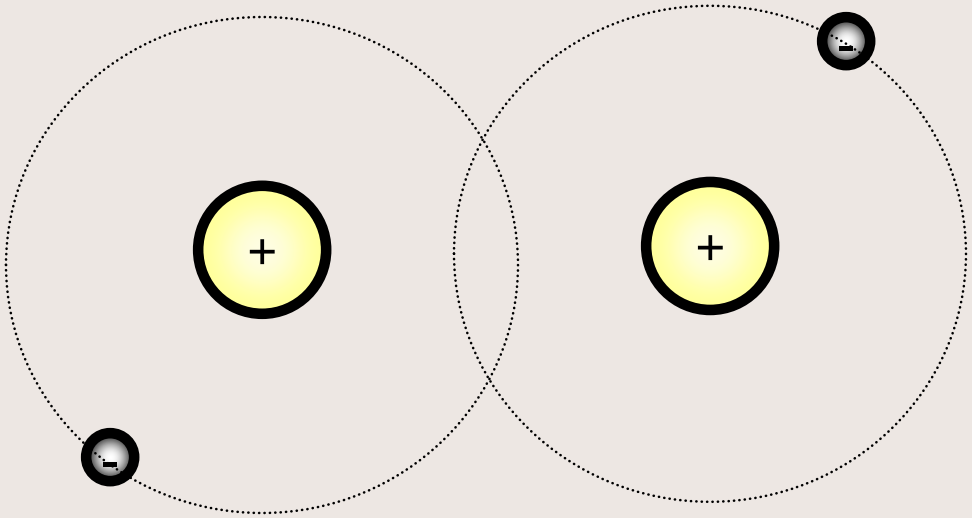
Chemical Bonds & Reactions

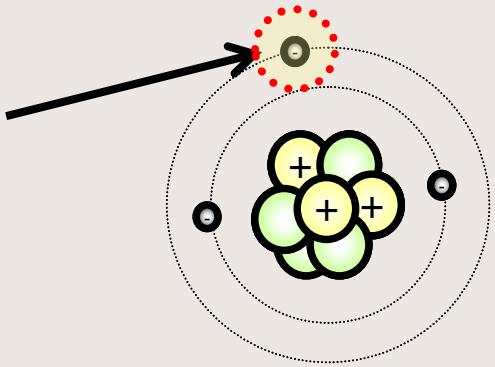


Chemical Bond

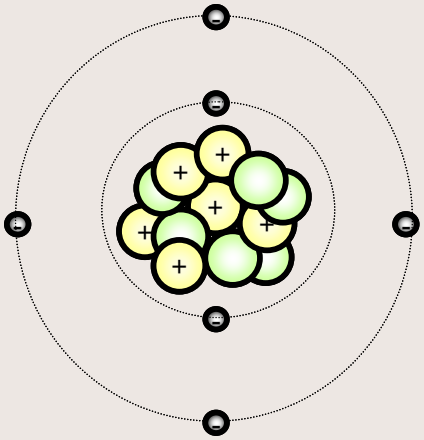
- A force of attraction that holds two atoms together
- Involves the valence electrons (they determine the chemical characteristics of the atom!)

Valence Electrons – the electrons in the outermost energy level of an atom

This Lithium Atom has one valence electron

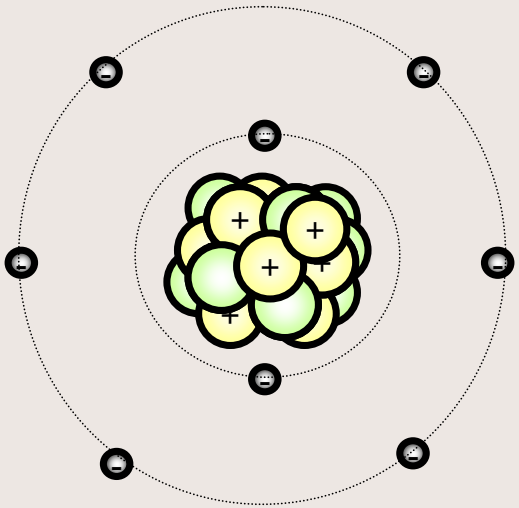


Counting Valence Electrons



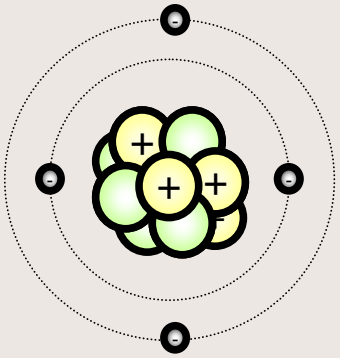
Carbon

4 valence electrons



Oxygen

6 valence electrons



Beryllium

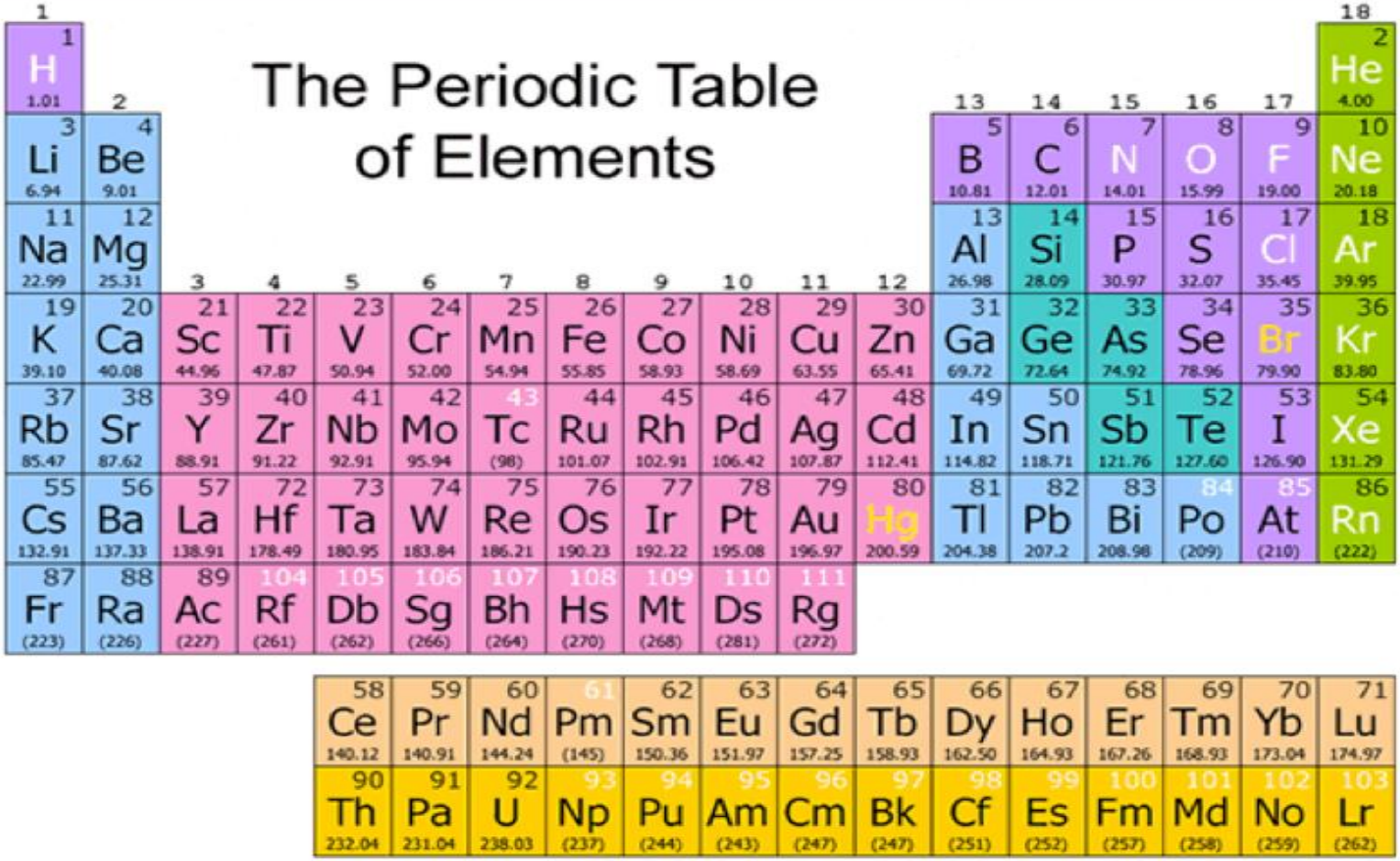
2 valence electrons

Determining the Number of Valence Electrons by Using the Periodic Table

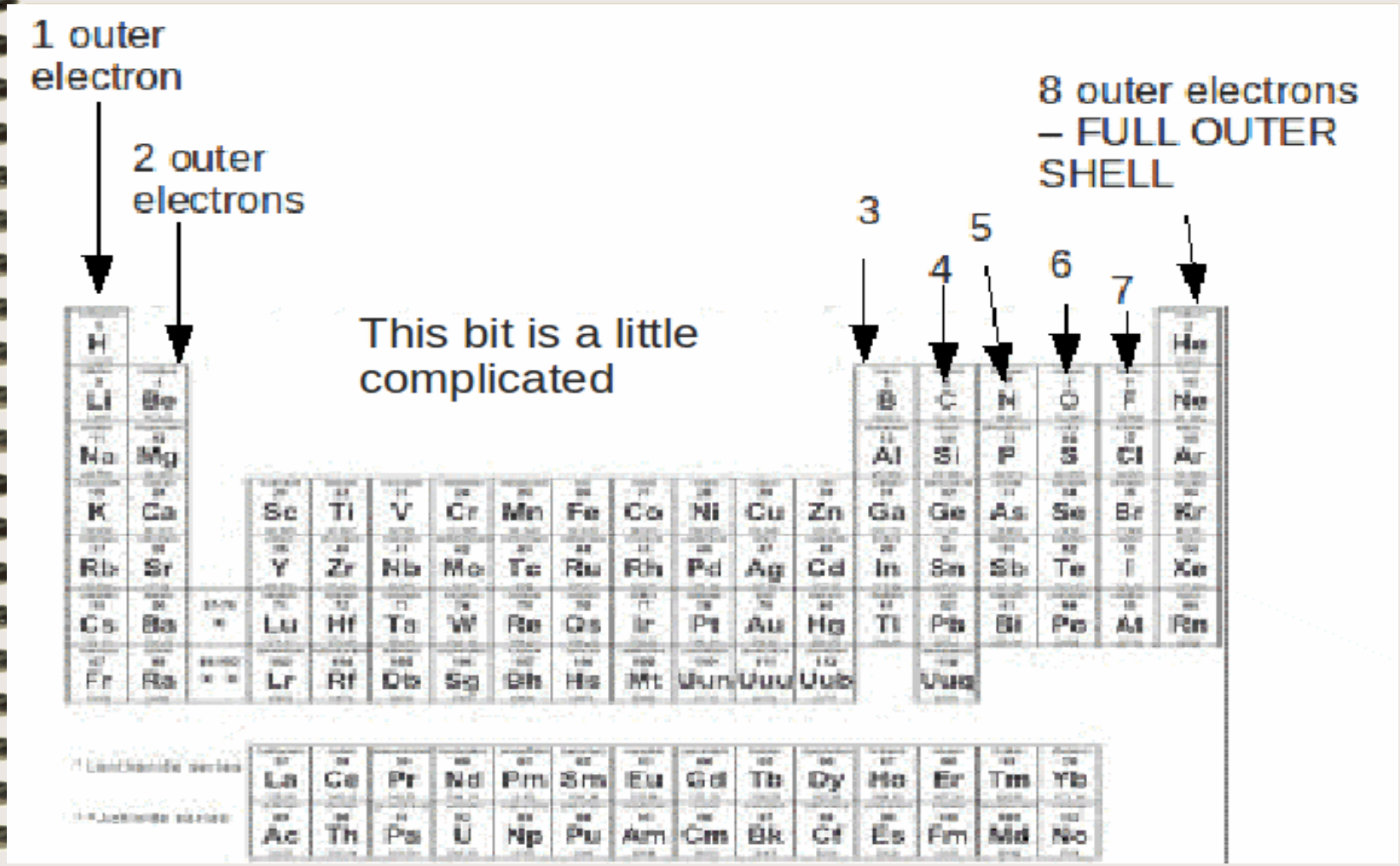
*Atoms of elements in Groups 1 and 2 have the same number of valence electrons as their group number.

*Atoms of elements in Group 3-12 do not have a general rule relating their valence electrons to their group number. However, they typically have between 1 or 2 valence electrons.

*Atoms of elements in Groups 13-18 have 10 fewer valence electrons than their group number. (*Exception* - *helium atoms have only 2 valence electrons, even though they are in group 18)*


The Periodic Table of Elements
1 H 1.01
2 He 4.00
3 Li 6.94
4 Be 9.01
5 B 10.81
6 C 12.01
7 N 14.01
8 O 15.99
9 F 19.00
10 Ne 20.18
11 Na 22.99
12 Mg 25.31
13 Al 26.98
14 Si 28.09
15 P 30.97
16 S 32.07
17 Cl 35.45
18 Ar 39.95
19 K 39.10
20 Ca 40.08
21 Sc 44.96
22 Ti 47.87
23 V 50.94
24 Cr 52.00
25 Mn 54.94
26 Fe 55.85
27 Co 58.93
28 Ni 58.69
29 Cu 63.55
30 Zn 65.41
31 Ga 69.72
32 Ge 72.64
33 As 74.92
34 Se 78.96
35 Br 79.90
36 Kr 83.80
37 Rb 85.47
38 Sr 87.62
39 Y 88.91
40 Zr 91.22
41 Nb 92.91
42 Mo 95.94
43 Tc (98)
44 Ru 101.07
45 Rh 102.91
46 Pd 106.42
47 Ag 107.87
48 Cd 112.41
49 In 114.82
50 Sn 118.71
51 Sb 121.76
52 Te 127.60
53 I 126.90
54 Xe 131.29
55 Cs 132.91
56 Ba 137.33
57 La 138.91
72 Hf 178.49
73 Ta 180.95
74 W 183.84
75 Re 186.21
76 Os 190.23
77 Ir 192.22
78 Pt 195.08
79 Au 196.97
80 Hg 200.59
81 Tl 204.38
82 Pb 207.2
83 Bi 208.98
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 (266)
107 Bh (264)
108 Hs (270)
109 Mt (268)
110 Ds (281)
111 Rg (272)
58 Ce 140.12
59 Pr 140.91
60 Nd 144.24
61 Pm (145)
62 Sm 150.36
63 Eu 151.97
64 Gd 157.25
65 Tb 158.93
66 Dy 162.50
67 Ho 164.93
68 Er 167.26
69 Tm 168.93
70 Yb 173.04
71 Lu 174.97
90 Th 232.04
91 Pa 231.04
92 U 238.03
93 Np (237)
94 Pu (244)
95 Am (243)
96 Cm (247)
97 Bk (247)
98 Cf (251)
99 Es (252)
100 Fm (257)
101 Md (258)
102 No (259)
103 Lr (262)

Valence Electrons



How Many Valence Electrons?

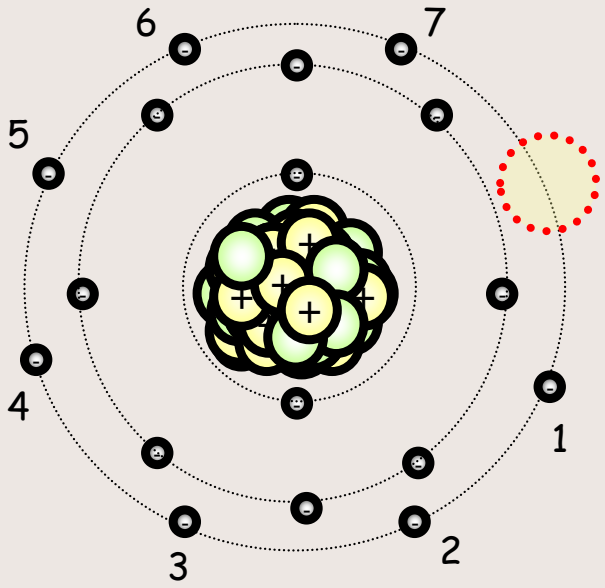
- Hydrogen → 1 Valence Electron
- Lead → 4 Valence Electrons
- Xenon → 8 Valence Electrons
- Sulfur → 6 Valence Electrons
- Rubidium → 1 Valence Electron

The Octet Rule

- *Atoms will combine to form compounds in order to reach eight electrons in their outer energy level.*
  - Atoms with less than 4 electrons tend to lose electrons.
  - Atoms with more than 4 electrons tend to gain electrons.
- **Be aware that there are some exceptions!**

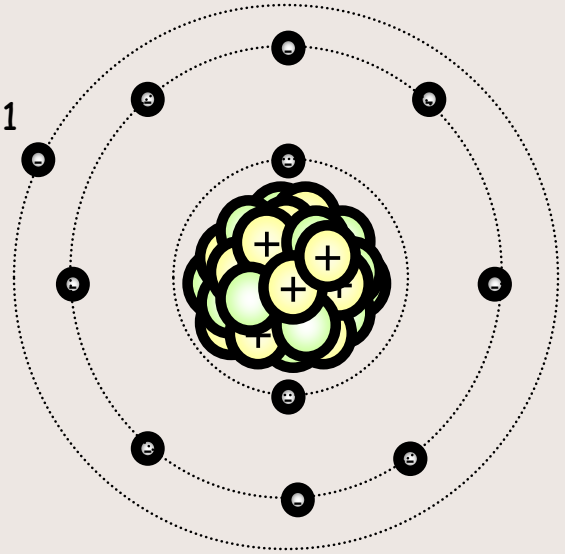
CONSIDER EIGHT A HAPPY NUMBER FOR ATOMS!

The Octet Rule In Action



Notice how this chlorine atom has seven valence electrons, one away from eight. It will try to gain one more according to the Octet Rule.

Notice how the sodium atom has one valence electron. It is this electron that it will try to get rid of according to the Octet Rule.



Where do you think Chlorine finds that one electron that it needs?

Lewis Structure (Electron Dot Diagram)

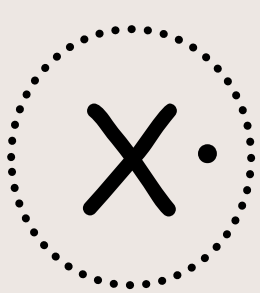
- A way of drawing the outer energy level electrons (valence) of an atom
- The symbol for the element surrounded by as many dots as there are valence electrons.
- Examples

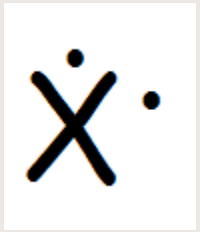
Aluminum Nitrogen Magnesium

How many valence electrons do each of these atoms have?

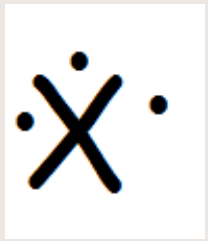
Making an Electron Dot Diagram

Element "X" has 8 valence electrons

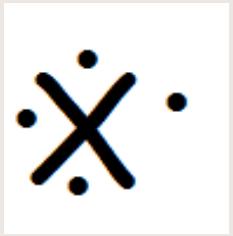




1



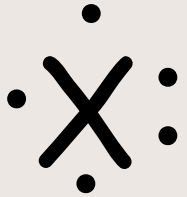
2



3

If this were an atom of an element from group 1, you would just place the one dot on any side of the element.

Place the rest of the dots in either a clockwise or counter clockwise manner around the symbol, with no side receiving two dots until each side gets one.



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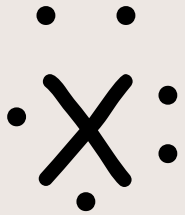

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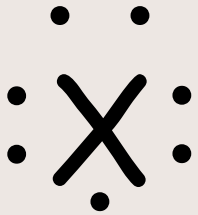

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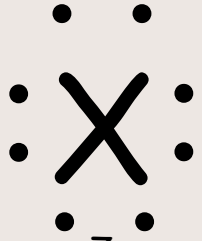


7

What Would the Electron Dot Diagram Look Like?

1 Valence Electron

H

6 Valence Electrons

O

How many valence electrons does each atom have?

Ne

8 Valence Electrons

Sr

2 Valence Electrons

Oxidation Number

- The charge that an atom would have if it lost or gained electrons; ion charge.
- Can be helpful in determining which atoms will interact or bond with each other
- Example:

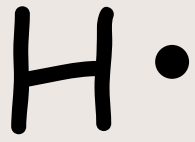
According to electron dot diagram for Magnesium, it has two valence electrons. Because Magnesium is "unhappy" with two, it will typically lose them. If this happens it will turn into a Magnesium ion. At this point it will have an oxidation number of +2.

Mg:

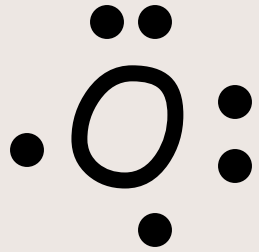
Magnesium

Mg^{2+}

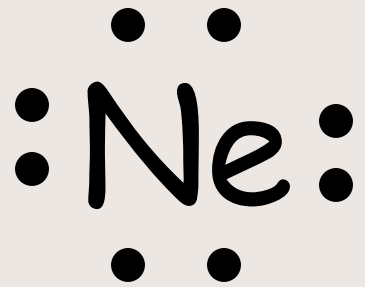
What Could the Oxidation Number Be?



+1 or -1 because it can gain or lose one electron



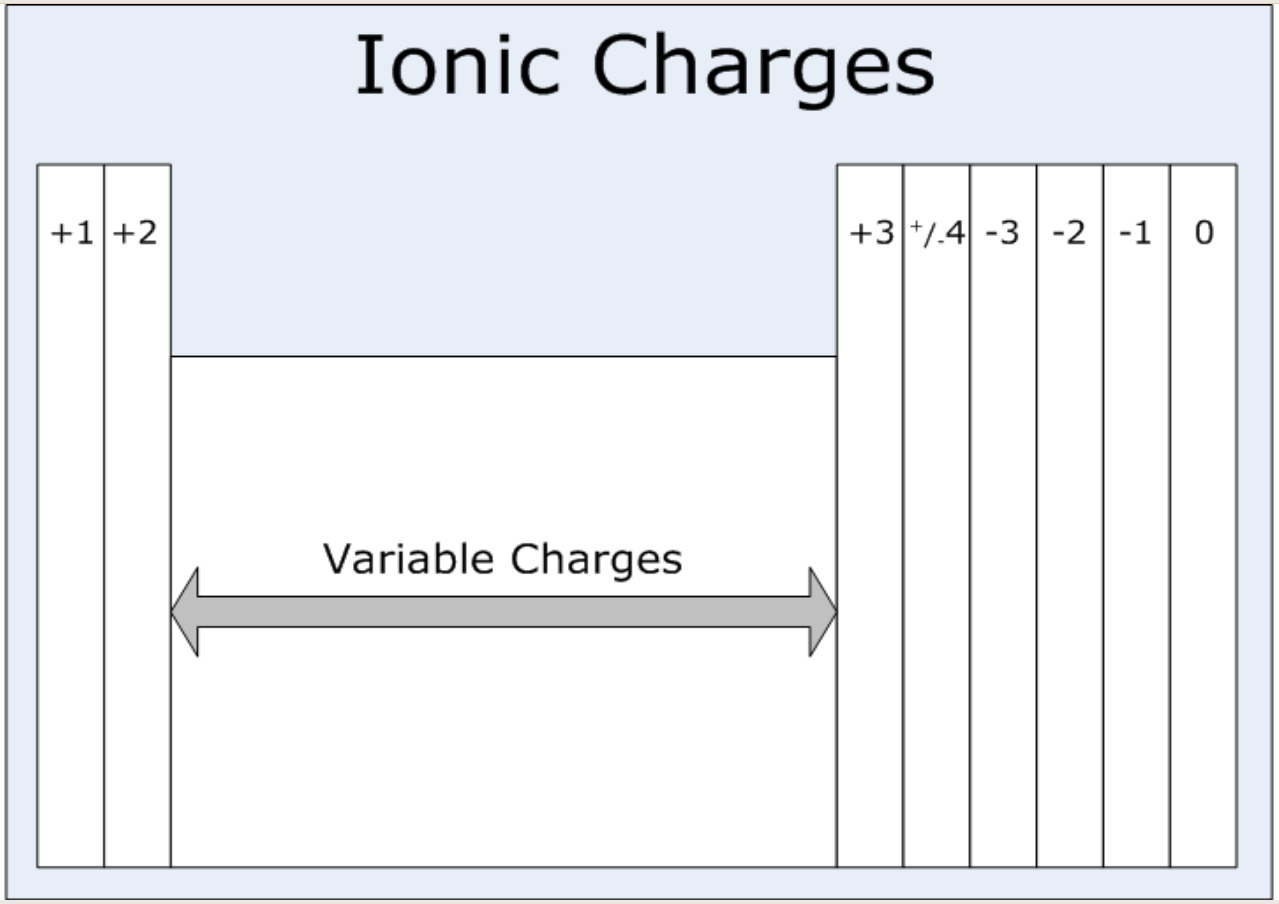
-2 because it will gain two electrons



0 because it will not gain or lose electrons

+2 because it will lose two electrons

Typical Oxidation Numbers



More on Valence Electrons

- https://www.youtube.com/watch?v=yADrWdNTWEc&spfreload=10

3 Types of Chemical Bonds

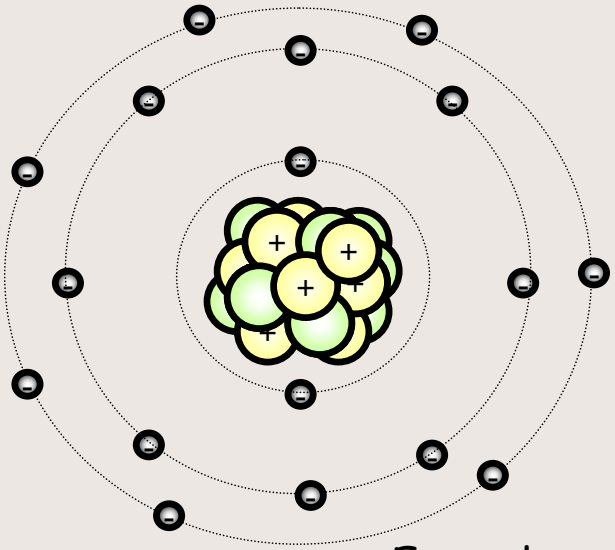
- Ionic
- Covalent
- Metallic

What can you describe about each of these bonds just by looking at the name?

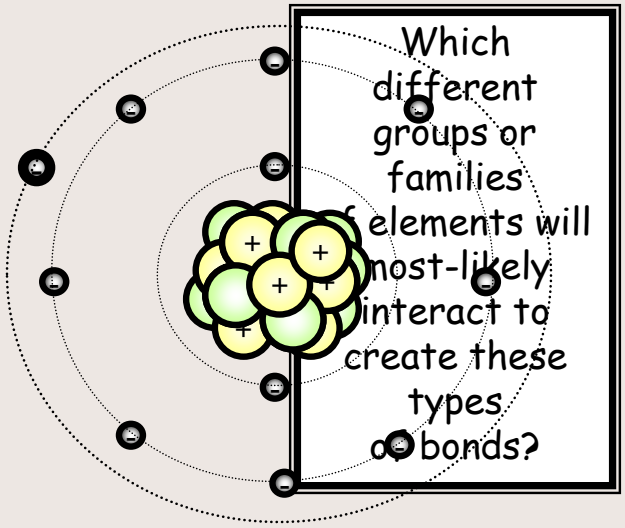
IONIC BONDS

- The force of attraction between oppositely charged ions.
- Occurs after a loss or gain of electrons
- Usually form between atoms of metals and atoms of non-metals
- Resulting compounds have a name that usually ends in –ide

Cl^{1-}

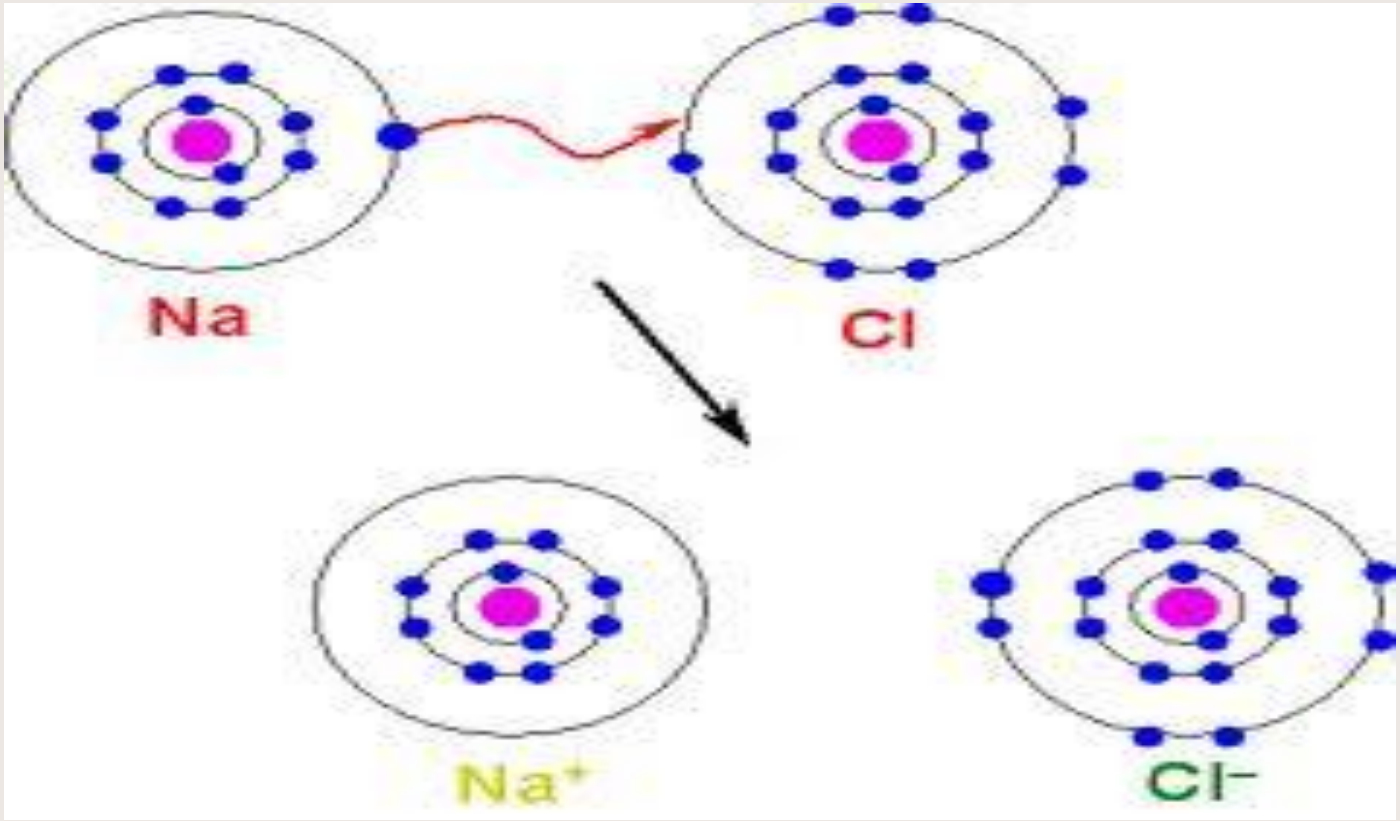


Na^{1+}



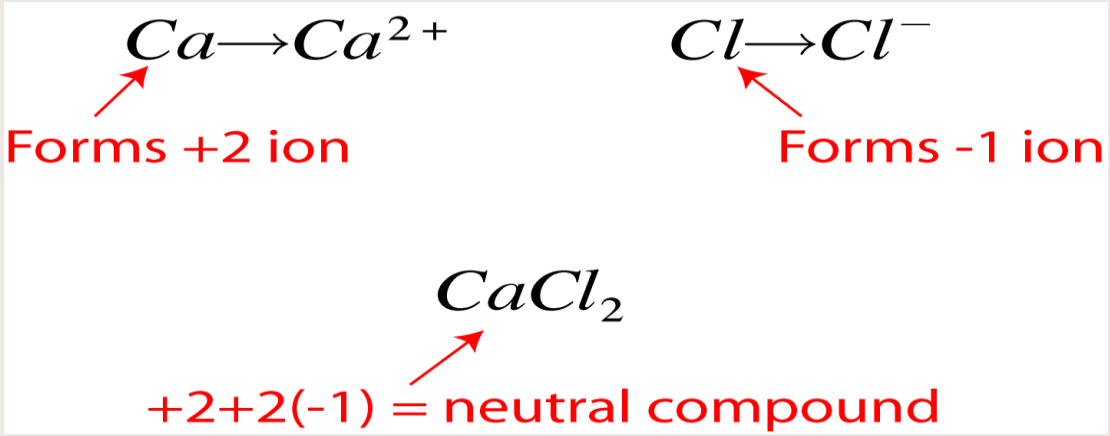
Example - Sodium Chloride (NaCl)

Their opposite charges attract each other!

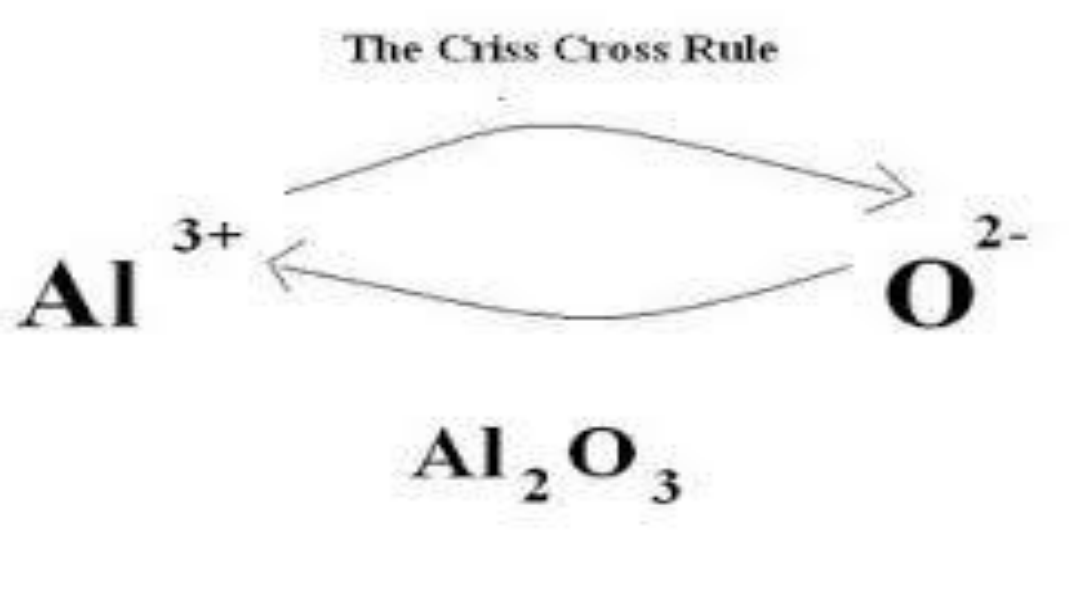


Writing Ionic Compounds

- Write the symbol for the positive ion first.
- Write the symbol for the negative ion next.
- Assign subscripts to make the compound neutral.



An Easy Trick…



$Ca^{+2}\ O^{-2} \rightarrow Ca_2\ O_2 \rightarrow CaO$

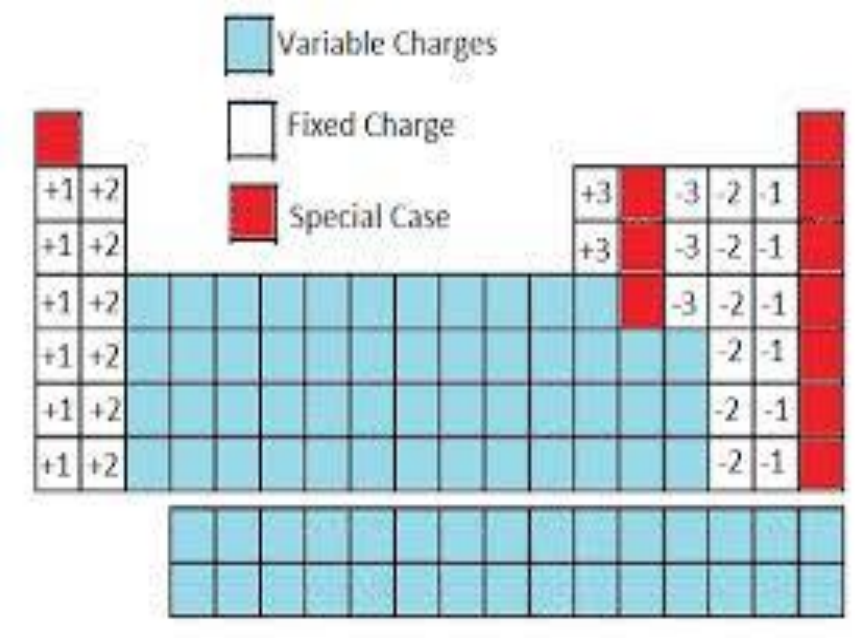
$Pb^{+4}\ O^{-2} \rightarrow Pb_2\ O_{4=2} \rightarrow PbO_2$

Practice Ionic Compounds

- Zinc chloride
- Beryllium oxide
- Potassium chloride
- Barium oxide

Variable Charge Ions

- Some atoms may lose or gain different numbers of electrons.
- Called "variable charge".



Single-Charge Ions		
Element	*Symbol*	*Charge*
Zinc	Zn	2+
Tungsten	W	6+
Silver	Ag	1+
Cadmium	Cd	2+

Variable-Charge Ions		
Element	*Symbol*	*Charge*
Chromium	Cr	2+,3+,6+
Manganese	Mn	2+,4+,7+
Iron	Fe	2+,3+
Cobalt	Co	2+,3+
Nickel	Ni	2+,3+
Copper	Cu	1+,2+
Tin	Sn	2+,4+
Gold	Au	1+,3+
Mercury	Hg	1+,2+
Lead	Pb	2+,4+

Polyatomic Ions

- When 2 or more atoms are bound together and act like a SINGLE ion!
- Common one is the Hydroxide Ion:

  OH^-

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
HCO_3^-	bicarbonate	SO_4^{2-}	sulfate
HSO_4^-	bisulfate	SO_3^{2-}	sulfite
HSO_3^-	bisulfite		

Practice Ionic Compounds

- Magnesium hydroxide
- Sodium hydroxide
- Tin (II) fluoride
- Iron (II) sulfate

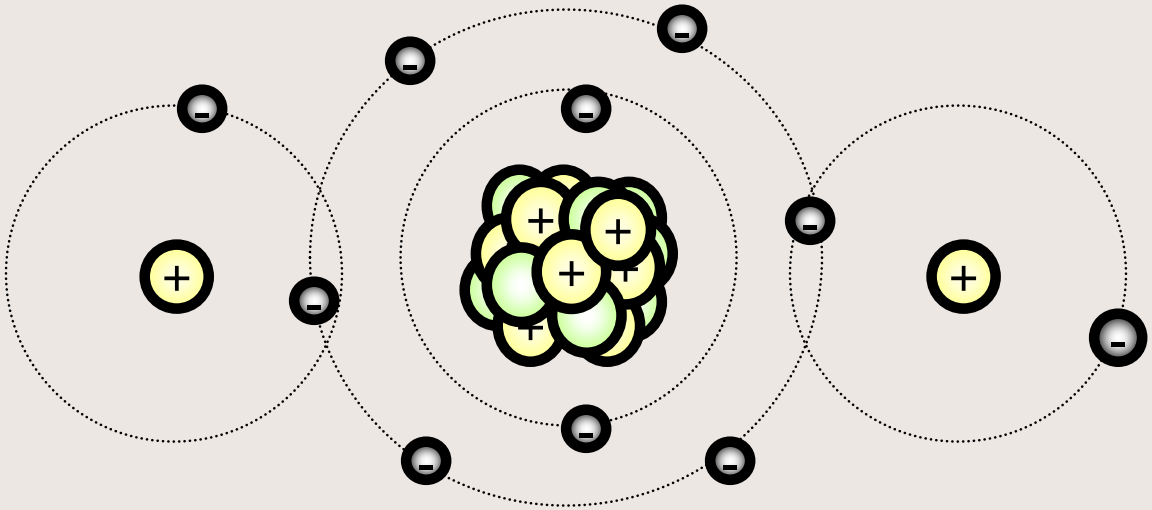
- $NaCl$
- MgO
- NH_4F
- K_2CO_3

More on Ionic Bonds

- https://www.youtube.com/watch?v=URc75hoKGLY&spfreload=10&spfreload=10
- https://www.youtube.com/watch?v=X_LVANMpJ0c&spfreload=10&spfreload=10&spfreload=10

COVALENT BOND

- Two atoms are bonded together by a sharing of electrons
- Each pair of shared electrons creates a bond
- Usually occurs between atoms of non-metals
- See how the electron shells overlap…



Example – Water (H_2O)

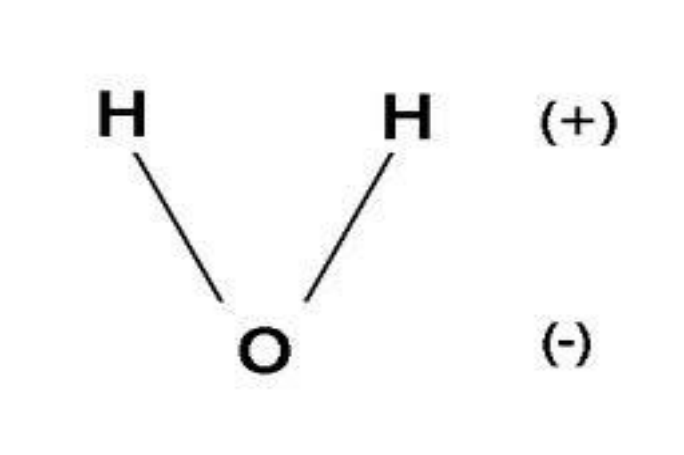
Structural Formulas

- Covalent bonds can be represented two ways:
  1. Chemical formula: H_2
  2. Structural formula: H-H

- Structural formulas tell us about the SHAPE of the molecule.

Water Molecule

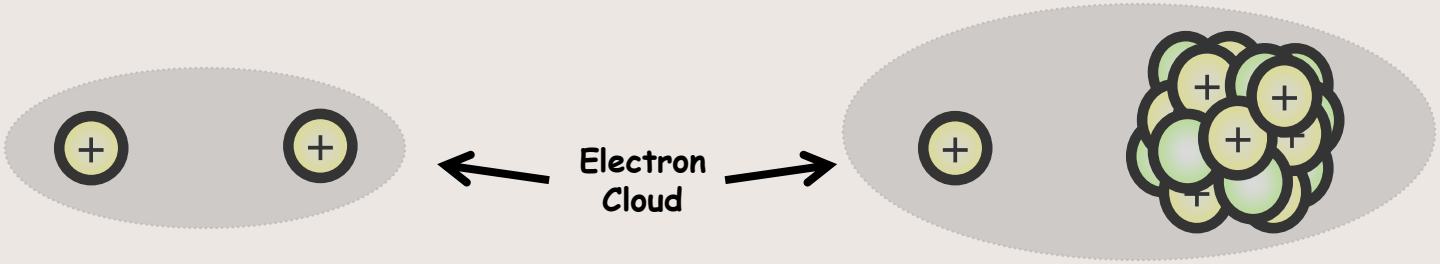
- The structural formula for water:



The positive and negative charges represent the "polarity" of water, a characteristic that gives water its unique properties!

Polar Covalent Bonds

- Its the unequal sharing of electrons between two atoms that gives rise to negative and positive regions of electric charge
- Results from an atom's electronegativity- the ability to attract electrons to itself



Bonded hydrogen atoms showing equal sharing of electrons

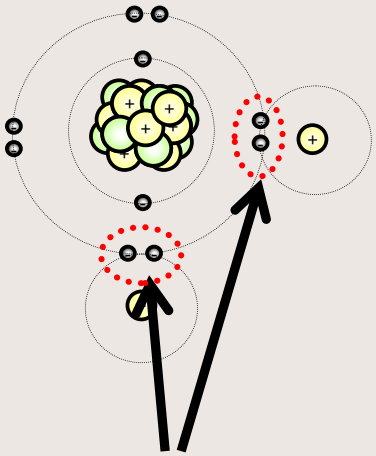
Hydrogen and fluorine bond with an unequal sharing of electrons

Why do you think the two Hydrogen atoms share equally, but the Hydrogen and fluorine do not?

Multiple Bonds

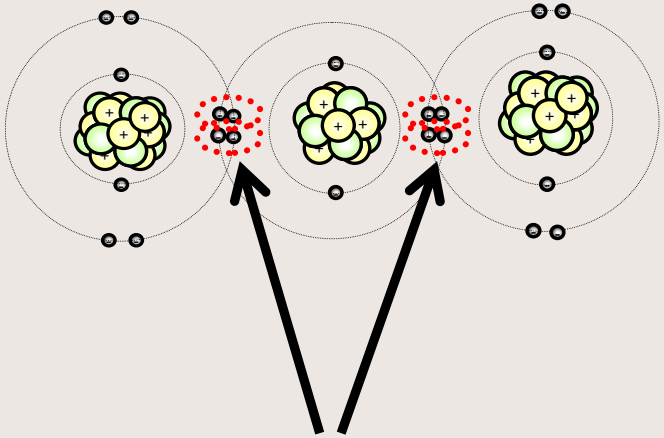
Sharing more than one pair of electrons!

Water (H_2O)



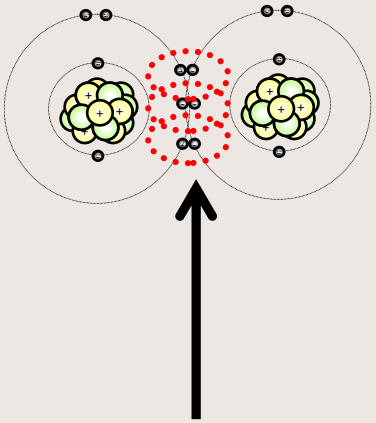
Single Bonds
Share 2 Electrons

Carbon Dioxide (CO_2)



Double Bonds
Share 4 Electrons

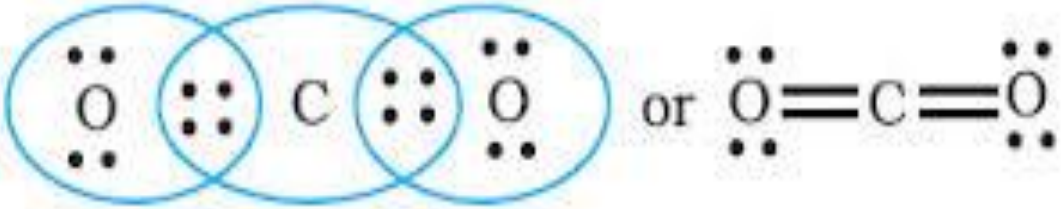
Nitrogen (N_2)



Triple Bonds
Share 6 Electrons

Sharing Electrons

Single bond	Double bond	Triple bond
H—H	O=O	N≡N
H : H	·Ö::Ö·	Ṅ:::Ṅ



Double bonds in CO_2 molecule

Naming Covalent Compounds

- Each element is named using a prefix to indicate the number of atoms of that element.
- The second element ends with the suffix "ide".
- Example: CO_2 = Carbon dioxide

Practice Naming Covalent Compounds

- Dinitrogen monoxide
- Carbon tetrachloride
- Sulfur trioxide
- Carbon monoxide

- H_2O_2
- CH_4
- O_3
- CF_4

More on Bonds

- https://www.youtube.com/watch?v=PKA4CZwbZWU&spfreload=10

Practice Writing Lewis Dot Structures for Compounds

- H_2
- CCl_4
- H_2S

O_2

N_2

CS_2

Single-Charge Ions

Element	*Symbol*	*Charge*
Zinc	Zn	2+
Tungsten	W	6+
Silver	Ag	1+
Cadmium	Cd	2+

Variable-Charge Ions

Element	*Symbol*	*Charge*
Chromium	Cr	2+,3+,6+
Manganese	Mn	2+,4+,7+
Iron	Fe	2+,3+
Cobalt	Co	2+,3+
Nickel	Ni	2+,3+
Copper	Cu	1+,2+
Tin	Sn	2+,4+
Gold	Au	1+,3+
Mercury	Hg	1+,2+
Lead	Pb	2+,4+

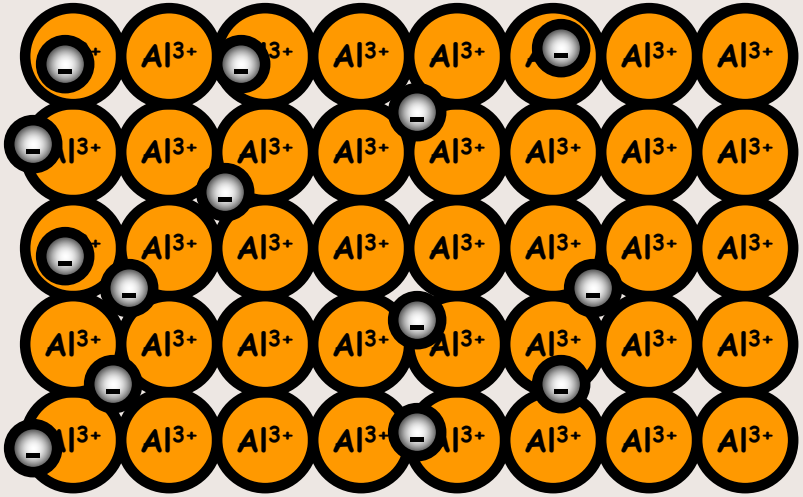
- Add titanium +3, +4

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
HCO_3^-	bicarbonate	SO_4^{2-}	sulfate
HSO_4^-	bisulfate	SO_3^{2-}	sulfite
HSO_3^-	bisulfite		

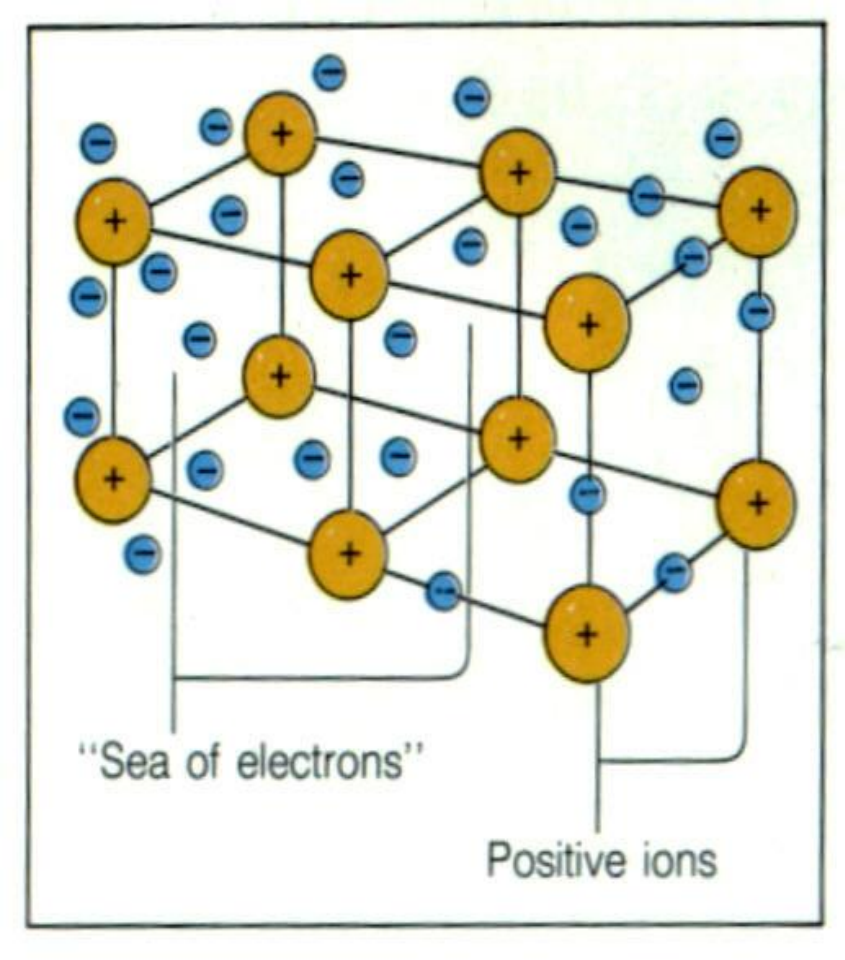
Metallic Bond

- A force of attraction between a positively charged metal ion and the electrons in a metal.
- Many metal ions pass along many electrons.
- Many properties of metals, such as conductivity, ductility, and malleability, result from the freely moving electrons in the metal.
- Usually occurs between atoms of metals.

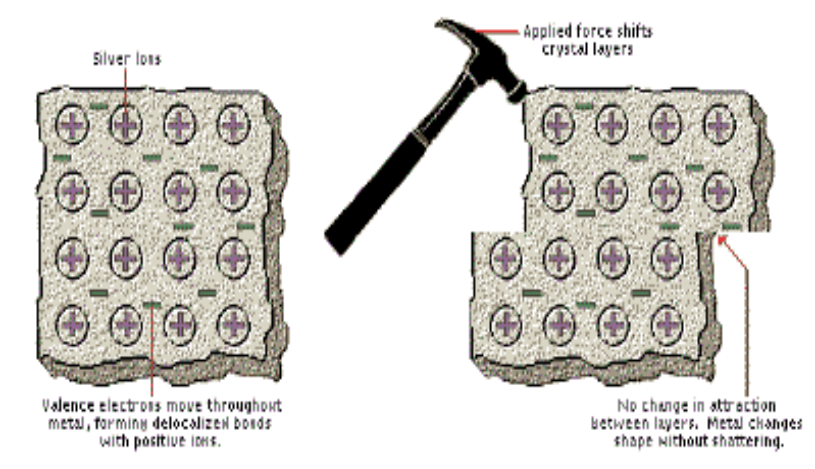


Notice how the electrons do not just stay with one ion

Metallic Bonds



- Valence electrons move freely around the nuclei of the metal ions.



Results of Bonding

Molecule

Two or more atoms chemically bonded together.

(alike or _____)

Example:

Diatomic - molecules consisting of two atoms of the same element bonded together

Examples:

H_2, F_2, O_2, N_2

Compound

Composed of two or more DIFFERENT atoms that are chemically bonded.

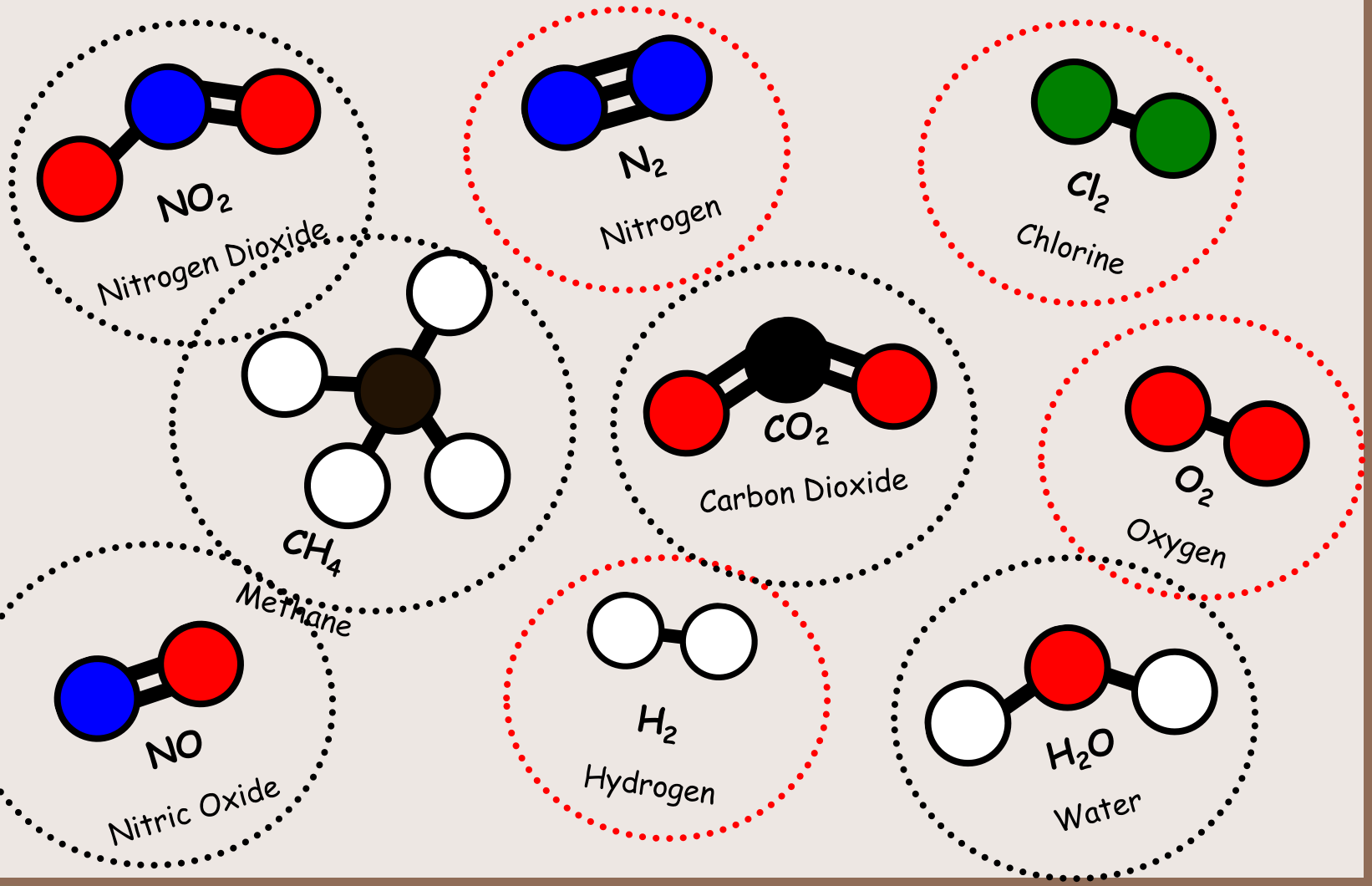
Example:

$CO, NO_2, NaCl$

https://www.youtube.com/watch?v=0gsrW0Vb5sw

What would you call something that has characteristics of both?

Molecule, Compound, or Both?



Chemical Reaction

- The process by which a chemical change occurs.
- Atoms are rearranged, and chemical bonds are broken and reformed.
- One or more substances change & produce one or more different substances.

Example:

$H_2O + CO_2 + \text{solar energy} \rightarrow C_6H_{12}O_6 + O_2$

Chemical Equation

- Represents a chemical reaction.
- Reactants on the right side.
- Products on the left side.
- Arrow indicates the direction of the reaction.

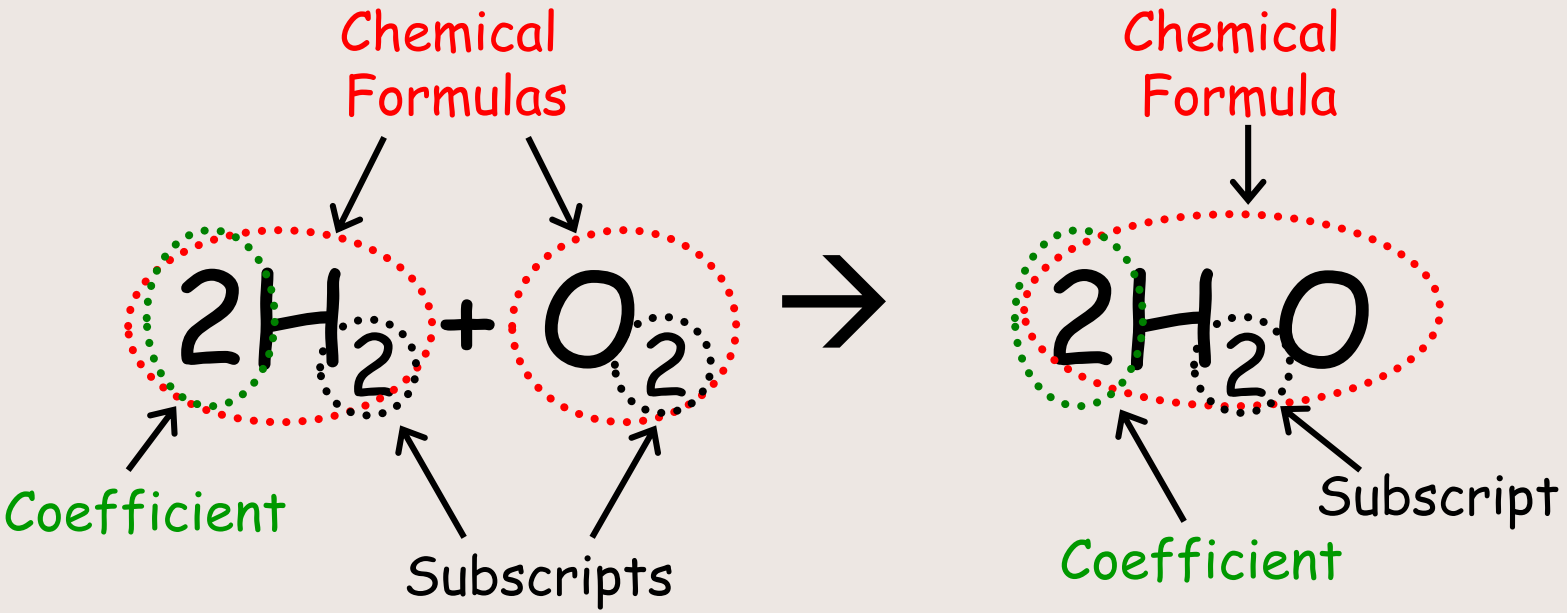
- Examples:

$$2H_2 + O_2 \rightarrow 2H_2O$$

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

Components of a Chemical Equation



(Reactants) *(Yield)* ***(Products)***

Sometimes you will see a "yields" sign that looks like this. What do you think it means?

Energy and Chemical Reactions

Exothermic Reaction

- A chemical reaction in which energy is released.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$

(respiration)

Endothermic Reaction

- A chemical reaction in which energy is absorbed.

$6CO_2 + 6H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2$

(photosynthesis)

Chemistry Comes Alive! Sample Movies
TeacherTube - Videos
Chemistry Demonstration Videos

Can you think of other reactions where energy is gained or released?

Rates of Chemical Reactions

The rates at which chemical reactions can take place are based on the interaction (collisions) between the different particles. These rates can be impacted by the following:

- Temperature –a measure of the average kinetic energy of the particles in a sample of matter
  - *Ex. Increasing the temperature when cooking*
- Surface area – amount of material that comes into contact with the reactants
  - *Ex. Cutting a potato into smaller pieces when cooking*
- Concentration – amount of substance per volume
  - *Ex. Adding extra potatoes will slow down how fast they will cook.*
- Catalysts (enzymes) – organic substances that help speed up chemical reactions, but are not consumed in the reaction
  - *Ex. Digestive enzymes speed up the breakdown of potatoes in your gut.*

Law of Conservation of Mass

- In a chemical reaction, atoms are neither created nor destroyed.
- All atoms present in the reactants are also present in the products
- Chemical equations must account for the conservation of mass - balancing equations!

In its present form, does this chemical equation show a conservation of mass?

$$2H_2 + O_2 \rightarrow 2H_2O$$

Reactants

H →	4
O →	2

How would you balance this equation to show the conservation of mass?

Products

H →	4
O →	2

Hints For Balancing Equations

- Count the atoms
  - *List the number of atoms of each element to see which elements must be balanced*
- Use a coefficient to add atoms to one side of the equation
  - *Start with the reactant or product that has the greatest number of different elements*
- Add a coefficient to another reactant or product
  - *Make sure that the coefficients in your balanced equation are the smallest whole numbers possible*https://www.youtube.com/watch?v=gskm-dfKv5g&spfreload=10

    https://www.youtube.com/watch?v=8ARlABEfPhQ

Tutorial on Balancing Equations

Types of Chemical Reactions

1) Synthesis Reaction:
   - When two or more substances combine to form a single compound

     $X + Y \rightarrow XY$

2) Decomposition Reaction:
   - Compound broken down into elements, simpler compounds or both

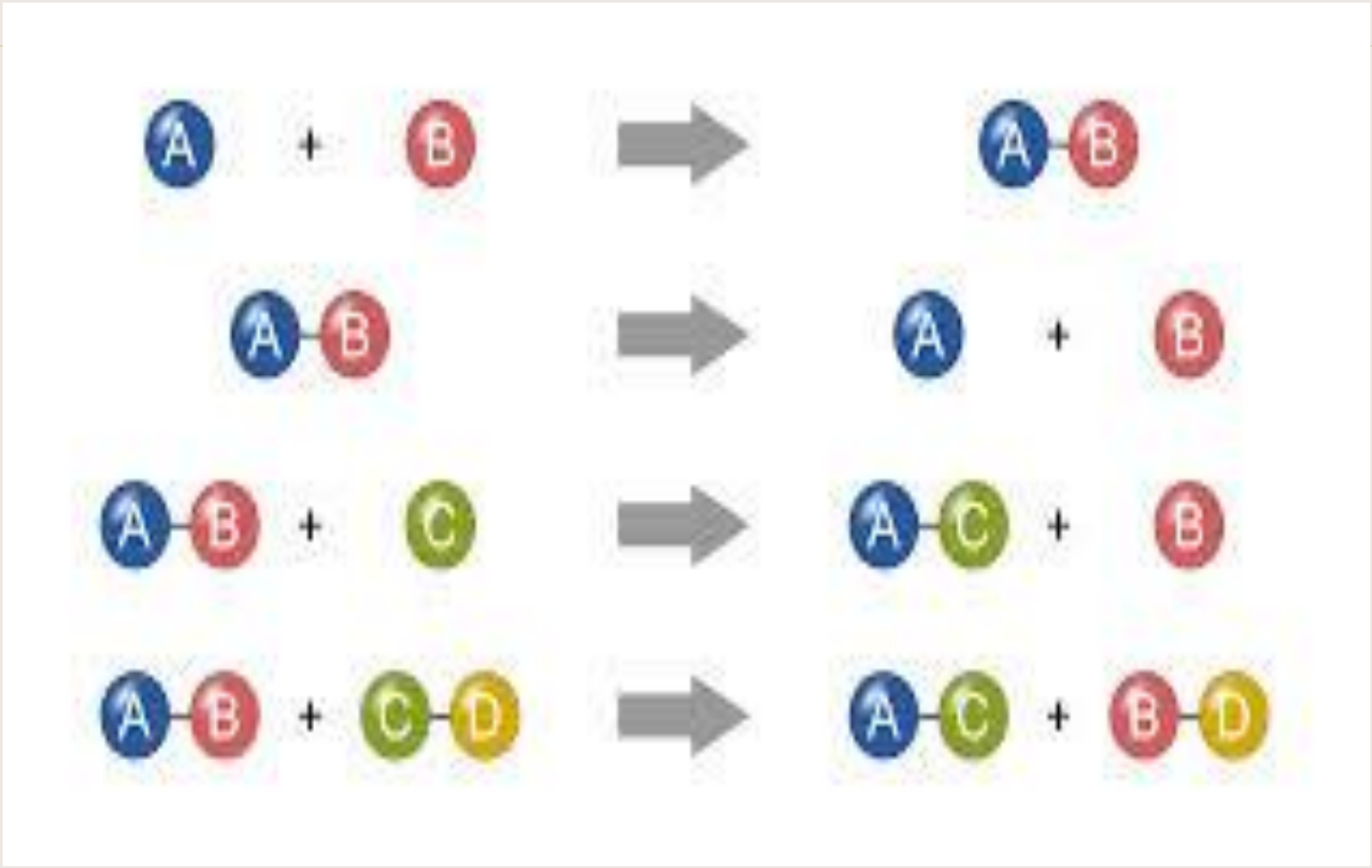
     (Opposite of combination) $XY \rightarrow X + Y$

3) Single Replacement Reaction:
   - Atom or polyatomic ion is replaced by a different atom or polyatomic ion

     $XY + Z \rightarrow XZ + Y$

4) Double Replacement Reaction:
   - Atoms of one compound trade places with another.

     $AX + BY \rightarrow AY + BX$


A + B
A B
A B
A + B
A B + C
A C + B
A B + C D
A C + B D

Practice Identifying Reactions

1. $ZnCO_3 \rightarrow ZnO + CO_2$

1. $2Na + Cl_2 \rightarrow 2NaCl$

1. $NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$

1. $C + ZnO \rightarrow Zn + CO$