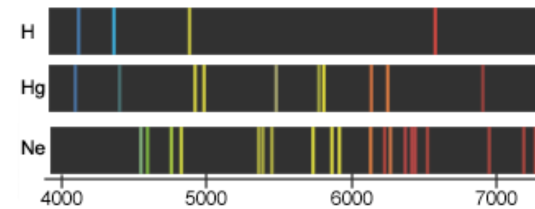
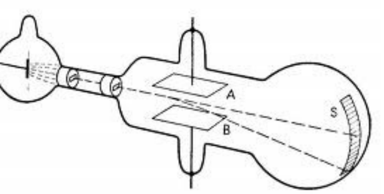
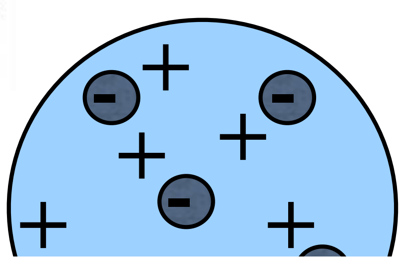
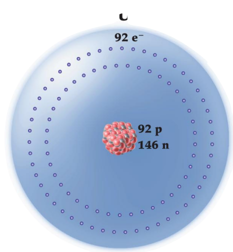
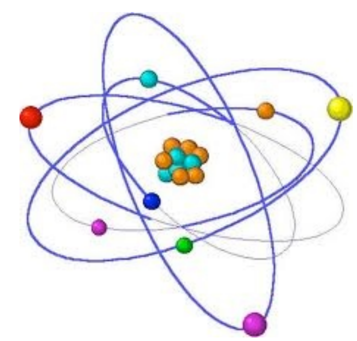
    - Isotopic Notation



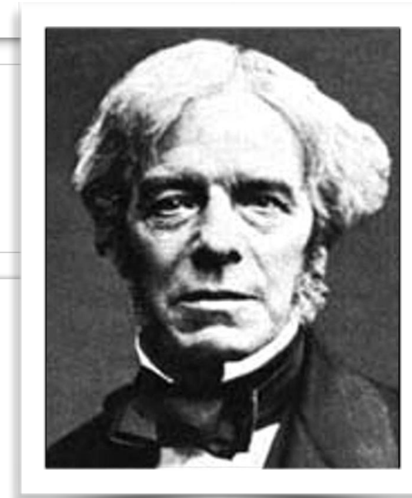








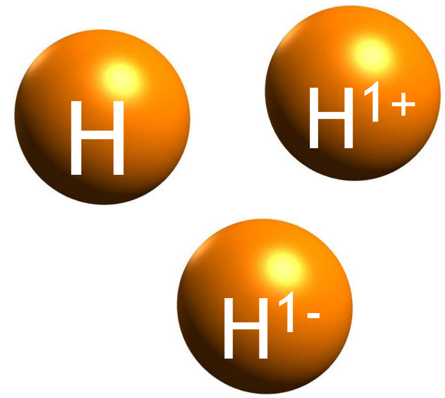
Ions vs Atoms

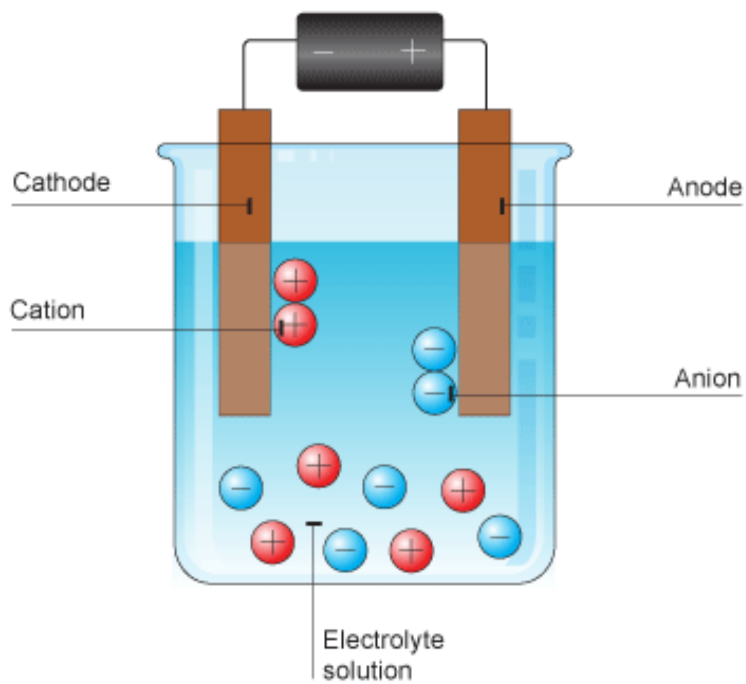

Faraday

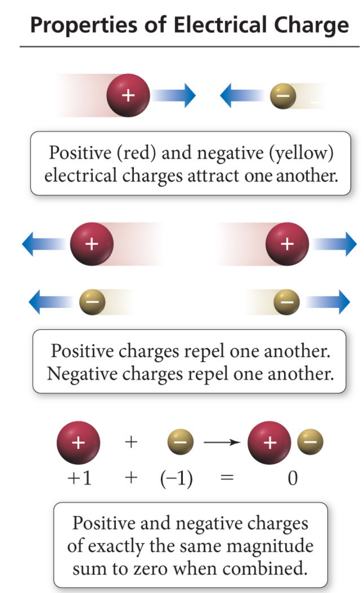
- Around the beginning of the 1900's chemists discovered some atoms could hold an electrical charge.
  - Charges can be positive or negative
  - Charges can be different sizes
- The properties of charged atoms were documented by Michael Faraday, who named them ions.
- Charged atoms move in solution, toward or away from electrically charged wires.
  - The word "ion" is greek for wanderer.
  - Ions that move towards a cathode (neg charged wire) are positively charged ions.
    - They're called cations.

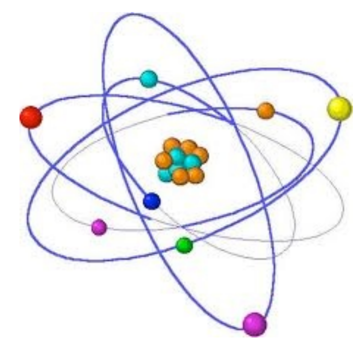
CA+IONS

  - Ions that move towards an anode (pos charged wire) are negatively charged ions.
    - They're called anions.
- Atoms and ions made from those same atoms have different properties.
  - Silver, Ag
    - Not soluble in water
    - Not attracted to magnets
  - Silver Ions, Ag^{1+}
    - Soluble in water
    - Attracted to magnets

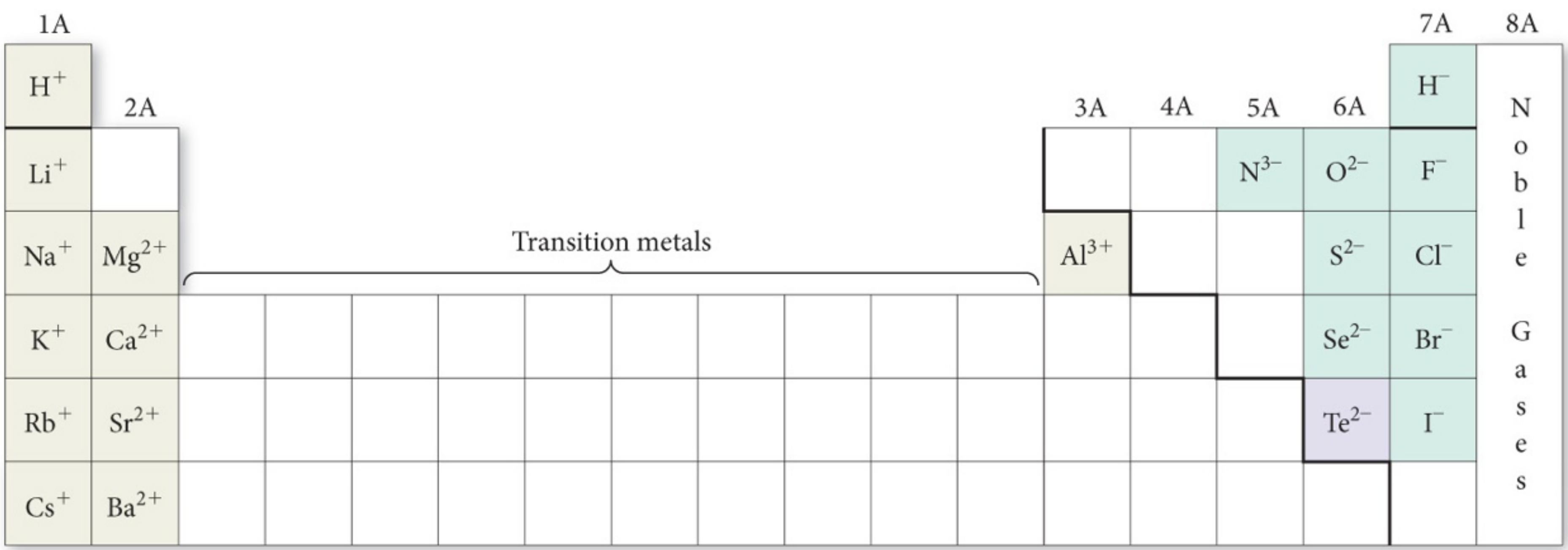








Many Ionic Charges are Predictable

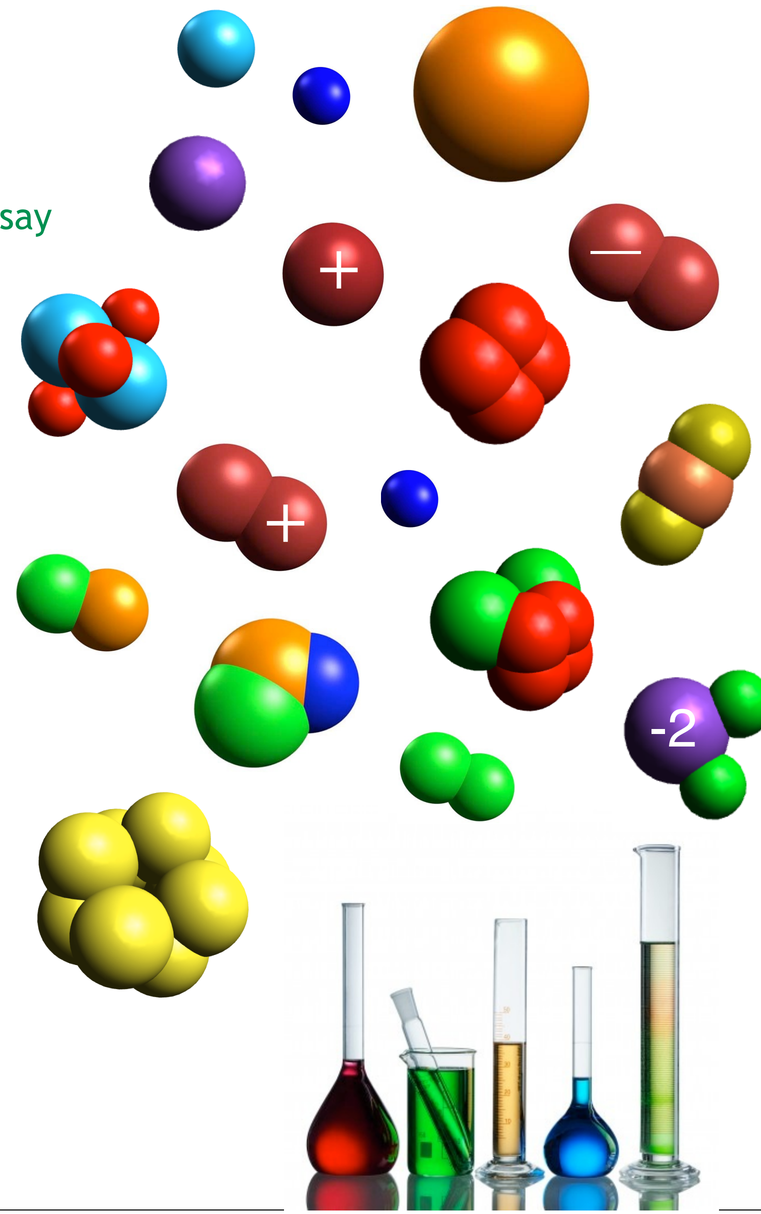


An Overview of Atomic Particles

We will discuss the details of these differences in the next few chapters. For now, I just want to share the "big picture" with you.

This slide will reappear a lot.

- Matter is made up of particles.
  - Particle is a generic term for small pieces of matter. We say particle when we want to be vague or comprehensive.
- Matter is made up of either ions or molecules.
  - Ions are <u>charged</u> particles (+ or -).
  - Molecules are neutral particles (no charge).
- Ions and molecules are made up of atoms.
  - Monatomic particles are just a single atom.
  - Diatomic particles are particles made of two atoms.
  - Polyatomic particles are made of more than two atoms.
- Atoms come in 118 flavors (elements).
  - If a sample of matter contains only one flavor atom, we say that sample is an element.
    - Yes, we use the word element two ways!
  - If a sample of matter contains two elements we say it is a binary compound or just a compound.
  - If a sample of matter contains more than two elements we say that sample of matter is a compound.



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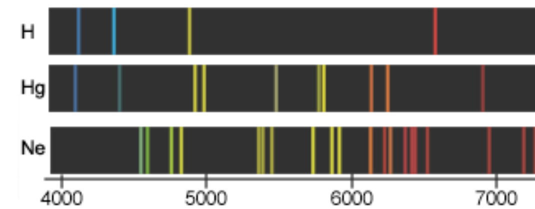

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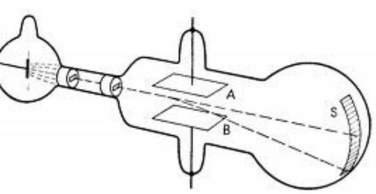
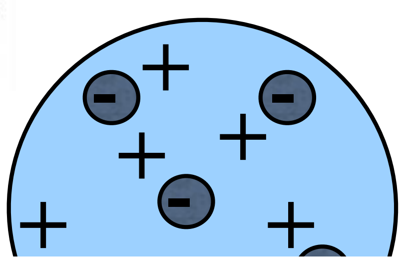
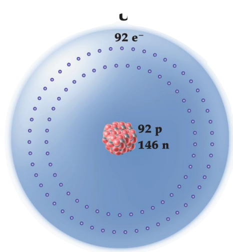
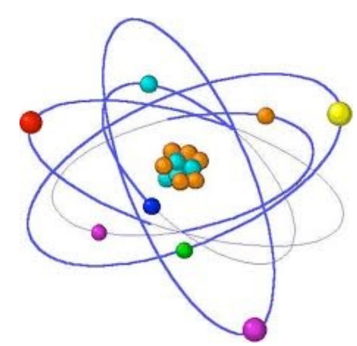


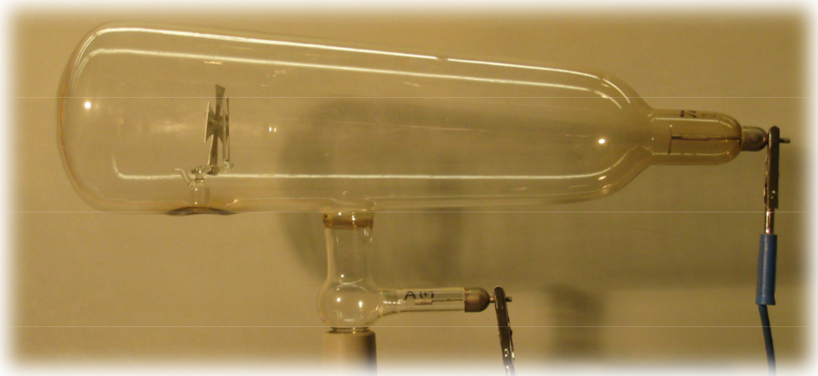


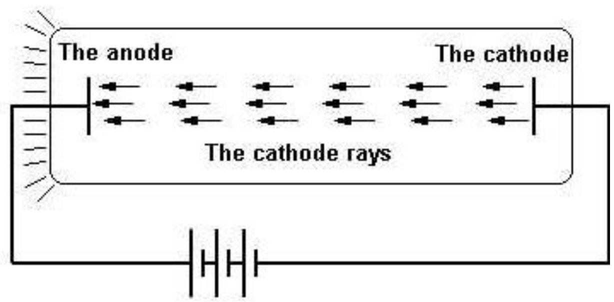


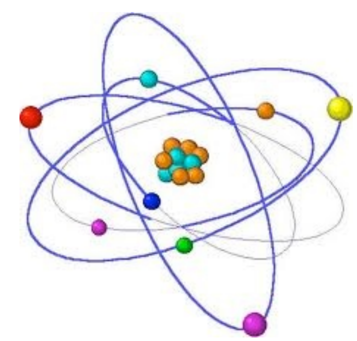


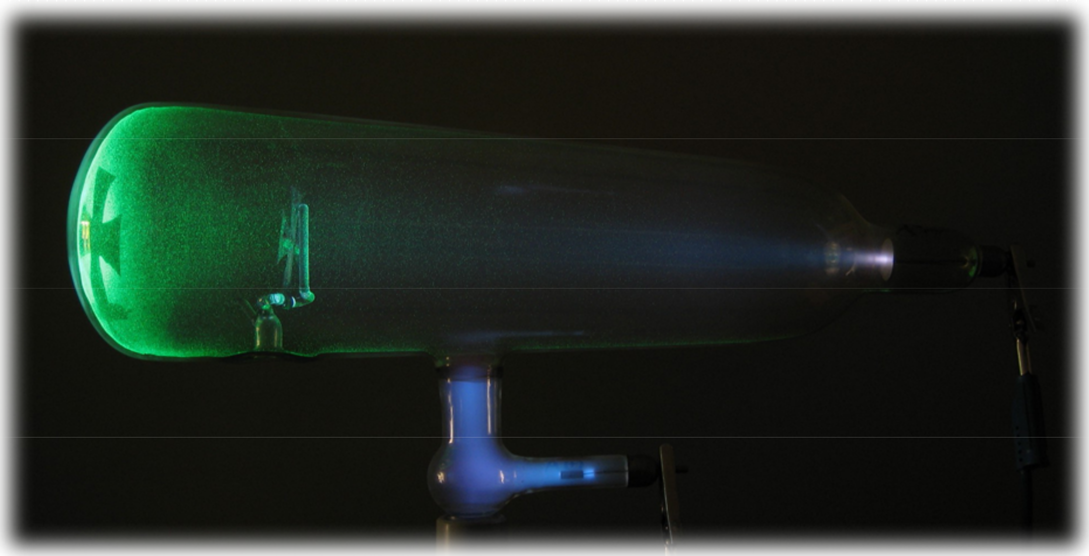
Cathode Ray Experiments

- Near the start of the 1900s electricity was one of the most exciting discoveries being explored in science.
- One electrical experiment conducted by many scientists was the exploration of cathode ray (or Röntgen ray) tubes.
- Cathode ray tubes are vacuum tubes with embedded wires, where an electrical charge is placed across the tube.
  - Different tubes were charged with different elemental gases, after being evacuated.
  - Properties of Cathode Rays
    - Travel in straight lines.
    - The ray is negatively charged.
    - The same rays come from all of the different elements explored.
    - The rays had mass (they can make a pin wheel spin).

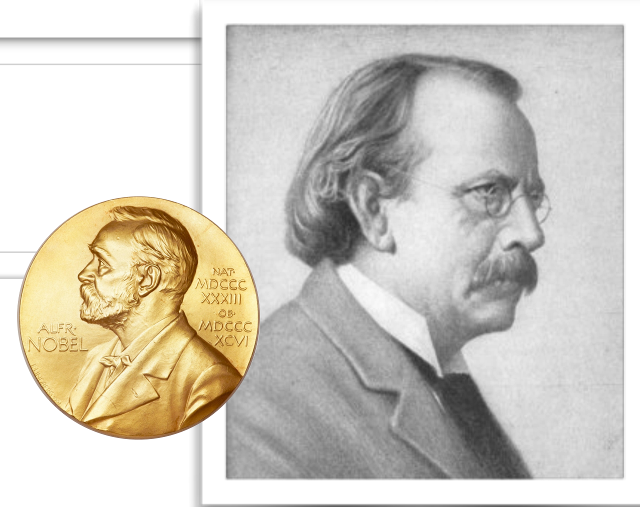








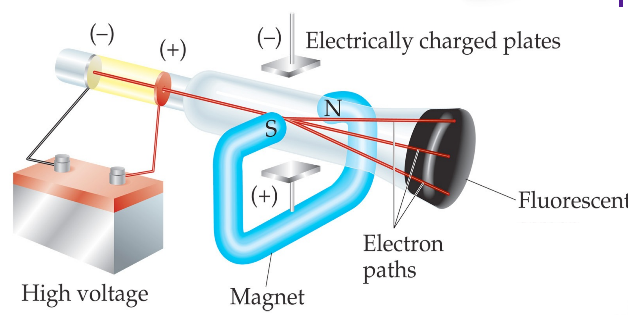
J.J. Thomson



Thomson

- Joseph John Thomson observed cathode rays in 1897.
  - Thomson hypothesized that atoms were composed of minute charged particles of mass.
  - He hypothesized that cathode rays were a stream of these small particles,
  - In seeking to demonstrate this, he observed cathode rays from various elemental gases and their behavior in electric fields.
  - He was able to demonstrate cathode ray particles have a charge to mass ratio of...

$$-1.76 \times 10^{8} \frac{C}{g}$$

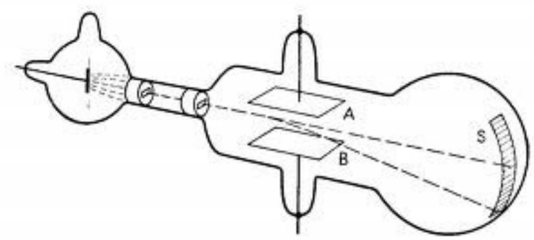


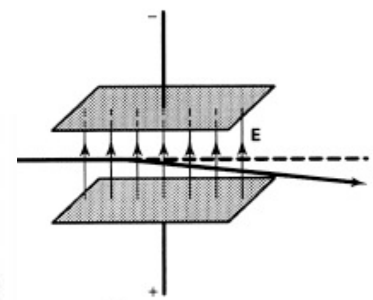
  - From the 1906 Nobel presentation speech:

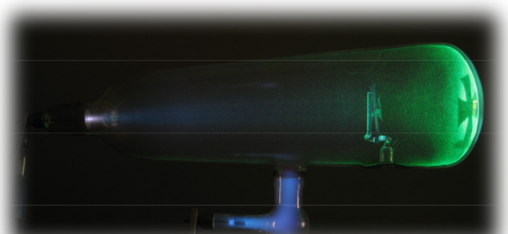
    “Every day that passes witnesses electricity obtaining an ever-increasing importance in practical life. The conceptions, which a few decades ago were the subject of investigation in laboratories, have by this time become the property of the public at large. ...

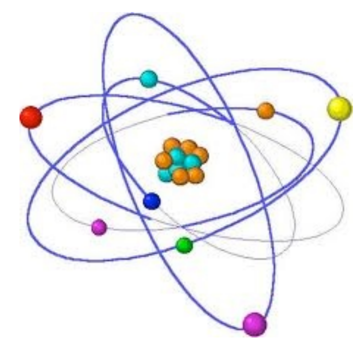
    Faraday's law may be expressed thus, that a gram of hydrogen, or a quantity equivalent thereto of some other chemical element, carries an electric charge of 28,950 x 10^{10} electrostatic units. Now if we only knew how many hydrogen atoms there are in a gram, we could calculate how large a charge there is in every hydrogen atom. ...

    If Thomson has not actually beheld the atoms, he has nevertheless achieved work commensurable therewith, by having directly observed the quantity of electricity carried by each atom.”







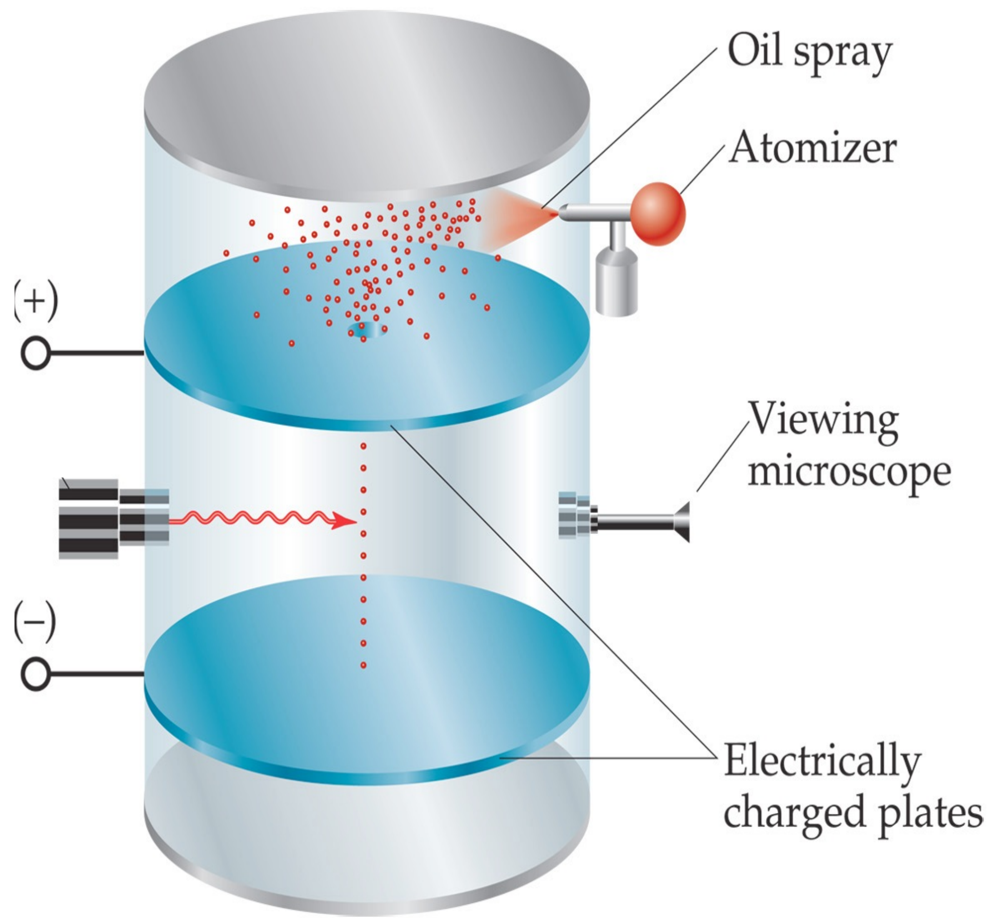


- In 1906 J.J. Thomson was awarded the Nobel prize "in recognition of the great merits of his theoretical and experimental investigations on the conduction of electricity by gases”.

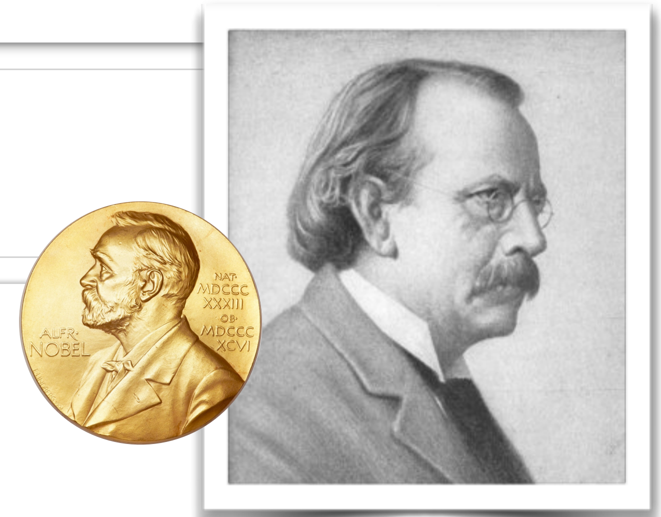
The Oil Drop Experiment

Millikan

- Robert Millikan experimented with oil drops in 1909:
  - He charged oil drops with cathode ray particles.
  - He determined the mass and charge of minute oil drops by suspending them between electrically charged plates.
    - By measuring the diameter of the drop he could calculate it’s size and therefore it’s mass. He therefore knew how much force gravity applied.
    - By carefully tuning the electrical field to provide just enough electrical force to offset the force of gravity he could determine it’s charge.
  - He recorded data for tens of thousands of oil drops.
  - He found every drop he created had a charge that was a multiple of 1.60×10^{-19}
  - He reasoned that the charge on a single cathode ray particle must be at least as small as 1.60×10^{-19}
  - Milikan proposed that the fundamental unit of electrical charge was 1.60×10^{-19} C (coulombs)
- Robert Millikan was awarded the Nobel prize in 1923 for "for his work on the elementary charge of electricity and on the photoelectric effect.”

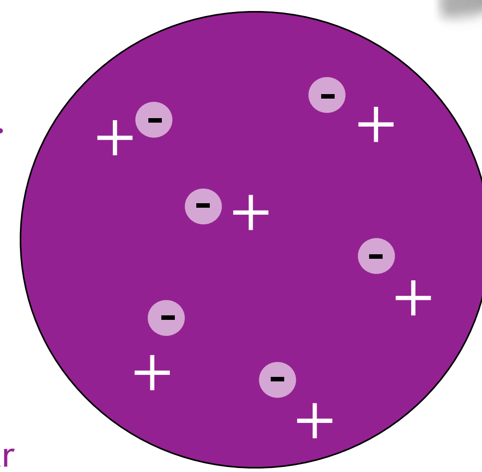


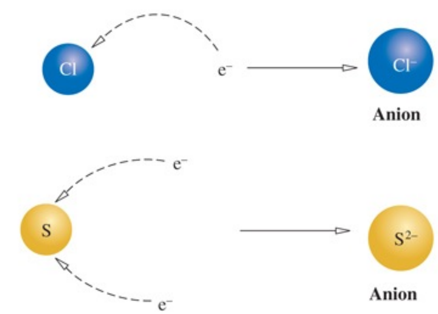
Atomic Theory 3.0

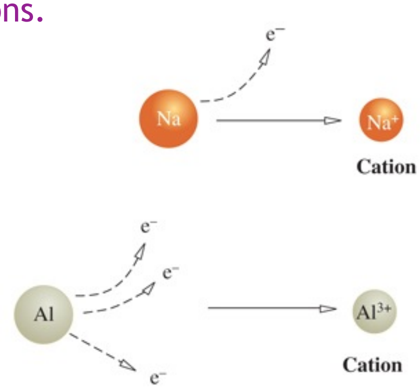


Thomson

- Combining Thomson's mass to charge ratio and Millikan's smallest unit of charge disproves the theory that the atom is the smallest particle of matter.
  - The mass of the cathode particles is 9.10×10^{-28} g
  - The smallest known particle was the hydrogen atom, it weighs 1.673×10^{-24} g — 2000 times heavier.
  - This demonstrated that there was something smaller than atoms.
  - … something from which atoms were built.
  - Thomson named this particle the electron.
- JJ Thompson proposed a new model of the atom (1903).
  - Proposed that atoms were positively charged spheres.
  - With embedded smaller negatively charged particles (electrons).
  - Thomson's Model was also called the plum pudding model (similar to the way raisins are embedded in plum pudding)
  - This improved model of the atom, explained the existence of ions.



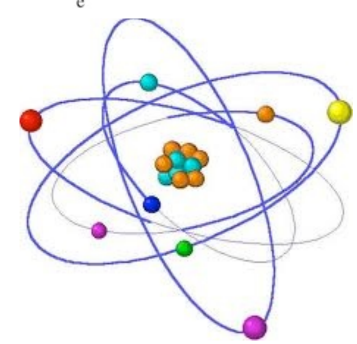




Dimensional Analysis

$$\text{charge} \times \frac{\text{mass}}{\text{charge}} = \text{mass}$$

$$-1.60 \times 10^{-19}\,\text{C} \times \frac{1\,\text{g}}{-1.76 \times 10^{8}\,\text{C}} = 9.10 \times 10^{-28}\,\text{g}$$



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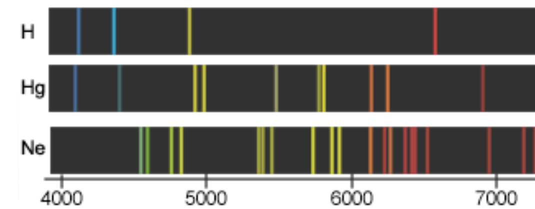
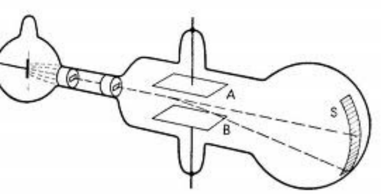
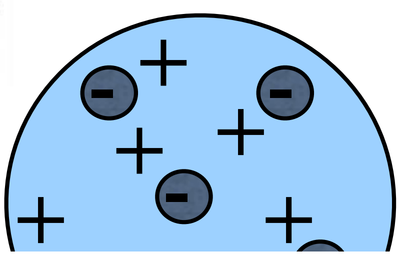
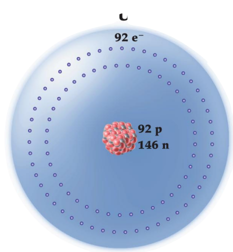
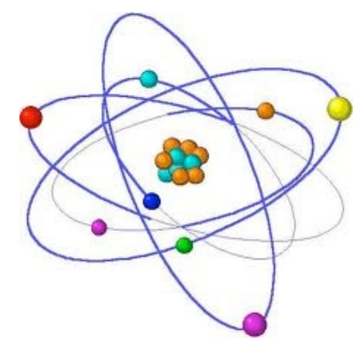






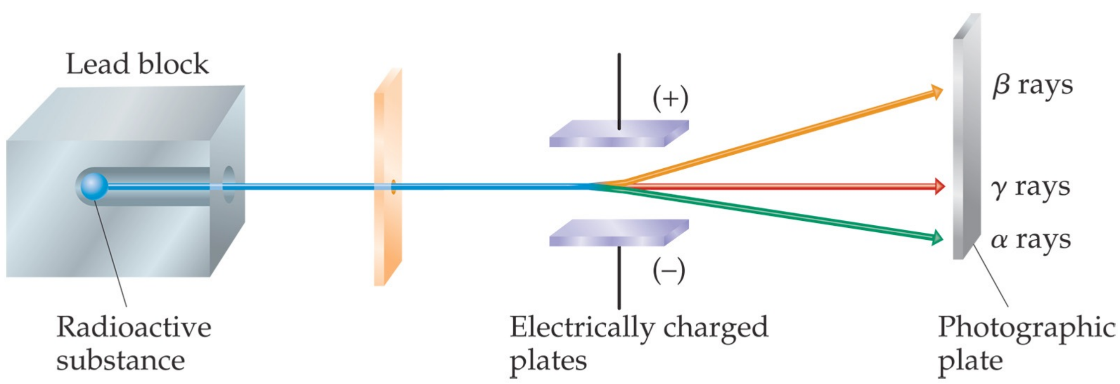


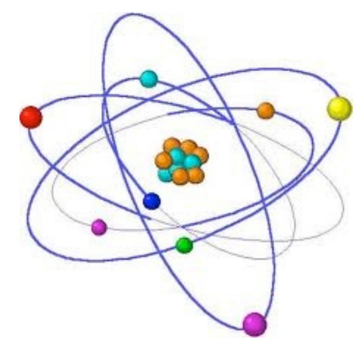


Radiation & Radioactivity

- Radiation is the emission of matter or energy.
- It can come from many sources.
  - Heating a wire produces radiant light (the lightbulb).
  - Running electricity through metal produces heat (stove).
- In 1986 Henri Becquerel discovered that some substances breakdown and emit radiation without any apparent cause.
  - No electricity, no heating… they just emit radiation.
  - Radioactivity is the property of a substance to spontaneously emit radiation.
- Marie and Pierre Curie identified, explored and documented many elements that are naturally radioactive.
- Ernest Rutherford discovered three forms of emissions that come from radioactive elements.
  - Gamma rays have no charge and and have no mass.
  - Beta particles have a negative charge, beta radiation like cathode rays, are a stream of electrons.
  - Alpha particles have a positive charge and as much mass as a helium atom. (four times the mass of a hydrogen atom)

	Mass	Charge
α particles	A Helium atom	positive
β particles	Electrons	negative
γ rays	none	none





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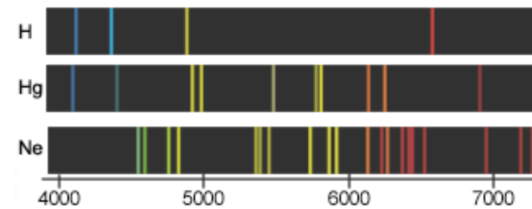
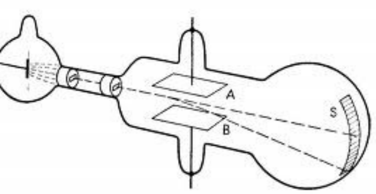
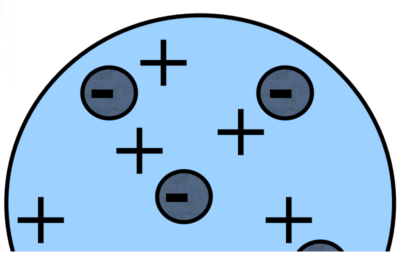
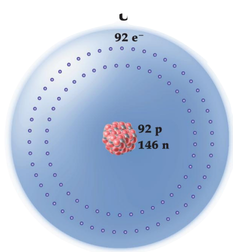
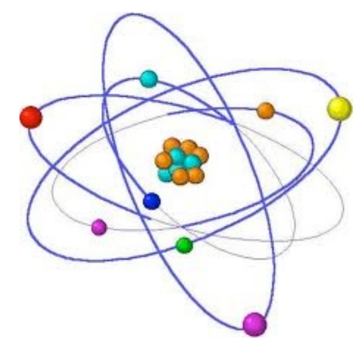


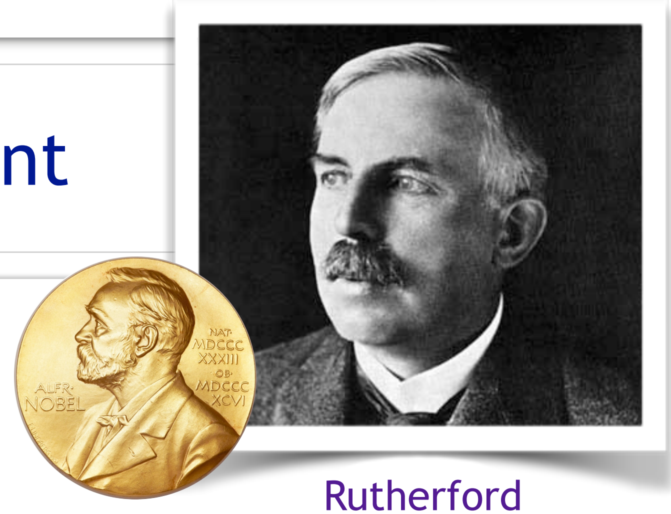






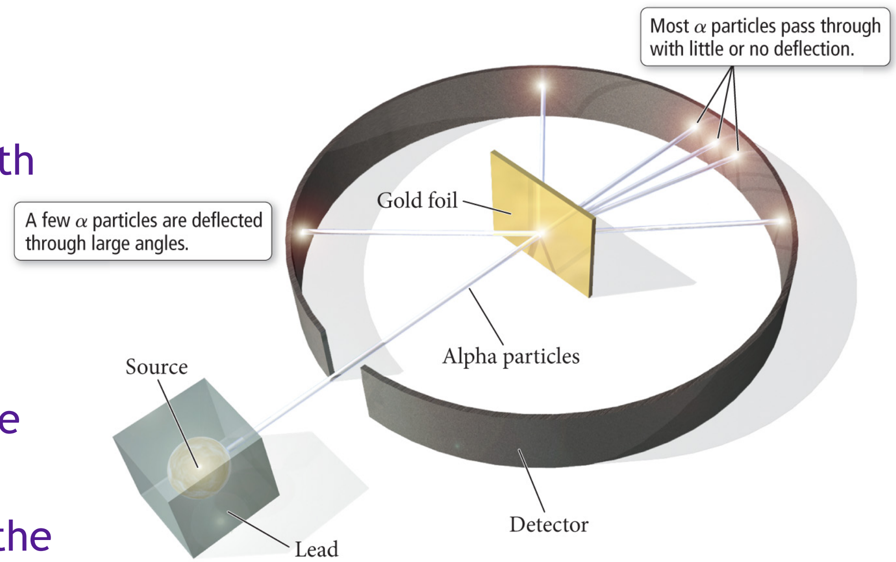


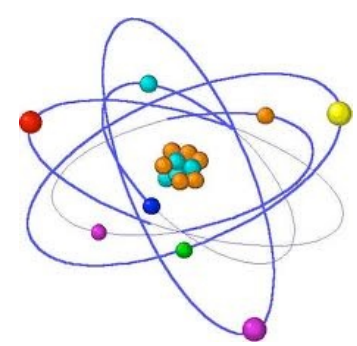
The Gold Foil Experiment



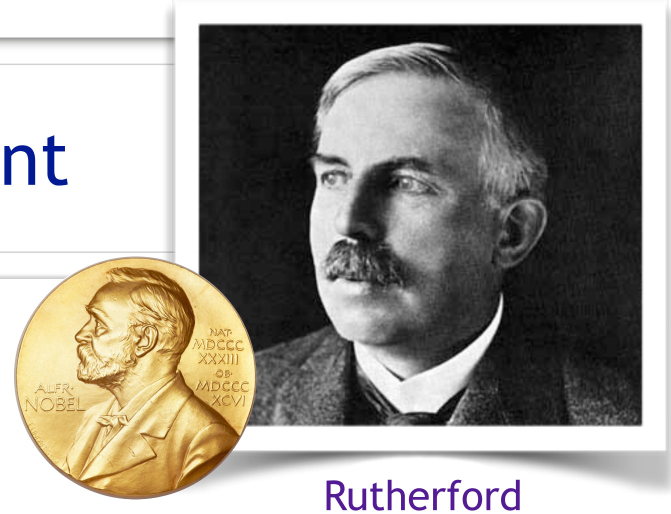
Rutherford

- Ernest Rutherford was a student of J.J. Thomson.
- In an attempt to support Thomson's plum-pudding theory of the atom Rutherford used alpha radiation to explore the structure of the atom.
  - His experiments disproved some of Thomson's theories,
- Rutherford shot a stream of alpha particles at a gold foil.
- Most of the alpha particles passed through the foil with little or no deflection.
- He found that a few were deflected at large angles .
- Some alpha particles even bounced back.
- An electron with a mass of 1/1837 amu could not have deflected an alpha particle with a mass of 4 amu.
- Because alpha particles have relatively high masses, the particles that bounced back led Rutherford to conclude that the nucleus was very heavy and dense.
- In 1908 Ernest Rutherford was awarded the Nobel prize "for his investigations into the disintegration of the elements, and the chemistry of radioactive substances".



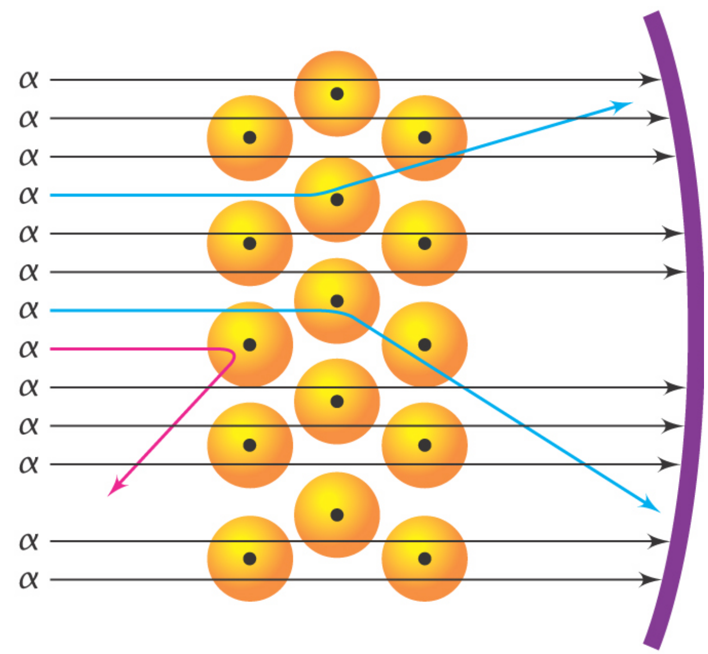


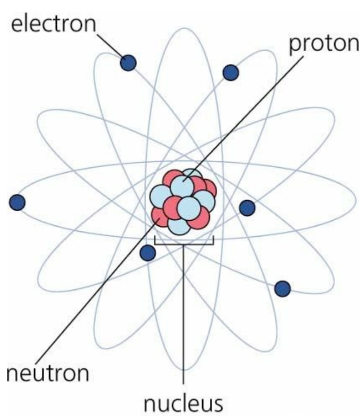
The Gold Foil Experiment

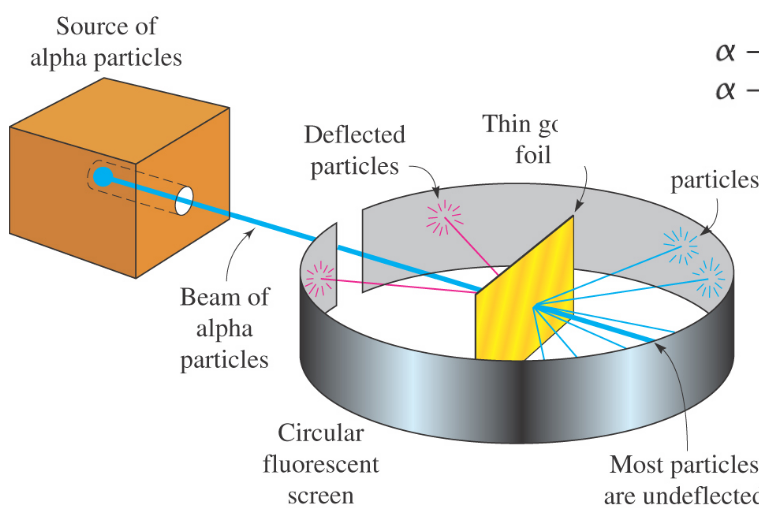


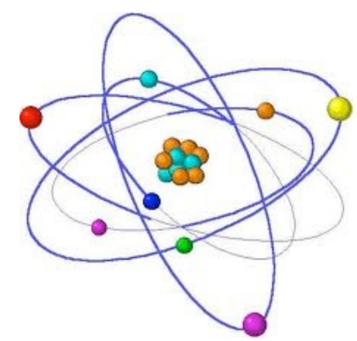
Rutherford

Observations		Hypothesis
Alpha particles mostly passed right through the gold.	→	Atoms are mostly empty space.
A small number bounced back.	→	There was something tremendously massive but very small inside the atom (more massive than a helium atom).
Some deflected as they passed through the atom..	→	The massive part was positively charged.



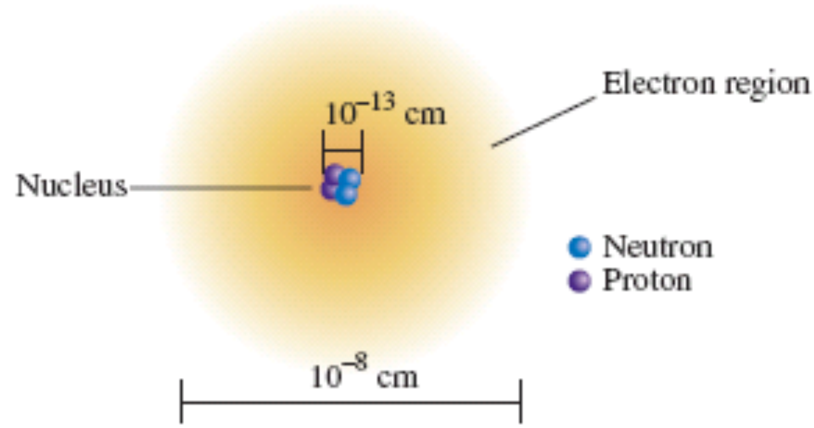


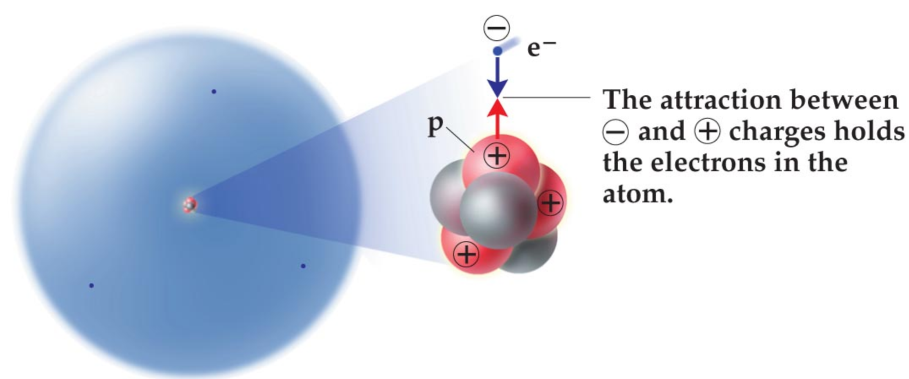


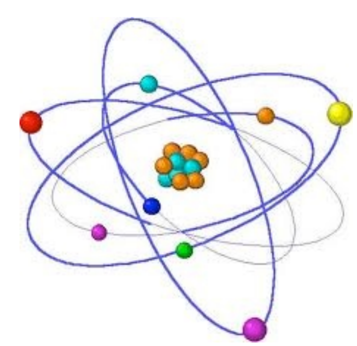


Atomic Theory 4.0 — The Nuclear Atom

- The smallest particle of an element that can enter into a chemical reaction is the atom.
- Atoms are neutral, containing the same number of positive and negative charges.
  - Atoms have a dense positively charged nucleus.
  - Electrons occupy the empty space outside the nucleus.
    - Ions are made by adding or removing electrons to produce a positive or negative net charge.
- Rutherford went on to explore the structure of the nucleous.
  - Rutherford discovered protons in 1919 (eight years after discovery of the nucleus)
    - Protons are positively charged particles 2000 times as massive as electrons.
  - Neutrons were discovered by James Chadwick in 1932.
    - Neutrons are slightly (0.1%) more massive than protons and have no charge.
  - The nucleus is composed of protons and neutrons.
  - A neutral atom contains the same number of electrons and protons.







Particle	Charge	Mass (amu)
Proton	Positive (1+)	1.0073
Neutron	None (neutral)	1.0087
Electron	Negative (1−)	5.486×10^{-4}

Ch03

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  - Electrical Charge
- JJ Thomson—Subatomic Particles
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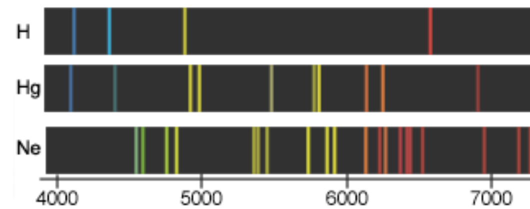
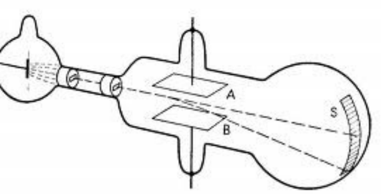
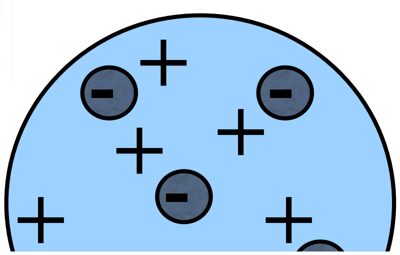
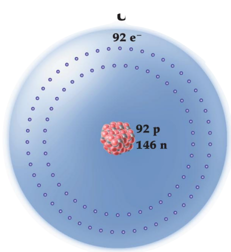
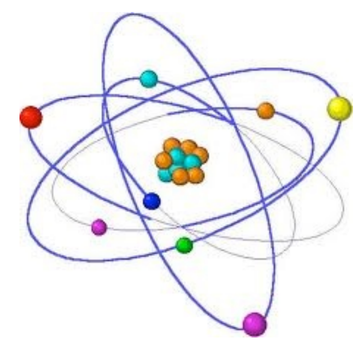


$^{A}_{Z}E$



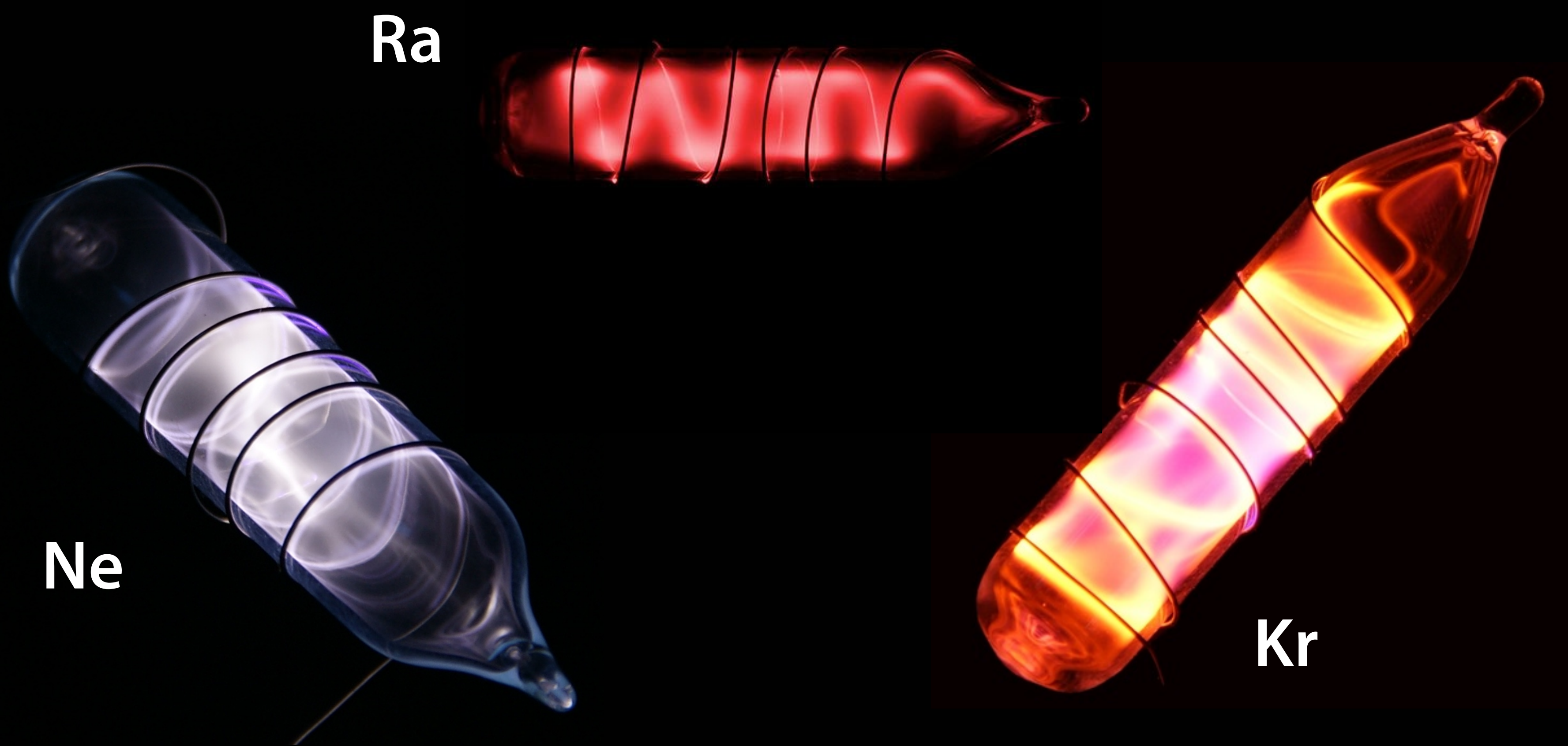


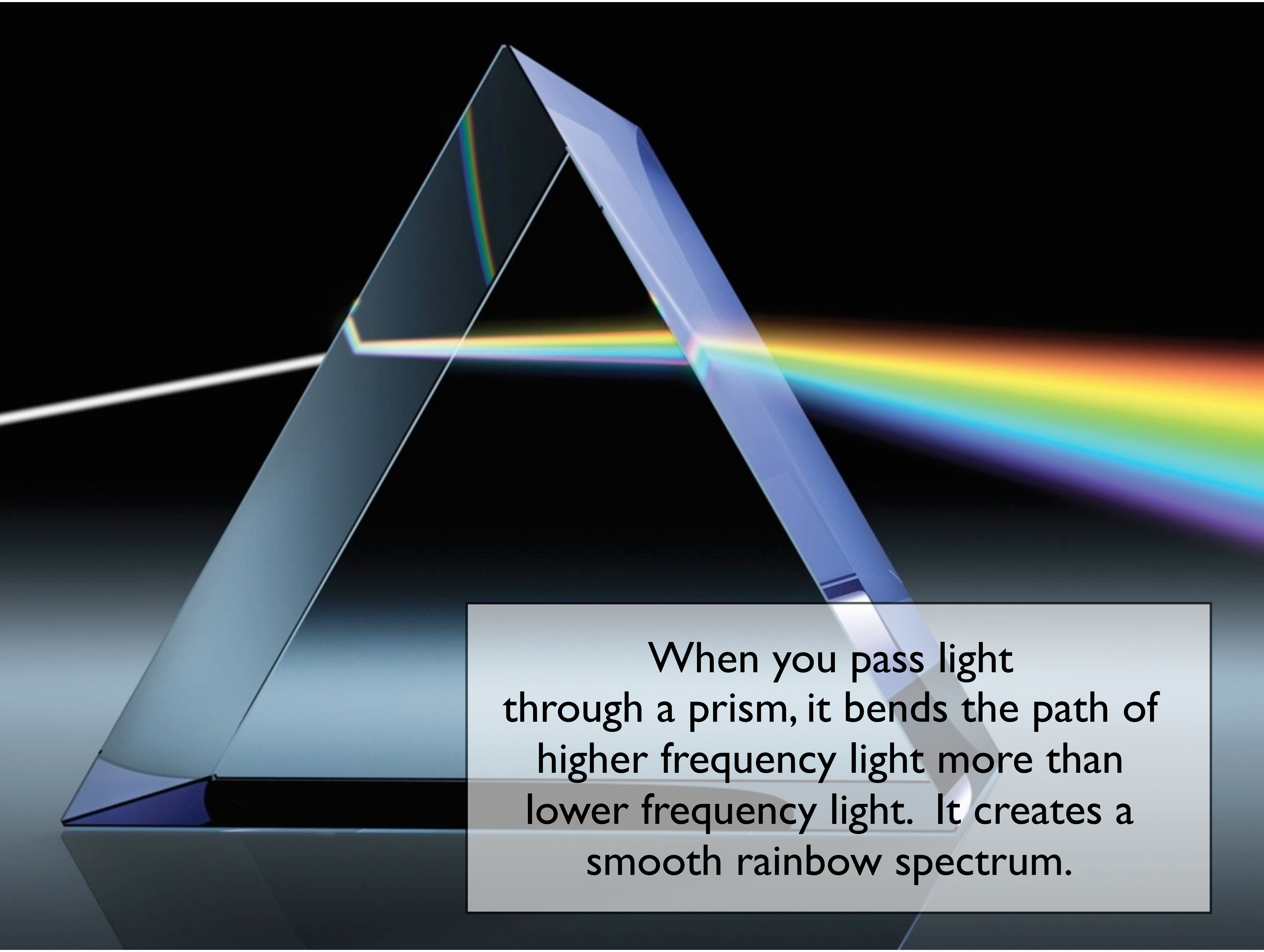


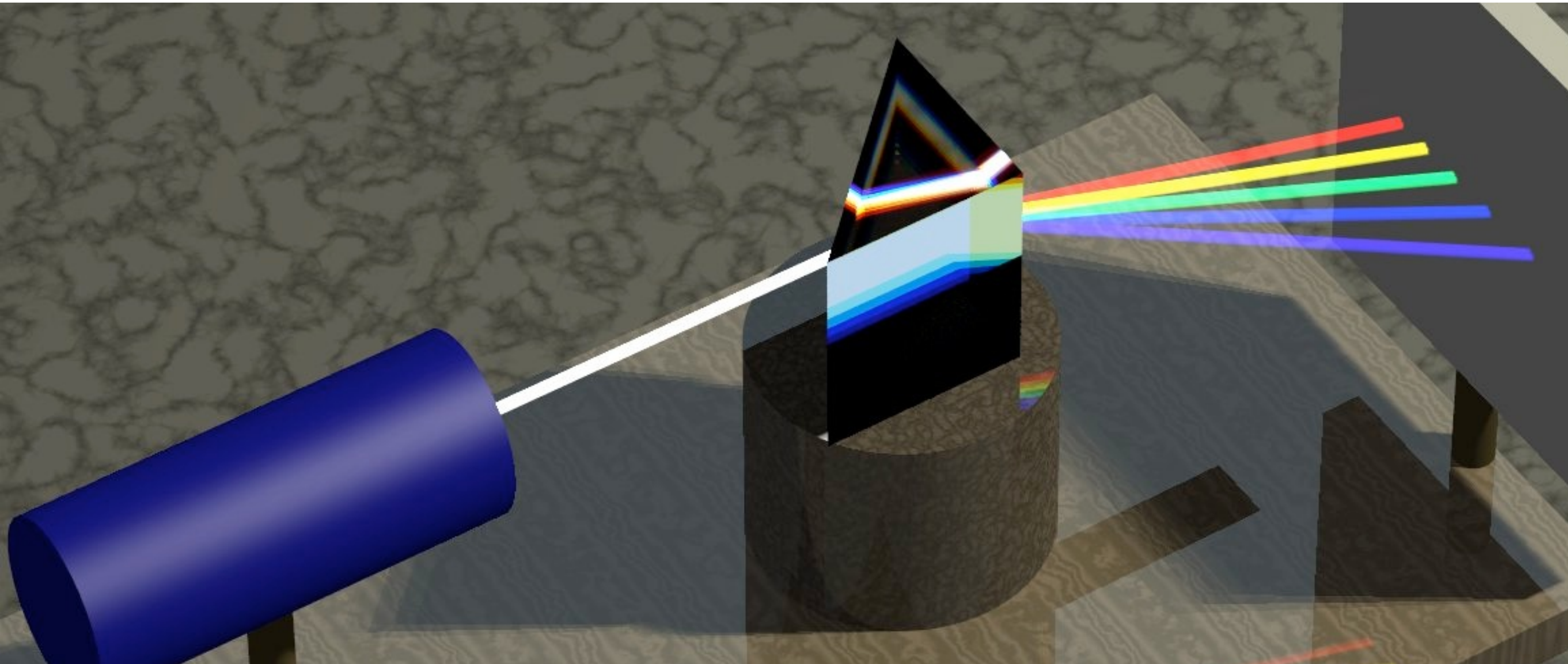


At high temperatures or voltages, pure elements in the gaseous state emit light of different colors.

There is something special about this light.

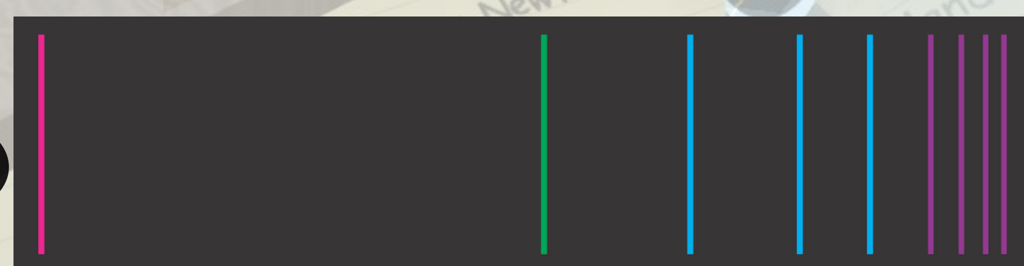



When you pass light
through a prism, it bends the path of
higher frequency light more than
lower frequency light. It creates a
smooth rainbow spectrum.



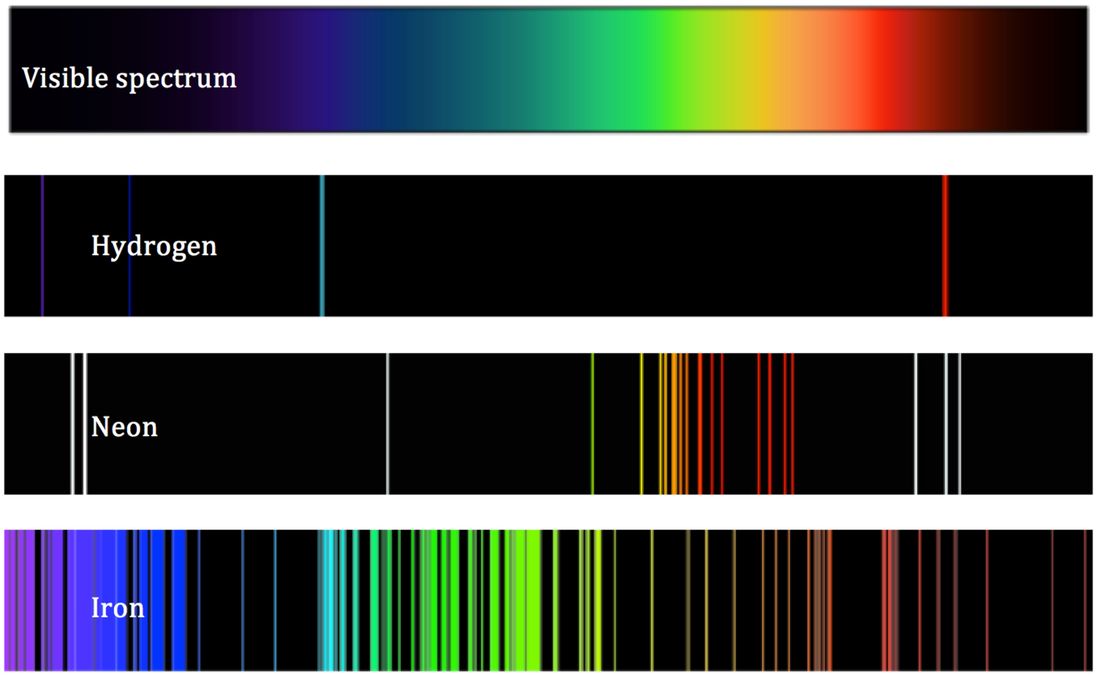
When the light of heated pure elements is passed through a prism or diffraction grating a line spectrum results. You get something that looks more like a computer readout than a rainbow.

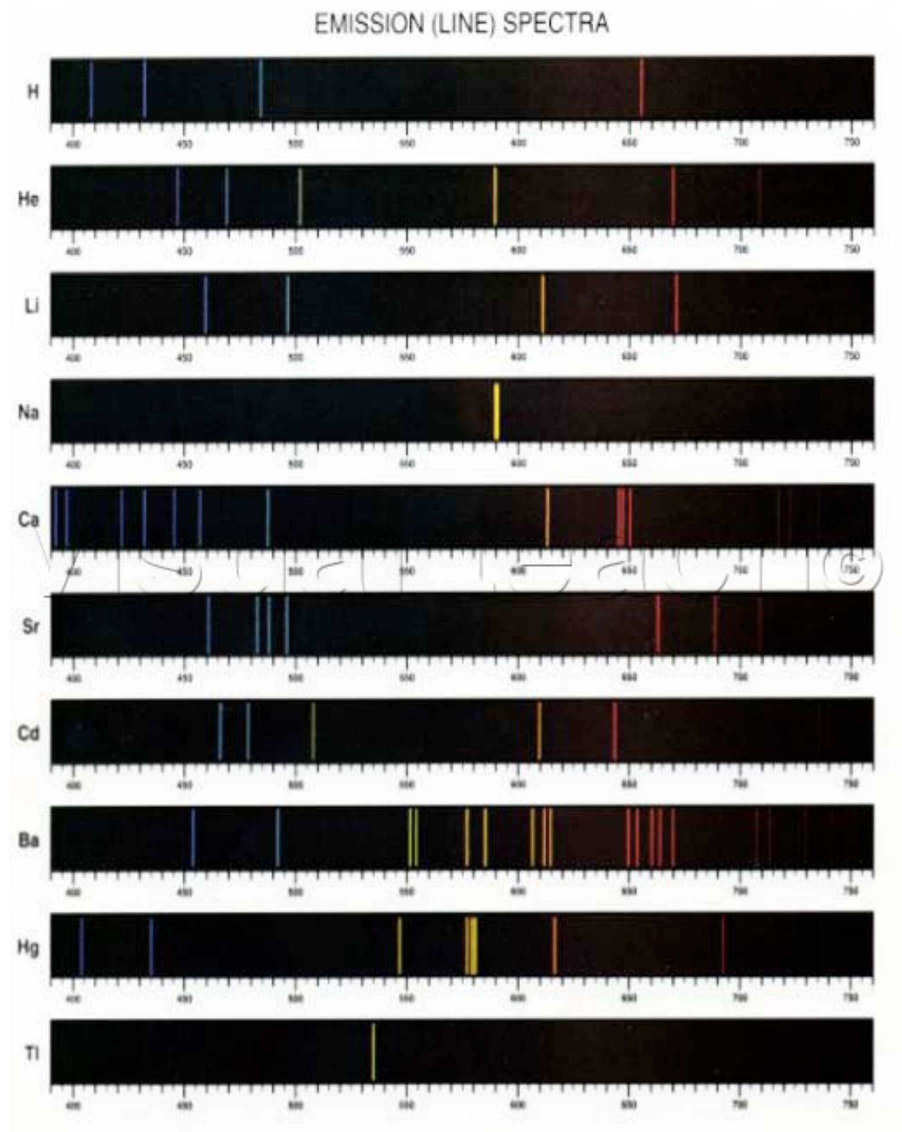
This demonstrates that only a few frequencies of light were in the original beam.

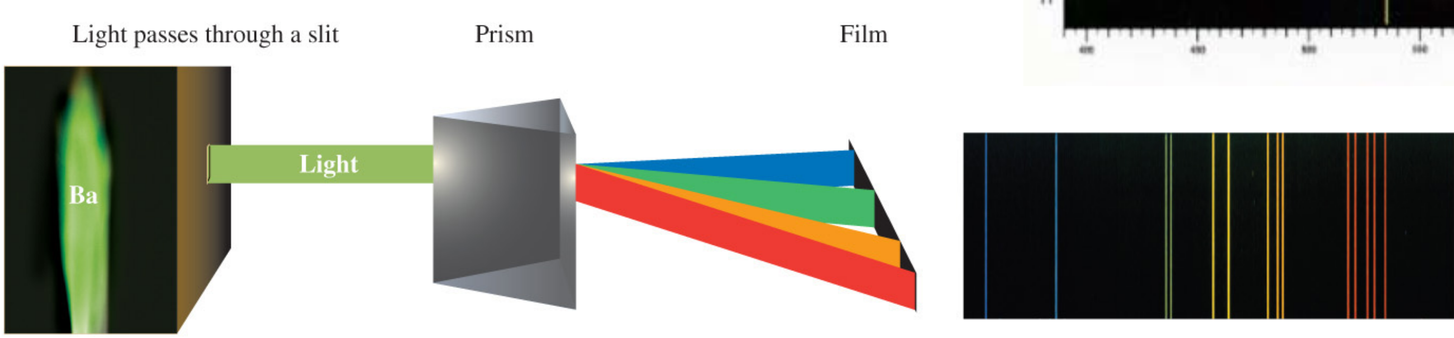


Line spectra of Hydrogen Gas

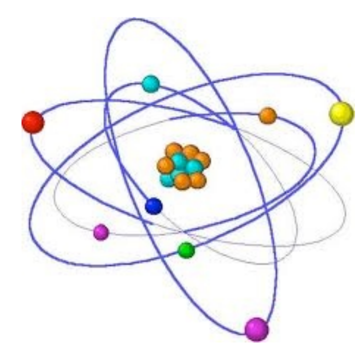
Each element has a different unique set of spectral emissions that distinguish it from the other elements.







Barium light spectrum



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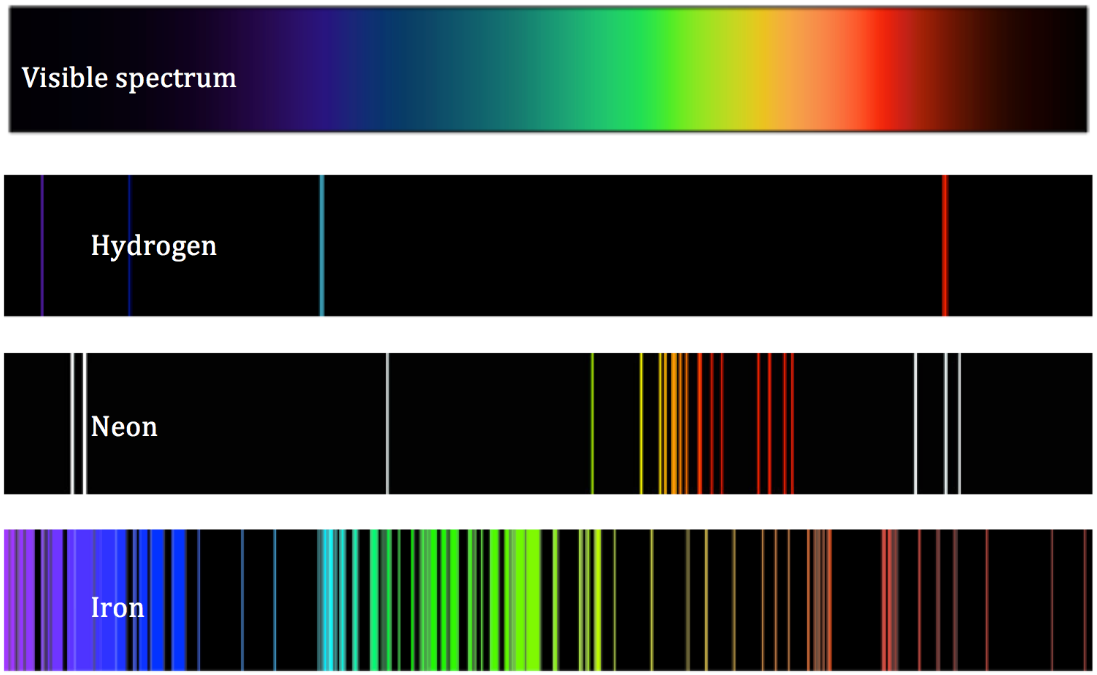
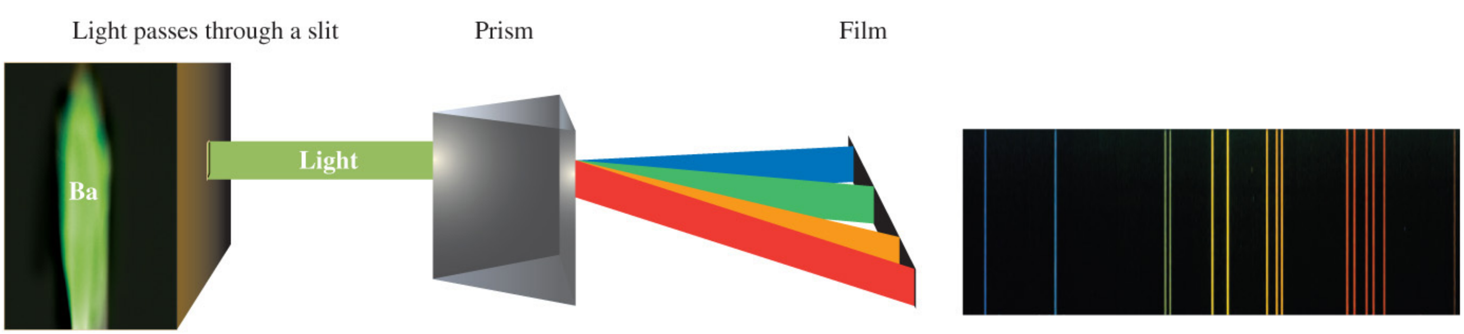
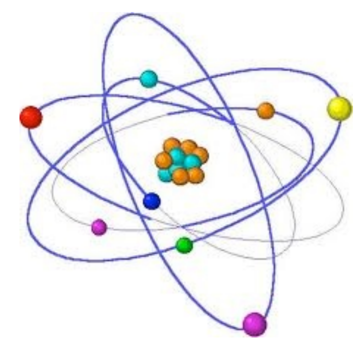


- At high temperature or voltages, elements in their pure state emit light — That light is special.
- Unlike most sources of light, it contains only discrete frequencies.
- Each element emits light with a unique set of frequencies.
- Line spectra of an element is essentially a signature or fingerprint of that element.
- It's how we determine what elements exist in stars on the other side of the galaxy.

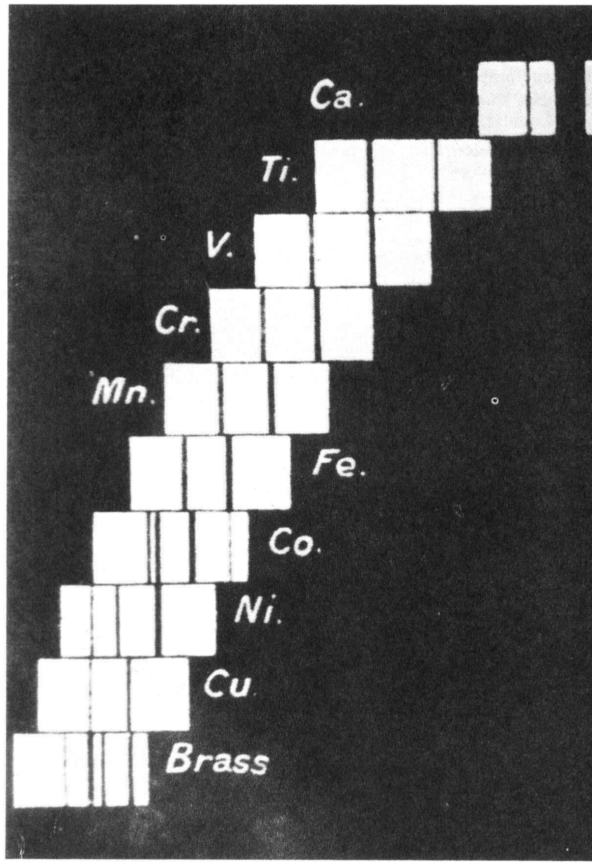


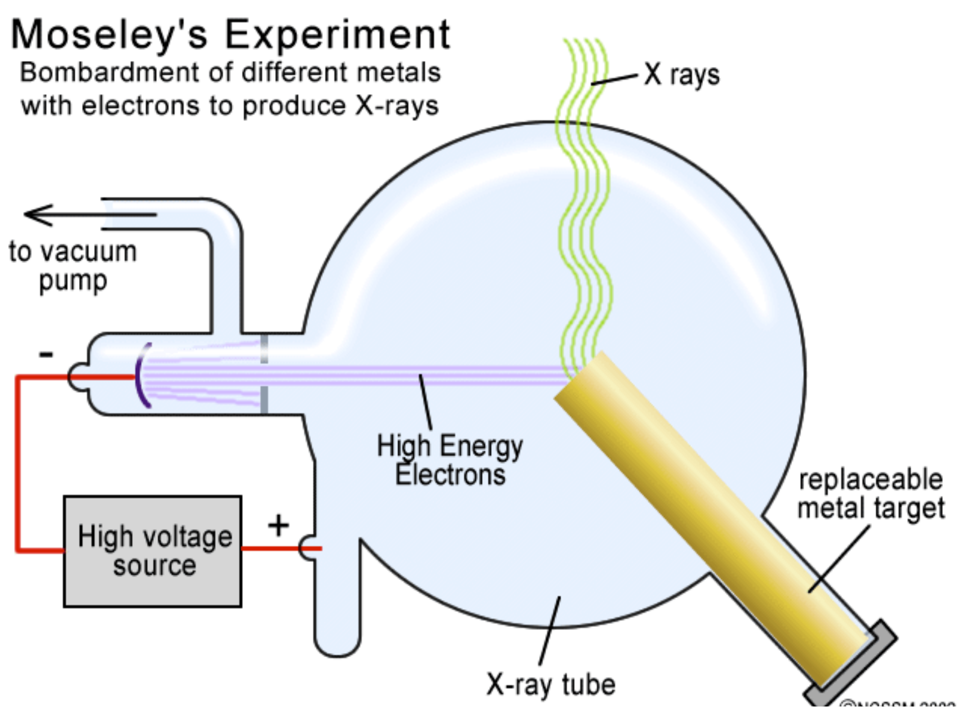
Barium light spectrum

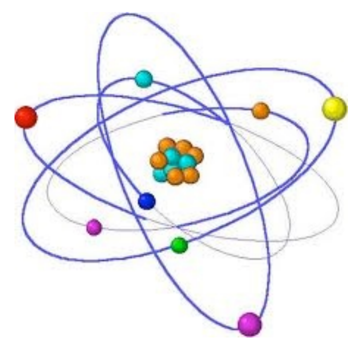


X-Ray Spectroscopy

- Line spectra appears in the visible region and also in higher energy regions of the electro-magnetic spectrum.
- In the X-Ray region a single very strong emission line occurs called the K-alpha line.
- This K-alpha line has a unique frequency for each element.
  - For hydrogen this line occurs outside of the X-ray spectrum, in the ultraviolet (almost visible) region.





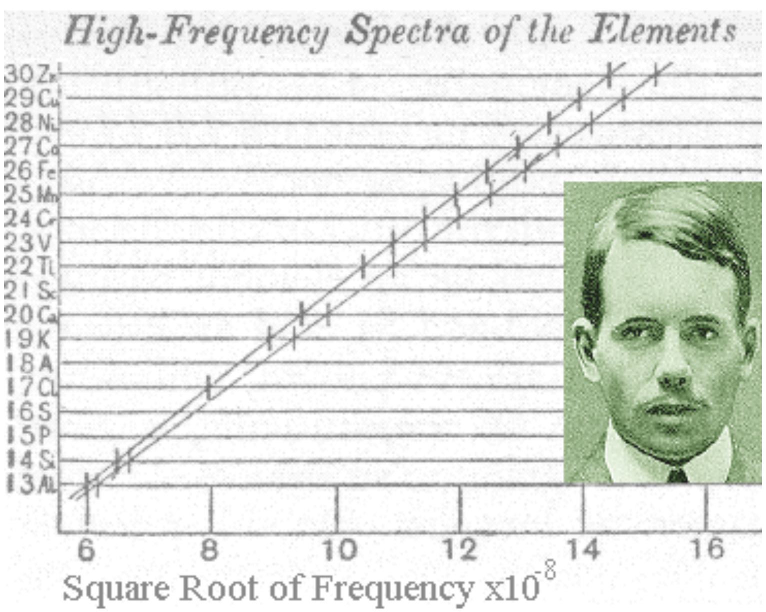


Moseley's Law

- Henry Moseley studied K-alpha emission lines and found the X-ray frequencies corresponded to a simple integer Z.
  - Z is unique for each element.
  - Z increases roughly the same way an elements relative mass increases.
  - Moseley was able to demonstrate Z represented the positive charge on the nucleus of the atom.
- Moseley discovered all elements have the same positive charge in their nucleus. And different elements have a different charge.


Henry Moseley 1887–1915

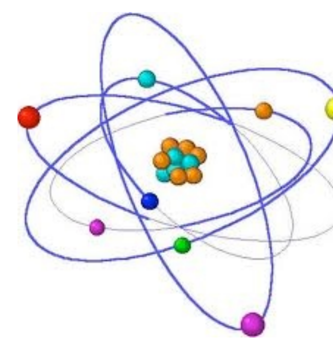
Moseley discovered that the number of protons in a nucleus is what defines an element.



Moseley's Law

$$\nu = \frac{(10.2eV)(Z-1)^2}{h}$$

$$E = (10.2eV)(Z-1)^2$$



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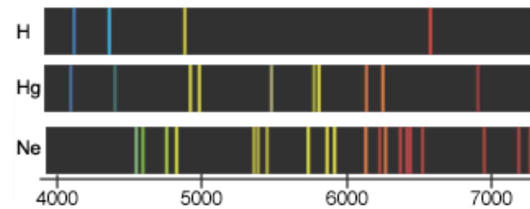
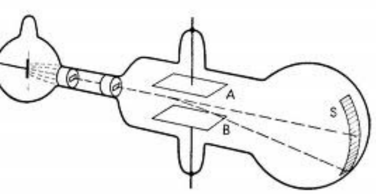
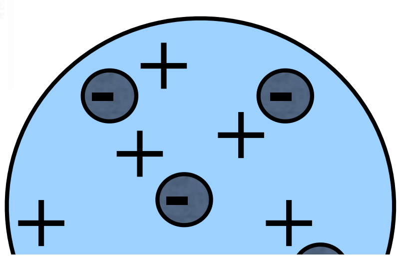
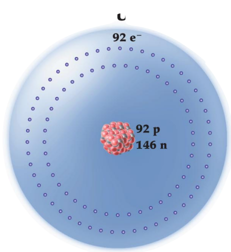
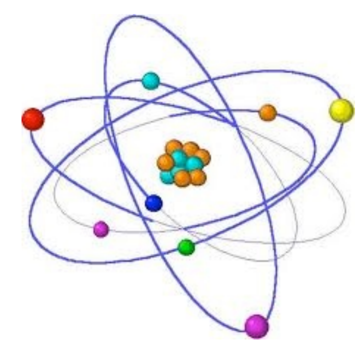


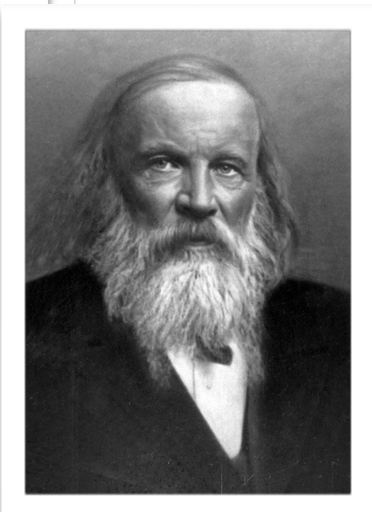




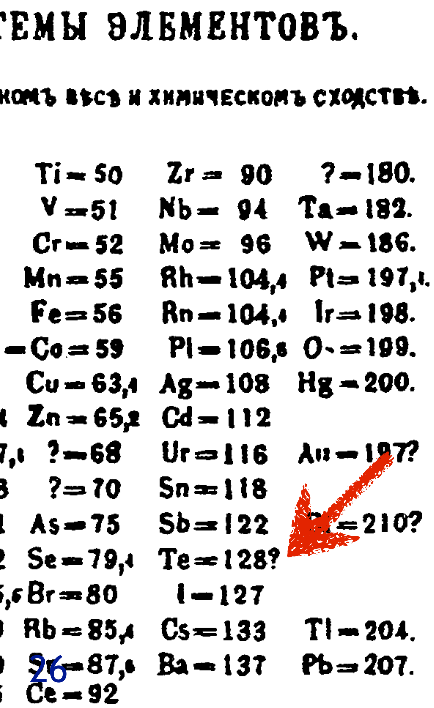




It’s about protons.



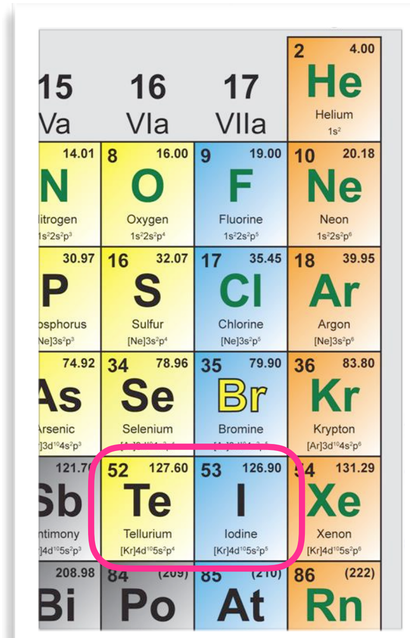
Dmitri Mendeleev
1834-1907



- Mendeleev had organized his periodic table by the increasing relative mass of the elements.
  - He had issued each element a serial number, it’s Atomic Number.
- But periodic law had required him to put some heavier elements before lighter ones.
- The element tellurium (mass 128) is heaver than iodine (mass 127).
  - But iodine has the same periodic properties of F, Cl, and Br.
  - … and tellurium has the same properties as oxygen, sulfur, and selenium.
  - So Tellurium became #52 and Iodine #53.
- Mendeleev was smart enough to know he needed to swap the atomic numbers of these two elements… because of periodic law… but he never understood why because atomic theory hand’t caught up to that question yet.
- Moseley offered the explanation.

Moseley showed Tellurium has 52 protons, and Iodine has 53.

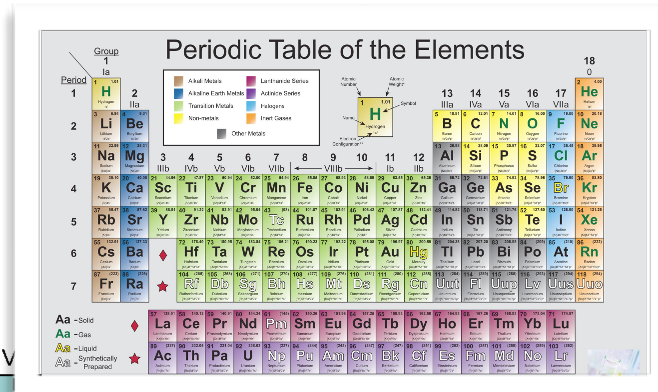
Henry Moseley
1887–1915

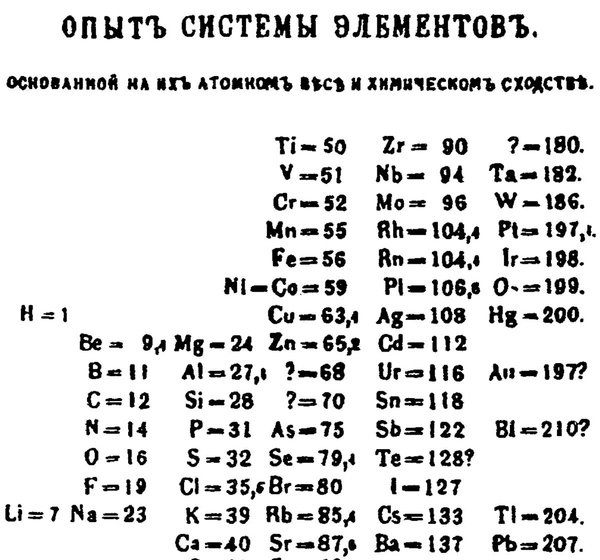


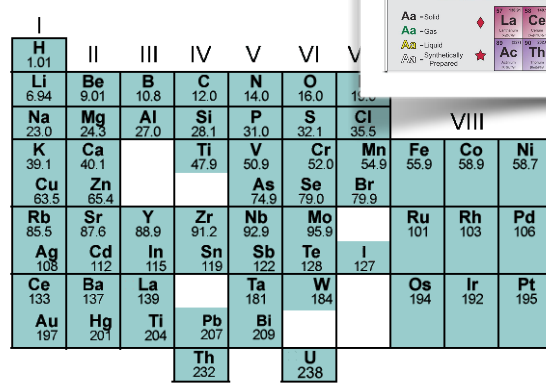
The single most costly…

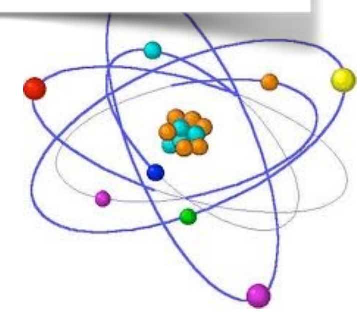
- Henry Moseley provided the last piece to the modern periodic table and an essential key to understanding the nuclear atom.
- When World War I broke out in Western Europe, Moseley left his research work at the University of Oxford behind to volunteer for the Royal Engineers of the British Army.
- Moseley was assigned to the force that invaded Gallipoli, Turkey, in April 1915, as a telecommunications officer.
- Moseley was shot and killed during the Battle of Gallipoli on 10 August 1915, at the age of 27.
  - Experts have speculated that Moseley could have been awarded the Nobel Prize in Physics in 1916, had he not been killed.
  - At 27 years old.
- Isaac Asimov called it ‘the single most costly death of the war’.

Henry Moseley 1887–1915









Ch03

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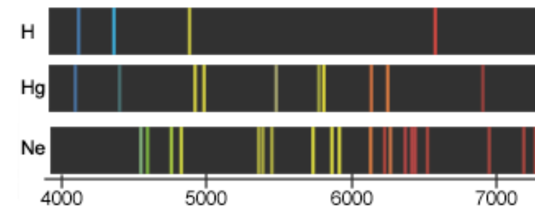

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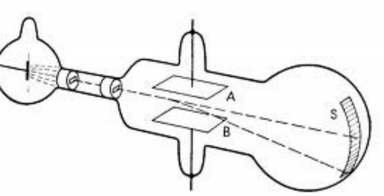
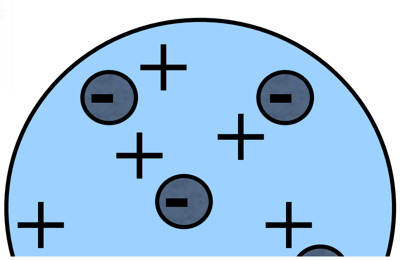
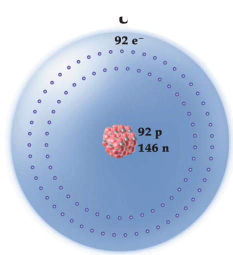
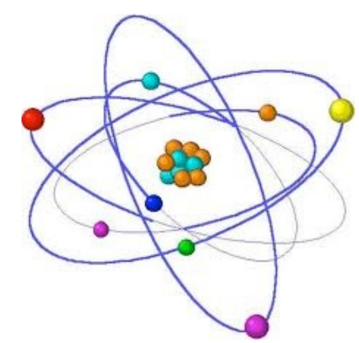


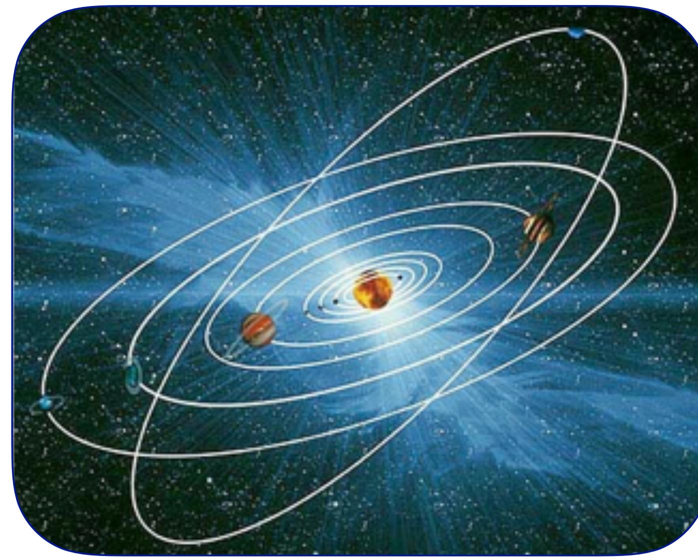






Explaining Line Spectra

- The K-alpha line is an important part of an elements spectra.
- But the rest of that spectra is very complicated and unique to each element.
- Niels Bohr offered us an explanation of that spectra.
- Niels Bohr started with Rutherford’s model that electrons floated around a heavy positively charged nucleus.
- He postulated that much the same way planets orbit the sun in only orbits of a fixed distance, that electrons are also constrained to orbits of a fixed distance from the nucleus.
  - There are reasons why planets must maintain those fixed orbits, those reasons don’t apply to negatively charged electrons orbiting a positive nucleus.
  - Bohr knew his hypothesis had this problem.



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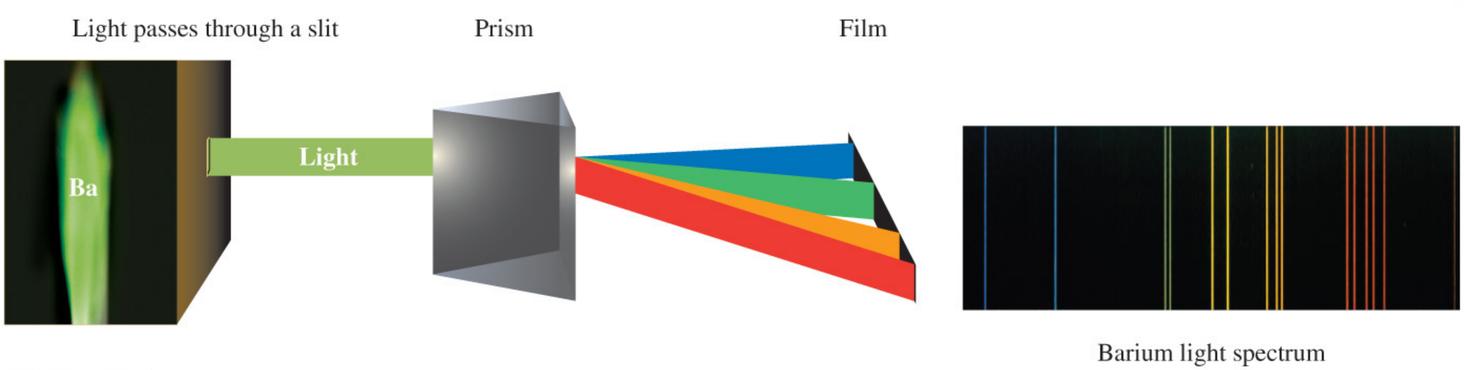

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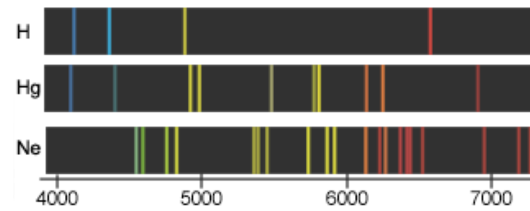

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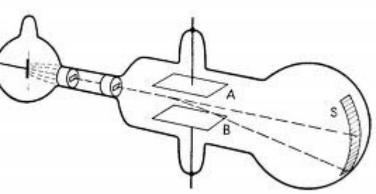

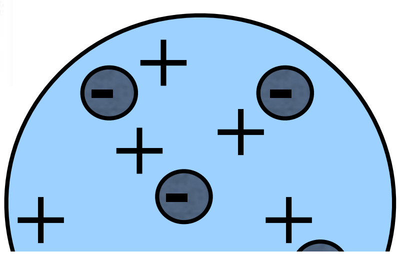

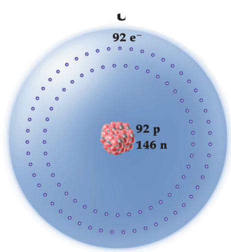

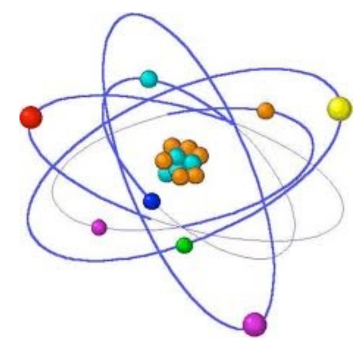

Line Spectra of the Elements

- Niels Bohr started with Rutherford's model that electrons floated around a heavy positively charged nucleus.
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    - A quantum leap.
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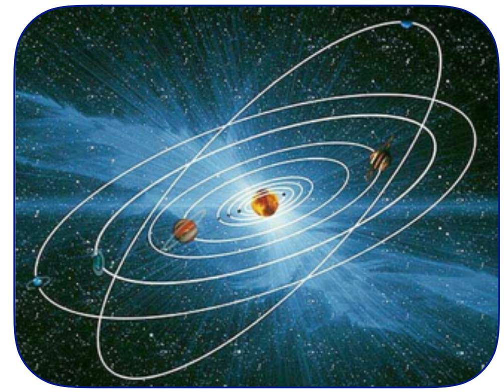

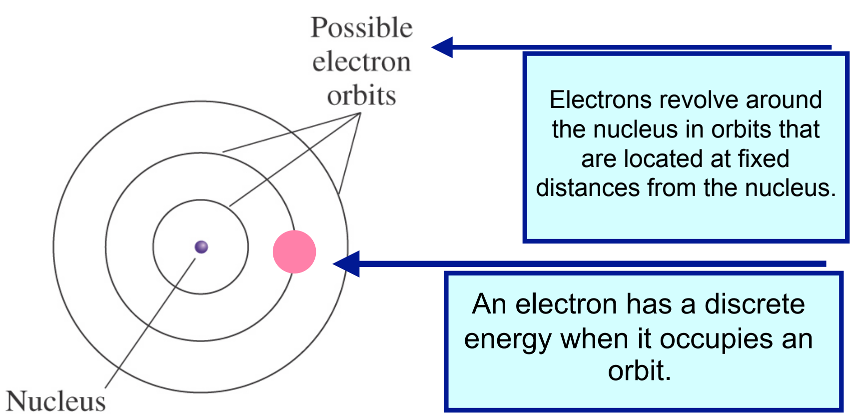

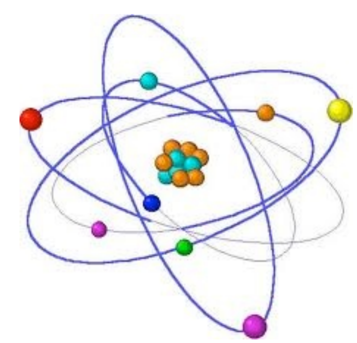

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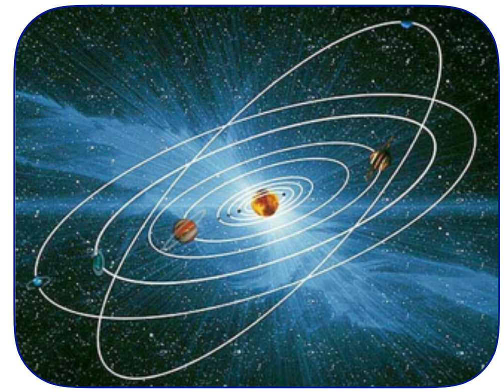

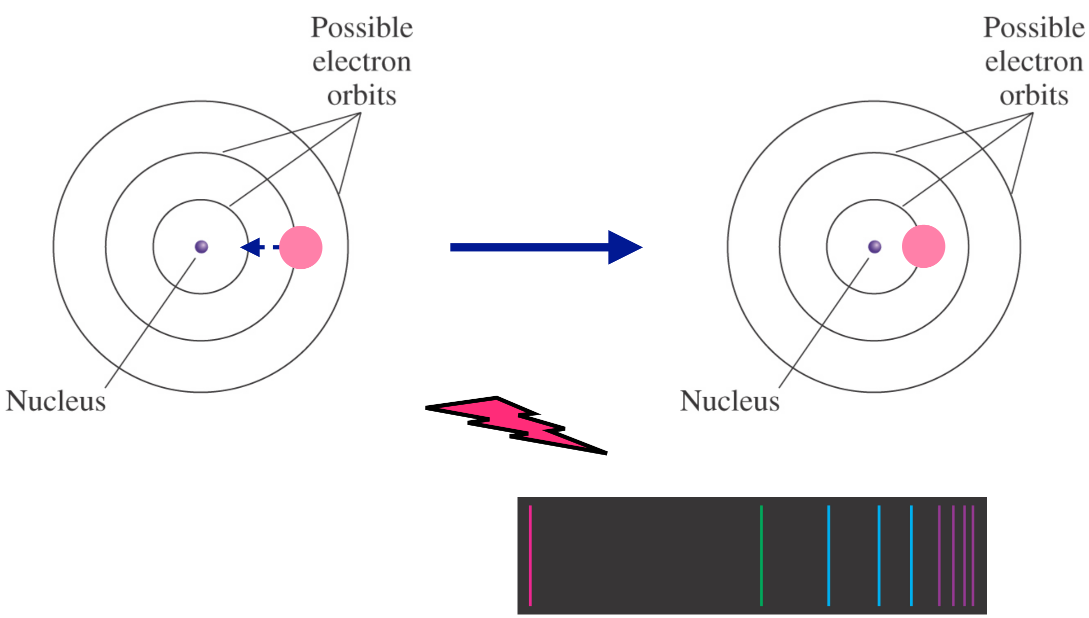

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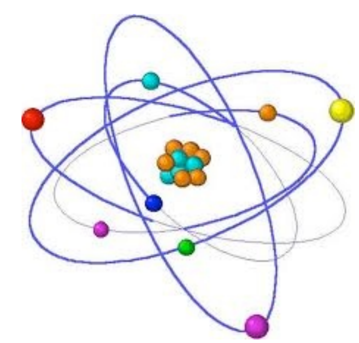

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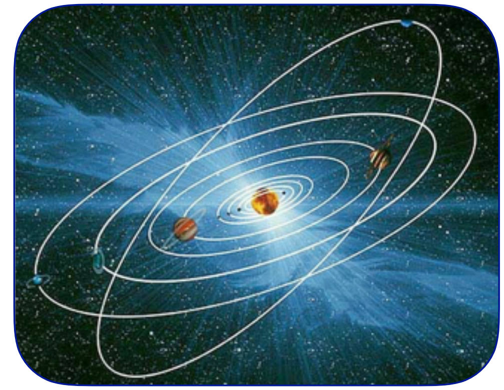
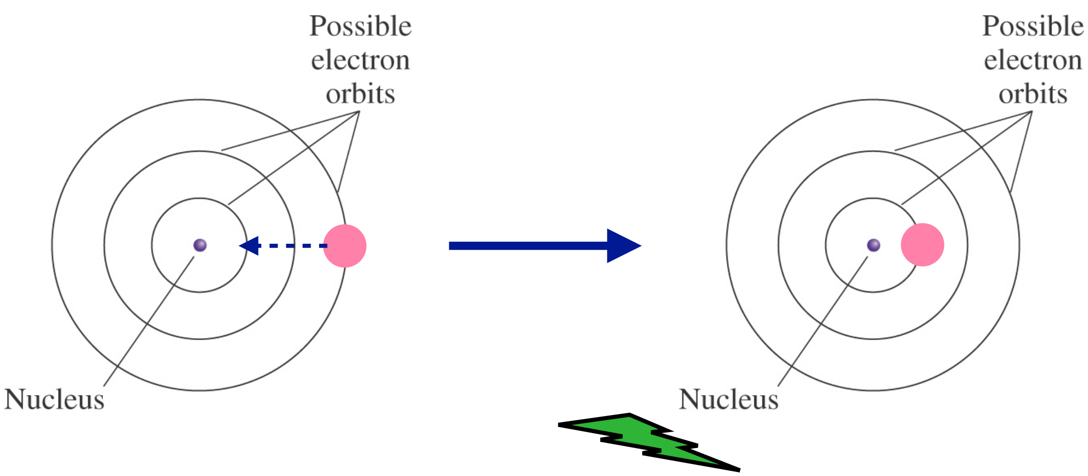
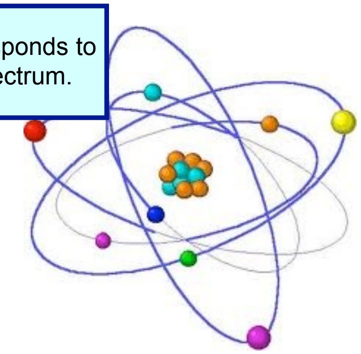




When an electron falls from a higher energy level to a lower energy level a quantum of energy in the form of light is emitted by the atom.

The color of the light emitted corresponds to one of the lines of the hydrogen spectrum.

$$E = h\nu$$



The Planetary Model

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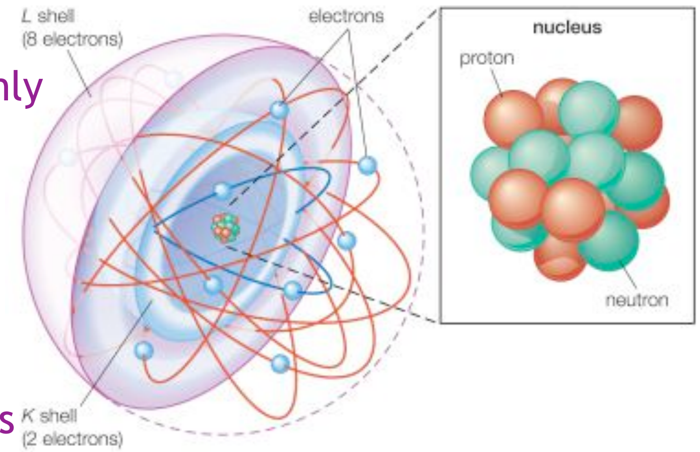

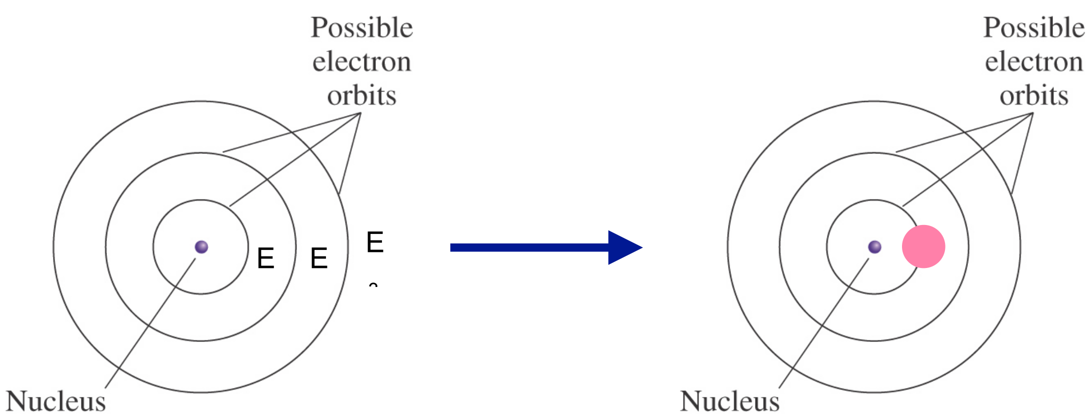

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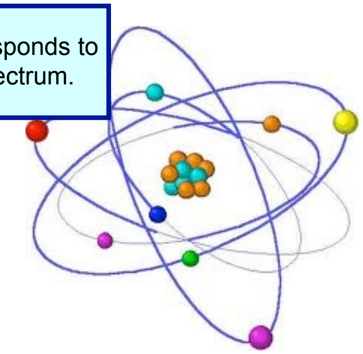
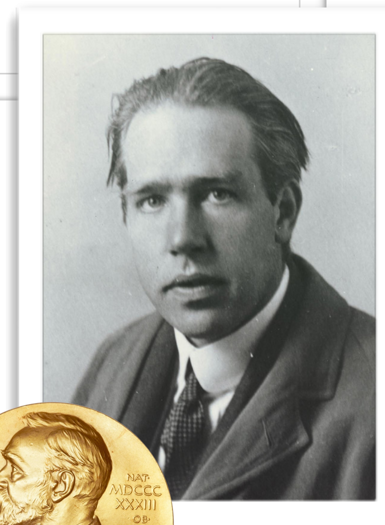


Niels Bohr



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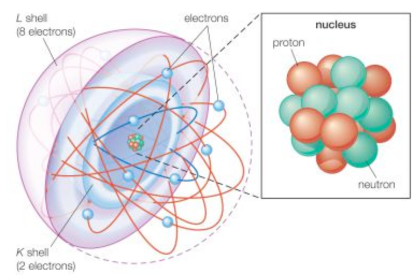
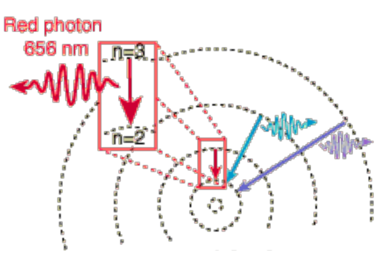
  - The color of that light depends on the wavelength, which depends on the energy difference between the two levels.
- With this model, only photons of with energy that equals the difference between levels can be emitted.
- This explained why only discrete colors are seen in the line spectra.



The Nobel Prize in Physics 1922 was awarded to Niels Bohr "for his services in the investigation of the structure of atoms and of the radiation emanating from them".



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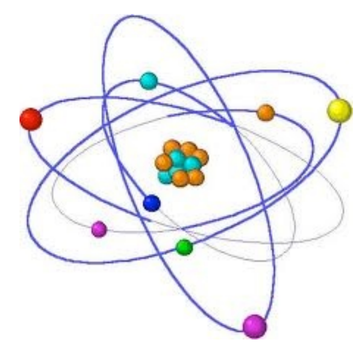
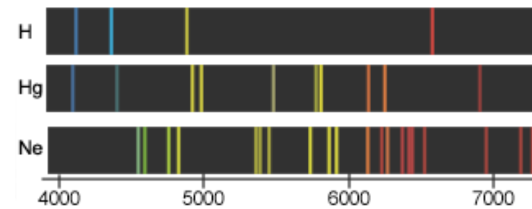
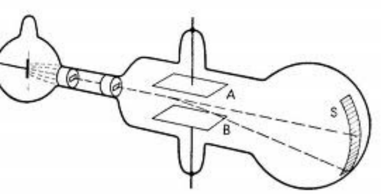
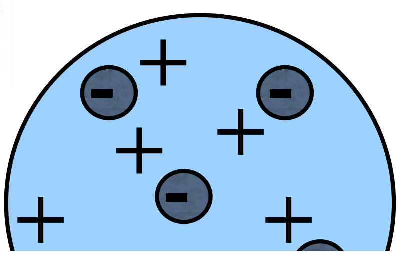


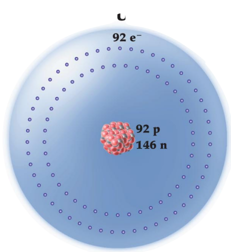
Atomic Structure

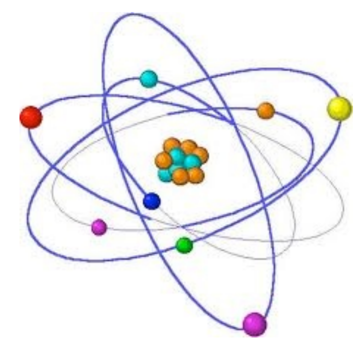
- Faraday—Wandering Atoms
  - Electrical Charge
- JJ Thomson—Subatomic Particles
  - Electrical Charge
    - Ions, Cathode Rays, Millikan's Oil Drop
  - The Electron
  - Atomic Theory 3.0 — Plum Pudding
- Radioactive Matter
- Rutherford—the Nuclear Age
  - Radiation, Gold Foil, the Nucleus
    - Protons & Neutrons
  - Atomic Theory 4.0 — Nuclear Atom
- Spectroscopy
  - Line Spectra
  - Moseley Law
    - Atomic Number
  - Atomic Theory 5.0 — Planetary Model
    - Electron Orbits (Shells)
    - Valence Electrons
- Explaining the Flavors of the Atom
  - Ions, electron count
  - Elements, proton count
  - Isotopes, mass
    (because they differ in neutron count)
    - Isotopic Notation



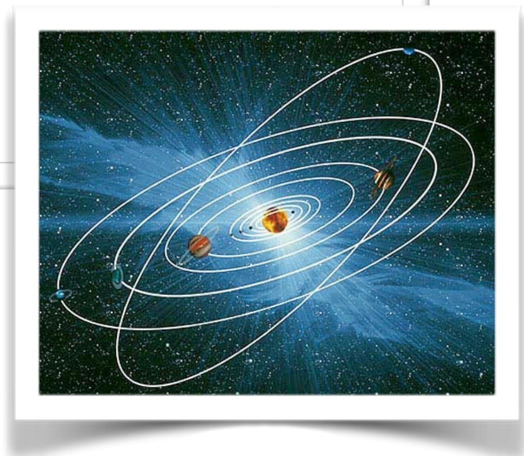




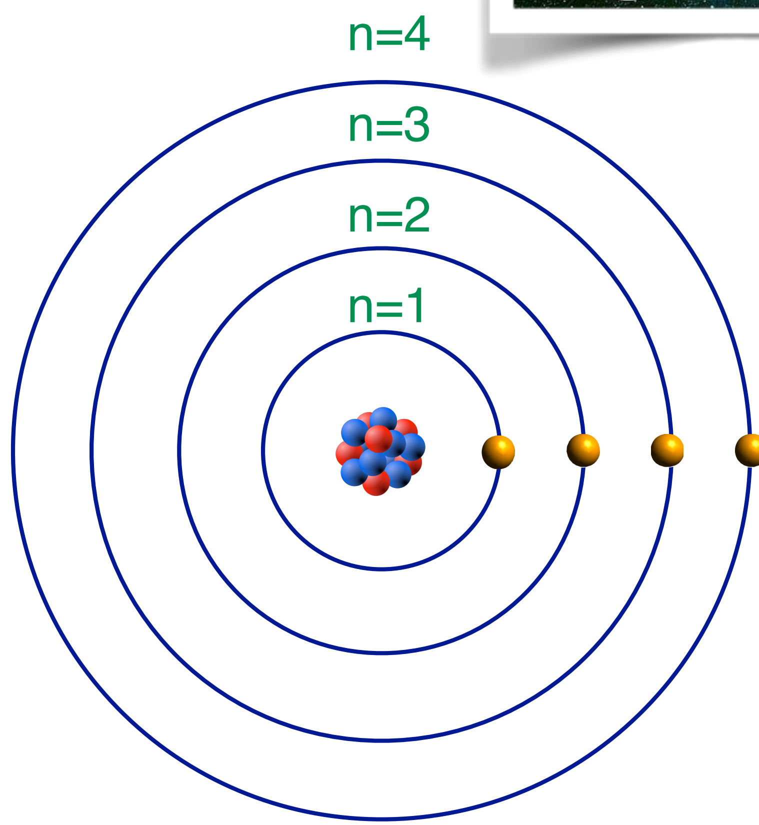




Electronic Structure



- Electrons exist at certain distances from the nucleus.
  - Similar to the way planets exist in discreet orbits around the sun.
    - The full story is more complex, but this is a good first approximation.
- The orbits are numbered, we indicate the orbit number with the variable n.
- n is the principle quantum number.
  - The closest orbit to the nucleus is n=1.
  - The next farther out is n=2.
  - … and so on.
- The electrons closer to nucleus have less energy.
    - Like a ball at the bottom of a hill has less energy.
- Electrons prefer to be in the lowest orbital (closest to the nucleus).



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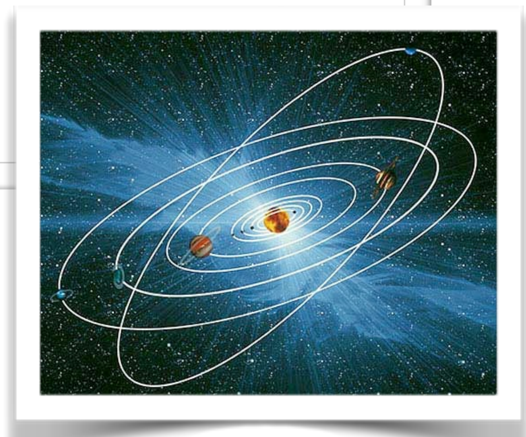
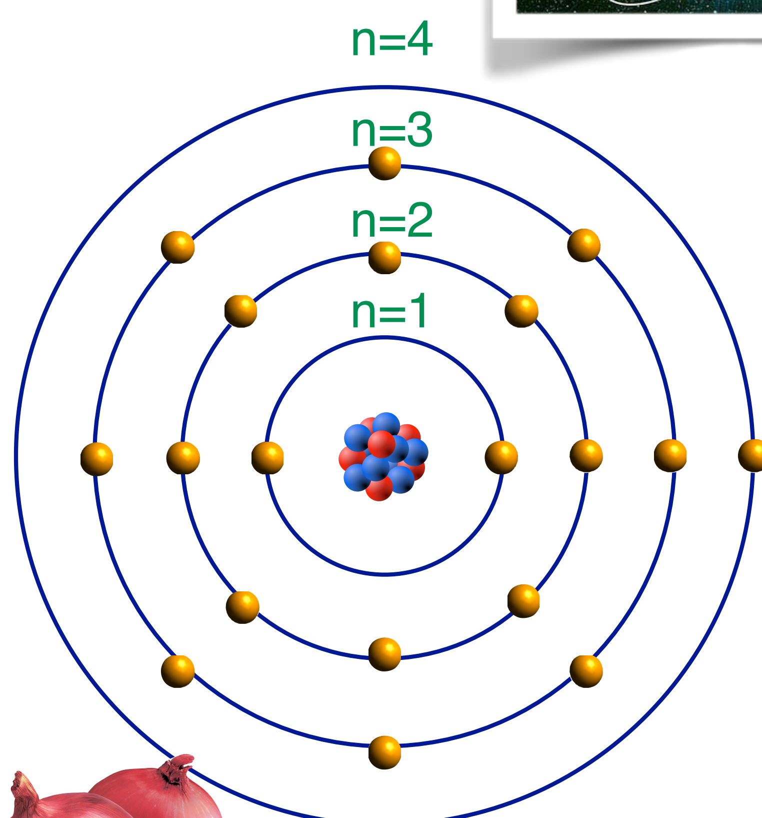
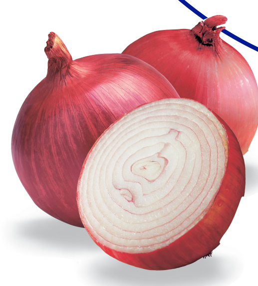


- More than one electron can orbit at each level.
- There is a maximum number of electrons that can orbit at each level.
- This creates layers or shells of electrons around the nucleus,
  - Two electrons can orbit at n=1
    - This is the n=1 shell.
  - Eight electrons can orbit at n=2.
    - This is the n=2 shell.
  - Eight electrons can orbit at n=3.
    - This is the n=3 shell.
  - At n=4 the shells get larger and some complicated things happen that we won't get into in this class.
    - But n=4 can hold at least two electrons.
  - You are responsible for knowing the capacity of each of the shells 1-3.





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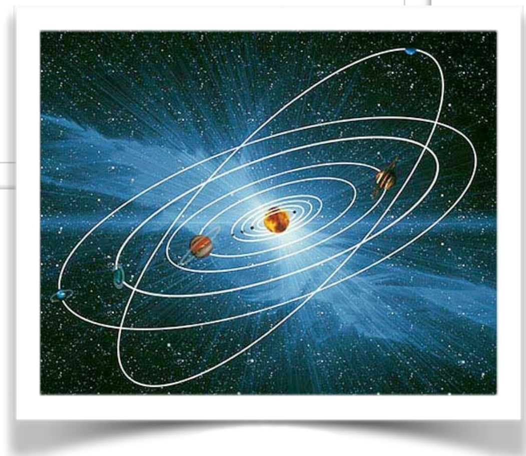
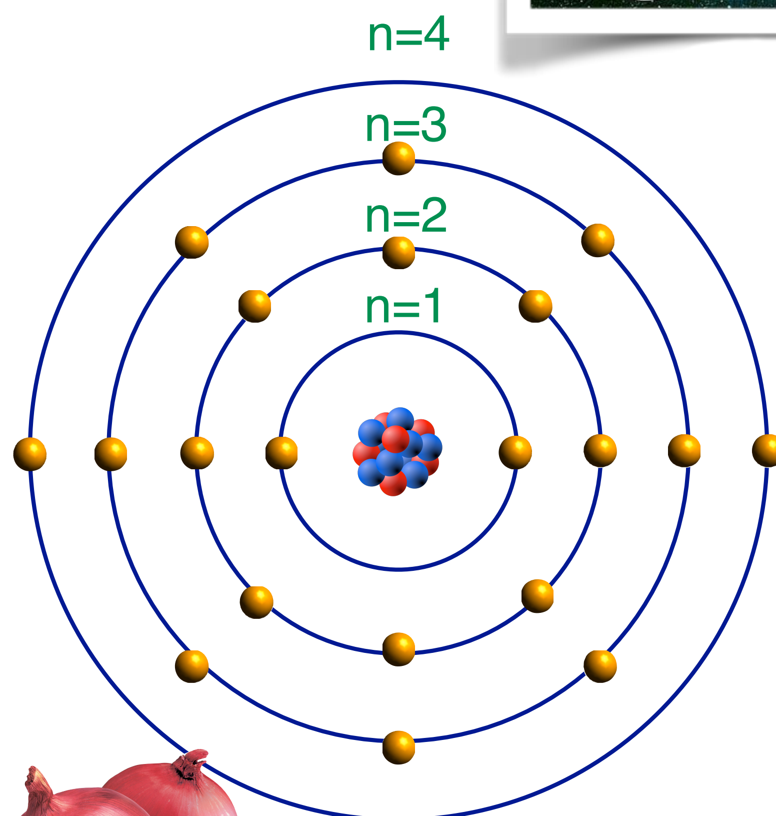


- Since electrons prefer to fill electron shells at lowest number possible n number, if you know how many electrons an atom has, you can predict it's electronic structure.
- Helium has two, both electrons are in n=1
  - Electronic structure 2
- Carbon has six, two in n=1 and four in n=2
  - Electronic structure 2, 4
- Chlorine has 17
  - 2, 8, 7
- Calcium has 20
  - 2, 8, 8, 2



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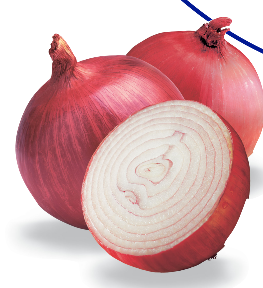

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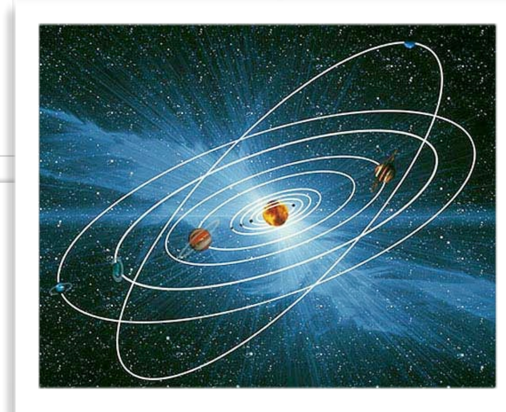
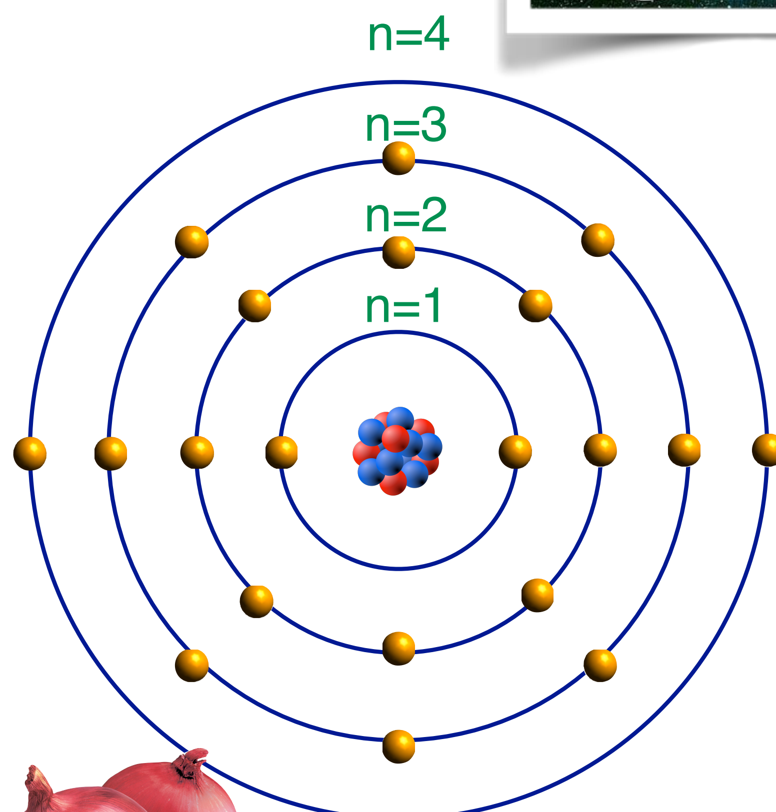


- The outermost shell is the one other atoms will “see” when they bump into an atom.
- That shell is the most important part of the atoms electronic structure.
- The outmost shell of the atom is it’s valence shell.
- The rest of the electrons are core electrons.
- An atom will have 1-8 electrons in it’s valence shell. This is the octet rule.



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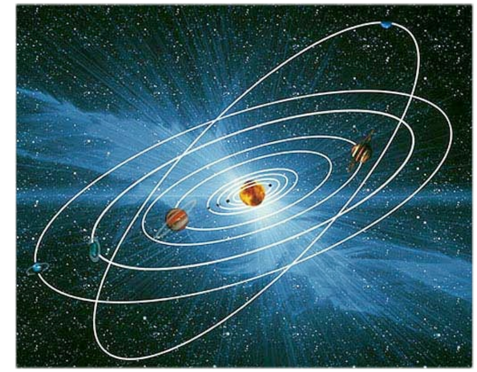

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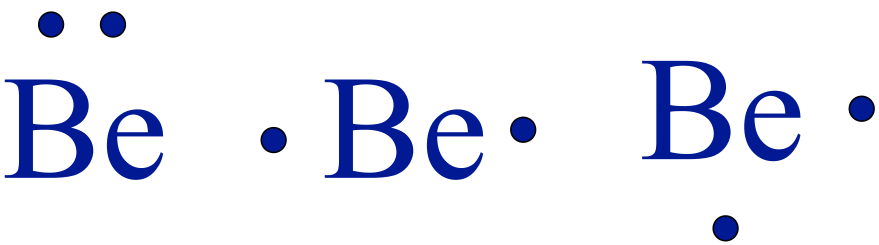
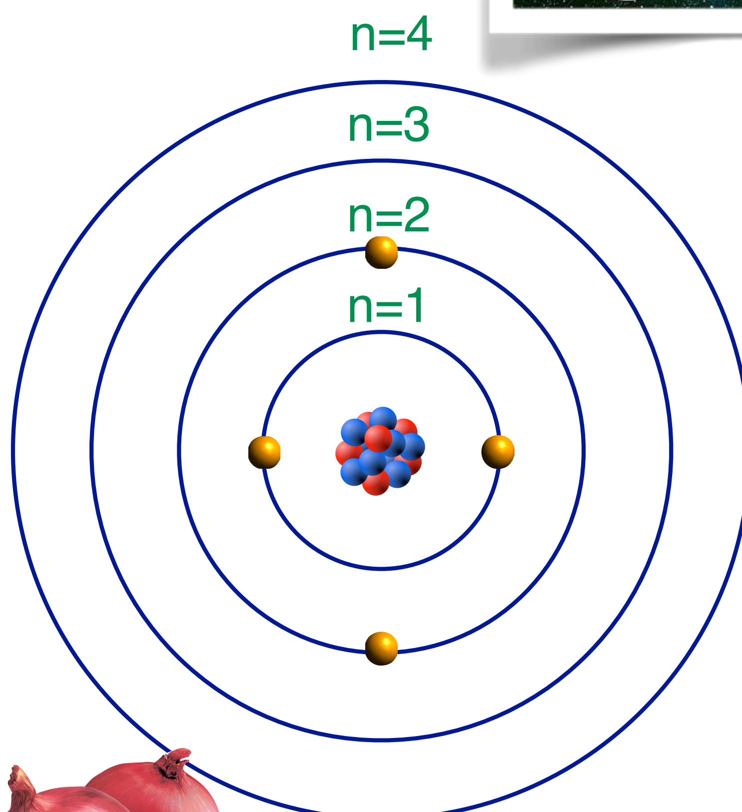
- A Lewis symbol starts with the symbol of the element, and adds to it the valence electrons in sets of two on each of the four sides of that symbol.
    - It does not matter which side, as long as you have 1-8 dots in sets of (at most) two.





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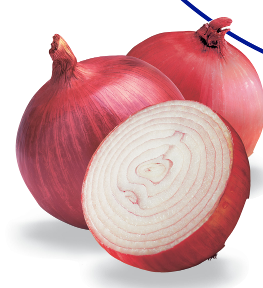
Be



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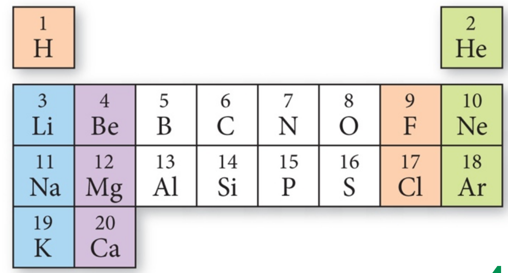

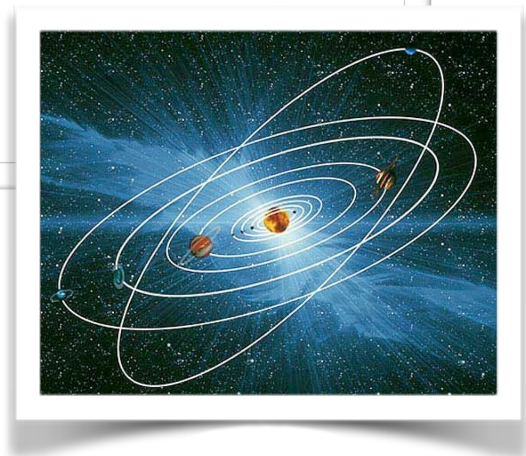

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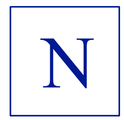

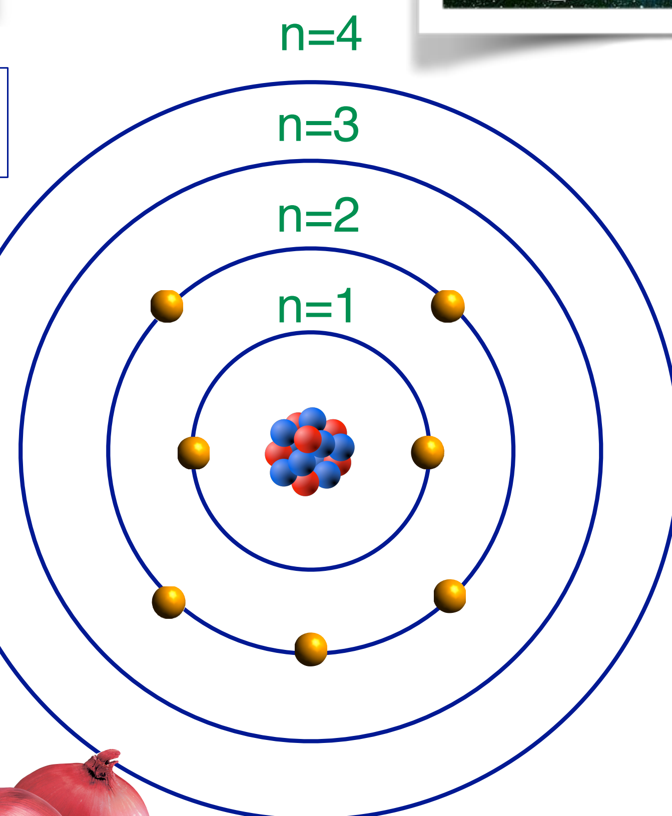

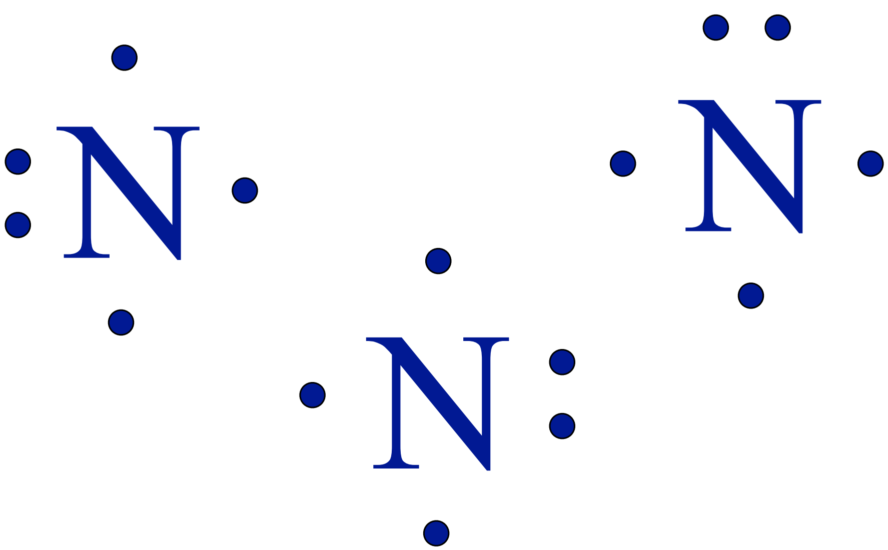

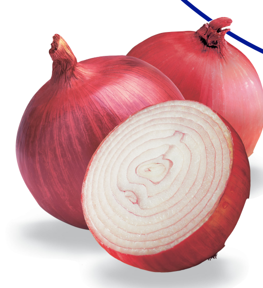

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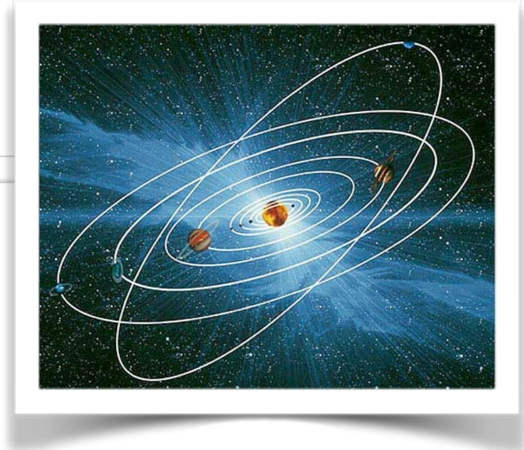

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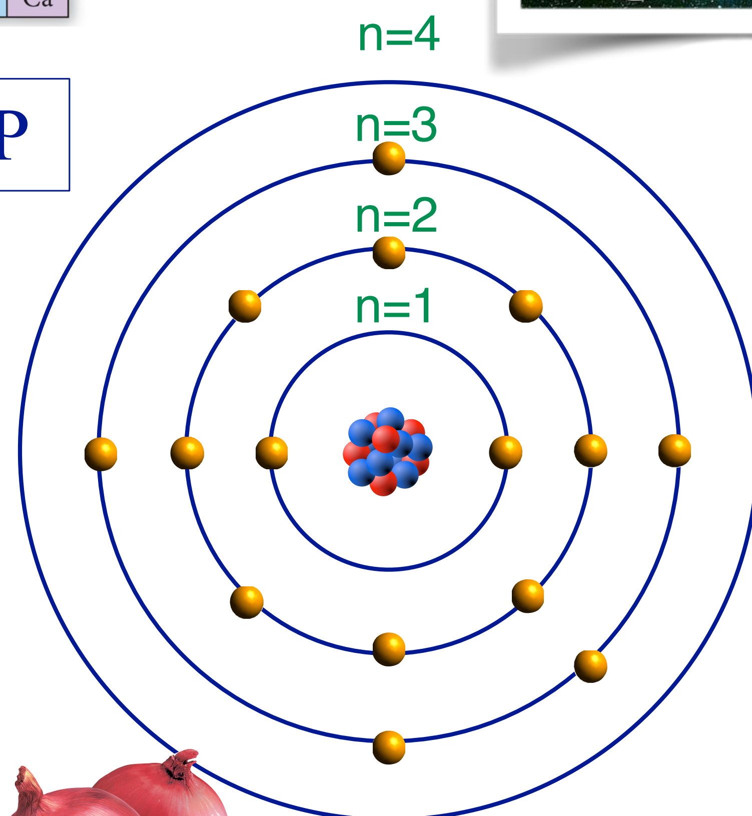
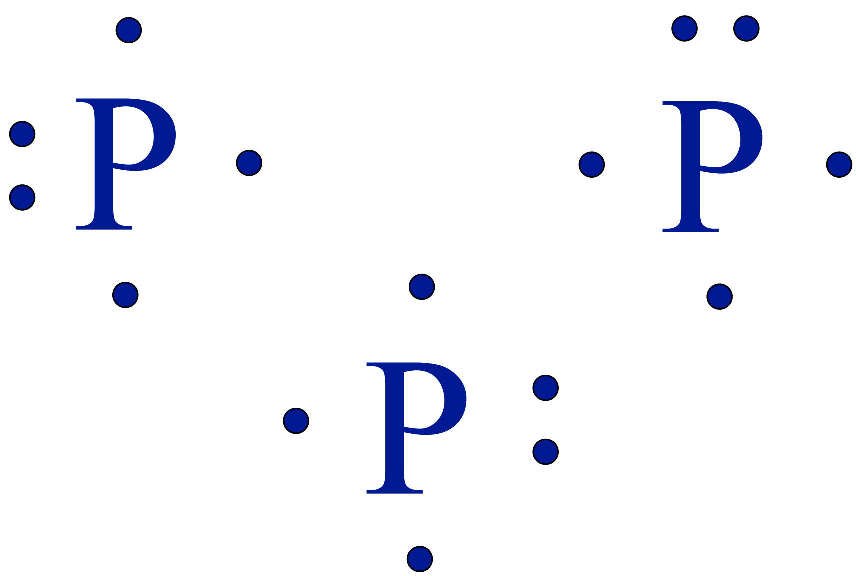
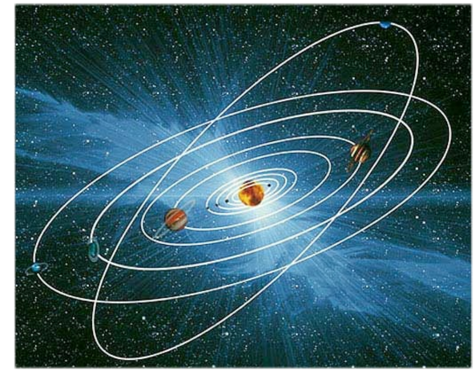
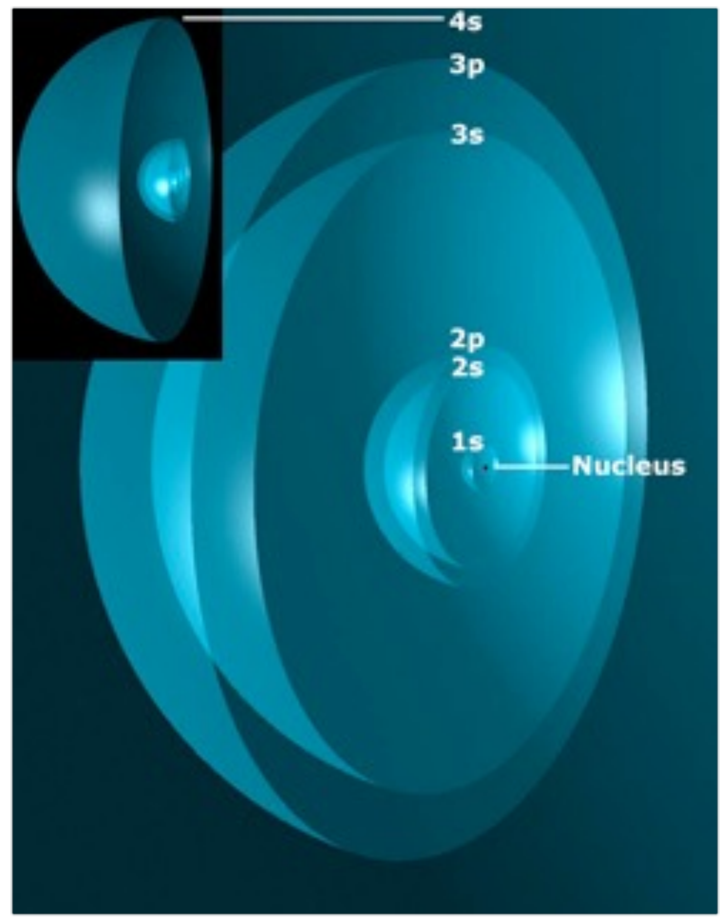




Electronic Structure

			Number of Electrons in Energy Level			
Group Number	**Element**	**Symbol**	**1**	**2**	**3**	**4**
1A (1)	Lithium	Li	2	**1**		
	Sodium	Na	2	8	**1**	
	Potassium	K	2	8	8	**1**
2A (2)	Beryllium	Be	2	**2**		
	Magnesium	Mg	2	8	**2**	
	Calcium	Ca	2	8	8	**2**
3A (13)	Boron	B	2	**3**		
	Aluminum	Al	2	8	**3**	
	Gallium	Ga	2	8	18	**3**
4A (14)	Carbon	C	2	**4**		
	Silicon	Si	2	8	**4**	
	Germanium	Ge	2	8	18	**4**
5A (15)	Nitrogen	N	2	**5**		
	Phosphorus	P	2	8	**5**	
	Arsenic	As	2	8	18	**5**
6A (16)	Oxygen	O	2	**6**		
	Sulfur	S	2	8	**6**	
	Selenium	Se	2	8	18	**6**
7A (17)	Fluorine	F	2	**7**		
	Chlorine	Cl	2	8	**7**	
	Bromine	Br	2	8	18	**7**
8A (18)	Helium	He	**2**			
	Neon	Ne	2	**8**		
	Argon	Ar	2	8	**8**	
	Krypton	Kr	2	8	18	**8**





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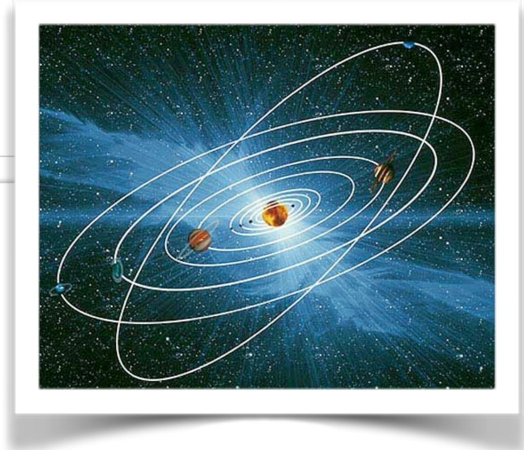
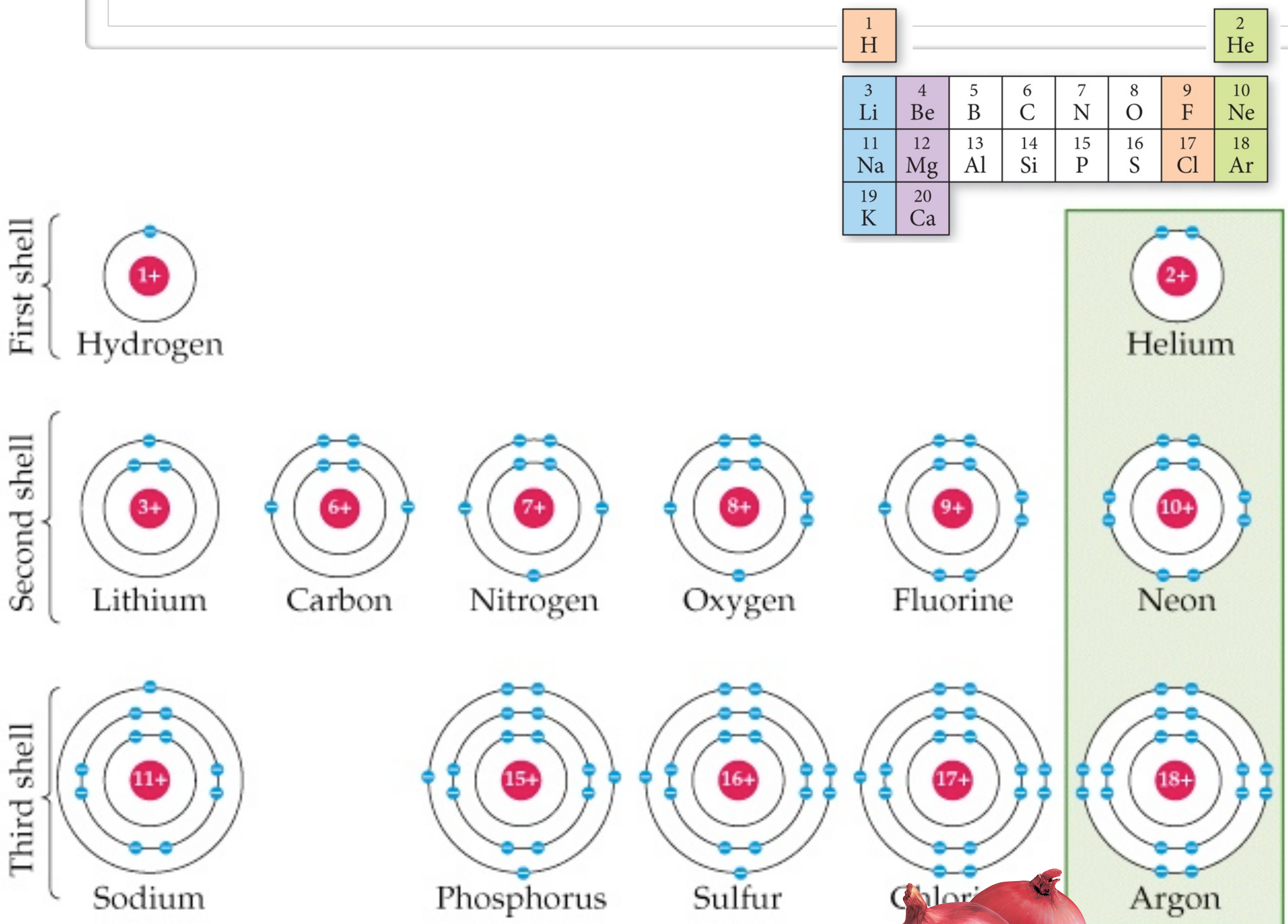
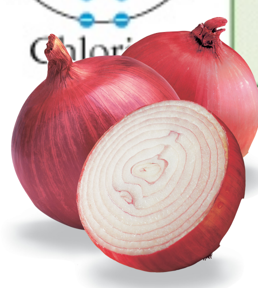
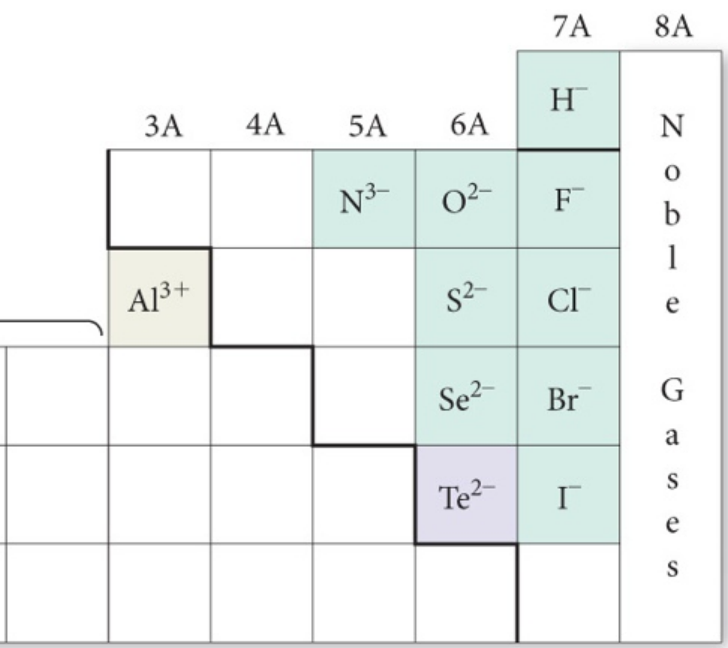
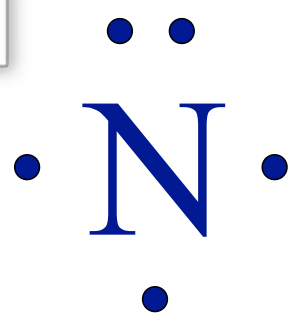


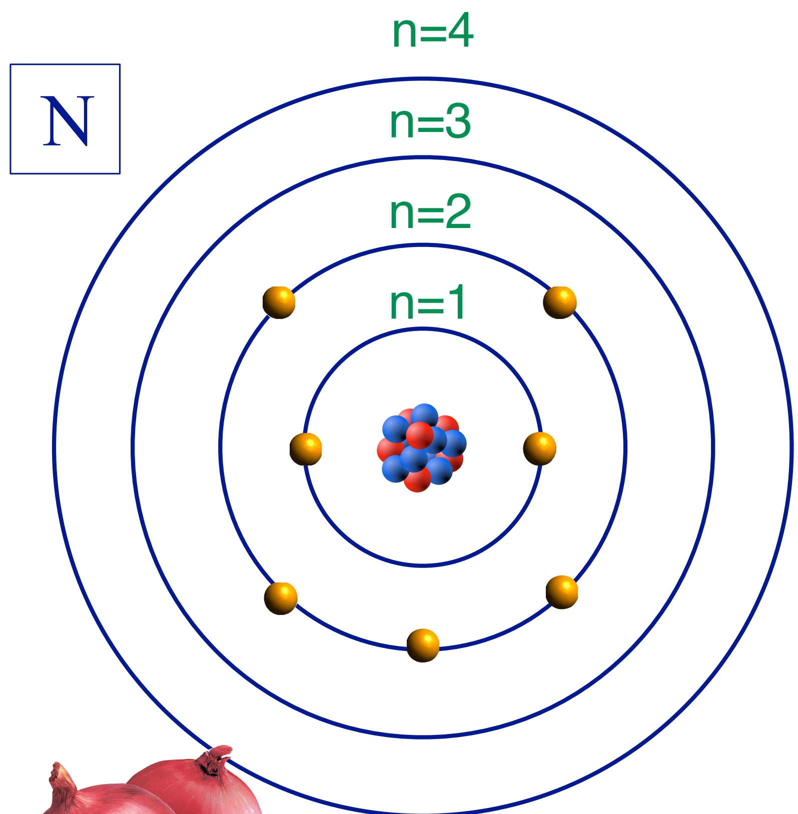




Ions form to Fill Electron Shells

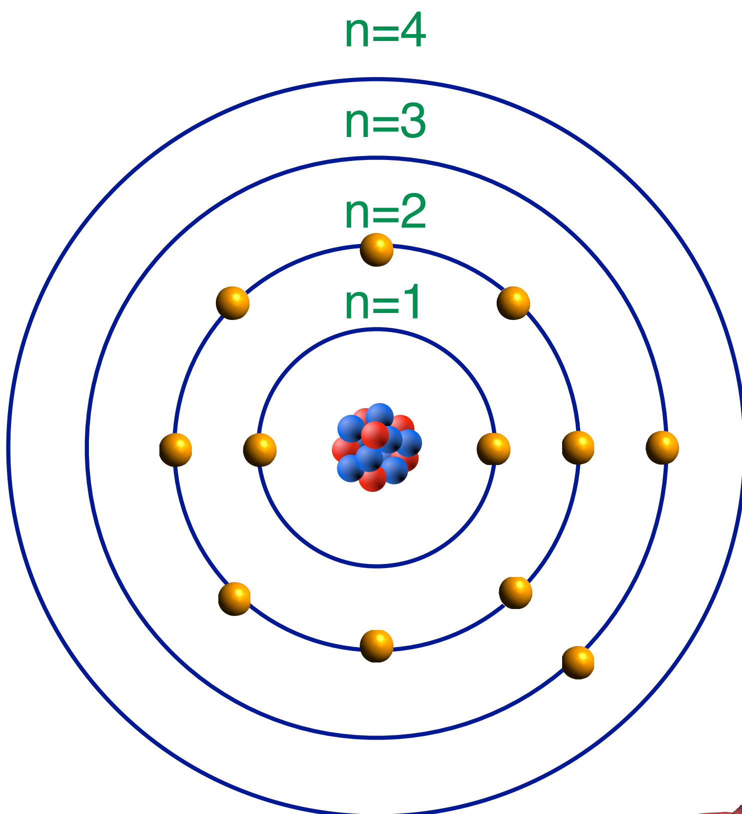


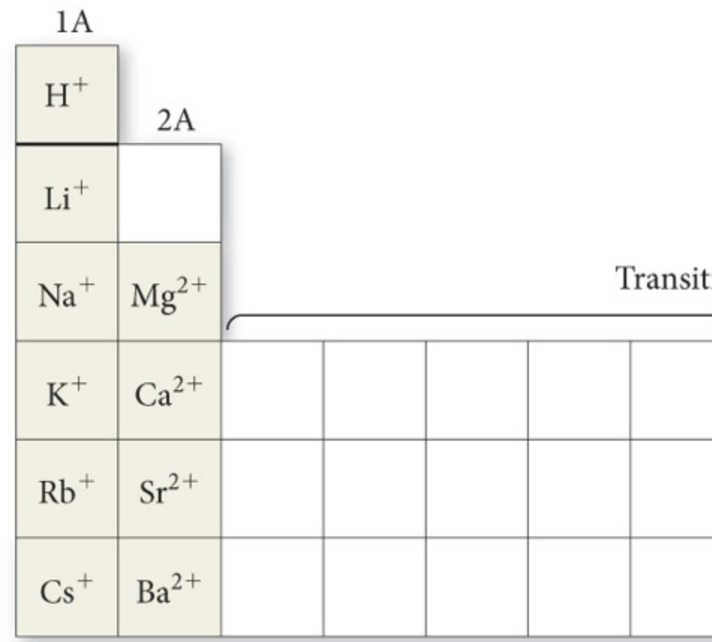




Ions form to Fill Electron Shells

Mg





Ch03

Atomic Structure

- Faraday—Wandering Atoms
  - Electrical Charge
- JJ Thomson—Subatomic Particles
  - Electrical Charge
    - Ions, Cathode Rays, Millikan's Oil Drop
  - The Electron
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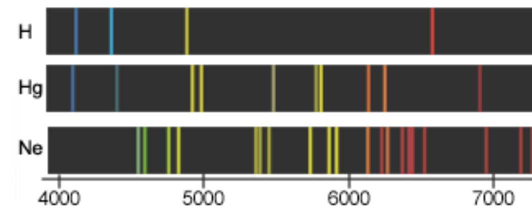
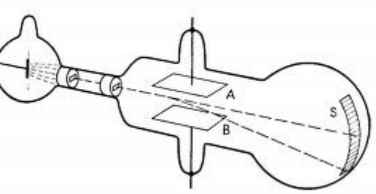
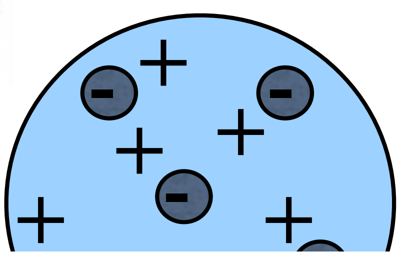
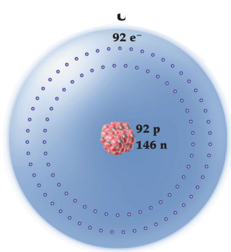
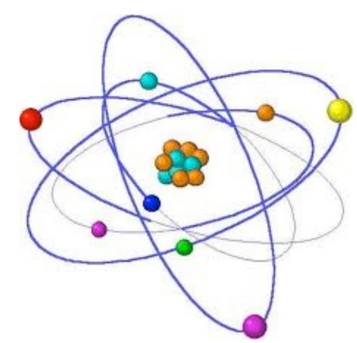


Explaining the Flavors of the Atom
  - Ions, electron count
  - Elements, proton count
  - Isotopes, mass
    (because they differ in neutron count)
    - Isotopic Notation



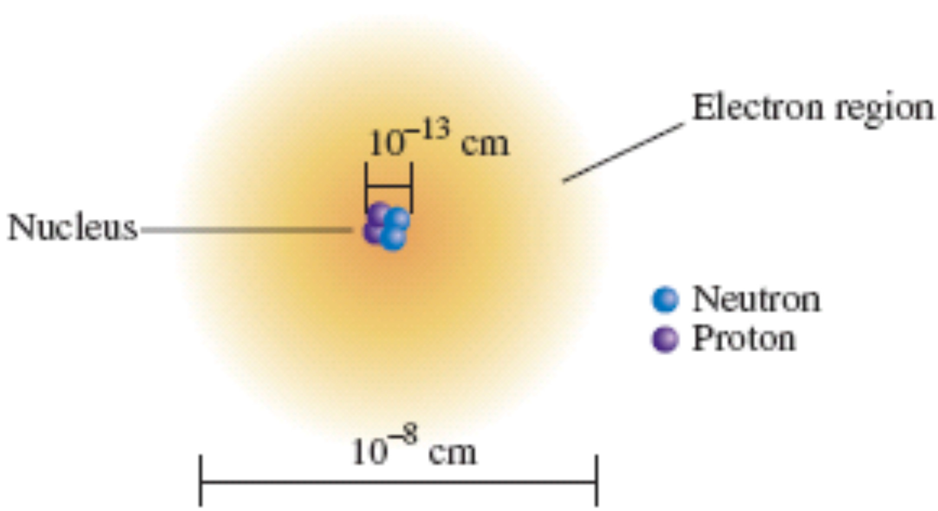


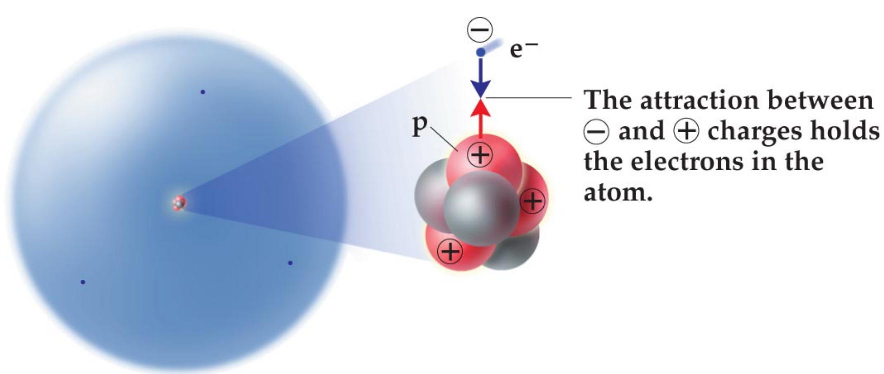




Pieces of the Atom

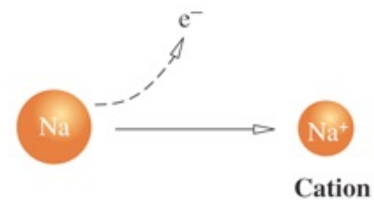
- Atoms are the smallest particle of an element that can enter into a chemical reaction.
- Protons and neutrons make up the dense, positive nucleus.
- Electrons occupy the empty space outside the nucleus.
- A neutral atom contains the same number of electrons and protons.

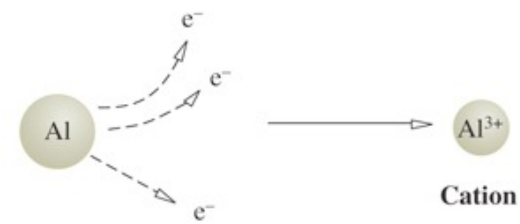


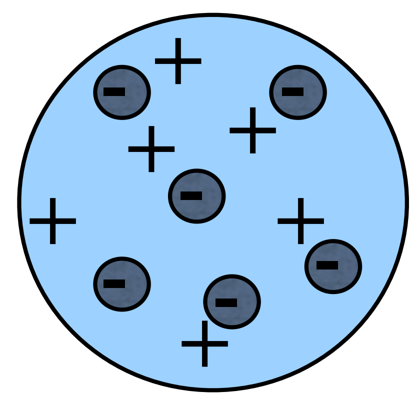


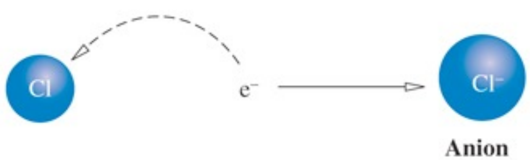
Ions

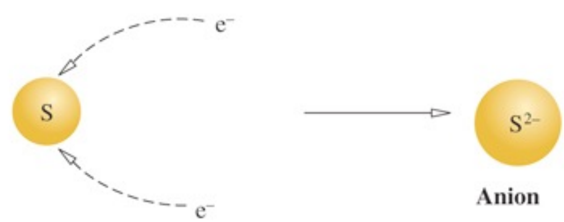
- JJ Thomson explained Michael Faraday's observations about some atoms being charged with his plumb pudding model (theory).
- Cations are formed by removing an electron from the atom.
  - Leaving more protons than protons and a net positive charge.
    - The difference between Al atom and Al^{3+} ion is the number of electrons.
    - The ion has ***very*** different properties than the atom.
      - Do not confuse them.
- Anions are formed by adding an electron to an atom.
  - Leaving more electrons than protons and a net negative charge.
    - The difference between S atom and S^{2-} ion is the number of electrons.
    - The ion has ***very*** different properties than the atom.
      - Do not confuse them.











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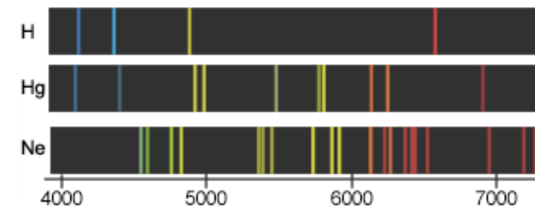
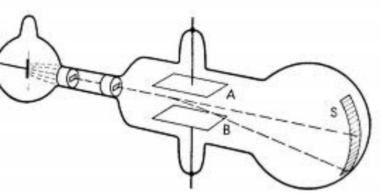
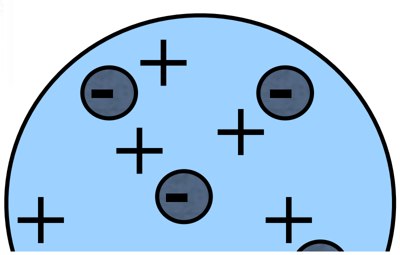
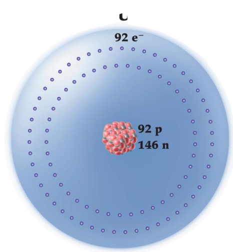
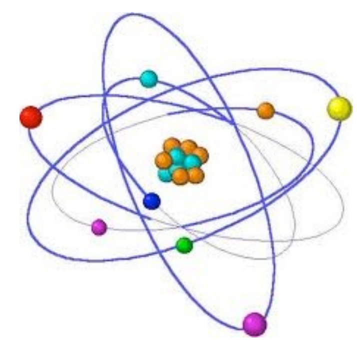




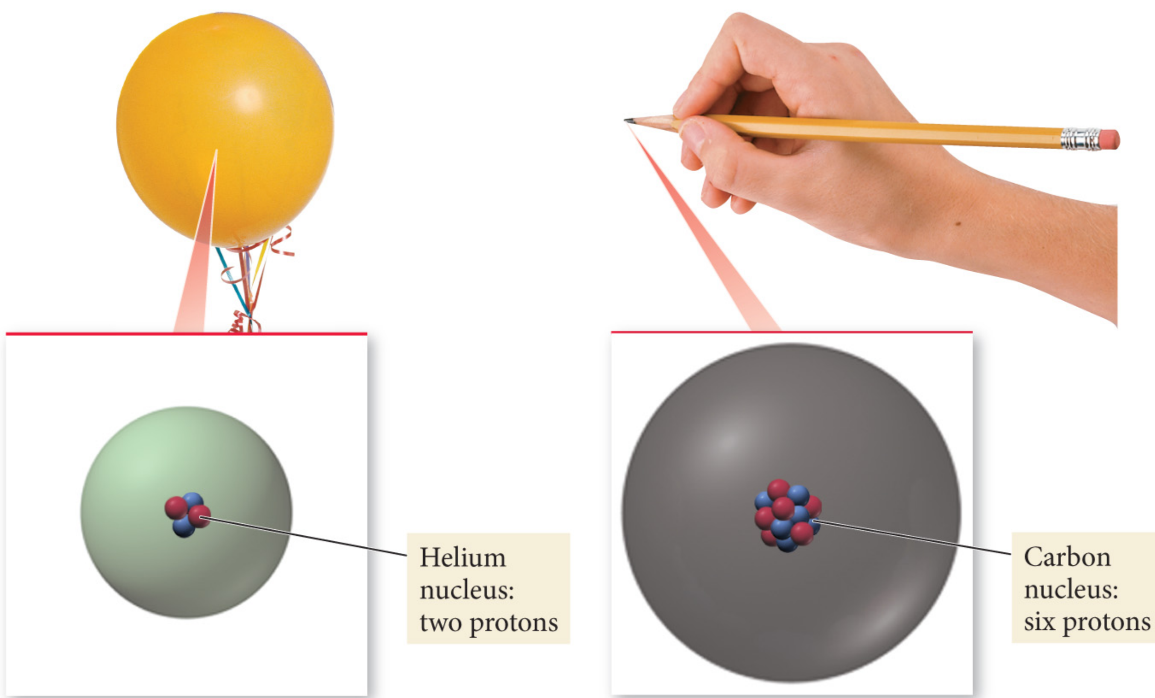






Elements differ in Protons

- If all atoms are made up of protons, neutrons, and electrons — what makes one element different from another?
- Elements differ by the number of protons.
- Carbon atoms have six protons. Helium atoms have two protons. Always.



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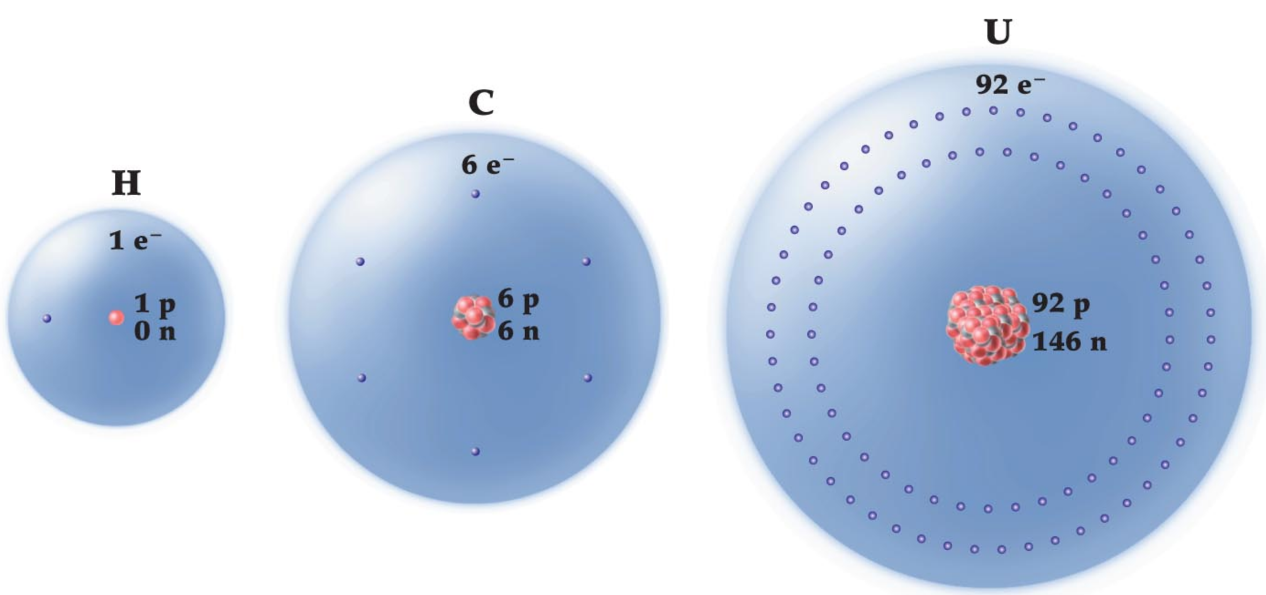
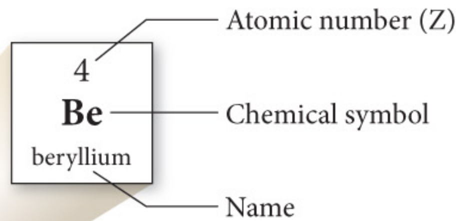


Elements differ in Protons

- The “serial number” in the periodic table is the atomic number.
- The atomic number equals the number of protons for that element.



1 H hydrogen																	2 He helium
3 Li lithium	4 Be beryllium											5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon
11 Na sodium	12 Mg magnesium											13 Al aluminum	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon
19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton
37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon
55 Cs cesium	56 Ba barium	57 La lanthanum	72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	82 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium	89 Ac actinium	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Cn copernicium	113 **	114 Fl flerovium	115 **	116 Lv livermorium	117 **	118 **

58 Ce cerium	59 Pr praseodymium	60 Nd neodymium	61 Pm promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb terbium	66 Dy dysprosium	67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium	71 Lu lutetium
90 Th thorium	91 Pa protactinium	92 U uranium	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

Ch03

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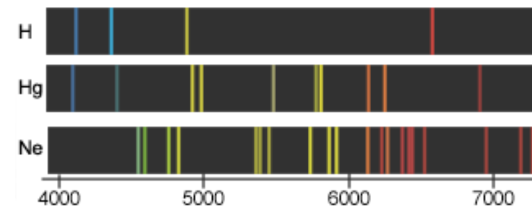
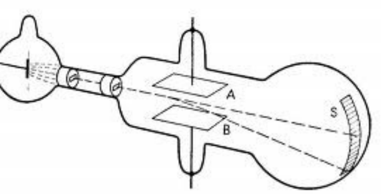
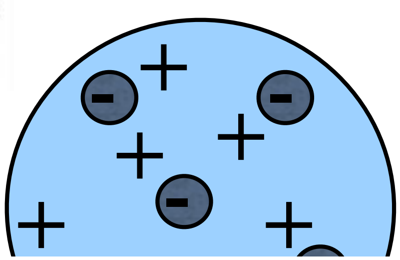
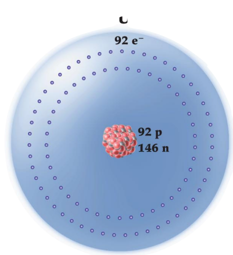
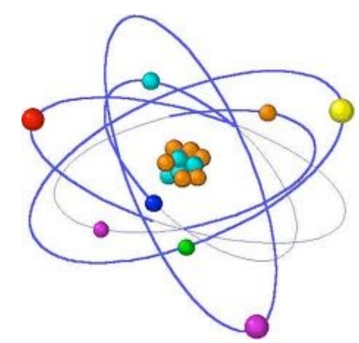




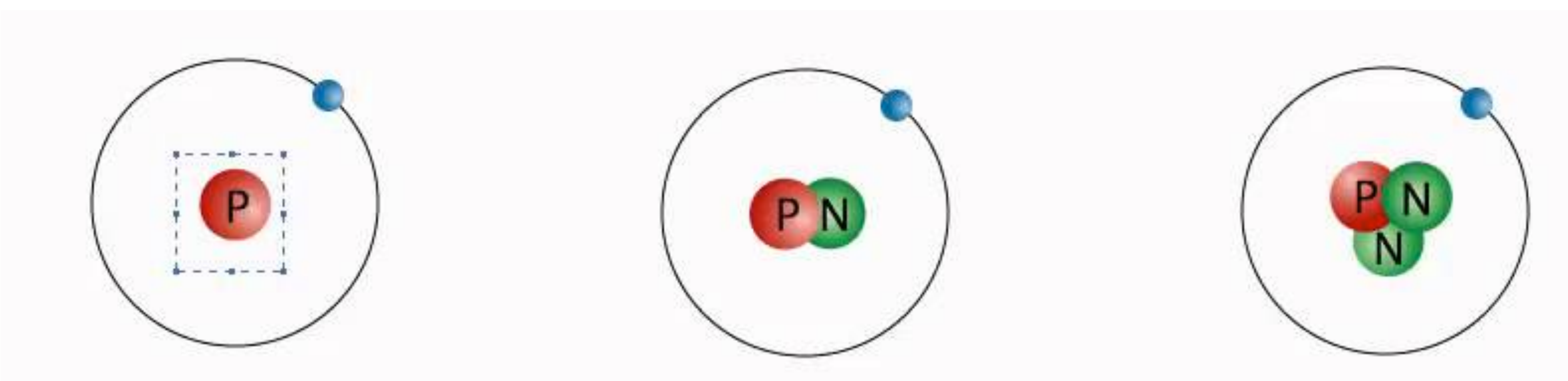






Isotopes differ in Mass

- All atoms of the same element, have the same number of protons.
- But may not have the same weight.
- Some hydrogen atoms weigh twice as much as other hydrogen atoms.
- The difference is in the number of neutrons.
- Atoms of the same element but different masses are called isotopes.



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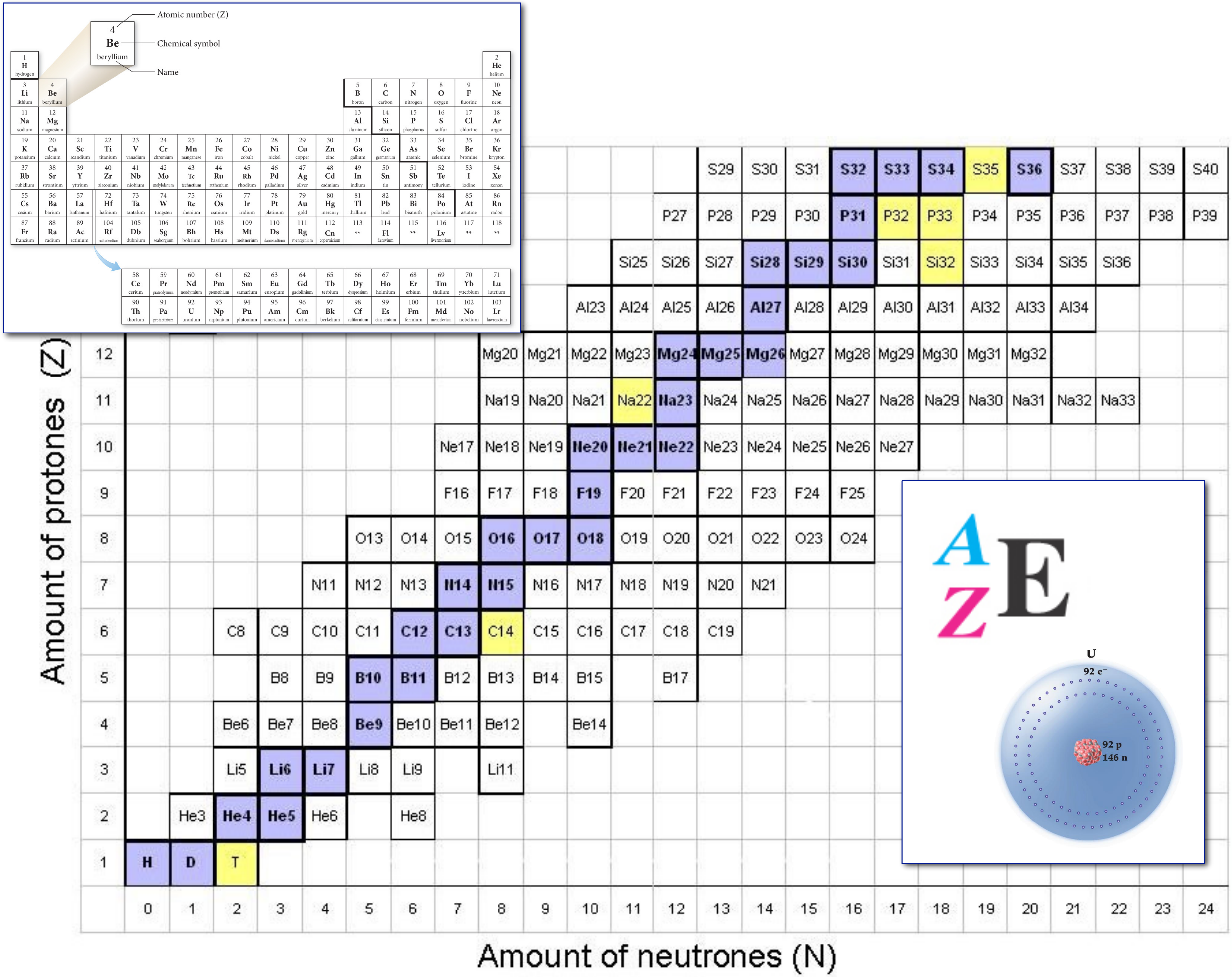
- Atoms of the same element but different masses are called isotopes.
- Isotopes are defined by their number of neutrons.
- We use isotopic notation to describe different isotopes.


Atomic number (Z)
Chemical symbol
Name
4
Be
beryllium
Amount of protones (Z)
Amount of neutrones (N)
S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40
P27 P28 P29 P30 P31 P32 P33 P34 P35 P36 P37 P38 P39
Si25 Si26 Si27 Si28 Si29 Si30 Si31 Si32 Si33 Si34 Si35 Si36
Al23 Al24 Al25 Al26 Al27 Al28 Al29 Al30 Al31 Al32 Al33 Al34
12 Mg20 Mg21 Mg22 Mg23 Mg24 Mg25 Mg26 Mg27 Mg28 Mg29 Mg30 Mg31 Mg32
11 Na19 Na20 Na21 Na22 Na23 Na24 Na25 Na26 Na27 Na28 Na29 Na30 Na31 Na32 Na33
10 Ne17 Ne18 Ne19 Ne20 Ne21 Ne22 Ne23 Ne24 Ne25 Ne26 Ne27
9 F16 F17 F18 F19 F20 F21 F22 F23 F24 F25
8 O13 O14 O15 O16 O17 O18 O19 O20 O21 O22 O23 O24
7 N11 N12 N13 N14 N15 N16 N17 N18 N19 N20 N21
6 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19
5 B8 B9 B10 B11 B12 B13 B14 B15 B17
4 Be6 Be7 Be8 Be9 Be10 Be11 Be12 Be14
3 Li5 Li6 Li7 Li8 Li9 Li11
2 He3 He4 He5 He6 He8
1 H D T
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
A
Z
E
U
92 e⁻
92 p
146 n

Isotopes differ in Mass

$^{A}_{Z}E$

- What would the symbol be for the Carbon-12 isotope?

6 protons + 6 neutrons

$^{12}_{6}C$

6 protons

- What would the symbol be for the Carbon-14 isotope?

6 protons + 8 neutrons

$^{14}_{6}C$

6 protons

Isotopes differ in Mass

$^{A}_{Z}E$

- Oxygen has three isotopes...

8 protons + 9 neutrons

$^{17}_{8}O$

8 protons

8 protons + 8 neutrons

$^{16}_{8}O$

8 protons

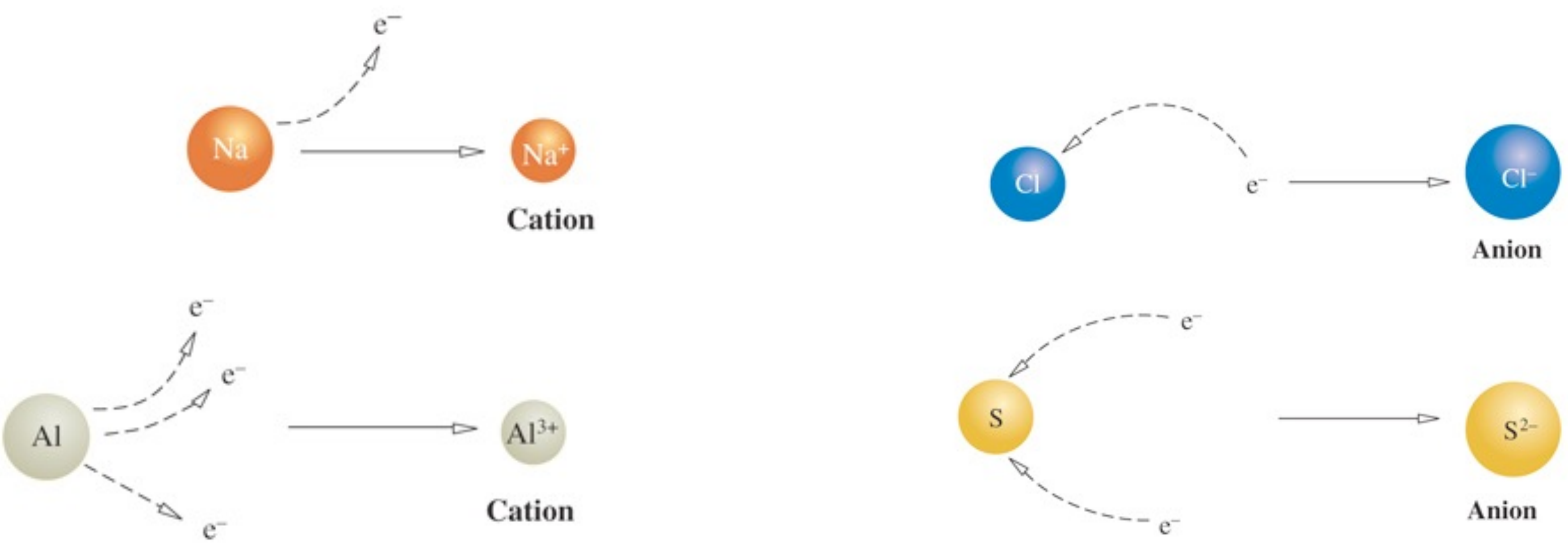
8 protons + 10 neutrons

$^{18}_{8}O$

8 protons

Ions differ in Electrons

- For a neutral atom, the number of protons equals the number of electrons.
- For a cation, there are less electrons than protons.
- For an anion, there are more electrons than protons.



Ions differ in Electrons

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$^{35}_{17}Cl$

17 protons,
17 electrons

$^{35}_{17}Cl^{-}$

17 protons,
18 electrons

Ions differ in Electrons

- For a neutral atom, the number of protons equals the number of electrons.
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- For an anion, there are more electrons than protons.

$${}^{1}_{1}\mathrm{H}$$

1 proton,
1 electron

$${}^{1}_{1}\mathrm{H}^{+}$$

1 proton,
0 electrons

Taking Atoms Apart

Symbol	Protons	Neutrons	Electrons	Mass
$^{44}_{11}Na$	11	33	11	44
$^{49}_{16}S$	16	33	16	49
$^{16}_{5}B$	5	11	5	16
$^{40}_{13}Al^{+3}$	13	27	10	40

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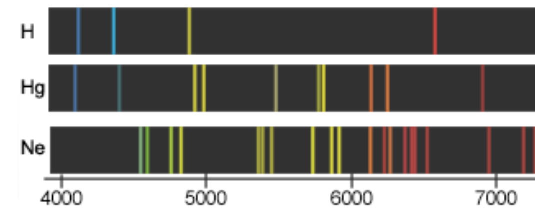

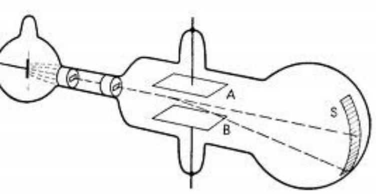

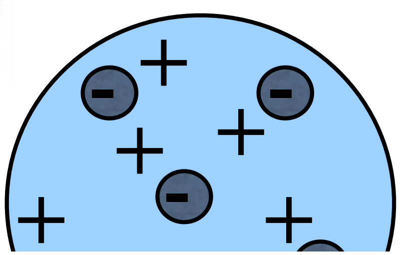

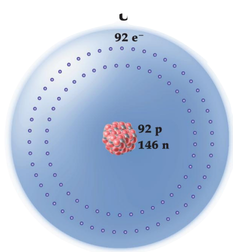

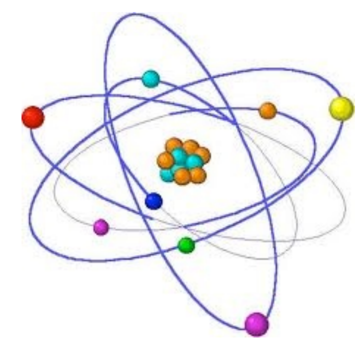

Questions?