Ch04

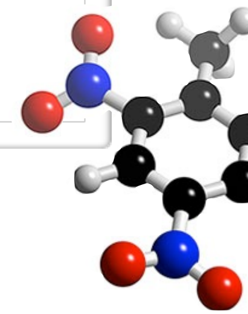
Flavors of the Atom

Not every atom is the same.

Differences between ions, elements, and isotopes.

version 1.5

Flavors of the Atom



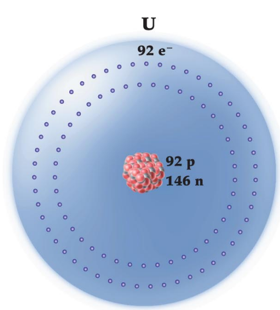
- Organizing the Elements
  - Chemical Symbols
  - Periodicity
- The Periodic Table
  - The First Periodic Table
  - Metals & Non-metals
    - Metallic Properties
  - Common Ions, Predicting Charge
  - Representative Elements
  - Periods, Groups & Families
    - Group Numbers
    - Family Names
  - Official Class Periodic Table

1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca						

- Pieces of the atom
  — electrons, protons, neutrons
  - Ions differ in electron count
  - Elements have different proton counts
  - Isotopes differ in total mass (because they differ in number of neutrons)
    - Isotopic Notation

$^{17}_{8}O$

- Regions of the atom
  - Electron Shells
    - Finding Electron Shells
    - Valence Electrons
    - Lewis Symbols
- Trends
  - in Size
  - in Ionization Energy



Organizing the Elements

- Finding new pure substances with useful and interesting properties made chemistry a valuable science.
- As chemists sought out more pure substances and documented their properties they explored how those substances could be made or decomposed.
- They quickly realized that every substance they discovered could be decomposed into one of a handful of unique substances that could not themselves be decomposed.
- The called those hand full of cornerstone substances elements.
- Between the early 1700's and mid 1800's chemists sought out and found over 50 of those those essential substances.
- At we found more and more elements we needed to organize them.
- So we started by making flash cards.
- We gave each element a symbol.

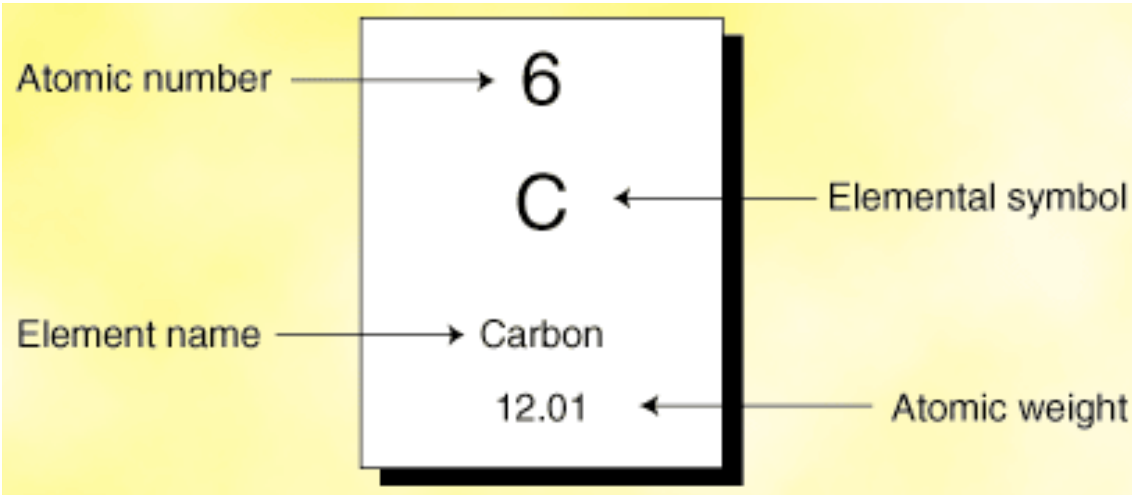
For the next exam:
Know the name and symbol of the first 18 elements.

Symbols for 18 Elements

Hydrogen (H)
Helium (He)
Lithium (Li)
Beryllium (Be)
Boron (B)
Carbon (C)
Nitrogen (N)
Oxygen (O)
Fluorine (F)

Neon (Ne)
Sodium (Na)
(latin: **Na**trium)
Mgagnesium (Mg)
Aluminum (Al)
Silicon (Si)
Phosphorus (P)
Sulfur (S)
Clhlorine (Cl)
Argon (Ar)

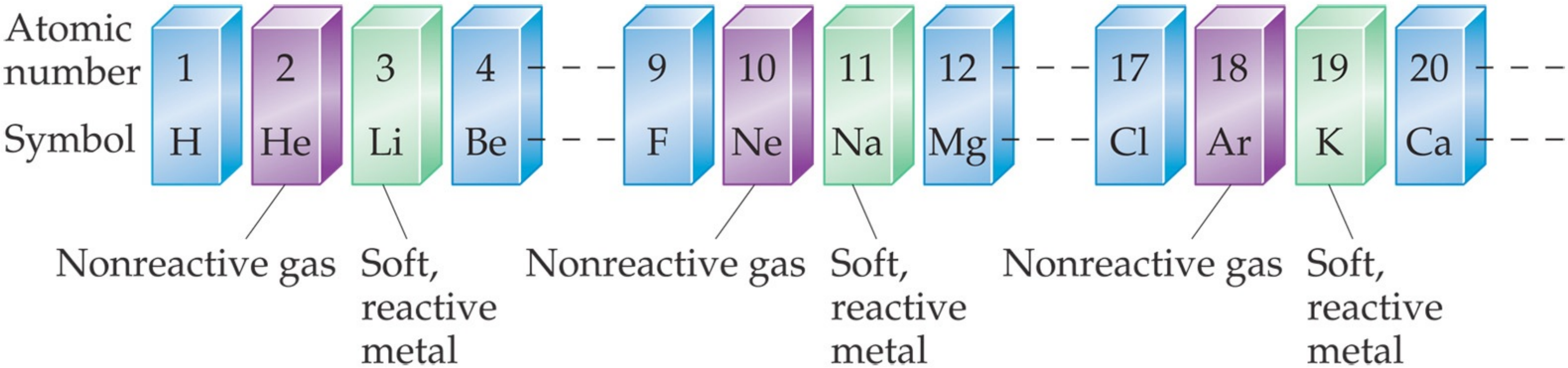
Organizing the Elements



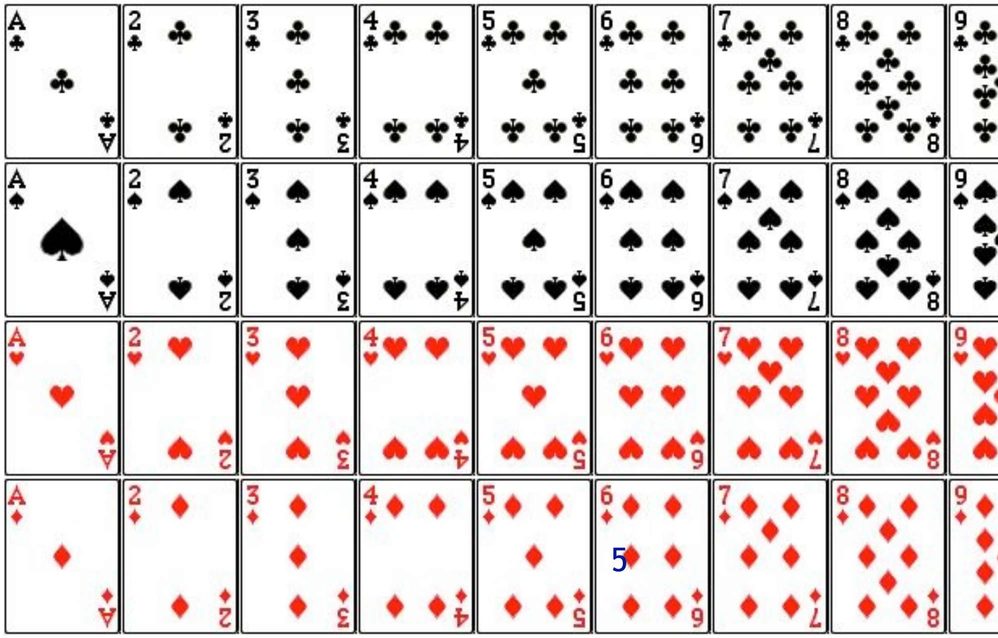
Symbols have 1, 2 or 3 letters. If 1 letter is used, it is capitalized. If 2 or 3 letters are used, only the first is capitalized.

- We started by making flash cards.
- We gave each element a symbol.
- Then we lined them up by increasing weight, just like you might organize a poker hand.
- We gave each element a serial number (atomic number), to indicate it's place in the sequence of increasing weight.

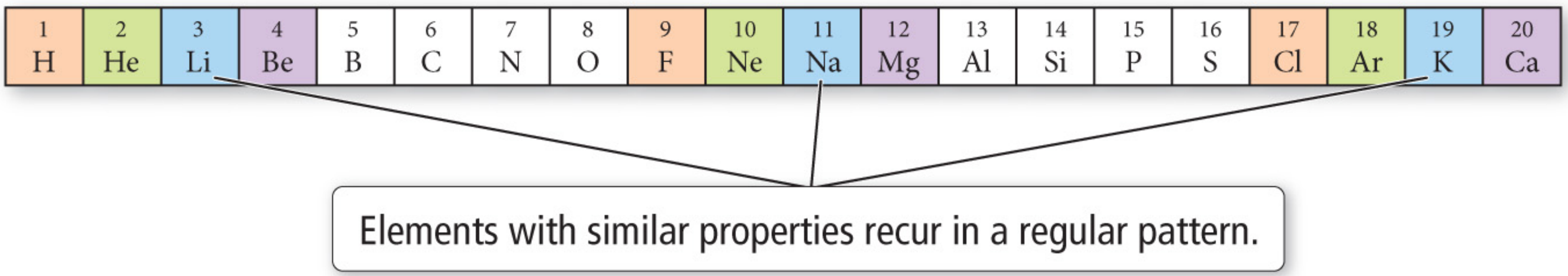
Periodicity



- We lined up all the cards by weight. From lightest to heaviest.
- Then we looked at their chemical and physical properties and saw a repeating pattern.
- Periodically, the same property shows up again and again and again.
- So instead of making it one really lone line, we wrapped our set of cards so that those periodic trends lined up.



Periodicity



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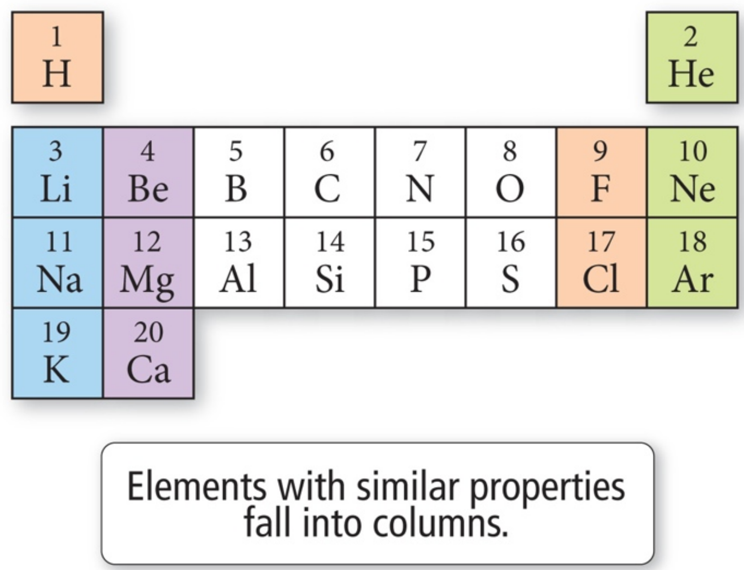

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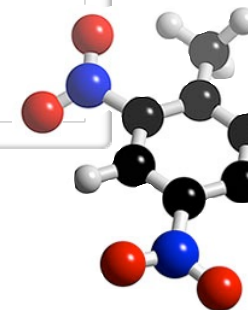
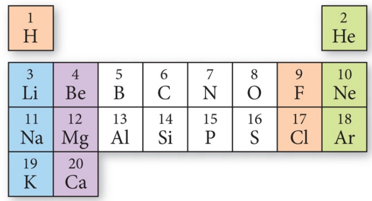


- Organizing the Elements
  - Chemical Symbols
  - Periodicity
- The Periodic Table



  - The First Periodic Table
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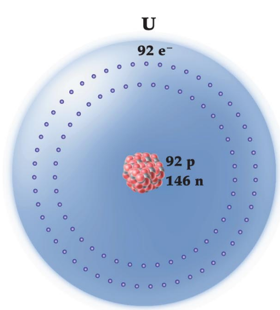

- Pieces of the atom — electrons, protons, neutrons
  - Ions differ in electron count
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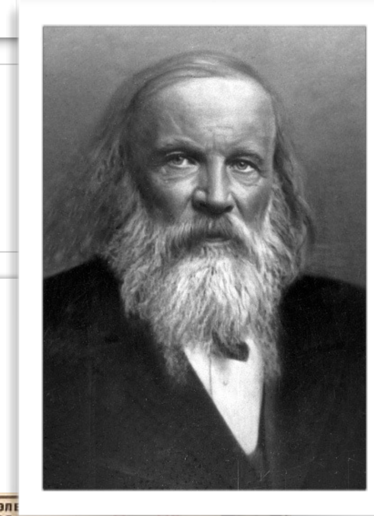
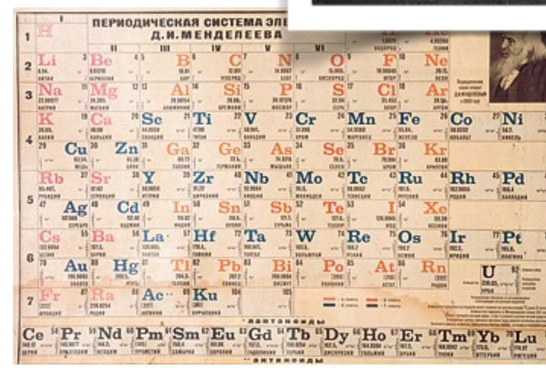
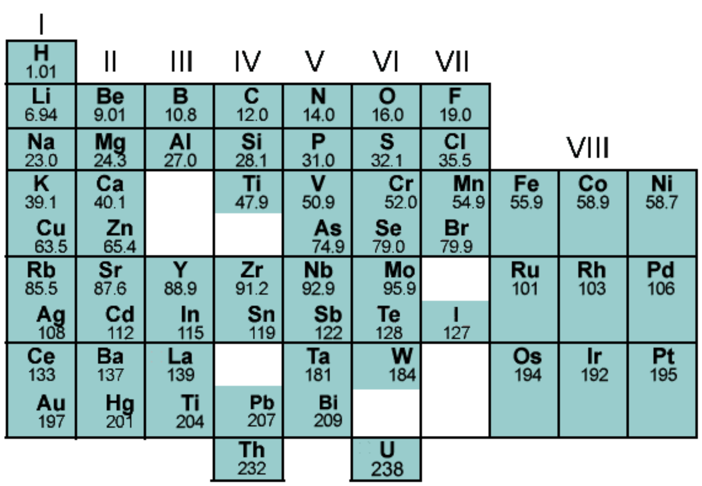
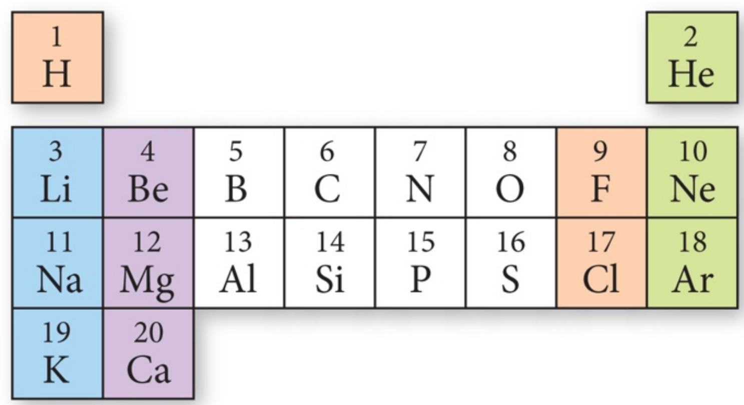
Periodic Table



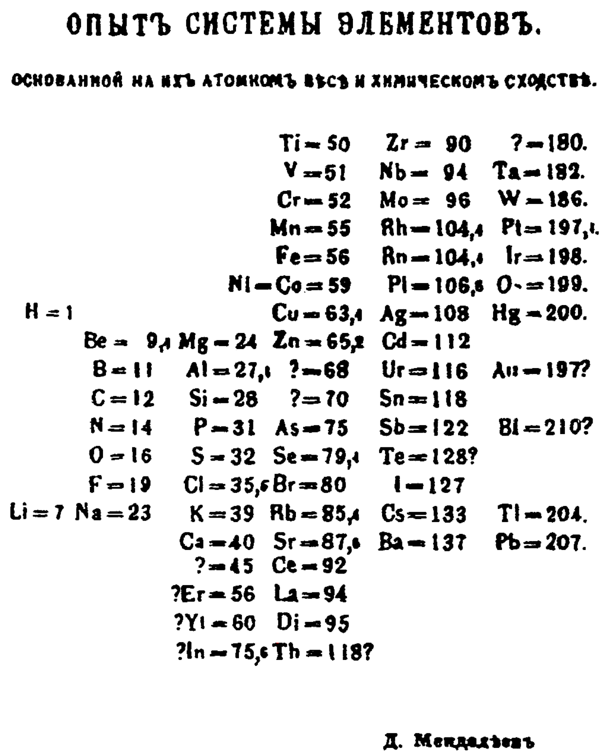
- Dmitri Ivanovich Mendeleev, a Russian chemistry teacher, is credited for producing the first periodic table in 1871.
- There were about 50 elements in his first table.
- Periodic law predicted elements that weren't yet know, so Medeleev left holes in his periodic table — to leave room for when they were discovered.







Periodic Table

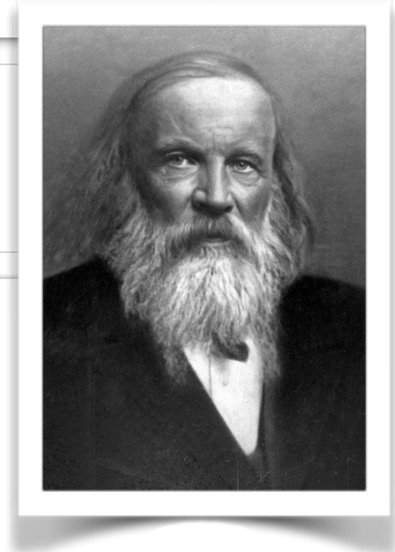


ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

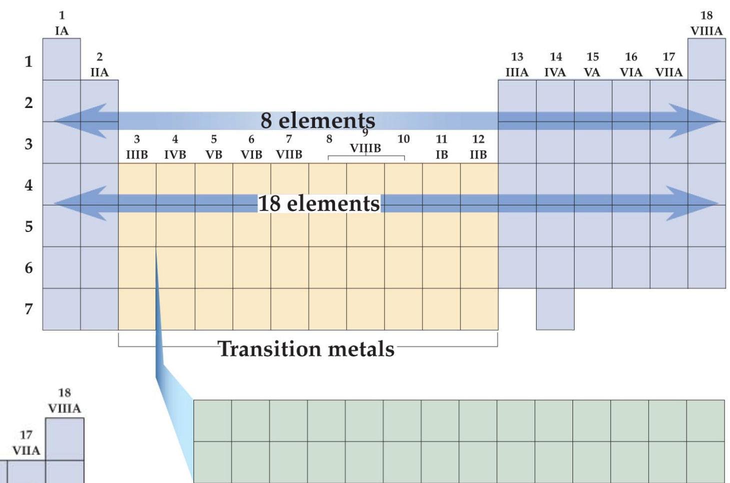
ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

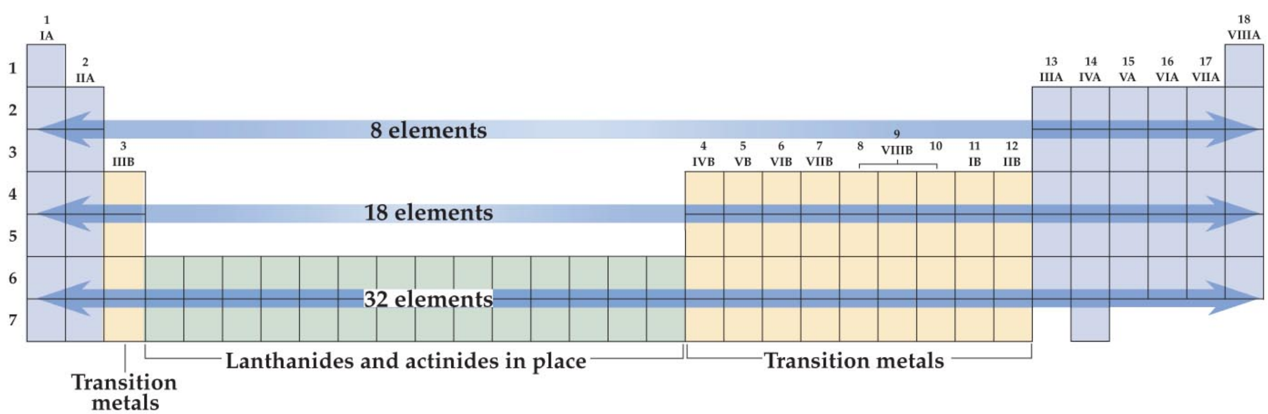
Ti = 50 Zr = 90 ? = 180.
V = 51 Nb = 94 Ta = 182.
Cr = 52 Mo = 96 W = 186.
Mn = 55 Rh = 104,4 Pt = 197,4.
Fe = 56 Rn = 104,4 Ir = 198.
Ni = Co = 59 Pl = 106,6 Os = 199.
H = 1 Cu = 63,4 Ag = 108 Hg = 200.
Be = 9,4 Mg = 24 Zn = 65,2 Cd = 112
B = 11 Al = 27,4 ? = 68 Ur = 116 Au = 197?
C = 12 Si = 28 ? = 70 Sn = 118
N = 14 P = 31 As = 75 Sb = 122 Bi = 210?
O = 16 S = 32 Se = 79,4 Te = 128?
F = 19 Cl = 35,5 Br = 80 I = 127
Li = 7 Na = 23 K = 39 Rb = 85,4 Cs = 133 Tl = 204.
Ca = 40 Sr = 87,6 Ba = 137 Pb = 207.
? = 45 Ce = 92
?Er = 56 La = 94
?Yt = 60 Di = 95
?In = 75,6 Th = 118?

Д. Менделѣевъ



- As we added more elements the table grew.
- To make it more manageable, we cut out the lanthanide and actinide cards and set them in a separate table.





The 118 Known Elements

Periodic Table of the Elements

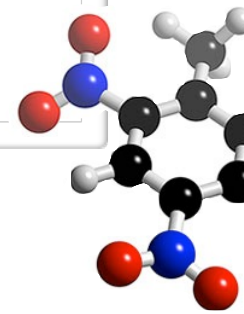
Atomic Number
Symbol
Name
Atomic Mass

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	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 [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Lanthanide Series	57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Alkali Metal | Alkaline Earth | Transition Metal | Basic Metal | Semimetal | Nonmetal | Halogen | Noble Gas | Lanthanide | Actinide

Flavors of the Atom



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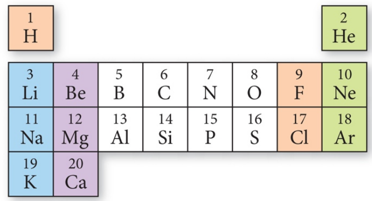

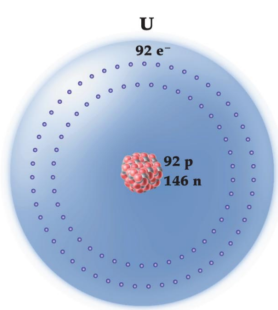

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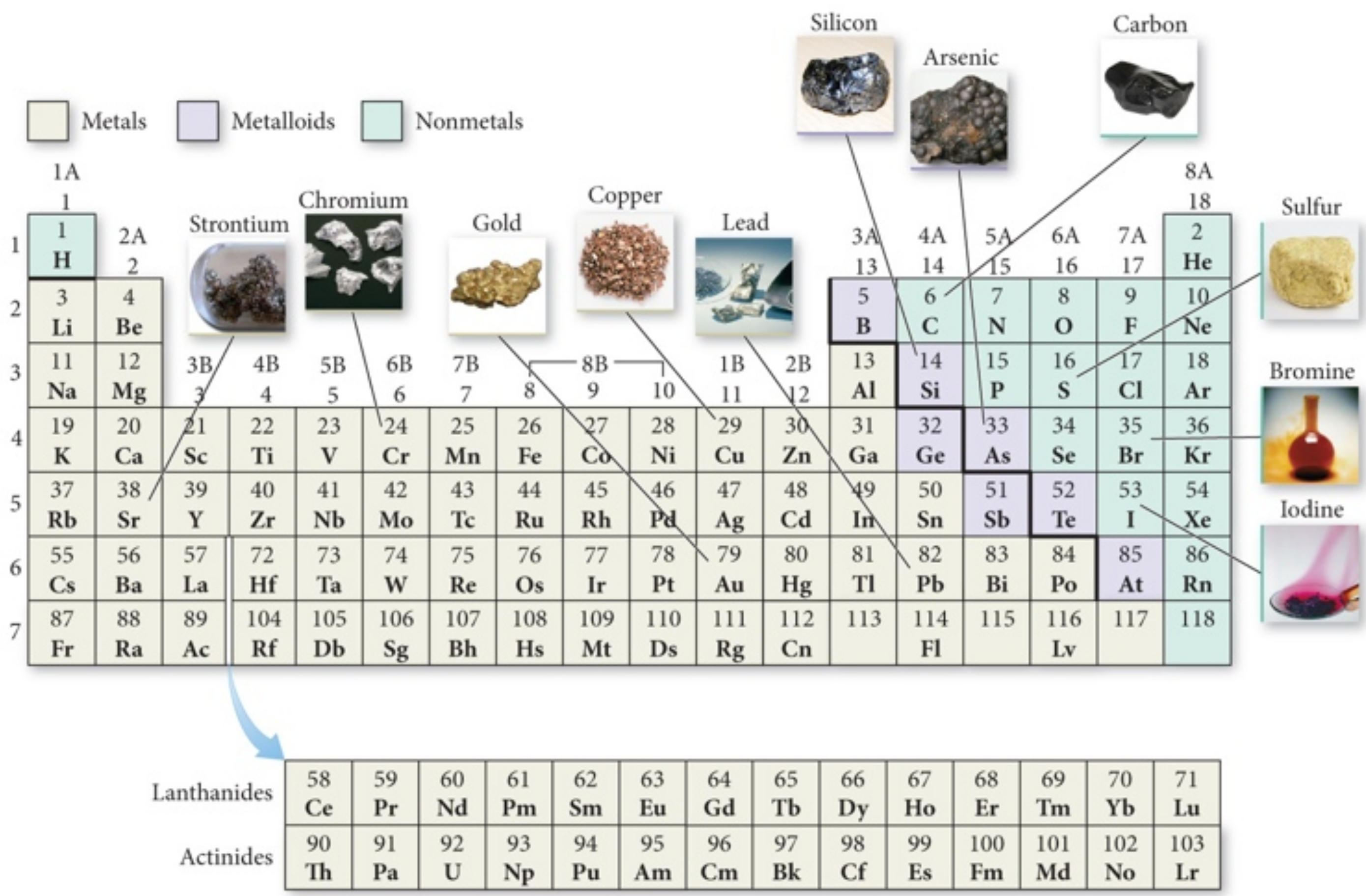
  - Electron Shells
    - Finding Electron Shells
    - Valence Electrons
    - Lewis Symbols

- Trends
  - in Size
  - in Ionization Energy

Metallic Character

- Most elements are metals (shiny, malleable, ductile, good conductors)
- Some are non-metals (dull, brittle, not-ductile, poor conductors)
- Seven are metalloids (kinda shiny, somewhat malleable, sorta ductile, semi-conductors)



Periodic Table

- We call each horizontal row a period.
- We call each vertical column a family or group.
- We divide sections of the table into the representative elements, the transition metals and the inner transition metals.

Periodic Table of the Elements

Element symbol coloring (at 25°C and 1 atm pressure)
- H Gas
- Li Solid
- Br Liquid
- Tc Not found in nature

Representative (main-group) elements: groups 1–2 and 13–18. Transition metals: groups 3–12.

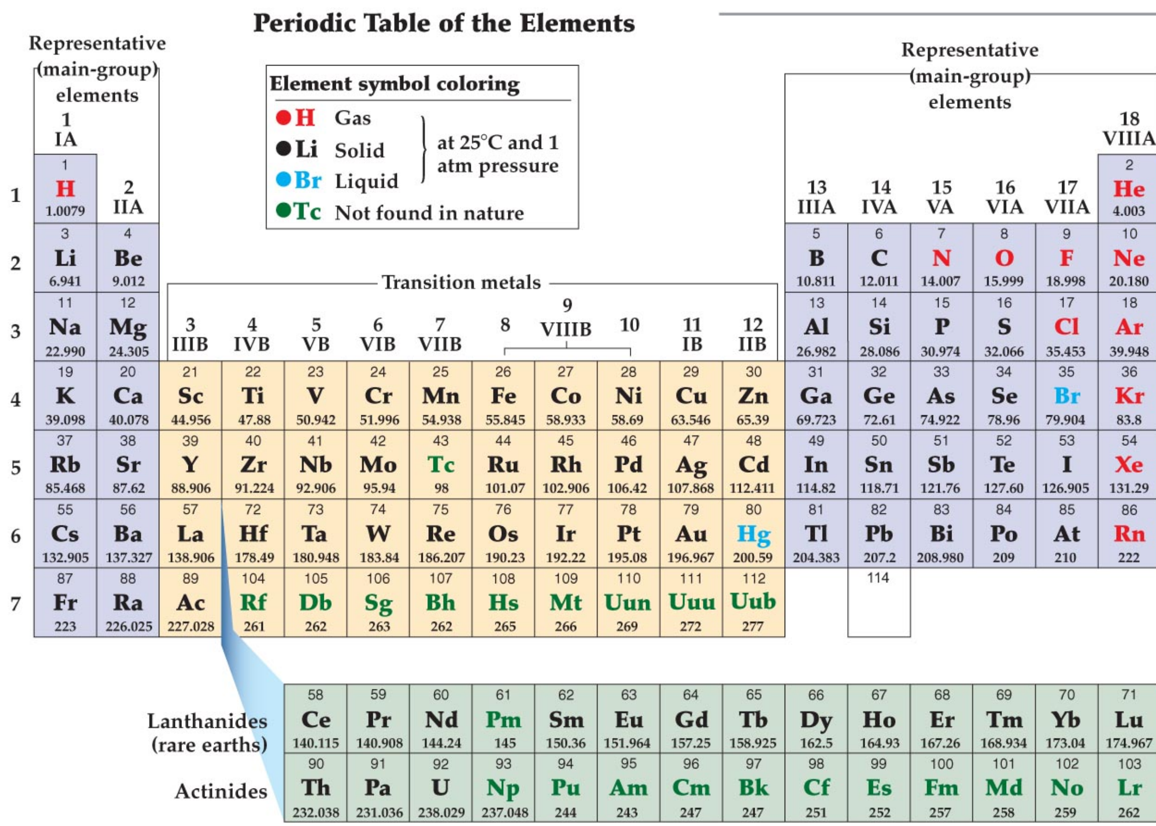
	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.0079																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
3	11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc 98	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.905	54 Xe 131.29
6	55 Cs 132.905	56 Ba 137.327	57 La 138.906	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po 209	85 At 210	86 Rn 222
7	87 Fr 223	88 Ra 226.025	89 Ac 227.028	104 Rf 261	105 Db 262	106 Sg 263	107 Bh 262	108 Hs 265	109 Mt 266	110 Uun 269	111 Uuu 272	112 Uub 277		114				

Lanthanides (rare earths)	58 Ce 140.115	59 Pr 140.908	60 Nd 144.24	61 Pm 145	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.925	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.967
Actinides	90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 262

Periodic Table

- Some families (groups) are important enough to have unique names.

Group	Name
1A	Alkali metals
2A	Alkaline earth metals
6A	Chalcogens
7A	Halogens
8A	Noble gases (or rare gases)



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Alkali metals	Alkaline earth metals														Chalcogens	Halogens	Noble gases
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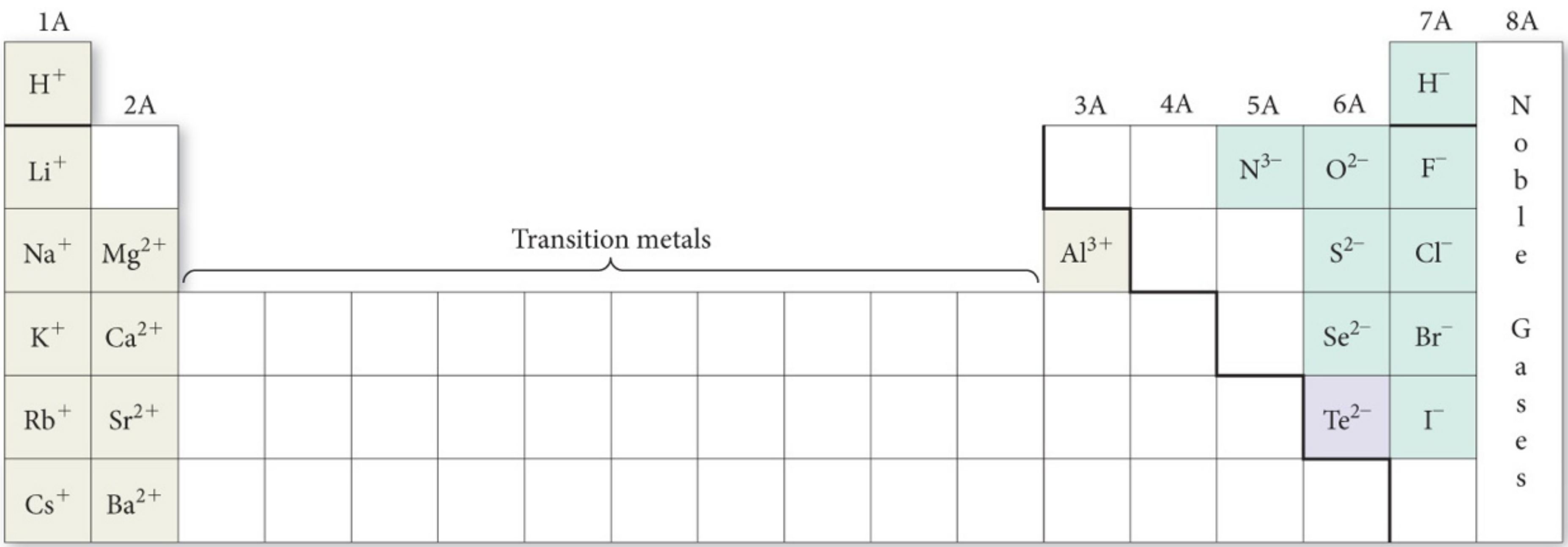
87 Fr 223	88 Ra 226.025	89 Ac 227.028	104 Rf 261	105 Db 262	106 Sg 263	107 Bh 262	108 Hs 265	109 Mt 266	110 Uun 269	111 Uuu 272	112 Uub 277		114				

Many Ionic Charges are Predictable



Ch04

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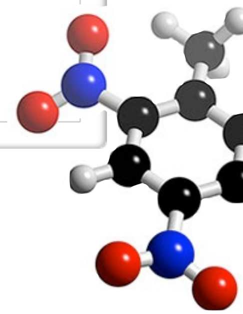

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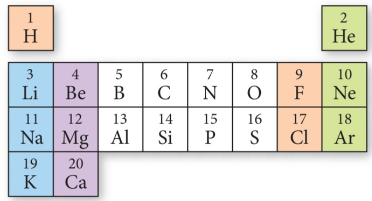

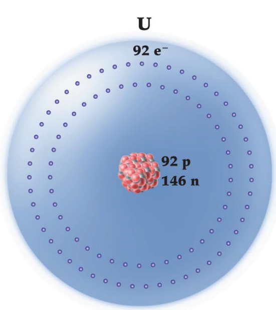

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    - Lewis Symbols
- Properties
  - Predicting Trends

$^{17}_{8}O$

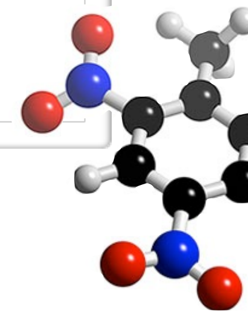
Official Class Periodic Table

Unless directed otherwise, use only this table for all classwork.
This table will be provided with all exams.
This table is printed in the front cover of your text book
and is available as a pop-up in mastering chemistry.

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 **H** 1.01 hydrogen																	2 **He** 4.00 helium
2	3 **Li** 6.94 lithium	4 **Be** 9.01 beryllium											5 **B** 10.81 boron	6 **C** 12.01 carbon	7 **N** 14.01 nitrogen	8 **O** 16.00 oxygen	9 **F** 19.00 fluorine	10 **Ne** 20.18 neon
3	11 **Na** 22.99 sodium	12 **Mg** 24.31 magnesium											13 **Al** 26.98 aluminum	14 **Si** 28.09 silicon	15 **P** 30.97 phosphorus	16 **S** 32.07 sulfur	17 **Cl** 35.45 chlorine	18 **Ar** 39.95 argon
4	19 **K** 39.10 potassium	20 **Ca** 40.08 calcium	21 **Sc** 44.96 scandium	22 **Ti** 47.88 titanium	23 **V** 50.94 vanadium	24 **Cr** 52.00 chromium	25 **Mn** 54.94 manganese	26 **Fe** 55.85 iron	27 **Co** 58.93 cobalt	28 **Ni** 58.69 nickel	29 **Cu** 63.55 copper	30 **Zn** 65.39 zinc	31 **Ga** 69.72 gallium	32 **Ge** 72.61 germanium	33 **As** 74.92 arsenic	34 **Se** 78.96 selenium	35 **Br** 79.90 bromine	36 **Kr** 83.80 krypton
5	37 **Rb** 85.47 rubidium	38 **Sr** 87.62 strontium	39 **Y** 88.91 yttrium	40 **Zr** 91.22 zirconium	41 **Nb** 92.91 niobium	42 **Mo** 95.94 molybdenum	43 **Tc** (99) technetium	44 **Ru** 101.07 ruthenium	45 **Rh** 102.91 rhodium	46 **Pd** 106.42 palladium	47 **Ag** 107.87 silver	48 **Cd** 112.41 cadmium	49 **In** 114.82 indium	50 **Sn** 118.71 tin	51 **Sb** 121.75 antimony	52 **Te** 127.60 tellurium	53 **I** 126.90 iodine	54 **Xe** 131.29 xenon
6	55 **Cs** 132.91 cesium	56 **Ba** 137.33 barium	57 **La** 138.91 lanthanum	72 **Hf** 178.49 hafnium	73 **Ta** 180.95 tantalum	74 **W** 183.85 tungsten	75 **Re** 186.21 rhenium	76 **Os** 190.2 osmium	77 **Ir** 192.22 iridium	78 **Pt** 195.08 platinum	79 **Au** 196.97 gold	80 **Hg** 200.59 mercury	81 **Tl** 204.38 thallium	82 **Pb** 207.2 lead	83 **Bi** 208.98 bismuth	84 **Po** (209) polonium	85 **At** (210) astatine	86 **Rn** (222) radon
7	87 **Fr** (223) francium	88 **Ra** (226) radium	89 **Ac** (227) actinium	104 **Rf** (261) rutherfordium	105 **Db** (262) dubnium	106 **Sg** (263) seaborgium	107 **Bh** (262) bohrium	108 **Hs** (265) hassium	109 **Mt** (266) meitnerium	110 **Ds** (281) darmstadtium	111 **Rg** (280) roentgenium	112 **Cn** (285) copernicium	113 — (284)	114 **Fl** (289) flerovium	115 — (288)	116 **Lv** (292) livermorium	117* — (294)	118 — (294)

58 **Ce** 140.12 cerium	59 **Pr** 140.91 praseodymium	60 **Nd** 144.24 neodymium	61 **Pm** (147) promethium	62 **Sm** 150.36 samarium	63 **Eu** 151.97 europium	64 **Gd** 157.25 gadolinium	65 **Tb** 158.93 terbium	66 **Dy** 162.50 dysprosium	67 **Ho** 164.93 holmium	68 **Er** 167.26 erbium	69 **Tm** 168.93 thulium	70 **Yb** 173.04 ytterbium	71 **Lu** 174.97 lutetium
90 **Th** (232) thorium	91 **Pa** (231) protactinium	92 **U** (238) uranium	93 **Np** (237) neptunium	94 **Pu** (244) plutonium	95 **Am** (243) americium	96 **Cm** (247) curium	97 **Bk** (247) berkelium	98 **Cf** (251) californium	99 **Es** (252) einsteinium	100 **Fm** (257) fermium	101 **Md** (258) mendelevium	102 **No** (259) nobelium	103 **Lr** (260) lawrencium

Flavors of the Atom



- Organizing the Elements
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- The Periodic Table
  - The First Periodic Table
  - Metals & Non-metals
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  - Common Ions, Predicting Charge
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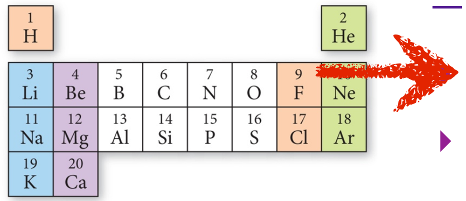
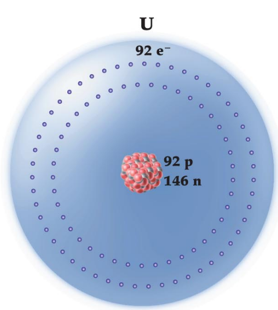


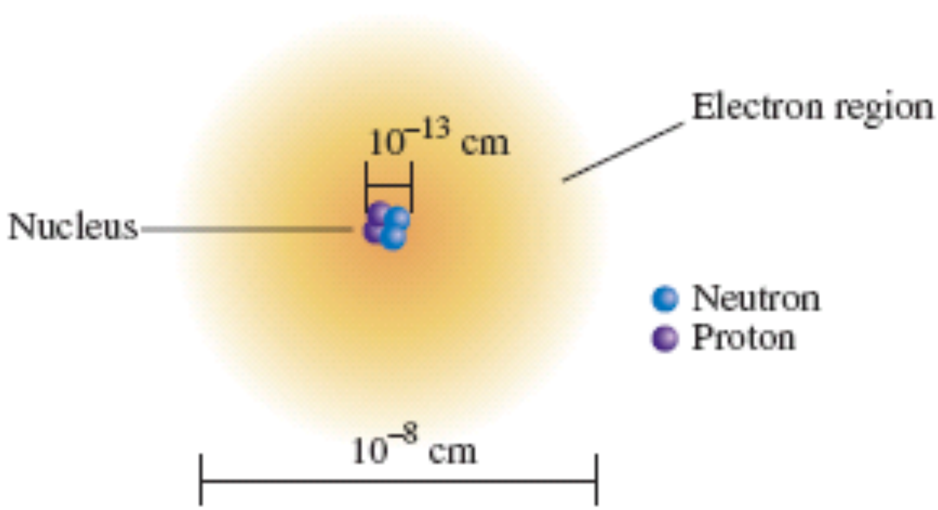


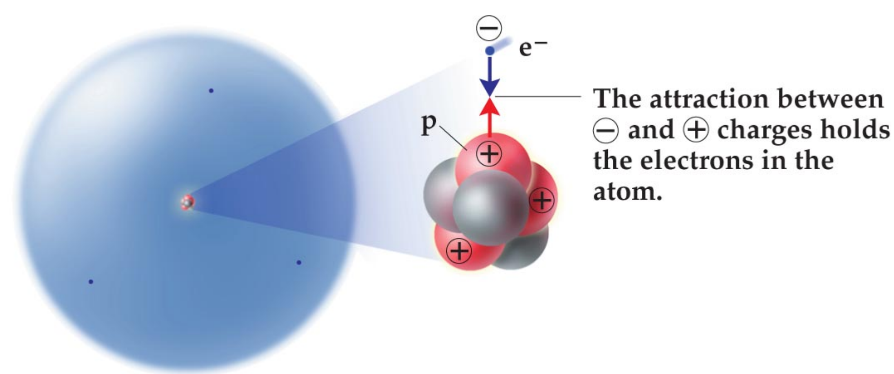
- Pieces of the atom
  – electrons, protons, neutrons
  - Ions differ in electron count
  - Elements have different proton counts
  - Isotopes differ in total mass (because they differ in number of neutrons)
    - Isotopic Notation

- Regions of the atom
  - Electron Shells
    - Finding Electron Shells
    - Valence Electrons
    - Lewis Symbols
- Properties
  - Predicting Trends

Pieces of the Atom

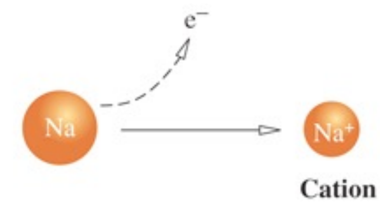
- Atoms are the smallest particle of an element that can enter into a chemical reaction.
- Protons and neutrons make up the dense, positive nucleus.
- Electrons occupy the empty space outside the nucleus.
- A neutral atom contains the same number of electrons and protons.

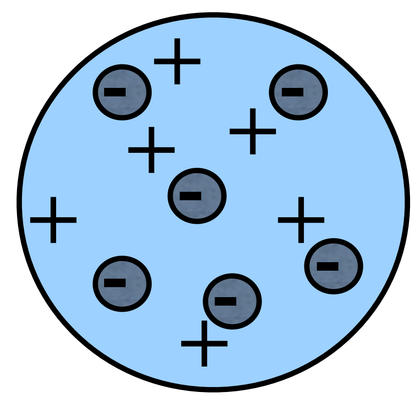


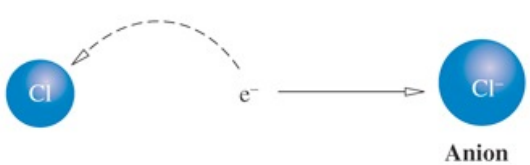


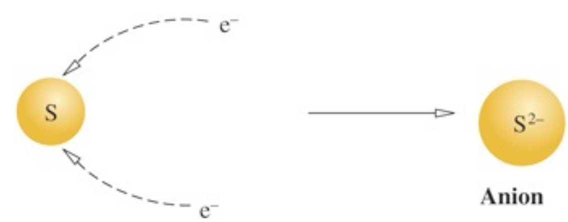
Ions

- 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.

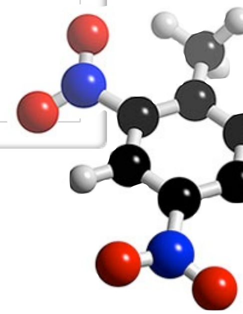








Flavors of the Atom



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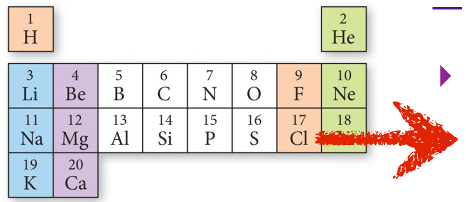

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$^{17}_{8}O$

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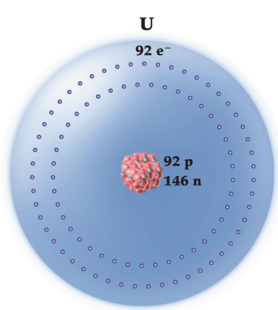
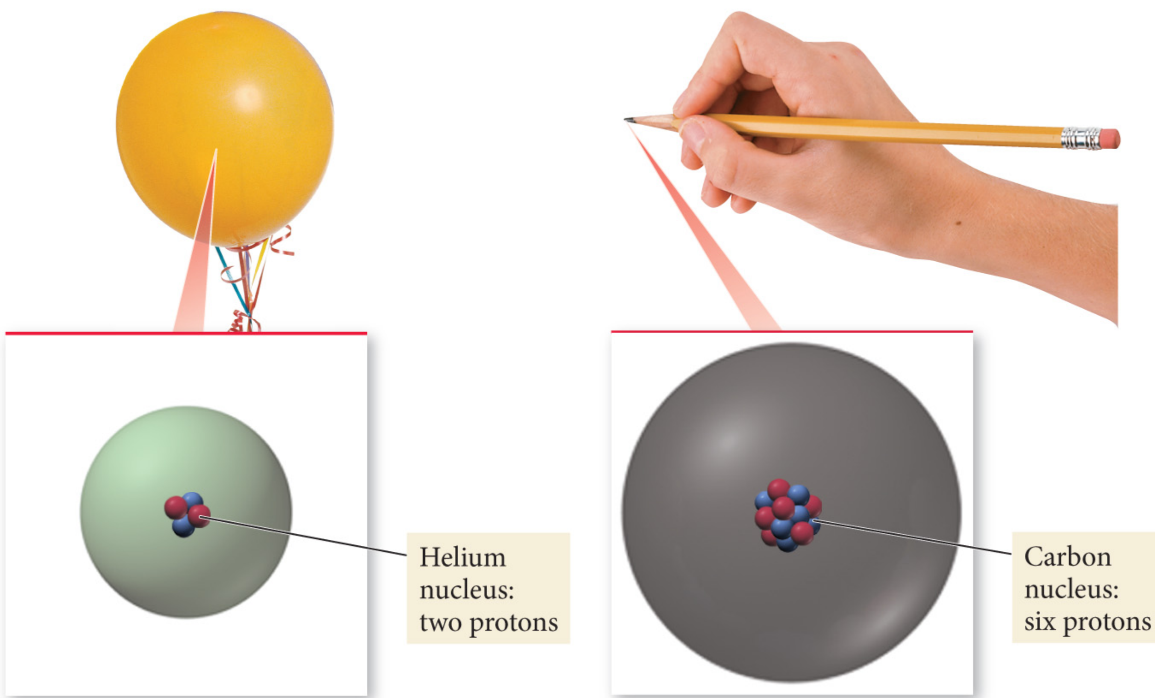


Elements differ in Protons

- 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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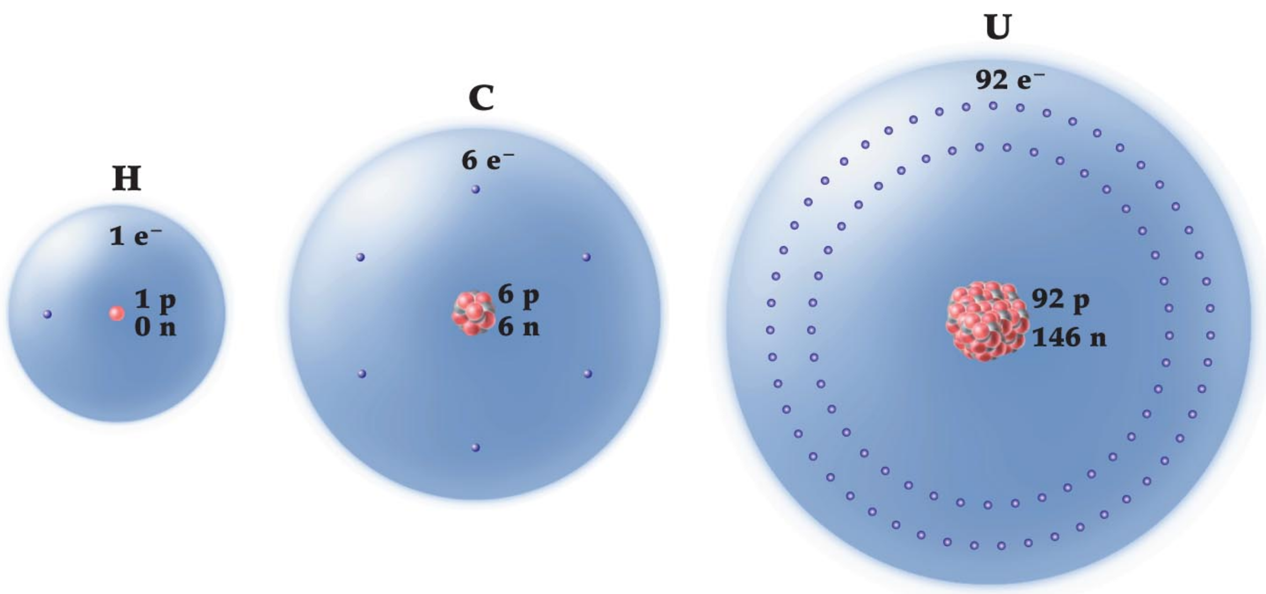
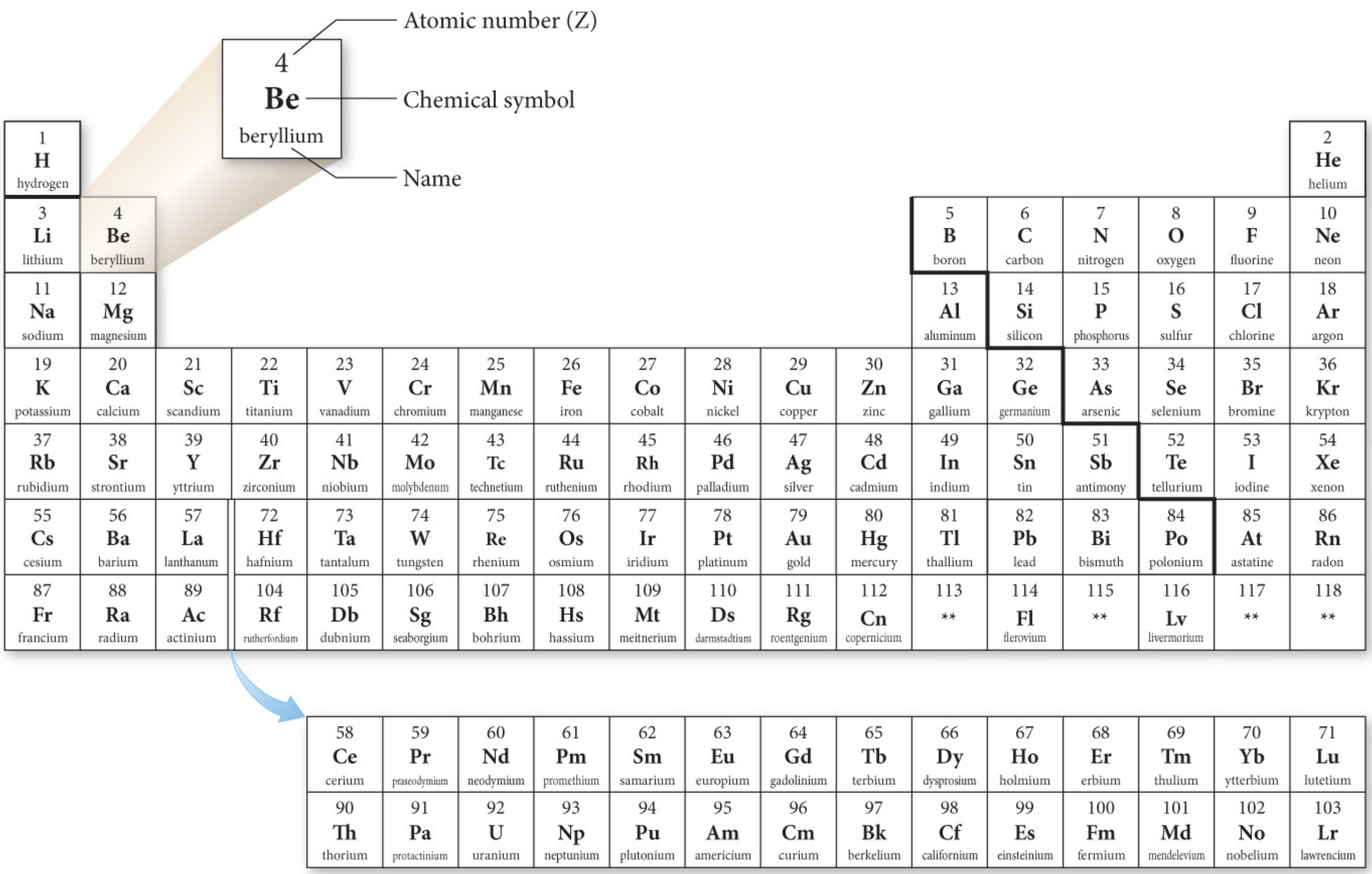
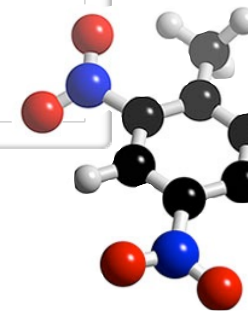


Elements differ in Protons

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



Flavors of the Atom



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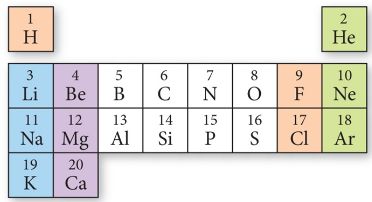

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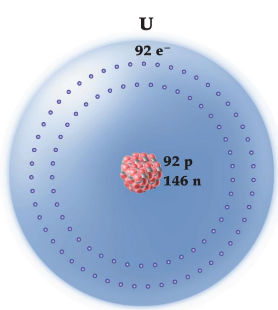
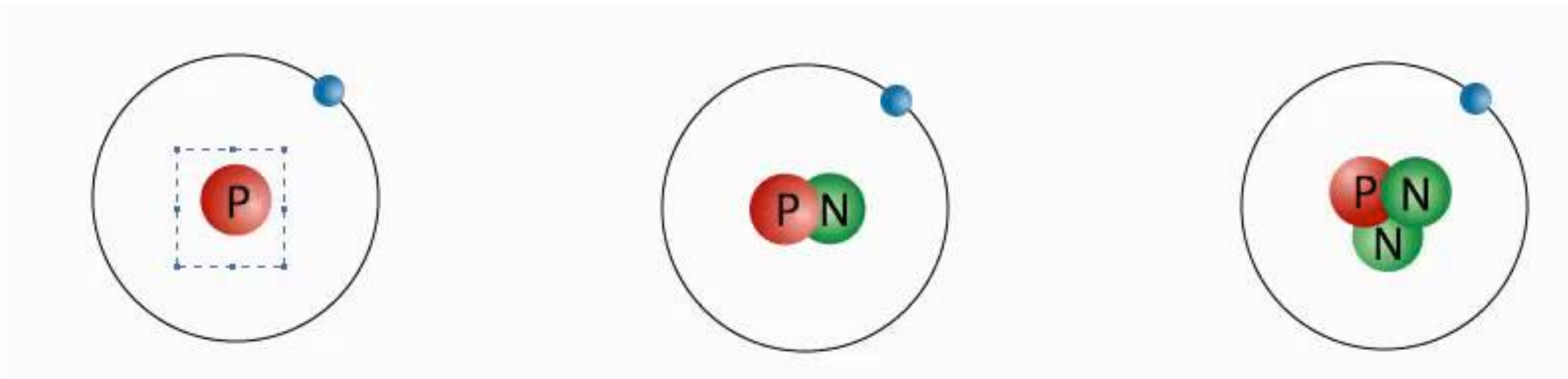


Isotopes differ in Mass

- 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.

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 + 8 neutrons

$^{16}_{8}O$

8 protons

8 protons + 9 neutrons

$^{17}_{8}O$

8 protons

8 protons + 10 neutrons

$^{18}_{8}O$

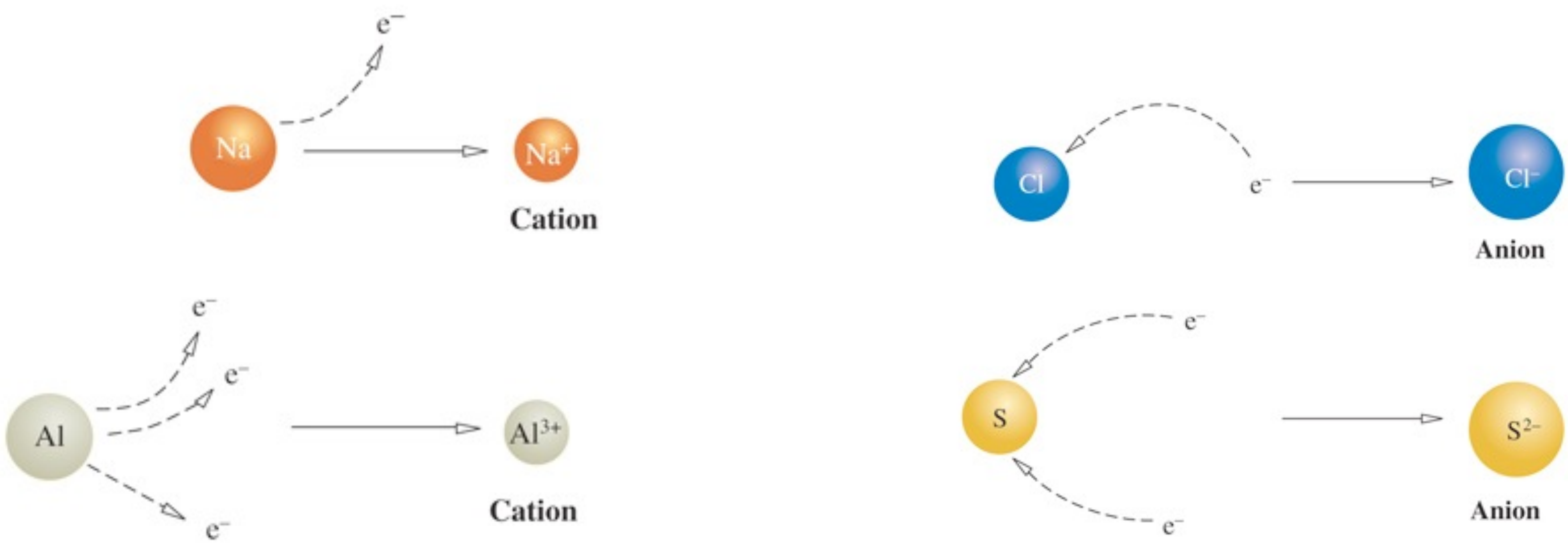
8 protons

Examples of Isotopes

Element	Protons	Electrons	Neutrons	Symbol
Hydrogen	1	1	0	
Hydrogen	1	1	1	
Hydrogen	1	1	2	
Uranium	92	92	143	
Uranium	92	92	146	
Chlorine	17	17	18	
Chlorine	17	17	20	

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.



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$$^{35}_{17}\mathrm{Cl}$$

17 protons,
17 electrons

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

17 protons,
18 electrons

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.

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

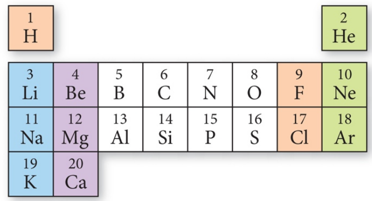
1 proton,
1 electron

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

1 proton,
0 electrons

Flavors of the Atom

- Organizing the Elements
  - Chemical Symbols
  - Periodicity



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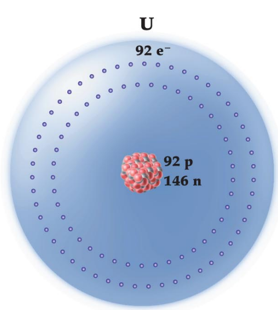

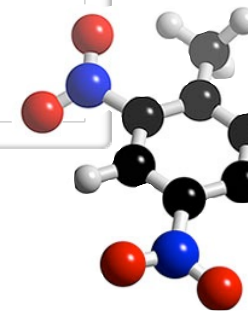

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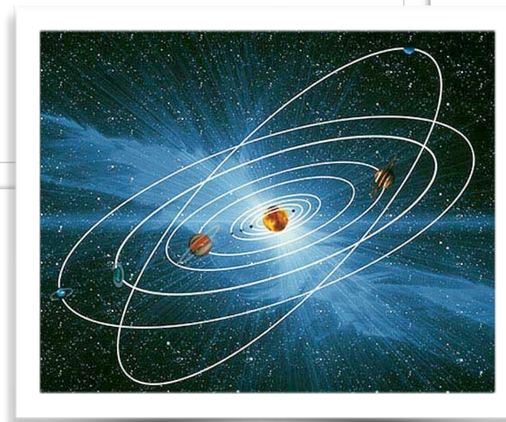
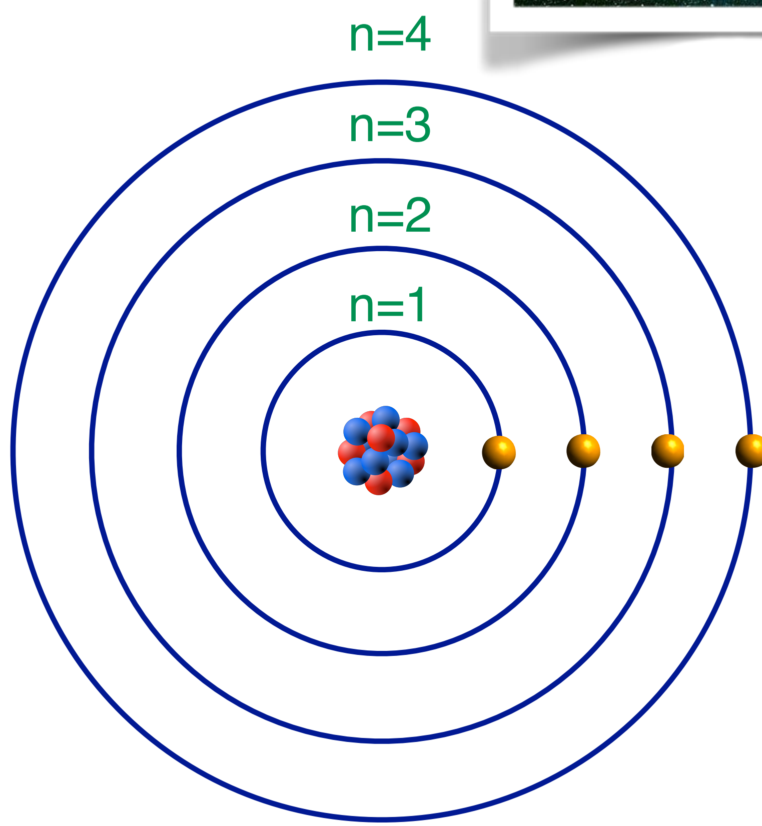
- Trends
  - in Size
  - in Ionization Energy

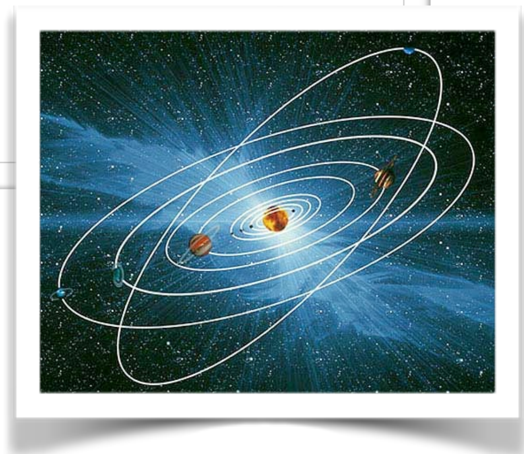
Electronic Structure



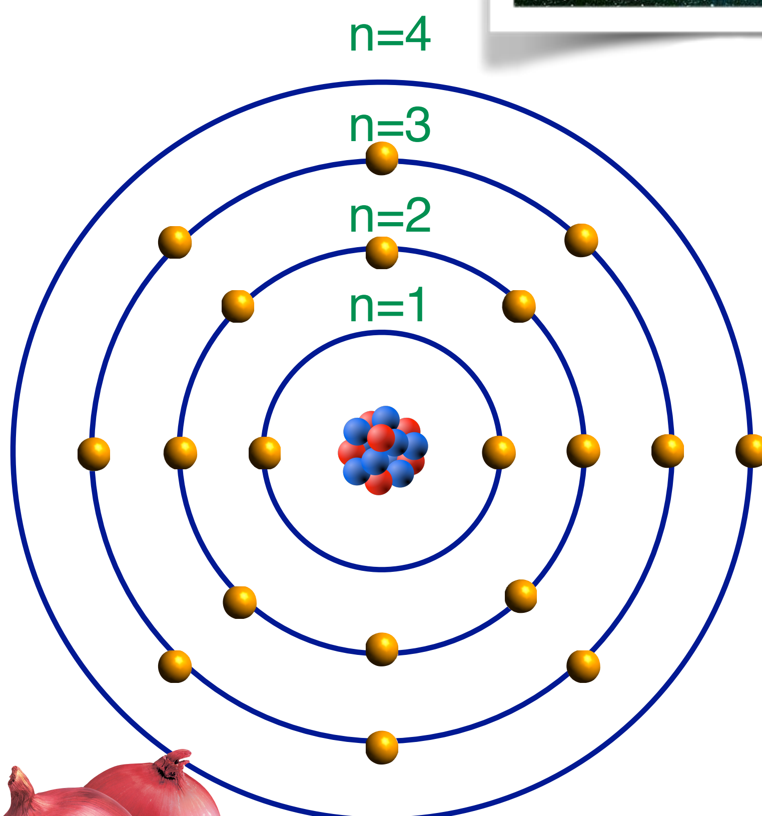
- Electrons exist at certain distances from the nucleus.
    - Similar to the way planets exist in discreet orbits around the sun.
        - The full story is more complex, but this is a good first approximation.
- The orbits are numbered, we indicate the orbit number with the variable n.
- n is the 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).

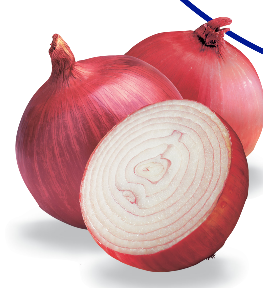


Electronic Structure



- 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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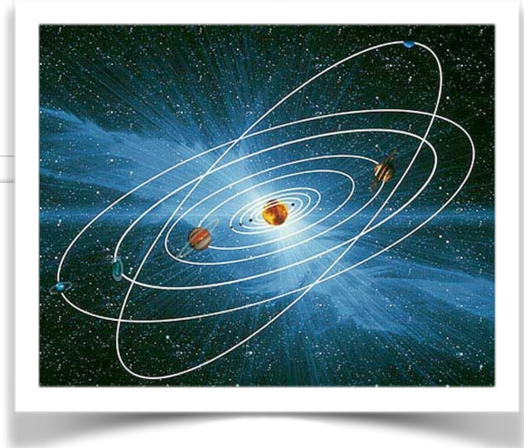
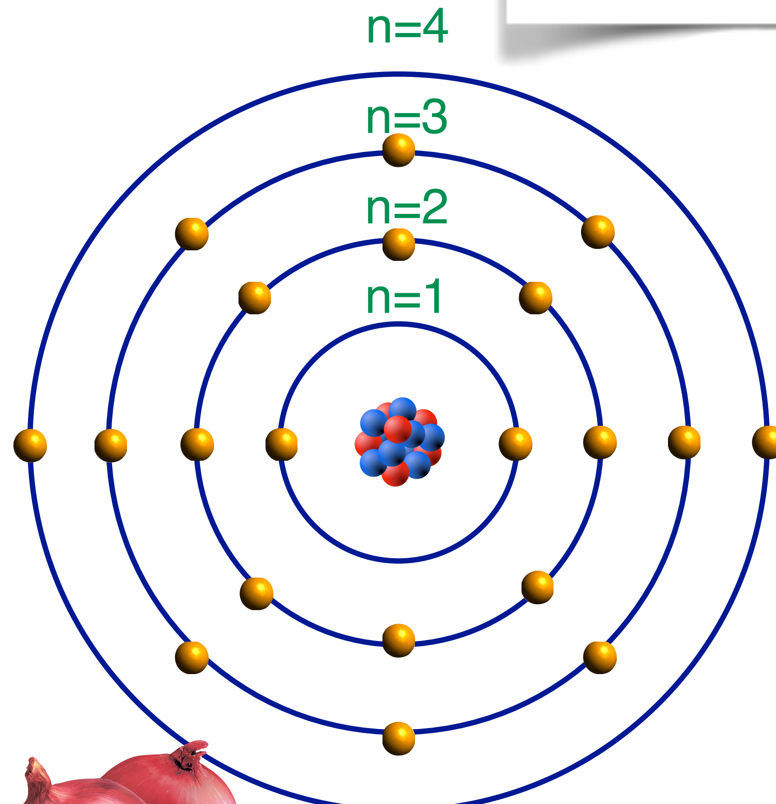
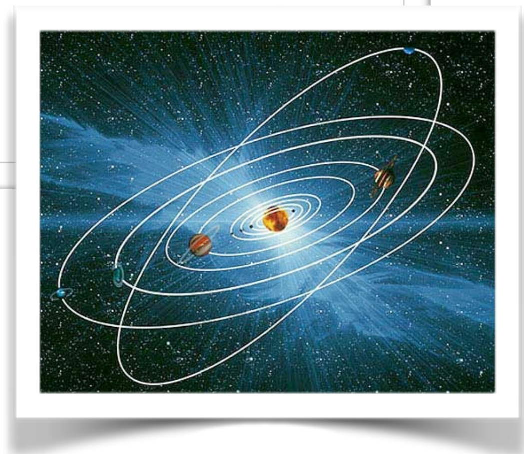


- Since electrons prefer to fill electron shells at lowest number possible n number, if you know how many electrons an atom has, you can predict it's electronic structure.
- Helium has two, both electrons are in n=1
  - Electronic structure 2
- Carbon has six, two in n=1 and four in n=2
  - Electronic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

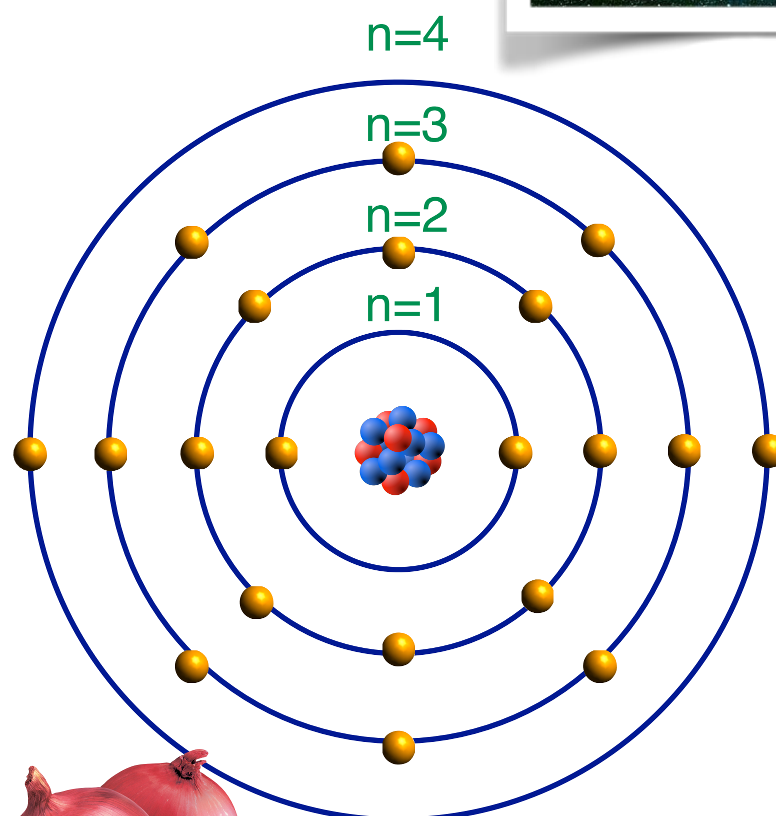


1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca						

Electronic Structure



- 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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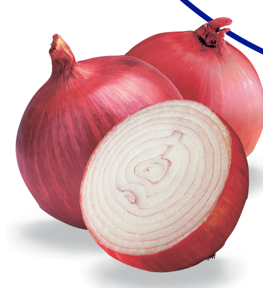

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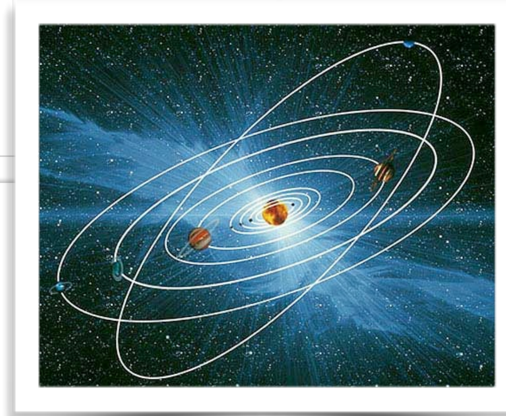
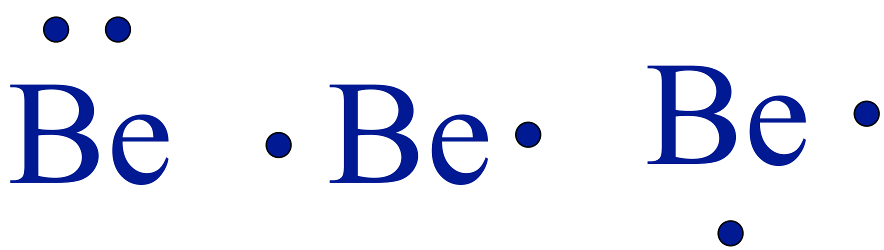
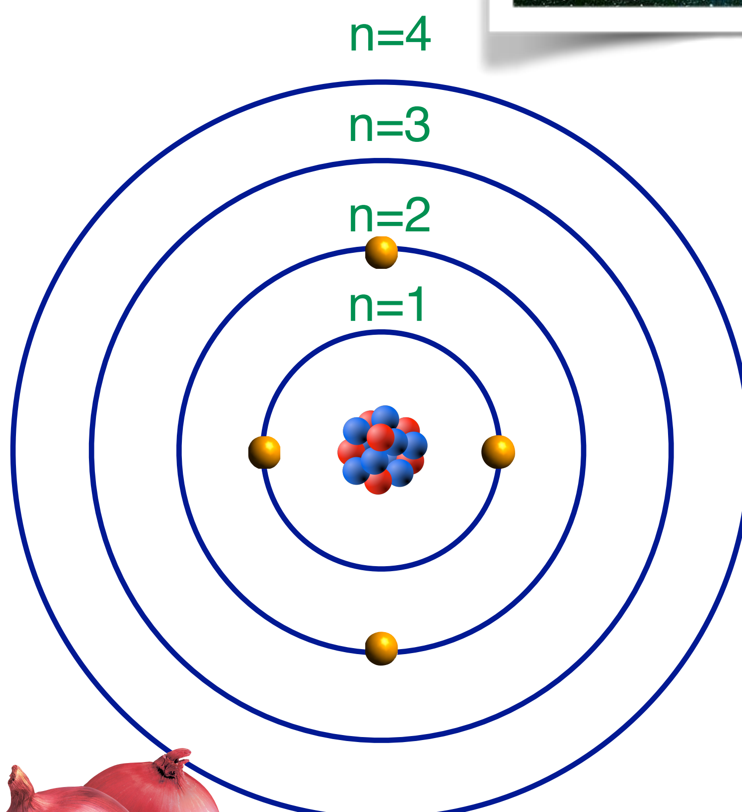


- As we start to understand chemical bonding, we will use Lewis symbols to indicate the number of electrons in an atoms valence shell.
- A Lewis symbol starts with the symbol of the element, and adds to it the valence electrons in sets of two on each of the four sides of that symbol.
    - It does not matter which side, as long as you have 1-8 dots in sets of (at most) two.





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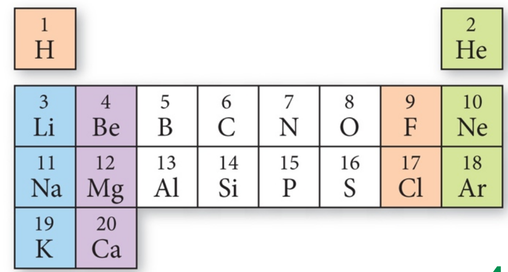
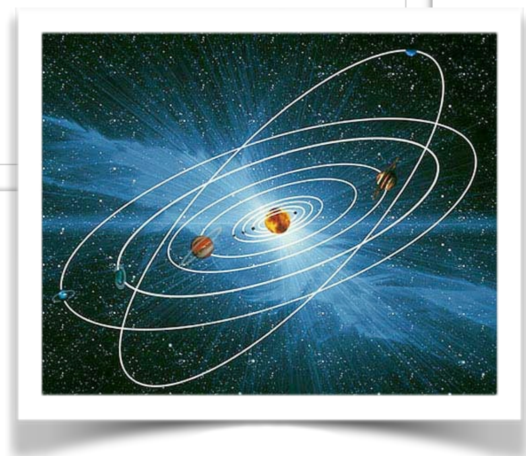
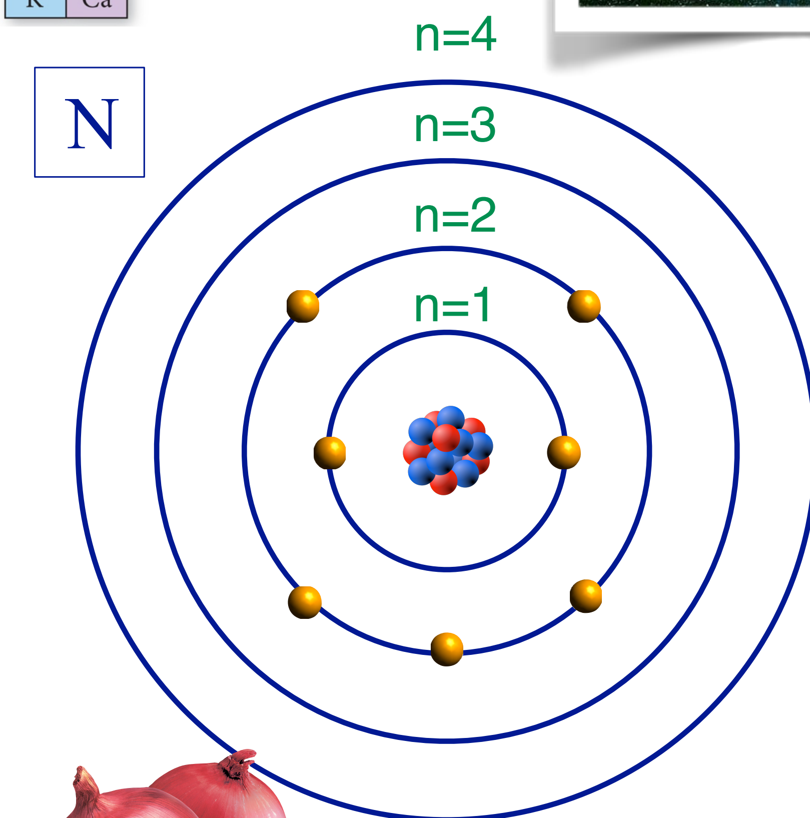
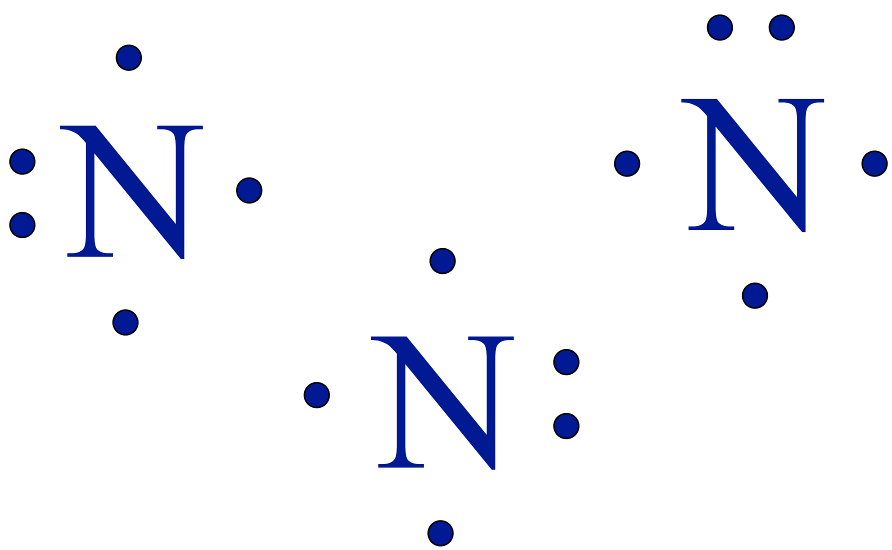


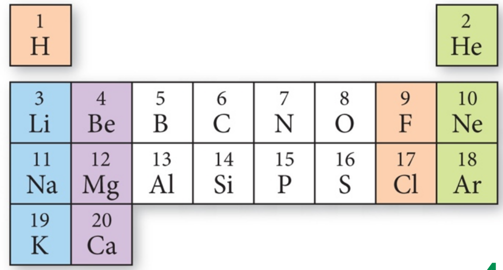


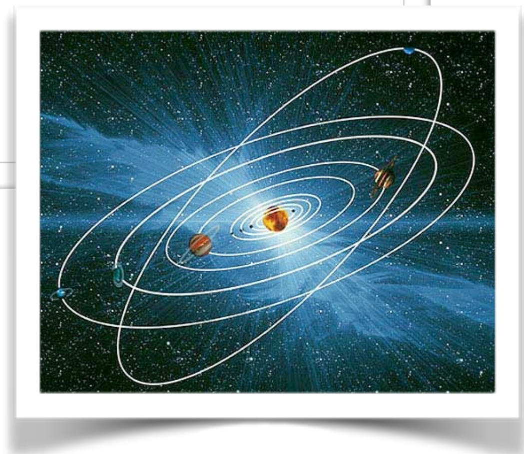


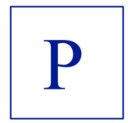


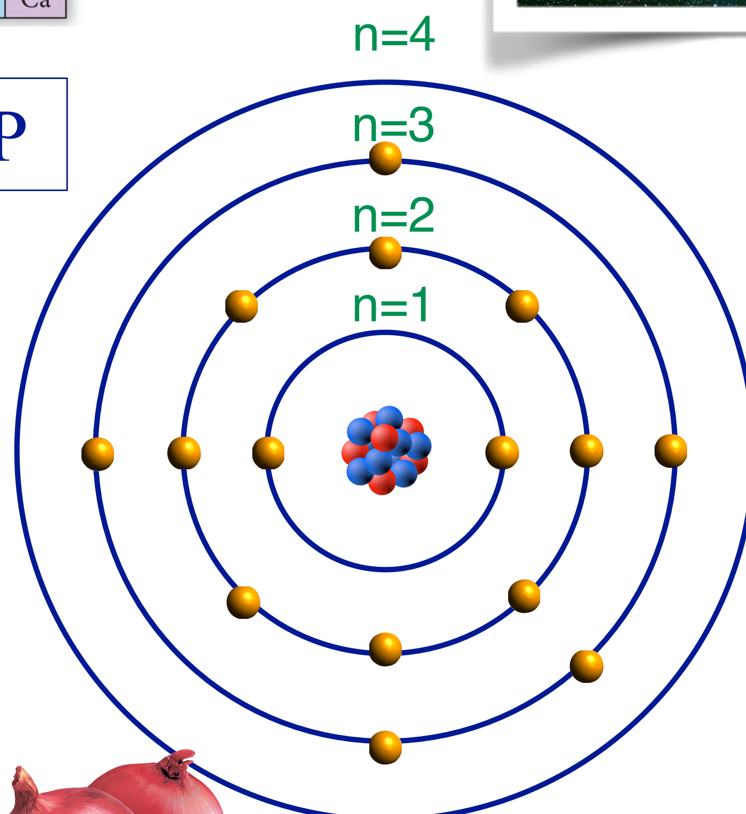
Electronic Structure

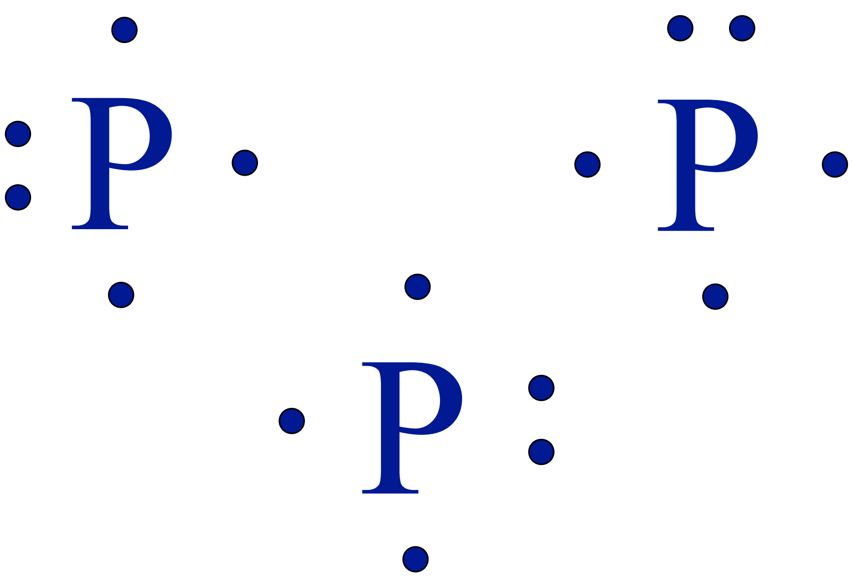
- As we start to understand chemical bonding, we will use Lewis symbols to indicate the number of electrons in an atoms valence shell.
- A Lewis symbol starts with the symbol of the element, and adds to it the valence electrons in sets of two on each of the four sides of that symbol.
    - It does not matter which side, as long as you have 1-8 dots in sets of (at most) two.

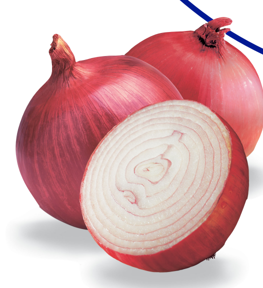




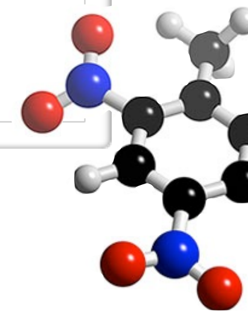








Flavors of the Atom



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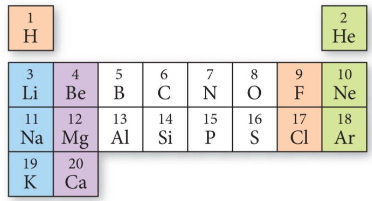

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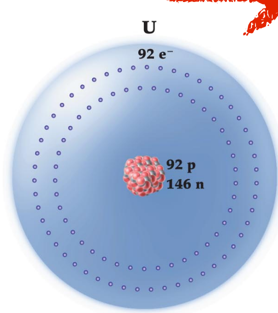
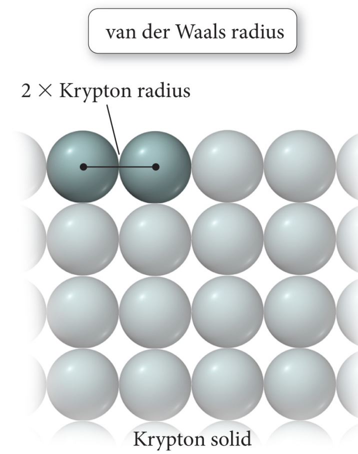
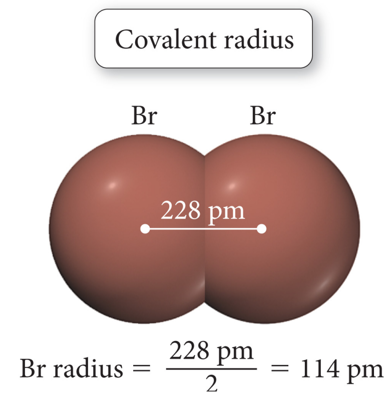
  - in Ionization Energy

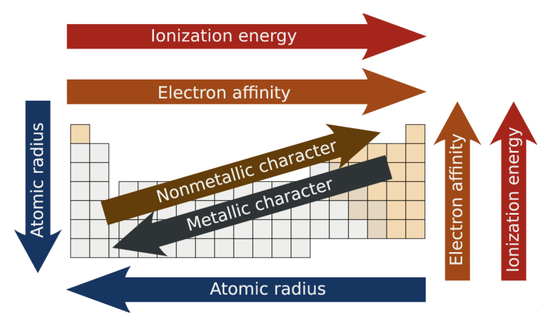


The size of Atoms

- The electron cloud of an atom defines it’s size.
- How do you measure the size of a cloud?
  - The edges of a cloud are uncertain.
- We measure the distance between two adjacent atoms.
  - Atomic size is measured by packing atoms close together, finding the distance between adjacent nuclei, and dividing that number by 2.
  - Atoms can be packed densely by capturing them in solid form or capturing them in a another compound that is a solid.
    - These atoms are not bonded, their electron orbitals don’t mix.
    - We describe the atomic size we get from this process as the nonbonding atomic radius or van der Waals radius.
  - For metals this involves analyzing metallic crystals (atoms held together with metallic bonds).
  - For non-metals, we look at a large number of compounds that contain the element.
    - We look at the average bond length between atoms.
    - There is overlap between the electron orbitals.
    - We describe the atomic radius found from covalently bonded compounds as the bonding atomic radius or covalent radius.
  - Which atomic radius we use depends on the context.
    - When we say atomic radius, we more often mean bonding atomic radius.
  - We can determine the relative atomic radius of two elements by their position in the periodic table.

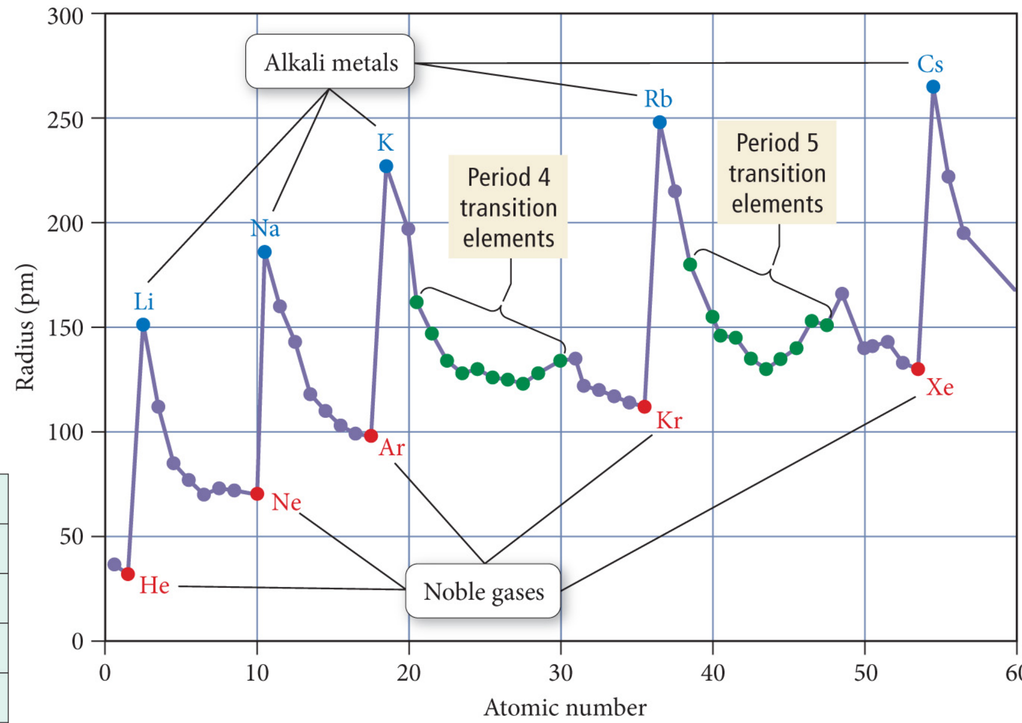


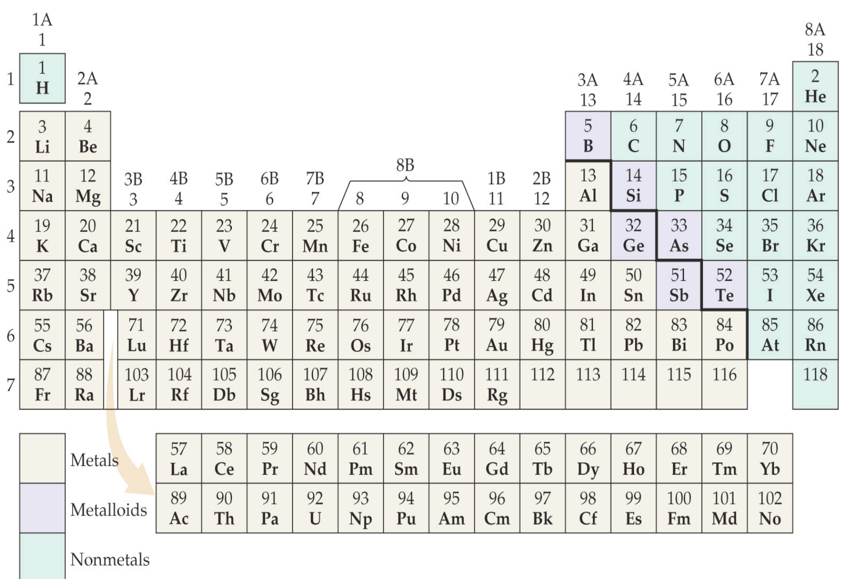


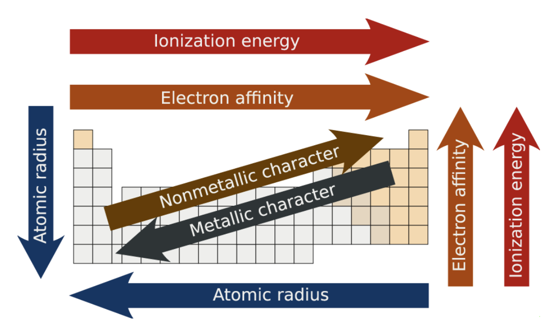


Relative Atomic Radius

- In general, as we move across the periodic table left to right the atomic radius decreases.
  - Transition metals of the same period are *roughly* the same size.
- In general, as we move down the periodic table the atomic radius increases.

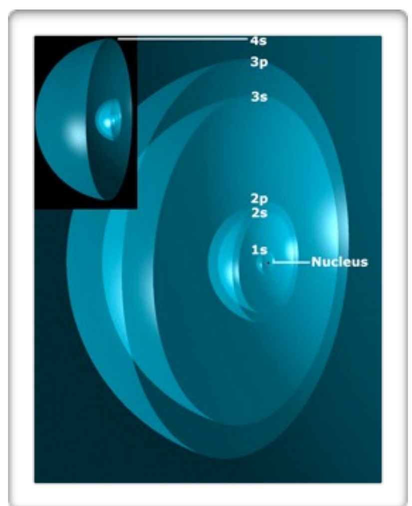


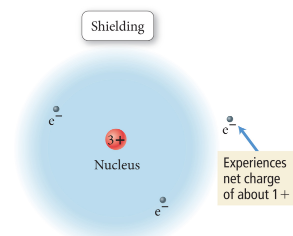


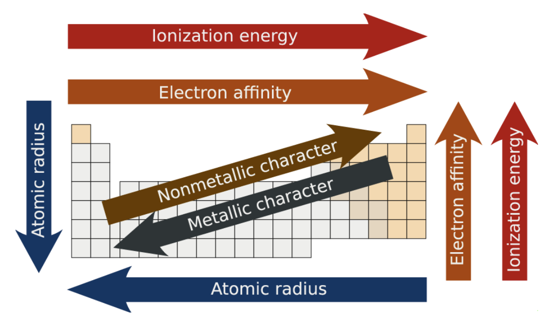


Atomic Size Increases as we go Down

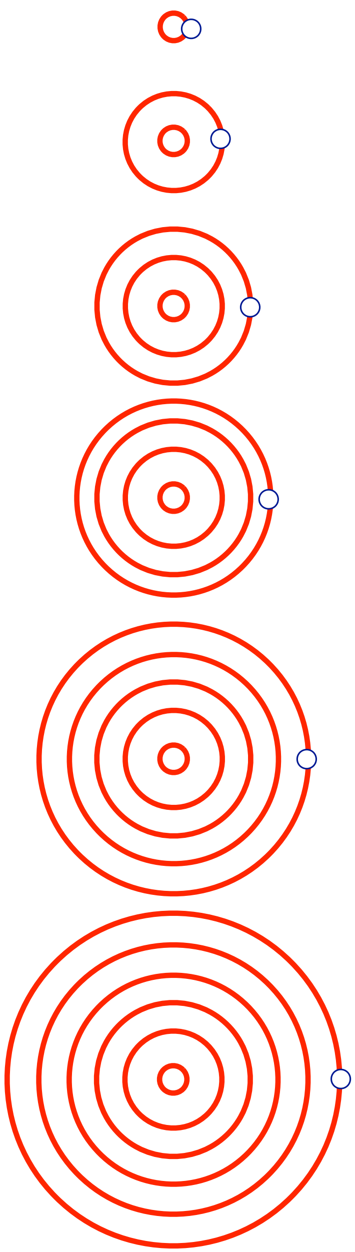
- Atomic Radius increases as we move down the periodic table because each period represents a new electron shell.
  - Each shell shields the previous shell from the nuclear charge reducing the pull of electrons to the nucleus.
  - The electrons in the inner shells repulse the electrons on the outer shells, pushing them farther from the nucleus.
- Each period corresponds to an increase in the principle quantum number n, which describes the size of that shell.
- As we add a larger shell, a new layer to the atom, it get’s bigger.



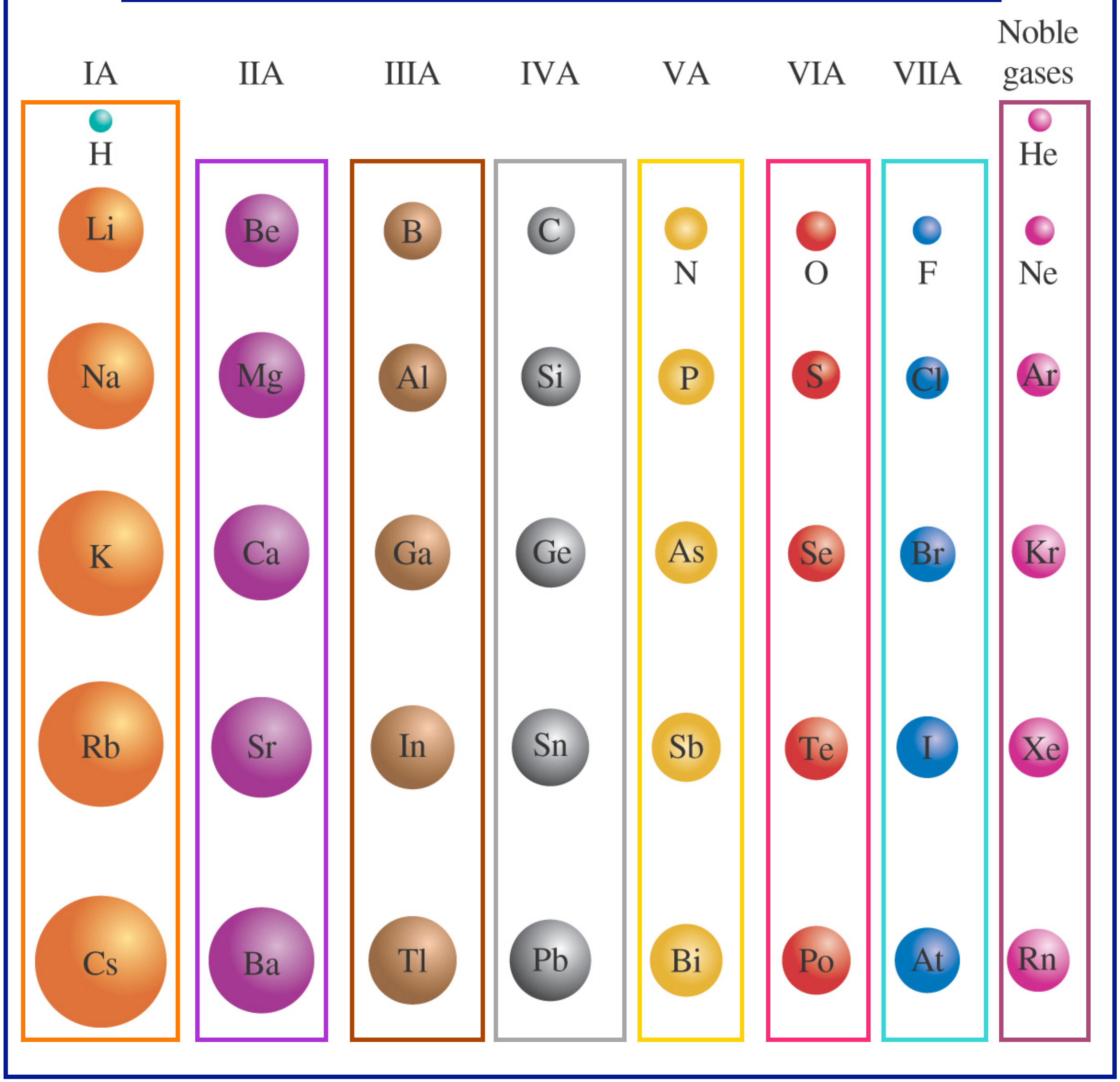




Atomic radii increase down a group.

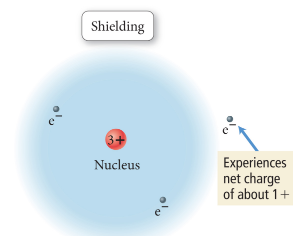


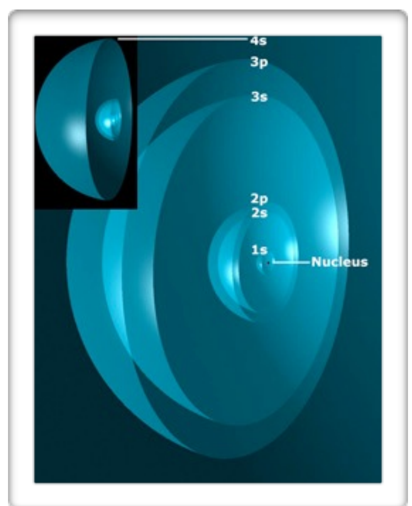
For each step down a group, electrons enter the next higher energy level.

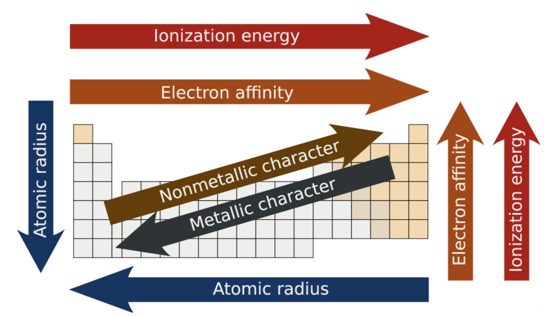


Atom Size decreases as we move Across

- Atomic Radius decreases as we move across the periodic table because the nuclear charge increases with each new row.
  - Shielding within a period is minimal.
  - Electrons have a minimal repulsion within a shell because they are in separate orbitals.
  - They fit together well.
- As the effective nuclear charge increases it nuclear attraction all electrons in that shell feel.
- It tightens the atom.
- The increased effective nuclear charge pulls all the electrons in the outer shell closer.
- It makes the atom smaller.





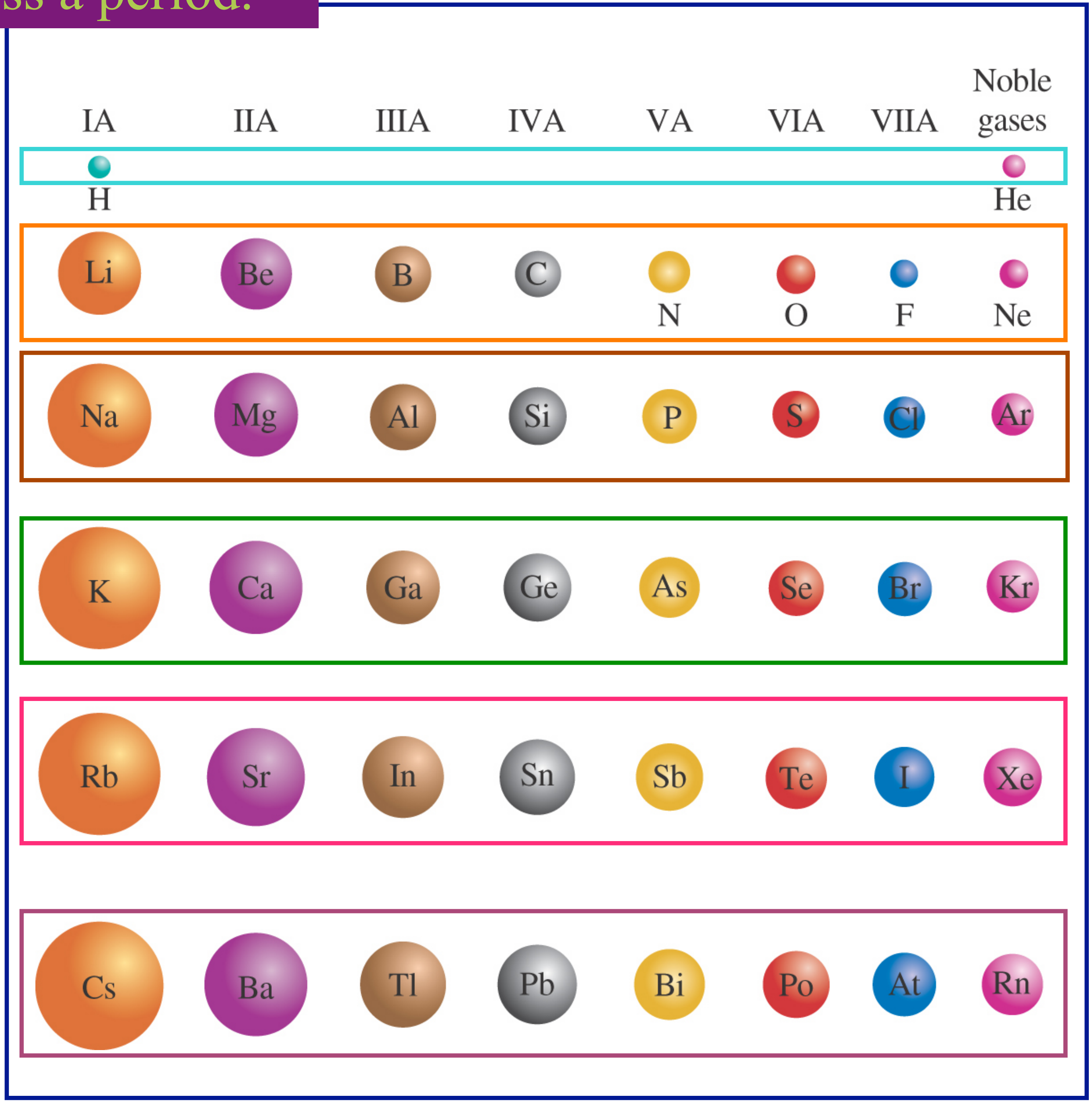


Radii of atoms tend to decrease from left to right across a period.

Each time an electron is added, a proton is also added to the nucleus.

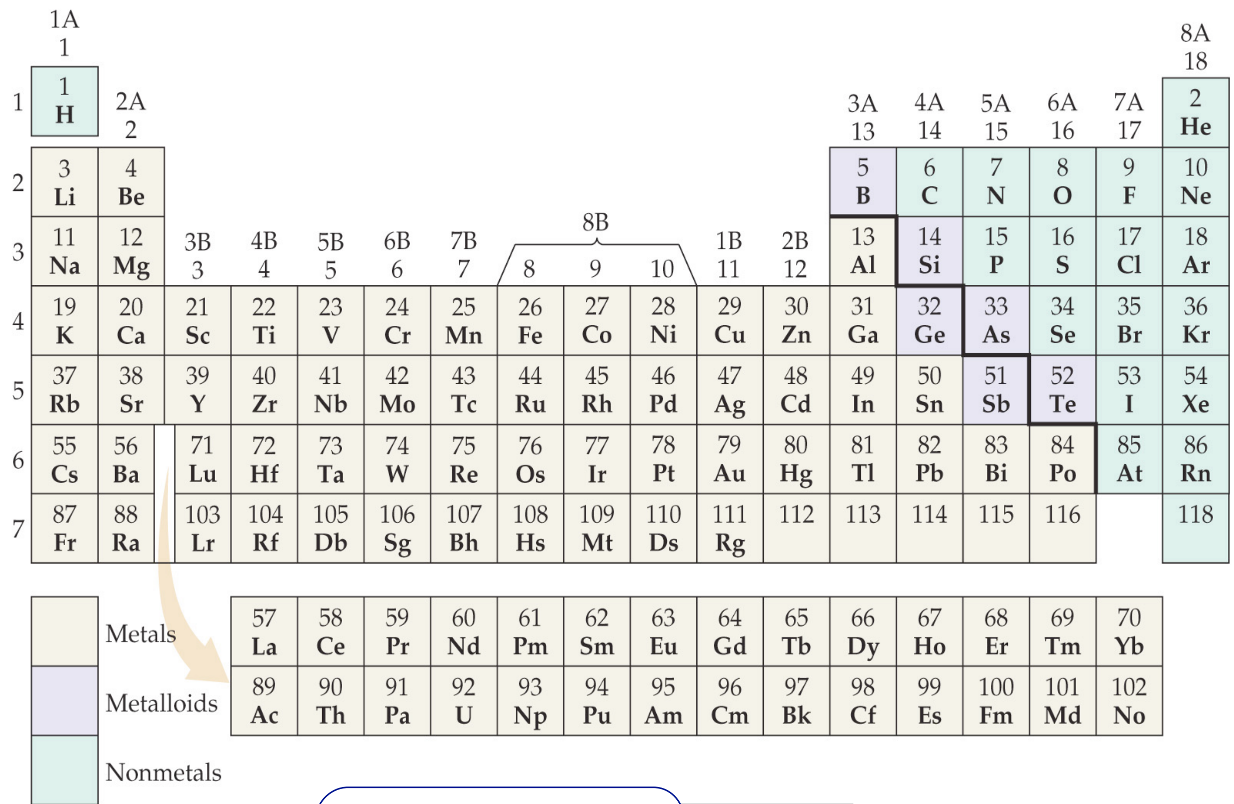
This increase in positive nuclear charge pulls all electrons closer to the nucleus.

For representative elements within the same period, the energy level remains constant as electrons are added.

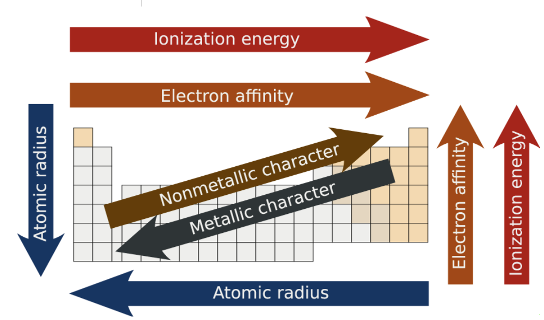


Which Atom is Larger?

- Which atom is larger?
  - F or Li — Li
  - Cl or Br — Br
  - Ge or Se — Ge
  - P or O — P
  - Al or Ge — Unclear
  - Al or Po — Po



Within the P block or within the S block, movie down the periodic table has a bigger effect than moving across it. But trust this only if the distance is two or more rows or columns.



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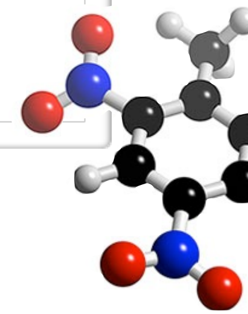
Flavors of the Atom



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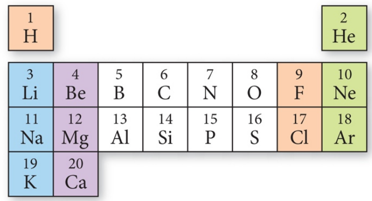

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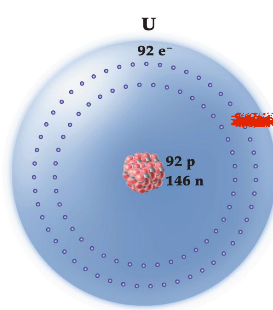
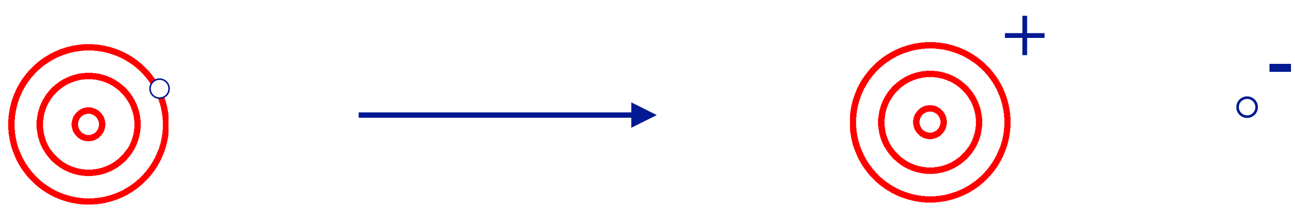
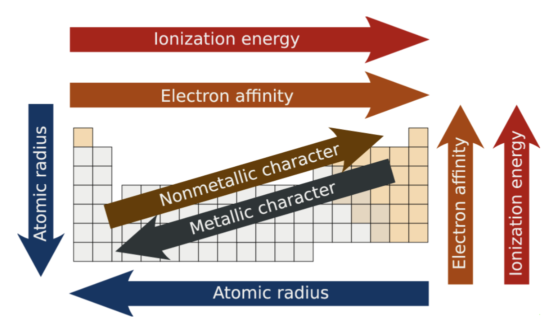


The **ionization energy** of an atom is the energy required to remove an electron from an atom.

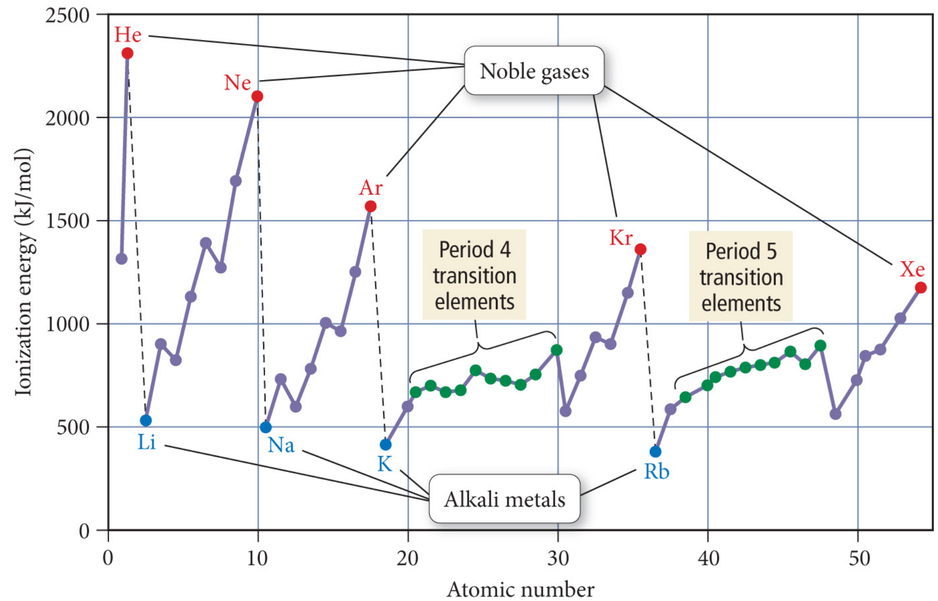
Na + ionization energy $\rightarrow Na^{+} + e^{-}$

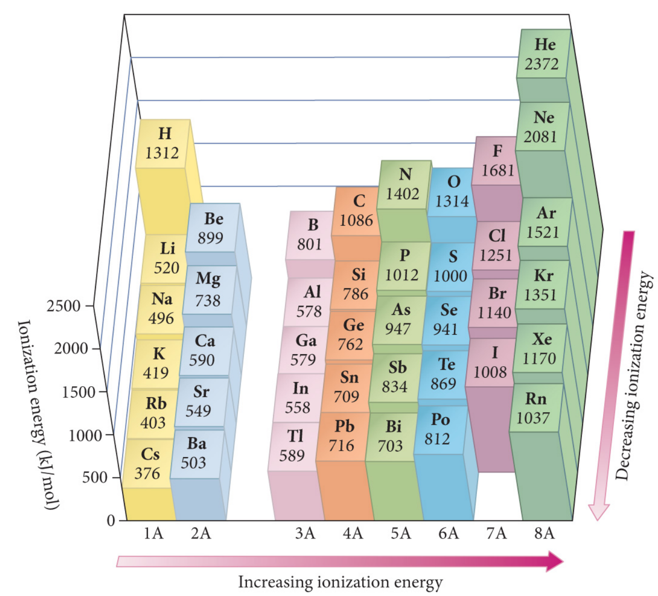




Ionization Energy

- Ionization energy is the energy required to remove an electron from an atom or ion.
- Ionization energy get's larger as you move across the periodic table from left to right.
  - As you move across the periodic table, the effective nuclear charge increases.
  - The pull on each electron in the outermost shell increases.
  - So it's harder to remove those electrons.
- Ionization energy get's smaller as you move down the periodic table.
  - As you move down the periodic table the radius of the valence shell increases.
  - While nuclear charge increases, shielding reduces the effect of that increased nuclear charge.
  - The outer electrons are held more loosely.
  - It's easier to remove electrons from these larger shells.
- Nobel gases are almost impossible to ionize.
- Of the remaining elements, Fluorine is the king, as you get farther from Fluorine it becomes easier to steel electrons.
- Hydrogen is an exception to the pattern.





Which Element has a higher IE?

- Which has a higher IE?
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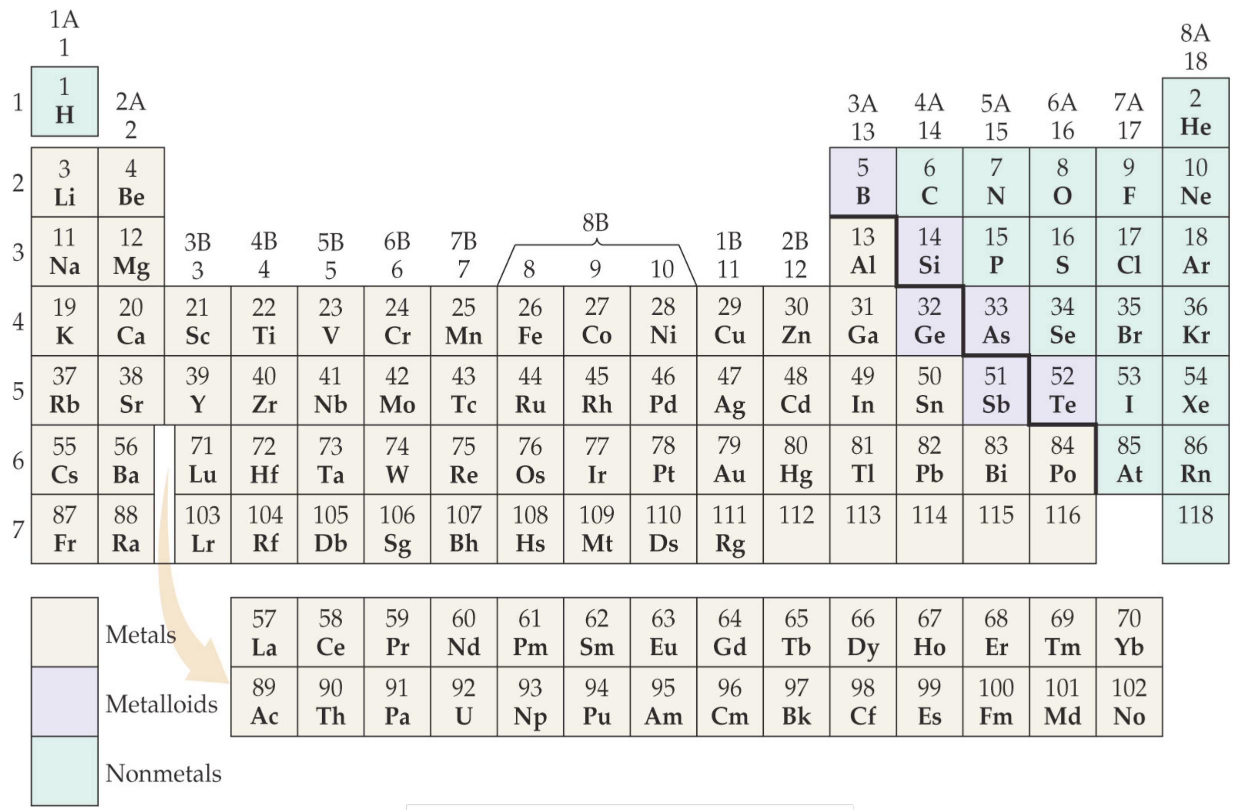

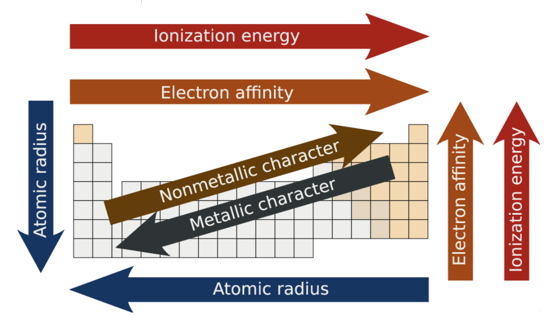

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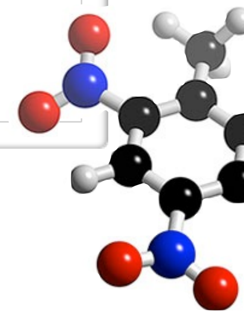

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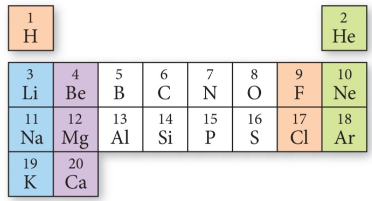

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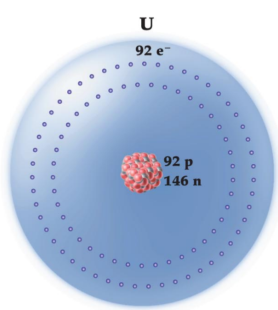

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$^{17}_{8}O$

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