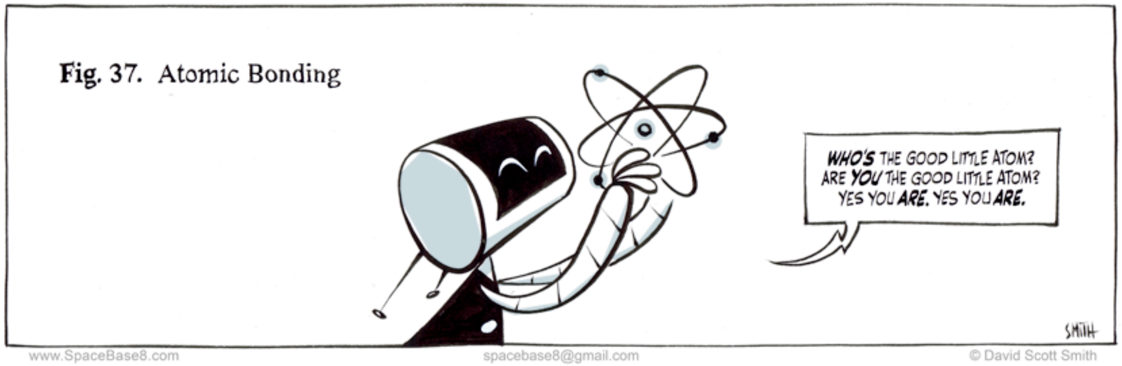
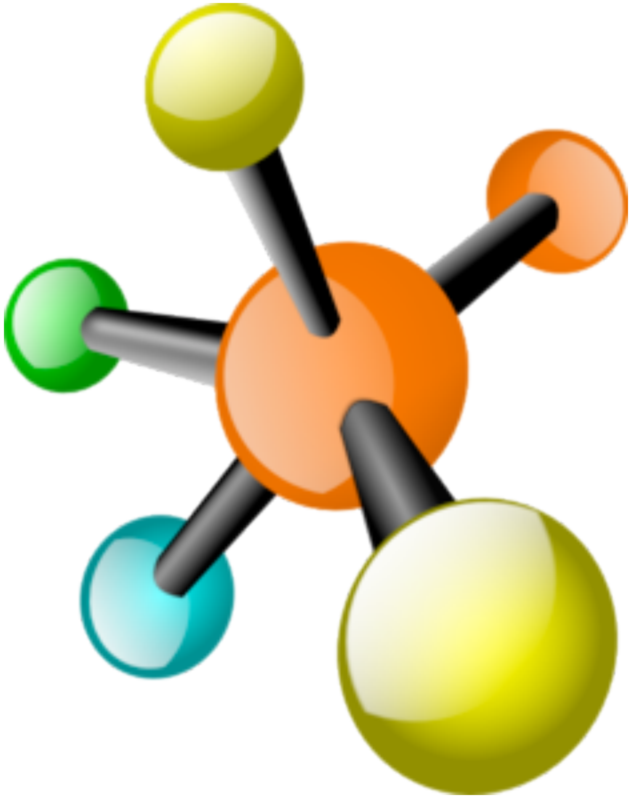
CHEMICAL BONDING

CHAPTER 6 & 7



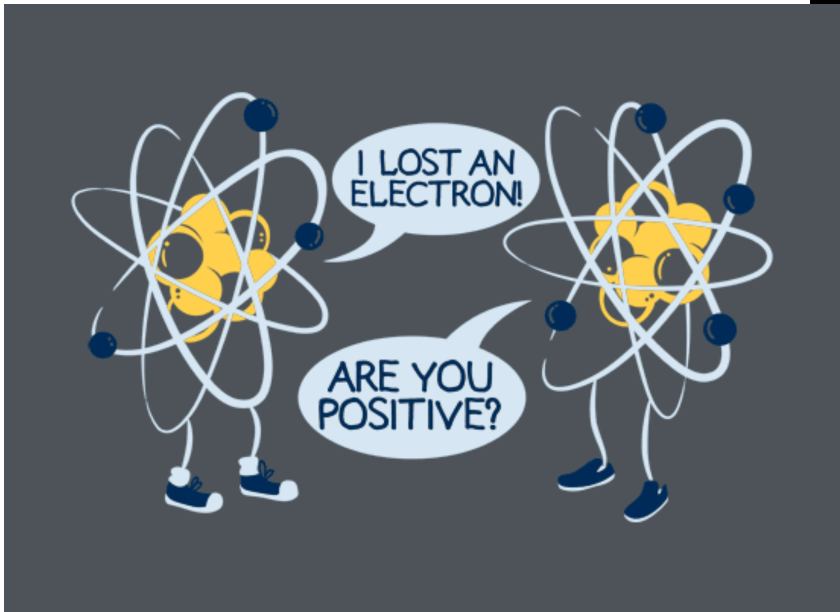


SO….

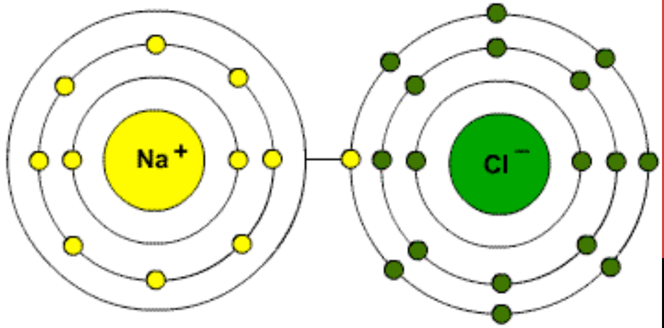
Two atoms are walking down the street. Says one atom to the other, “hey, I think I lost an electron!”

The other says, “Are you sure?”

“Yes, I’m positive!”



WARM UP



Briefly **explain the following:**

<u>1. IONS</u>:

positively or negatively charged atoms.

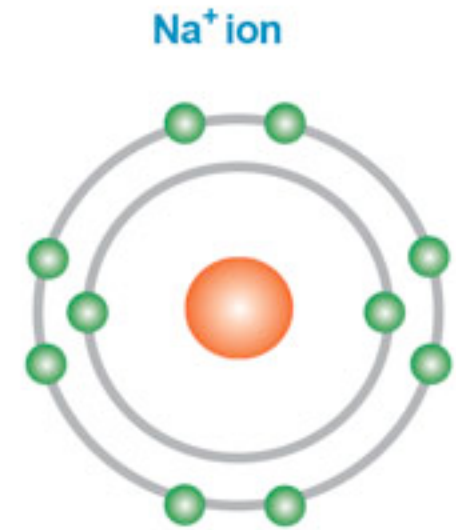
<u>2. Valence</u> e-

- Found in outermost shell
- Determine chemical properties
- Group # = # of valence e-
- e- dot structures show symbol + valence e-

<u>3. Lewis Dot Structure:</u>

- Shows number of valence e-

REVIEW CONTINUED: LEWIS' OCTET RULE



<u>8</u> is the magic #...The GOAL!!

<u>Metals</u> tend to lose their valence e-

Non-metals tend to <u>gain</u> e- or share e-

Goal is to reach a complete Octet

In forming compounds, atoms tend to achieve the e- configuration of a <u>noble gas</u> (that is to say, STABLE!)

THE COOL KIDS…

Every element wants to be like the noble gases.

This will be important this chapter.

FORMING IONS

Cation is a + charged ion; lost e-

Anion is – charged ion; gain e-

Names between atoms and ions are the <u>same</u>.

Properties are VERY different

- Atoms are <u>reactive</u>; ions are <u>stable</u> (like a noble gas)

<u>Oxidation number</u> = charge of the ion

Na's oxidation number is +1

Oxygen's oxidation number is -2

CHEMICAL BONDING

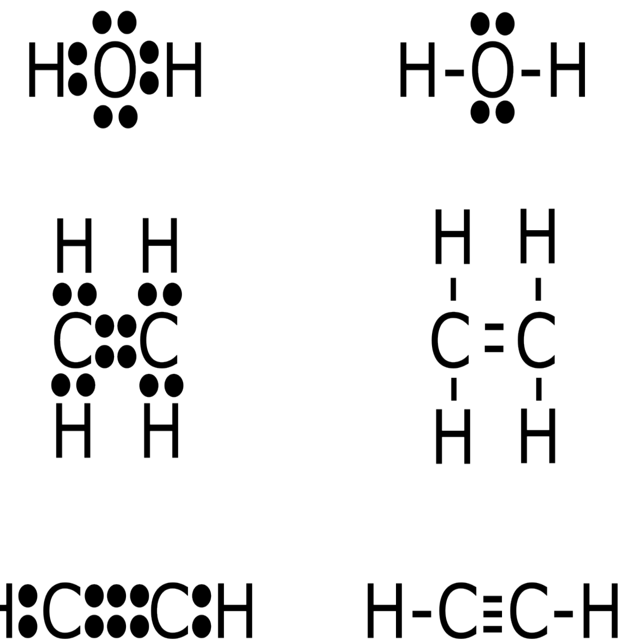
Formed when two or more atoms chemically join together

- **the resulting compound is unique both chemically and physically from it's parent atoms.**
- **This allows for the diversity of the universe!**

Water

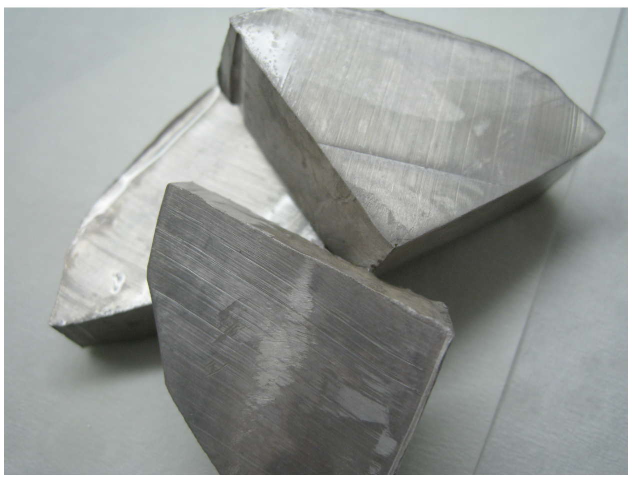
Ethylene

Acetylene



COMPOUNDS VS. ELEMENTS

Once bonded, the compound has VERY <u>different</u> properties than the individual elements.



Na, sodium

+

Cl, chlorine

= NaCl

= Salt

COVALENT VS. IONIC BONDS

Share electrons vs Transfer electrons

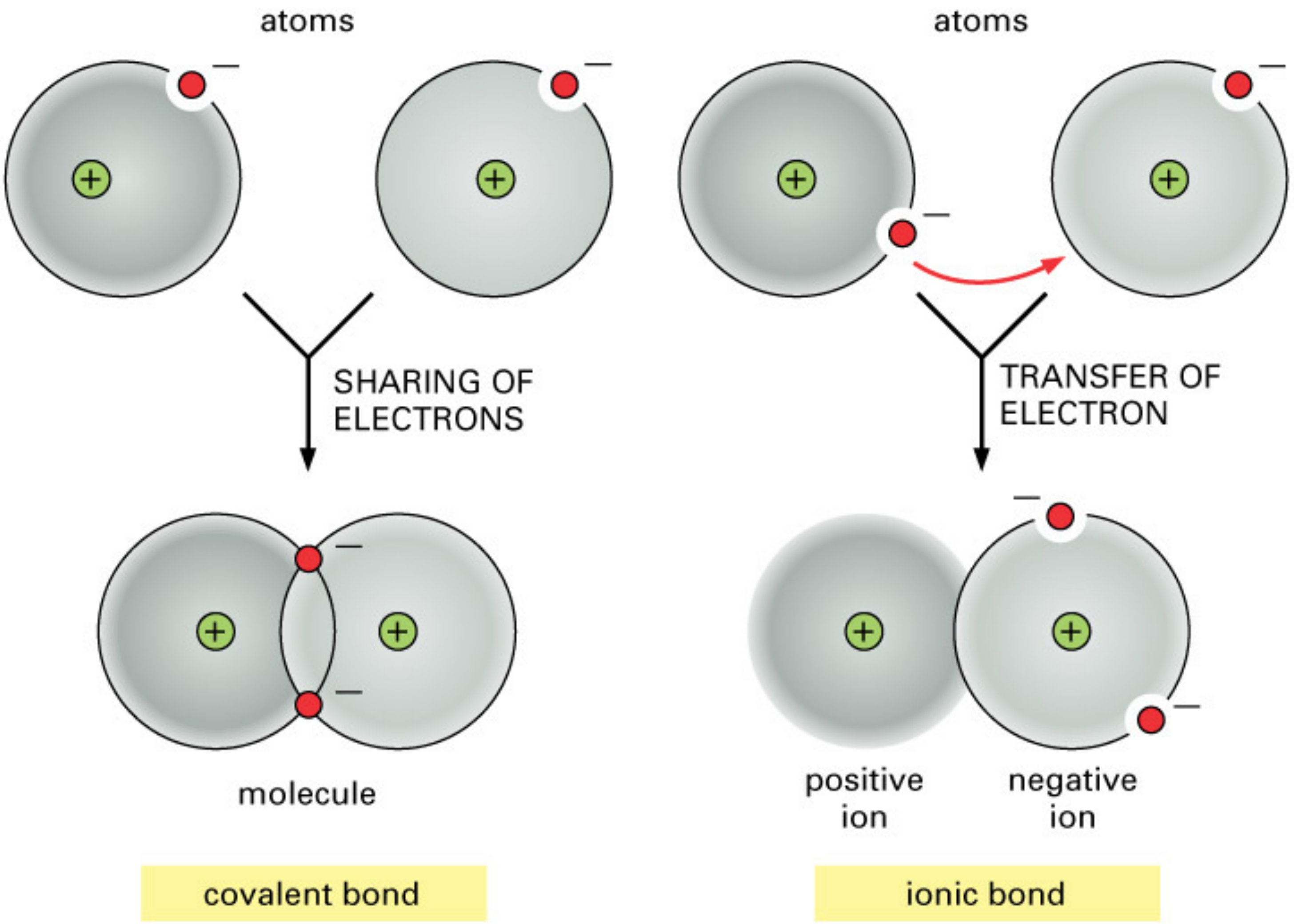
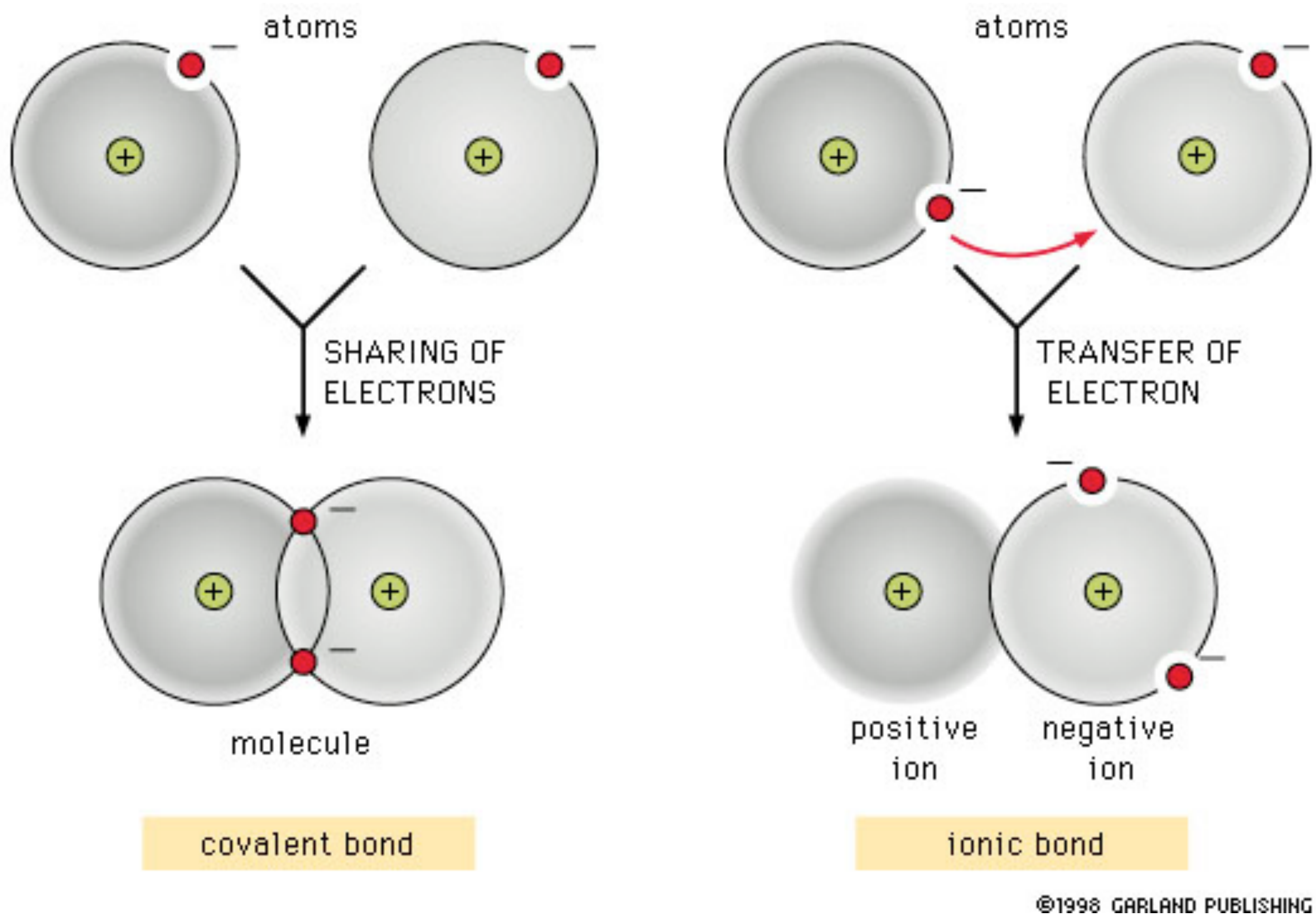


Figure 2.6 Essential Cell Biology, 2/e. (© 2004 Garland Science)

CHEMICAL BONDING

We know that atoms can join together to form molecules.
But what joins the atoms to each other in a molecule?
What is the "glue" that holds the molecule together?

Electrons!



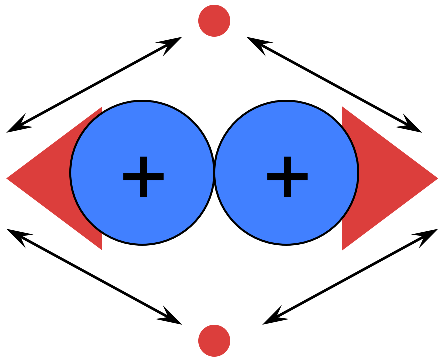
Some substances exist as single atoms… they do not bond.. For example: noble gases

HOW DOES H_2 FORM?

The nuclei repel

But they are attracted to electrons

They share the electrons

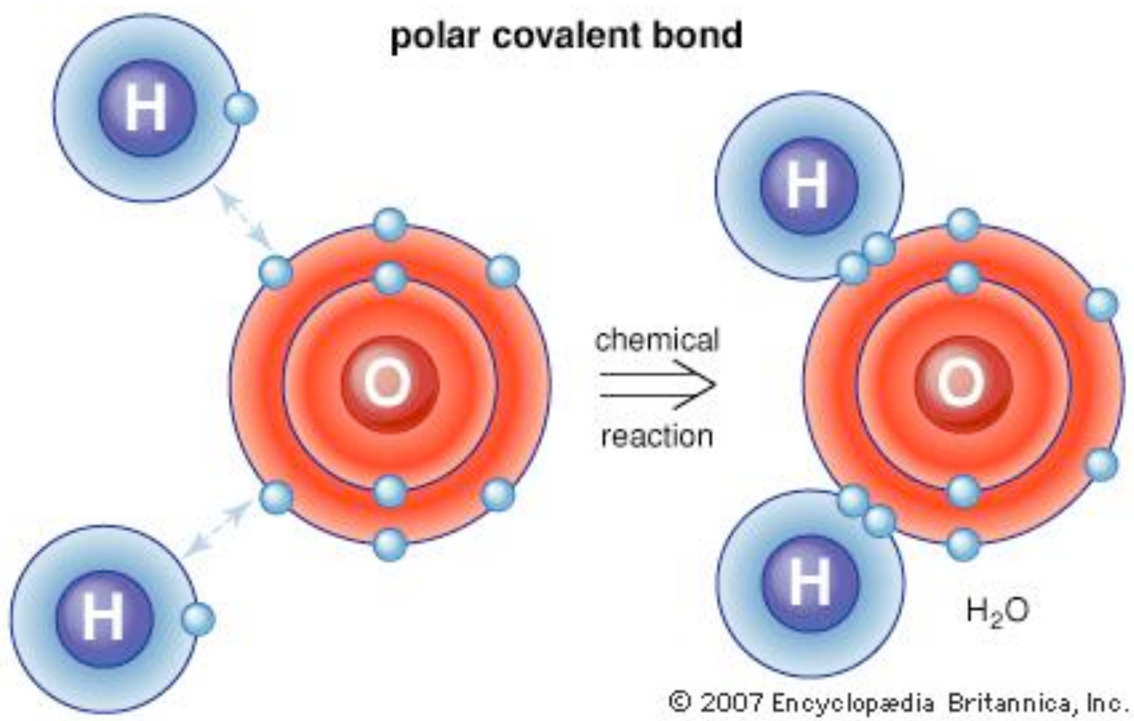


COVALENT BONDS:

a <u>sharing</u> of electrons between two atoms

- Usually between 2 nonmetals

- rather that an attraction of opposite electrical charges, it's more like a "tug-of-war" or fight (vs. a "glue")



Looking at the word:

Co = being with or together

Valere = Latin, meaning very strong

COVALENT BONDS

Nonmetals hold onto their valence electrons.

They can't give away electrons to bond.

…eight valence electrons (stable octet)

Still want noble gas configuration.

Get it by sharing valence electrons with each other.

By sharing both atoms get to count the electrons toward noble gas configuration.

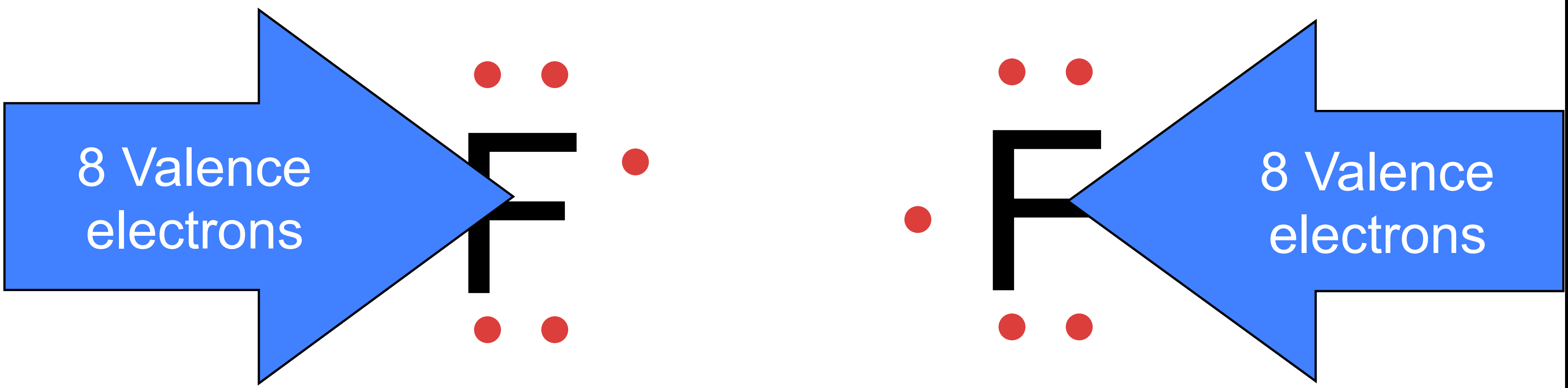
COVALENT BONDING

Fluorine has seven valence electrons

- A second atom also has seven

By sharing electrons

…both end with full orbitals



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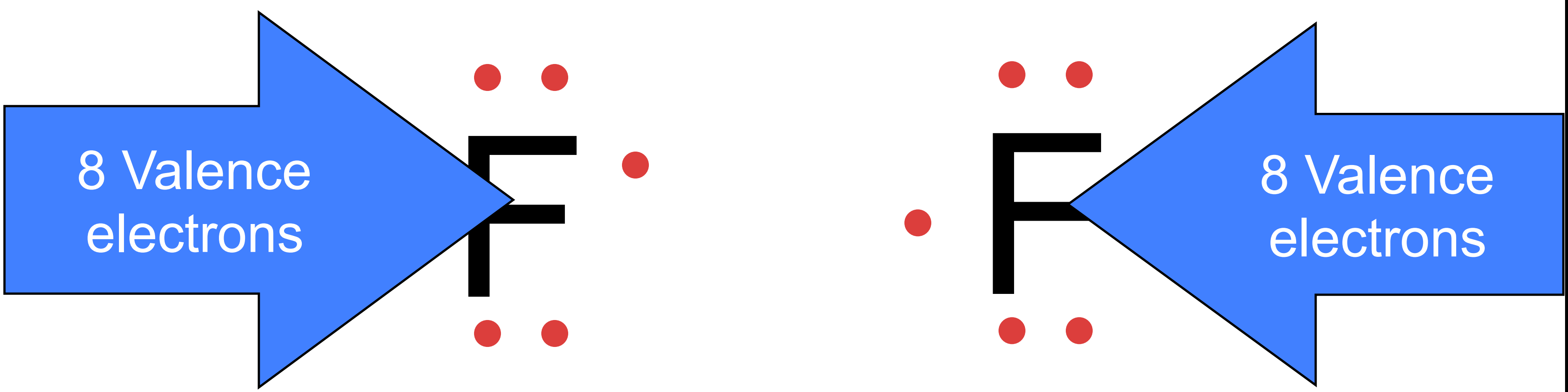


SINGLE COVALENT BOND

A sharing of two valence electrons.

Only nonmetals and Hydrogen.

Different from an ionic bond because they actually form molecules.

Two specific atoms are joined.

In an ionic solid you can't tell which atom the electrons moved from or to.

HOW TO SHOW HOW THEY FORMED

It's like a jigsaw puzzle.

I have to tell you what the final formula is.

You put the pieces together to end up with the right formula.

For example- show how water is formed with covalent bonds.

WATER

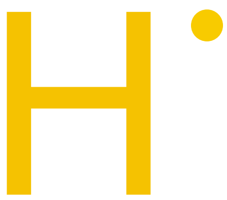
Each hydrogen has 1 valence electron

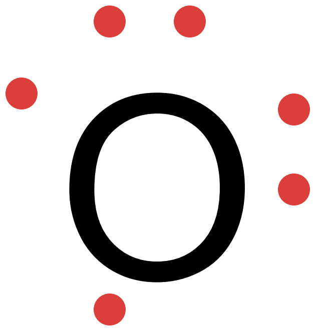
Each hydrogen wants 1 more

The oxygen has 6 valence electrons

The oxygen wants 2 more

They share to make each other happy





WATER

Put the pieces together

The first hydrogen is happy

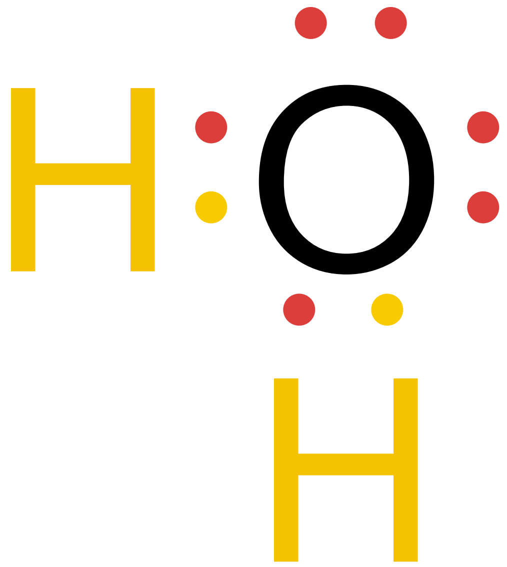
The oxygen still wants one more

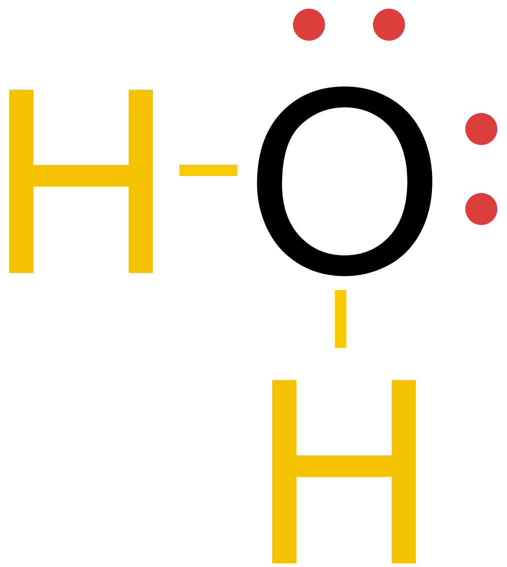
WATER

The second hydrogen attaches

Every atom has full energy levels

A pair of electrons is a single bond





LEWIS STRUCTURES

1) Count up total number of valence electrons
2) Connect all atoms with single bonds

   - "multiple" atoms usually on outside

   - "single" atoms usually in center;

     C **always** in center,

     H **always** on outside.
3) Complete octets on exterior atoms (not H, though)
4) Check

   - valence electrons math with Step 1

   - all atoms (except H) have an octet; if not, try multiple bonds

   - any extra electrons? Put on central atom

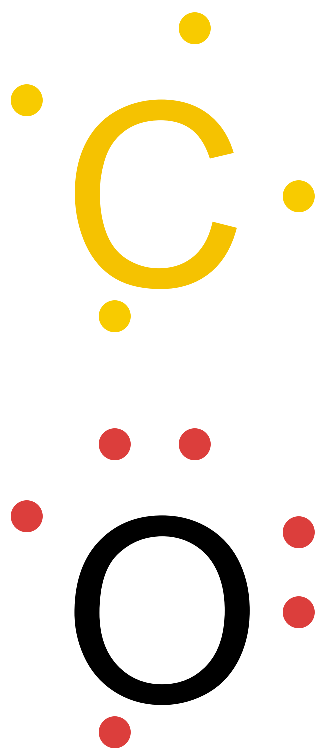
MULTIPLE BONDS

Sometimes atoms share more than one pair of valence electrons.

A double bond is when atoms share two pair (4) of electrons.

A triple bond is when atoms share three pair (6) of electrons.

CARBON DIOXIDE



CO_2 - Carbon is central atom (I have to tell you)

Carbon has 4 valence electrons

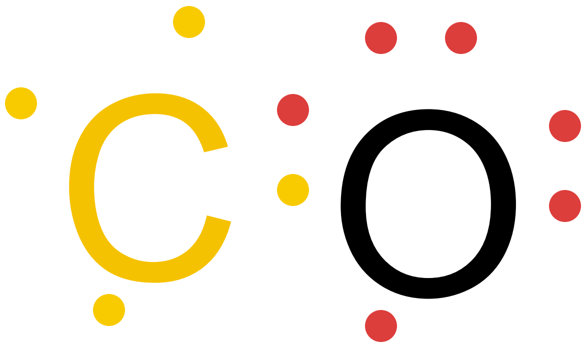
Wants 4 more

Oxygen has 6 valence electrons

Wants 2 more

CARBON DIOXIDE

Attaching 1 oxygen leaves the oxygen 1 short and the carbon 3 short

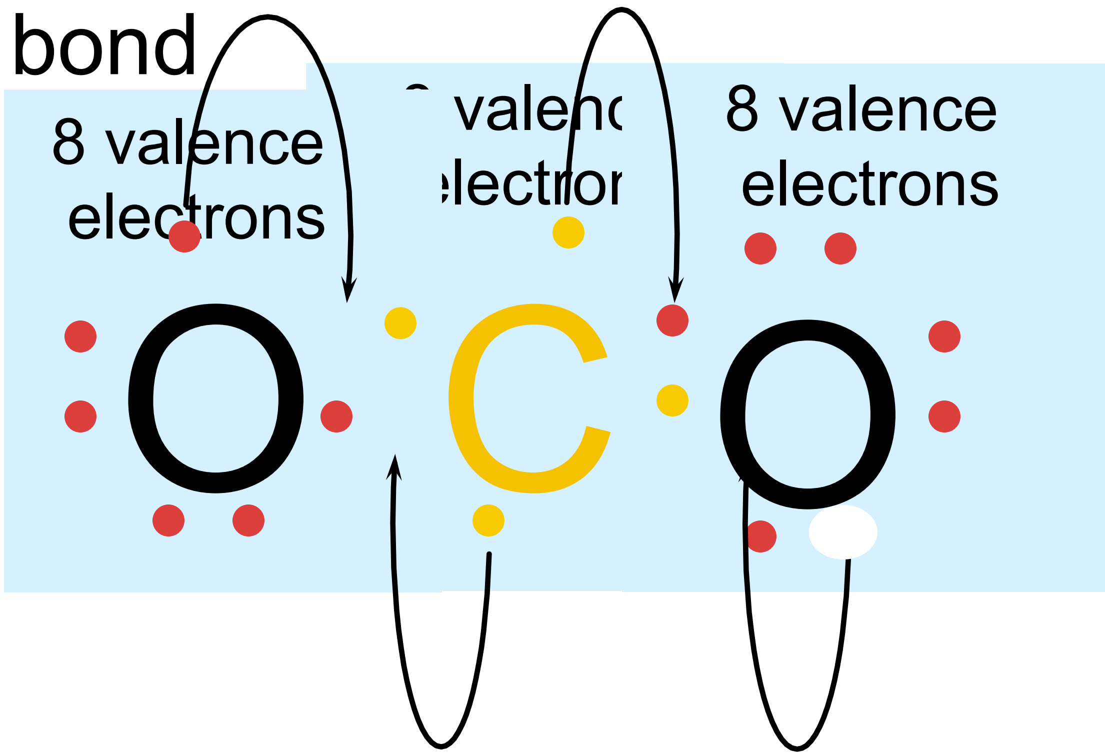


Carbon dioxide

- Attaching the second oxygen leaves both oxygen 1 short and the carbon 2 short

Carbon dioxide

- The only solution is to share more
- Requires two double bonds
- Each atom gets to count all the atoms in the bond



HOW TO DRAW THEM

Add up all the valence electrons.

Count up the total number of electrons to make all atoms happy.

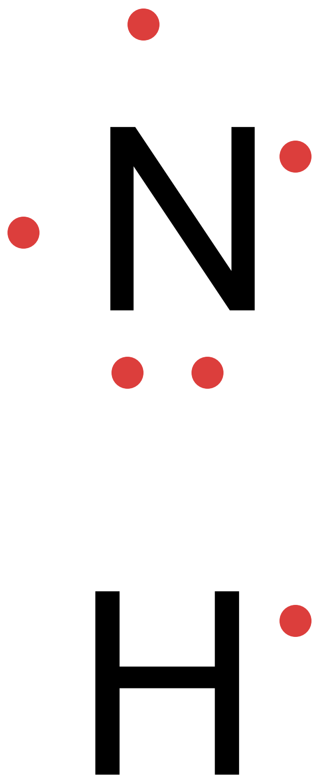
Subtract.

Divide by 2

Tells you how many bonds - draw them.

Fill in the rest of the valence electrons to fill atoms up.

EXAMPLES



NH_3

N - has 5 valence electrons wants 8

H - has 1 valence electrons wants 2

NH_3 has 5+3(1) = 8

NH_3 wants 8+3(2) = 14

(14-8)/2= 3 bonds

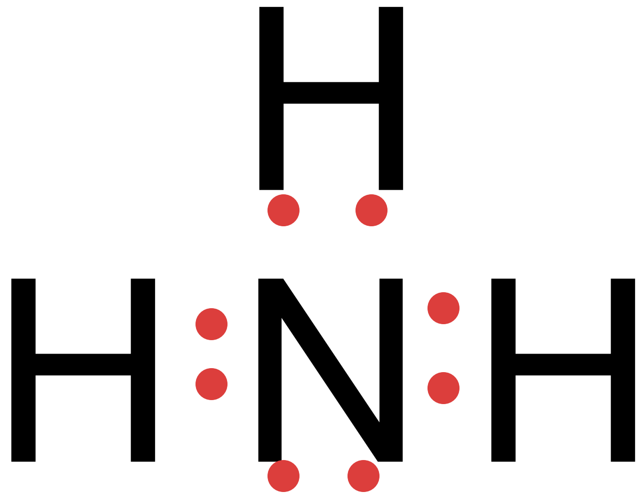
4 atoms with 3 bonds

EXAMPLES

Draw in the bonds

All 8 electrons are accounted for

Everything is full



EXAMPLES

HCN C is central atom

N - has 5 valence electrons wants 8

C - has 4 valence electrons wants 8

H - has 1 valence electrons wants 2

HCN has 5+4+1 = 10

HCN wants 8+8+2 = 18

(18-10)/2= 4 bonds

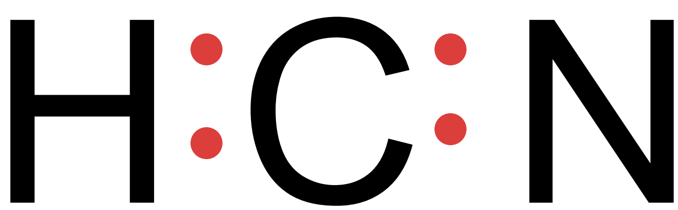
3 atoms with 4 bonds -will require multiple bonds - not to H

HCN

Put in single bonds

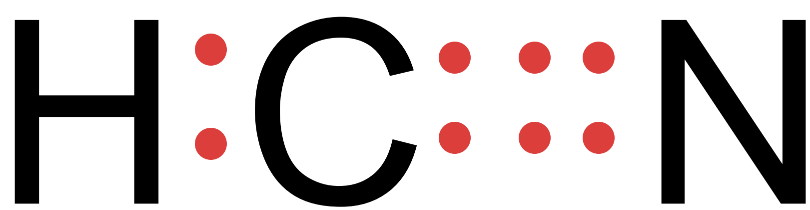
Need 2 more bonds

Must go between C and N



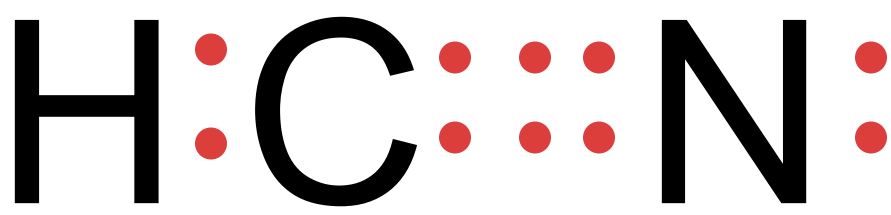
HCN

- Put in single bonds
- Need 2 more bonds
- Must go between C and N
- Uses 8 electrons - 2 more to add



HCN

- Put in single bonds
- Need 2 more bonds
- Must go between C and N
- Uses 8 electrons - 2 more to add
- Must go on N to fill octet

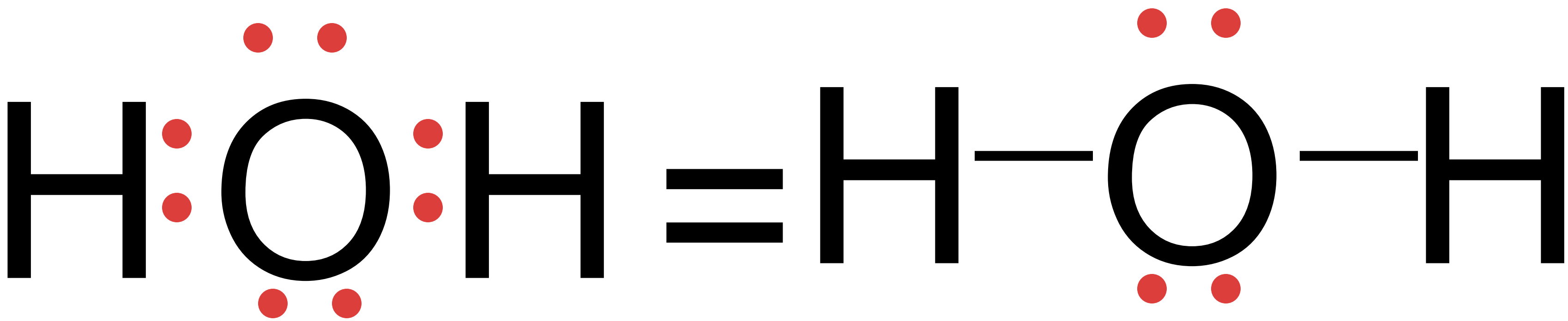


ANOTHER WAY OF INDICATING BONDS

Often use a line to indicate a bond

Called a structural formula

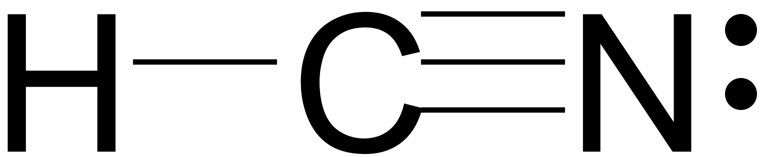
Each line is 2 valence electrons



STRUCTURAL EXAMPLES

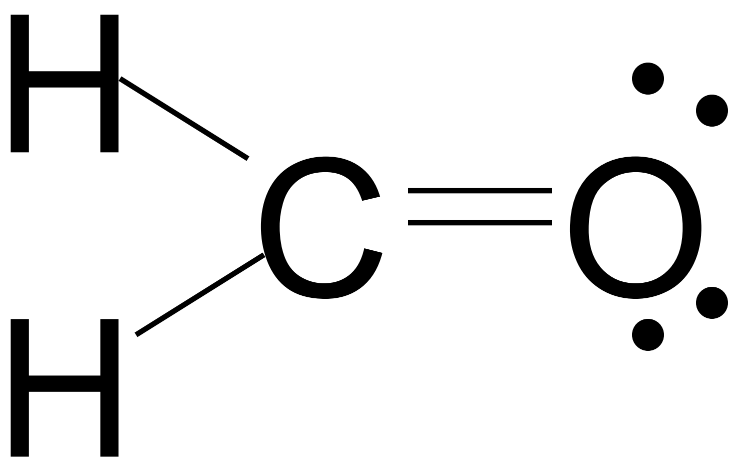
C has 8 electrons because each line is 2 electrons

Ditto for N



Ditto for C here

Ditto for O

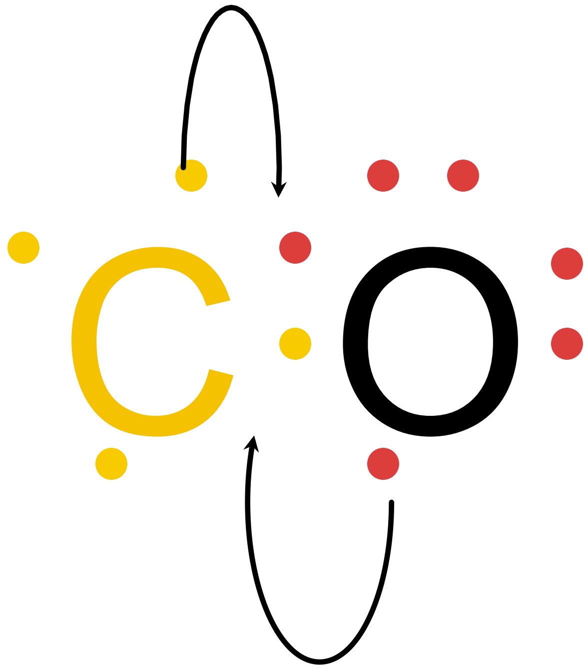


COORDINATE COVALENT BOND

When one atom donates both electrons in a covalent bond.

Carbon monoxide

CO



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- Carbon monoxide
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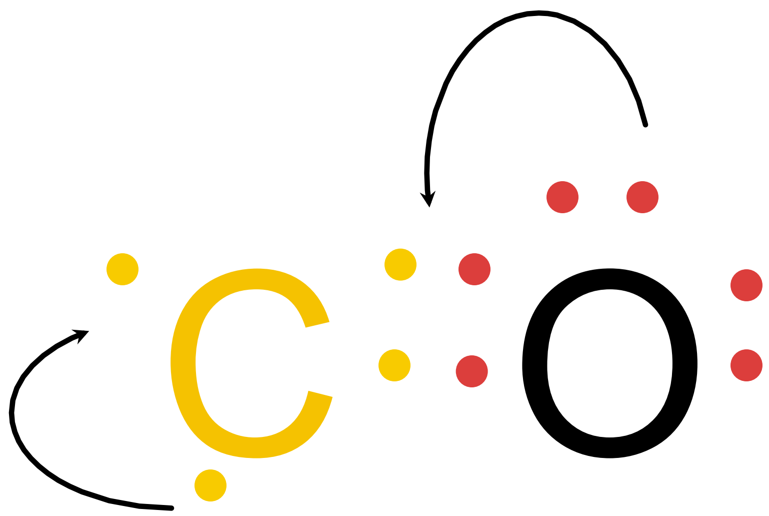

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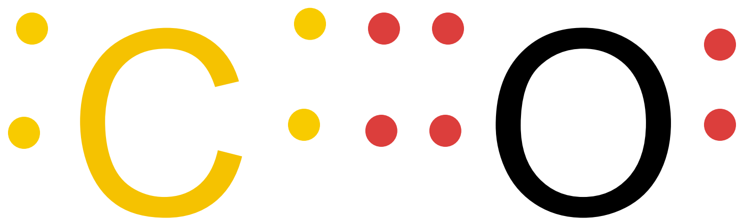


HOW DO WE KNOW IF

Have to draw the diagram and see what happens.

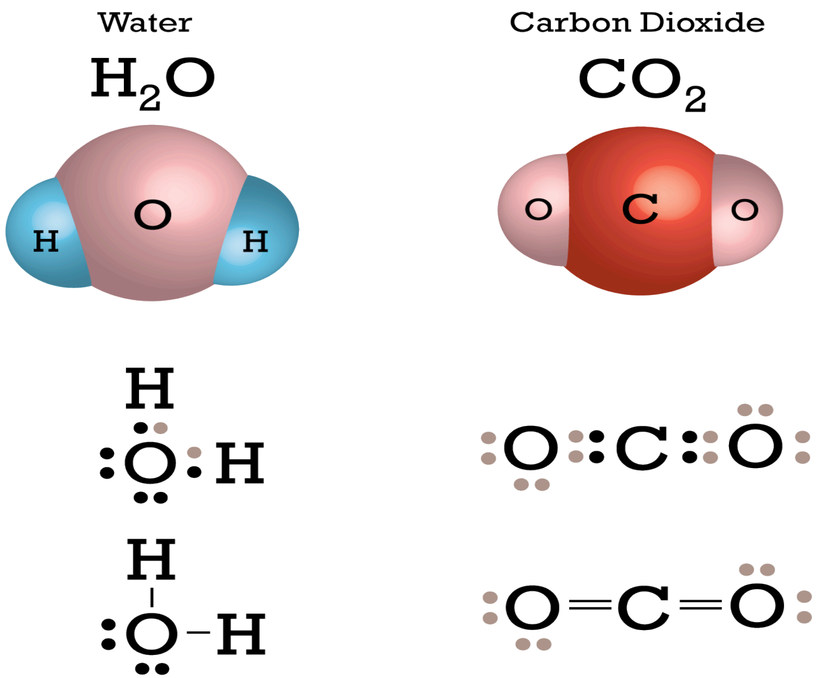
Often happens with polyatomic ions and acids.

COVALENT BONDS (CONTINUED)

So in covalent bonds, there are going to be two electrons that share with one other to form a very strong bond.

For example: water, CO_2

Molecule: smallest unit of a covalent compound is a ex: H_2O, CO_2



Molecular formulas: show how many atoms of each element a molecule contains.

Ex: H_2O

CO_2

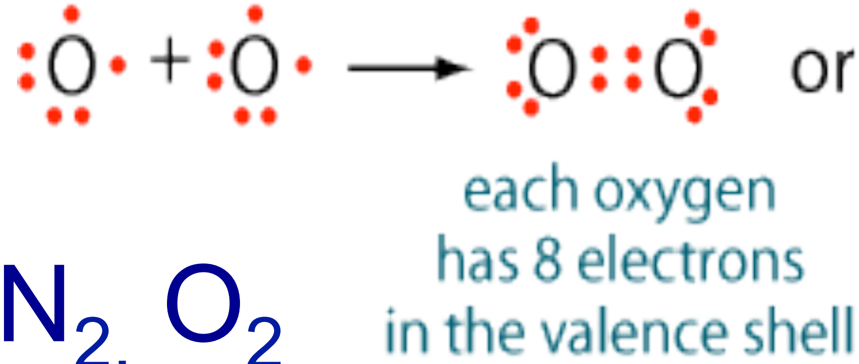
$C_6H_{12}O_6$

Covalent molecules can consist of more than 2 elements.

Not always written in lowest whole # ratio

- For example: C_2H_6

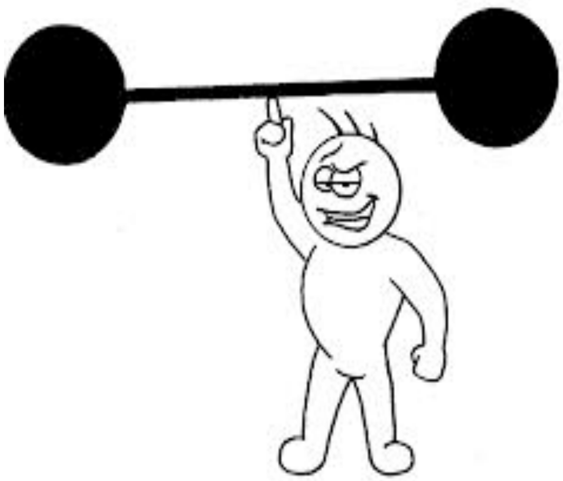
Diatomic molecules: non-metals that exist in nature as molecules covalently bonded to themselves



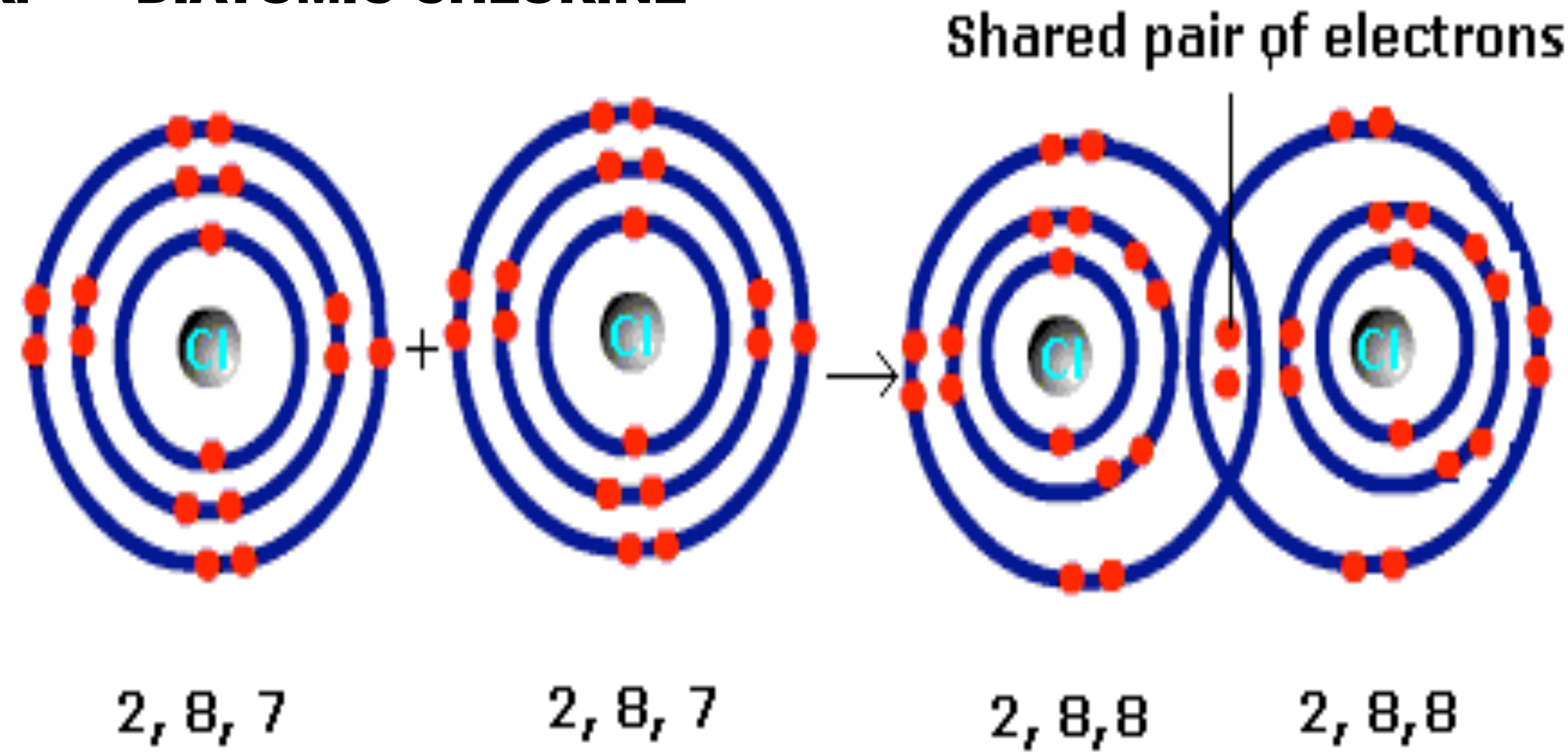
There are 7 key ones, they are:

- H_2, Cl_2, Br_2, F_2, I_2, $N_{2,}$ O_2

Their names are the same as their element name.



EX: DIATOMIC CHLORINE



A molecular formula does <u>NOT</u> tell you about the <u>structure</u> of the molecule. Cl_2 or $C_6H_{12}O_6$

- Will not tell the arrangement of the atoms or who is bonded to whom (especially in the case of 3 or more elements)

WRITING AND NAMING COVALENT COMPOUNDS

Prefixes:

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

- **Prefix must go on both elements UNLESS the 1st one is a mono-**
- **2nd element will end in –ide**
  - CO_2 carbon dioxide (not monocarbon dioxide)
  - P_4S_3 Tetraphosphorus trisulfide

You need not worry about charges or crisscrossing tricks!

WRITING AND NAMING (CONTINUED)

- **Prefix must go on both elements UNLESS the 1st one is a mono-**
- **2nd element will end in –ide**
  - CO_2 carbon dioxide (not monocarbon dioxide)
  - P_4S_3 Tetraphosphorus trisulfide

ex: **CO**

- Carbon monoxide

CF_4

- Carbon tetrafluoride

P_3Br_5

- Triphosphorus pentabromide

SO_3

- Sulfur trioxide

SiO_2

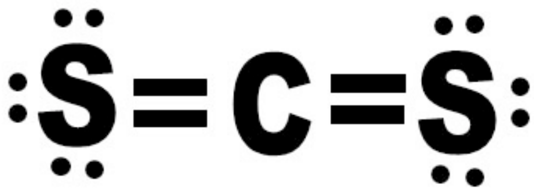
- Silicon dioxide

SF_6

- Sulfur hexafluoride

Generally, elements are listed in the same left-to-right order that they have on the periodic table.

EXAMPLES: WRITE THE FORMULA



1. **Nitrogen triodide**
   - NI_3
2. **Carbon disulfide**
   - CS_2
3. **Phosphorus pentachloride**
   - PCl_5
4. **Diboron hexahydride**
   - B_2H_6

Exceptions

58 140.116 78 195.084 7 14.0067

SOME JUST HAVE SPECIAL NAMES

F_2 = fluorine gas

H_2O = water

$C_{12}H_{22}O_{11}$ = sucrose

H_2O_2 = hydrogen peroxide

NH_3 = ammonia

CH_4 = methane

CH_3OH = methanol

H_2O

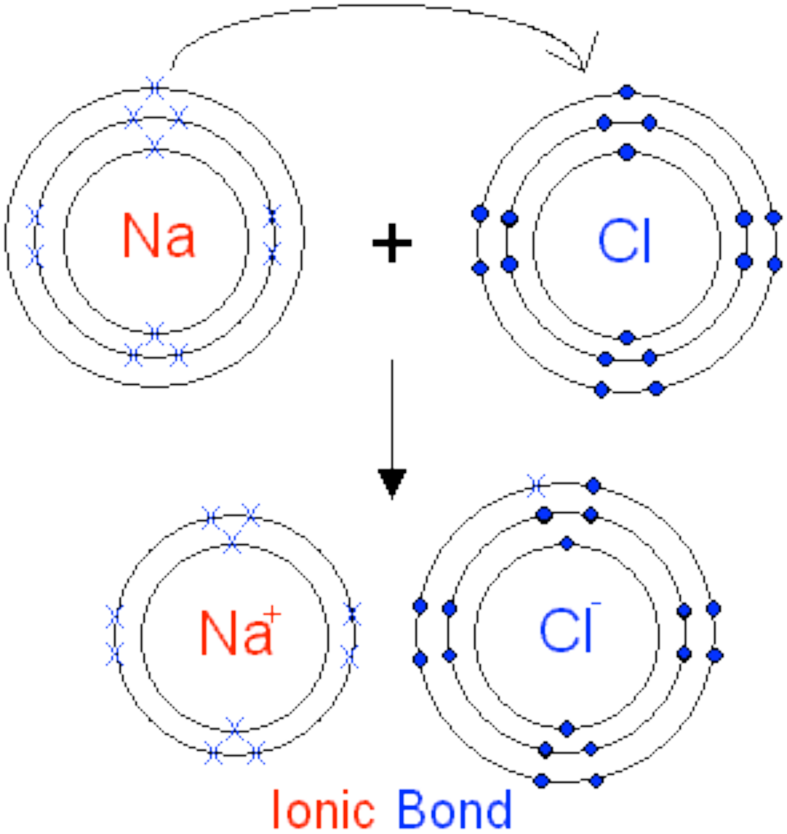
IONIC BONDS:

one or more e- is transferred to another element, causing an attraction between a *<u>metal cation</u>* to a *<u>non-metal anion</u>*.

Once combined the compound is electrically neutral

Charges must add up to **<u>zero</u>**

$Na^{+}\ Cl^{-} = 0$

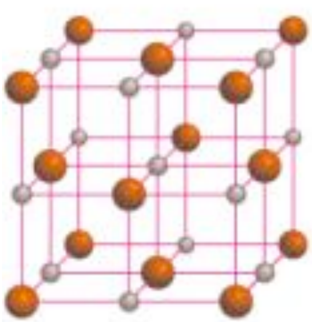
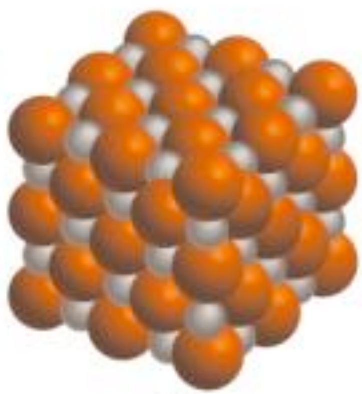


Will the following elements form IONIC COMPOUNDS?? Why or why not??

1. K and I — Yes
2. Na and F — Yes
3. K and Ca — No
4. N and O — No
5. Li and O — Li_2O

PROPERTIES OF IONIC COMPOUNDS

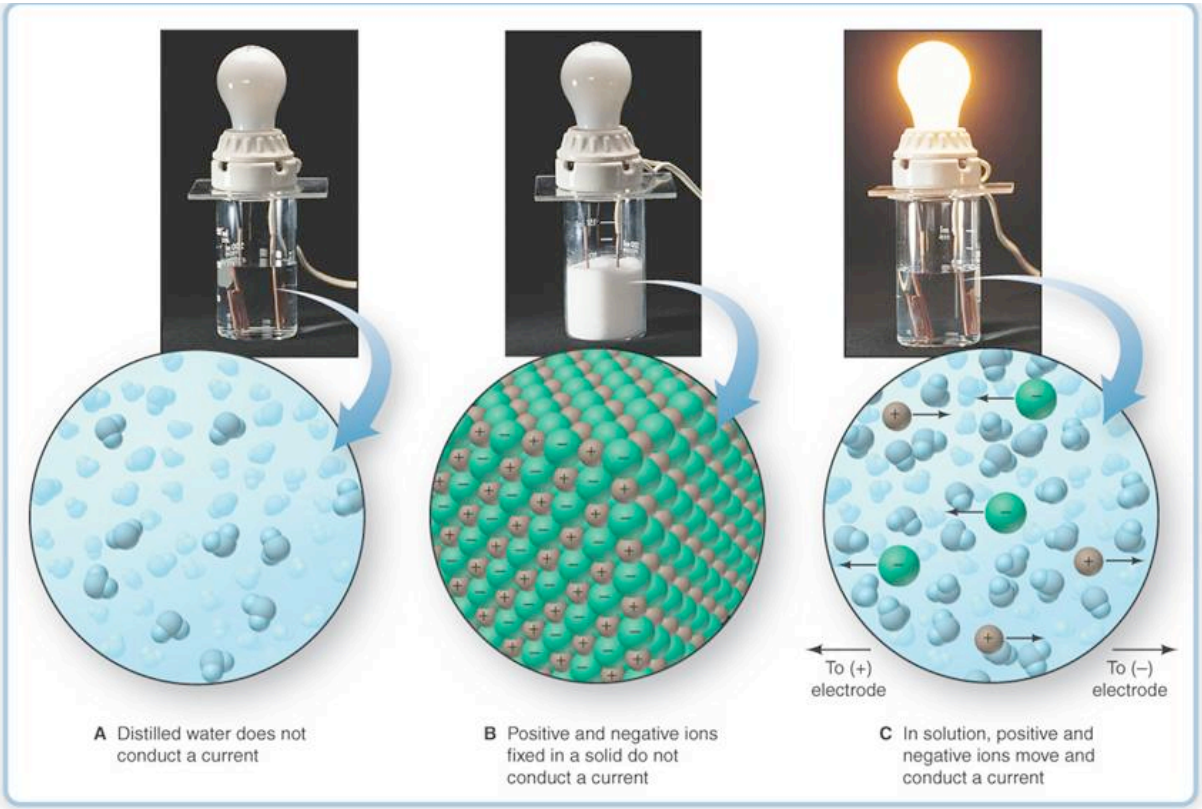
1. **They are crystalline solids at room temperature.**
   - Crystals are any substance with a regular, <u>repeating</u> pattern.
   - Highly organized
   - Hard, rigid

FeS_2

IONIC PROPERTIES CONTINUED…

2. **generally have high melting points.**
3. **can conduct an electric current when dissolved in water.**
4. **Strong:** **Would require lots of energy to break them.**



WRITING AND NAMING IONIC COMPOUNDS

Chemical formulas show the kinds and numbers of atoms in a substance.

Formula: lowest whole-number ratio of ionic compound.

Ex: formula Mg and Cl

a. Write the element w/ is charge (oxidation #)

- Mg^{+2}, Cl^{-}

b. Make sure charges add up to zero!

+2 -1 -1 = 0

c. Write formula using subscripts…need 1 Mg and 2 Cl…

- so $MgCl_2$

NAMING…

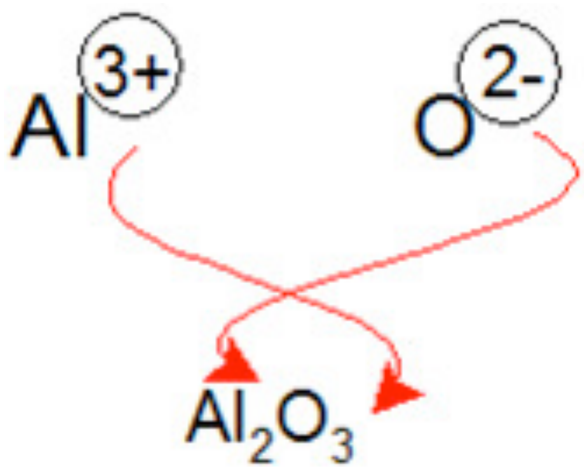
$MgCl_2$

1. Cation names stays the same, listed 1st
2. Anion name 2nd, ends in –ide

Ex: Magnesium Chloride

Criss cross "Trick" for formula writing

Al^{3+} and O^{2-}



PRACTICE:
WRITE THE FORMULA AND NAME THE BINARY COMPOUND

1. **Al with Br**
2. **Ca with O**
3. **Ga with S**
4. **K with Se**
5. **Be with F**
6. **Li with I**

1. $AlBr_3$ Aluminum Bromide
2. CaO Calcium Oxide
3. Ga_2S_3 Gallium Sulfide
4. K_2Se Potassium Selenide

	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 H Hydrogen 1.01																	2 He Helium 4.00
2	3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
3	11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
6	55 Cs Cesium 132.91	56 Ba Barium 137.33	57 La Lanthanum 138.91	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)									

Key

11 — Atomic number
Na — Element symbol
Sodium — Element name
22.99 — Average atomic mass*

58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

* If this number is in parentheses, then it refers to the atomic mass of the most stable isotope.

1. **Al with Br**
2. **Ca with O**
3. **Ga with S**
4. **K with Se**

1. $AlBr_3$ Aluminum Bromide
2. CaO Calcium Oxide
3. Ga_2S_3 Gallium Sulfide
4. K_2Se Potassium Selenide

POLYATOMIC IONS:

composed of more than one type of element but carry a single charge.

Have "special" names…see chart pg 226 for names and charges

Polyatomic ions:

Positive ions					
1+ ion:	Ammonium	NH_4^{1+}	Hydronium	H_3O^+	
Negative ions					
1- ions		2- ions		3- ions	
Acetate	$C_2H_3O_2^{1-}$	Carbonate	CO_3^{2-}	Phosphate	PO_4^{3-}
Chlorate	ClO_3^{1-}	Chromate	CrO_4^{2-}		
Chlorite	ClO_2^{1-}	Dichromate	$Cr_2O_7^{2-}$		
Cyanide	CN^{1-}	Hydrogen Phosphate	HPO_4^{2-}		
Dihydrogen Phosphate	$H_2PO_4^{1-}$	Peroxide	O_2^{2-}		
Hydrogen Carbonate	HCO_3^{1-}	Sulfate	SO_4^{2-}		
Hydrogen Sulfate	HSO_4^{1-}	Sulfite	SO_3^{2-}		
Hydroxide	OH^{1-}	Thiosulfate	$S_2O_3^{2-}$		
Hypochlorite	ClO^{1-}				
Nitrate	NO_3^{1-}				
Nitrite	NO_2^{1-}				
Perchlorate	ClO_4^{1-}				
Permanganate	MnO_4^{1-}				
Thiocyanate	SCN^{1-}				

WRITING FORMULAS WITH POLYATOMIC IONS

Remember:

- **Criss cross rule still applies**
- **You may need to use <u>parenthesis</u>**

Practice

1. Sodium Chlorate
2. Calcium Phosphate
3. $MgCO_3$
4. $Al(OH)_3$

Common Polyatomic Ions			
$C_2H_3O_2^-$	acetate	OH^-	hydroxide
NH_4^+	ammonium	ClO^-	hypochlorite
CO_3^{2-}	carbonate	NO_3^-	nitrate
ClO_3^-	chlorate	NO_2^-	nitrite
ClO_2^-	chlorite	$C_2O_4^{2-}$	oxalate
CrO_4^{2-}	chromate	ClO_4^-	perchlorate
CN^-	cyanide	MnO_4^-	permanganate
$Cr_2O_7^{2-}$	dichromate	PO_4^{3-}	phosphate

Answers:

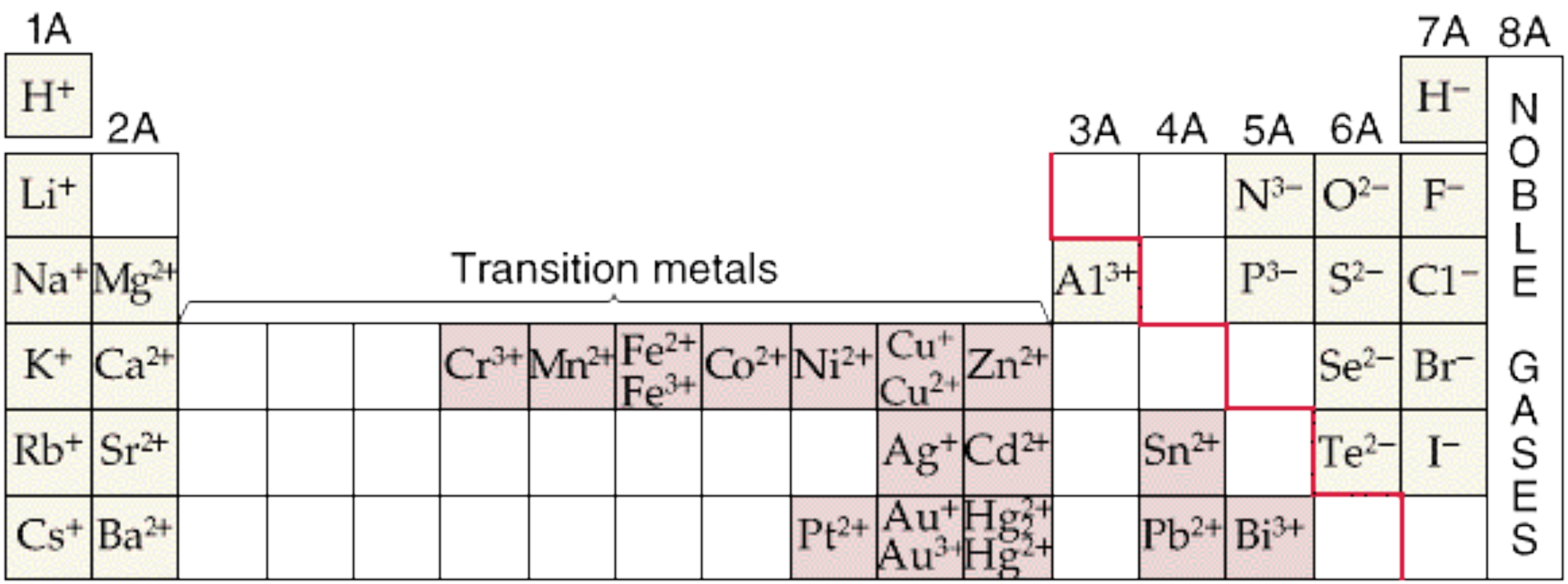
1. $NaClO_3$
2. $Ca_3(PO_4)_2$
3. Magnesium Carbonate
4. Aluminum Hydroxide

IONS OF TRANSITION METALS (B GROUP, D-BLOCK)

Transition metals will form <u>cations</u> and lose e-, but may have more than one possible charge

example:

- **Lead—lead <u>II</u>: Pb^{+2}, lead IV: Pb^{+4}**
- **Cobalt—cobalt II: Co^{+2}, cobalt III: <u>Co^{+3}</u>**



WRITING FORMULAS WITH TRANSITION METALS

Roman numerals used to represent the charge of the cation.

Example:

Iron (II) Oxide

- **FeO**

Lead (IV) Nitride

- **Pb_3N_4**

Practice:

Copper (II) Chloride

- **$CuCl_2$**

Mercury (I) Sulfide

- **Hg_2S**

When the name is said, the number is said as well.

example: Iron (II) Oxide is read as "Iron Two Oxide"

CrO

- **Chromium (II) Oxide**

Cr_2O_3

- **Chromium (III) Oxide**

All of these would be IONIC compounds!! WHY??

Period	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 **H** Hydrogen 1.01																	2 **He** Helium 4.00
2	3 **Li** Lithium 6.94	4 **Be** Beryllium 9.01											5 **B** Boron 10.81	6 **C** Carbon 12.01	7 **N** Nitrogen 14.01	8 **O** Oxygen 16.00	9 **F** Fluorine 19.00	10 **Ne** Neon 20.18
3	11 **Na** Sodium 22.99	12 **Mg** Magnesium 24.31											13 **Al** Aluminum 26.98	14 **Si** Silicon 28.09	15 **P** Phosphorus 30.97	16 **S** Sulfur 32.07	17 **Cl** Chlorine 35.45	18 **Ar** Argon 39.95
4	19 **K** Potassium 39.10	20 **Ca** Calcium 40.08	21 **Sc** Scandium 44.96	22 **Ti** Titanium 47.87	23 **V** Vanadium 50.94	24 **Cr** Chromium 52.00	25 **Mn** Manganese 54.94	26 **Fe** Iron 55.85	27 **Co** Cobalt 58.93	28 **Ni** Nickel 58.69	29 **Cu** Copper 63.55	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.72	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92	34 **Se** Selenium 78.96	35 **Br** Bromine 79.90	36 **Kr** Krypton 83.80
5	37 **Rb** Rubidium 85.47	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.91	40 **Zr** Zirconium 91.22	41 **Nb** Niobium 92.91	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.91	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.87	48 **Cd** Cadmium 112.41	49 **In** Indium 114.82	50 **Sn** Tin 118.71	51 **Sb** Antimony 121.76	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90	54 **Xe** Xenon 131.29
6	55 **Cs** Cesium 132.91	56 **Ba** Barium 137.33	57 **La** Lanthanum 138.91	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.95	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.21	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.22	78 **Pt** Platinum 195.08	79 **Au** Gold 196.97	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.38	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
7	87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (266)	107 **Bh** Bohrium (264)	108 **Hs** Hassium (269)	109 **Mt** Meitnerium (268)									

58 **Ce** Cerium 140.12	59 **Pr** Praseodymium 140.91	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.96	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.93	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.97
90 **Th** Thorium 232.04	91 **Pa** Protactinium 231.04	92 **U** Uranium 238.03	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Key

11 — Atomic number
Na — Element symbol
Sodium — Element name
22.99 — Average atomic mass*

* If this number is in parentheses, then it refers to the atomic mass of the most stable isotope.

CrO

- **Chromium (II) Oxide**

Cr_2O_3

- **Chromium (III) Oxide**

Warm Up:

1. Name the following:

a. LiCl

b. K_3PO_4

c. SnF_2

2. Write the formula:

a. Magnesium Chloride

b. Sodium Nitrite

c. Iron (III) Oxide

Key: 11 — Atomic number; Na — Element symbol; Sodium — Element name; 22.99 — Average atomic mass*

	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 H Hydrogen 1.01																	2 He Helium 4.00
2	3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
3	11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
6	55 Cs Cesium 132.91	56 Ba Barium 137.33	57 La Lanthanum 138.91	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)									

SUMMARY OF NAMING

- Formula must balance our to a charge of 0.
- Cation first, anion 2nd, ending in *ide*
- If polyatomic, use name/formula from chart on pg 226, use parenthesis as needed
- If transition metal, use roman numeral to show charge

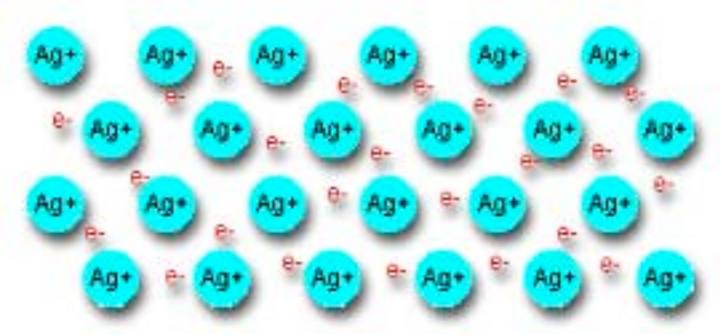
Ex:

$MgCl_2$ = Magnesium Chloride

$Ca(NO_2)_2$ = Sodium Nitrite

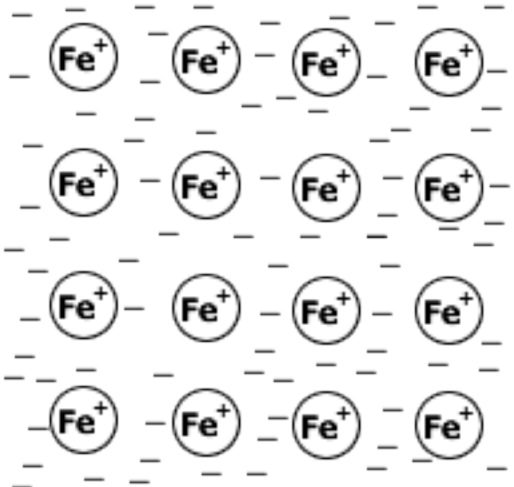
$SnFl_2$ = Tin(II) Fluoride

METALLIC BONDS



Can 2 metals "bond"?

- Not really
- They become a "sea of electrons"
- Attraction between the sea of e- lost by metals and positive cation that they form, which "hold" it together



PROPERTIES OF METALS (REVIEW)

High Melting points

High boiling points

Malleable

Ductile

Durable

Conduct heat

Conduct electricity

Hard and Strong

- The more valence e-, the greater the hardness
- Alkali metals are soft

ALLOYS:

<u>mixtures</u> of 2 or more elements, at least one of which is a metal.

- Most metals are not used in <u>pure</u> form
- Alloy properties are often <u>superior</u>
  - Increased hardess, durability, easier to work with, corrosion resistant

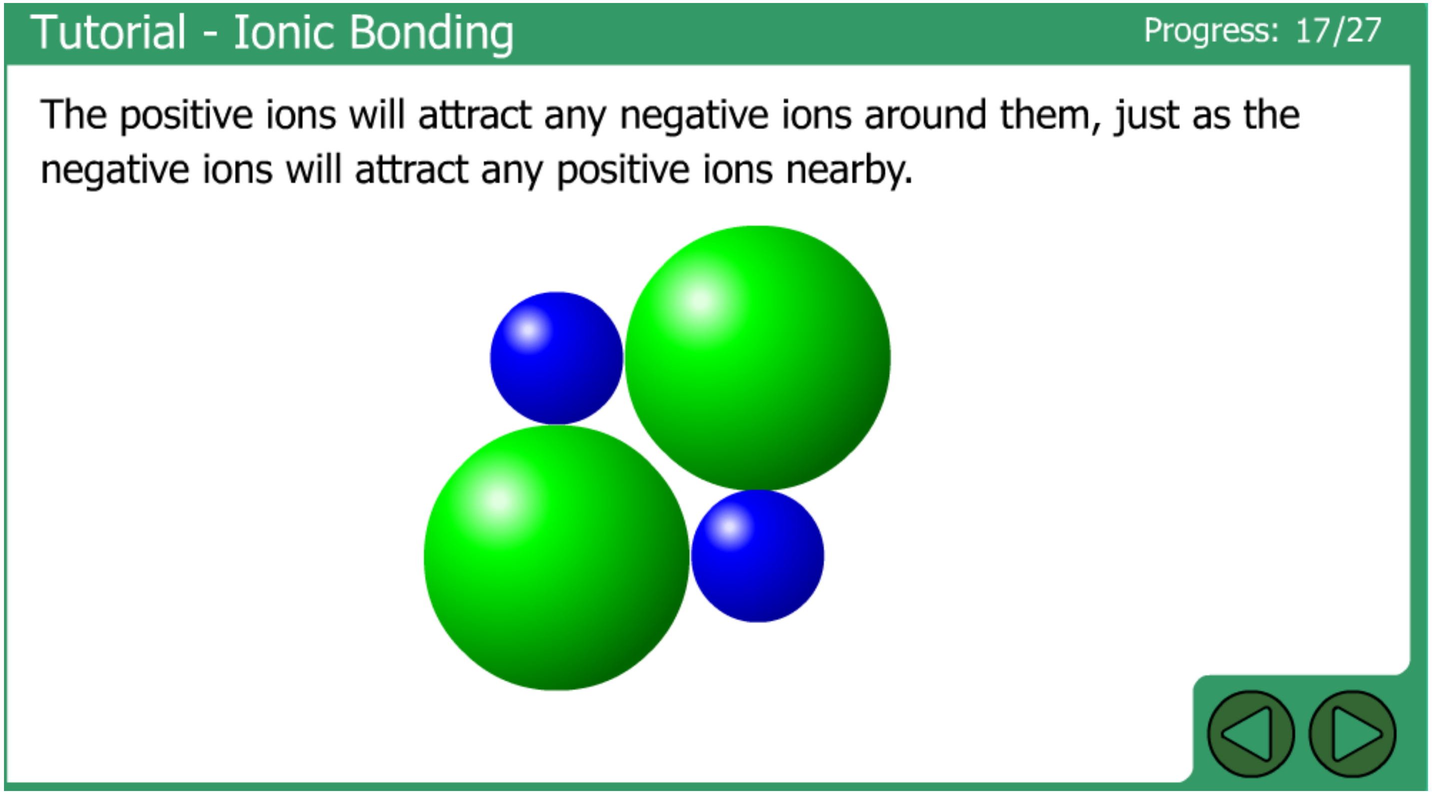
Examples:

- <u>Brass</u>—Cu + Zn
- Sterling silver (Ag + Cu), bronze (Cu + Sn)
- <u>Steel</u>—iron + a whole lot of other stuff
  - <u>Ie </u>carbon + boron + chromium + manganese + molybdenum + nickel + tungsten + vanadium

STILL CONFUSED?

ionic bonding and shapes: this is a great online tutorial about ionic bonding

http://www.pbslearningmedia.org/resource/lsps07.sci.phys.matter.ionicbonding/ionic-bonding/



CAN YOU NAMES THESE…

BeC_2O_4

- Beryllium Oxalate

K_3PO_4

- Potassium Phosphate

$Pb_2 (SO_3)_4$

- Lead (IV) Sulfite

$Cu(MnO_4)_2$

- Copper (II) Permanganate

LiCN

- Lithium Cyanide

$NH_4C_2H_3O_2$

- Ammonium Acetate

Since all of these are made of a $\underline{+}$ cation with a $\underline{-}$ polyatomic ion,

- these are all **IONIC** compounds.

Polyatomic ions:

Positive ions					
1+ ion:	Ammonium	NH_4^{1+}	Hydronium	H_3O^+	
Negative ions					
1- ions		2- ions		3- ions	
Acetate	$C_2H_3O_2^{1-}$	Carbonate	CO_3^{2-}	Phosphate	PO_4^{3-}
Chlorate	ClO_3^{1-}	Chromate	CrO_4^{2-}		
Chlorite	ClO_2^{1-}	Dichromate	$Cr_2O_7^{2-}$		
Cyanide	CN^{1-}	Hydrogen Phosphate	HPO_4^{2-}		
Dihydrogen Phosphate	$H_2PO_4^{1-}$	Peroxide	O_2^{2-}		
Hydrogen Carbonate	HCO_3^{1-}	Sulfate	SO_4^{2-}		
Hydrogen Sulfate	HSO_4^{1-}	Sulfite	SO_3^{2-}		
Hydroxide	OH^{1-}	Thiosulfate	$S_2O_3^{2-}$		
Hypochlorite	ClO^{1-}				
Nitrate	NO_3^{1-}				
Nitrite	NO_2^{1-}				
Perchlorate	ClO_4^{1-}				
Permanganate	MnO_4^{1-}				
Thiocyanate	SCN^{1-}				

Ionic Bonding Activity

1. What is a ionic bond?
2. Why do elements bond?
3. What are some types of bond other than ionic?

The goal of all Chemical Bonds:
Elements bond to have a full outer shell like noble gases.

ACIDS: MORE EXCEPTIONS

Acids are named differently: table on pg 230

TABLE 5 Common Binary Acids and Oxyacids

HF	hydrofluoric acid	HNO_2	nitrous acid
HCl	hydrochloric acid	HNO_3	nitric acid
HBr	hydrobromic acid	H_2SO_3	sulfurous acid
HI	hydriodic acid	H_2SO_4	sulfuric acid
H_3PO_4	phosphoric acid	CH_3COOH	acetic acid
		HClO	hypochlorous acid
		$HClO_2$	chlorous acid
		$HClO_3$	chloric acid
		$HClO_4$	perchloric acid
		H_2CO_3	carbonic acid

NATURE OF COVALENT BONDING

Octet rule STILL applies for covalent bonding.

- e- will be shared to total 8 around the central atom

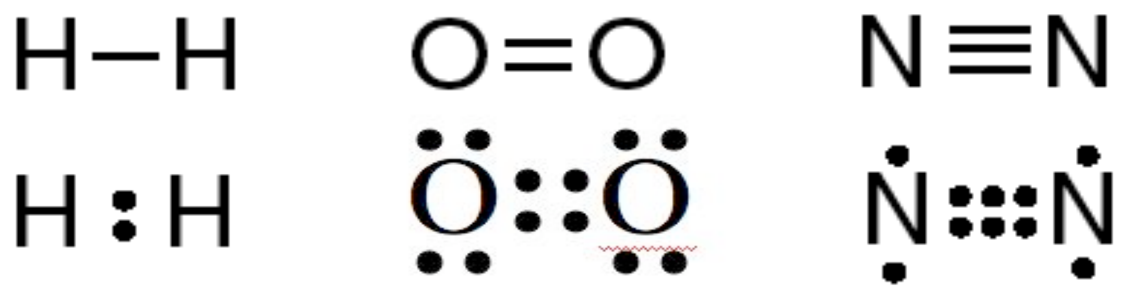
Can form multiple bonds between the same elements to get to 8 valence:

Types of covalent bonds:

Single bonds: when a single pair of e- is shared.

Double Bond: 2 pairs of e- are shared

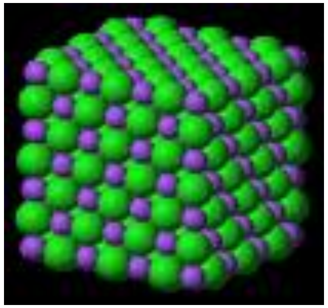
Triple Bond: 3 pairs of e- are shared

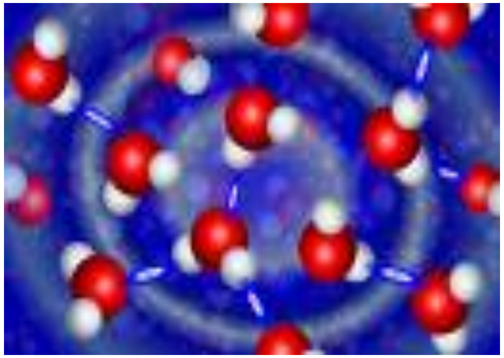


IONIC VS. COVALENT BONDS

Observe the structure of NaCl vs. Water (H_2O)

What can you infer about their properties?





Bonding will determine its physical properties

- State of matter at room temp.
  - Covalent compounds can be solids or liquids or gases
  - Ionic compounds are all solids
- Melting and boiling points
  - Tend to be lower for covalent compounds
- Electrical Conductivity
  - Ionic > covalent

WARM UP

Identify the following as ion or covalent Then name/ write formulas for each?

1. SF_6
2. $CuCl_2$
3. Magnesium Nitride
4. Carbon disulfide

5. Draw a diagram comparing ionic and covalent bonds.

WARM UP

Compare and contrast ionic and covalent bonds. Use a diagram.

Ionic

- Transfer electron
- b/w metal cation and nonmetal anion
- NaCl
- Formula
- More conductive
- Crystal solid
- Higher melting/ boiling point

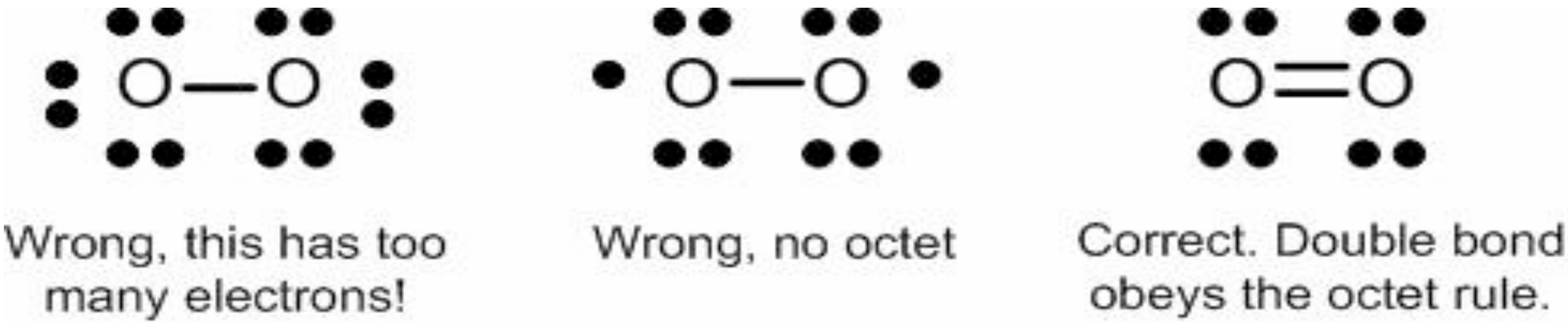
Both

- Strong
- Combine elements
- Involve V. electrons

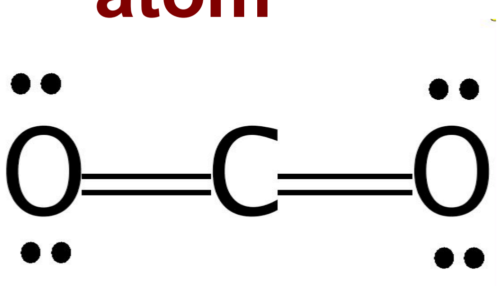
Covalent

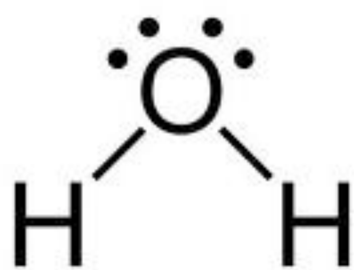
- share electron
- b/w 2 nonmetals
- CO_2 H_2O
- Molecular formula
- Called molecules
- Strongest
- Solid, liquid, gas
- Lower melting/ boiling point

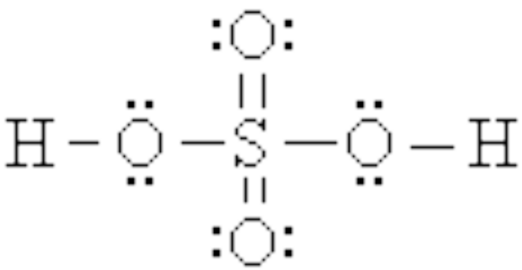
USING DOT STRUCTURES TO SHOW COVALENT BONDS



- Dash= shared e^- = 2 electrons
- Dot: unshared e-
- Need a total of 8 electrons around each atom





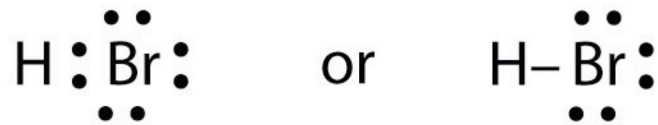


sulphuric acid

REMEMBER…

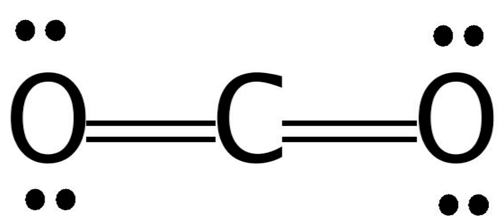
- **Remember, H and He are exceptions, they can have just <u>2 dots</u>**

  ex: HBr



- **If you run out of dots, you might need to make a double or triple bond.**
  - Double bonds: atoms share TWO PAIRS of electrons. (4 electrons total)
  - Triple Bonds: atoms share THREE pairs of electrons. (6 electrons total)

  ex: CO_2



HOW TO DRAW LEWIS DOT STRUCTURES

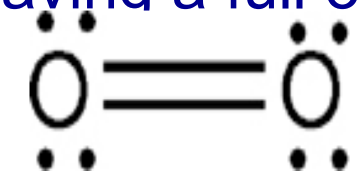
1. Determine the number of valence electrons for each atom by using the periodic table.
2. Calculate the total number of valence e-

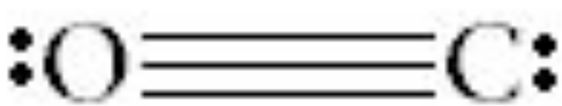
    Be sure to multiply the number of valence electrons if there is more than one atom of the element in a compound

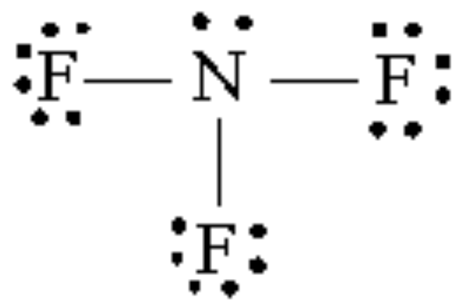
3. Determine a central atom and connect all other atoms with lines to each other
4. Add lines and dots as needed till all e- are used, with each element having a full outer shell

Examples:

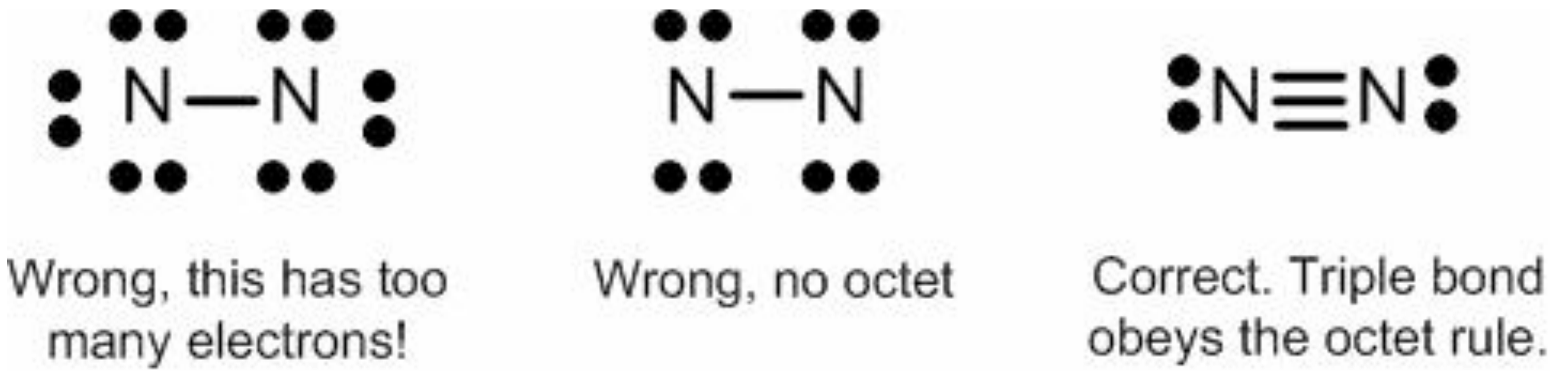
1. O_2
2. NF_3
3. CO
4. N_2







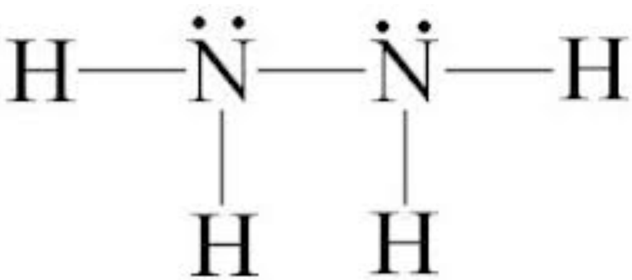
N_2



What order do I write the symbols in for a molecule?

a. Generally the first element in the formula goes in the center.
b. Good rule of thumb – the least electronegative element goes in the center.
c. Some elements __NEVER__ go in the center (like: H, halogens)

Ex: N_2H_4



HOCN

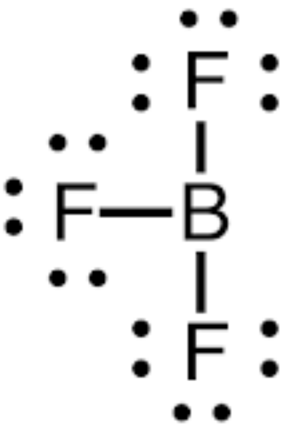
Cyanuric acid

EXCEPTIONS TO THE OCTET RULE

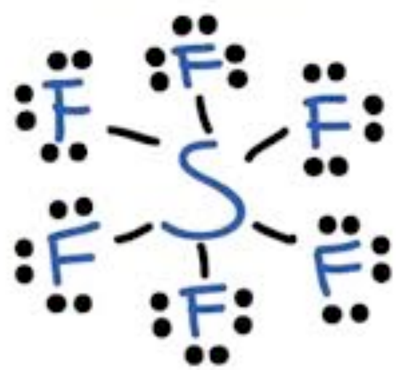
There are molecules that exist, are STABLE, but their e- dot structures cannot be made to satisfy the Octet rule.

- Some have less than 8 e- and some have more
  - BF_3 has less than 8
  - PCl_5 and SF_6 have more

  Ones with MORE are called EXPANDED Octet

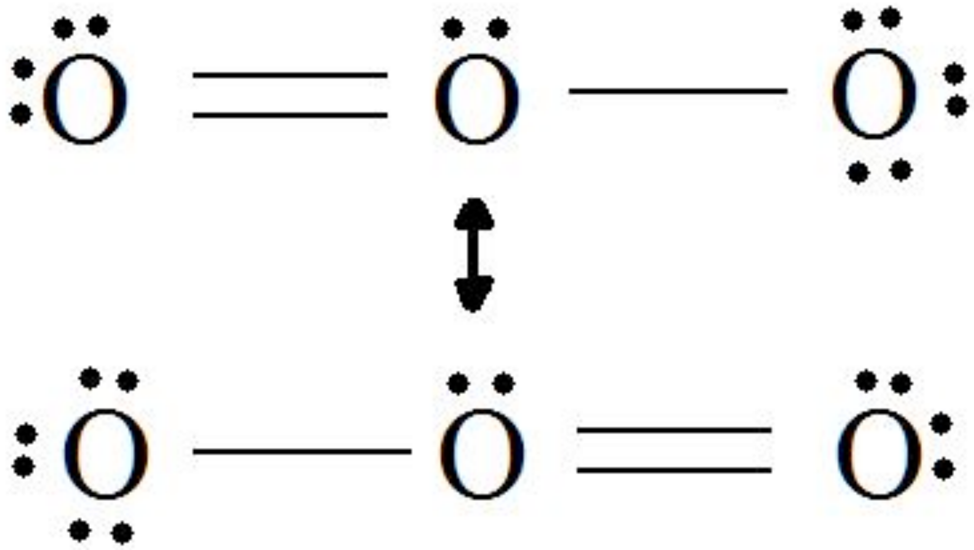


Sulfur Hexafluoride



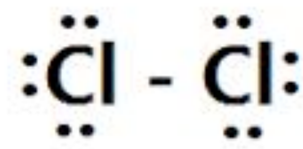
Resonance: when there is more than one correct way to write a Lewis dot structure.

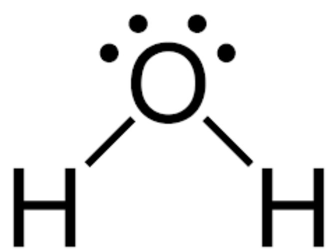
Example: O_3

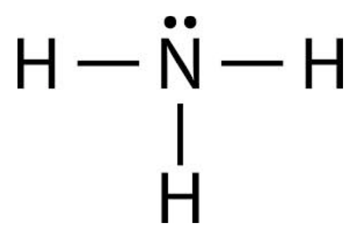


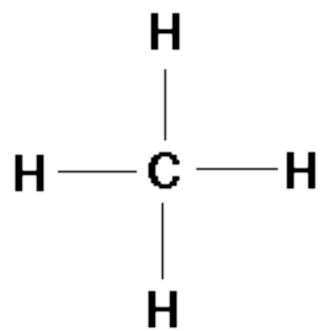
MORE PRACTICE: DRAW DOT STRUCTURES FOR THESE

1. Cl_2
2. HCl
3. H_2O
4. NH_3
5. CH_4





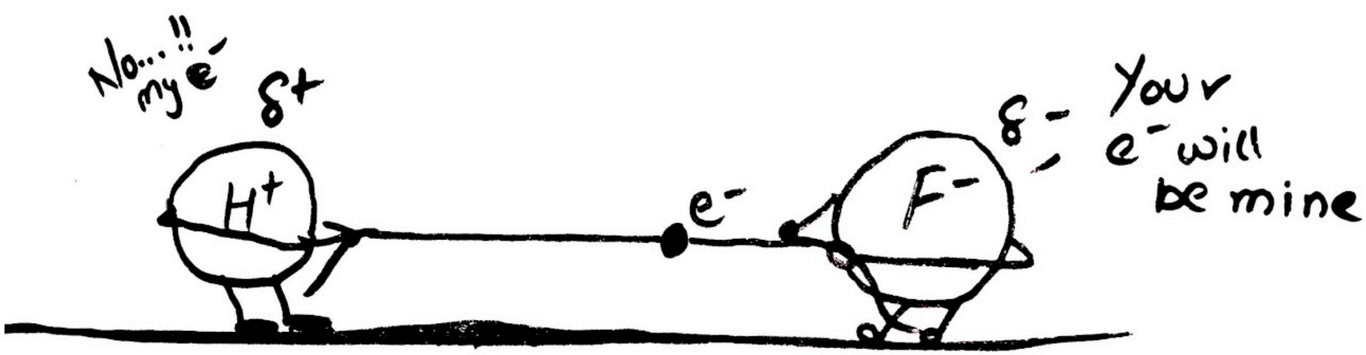




BOND POLARITY

Atoms participating in covalent bonds share electrons, but they do not always share equally.

Remember: Electronegativity: the tendency for an atom to attract electrons to itself when chemically combined with another element.



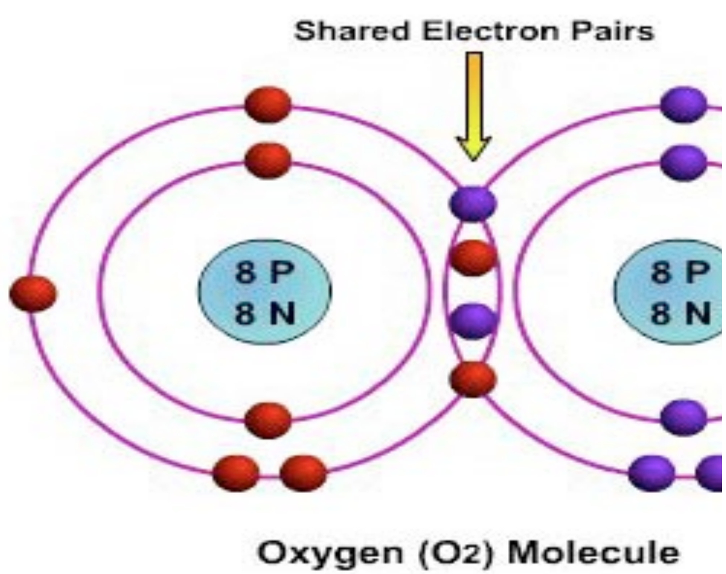
Nonpolar covalent bonds: e⁻ are shared equally ☺

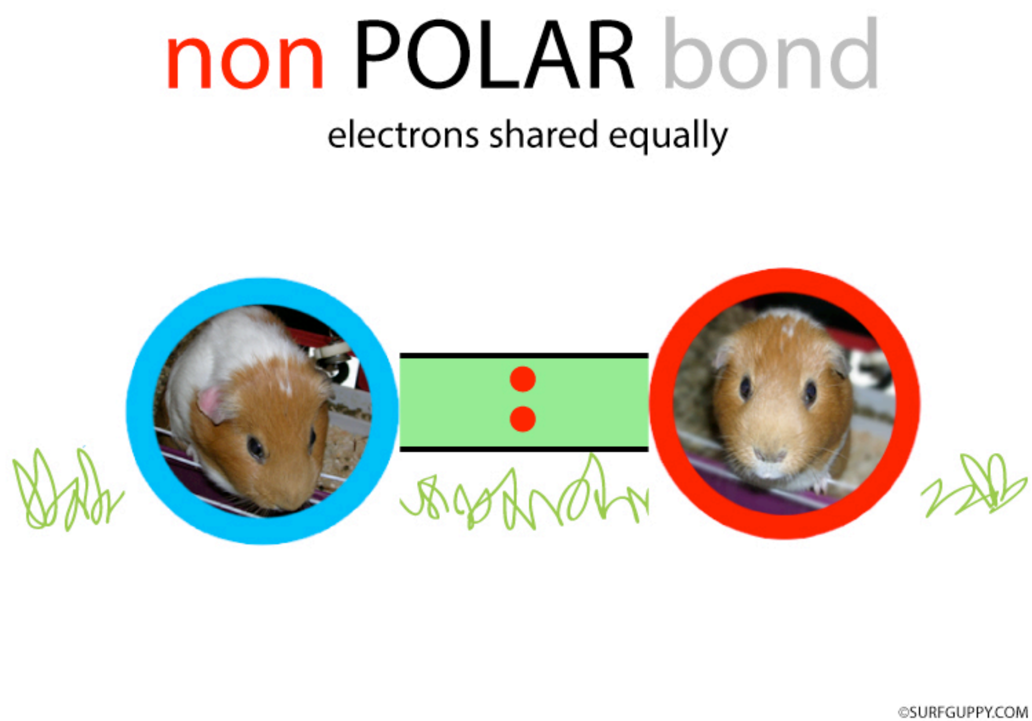
Ex: H_2, O_2, N_2

Tend to have symmetric shapes with similar atoms.

How do we know?

- Think about tug of war…
- Equal electronegativy = share electrons equally = nonpolar bond





You can also compare *difference* in electronegativity to determine types of bonds:

COVALENT BOND	NON POLAR	< 0.5
COVALENT BOND	POLAR	0.5 to 1.7
IONIC BOND	IONIC	> 0.5

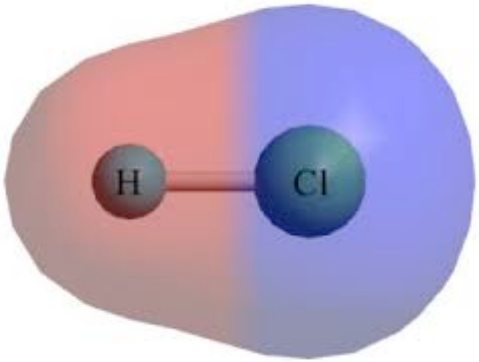
Polar Covalent Bonds: unequal sharing of e⁻

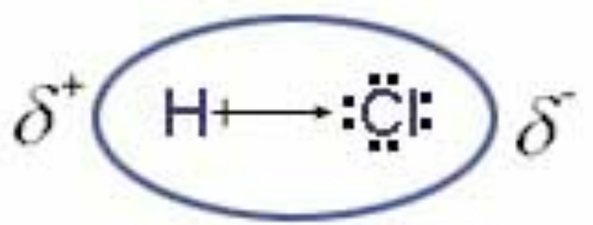
- Tend to be different atoms that lack symmetry

Have a difference in electronegativity of .4 – 2

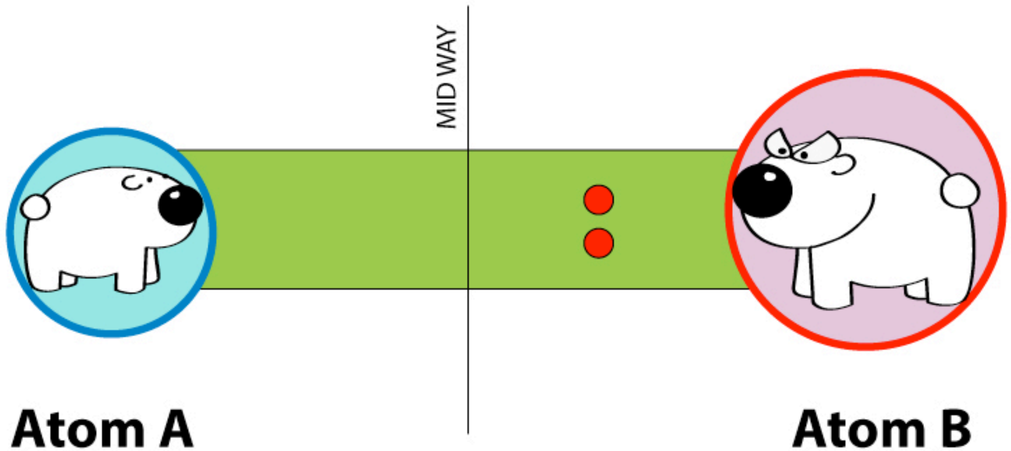
Ex) HCl

- H: 2.1
- Cl: 3.0
- Difference of .9 so polar bond.

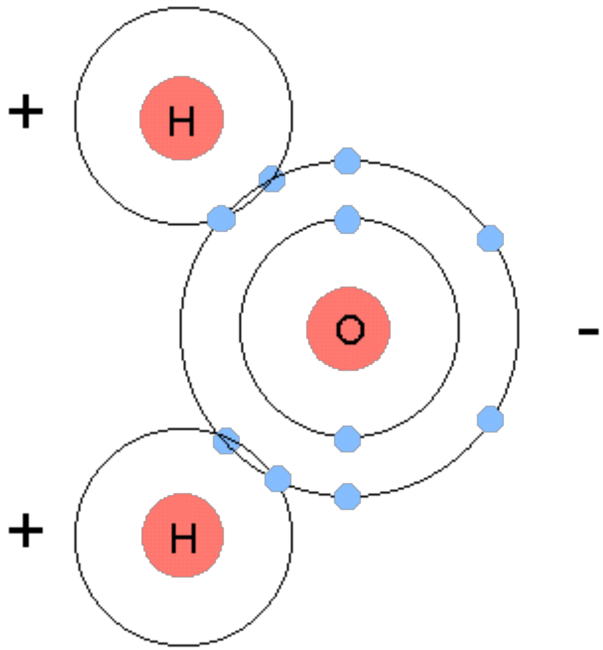


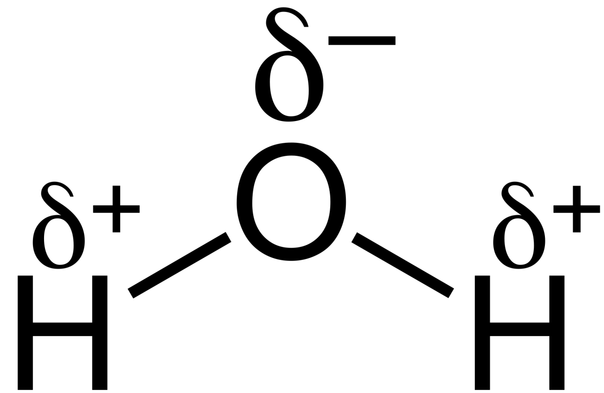


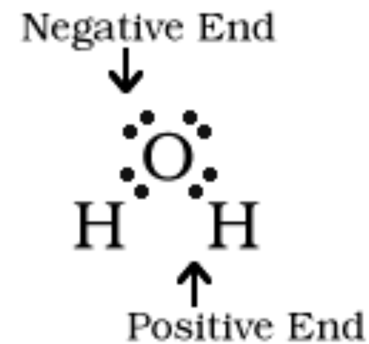
The symbol, δ, indicates the slight charge on that end of the molecule



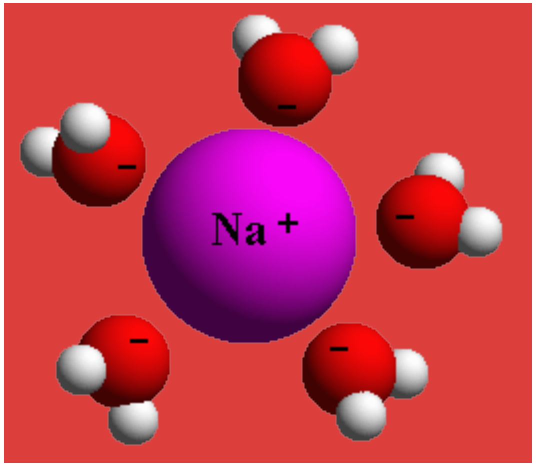
WATER IS POLAR!







Dipole: molecule with two charged regions (or "poles") (like H_2O)



POLAR COVALENT

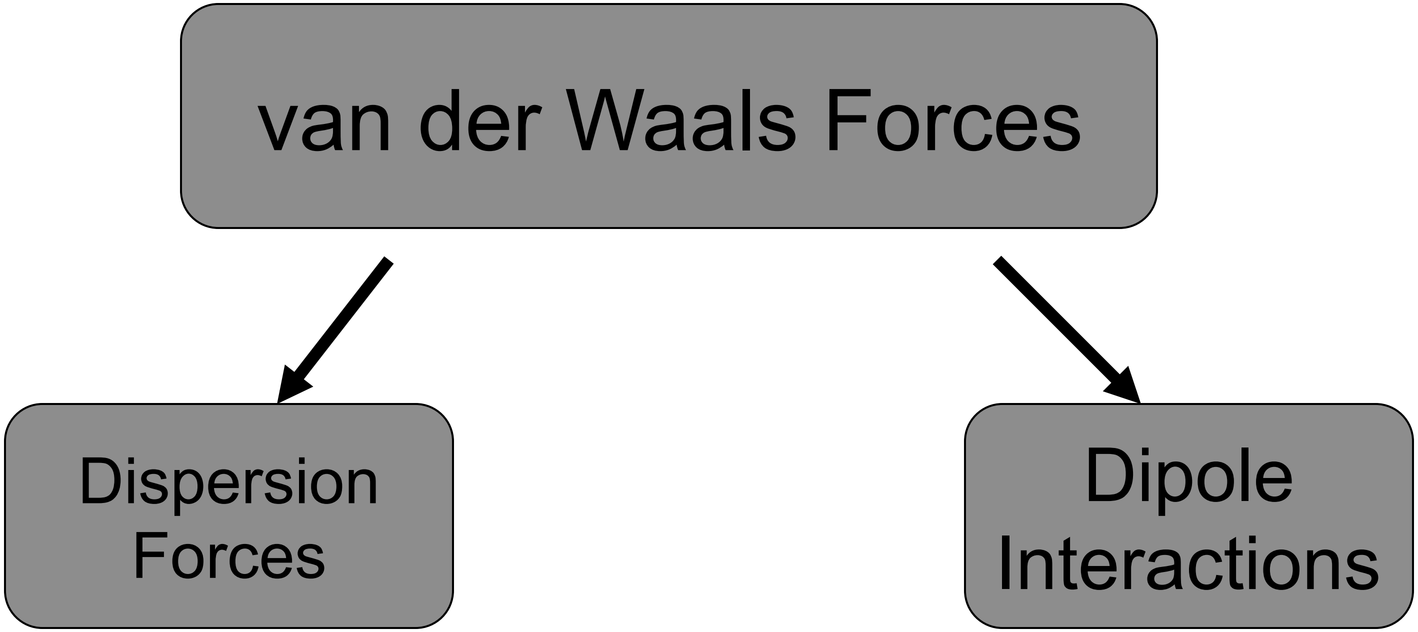
In a polar covalent bond, two atoms still share bonded pairs of electrons, but those electrons are decidedly more attracted to one atom than the other. Examples include bonds between carbon and oxygen atoms, or between hydrogen and fluorine atoms.

NONPOLAR COVALENT

The clearest examples of nonpolar covalent bonds are those between identical atoms, such as H_2, N_2, O_2, or Cl_2. Bonds between atoms with nearly the same electronegativity value, such as carbon and hydrogen atoms, are usually also considered nonpolar. Remember, this is really a continuum, and conventional distinctions are somewhat artificial.

<u>Intermolecular Forces</u> (IMF): Attractions between MOLECULES

- **Occur after forming covalent bonds**



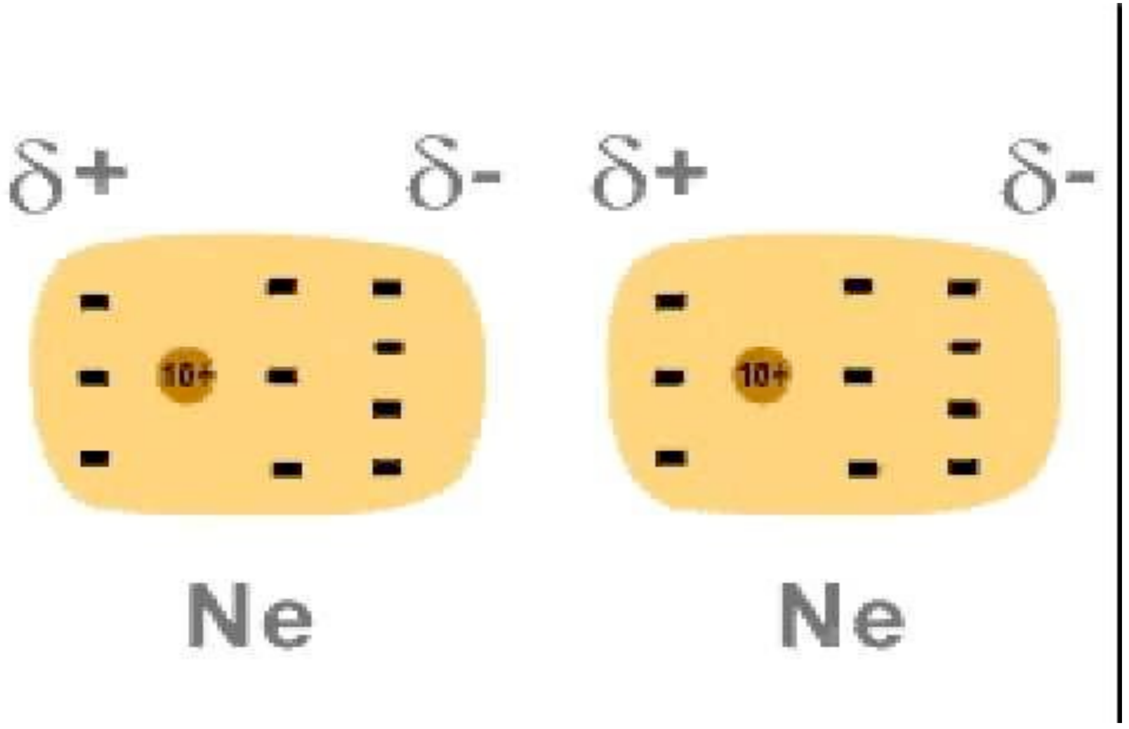
Weakest type of intermolecular interactions

DISPERSION FORCES

Weakest of all IMFs, Caused by motion of electrons

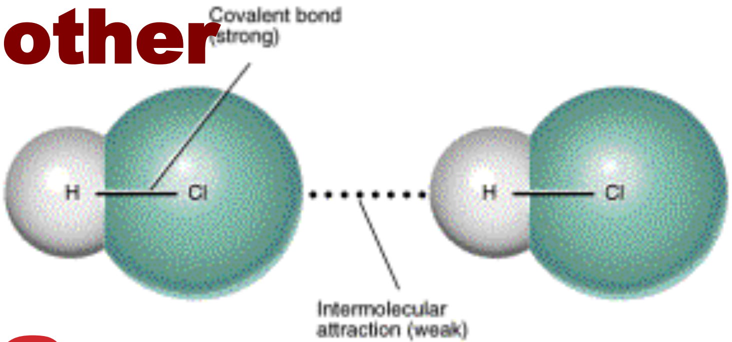
Strength of Dispersion forces increases with increasing size (molecular weight).

Include dipole interaction and hydrogen bonds



DIPOLE INTERACTIONS

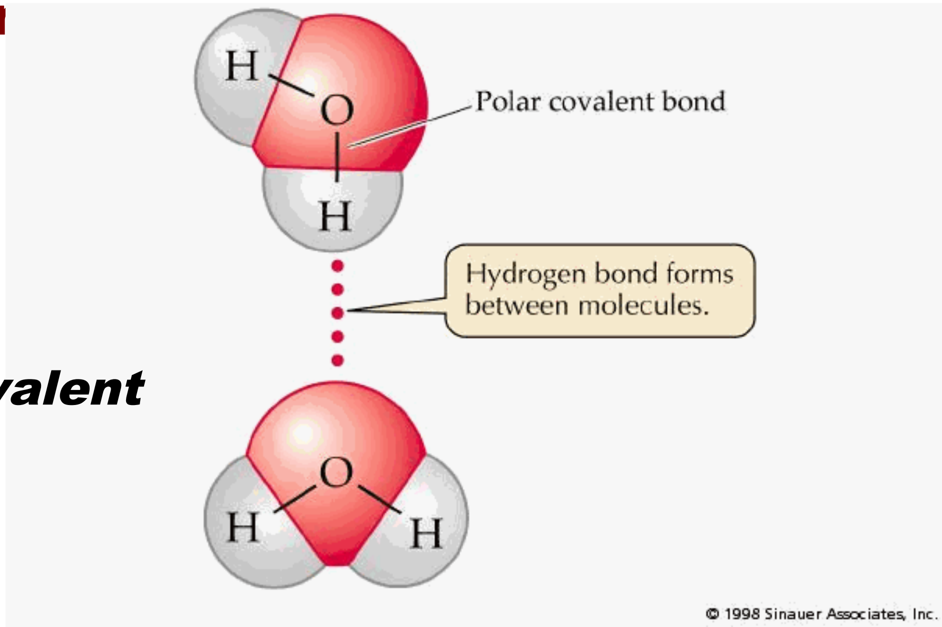
Occurs when polar (dipole) molecules are attracted to each other



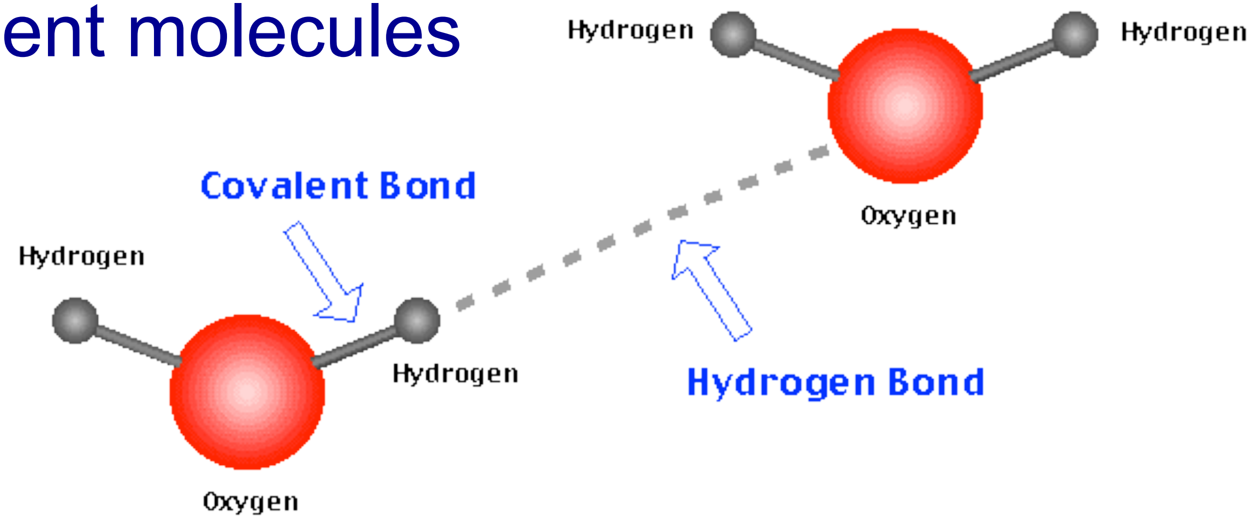
HYDROGEN BONDING

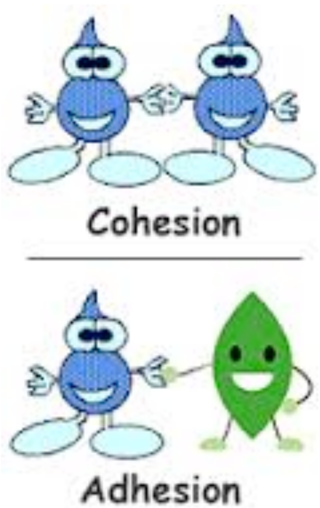
Very strong dipole interaction between H and F, N, or O.

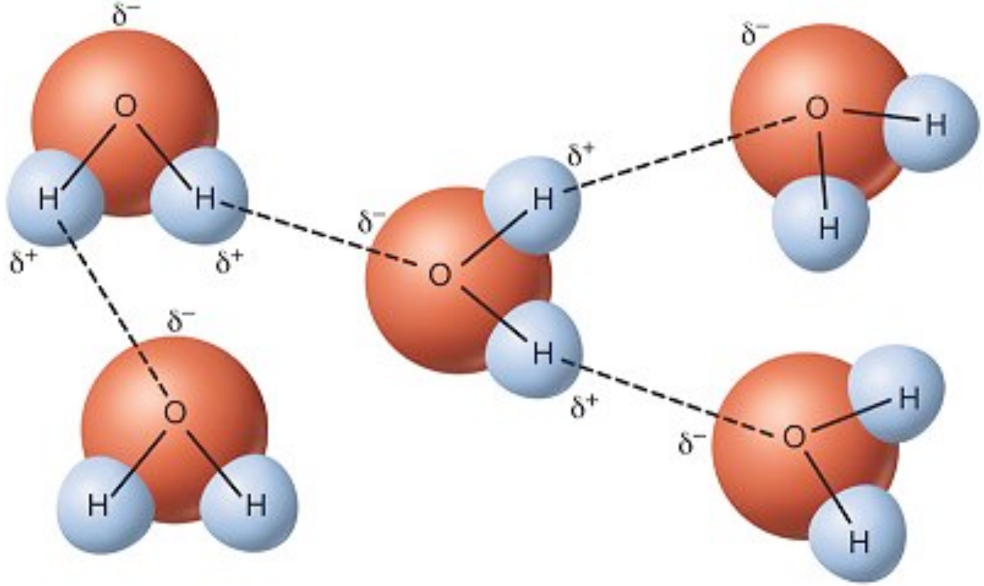
A hydrogen bond is 5% the strength of the average covalent bond



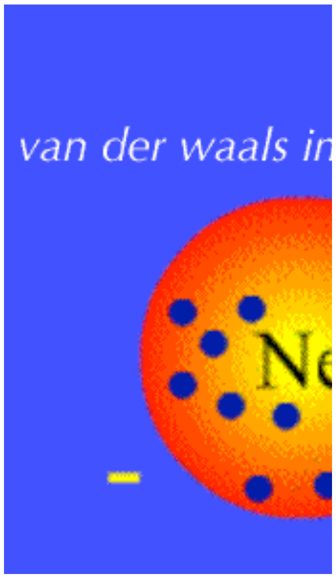
Hydrogen (all dipole forces) form between polar covalent molecules

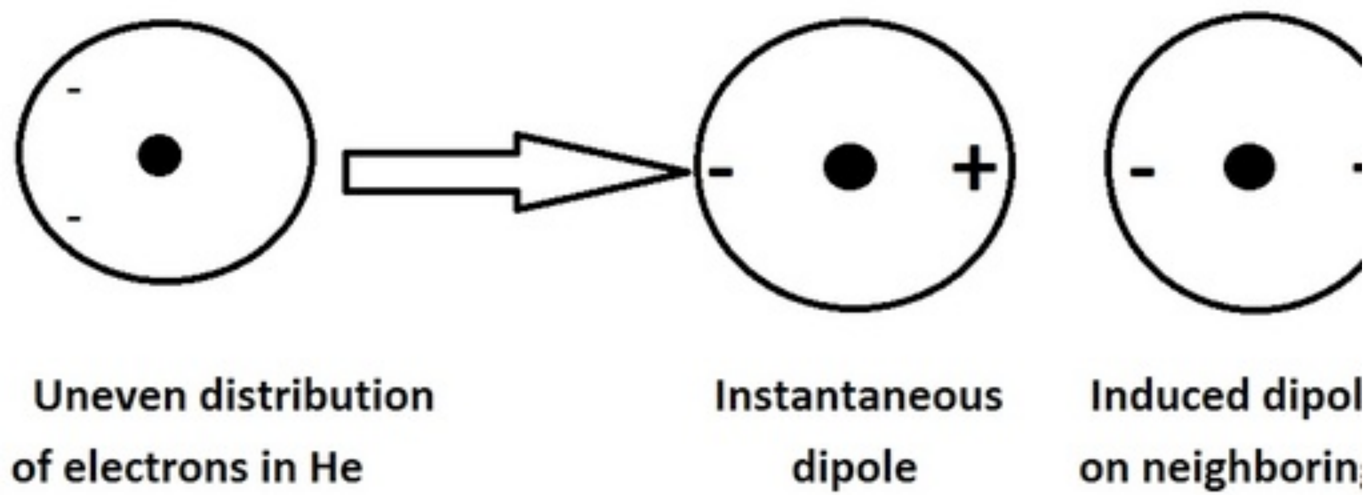






LONDON DISPERSION/ (VAN DER WAALS INTERACTION)





Form from random e^- movement causing instantaneous dipoles: weakest bond!

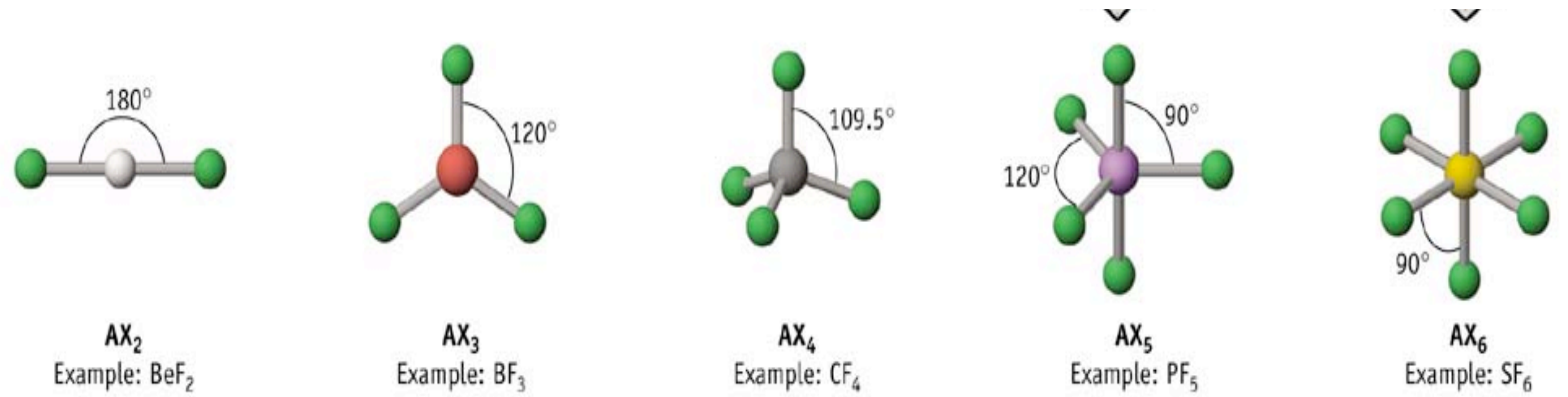
http://besocratic.colorado.edu/CLUE-Chemistry/activities/LondonDispersionForce/1.2-interactions-0.html

MOLECULAR GEOMETRY

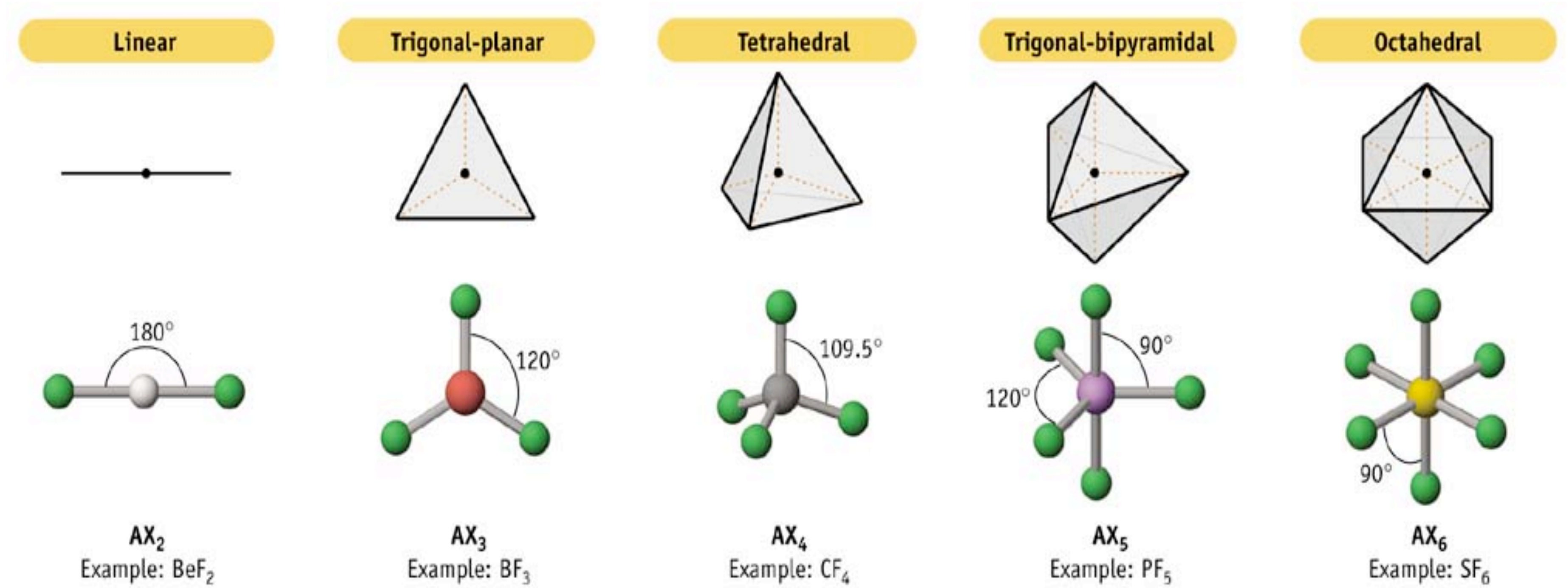
- Dot structure do NOT explain the <u>3D</u> nature of atoms

<u>VSEPR theory</u>: the repulsion between e- pairs (both shared and lone pairs) drives molecular SHAPE

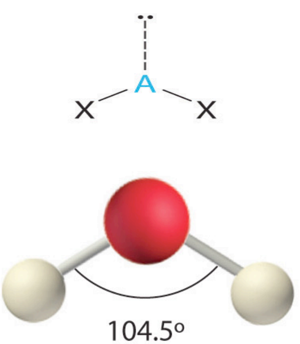
VSEPR= Valence Shell Electron Pair Repulsion



Linear | **Trigonal - Planar** | **Tetrahedral** | **Trigonal - bipyramidal** | **Octehedral**

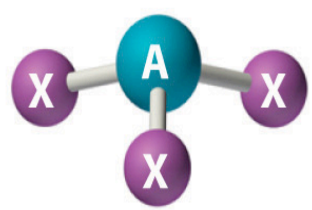


Bent



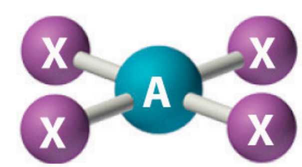
Trigonal

- Pyramidal

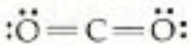
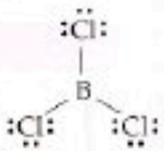
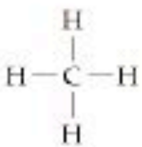
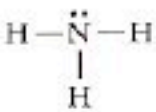
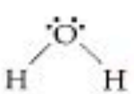


Square

- Planar



Small Molecule Shapes

Shape (and structural formula example)	# of atoms bonded to central atom	# of unshared pairs of electrons on central atom	Bond angle	Picture	Hybrid Orbital
Linear 	1 or 2	0	180°		sp
Trigonal Planar 	3	0	120°		sp^2
Tetrahedral 	4	0	109.5°		sp^3
Pyramidal 	3	1	107°		sp^3
Bent 	2	2	105°		sp^3

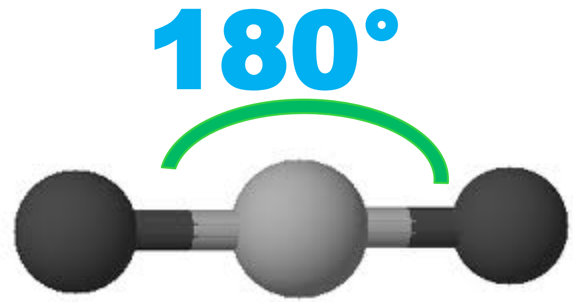
WARM UP

Draw the Lewis dot diagram for:

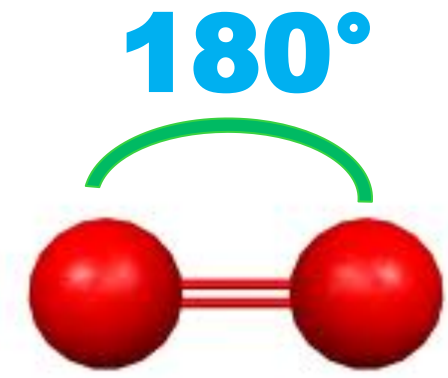
1. NH_3
2. What is the VSEPR shape of H_20
3. Write the name of P_3Br_5
4. Write the formula for potassium sulfide

Name the Shape:

LINEAR



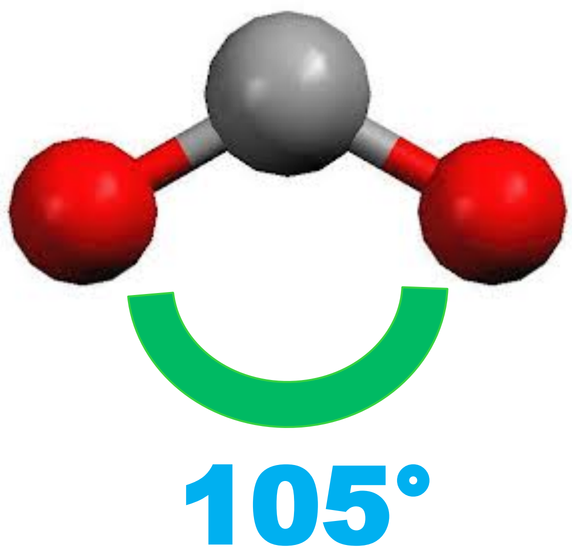
Example: CO_2



Br_2

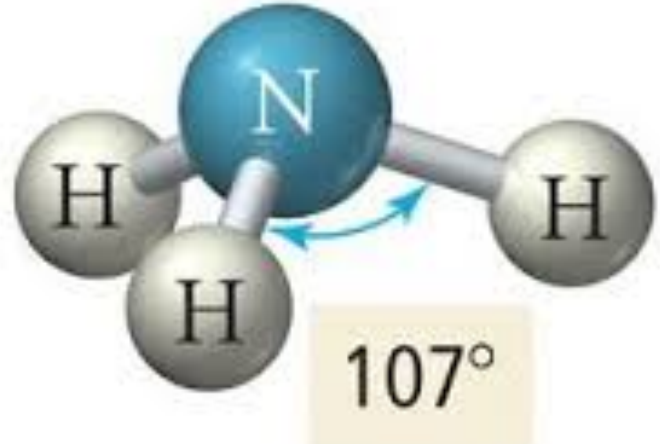
BENT

Example: Water



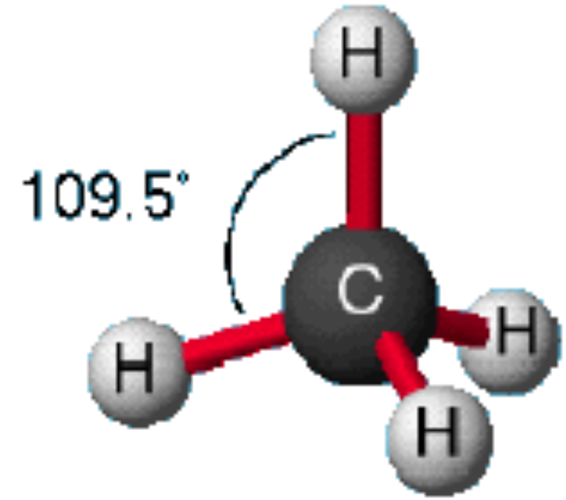
TRIGONAL PYRAMIDAL

Example: Ammonia



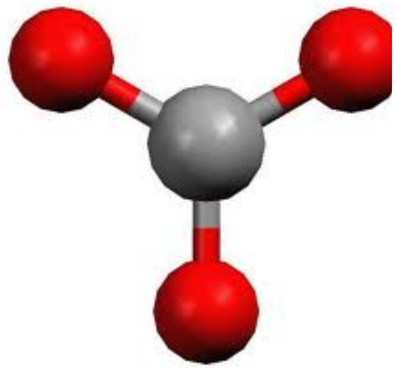
TETRAHEDRAL

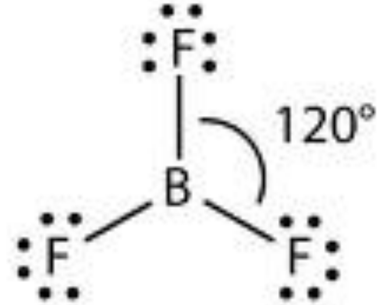
Example: CCl_4



TRIGONAL PLANAR

Example: SO_3



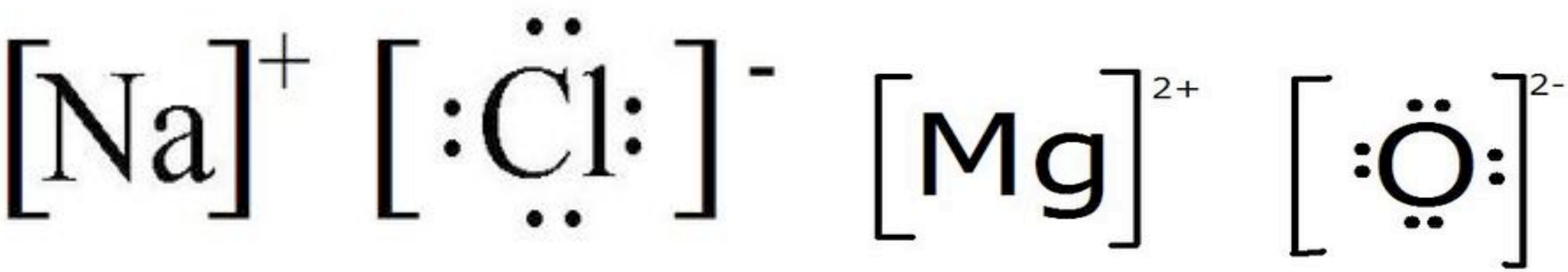


LEWIS DOT STRUCTURES FOR IONS

Works almost the same way, BUT

- **For each + charge subtract an electron, usually empties the outer shell**
- **For each – charge add an electron, usually fills the outer shell**
- **Often show number of atoms before the element**

Ex) Na+ → loses it's one e-,   Cl- → 8 valence electrons,



Magnesium oxide

Ionic compounds: Lewis structures

$$NaCl \rightarrow Na^{+} + [\,:\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}:\,]^{-}$$

$$MgBr_2 \rightarrow Mg^{2+} + 2\,[\,:\underset{\cdot\cdot}{\overset{\cdot\cdot}{Br}}:\,]^{-}$$

$$K_2S \rightarrow 2\,K^{+} + [:\underset{\cdot\cdot}{\overset{\cdot\cdot}{S}}:\,]^{2-}$$

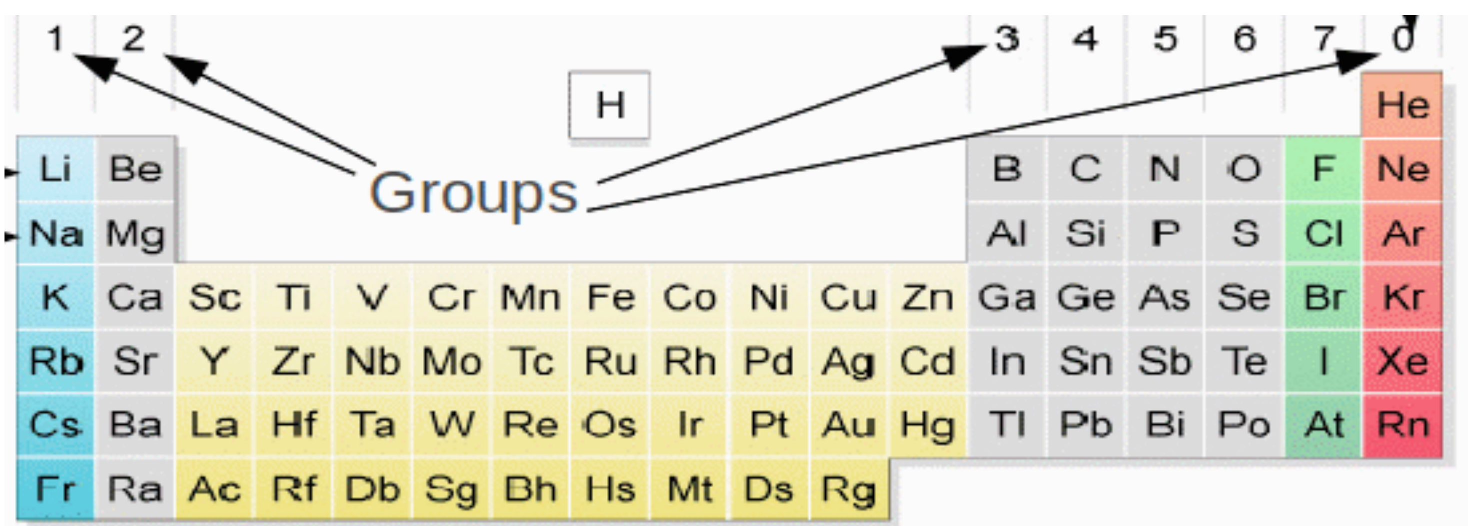
$$Al_2O_3 \rightarrow 2\,Al^{3+} + 3\,[:\underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}:\,]^{2-}$$

OF BOND FORMED

Generally to complete an octet Group 4A will form four bonds, Group 5A will form 3 bonds, Group 6A will form 2 bonds, etc

B: 3 bonds (group 3A)
C: 4 bonds (group 4A)
N: 3 bonds (group 5A)
O: 2 bonds (group 6A)
F, Cl, Br, I: 1 bond (group 7A)

P: 3 or 5
S: 2 or 6
- Can form expanded octets



WHICH IS WHICH??

Br_2, KBr, CH_4, SO_3, N_2H_2, Ne_2

1. Which substance does not exist?
2. Which one is ionic?
3. Which formulas represent molecules?
4. Which formulas represent compounds?
5. How many atoms are in SO_3?

CLASS PRACTICE

Draw the electron dot structure of the hydroxide ion (OH^-).

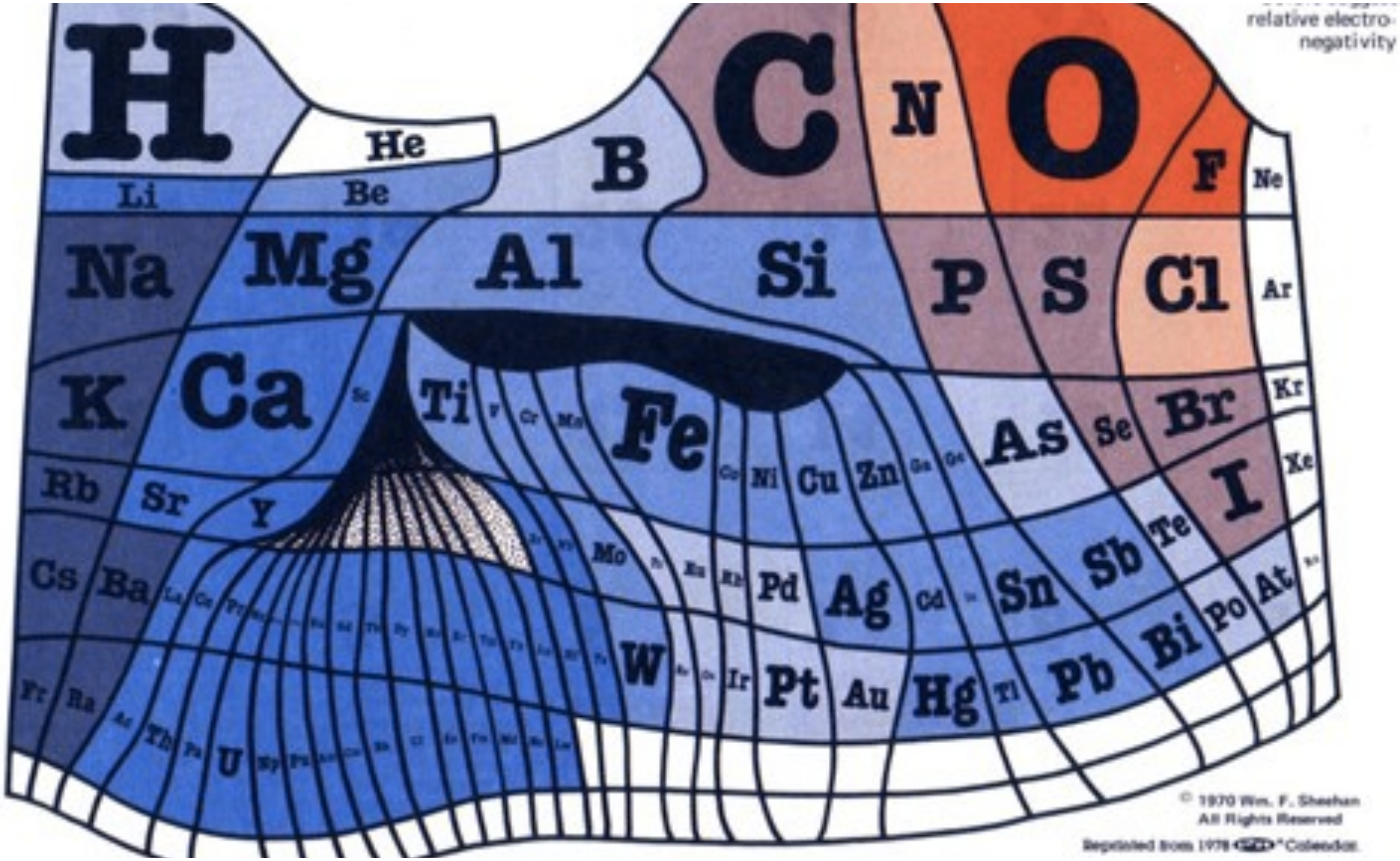
Draw the electron dot structure of the polyatomic boron tetrafluride anion (BF_4^-).

Draw the electron dot structures for sulfate (SO_4^{2-}) and carbonate (CO_3^{2-}). Sulfur and carbon are the central atoms, respectively.

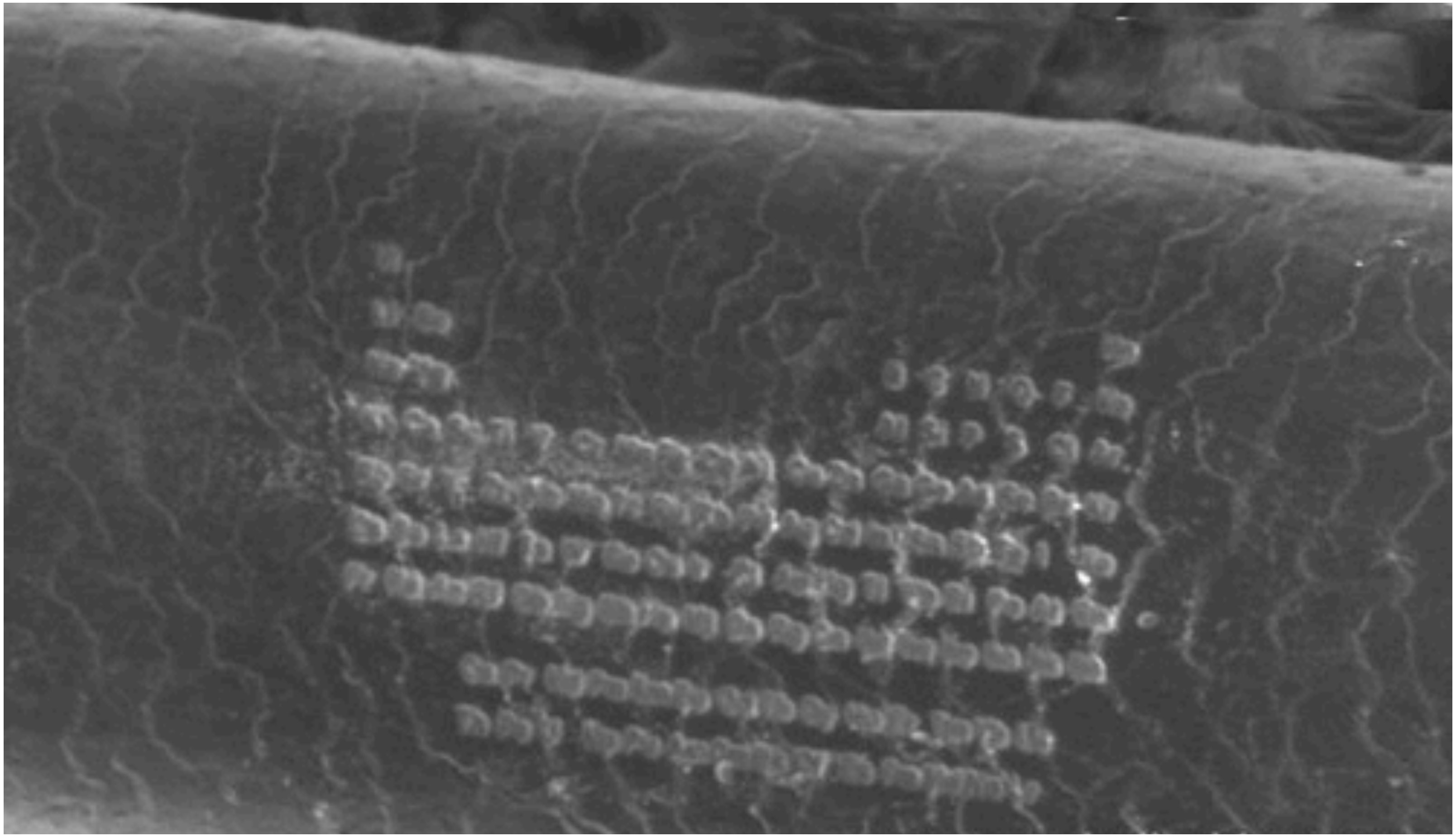
True or False?

1. Molecular is another way to say covalent. T
2. All molecular compounds are composed of atoms of two or more different elements. F
3. No elements exist as molecules. F
4. Most molecular compounds are composed of two or more nonmetallic elements. T
5. Atoms in covalent compounds share electrons. T
6. Ionic compounds tend to be composed of 2 metals F
7. Compare and contrast ionic and covalent bonds. Use a diagram.

ELEMENT ABUNDANCE



SMALLEST PERIODIC TABLE ON A SINGLE HUMAN HAIR



COMMON CORE STANDARDS

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles