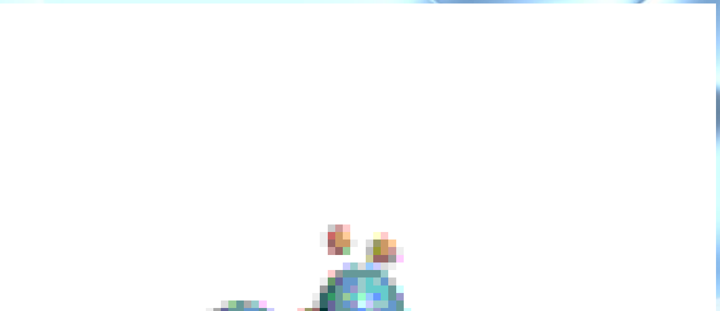
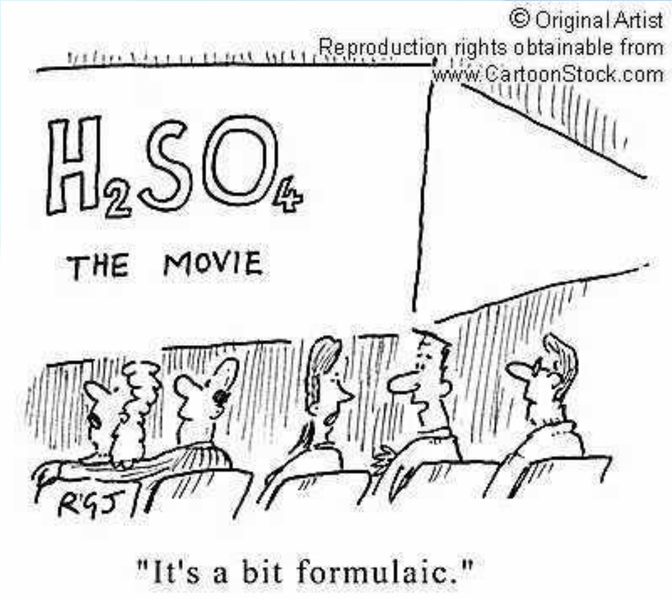
Unit II
Chemical Formulas, Bonding, & Molecular Shapes





The Elements

- Presently 118 different elements are known
  - 88 (of which) occur naturally
  - The rest are synthetic (created in laboratories)
    - **Question**: Where are the synthetic elements in the periodic table? How can you tell?

- The elements vary tremendously in abundance
  - 9 elements account for 98% of the composition of the Earth's crust

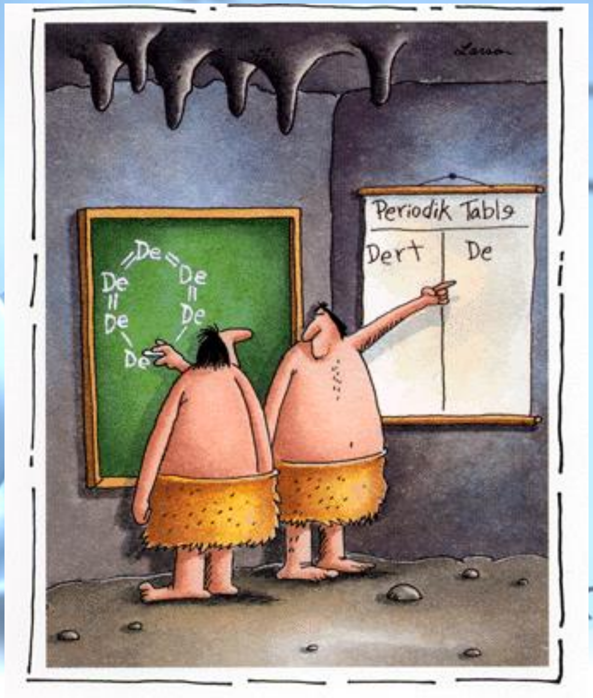
Element	%	Element	%
oxygen	49.2	sodium	2.63
silicon	25.7	potassium	2.40
aluminum	7.50	magnesium	1.93
iron	4.71	hydrogen	.67
calcium	3.39		

- The elements in living matter differs from that in the earth's crust
  - O, C, H, & N form the basis of all biologically important compounds

Element	%	Element	%
oxygen	65	hydrogen	10
carbon	18	nitrogen	3.0

  - Some **trace elements** are important for life
    - Found in small quantities
    - **Example**: Cr – helps the body to produce sugars for energy

- As we have seen, elements are fundamental to understanding chemistry



Early chemists describe the first dirt molecule.

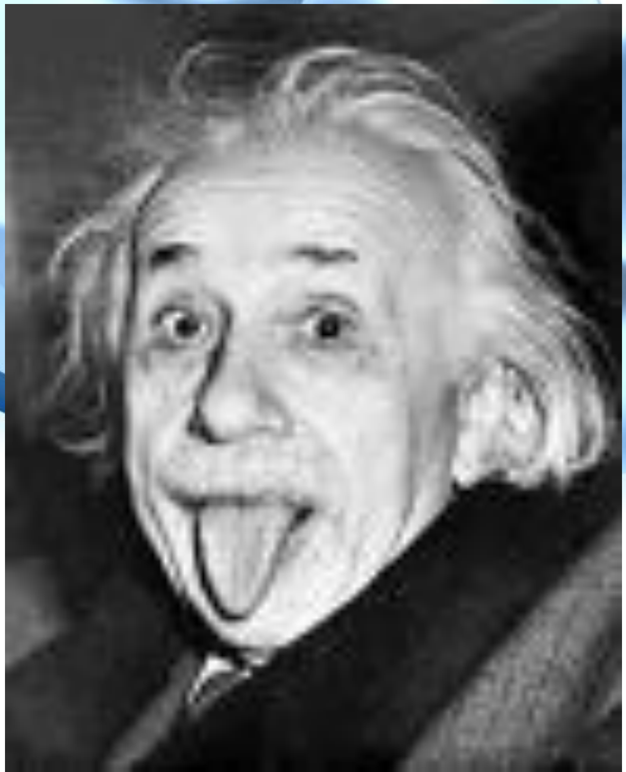
- The **names** for chemical elements have **come from many sources**
  1. Often derived from Latin, Greek, or German
     - **Examples**:
       - A. Gold (Au) - *aurum* (Latin for "shining down")
       - B. Lead (Pb) - *plumbum* (Latin for "heavy")
       - C. Bromine (Br) – (Greek for "stench")

2. Also named for the place where it was discovered

- **Examples**: Francium (Fr), Germanium (Ge), Californium (Cf), & Berkelium (Bk)

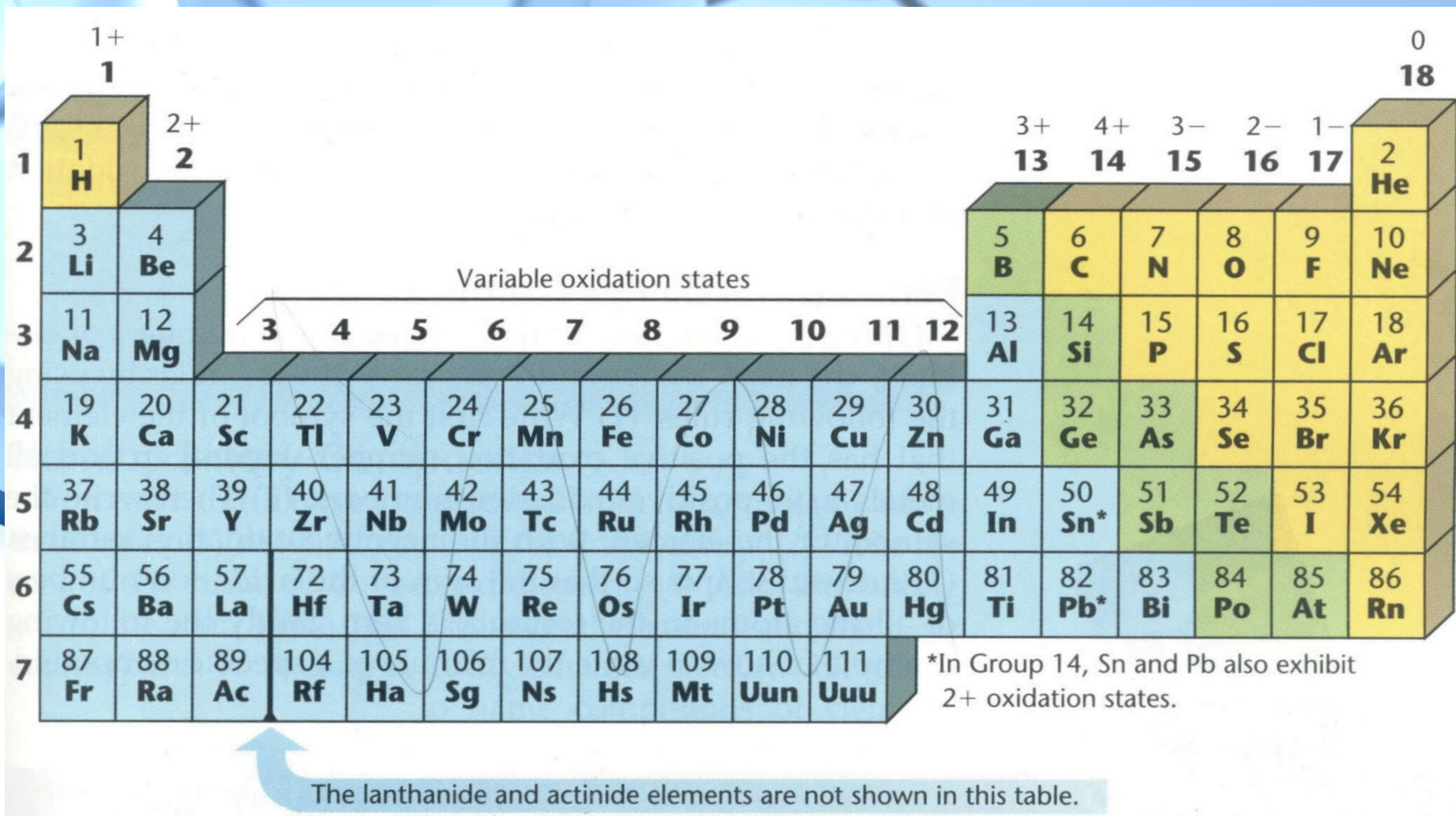
3. Also for famous scientists

- **Examples**: Einsteinium (Es), & Nobelium (No)



- **Chemical symbols** are used to **abbreviate the names** of the elements
  - The chemical symbols could be:
    1. The 1st letter in an elements name
       - **Examples**: Carbon (C) , Oxygen (O)
    2. The 1st letter in an element's name + another letter (usually 2nd)
       - **Examples**: Cobalt (Co), Calcium (Ca), Chlorine (Cl)
    3. Sometimes derived from Latin, Greek,or German
       - **Examples**:
         - A. Latin - Silver (Ag) - argentum
         - B. Greek - Sodium (Na) - natrium
         - C. German – Tungsten (W) - wolfram

- **Rules:**
  - The **<u>1st letter</u>** is always **CAPITALIZED**
  - If needed, the **2nd** (or **3rd**) letter is always lower case



The Elements Song

Introduction to the Periodic Table

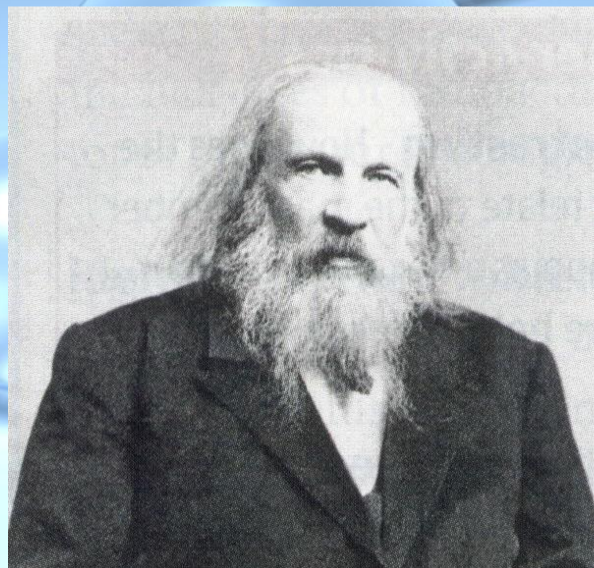
- In any room where Chemistry is taught or practiced, a **Periodic Table** will be sitting on the wall

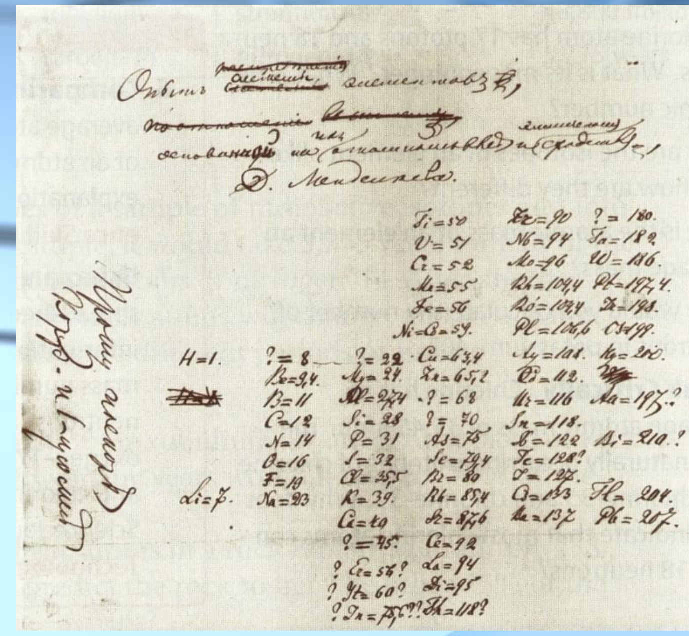
Alkali metals (group 1) · Alkaline earth metals (group 2) · Transition metals (groups 3–12) · Halogens (group 17) · Noble gases (group 18)

1 1A	2 2A	3	4	5	6	7	8	9	10	11	12	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
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	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac†	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub						

*Lanthanides	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
†Actinides	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

- The Periodic Table was first organized by **Dmitri Mendeleev** (A Russian Chemist) in **1869**





- Gathered information about **63** elements
- He noticed that they had similar and different properties
    - So, he decided to organize them (in order of **increasing atomic mass**)

- Mendeleev's table was not perfect
  - Some items were misplaced in terms of their properties
  - **Examples**:The mass # of Cobalt (Co) & Nickel (Ni) actually decreases from left to right
    - The same goes for Copper (Cu) & Zinc (Zn)
    - This problem was cleared up 30 years later
  - British Scientist, **Henry Mosely**, **determined the atomic number** of the elements

- Columns of elements are called **groups** or **families**
  - Elements in the same group have similar, yet not identical properties
  - Often referred to as the number over the column
  - There are **18 Families**
  - **Example**: **Family 1** – Li, Na, K, etc.
    - All are white, shiny metals
    - All are highly reactive
    - Have 1 electron in their outer orbital

- Some groups have special names:
  - **1** – **Alkali metals**
  - **2** – **Alkaline Earth Metals**
  - **17** – **Halogens**
  - **18** – **Noble Gases**
  - **3-12** – **Transition Elements**

Alkaline earth metals

Noble gases

Halogens

Transition metals

Alkali metals

1 1A	2 2A	3	4	5	6	7	8	9	10	11	12	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
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	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac†	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub						

*Lanthanides	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
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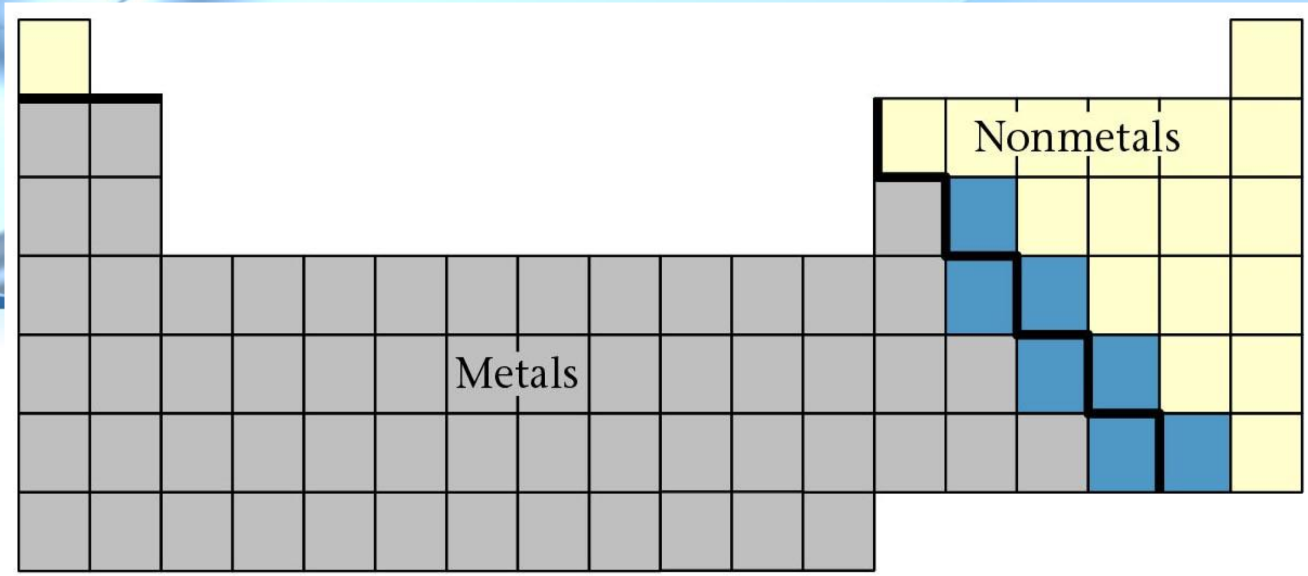
- There are **7 periods** of elements
  - Rows have been separated out of 6 & 7
  - Made the P.T. shorter and easier to read
  - Elements in these rows are **Rare Earth Metals**
- Most elements in the P.T. are metals
  - Located to the **left** of the **stair-step line**
  - Characteristics of metals:
    1 & 2. Good conductors of heat and electricity
    3. Luster
    4. Ductility
    5. Malleability

GROUPS

PERIODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub		114 Uuq		116 Uuh		118 Uuo

6th-period subset	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
7th-period subset	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

- Elements to the **right** of the **stair-step line** are **non-metals**
  - Physical properties – Opposite of the metals
  - Chemical properties – tend to gain electrons
- Elements to **either side** of the **stair-step** line are **metalloids**
  - Show properties of both metals and non-metals



The Modern View of Atomic Structure

- Summary of findings:

Particle	Charge	Mass (kg)	Location
Electron	-1	9.109×10^{-31}	Electron cloud
Proton	+1	1.673×10^{-27}	Nucleus
Neutron	0	1.675×10^{-27}	Nucleus

- All atoms have **atomic mass**
  - The average mass of all the **isotopes**
    - Atoms with the same number of protons, but a different number of neutrons
    - **Examples**: Carbon (C)= 12.01,Argon (Ar)= 39.93

Isotope	Symbol	Composition of the nucleus	% in nature
Carbon-12	^{12}C	6 protons 6 neutrons	98.89%
Carbon-13	^{13}C	6 protons 7 neutrons	1.11%
Carbon-14	^{14}C	6 protons 8 neutrons	<0.01%

- All atoms have a **mass number**
  - The sum of the protons (**+**) and neutrons (**0**) in the nucleus
  - **Mass #** = The atomic mass rounded to the nearest whole #
  - **Examples**: Carbon (C) = 12, Argon (Ar) = 40
  - **# of Neutrons (0) = Mass # - Atomic #**
- The **number of protons** in a nucleus is called the atom's **atomic number**
  - **Examples**: H (1), He (2), Fe (26)

- Fill in the following chart

Ion	Element	Atomic #	Atomic Mass	Mass #	Charge	+	0	–
	Boron	5	10.81	11	0	5	6	5
	Chlorine	17	35.45	35	-1	17	18	18
	Gallium	31	69.74	70	+3	31	39	28

- **Ion**

A → **Mass #**

(charge) → **Ionic Charge**

X → **Symbol**

Z → **Atomic #**

Example:

$^{70}_{31}Ga^{+3}$

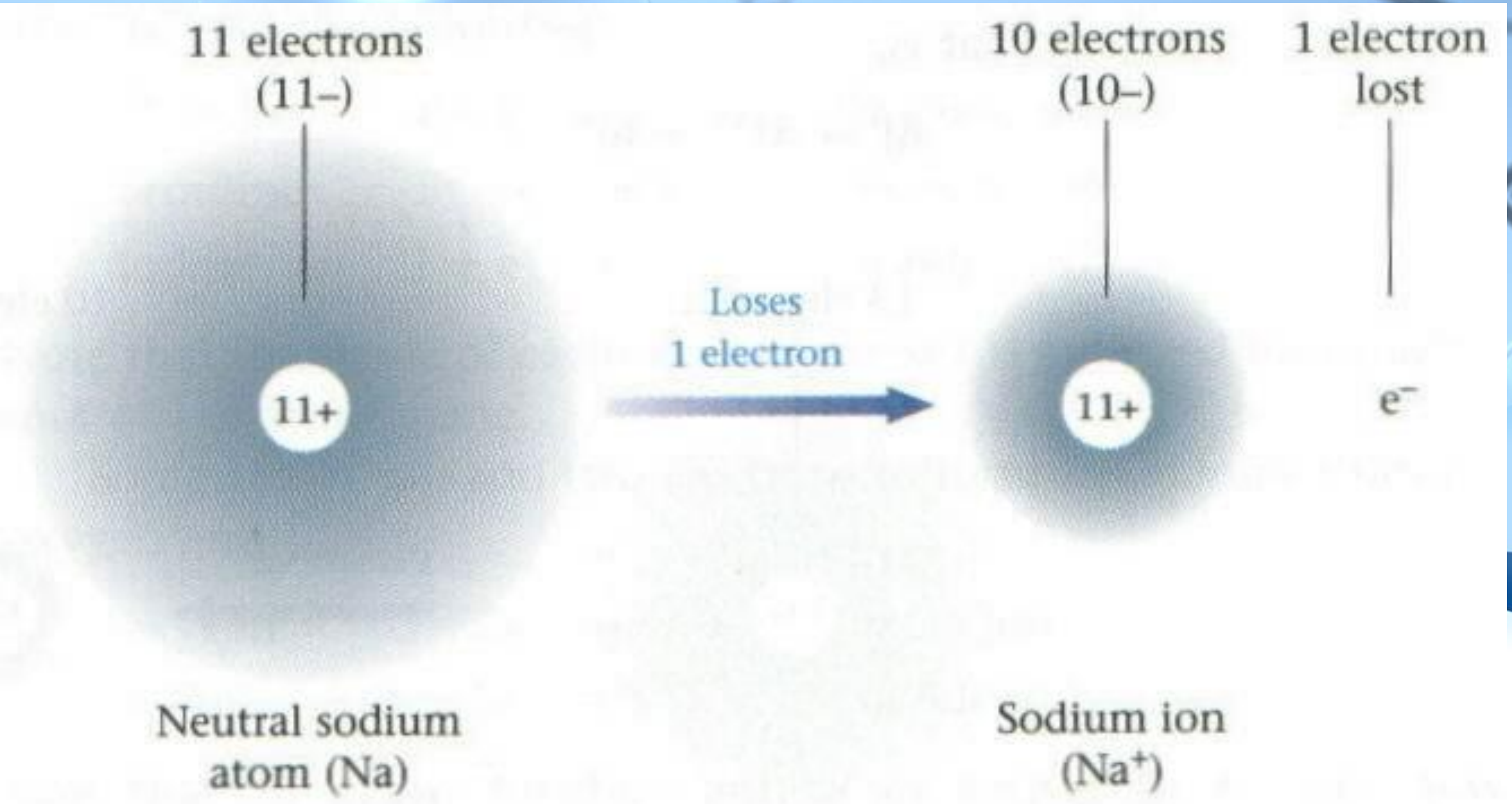
Ion Formation

- If an atom's charge is neutral, we say it has an equal number of "+" 's and "-" 's
  - Each energy level in the P.T. can only hold a maximum # of electrons
    - **Example**:

Energy Level	Max. # of Electrons
1	2
2	8
3	18
4	32

- An element will either have to gain or release electrons to get to this #

- An **ion** can be **formed** by **adding or removing** one or more **electrons**
- **Example**:

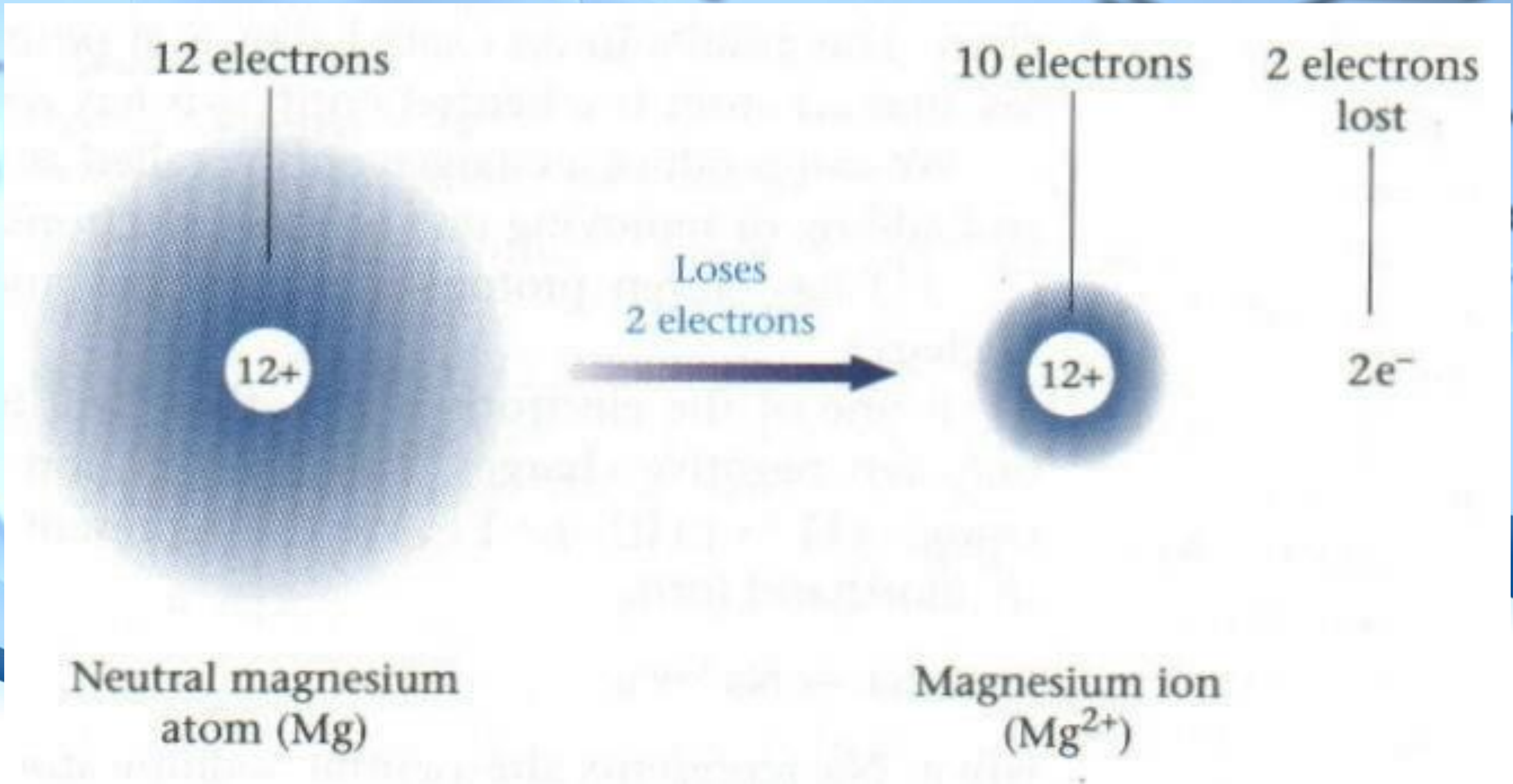


- **Shorthand form**:

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

– A positive "+" ion is called a **cation**

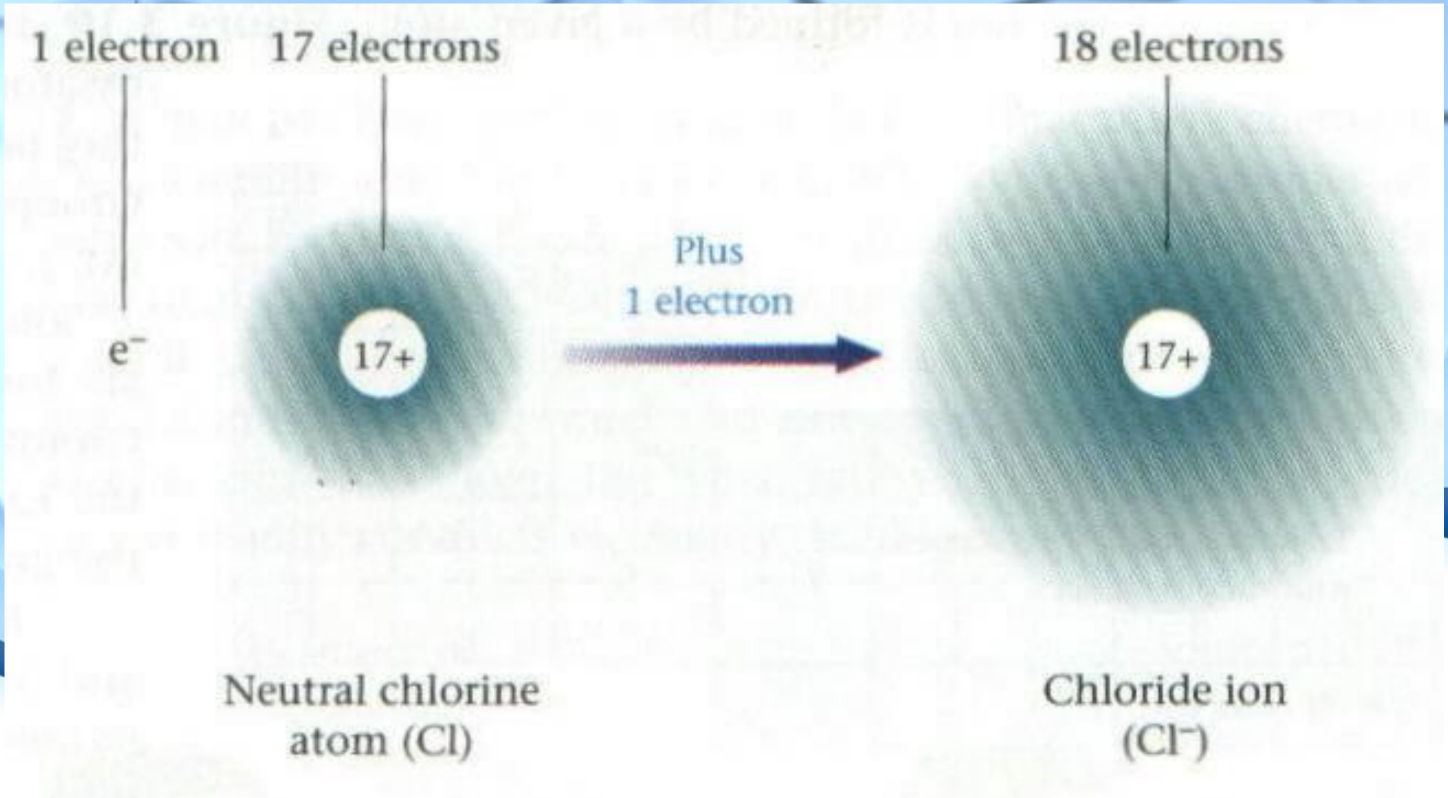
- Produced when 1 or more electrons are lost from a neutral atom
- **Example**:



- **Shorthand form**: $Mg \rightarrow Mg^{2+} + 2e^{-}$

– A negative "-" ion is called an anion

- Produced when 1 or more electrons are gained from a neutral atom
- **Example**:



- **Shorthand Form**: $Cl + e^- \rightarrow Cl^-$

Predicting Ionic Charges

Group 1: Lose 1 electron to form 1+ ions

H^+ Li^+ Na^+ K^+

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

Group 2: Loses 2 electrons to form 2+ ions

Be^{2+} Mg^{2+} Ca^{2+} Sr^{2+} Ba^{2+}

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 4.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

Group 13: Loses 3 electrons to form 3+ ions

B^{3+} Al^{3+} Ga^{3+}

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

Caution! C_2^{2-} and C^{4-} are both called *carbide*

Group 14: Loses 4 electrons or gains 4 electrons

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

N^{3-} Nitride

P^{3-} Phosphide

As^{3-} Arsenide

Group 15: Gains 3 electrons to form 3- ions

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
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55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

O^{2-} Oxide

S^{2-} Sulfide

Se^{2-} Selenide

Group 16: Gains 2 electrons to form 2- ions

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

F^{1-} Fluoride

Br^{1-} Bromide

Cl^{1-} Chloride

I^{1-} Iodide

Group 17: Gains 1 electron to form 1- ions

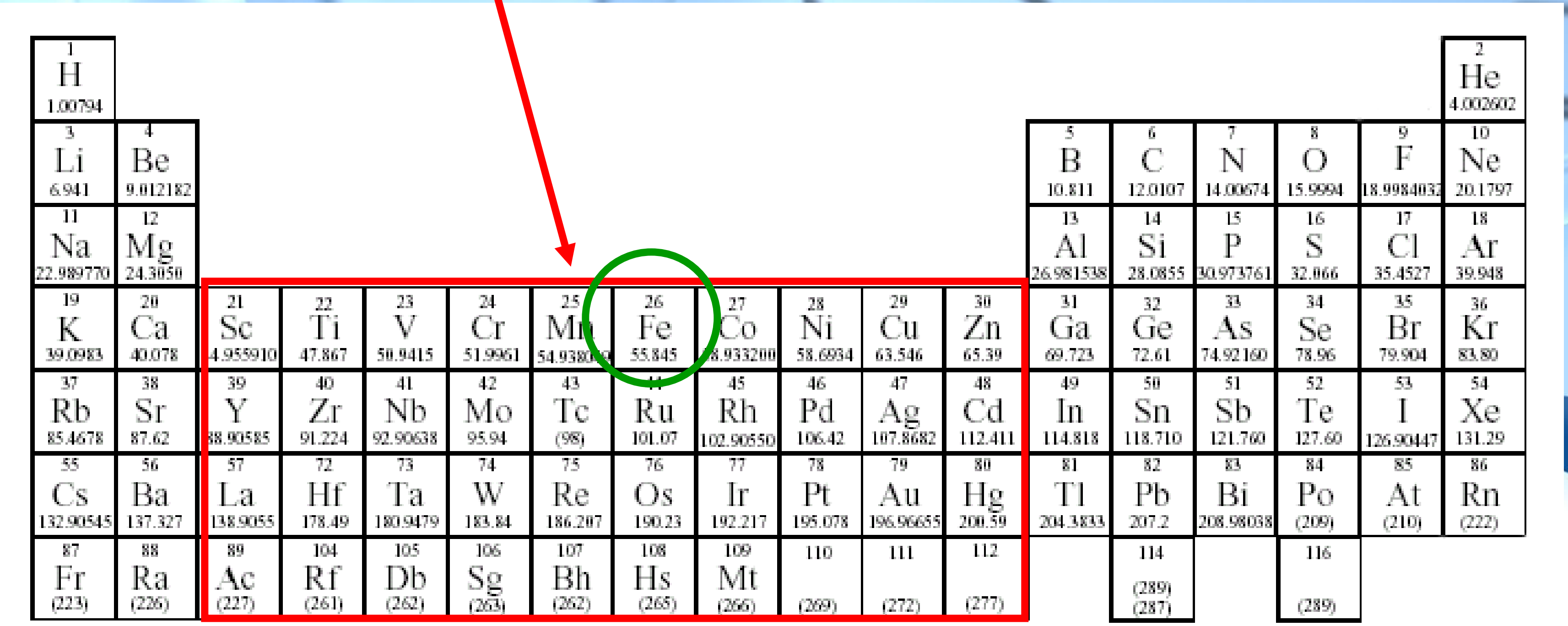
1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

Group 18: Stable Noble gases **do not** form ions!

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.998403	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.9044	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		

Groups 3 - 12: Many transition elements have more than one possible oxidation state.

Iron(II) = Fe^{2+} Iron(III) = Fe^{3+}



Groups 3 - 12: Some transition elements have only one possible oxidation state.

Zinc = Zn^{2+} Silver = Ag^{+}

1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
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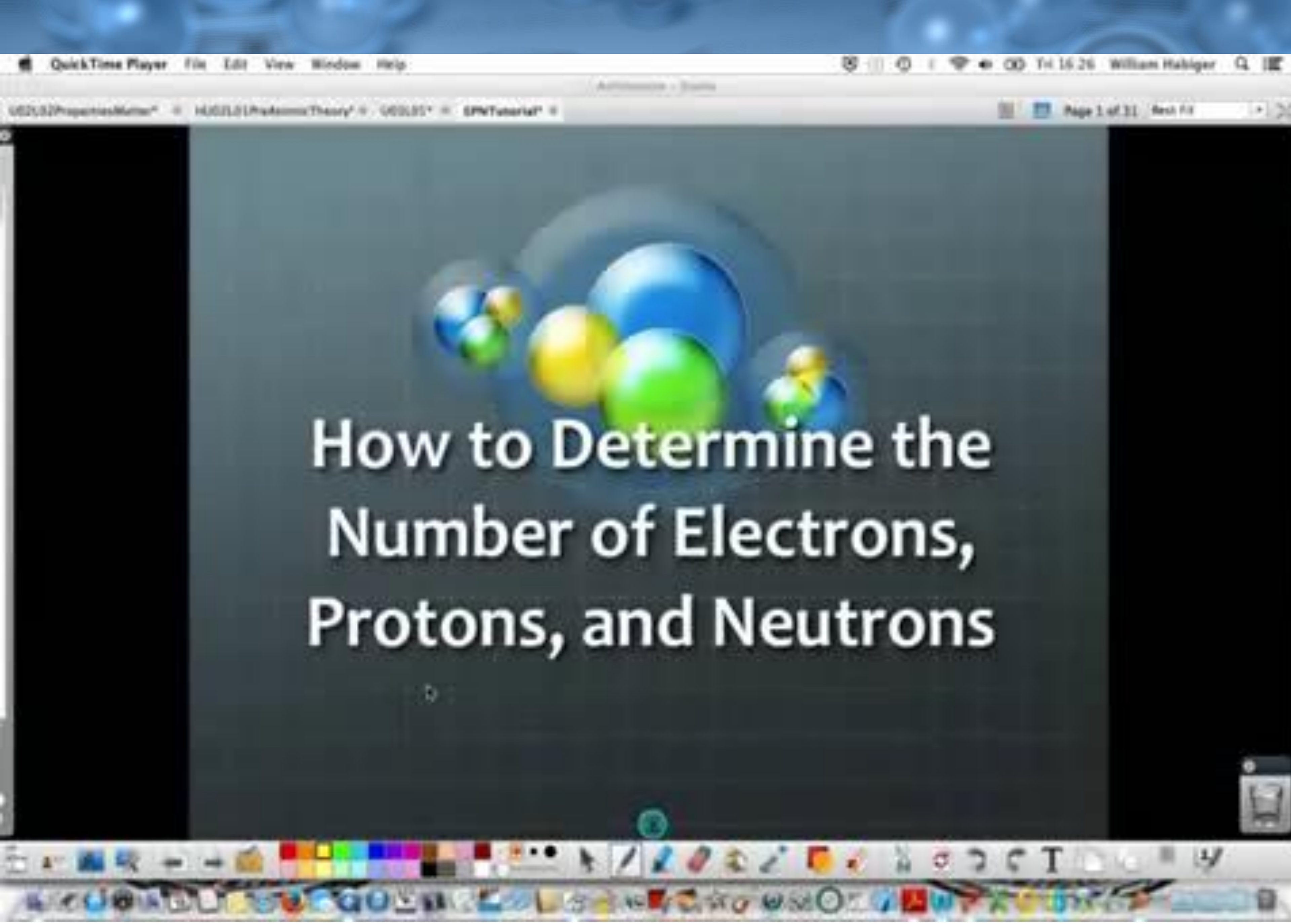
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.4[illegible]	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		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William Habiger
How to Determine the Number of Electrons, Protons, and Neutrons

Quantifying p^+, n°, & e^-

p^+ - proton

n° - neutron

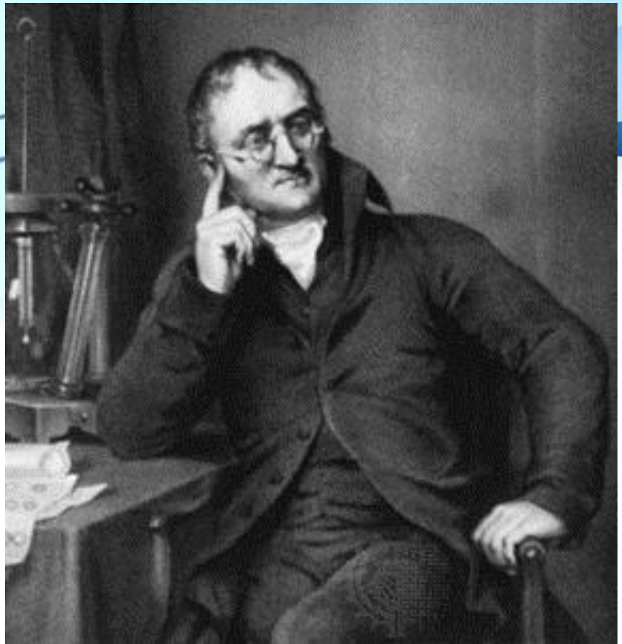
e^- - electron

Dalton's Atomic Theory

- As scientists studied materials in the 18th century, 3 things became clear:
  1. Most natural materials are mixtures of pure substances
  2. Pure substances are either elements or compounds
  3. A given compound contains the same proportions (by mass) of the elements

- #3 is known as the **Law of Constant Composition**
  - A given compound always has the same composition, regardless of where it comes from

- **John Dalton** (1766 – 1844) was aware of these observations
  - In 1808 he published *A New System of Chemical Philosophy*



– In this text, he said…

1. All elements are composed of extremely small particles called atoms
2. Atoms of a given element are identical in size, mass, and other properties
   – Atoms of different elements differ in size, mass, and other properties
3. Atoms **can not** be subdivided, created, nor destroyed
4. Atoms of different elements combine in simple whole number ratios to form chemical compounds
5. In chemical reactions, atoms are combined, separated, or rearranged

- Modern Atomic Theory says…
  - Several changes have been made to Dalton's Theory:
  - **Change 1**:
    - Dalton said…

      Atoms of a given element are identical in size, mass and other properties; atoms of different elements differ in size, mass, and other properties
    - Modern Theory States…

      Atoms of elements have characteristic average masses which is unique to that element

– **Change #2**:

- Dalton said…

  Atoms cannot be subdivided, created, or destroyed

- Modern Theory States…

  Atoms cannot be subdivided, created, or destroyed in ordinary chemical reactions. However, the changes can occur in nuclear reactions

Dalton's Atomic Theory

Observations about the nature of matter

1. Most natural materials are mixtures of pure substances.
2. Pure substances are either elements or combinations of elements called compounds.
3. A given compound always contains the same proportions (by mass) of the elements.

Return to TOC

Compounds & Bonding

- A **compound** is a distinct substance that is composed of the atoms of 2 or more elements
  - Always contains the same relative masses of those elements
  - **Examples**:
    - Empirical Formulas: H_2O (2:1 ratio)
    - Molecular Formulas: H_4O_2 "

H_6O_3 "

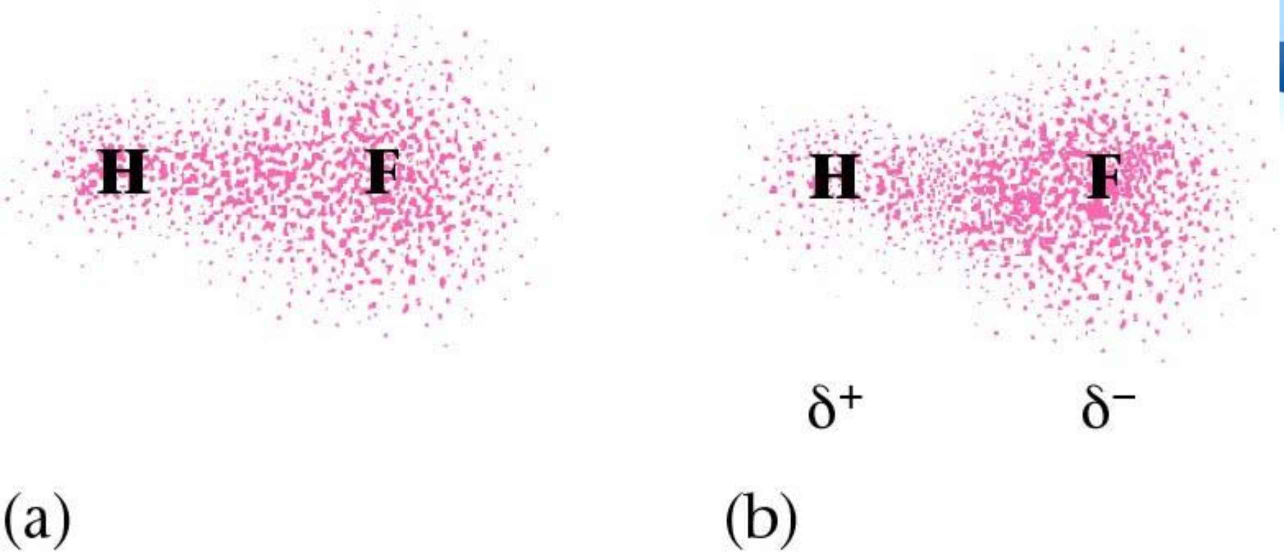
H_8O_4 "

$H_{10}O_5$ "

- Forces that hold atoms together in compounds are called **chemical bonds**
  - There are 3 types of **bonds**:
    1. **Ionic Bond**
       - A bond between a metal and a nonmetal
       - Electrons are transferred
       - Electronegativity differences are > 1.7
       - **Cations** (**+ ions**) & **Anions** (**- ions**)
       - Type's I & II
    2. **Covalent Bond**
       - A bond between 2 nonmetals
       - Electrons are shared
       - Electronegativity differences between 0 & 0.3
       - Type III

3. Polar Covalent Bond

- **Between ionic and covalent bonds**
- Electrons are completely transferred and an unequal sharing of electrons results
- Electronegativity differences between .3 & 1.7
- **Always involves a hydrogen** (+ ion) and another nonmetal
- **Example**:



Bonding Summary:

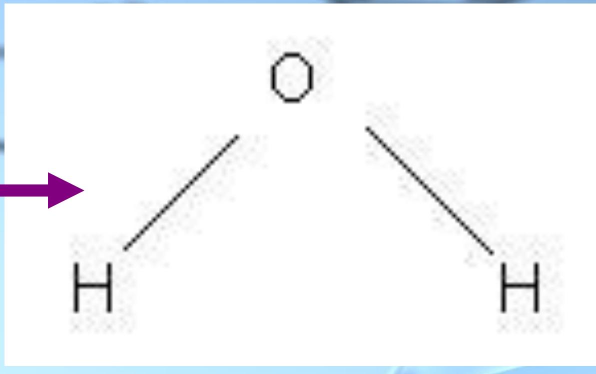
TABLE 12.1

The Relationship Between Electronegativity and Bond Type

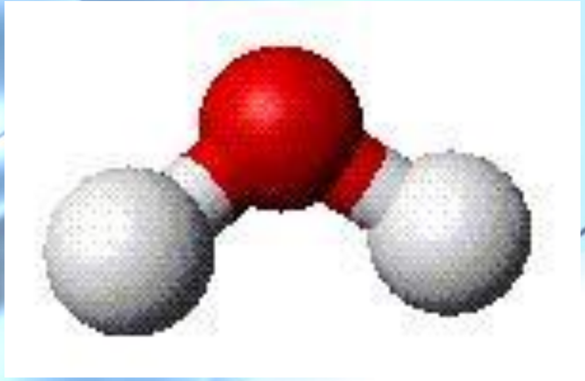
Electronegativity Difference Between the Bonding Atoms	Bond Type	Covalent Character	Ionic Character
Zero	Covalent		
↓	↓		
Intermediate	Polar covalent	↑ Increase	Increases ↓
↓	↓		
Large	Ionic		

- A resulting collection of bonds is called a **molecule**
  - Can be represented in **3** main ways:
  - All representations for H_2O

1. **Structural Formula**



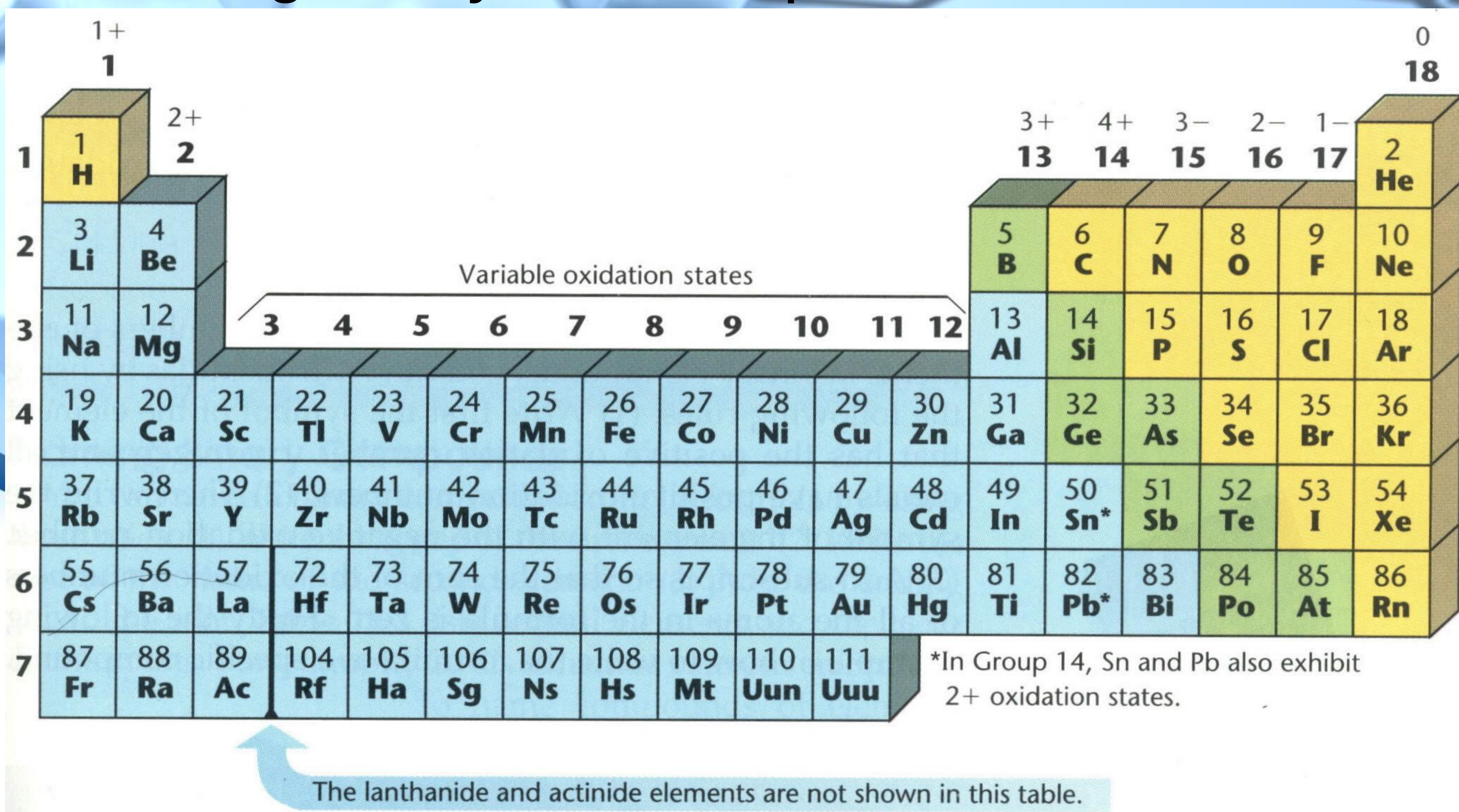
2. **Ball & Stick**



3. **Space Filling**

Naming Compounds

- You can figure out chemical formulas with the help of oxidation numbers
  - A + or – number assigned to an element to show its combining ability in a compound



- Oxidation numbers are useful in showing how **binary compounds** form
  - Composed of 2 elements
  - Can divide into **2 classes**:
    1. **Metal and Nonmetal** (**Ionic Bond**)
       - Type I & Type II Compounds
       - Examples: **Type I** → Calcium phosphide (Ca_3P_2);
         Type II → Iron (III) oxide (Fe_2O_3)
    2. **2 Nonmetal's** (**Covalent Bond**)
       - Type III Compounds
       - Example: **Type III** → Diphosphorous trisulfide (P_2O_3)

Type I Compounds

- The cation (+ ion) is in Families 1-2, or 13
- Rules for naming Type I Compounds:
  1. The **cation** (**+**) is named **1st** & the **anion** (**-**) is named **2nd**
  2. The **cation** takes its name from the **name of the element**
  3. Take the **root of the anion** and **add –ide** to the end
     - **Note**: If a polyatomic ion is used, just write the name of the entire polyatomic ion itself
     - **Don't** take the anion root and add -ide

- Writing **Type I** chemical formulas can be used using the **swap-n-drop method**
  - The charge of one ion will be the # of atoms of the other element/ion (& vice – versa)
  - The # of atoms must always be in their lowest terms
- **Example 1**: sodium chloride
  - Write down the ions Na^{+1} Cl^{-1}
  - Swap them Na_1Cl_1
  - Always reduce the terms $NaCl$

Example 2: magnesium bromide

- Write down the ions Mg^{+2} Br^{-1}
- Swap them Mg_1Br_2
- Always reduce the terms $MgBr_2$

Example 3: boron oxide

- Write down the ions B^{+3} O^{-2}
- Swap them B_2O_3
- Always reduce the terms B_2O_3

Example 4: calcium carbide

- Write down the ions Ca^{+2} C^{-4}
- Swap them Ca_4C_2
- Always reduce the terms Ca_2C

Example 5: gallium borate

- Write down the ions Ga^{+3} BO_3^{-3}
- Swap them $Ga_3(BO_3)_3$
- Always reduce the terms $GaBO_3$

Example 6: strontium phosphate

- Write down the ions Sr^{+2} PO_4^{-3}
- Swap them $Sr_3(PO_4)_2$
- Always reduce the terms $Sr_3(PO_4)_2$

Type II Compounds

- The cation is in **Families 3-12**, or the element is Sn, Pb, Sb, or Bi
  - **Examples**:
    A. Lead (Pb) = Pb^{+2} or Pb^{+4}
    B. Gold (Au) = Au^{+1} or Au^{+3}
    - If we saw the compound gold chloride, we would not know which ion (+1 or +3) was present
    - Chemists use a **Roman Numeral** to specify the charge on the cation
    - **Note**: Otherwise, **follow the rules for writing Type I compounds**

Example 1: Fe_2O_3

- Iron (?) oxide
- The charge to iron can be a +2 or +3
- Do a **reverse swap-n-drop**
- **Example**: Fe_2O_3

  Fe^{+3} O^{-2}

  iron (III) oxide

- This **can not** be done for subscripts that are:
  - 1:1 ratio → NiS (Ni^{+2} & S^{-2})
  - 1:2 ratio → $SnSe_2$ (Sn^{+4} & Se^{-2})
  - 2:1 ratio → Pb_2C (Pb^{+2} & C^{-4})

- The metallic valences can also be noted by utilizing the ***latinized endings***
  - **-ic** → The **higher** of the 2 charges
  - **-ous** → The **lower** of the 2 charges

TABLE 4.2

Common Type II Cations

Ion	Systematic Name	Older Name
Fe^{3+}	iron(III)	ferric
Fe^{2+}	iron(II)	ferrous
Cu^{2+}	copper(II)	cupric
Cu^{+}	copper(I)	cuprous
Co^{3+}	cobalt(III)	cobaltic
Co^{2+}	cobalt(II)	cobaltous
Sn^{4+}	tin(IV)	stannic
Sn^{2+}	tin(II)	stannous
Pb^{4+}	lead(IV)	plumbic
Pb^{2+}	lead(II)	plumbous
Hg^{2+}	mercury(II)	mercuric
Hg_2^{2+}*	mercury(I)	mercurous

*Mercury(I) ions always occur bound together in pairs to form Hg_2^{2+}.

Type III Compounds

- **Contains only nonmetals**
  - Otherwise, the 1st element is not in…
    - **A.** Families 1-2, 13
    - **B.** Families 3-12, or Sn, Pb, Sb, or Bi
- Rules for naming **Type III Compounds**:
  1. The 1st element in the formula is named 1st (full elemental name)
  2. The 2nd element is named as if it were an anion (i.e. root)
  3. **Prefixes** denote the number of atoms present
  4. The prefix mono- is never used for naming the 1st element
     - CO → carbon monoxide, **not** monocarbon monoxide

- List of covalent prefixes:

Prefix	Number
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10

- Several polyatomic ions exist that have different numbers of oxygen atoms
  - These are called **oxyanions**
  - When 2 members are in a series…

    A. The **smaller** # ends in ***–ite***

    B. The **larger** # ends in ***–ate***

    - Much like the *–ous/-ic* endings when naming metals
    - **Examples**: SO_3^{-2} = **sulfite**; SO_4^{-2} = **sulfate**

      BO_2^{-3} = **borite**; BO_3^{-3} = **borate**

- **When more than 2** oxyanions make up a series, ***hypo-*** (**less** than) and ***per-*** (**more** than) are used as prefixes
  - **Examples**:

ClO^-	=	**hypo**chlor**ite**
ClO_2^-	=	chlor**ite**
ClO_3^-	=	chlor**ate**
ClO_4^-	=	**per**chlor**ate**

Rules for Naming Acids

1. If the anion does not contain oxygen…

- Use the prefix ***hydro-*** with the suffix ***–ic*** attached to the root name for the element
- Place the term "acid" at the end
- **Examples**: HCN = hydrocyanic acid

  H_2S = hydrosulfuric acid

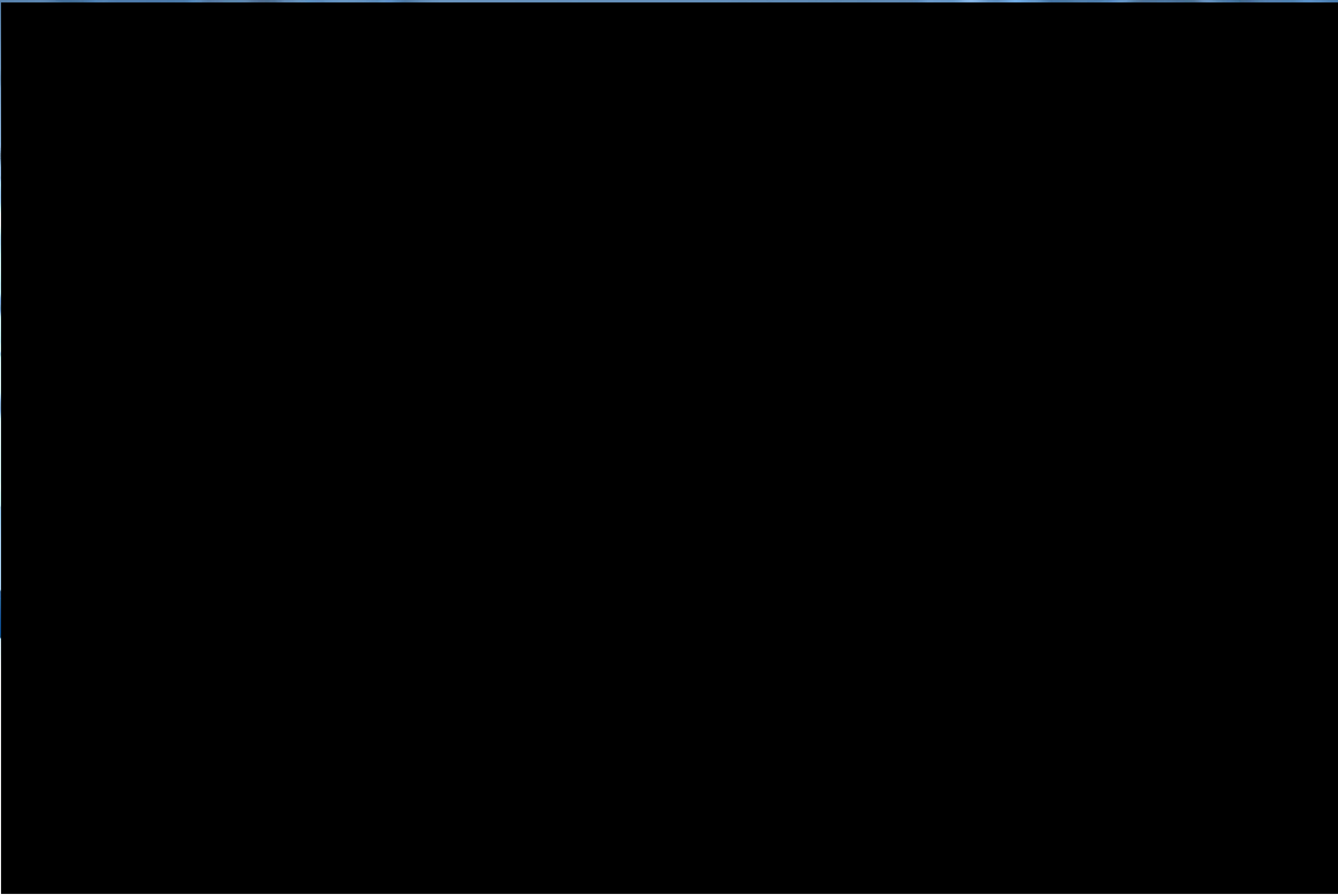
2. When the anion **does contain oxygen**…

- When the anion name ends in *–ate*, the suffix ***–ic*** is used
- **Examples**:

Acid	Anion	Name
H_2SO_4	SO_4^{-2} (sulfate)	sulfur**ic** acid
H_3PO_4	PO_4^{-3} (phosphate)	phosphor**ic** acid

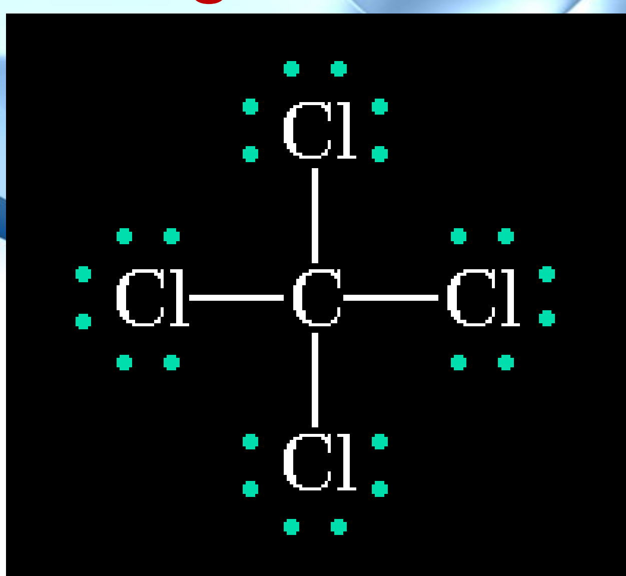
- When the anion name ends in –ite, the suffix ***–ous*** is used
- **Examples**:

Acid	Anion	Name
H_2SO_3	SO_3^{-2} (sulfite)	sulfur**ous** acid
HNO_2	NO_2^{-2} (nitrite)	nitr**ous** acid

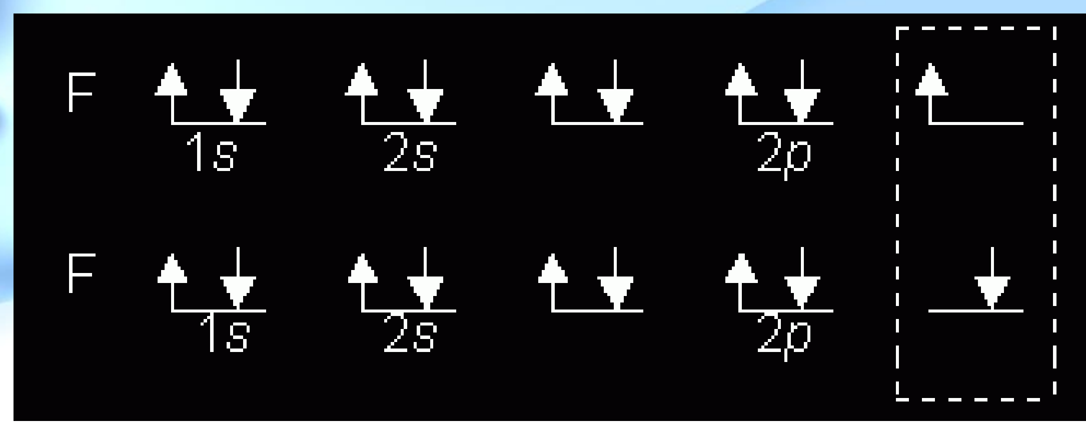


Lewis Structures

- The **Lewis Structure** is a representation of a molecule that shows how valence electrons are arranged in atoms of a molecule
  - Most important…Atoms achieve a noble gas configuration

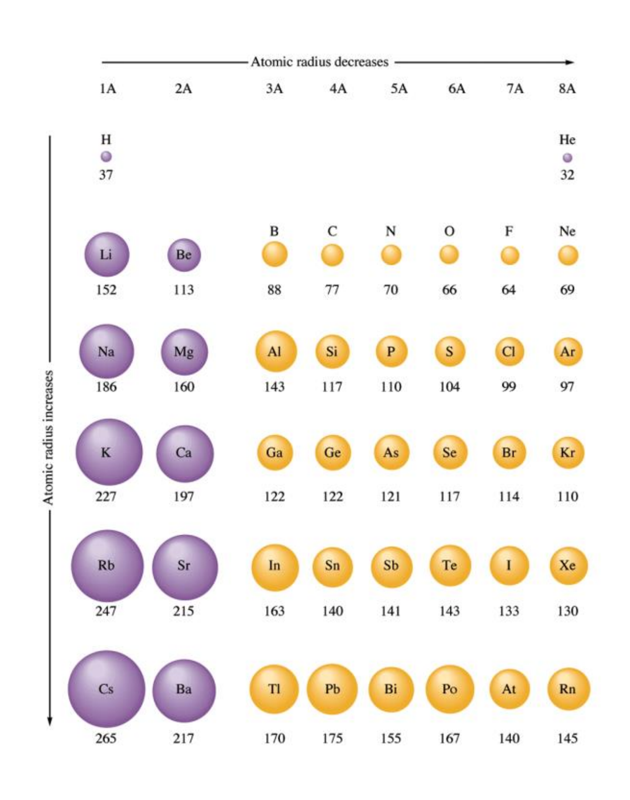


diatomic fluorine

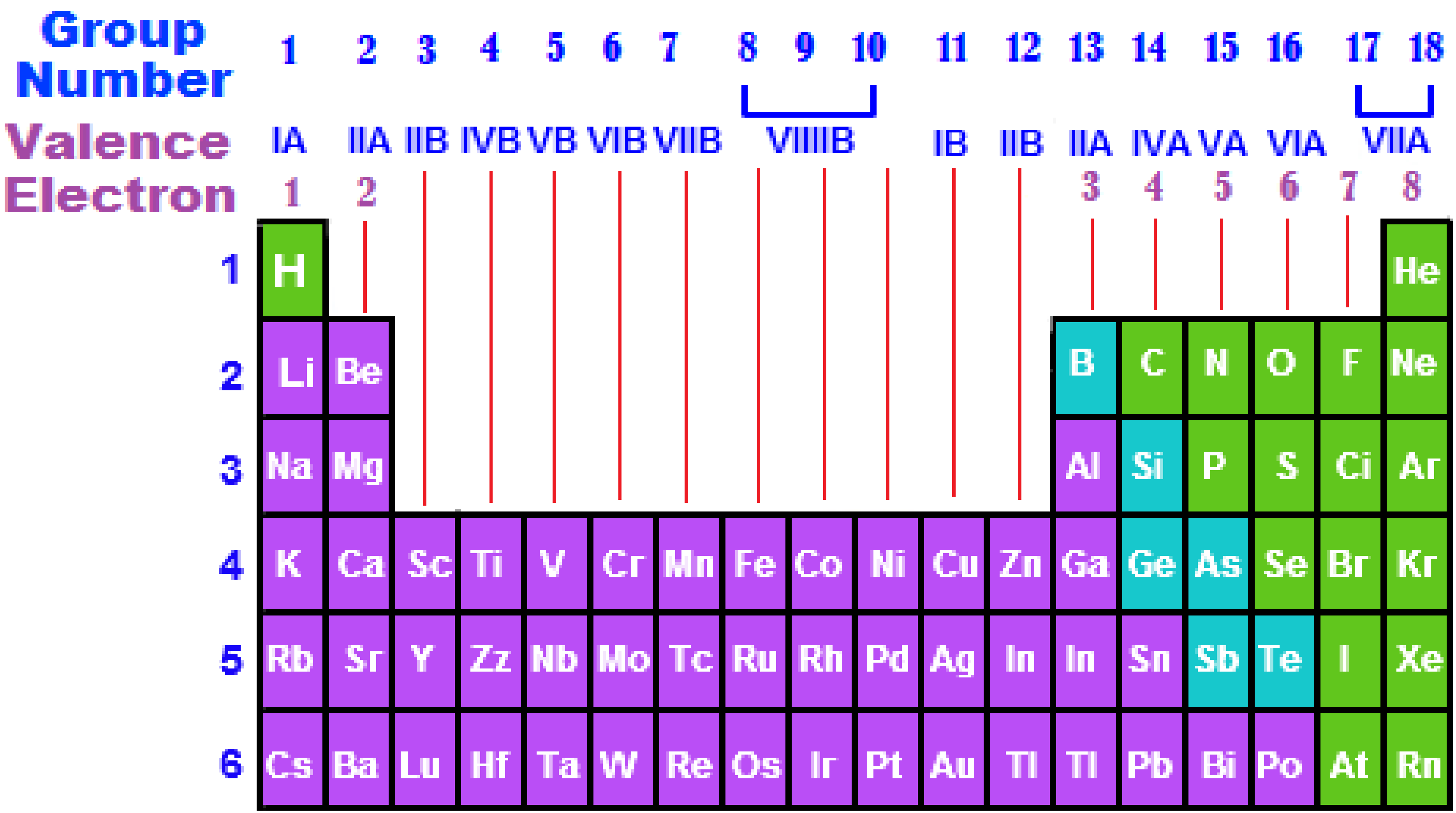


Lewis Structure Rules

1. Only include the **valence electrons**
   - Count the total number in the compound
   - Represented by dots
2. Identify the central atom(s)
   - It will have the largest atomic radii
   - It is generally the atom that is most singular



Valence Electron Chart

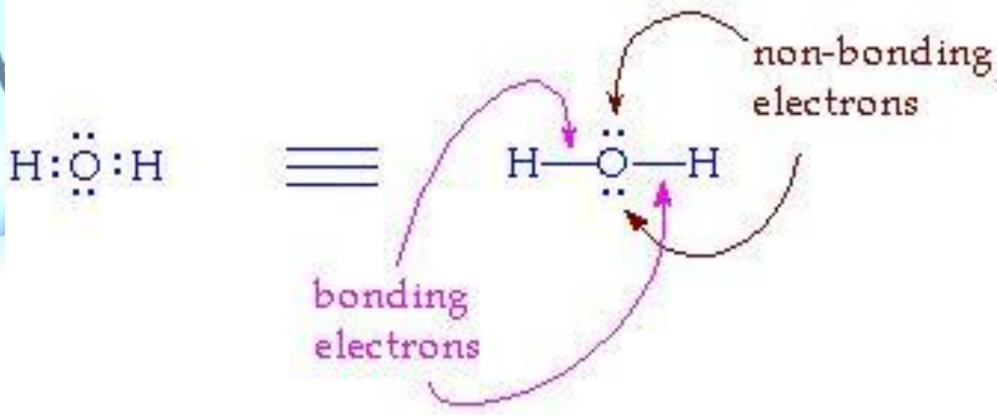


3. Draw in single lines between the central atom(s) and the other atoms in the compound

- These lines represent single bonds
- Represents 2 electrons
- **Example**: (-)… C – 0

4. Add in single dots to the remaining atoms in the compound

- These represent unbonded electrons



5. Make sure that the elements in the compound follow 1 of the following rules:

A. Duet rule

- Only applies to H
- Forms stable molecules when it shares 2 electrons
  - In effect, this gives H a filled 1st valence shell

B. Octet Rule

- Applies to most other elements
- **Exceptions**: B & Be (6), S (12)

- *Advanced* Octet Rule Comments…
  - 2nd row elements (C, N, O, F) observe the octet rule
  - 2nd row elements (B, Be) often have fewer than 8 electrons around themselves – they are very reactive
  - 3rd row and heavier elements **CAN** exceed the octet rule using empty valence *d* orbitals
  - When writing Lewis Structures, satisfy octets first, then place electrons around elements having available *d* orbitals

6. Recheck the total number of valence electrons

- **Remember** → 1 dot = 1 electron
  1 line (-) = 2 electrons
- If the # matches, you are done
- If the # is too many, you will need to add double or triple bonds

A. **Double bond** – involves sharing **2 pairs** of electrons

- Represented by a double line (=)

B. **Triple bond** – involves the sharing of **3 pairs** of electrons

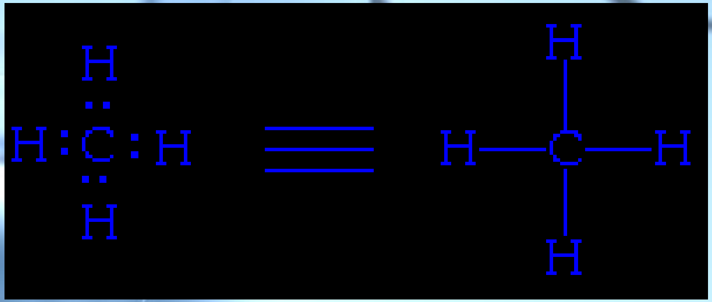
- Represented by a triple line (≡)

7. Double check your work

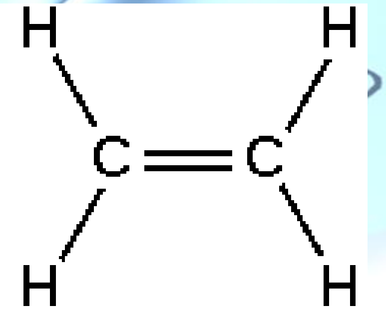
- If the total # of valence electrons does not work out, go back to step 6

Examples:

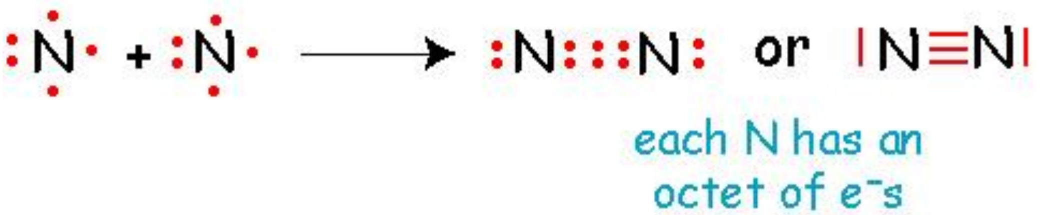
- Single Bonds (Alkanes)



- Double Bonds (Alkenes)



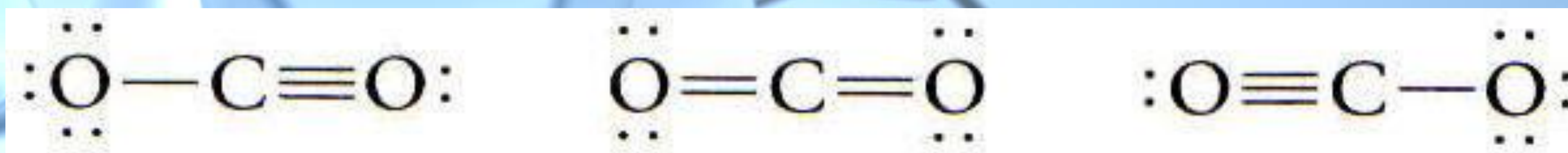
- Triple Bonds (Alkynes)



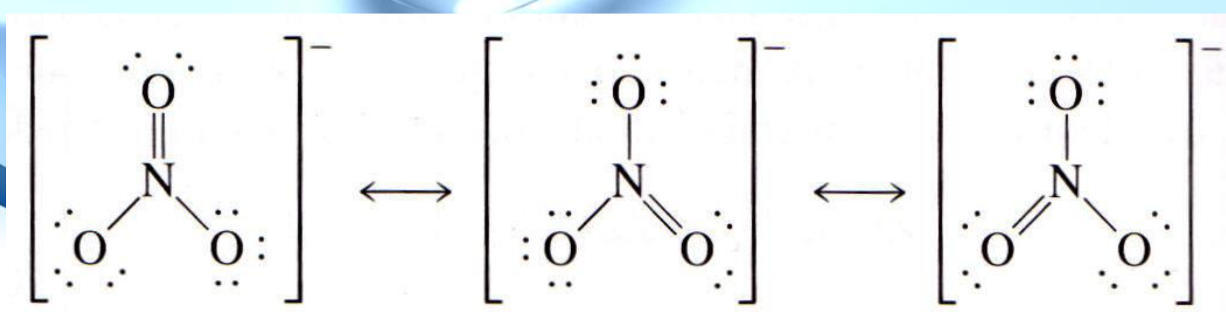
How to Draw Lewis Structures

Resonance

- Sometimes it is possible for more than 1 Lewis Structure to be drawn for a given molecule
  - **Example**: CO_2 (16 valence electrons)



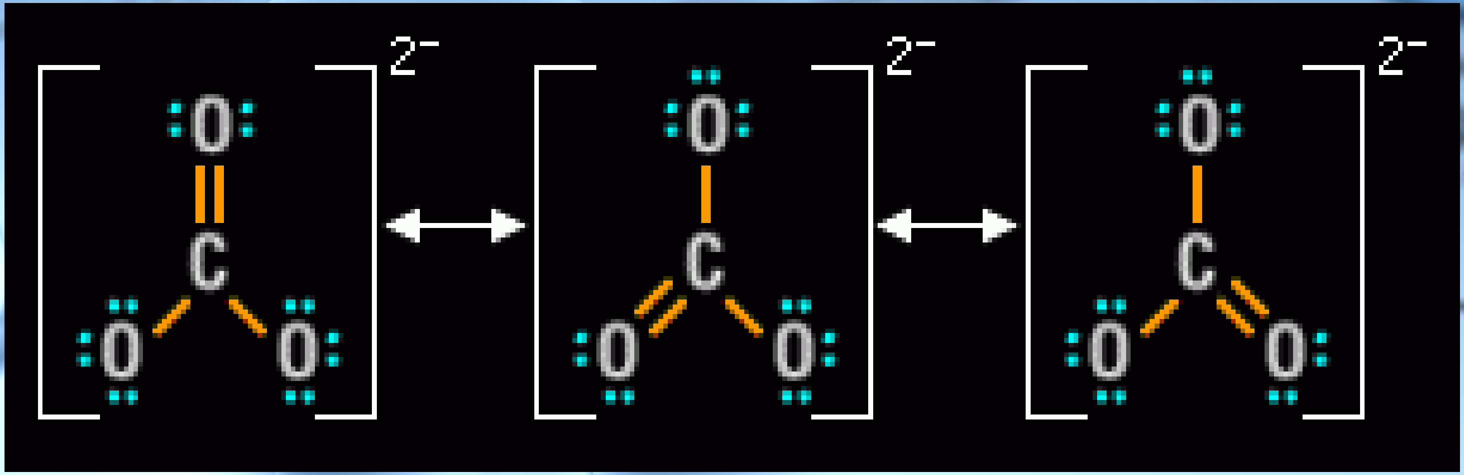
    - **Note**: The total number of valence electrons still add up
  - **Example**: NO_3 ion (23 valence electrons)



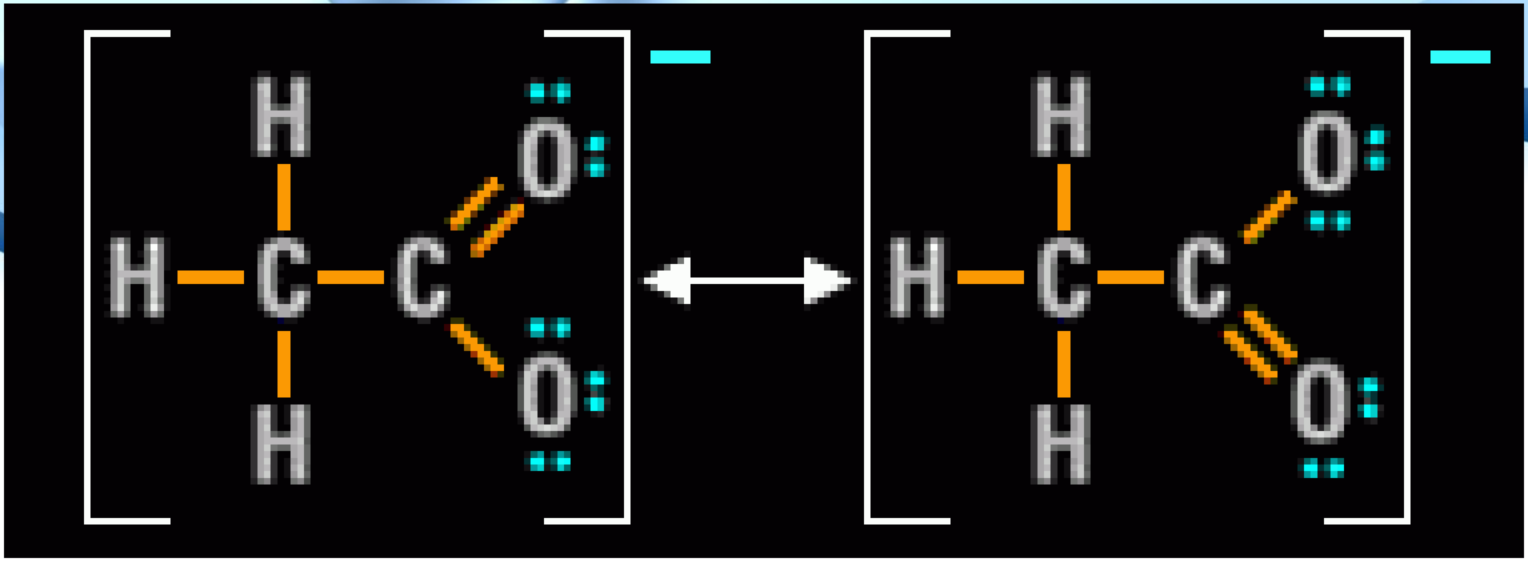
    - **Note**: Ions use brackets [ ] to symbol that they posses more electrons than they should
    - Represented with double-sided arrows

Other resonance examples:

- Carbonate ion (CO_3^{2-})



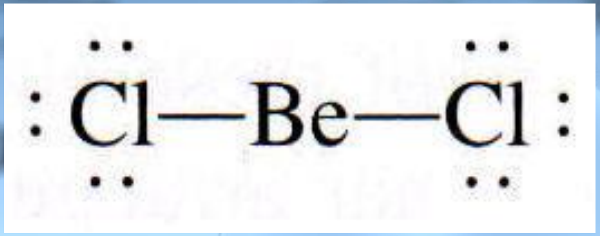
- Acetate ion ($C_2H_30_2^-$)

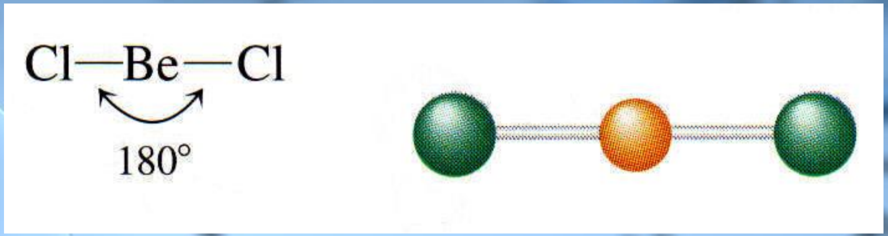


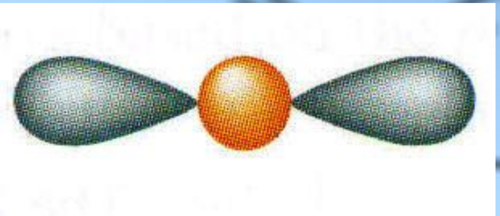
Molecular Structure

- Molecular structure is extremely important in determining chemical properties
  - The valence shell electron-pair repulsion (VSEPR) model is useful in predicting molecular geometry
  - Main postulate of model…the structure around a given atom is determined by minimizing electron-pair repulsions

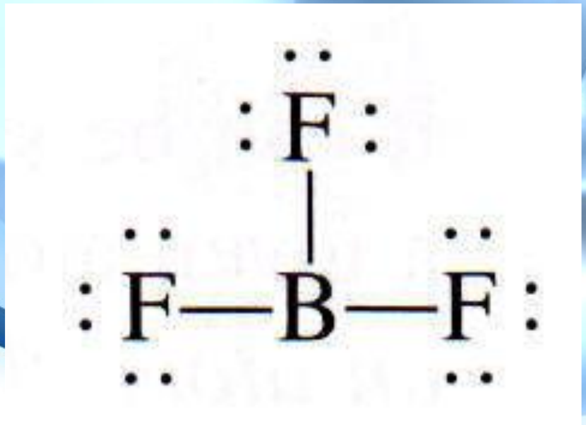
- **Example 1**: $BeCl_2$

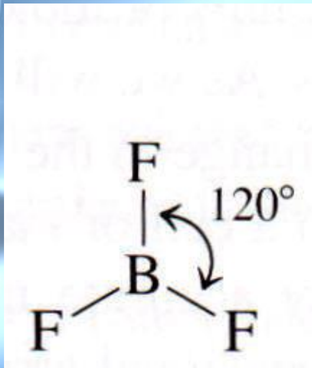


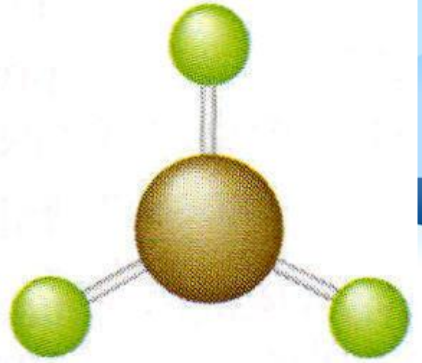


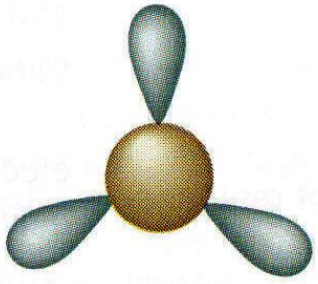


- **Example 2**: BF_3









VSEPR Chart:

X + E	Overall Structure	Forms	Bond Angle(s)
2	Linear	AX_2	180
3	Trigonal Planar	AX_3, AX_2E	120
4	Tetrahedral	AX_4, AX_3E, AX_2E_2	109.5
5	Trigonal bipyramidal	AX_5, AX_4E, AX_3E_2, AX_2E_3	90 / 120
6	Octahedral	AX_5, AX_5E, AX_4E_2	90 / 90

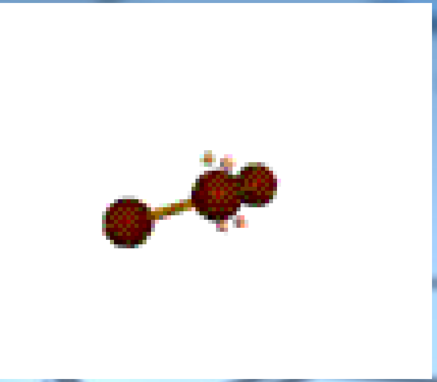
A = central atom

X = atoms bonded to A

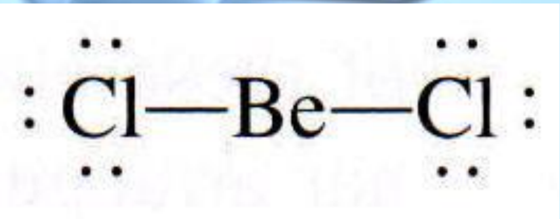
E = nonbonding electron pairs on A

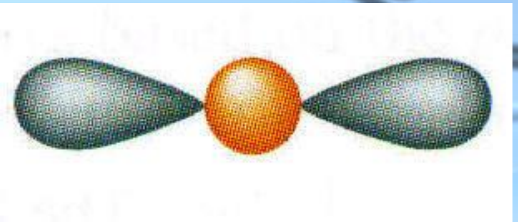
VSEPR Examples:

- Bent (90°)
  - **Example**: H_20
    (not previously mentioned)

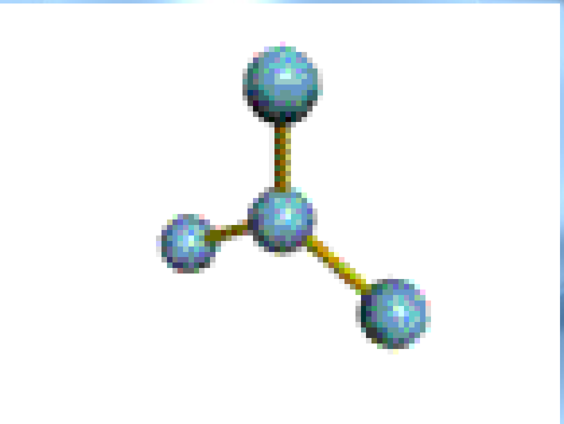


- Linear (180°)
  - **Example**: CO_2

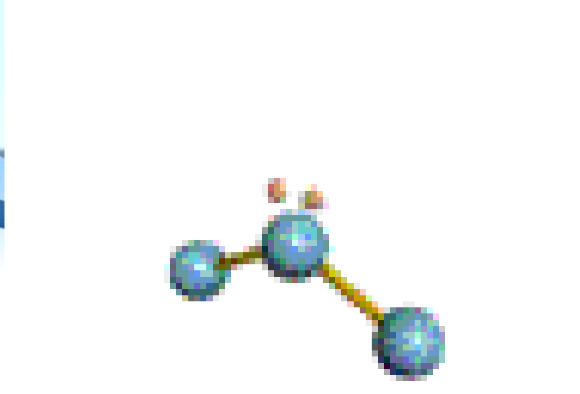




- Trigonal Planar (120°)
  - **Examples**:
    - **BF_3** (AX_3)

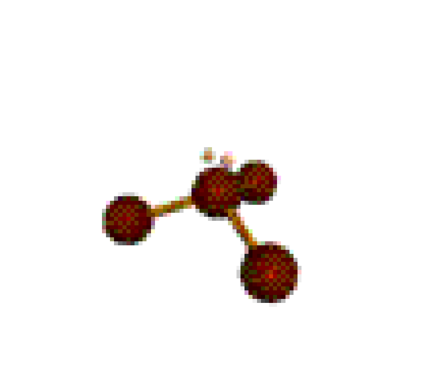


    - **$SnCl_2$** (AX_2E)

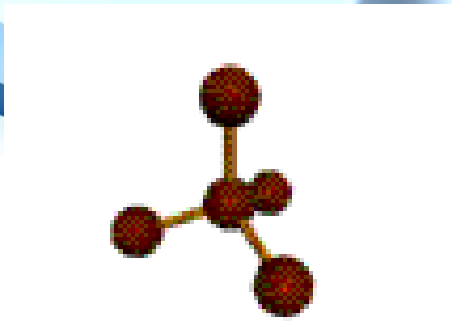


- Tetrahedral (109.5°)
  - **Examples**:
  - **CCl_4** (AX_4)

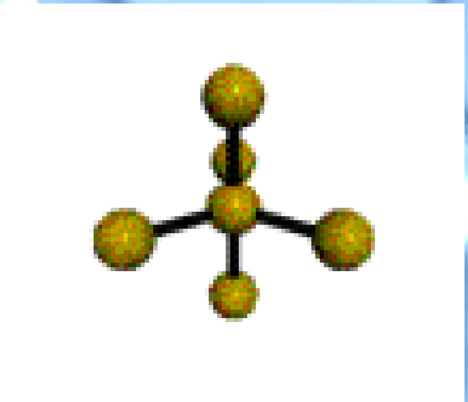
PCl_3 (AX_3E)



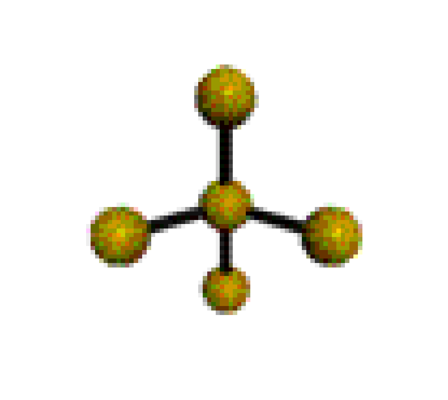
  - Cl_2O (AX_2E_2)



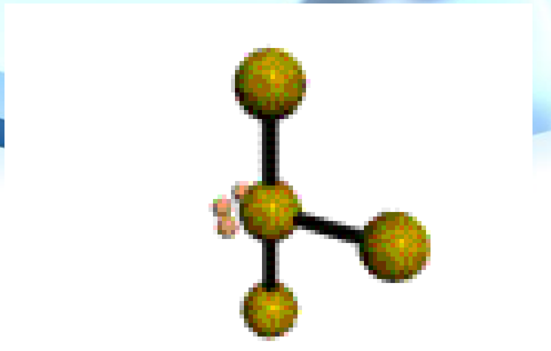
- Trigonal bipyramidal (90° & 120°)
  - **Examples**:
    - **PCl_5** (AX_5)



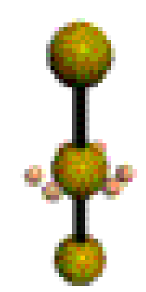
    SF_4 (AX_4E)



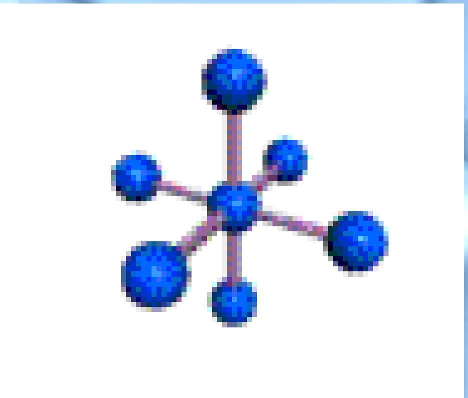
    - **ClF_3** (AX_3E_2)



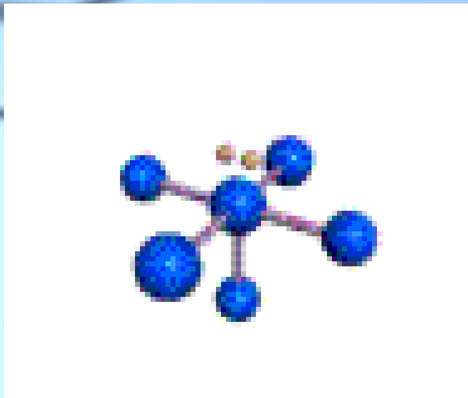
    I_3^- (AX_3E_3)



- Octahedral (90° & 90°)
  - Examples:
    - **SF_6** (AX_6)



BrF_5 (AX_5E)



- **ICl_4^-** (AX_4E_2)

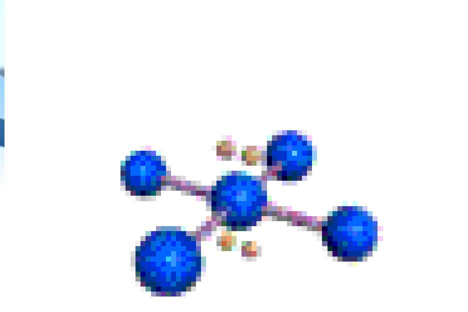
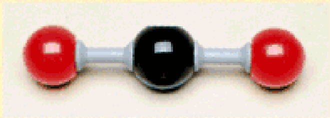
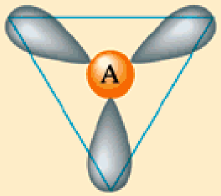
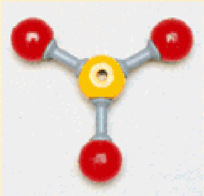
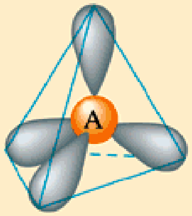
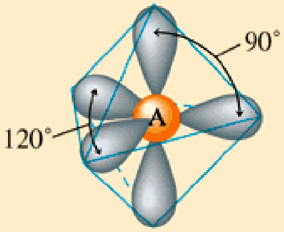
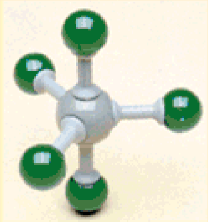


TABLE 8.6 Arrangements of Electron Pairs Around an Atom Yielding Minimum Repulsion

Number of Electron Pairs	Arrangement of Electron Pairs		Example
2	Linear		
3	Trigonal planar		
4	Tetrahedral		
5	Trigonal bipyramidal		
6	Octahedral