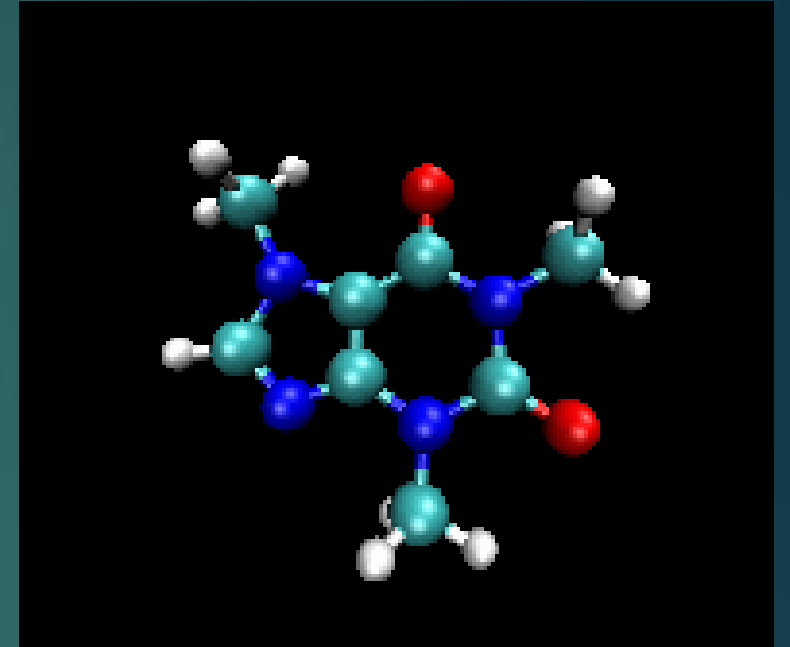


Science 10 Chemistry Unit

THE PERIODIC TABLE, ATOMS, COMPOUNDS AND CHEMICAL REACTIONS

TEXTBOOK REFERENCE: CHAPTERS 5 & 6



Brief History of Chemistry



The Creation of Chemistry - The Fundamental Laws: Crash Course Chemistry #3

CrashCourse

Chemistry

- ▶ The study of matter, its properties, and its changes or transformations.
- ▶ **Matter:** Anything that has mass and takes up space.

The Atom

- ▶ The smallest part of an element.
 - ▶ If you could zoom in on elements, like iron, oxygen, helium, plutonium, etc., you would see the atoms that make up that element.
- ▶ Theorized by Democritus around 2500 years ago.
 - ▶ Not based on a scientific investigation.
 - ▶ Could not explain chemical properties of matter.
 - ▶ Would remain undeveloped until the early 1800s.

John Dalton's Atomic Theory: 1803



1. All elements are composed of tiny indivisible particles called atoms.
2. Atoms of the same element are identical. The atoms of any one element are different from those of any other element.

John Dalton's Atomic Theory: 1803

3. Atoms of different elements can physically mix together or chemically combine in simple whole-number ratios to form compounds (like H_2O , CO_2).
4. Chemical reactions occur when atoms are separated, joined, or rearranged. Atoms of one of the element, however, are never changed to atoms of another element as a result of a chemical reaction. (Nuclear reactions change atoms from one type to another – happens naturally in the Sun and on Earth).

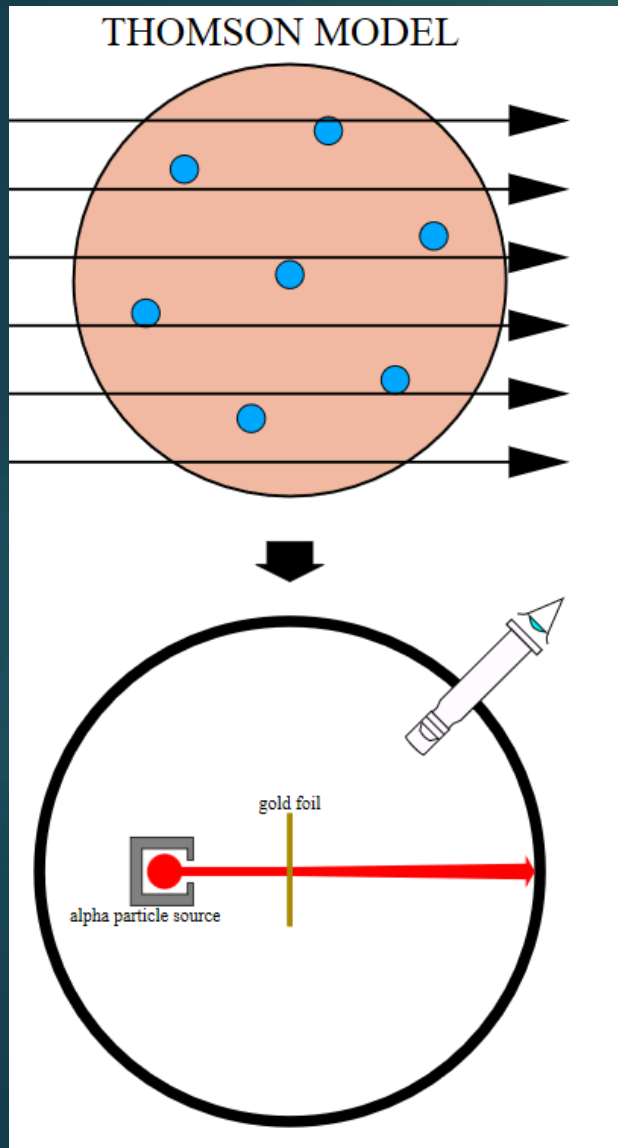
Incorporation of Electrons

- ▶ Electrons, as particles, were first theorized in 1897 by English physicist J.J. Thompson. He invented the cathode ray tube to test for charges. That work eventually became the CRT television.
- ▶ Thompson adjusted the model of the atom to incorporate electrons; he proposed the atom is a lump of positive charge with electrons evenly spaced within it – dubbed the “plum pudding” model of the atom.

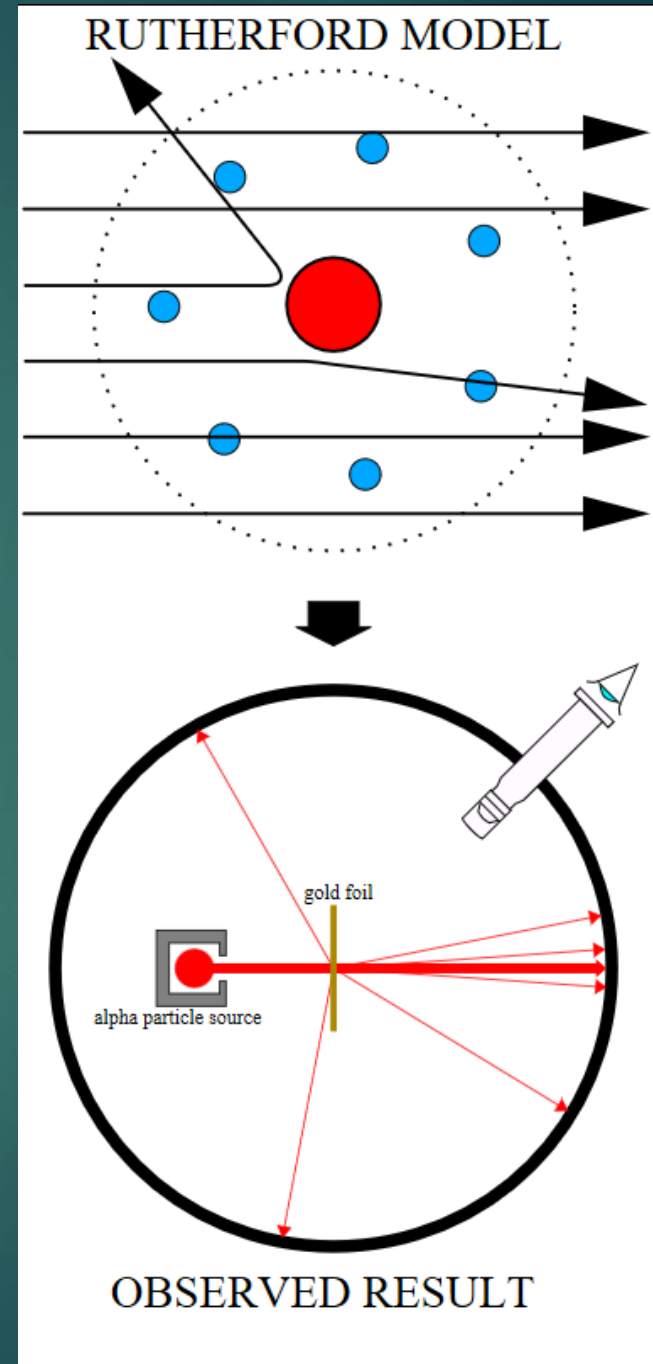
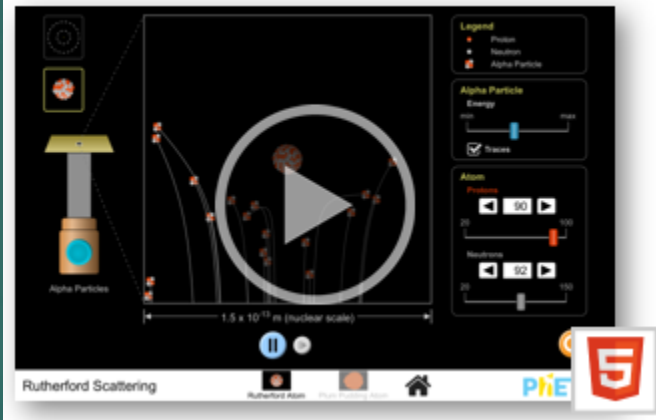
Discovery of the Nucleus

- ▶ Ernest Rutherford and coworkers at University of Manchester, England, were the first to theorize, based on experimental evidence, the existence of the atomic nucleus.
- ▶ In 1911 he performed the “Gold-Foil” experiment.
- ▶ His discovery changed the model of the atom significantly – the first evidence of the atomic nucleus and that atoms are mostly empty space.

Rutherford Experiment

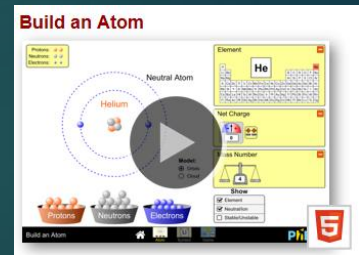


Rutherford Scattering



The Atomic Nucleus

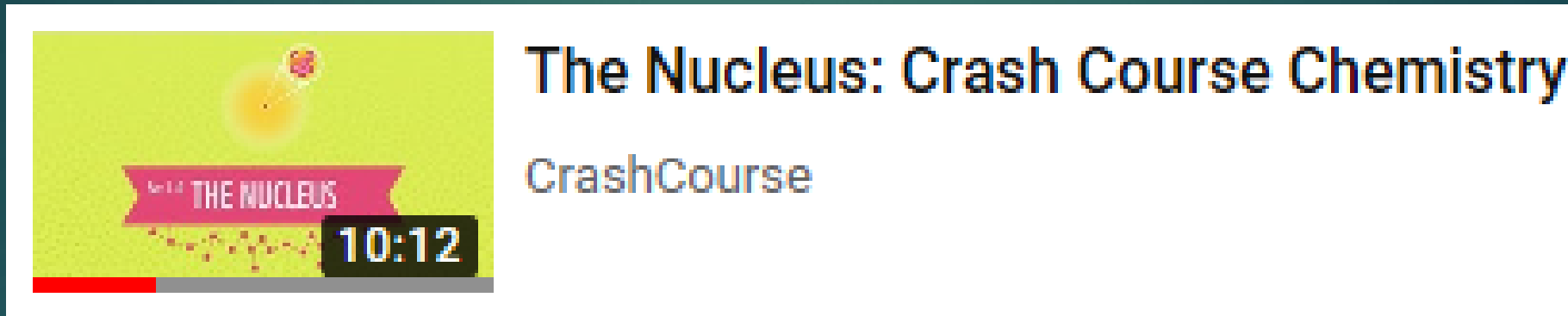
- ▶ Rutherford's experiment confirmed the presence of a small, dense, area of positive charge. The term **proton** was used to name the unseen positive particles. Also, that atoms are mostly empty space.
- ▶ It would be 21 years later, in 1932, when physicist James Chadwick discovered the **neutron**, which also exists within the nucleus to keep protons apart. The neutron is neutral in charge (a charge of zero). The # of neutrons does not have to equal the # of protons in an atom.
- ▶ Protons (p^+) and neutrons (n^0) are very close to the same size and mass. Both have a much, much larger mass than the electron (e^-)



Build an Atom

A screenshot of a simulation titled "Build an Atom". The central part shows a "Neutral Atom" with a nucleus containing two protons (orange) and two neutrons (grey), and two electrons (blue) orbiting. A play button is in the center. To the right is a periodic table window for Helium (He) with fields for Atomic Number, Mass Number, and Net Charge. At the bottom are buttons for "Protons", "Neutrons", and "Electrons".

The Nucleus: Summary Video



- But what about *electrons*?
- Chemical and physical properties are the result of electrons in the atom.

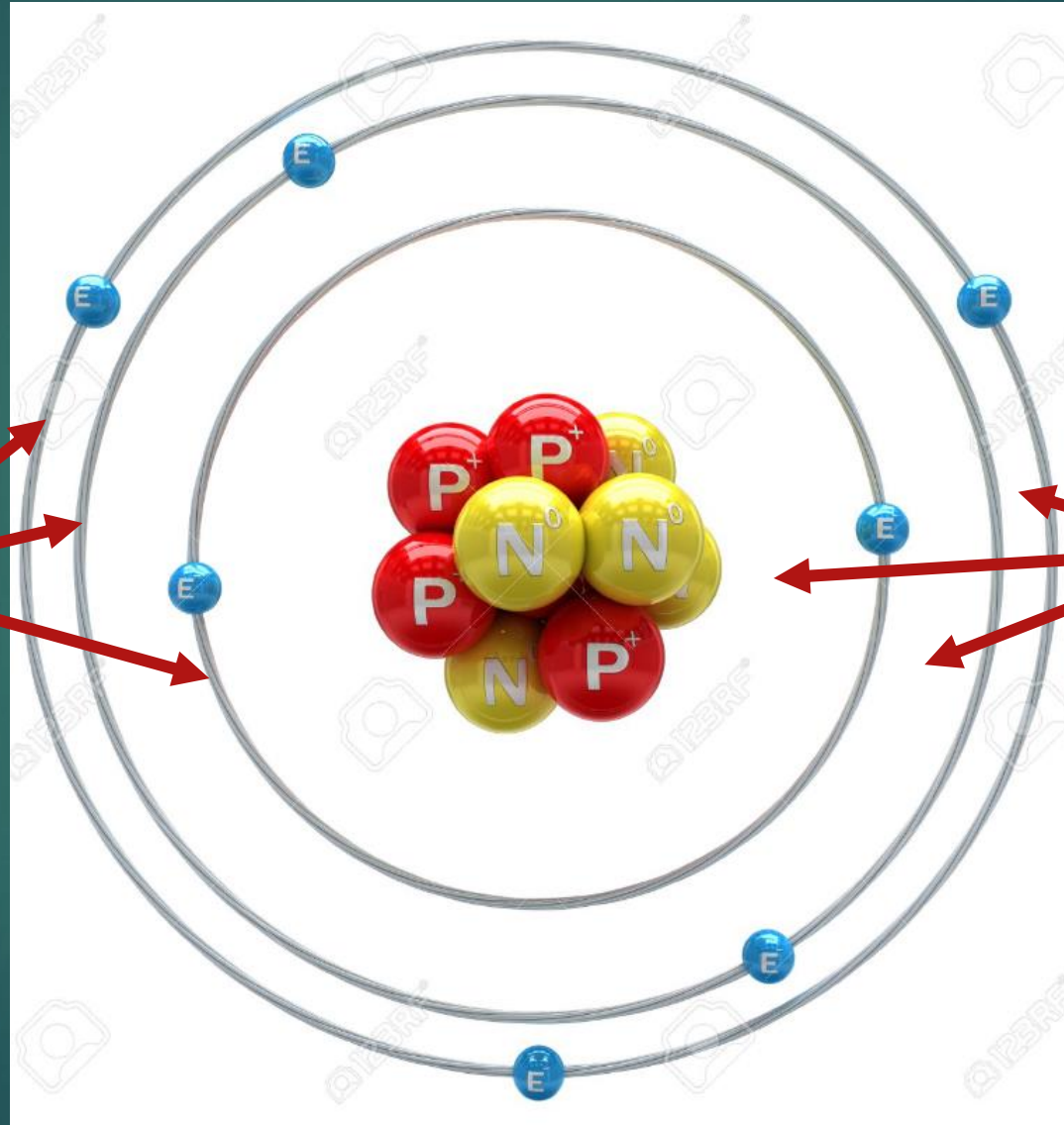
Atomic Structure – Electron Orbitals

- ▶ 1897: Thompson theorized electrons were static in a clump of positive charge.
- ▶ 1904: Japanese physicist suggests a central nucleus exists and electrons travel around it like the rings around the planet Saturn.
- ▶ 1911: Rutherford's experimental results support the nucleus and he agreed that electrons orbit the nucleus like planets around the Sun. However, it could not explain properties of elements, like why heated metal glowed red/orange.
- ▶ 1913: New Zealand physicist Niels Bohr adjusts the model such that electron's have fixed distances from the nucleus, but that electrons can change where they are located in the atom by gaining/losing energy.

Bohr Model of the Atom

- ▶ Explains observations of light coming from the simplest element, hydrogen, but failed for larger atoms, like metallic elements change color when heated.
- ▶ The energy electrons have is **quantized**, they can only have a specific amount of energy at each orbit and they cannot be found at any other orbit.
- ▶ Electrons gain or lose a **quantum** of energy to change orbital locations around the nucleus.

Bohr Model of the Atom

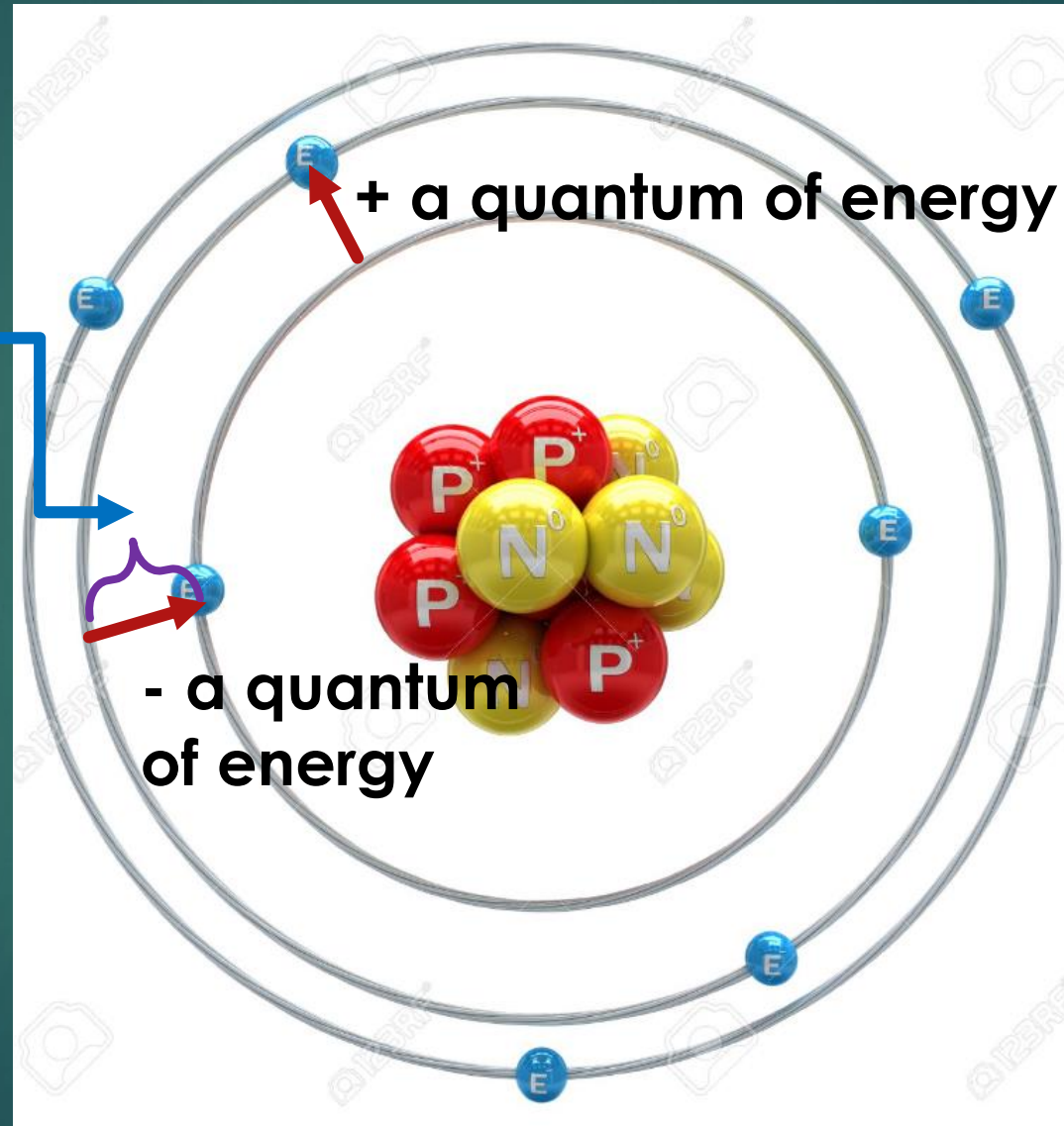


Quantized energy orbitals

Electrons can't be here!

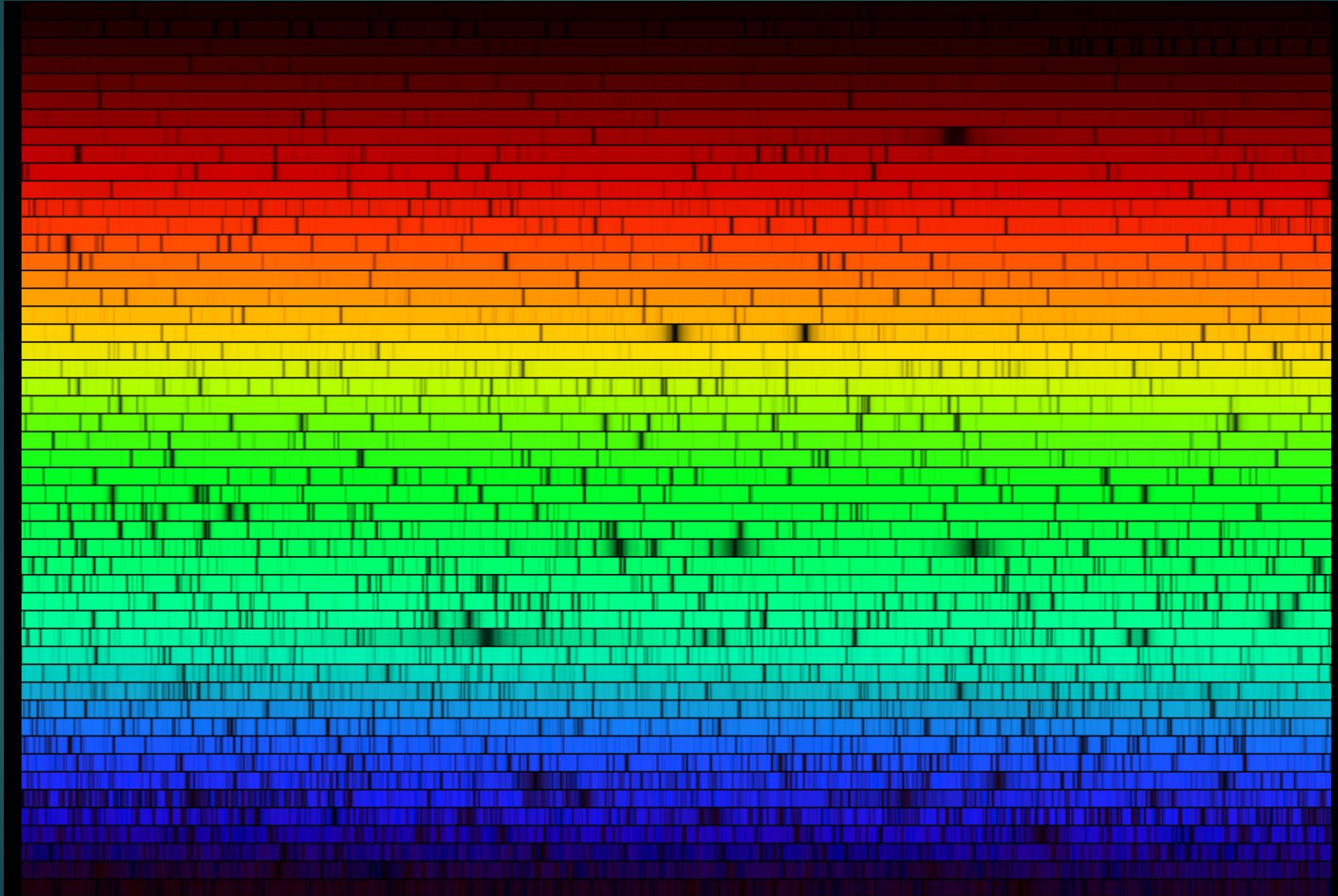
Bohr Model of the Atom

Change in energy is released as radiation, in the case of metals, it could be orange light!



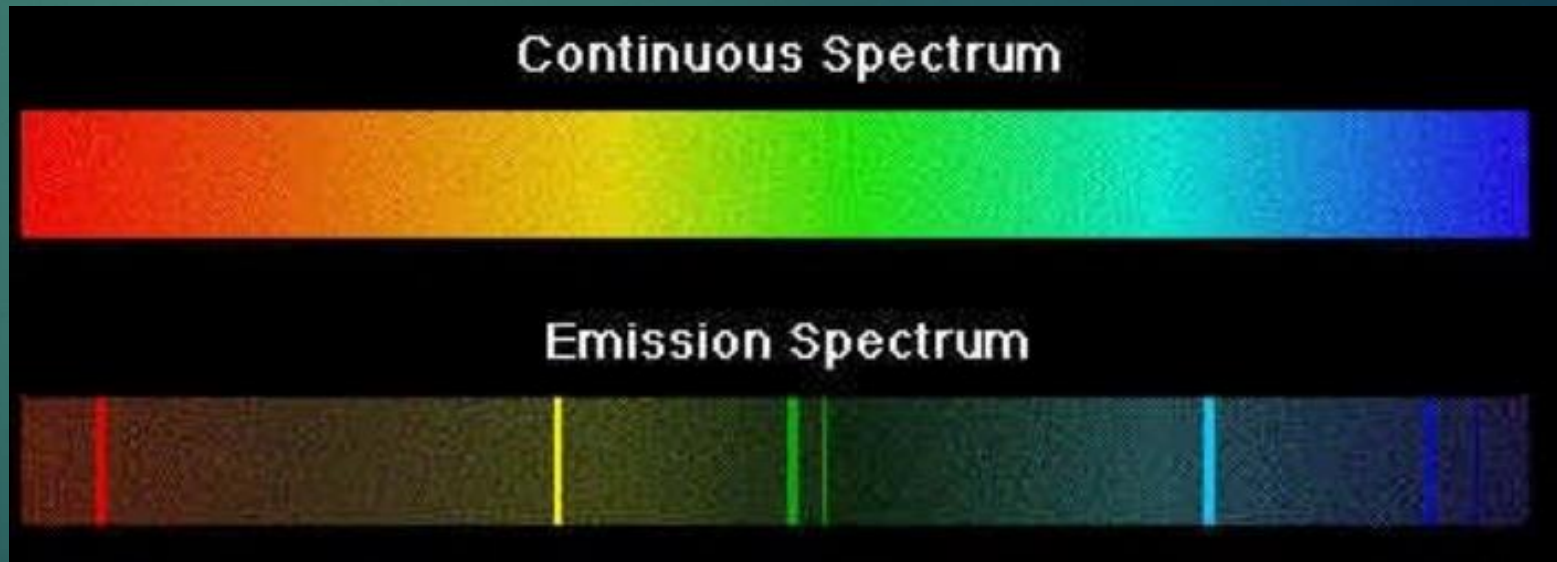
- Again, this model explained hydrogen, but failed for the larger atoms.
- This theory was refined by Erwin Schrodinger in 1926.

Absorbing Energy: Absorption Spectra



Emitting Energy: Emission Spectrum

- ▶ Helium was discovered on the Sun before it was found on Earth.
- ▶ During a solar eclipse, extra energies were found being emitted from the hot gas, called the solar corona, surrounding the Sun.



Emitting Energy: Emission Spectrum

TOTAL SOLAR ECLIPSE 11/07/2010 EASTER ISLAND. CHILE

FLASH SPECTRUM VIA SPECTROGRAPH 300lines/mm Voulgaris A., Seiradakis J., Economou T.

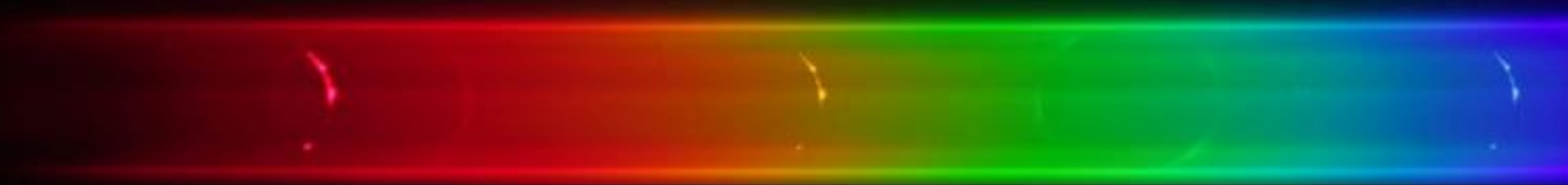
H α

FeX

HeI

FeXIV

H β



Ingress 20:08:47 UT

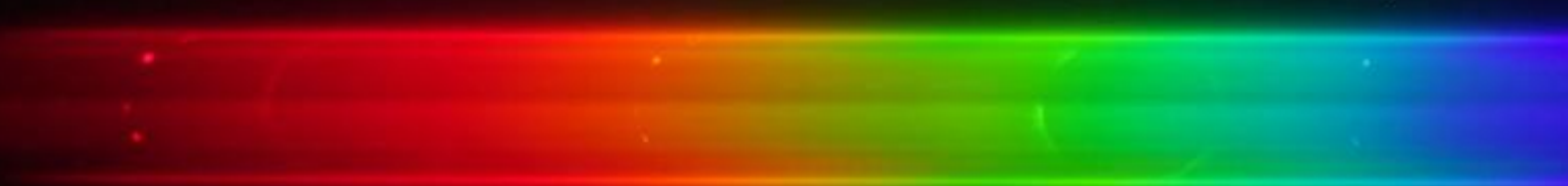
H α

FeX

HeI

FeXIV

H β



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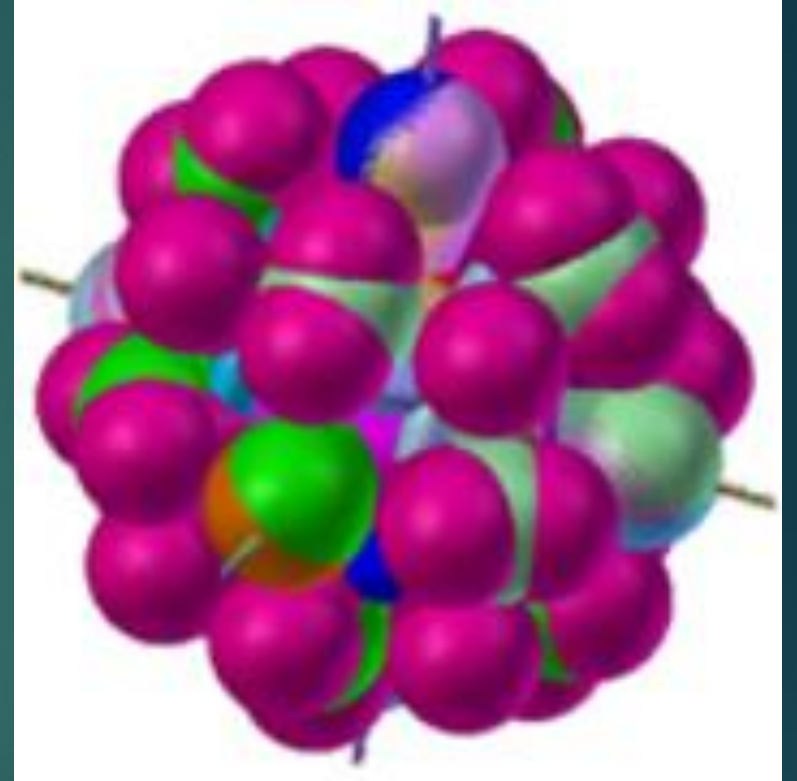
The Flash Spectrum after the 2nd and before 3rd contact from TSE 2010, Easter Island

Quantum Mechanical Model

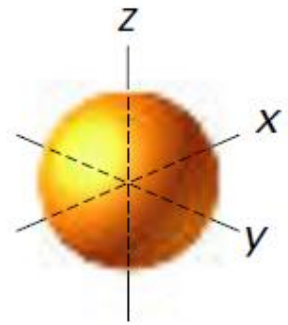
- ▶ In 1926 Austrian physicist Erwin Schrodinger spearheaded the development of basis for our current model of the atom, the Electron Cloud Model or Quantum Mechanical Model.
- ▶ His model of the atom was mathematical. A mathematical representation of the atom based on all know numerical and scientific information at the time.
- ▶ This resulted in a model where electrons have a high probability of being found in a specific region around the nucleus.

Quantum Mechanical Model

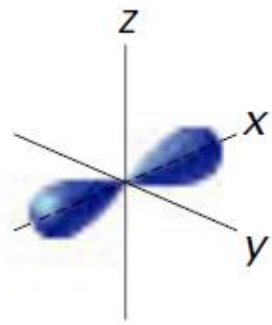
- ▶ The regions were not circular orbitals, but blob-shaped 3D spaces.
- ▶ Electrons were found to have wave and particle properties.
- ▶ Expanded upon Bohr's work and explained the properties of all elements (to a degree, they did not have any electronically powered computers for calculations).



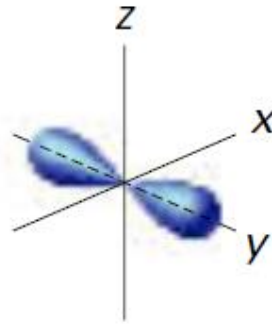
Quantum Mechanical Model



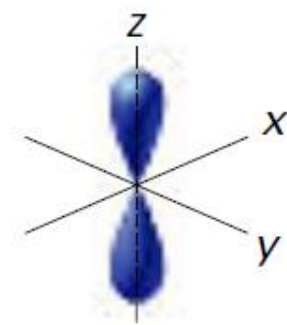
s orbital



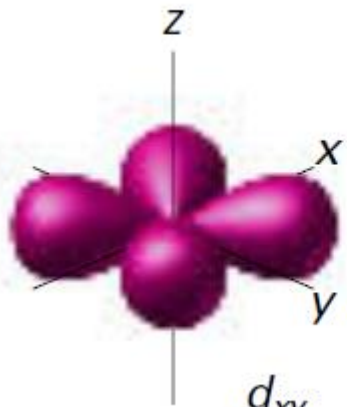
p_x orbital



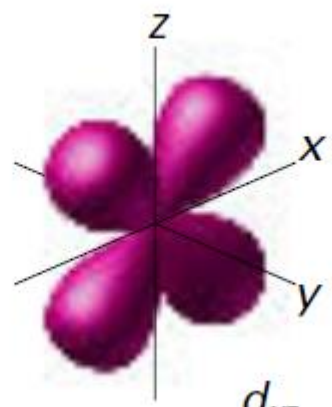
p_y orbital



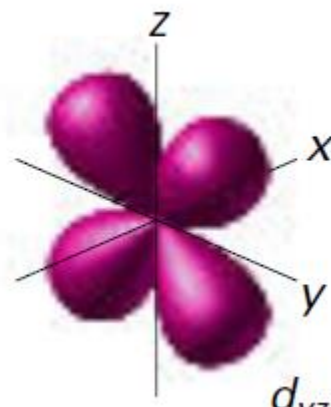
p_z orbital



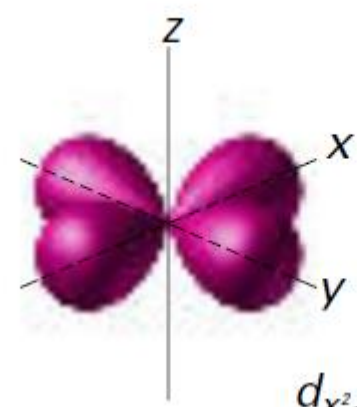
d_{xy}



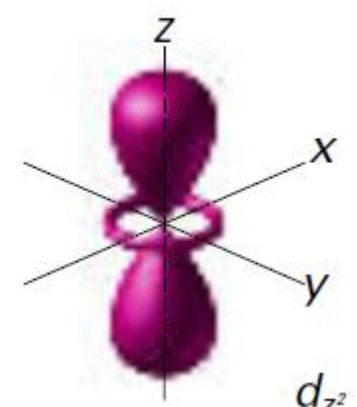
d_{xz}



d_{yz}

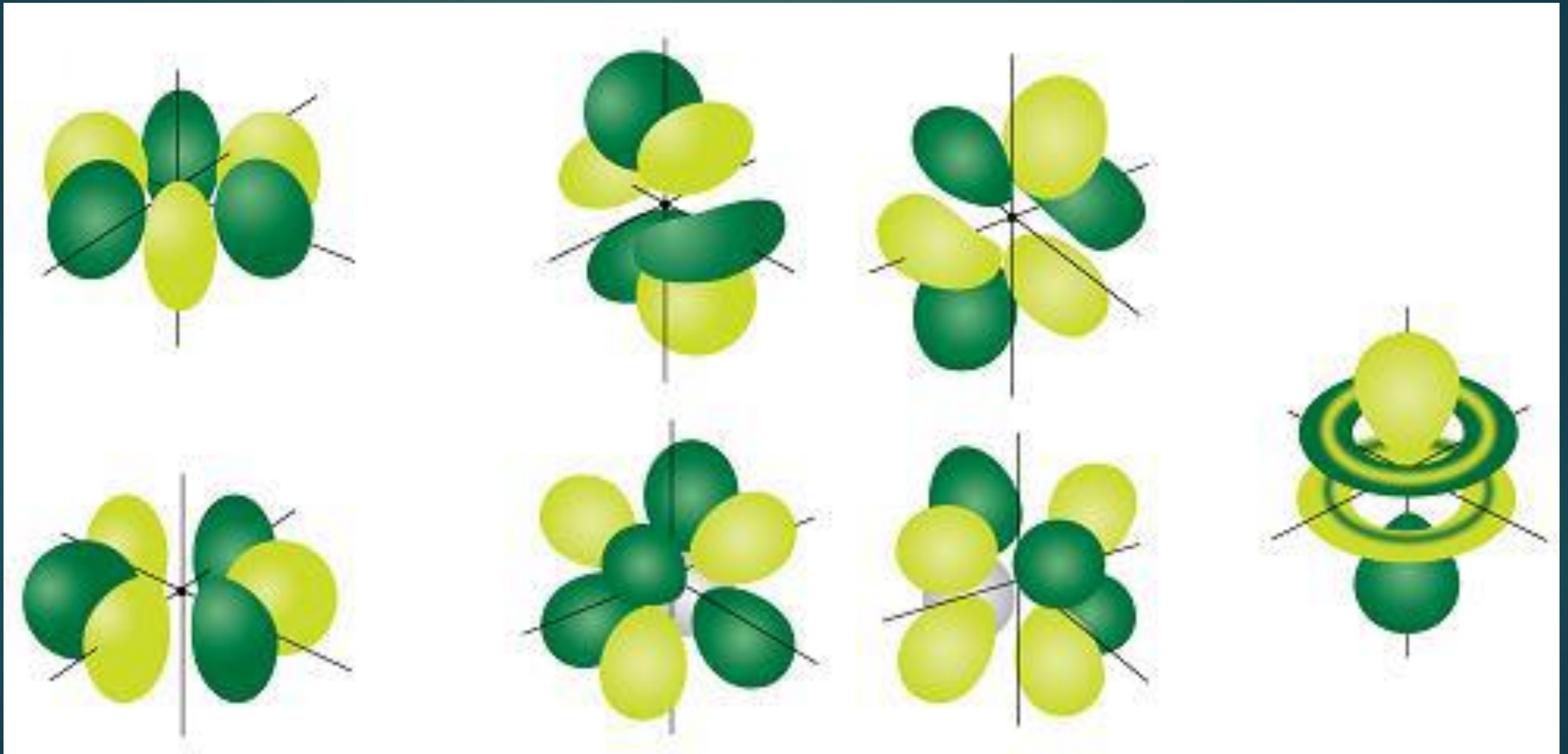


$d_{x^2-y^2}$



d_{z^2}

Quantum Mechanical Model

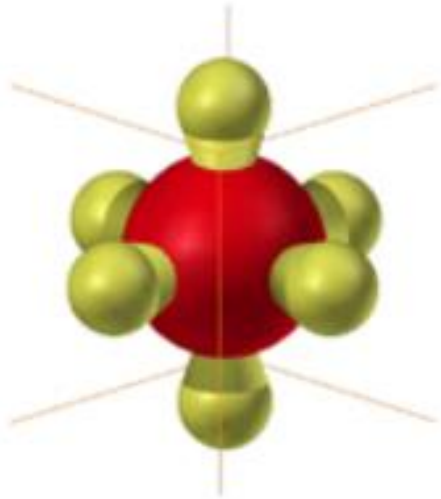


Overlapping Orbitals = Electron Cloud

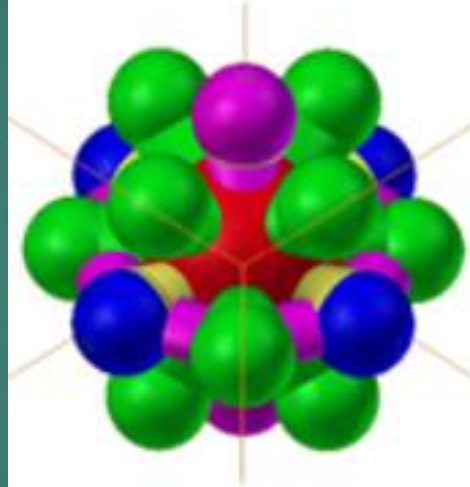
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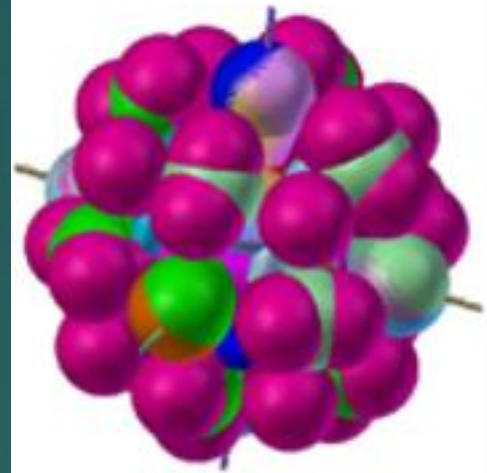
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18



32



The Electron: Summary Video



The Electron: Crash Course Chemistry
CrashCourse
12:48

Organizing Elements: The Periodic Table



The Periodic Table: Crash Course Chemistry

CrashCourse

The Periodic Table of the Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18					
1	1 H Hydrogen 1.00794	<div style="display: flex; justify-content: space-between;"> <div style="width: 15%;"> <p>Atomic #</p> <p>Symbol</p> <p>Name</p> <p>Atomic Mass</p> </div> <div style="width: 30%;"> <p>C Solid</p> <p>Hg Liquid</p> <p>H Gas</p> <p>Rf Unknown</p> </div> <div style="width: 40%;"> <p>Metals</p> <p>Alkali metals</p> <p>Alkaline earth metals</p> <p>Lanthanoids</p> <p>Actinoids</p> <p>Transition metals</p> <p>Poor metals</p> <p>Other nonmetals</p> <p>Noble gases</p> </div> </div>																	2 He Helium 4.002602				
2	3 Li Lithium 6.941	4 Be Beryllium 9.012182																5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
3	11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050																13 Al Aluminum 26.9815386	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.796					
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.290					
6	55 Cs Cesium 132.9054519	56 Ba Barium 137.327	57-71 Lanthanoids	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.222	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (209.9824)	85 At Astatine (209.9871)	86 Rn Radon (222.0176)					
7	87 Fr Francium (223)	88 Ra Radium (226)	89-103 Actinoids	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (282)	117 Uus Ununseptium (286)	118 Uuo Ununoctium (294)					

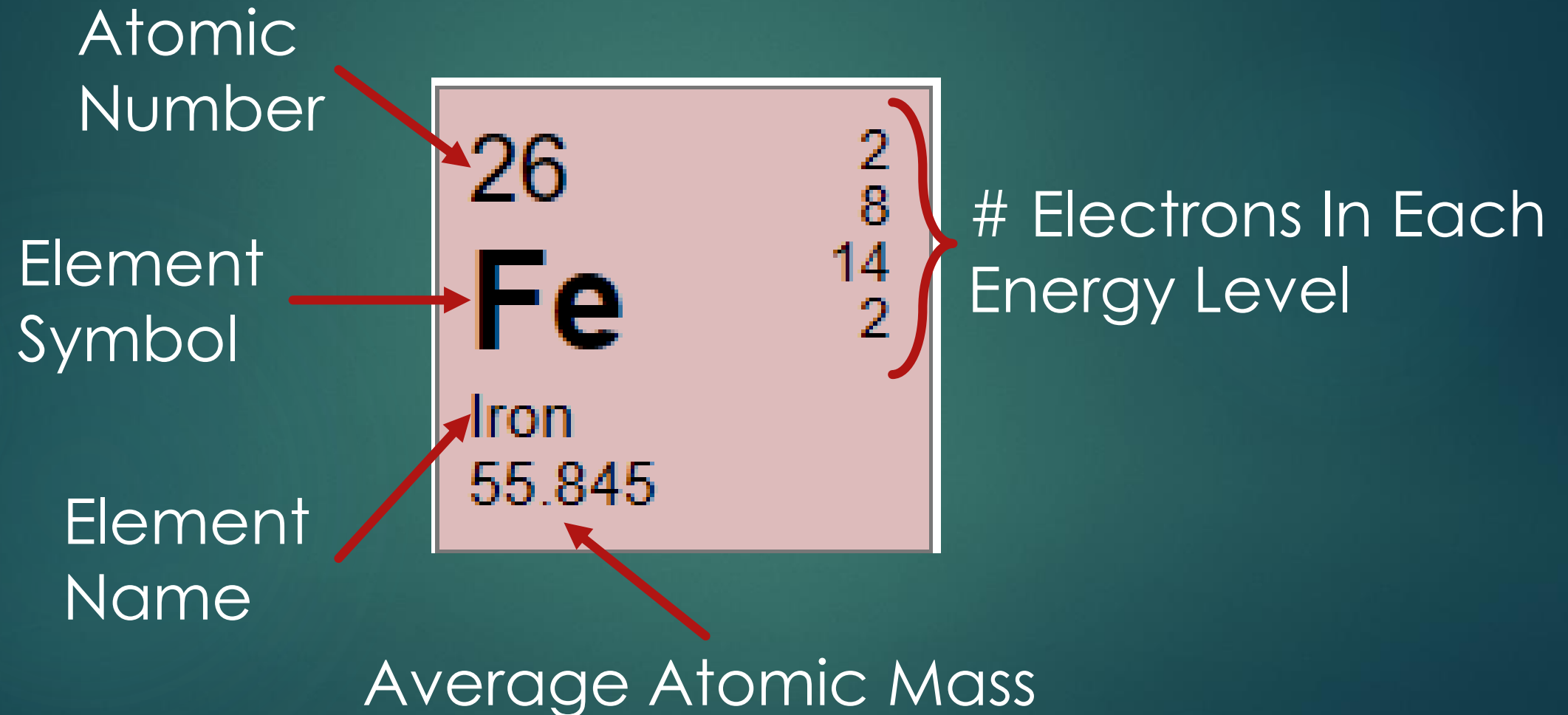
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90768	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03688	92 U Uranium 238.02891	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)



Our Periodic Table



Periodic Table: Element Information

- ▶ **Element Symbol**: First letter is always a capital letter. If there is a second letter it is lower case. Two letters maximum.
- ▶ **Atomic Number**: The number of **protons** in the nucleus; how the table is organized. The number of protons defines the element.
- ▶ **Average Atomic Mass**: The mass of the element taking into account its various **isotopes** (atoms of the same element but a different number of neutrons). The unit is the **atomic mass unit, amu**.
- ▶ 1 amu is defined as exactly one-12th (1/12) the mass of the Carbon-12 atom (6 protons and 6 neutrons).

The Periodic Law

- ▶ When elements are tabled in order of increasing atomic number, there is a periodic repetition of chemical and physical properties.
- ▶ **Groups**: The vertical columns; elements in the same column have similar chemical and physical properties (boiling points, luster, conductivity, reactivity, etc.).
- ▶ **Periods**: The horizontal rows. As you read left to right, elements get properties of non-metals.

The Periodic Table of the Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18					
1	1 H Hydrogen 1.00794	<div style="display: flex; justify-content: space-between;"> <div style="width: 15%;"> <p>Atomic #</p> <p>Symbol</p> <p>Name</p> <p>Atomic Mass</p> </div> <div style="width: 30%;"> <p>C Solid</p> <p>Hg Liquid</p> <p>H Gas</p> <p>Rf Unknown</p> </div> <div style="width: 30%;"> <p>Metals</p> <p>Alkali metals</p> <p>Alkaline earth metals</p> <p>Lanthanoids</p> <p>Actinoids</p> <p>Transition metals</p> <p>Poor metals</p> </div> <div style="width: 15%;"> <p>Nonmetals</p> <p>Other nonmetals</p> <p>Noble gases</p> </div> </div>																	2 He Helium 4.002602				
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For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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Using the Periodic Table

- ▶ What element is atomic number 74?
- ▶ What is the symbol for the element with atomic number 82?
- ▶ What is the atomic mass of cesium (located in group 1)?
- ▶ How many electrons in the 3rd energy level of cadmium?
- ▶ What element has the most electrons in group 2?
- ▶ What element is located in period 4 group 11?
- ▶ How many protons in an atom of carbon?
- ▶ How many electrons in the highest energy level of group 1?
17? 18?

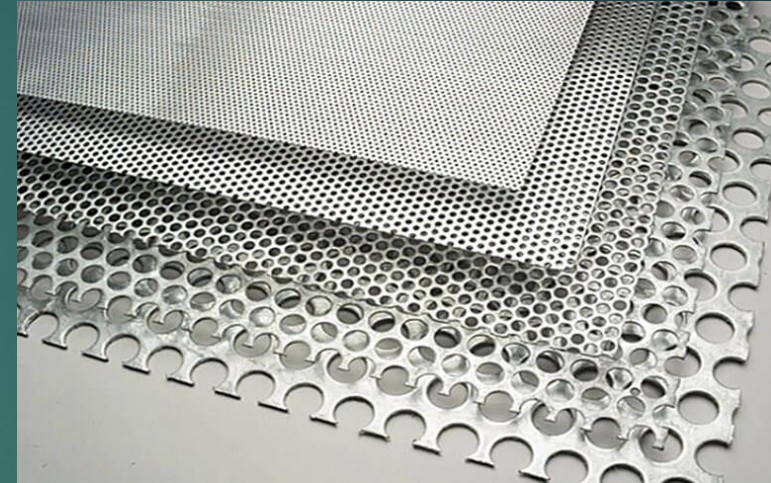
Metals, Nonmetals & Metalloids

- ▶ The periodic table classifies/divides elements into one of three groups: **metals**, **non-metals** and **metalloids**.
- ▶ Scanning across the periodic table (from left-to-right), the properties of elements becomes less metallic and more nonmetallic.

1																	2
H																	He
3	4	Metal										5	6	7	8	9	10
Li	Be											B	C	N	O	F	Ne
11	12											13	14	15	16	17	18
Na	Mg											Al	Si	P	S	Cl	Ar
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
55	56	57-71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
87	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71			
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu			
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103			
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr			

Physical Properties of Metals

- ▶ Most elements are metals.
- ▶ Good conductors of heat and electricity.
- ▶ High luster and sheen; shiny.
- ▶ Malleable – hammered into thin sheets.
- ▶ Ductile – drawn into wires.
- ▶ Solids at room temperature (except for mercury).



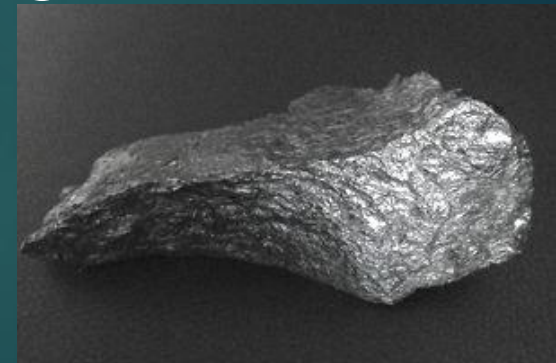
Physical Properties of Nonmetals

- ▶ State at room temperature varies as many are gases but some are liquids and a few are solids.
- ▶ Properties opposite of metals.
- ▶ Not good conductors of electricity and heat (carbon is an exception to this)
- ▶ Not shiny, so they are dull.
- ▶ Not malleable.
- ▶ Not ductile.



Physical Properties of Metalloids

- ▶ There is a heavy staircase, bolded line that separates metals and nonmetals.
- ▶ The metals that border the line are the metalloids.
- ▶ Metalloids tend to have properties of metals and nonmetals; this depends on the conditions the element is under.
- ▶ For example, silicon is a poor conductor of electric current, but mix in a small amount of boron and the mixture is a good conductor of electricity (used in electronics).



Groups on the Periodic Table



- ▶ Many groups on the periodic table are given a unique name, based on the properties of the elements in that group.

Periodic Table: Group Names

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	8	8B	10	11B	12B	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)		

Group 1: Alkali Metals

- ▶ All shiny, silvery metals.
- ▶ Very violently reactive with water.
- ▶ Forms basic compounds with water (baking soda, soaps are bases)
- ▶ Form compounds that are mostly white solids and those compounds are very soluble in water (table salt – NaCl).

3 Li Lithium 6.938
11 Na Sodium 22.990
19 K Potassium 39.098
37 Rb Rubidium 85.468
55 Cs Cesium 132.91
87 Fr Francium (223)