Ionic and Covalent Bonding

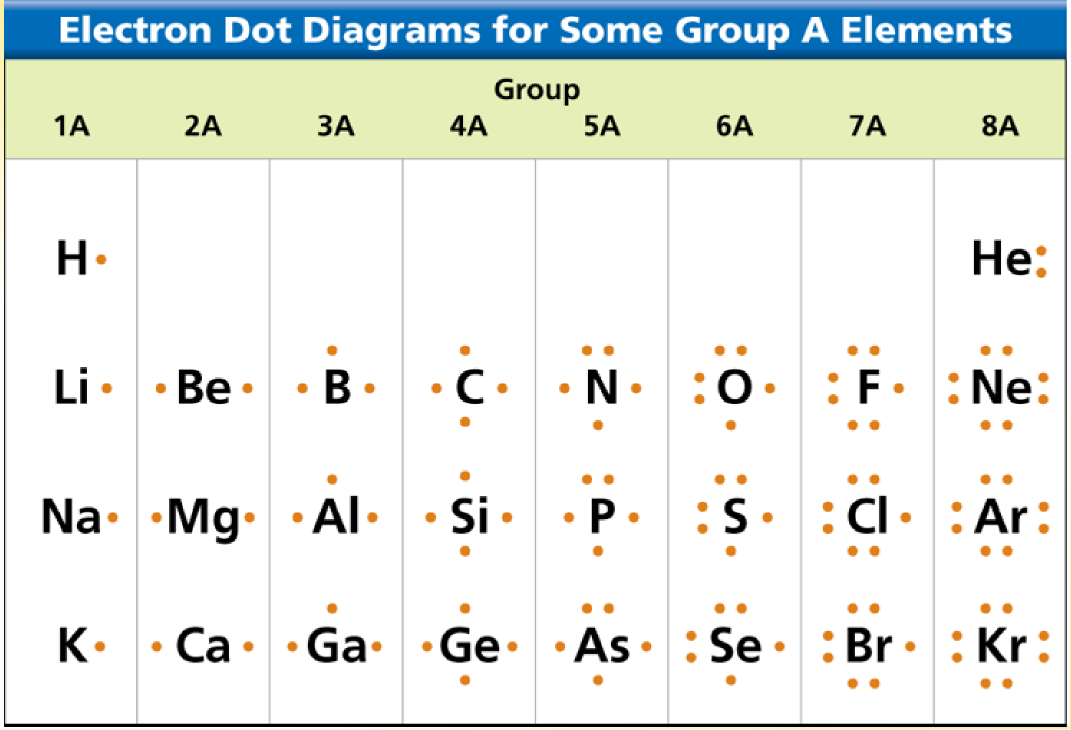
Chapter 6.1 – 6.2

Ionic and Covalent Bonding

Atom Stability

Ionic Bonds & Compounds

Covalent Bonds & Molecules

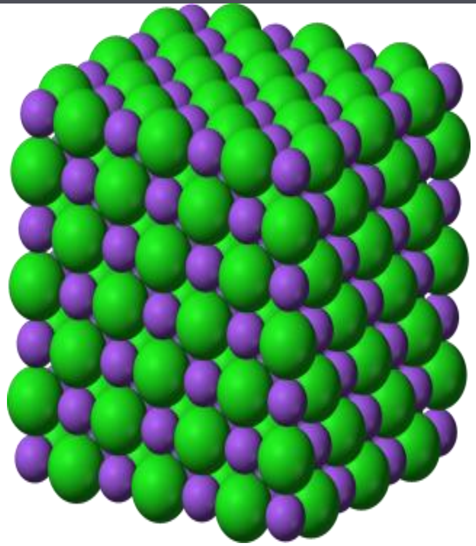


Ionic & Covalent Bonding

Focus Points

- Understand the conditions of stability for atoms and explain why atoms bond.
- Draw electron dot diagrams for elements 1-20 and for bonded atoms showing a full valence (8).
- Explain and show how elements become ions (cations and anions).
- Distinguish ionic bonds from covalent bonds, listing properties of ionic compounds and covalent molecules.
- Explain covalent bonding in terms of bonds (nonpolar and polar) and molecules (nonpolar & polar).

There are three main ways that elements can come together to form bonds.



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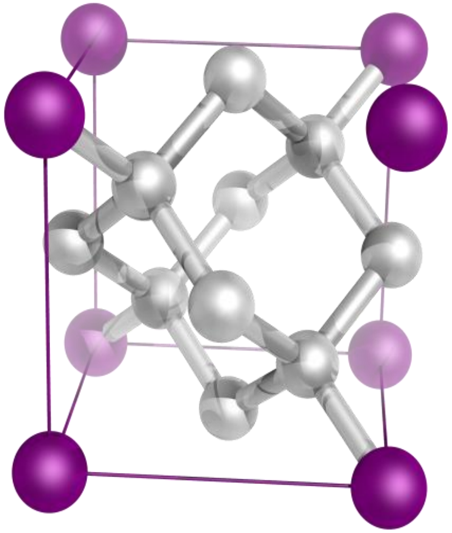

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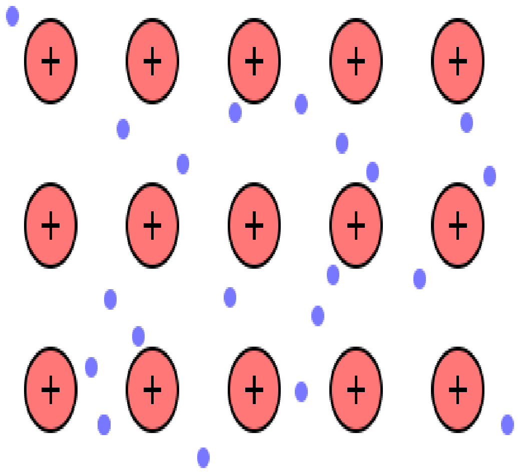

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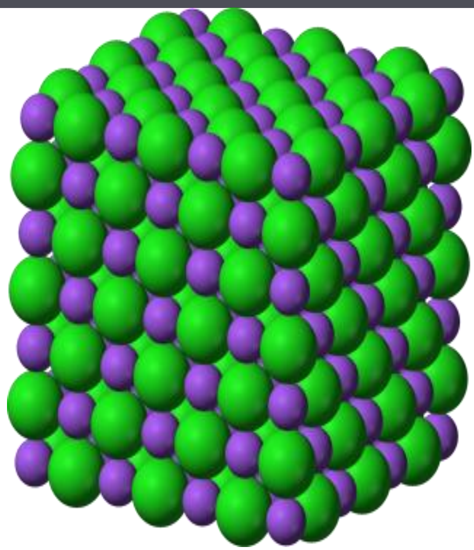
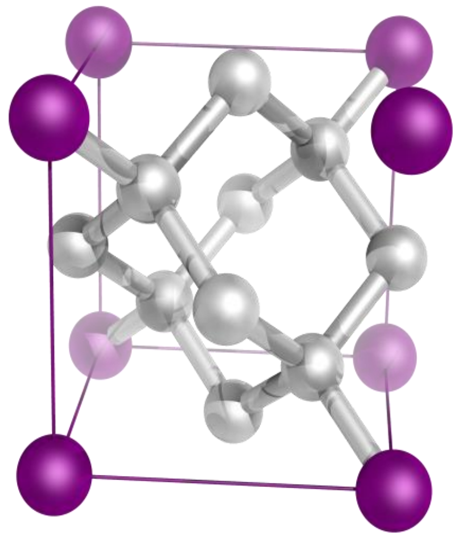
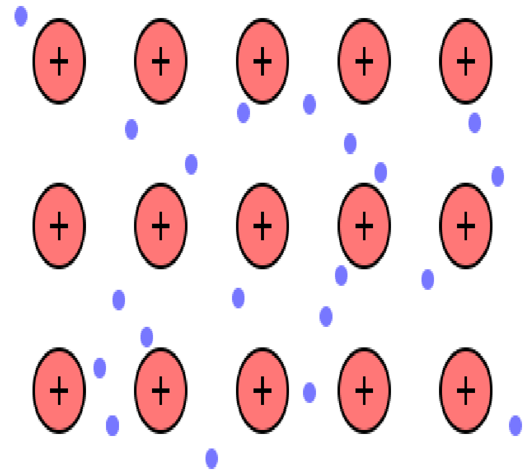
There are three main ways that elements can come together to form bonds.



Ionic



Covalent



Metallic

Conditions for Atoms to Bond

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Conditions for Atoms to Bond

Electrical Neutrality

- Atoms are neutral before bonding.
- But RARELY have a complete valence … so almost all unbonded atoms are unstable.

Complete Valence

- Atoms have incomplete valence prior to bonding.
- Their outermost electrons are unstable.

Conditions for Atoms to Bond

Electrical Neutrality

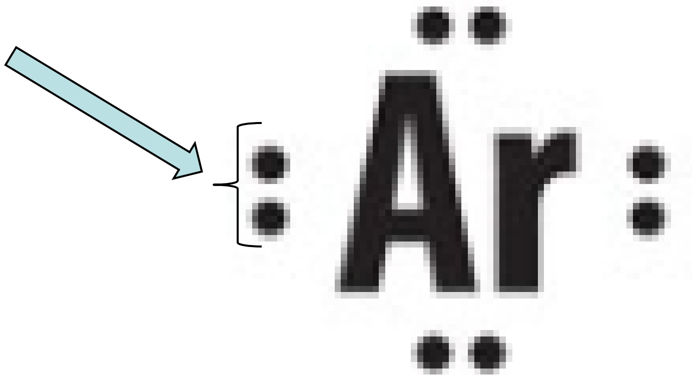
- Atoms Bond and become neutral as a unit.
- Ionic compounds are neutral because they have both cations and anions.

Complete Valence

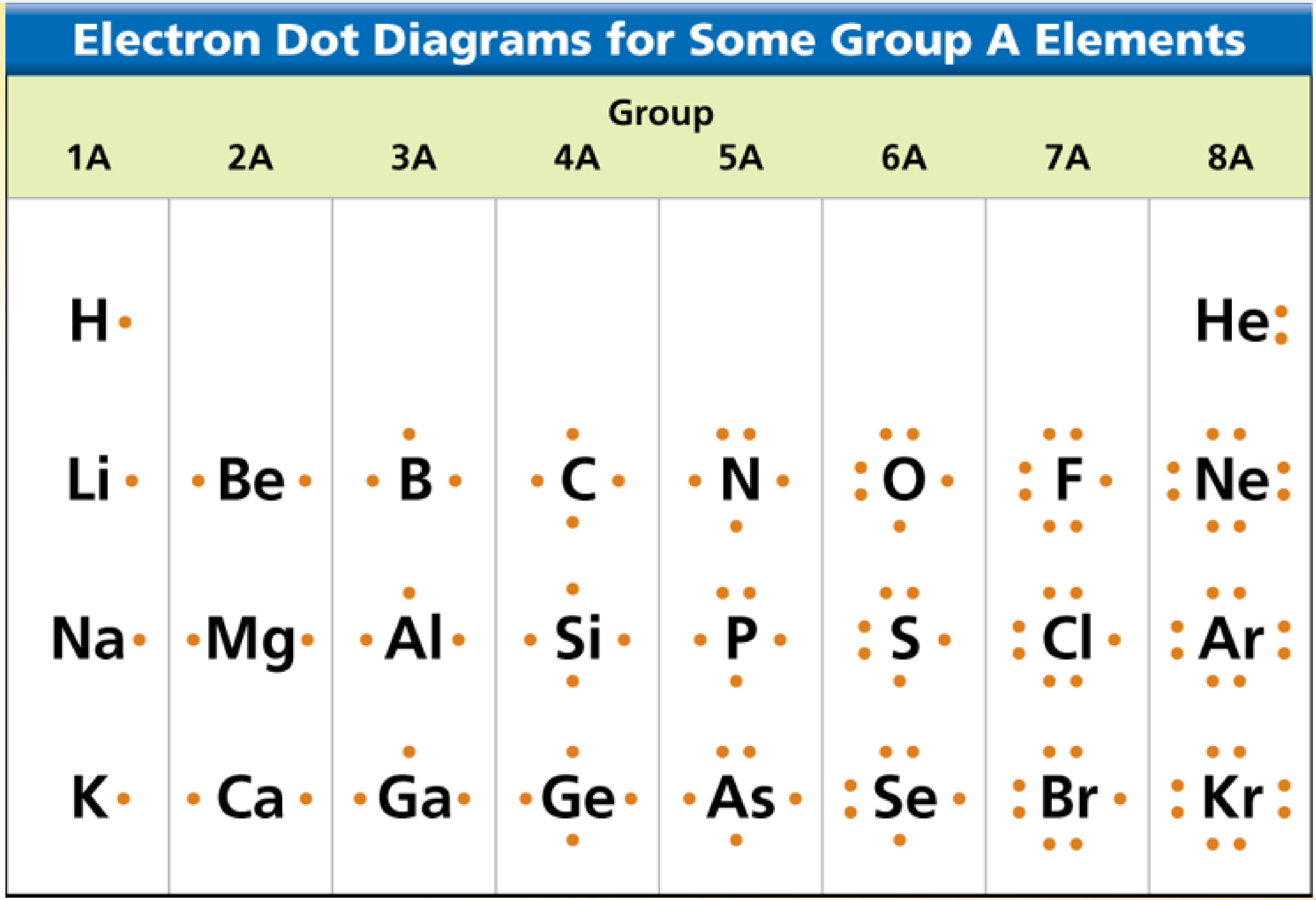
- Atoms bond to complete their outer shell of electrons.
- 8 is the “magic” number
- Octet rule.

Electron Dot Diagrams

- The chemical properties of an element depend on the number of valence electrons.
- An **electron dot diagram** is a model of an atom in which dots represent valence electrons.
- Valence electrons include ONLY the outermost orbitals of electrons.
- ***Each orbital can contain up to 2 e-***



The valence is indicated by the “A” group number, which gives the number of dots needed.



Electron Dot Diagrams

Lewis Structures (5 steps) (4:57)

https://screencast-o-matic.com/watch/cFQ3lKqS4e

TRY IT

Give the nuclear symbol and e- dot diagrams:

Lithium

Magnesium

Gallium

Silicon

Phosphorus

Oxygen

Fluorine

Argon

Lewis (Electron dot) Structures

TRY IT

Electron Dot Structures of Some Group A Elements

Period	IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA
	Group							
1	H·	$_{12}Mg^{24}$		$_{14}Si^{28}$	$_{15}P^{31}$	$_{8}O^{16}$	$_{9}F^{19}$	He:
2	Li·	·Be·	·Ḃ·	·Ċ·	·N̈·	:Ö·	:F̈·	:N̈e:
3	Na·	·Mg·	·Ȧl·	·Ṡi·	·P̈·	:S̈·	:C̈l·	:Är:
4	K·	·Ca·	·Ġa·	·Ġe·	·Äs·	:S̈e·	:B̈r·	:K̈r:

$_{3}Li^{7}$

$_{18}Ar^{40}$

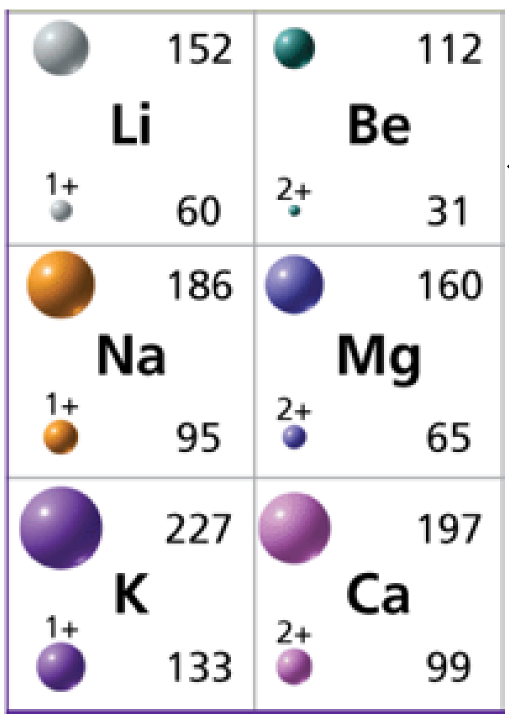
$_{31}Ga^{70}$

Notice that all the electrons within a given "A" group (*with the exception of helium*) have the same number of electron dots in their structures.

Formation of Ions

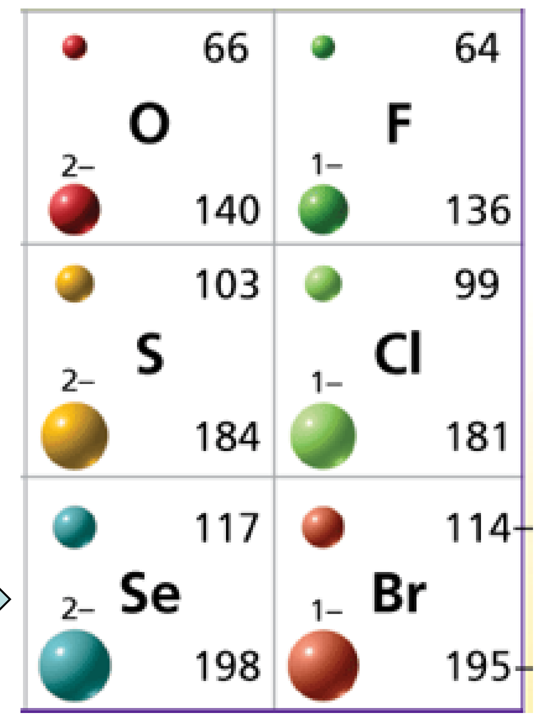
A neutral atom (*unbonded*) is electrically neutral because it has equal numbers of **protons (+)** and **electrons (-)**.

An **ion** forms when an atom or group of atoms loses or gains electrons.



A positively charged ion (**cation**) is produced when an atom loses valence electrons.

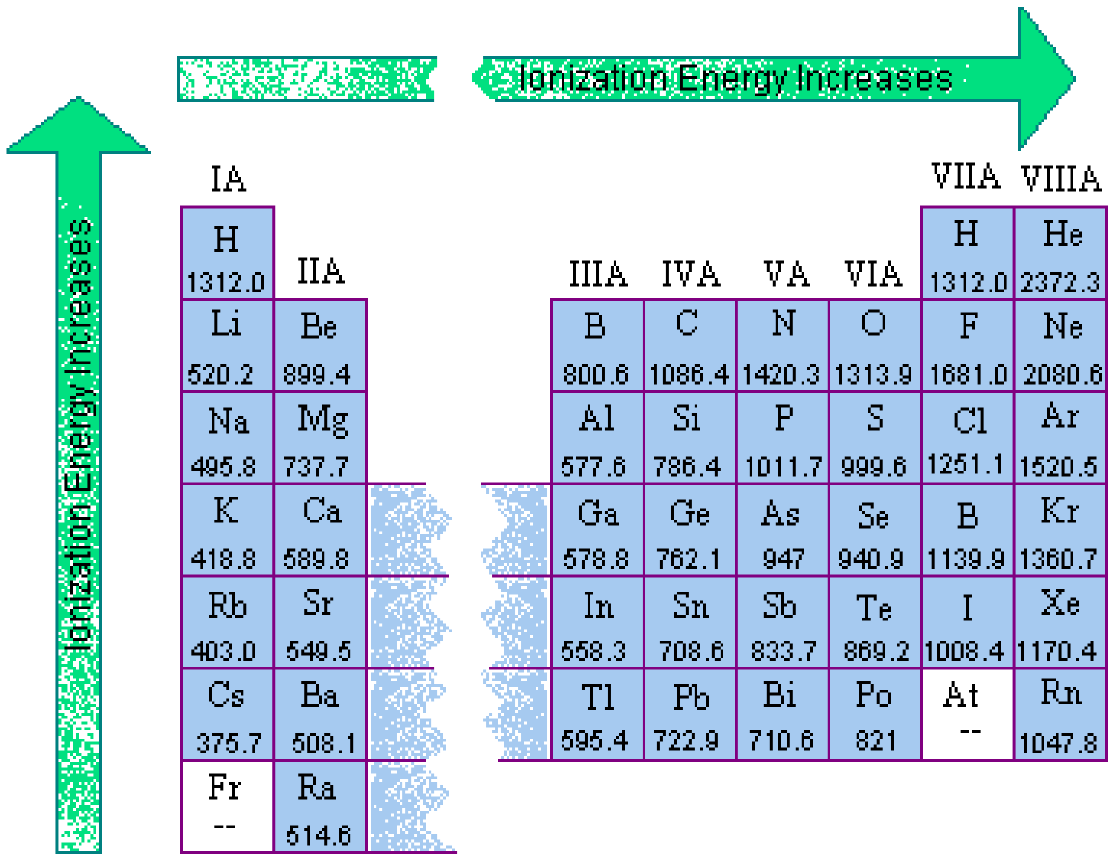
A negatively charged ion (**anion**) is produced when an atom gains valence electrons.



Formation of Ions

Ionization Energy is the amount of energy needed to remove an electron from its valence.

- The lower the ionization energy, the easier it is to remove an electron from an atom.

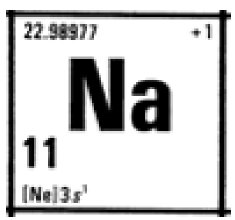


Formation of Cations

Metals tend to **lose** their valence electrons due to **LOW Ionization Energy**, leaving a complete octet or valence in the next-lowest energy level.

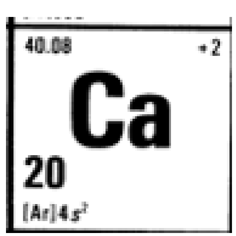
- A sodium atom (Na), group 1A, forms a sodium cation (**Na^{+}**).

+11 p 11 e- → +11 p 10 e- = +1 cation



- A calcium atom (Ca), group 2 A, forms a calcium cation (**Ca^{2+}**).

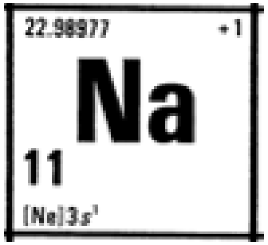
+20 p 20 e- → +20 p 18 e- = +2 cation



Alkali Metals (Group IA)

- Group 1 or IA
- Easily lose an electron to form a +1 cation *in order to gain ideal electron configuration*
- **"Magic number is "8" … s2 + p6**
- *Is it easier for the metals to gain 7 electrons to make 8 or to lose 1 electron to have a full valence in the next lowest energy level?*

$_{11}Na^{23}$ neutral atom



+11 p
<u>-11 e</u>
0

+11 p
<u>-10 e</u>

+1 charge

Alkaline Earth Metals (Group IIA)

- Group 2 or IIA
- Lose two electrons to form a **+2 cation** *in order to gain ideal electron configuration*

$_{12}Mg^{24}$ neutral atom

+12 p
<u>-12 e</u>
0

- **"Magic number is "8" … s2 + p6**
- *Is it easier for the metals to gain 6 electrons to make 8 or to lose 2 electron to have a full valence in the next lowest energy level?*

+12 p
<u>-10 e</u>
+2 charge

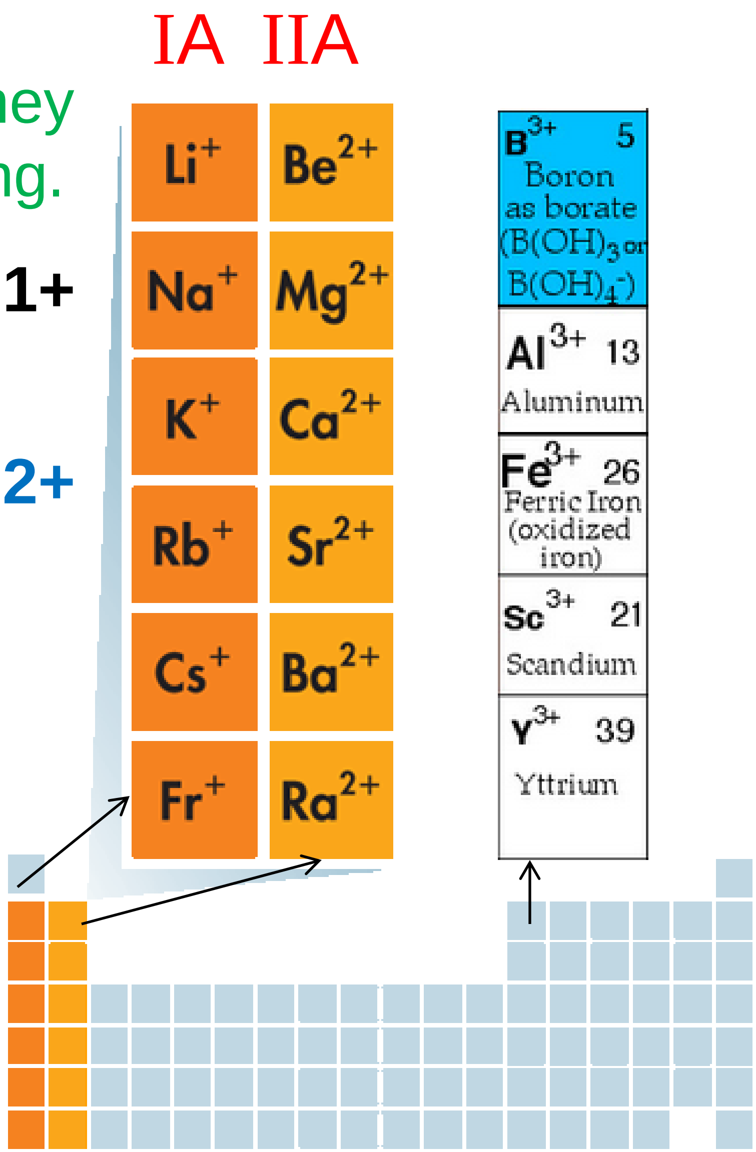
Formation of Cations

Remember that metals have a **LOW Ionization Energy (I.E.)**, meaning they easily give up electrons when bonding.

Group 1A elements always form 1+ cations.

Group 2A elements always form 2+ cations.

Group 3A elements usually form +3 cations.



Practice Making Cations

TRY IT

Give the nuclear symbol, *p+*, *e-*, *charge*, *valence* of each element BEFORE bonding.

Aluminum

Magnesium

Potassium

Boron

Practice Making Cations

TRY IT

Give the nuclear symbol, *p+*, *e-*, *charge*, *valence* of each element BEFORE bonding.

Aluminum (group 3A)

$_{13}Al^{27}$

13p 13e- = 0

Valence = 3

Magnesium (group 2A)

$_{12}Mg^{24}$

12p + 12e- = 0

Valence = 2

Potassium (group 1A)

$_{19}K^{39}$

19p + 19e- = 0

Valence = 1

Boron (group 3A)

$_{5}B^{11}$

5 p + 5e- = 0

Valence = 3

Practice Making Cations

TRY IT

Give the cation of each element AFTER bonding (*include p+, e-, charge, valence*)

Aluminum

Magnesium

Potassium

Boron

Practice Making Cations

TRY IT

Give the cation of each element AFTER bonding (*include p+, e-, charge, valence*)

Aluminum (group 3A)

Al^{+3}

13p 10e-

Valence = 8

Magnesium (group 2A)

Mg^{+2}

12p 10e-

Valence = 8

Potassium (group 1A)

K^{+}

19p 18e-

Valence = 8

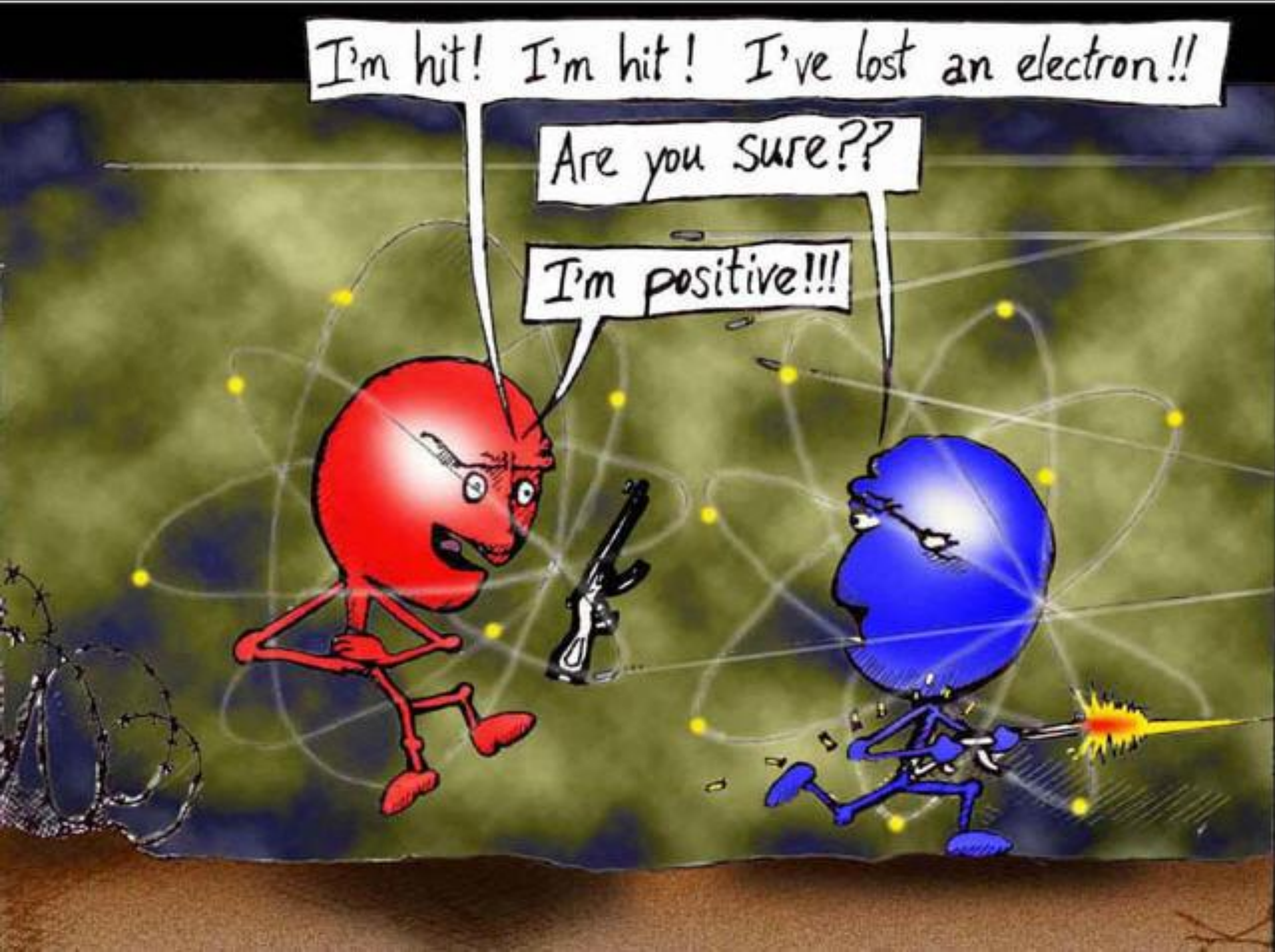
Boron (group 2A)

B^{+3}

5 p 2e-

Valence = 2*

*Period 1 energy level

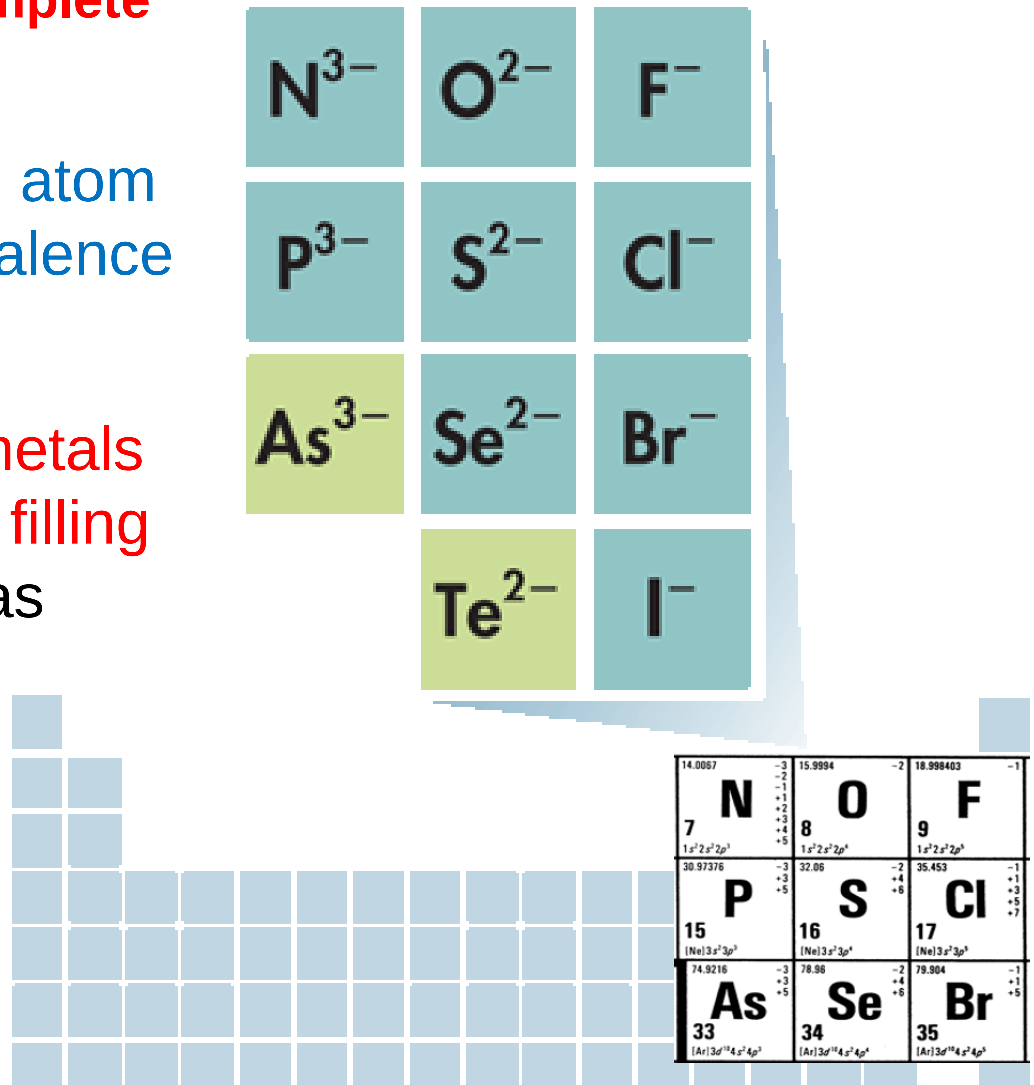

I'm hit! I'm hit! I've lost an electron!!
Are you sure??
I'm positive!!!

Formation of Anions

Non-metals tend to gain their valence electrons due to HIGH Ionization Energy, creating a complete octet or valence.

An anion is produced when an atom gains or shares one or more valence electrons.

As with metals, atoms of nonmetals and metalloids form anions by filling their valence to attain noble gas electron configuration.

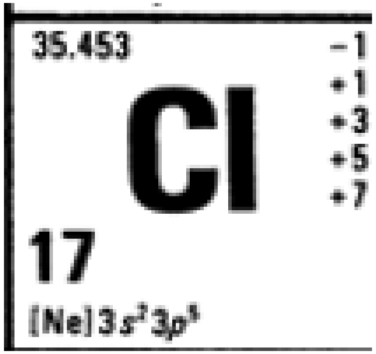


Halogens (Group VIIA)

- Group 17 or VIIA
- Easily gain an electron to form a –1 anion *in order to gain ideal electron configuration*
- **"Magic number is "8" … s2 + p6**
- *Is it easier for the non-metal to gain 1 electron to make 8 or to lose 7 electrons to have a full valence in the energy level?*

$_{17}Cl^{35}$

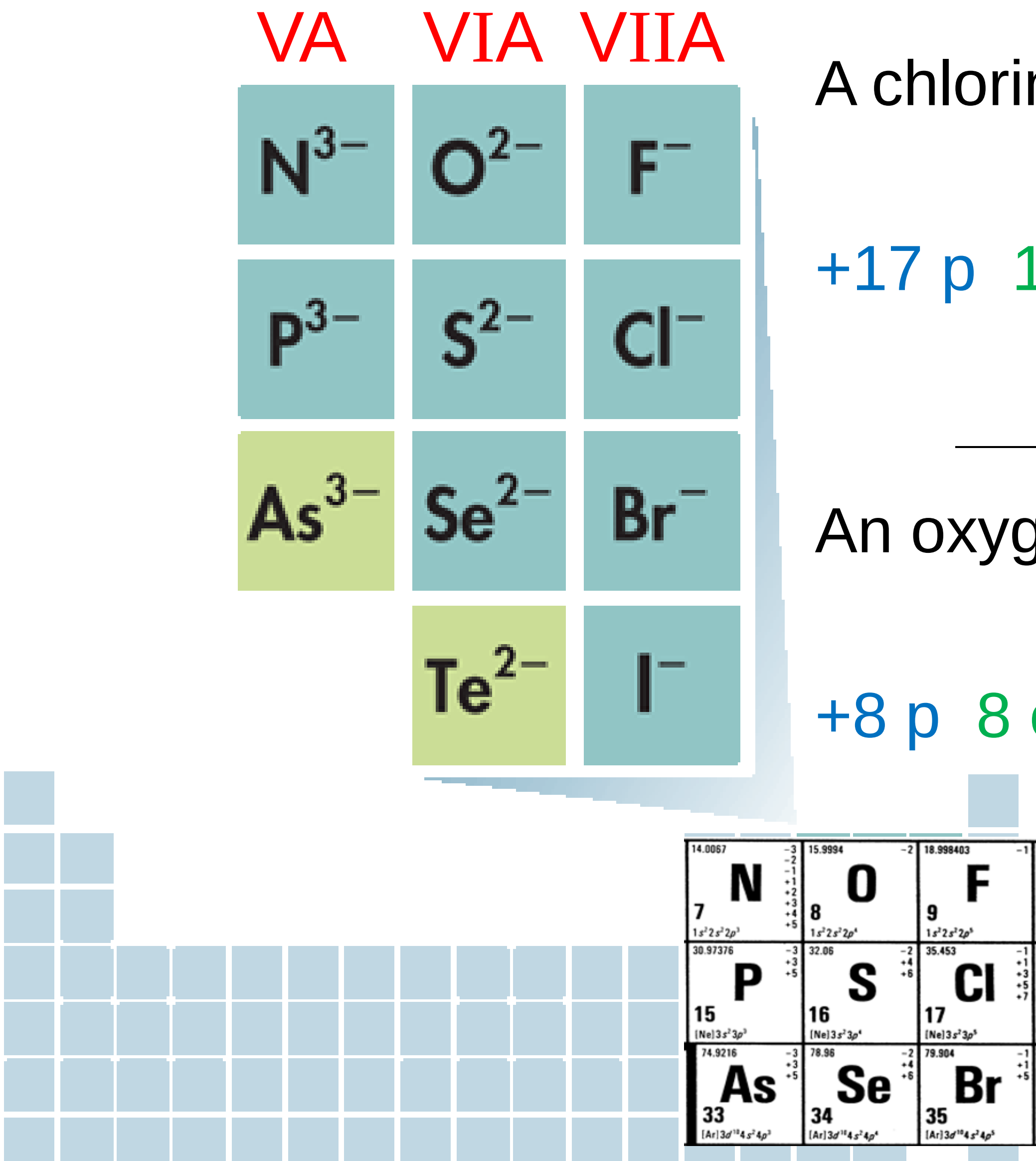
+17 p
-17 e
0



+17 p
-18 e

-1 charge

Formation of Anions



A chlorine atom (Cl) forms
a chloride anion (Cl-)

+17 p 17 e- → +17 p 18 e- = -1 anion

An oxygen atom (O) forms
an oxide anion (O^{2-})

+8 p 8 e- → +8 p 10 e- = -2 anion

QUICK CHECK

Show *e- dot diagram* of the following atoms BEFORE bonding & then how they become ions (*p+*, *e-*, *charge*):

Potassium

Nitrogen

Sulfur

Beryllium

Aluminum

Bromine

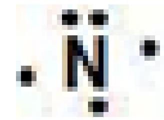
QUICK CHECK

Show *e- dot diagram* of the following atoms before bonding & then how they become ions (*p+*, *e-*, *charge*):

Potassium 

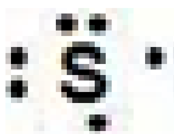
+19 p 18 e-

+1 cation, K^{+1}

Nitrogen 

+7 p 10 e-

-3 anion, N^{-3}

Sulfur 

+16 p 18 e-

-2 anion, S^{-2}

Beryllium 

+4 p 2 e-

+2 cation, Be^{+2}

Aluminum 

+13 p 10 e-

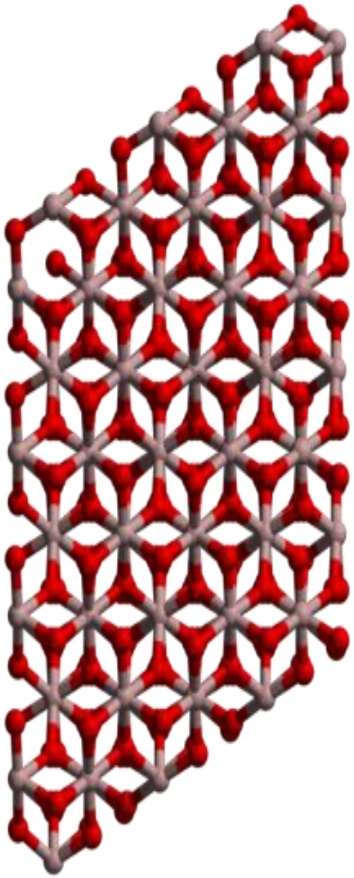
+3 cation, Al^{+3}

Bromine 

+35 p 36e-

-1 anion, Br^{-1}

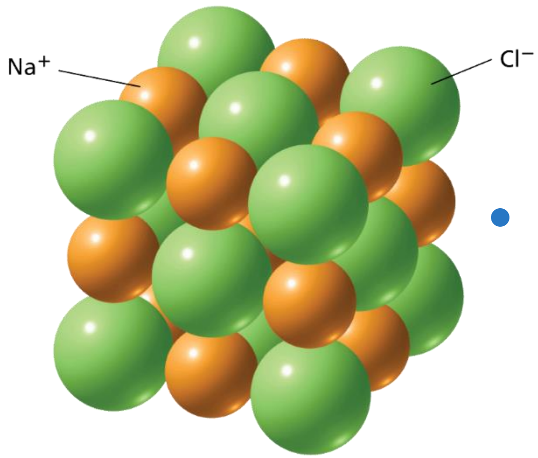
How Do Atoms become stable overall?



Electrons may be transferred or shared between atoms.

- Ionic compounds are formed when electrons are **transferred** (*lost or gained*) between atoms.
- Covalent molecules are formed when electrons are **shared** (*equally or unequally*) between atoms.

How Ionic Compounds Form.



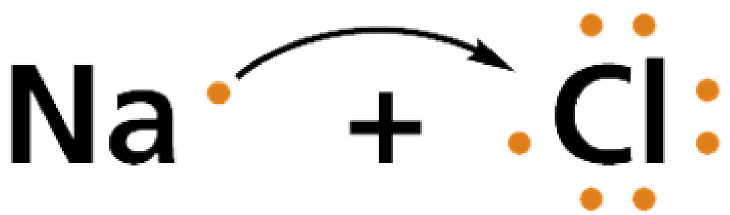
- An **ionic compound** is a compound composed of cations and anions.
- *Sodium chloride, or table salt, is an ionic compound consisting of sodium cations and chloride anions.*
- Although they are composed of ions, ionic compounds are electrically neutral overall.
- The total positive charge of the cations equals the total negative charge of the anions.

Formation of Ionic Compounds

Ionic Bonds

Anions and cations have opposite charges and attract one another by means of **electrostatic forces** which are called **ionic bonds**.

When sodium and chlorine react to form a compound, the sodium atom **transfers** its valence electron to the chlorine atom.

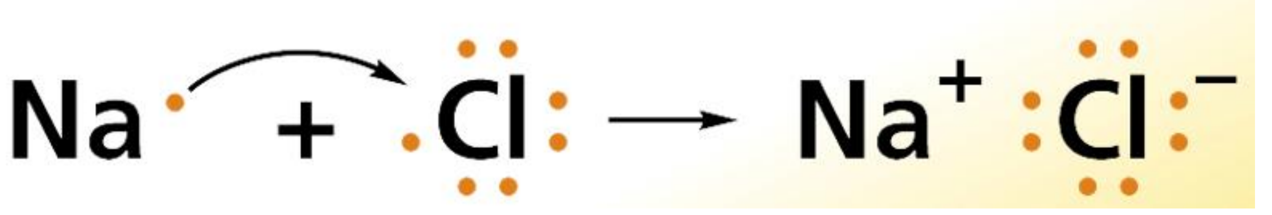


Each atom ends up with a more stable electron configuration than it had before the transfer.

Formation of Ionic Compounds

Ionic Bonds

To obtain electrical neutrality and stable octets (valence), sodium and chlorine atoms combine.



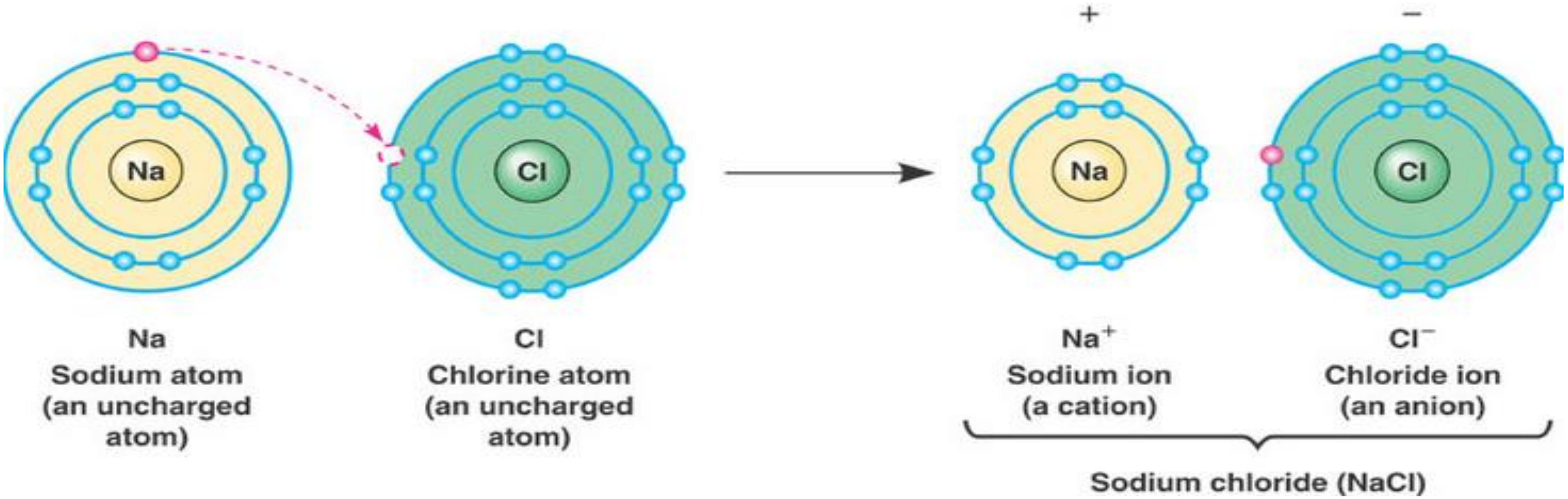
NOTICE: +1 -1 = 0 (neutral)

- **The sodium atom became a cation (+) and the chlorine atom became an anion (-).**
- **The overall charge of bonded atoms must equal zero to gain stability.**

Ionic Bonds

An **ionic bond** is an attraction between two oppositely charged ions.

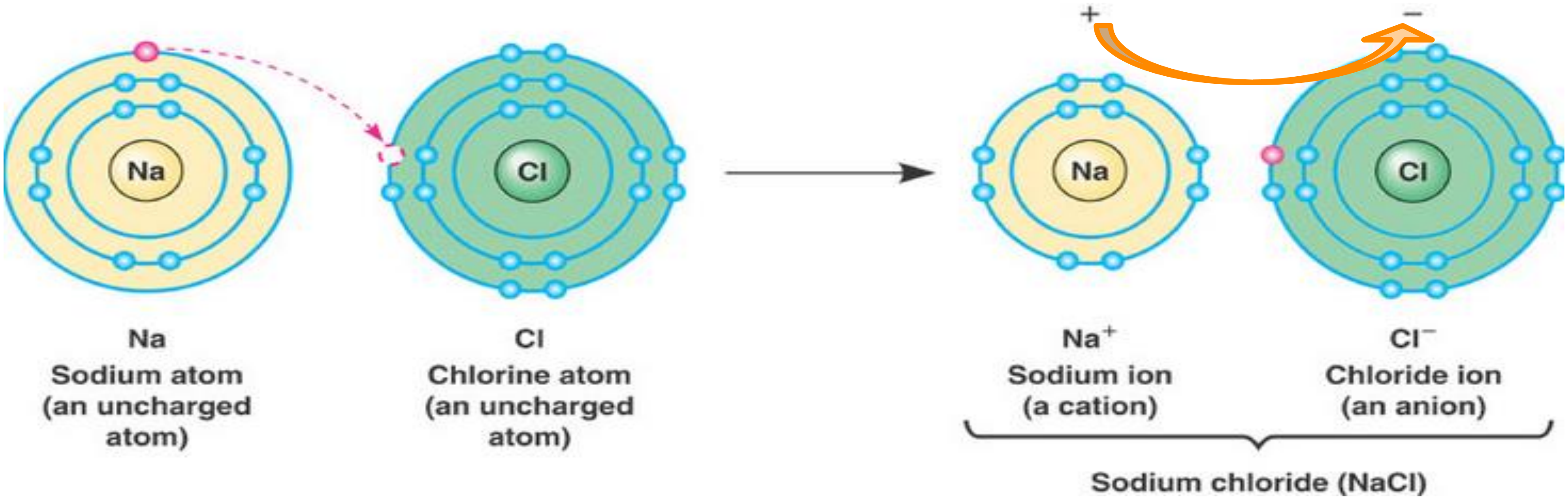
Atoms are most stable with electrical neutrality and full valence.



Ionic Bonds

An **ionic bond** is an attraction between two oppositely charged ions.

Atoms are most stable with electrical neutrality and full valence.

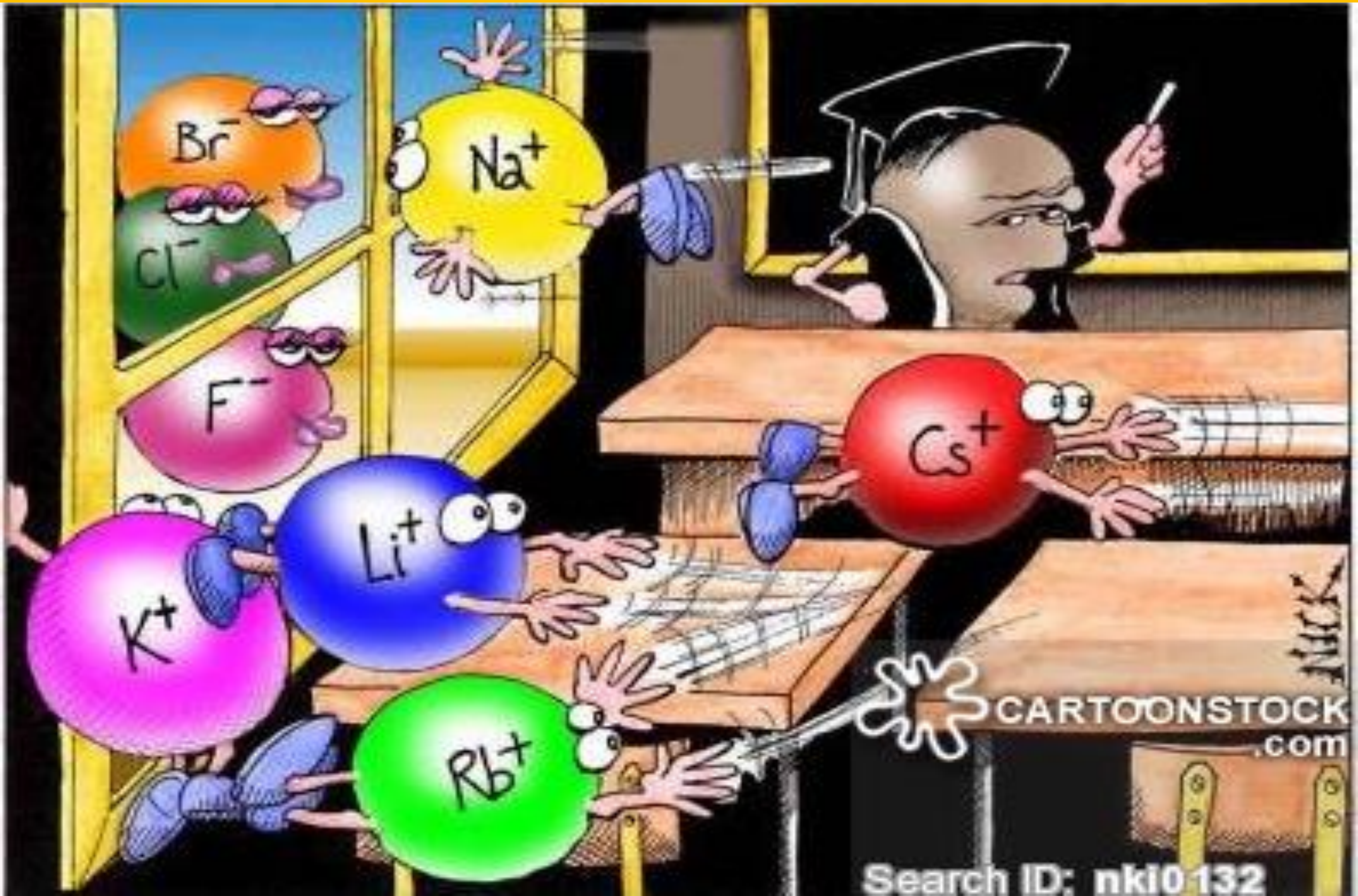


Na and Cl are electrically neutral, but their valence is NOT full

To become more stable, sodium transfers its electron to Chlorine

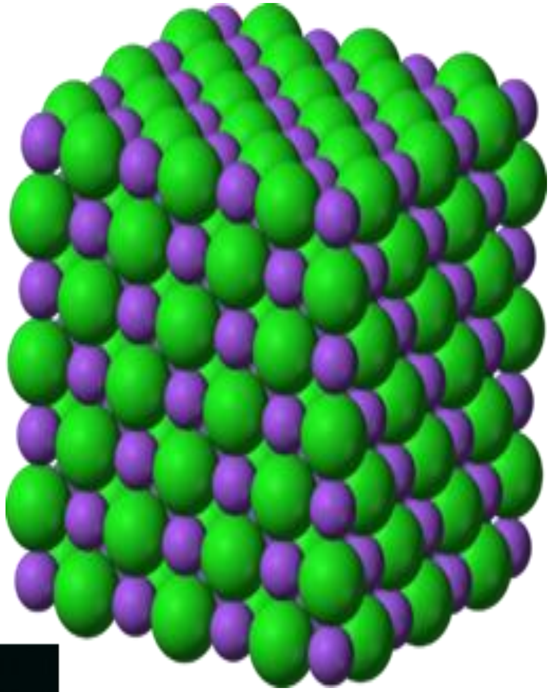
Electrostatic attraction between ions

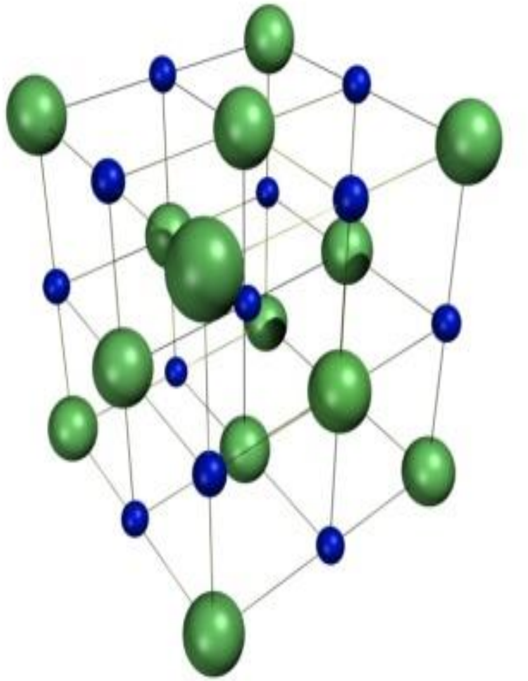
Perhaps one of you gentlemen would mind telling me just what it is outside the window that you find so attractive?



Properties of Ionic Compounds

- High melting point (801°C).
- Mostly solids.
- As **solids**, ionic compounds are **poor conductors** of electric current.
- When melted or **dissolved**, they are **good conductors** of electric current.
- Form **crystal** structures that shatter when struck with a hammer.

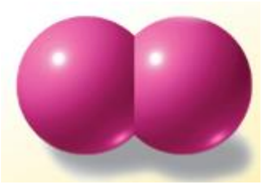




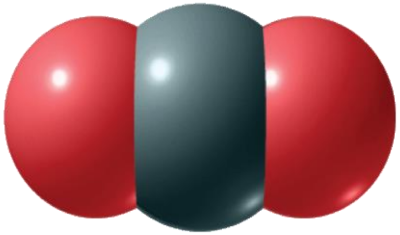
Crystal Lattices

LESSON QUESTION

How Covalent Molecules Form.

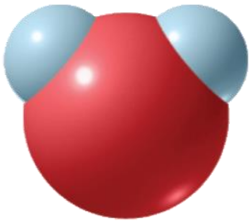


- A **covalent bond** is a chemical bond in which two atoms **share** a pair of valence electrons.



CO_2

- Covalent molecules are neutral because the atoms bonded together contain the same number of protons (+) as electrons (-).



H_2O

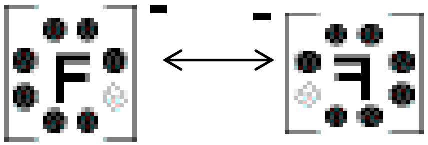
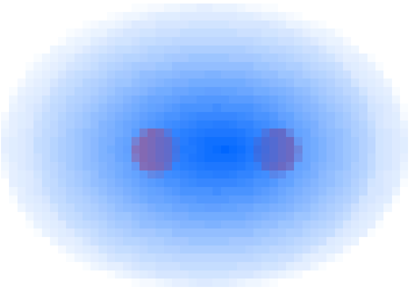
- However, the sharing may not be equal between the atoms.

A covalent bond is formed when two or more atoms SHARE electrons ... but HOW are the electrons shared?

There are different types of covalent bonds:

1. Non-polar covalent
2. Polar covalent

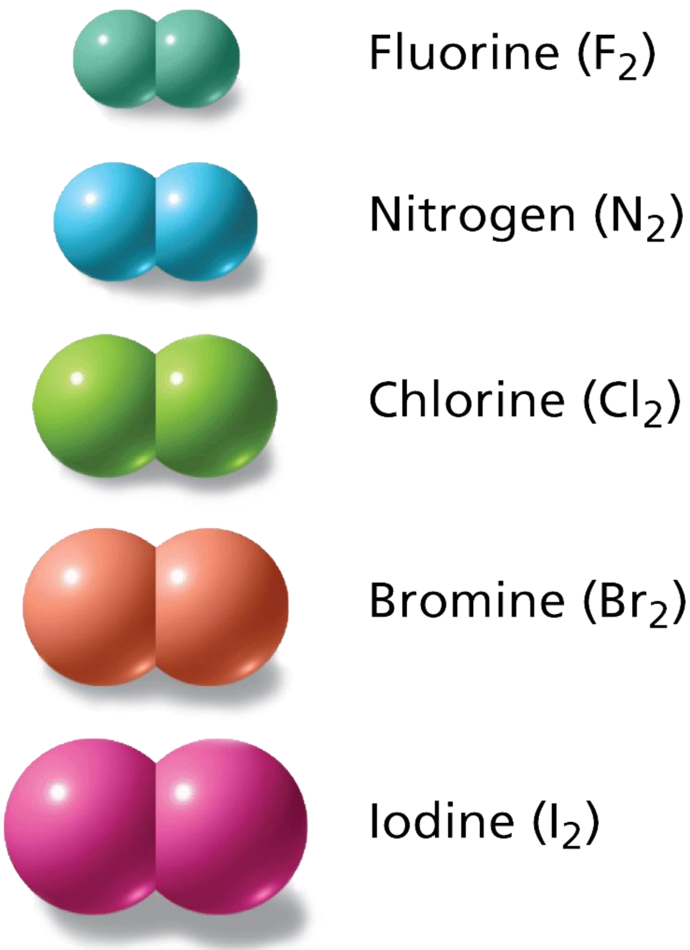
Non-Polar bonds mean that electrons are shared **EQUALLY** between atoms.

- Both atoms have a complete electron configuration.
- Electron dot diagram of F_2 
  [*Each atom has a valence of 8 when bonded*]
- Symbol of bond F–F
- Electron cloud graphic → 

Non-Polar bonds

There are 7 diatomic ("two atom") elements that exist in nature.

Professor "HOFBrINCl"

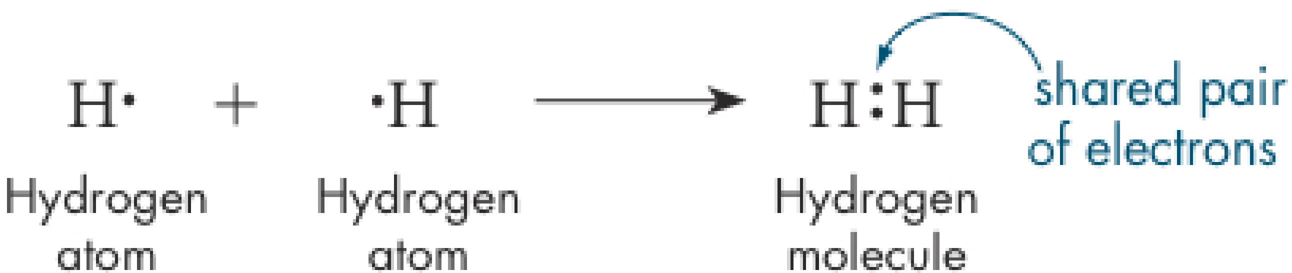


Single Covalent Bonds

- Form from the sharing of **ONE <u>PAIR</u> of electrons** between atoms.

  e.g. Hydrogen gas consists of diatomic molecules whose atoms share only one pair of electrons attracted to the nuclei, forming a single covalent bond.

H_2

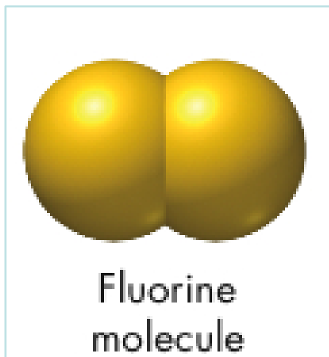


H—H

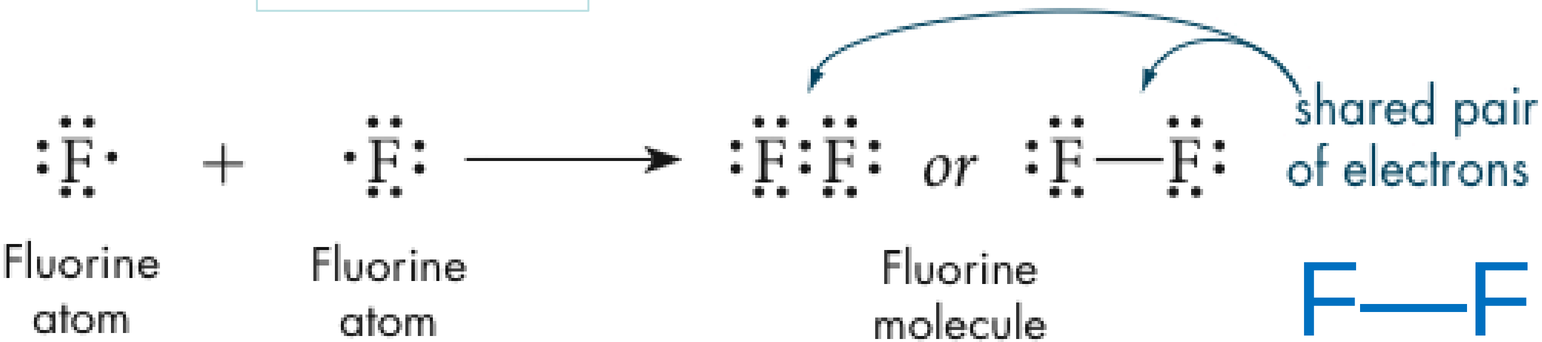
Atoms bond to complete their valence (octet rule) and achieve the electron configuration of a noble gas.

Two atoms of fluorine bond to make a F_2 molecule, each fluorine atom contributing one electron to complete the octet.

F_2



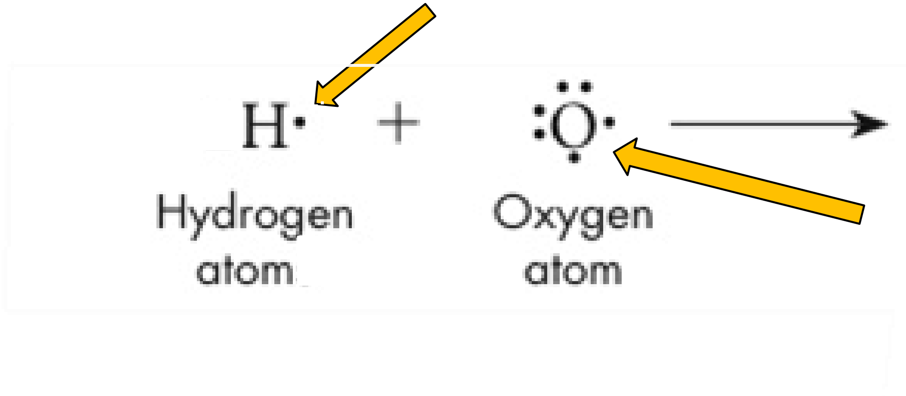
Notice that there are unbonded or unshared pairs of electrons.



F—F

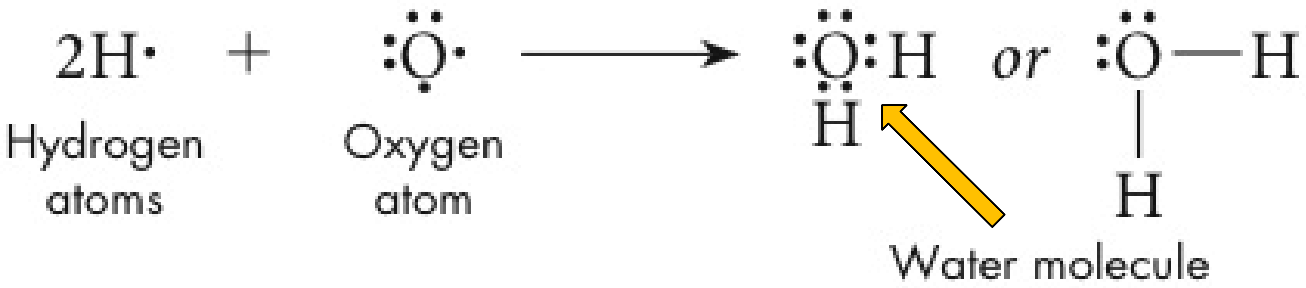
The Octet Rule in Covalent Bonding

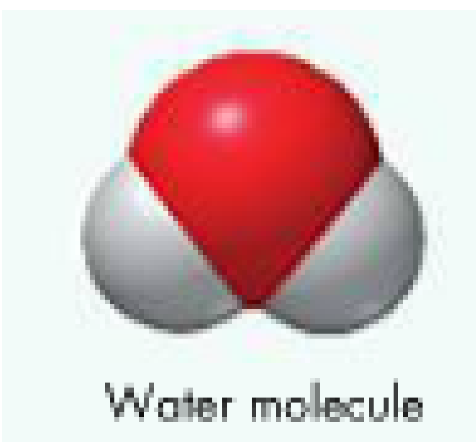
The oxygen atom has two unshared pairs of valence electrons and the hydrogen atom has one unshared electron. How can these atoms form a stable bond?



The Octet Rule in Covalent Bonding

Two hydrogen atoms share their electrons with the oxygen atom to form a full octet (8 valence e-).



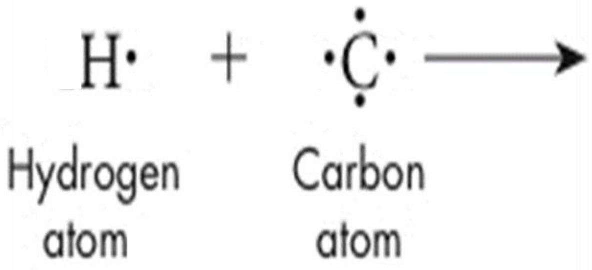


H—O—H

H_2O

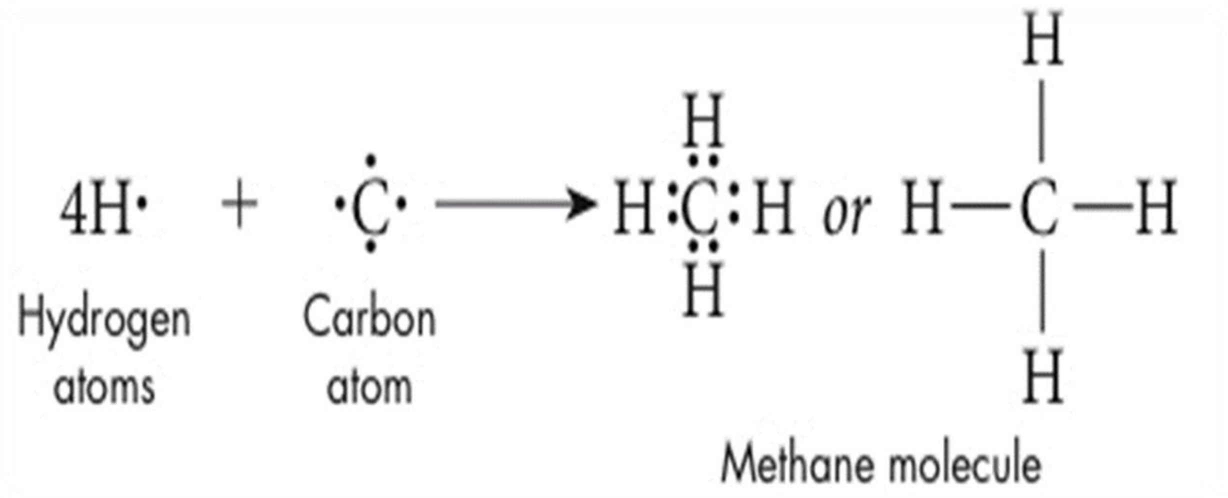
Single Covalent Bond

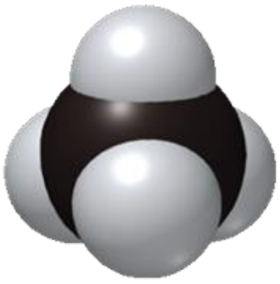
The carbon atom has four unshared valence electrons and needs four more valence electrons to attain a noble-gas configuration (full octet). How can these atoms form a stable bond?



Single Covalent Bond

Four hydrogen atoms share their electrons with the carbon atom to form a noble-gas configuration with a full octet (8 valence e-). Methane contains four SINGLE covalent bonds.





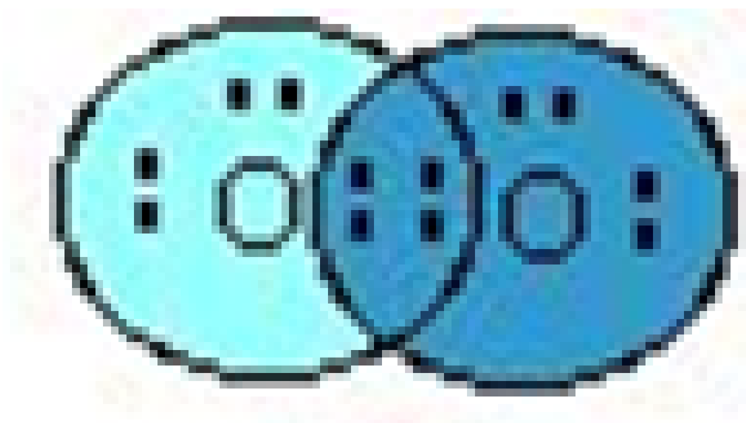
Methane molecule

CH_4

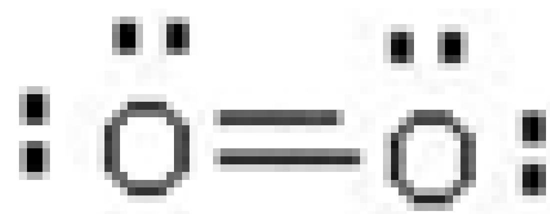
Double Covalent Bonds

A double covalent bond is a bond that involves TWO shared PAIRS of electrons.

- Oxygen gas is a diatomic molecule containing a double bond (*4 e- are shared in each O=O bond*).
- Both oxygen atoms share two electrons to form a double bond.
- Notice that both oxygen atoms have a full octet (8 valence e-).



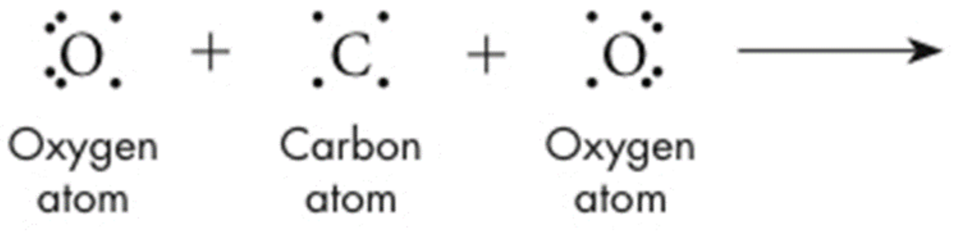
O_2



O=O

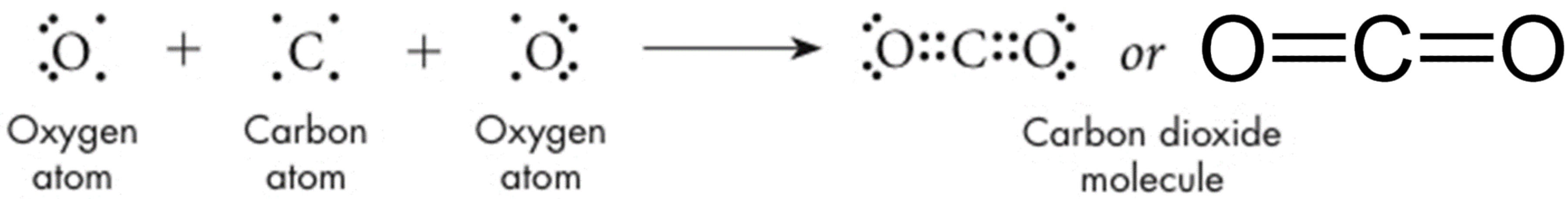
Double Covalent Bonds

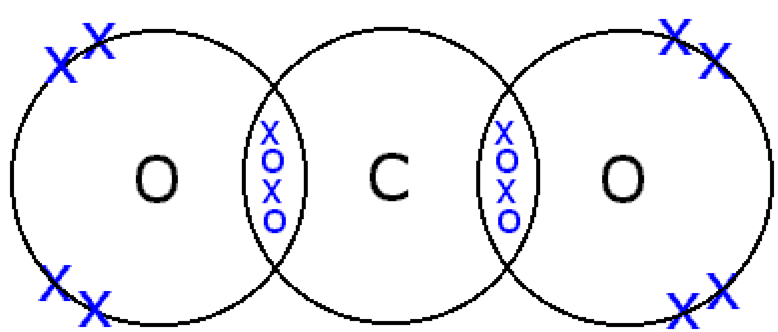
How can these atoms bond to form a stable noble gas configuration?



Double Covalent Bonds

- The oxygen atoms in a carbon dioxide (CO_2) molecule both share TWO electrons with carbon to form TWO carbon=oxygen double bonds (*4 e- are shared in each C=O bond*).

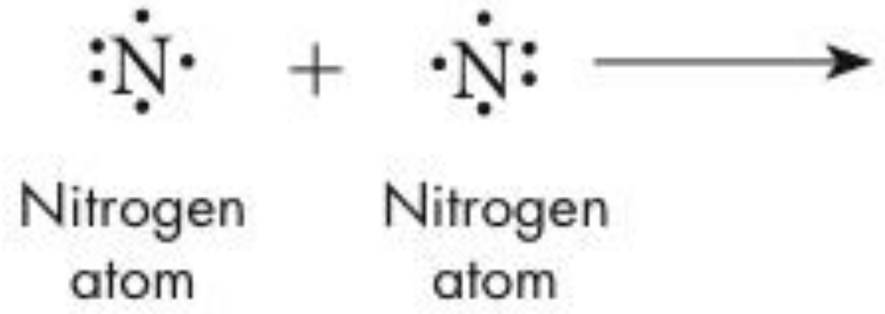




Notice that oxygen and carbon atoms have full octets (8 valence e-)

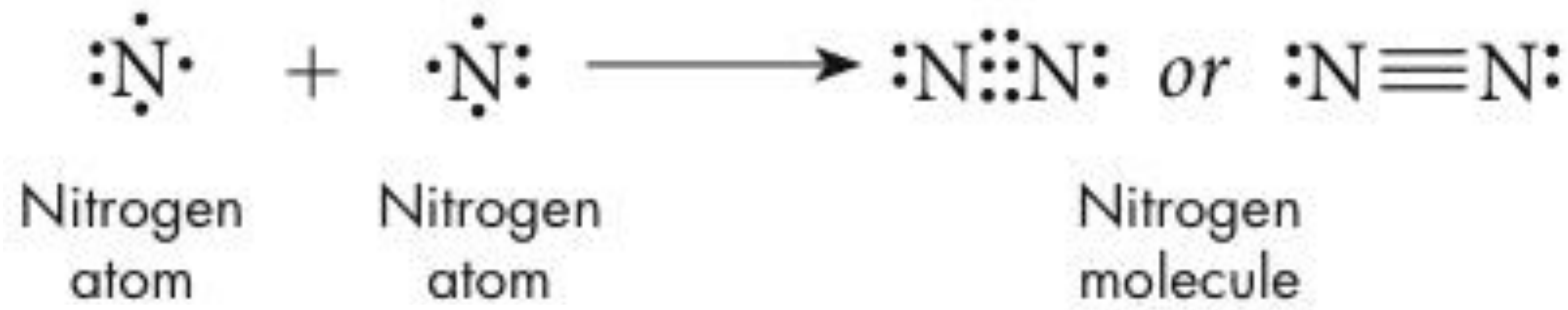
Triple Covalent Bonds

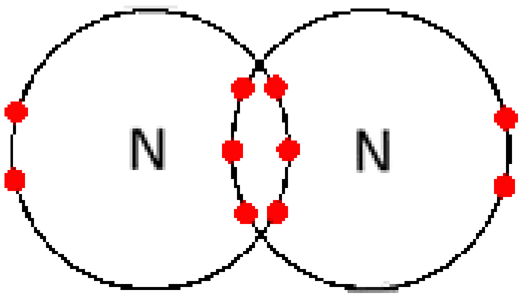
How can these atoms bond to form a stable noble gas configuration?

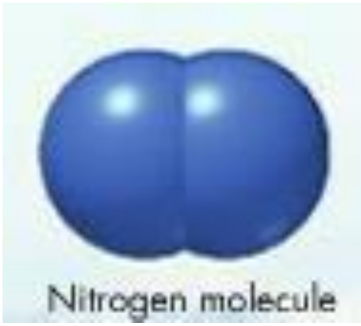


Triple Covalent Bonds

- The nitrogen atoms share THREE PAIRS of electrons, forming a triple covalent bond (*6 e- are shared in* N≡N *bond*).







N≡N

N_2

Polar Covalent Bonds

- When electrons are shared UNEQUALLY between atoms they form polar bonds.

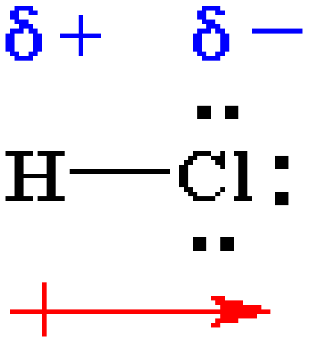
$\delta+ \quad \delta-$

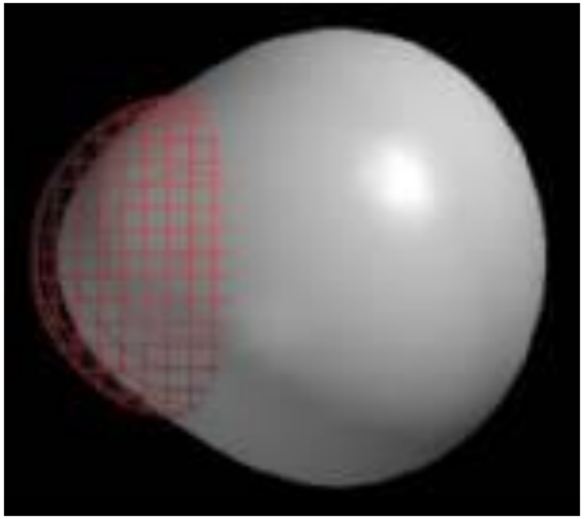
H—Cl

- Formation of HCl
  - In a hydrogen chloride molecule, the shared electrons spend more time near the chlorine atom than near the hydrogen atom.
  - Hydrogen takes on a partially positive charge while chlorine takes on a partially negative charge.
  - The symbols **$\delta-$** and **$\delta+$** are used to indicate a partial charge.

Polar Covalent Bonds

- Electrons are shared UNEQUALLY between atom.
- Formation of HCl





Bond Polarity

There is no sharp boundary between ionic and covalent bonds.

Type of Bond	Example
Nonpolar covalent	H—H
Moderately polar covalent	$\delta+$ $\delta-$ H—Cl
Very polar covalent; 50% ionic	$\delta+$ $\delta-$ H—F
Ionic (*electrostatic attraction*)	Na^+Cl^-

Bond Polarity

QUICK CHECK

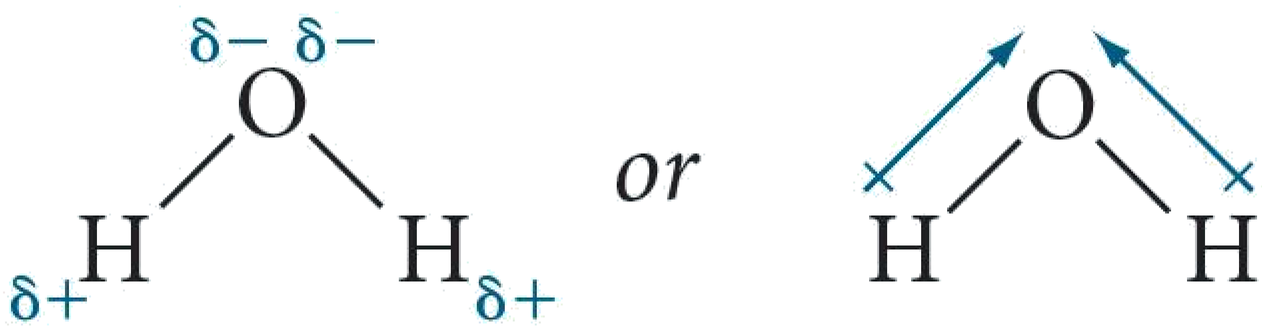
Classify each type of bond below as polar, non-polar or ionic.

N – H

F – F

Ca^{+2} Cl^{-1}

Al – Cl

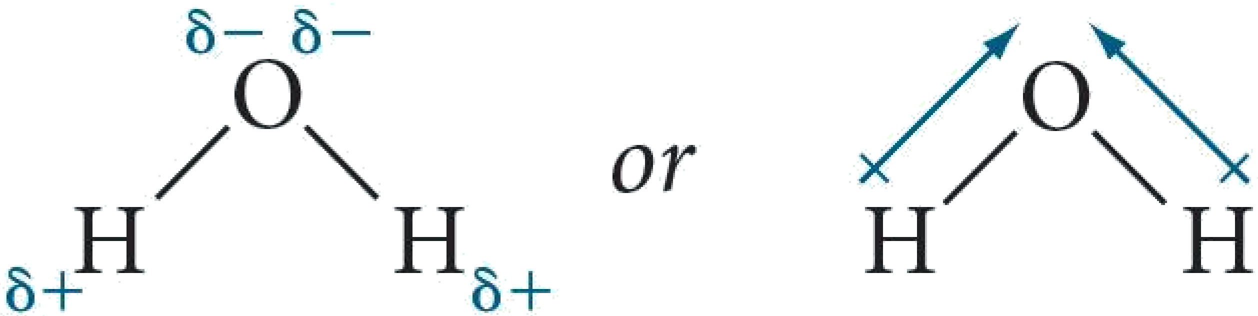


Bond Polarity

QUICK CHECK

Classify each type of bond below as polar, non-polar or ionic.

N – H	polar covalent
F – F	nonpolar covalent
Ca^{+2} Cl^{-1}	ionic (notice cations / anions)
Al – Cl	polar covalent



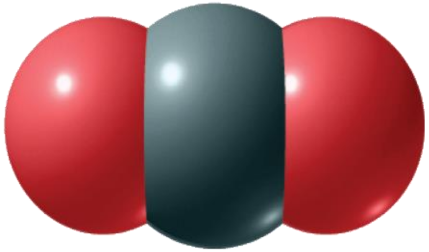
polar covalent (*partial charges*)

Covalent **Molecules**

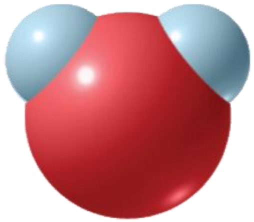
A **molecule** is a discrete, neutral particle which results from covalent bonding.

The type of atoms in a molecule and its **SHAPE** are factors that determine whether a molecule is polar or non-polar.

What type of molecules are Iodine (left), carbon dioxide, and water in terms of polarity?



CO_2



H_2O

Covalent **Molecules**

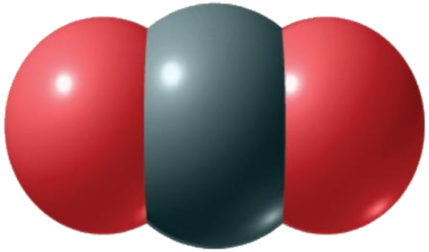
Notice the SHAPE of each molecule.

If it is symmetrical (balanced on all sides) that is a non-polar molecule.

If it is unsymmetrical (not balanced on all sides) that is a polar molecule.

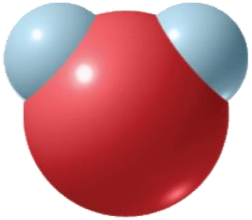
Non-polar

non-polar



CO_2

polar

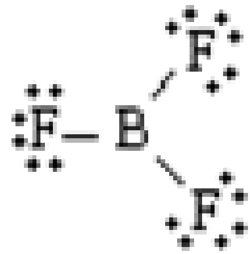


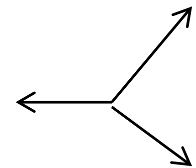
H_2O

Covalent **Molecules**

Non-Polar Molecule

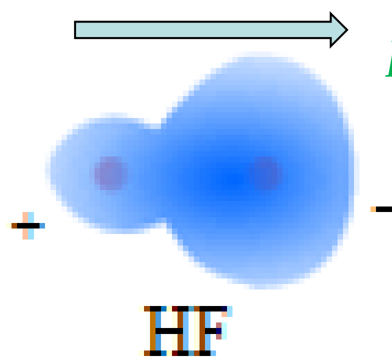
Electrons are shared <u>equally</u> throughout the molecule.





Polar Molecule

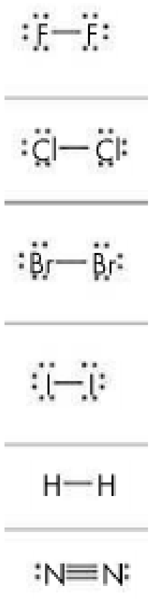
Electrons are shared <u>UNequally</u> throughout the molecule



Be sure to distinguish between polarity in bonds & polarity in molecules. Both molecules above have polar bonds between atoms.

Non-polar Covalent Molecules

- Diatomic (*2 atoms*) Molecules of <u>ONE</u> element are **non-polar**.



- There are 7 non-polar diatomic molecules:

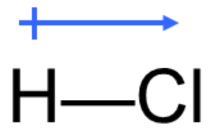
H_2 O_2 F_2 Br_2 I_2 N_2 Cl_2

"Professor *HOFBrINCl*"

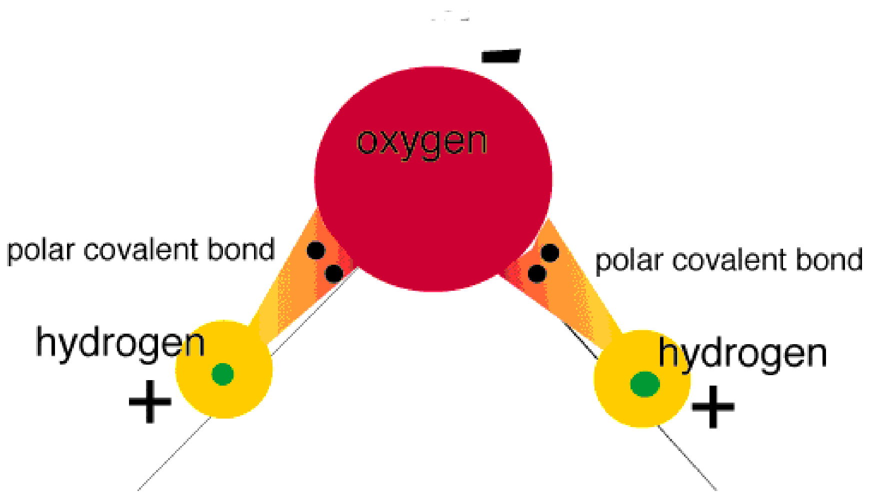
- All other non-polar molecules have at least TWO different elements. E.g. F−Be−F

Polar Covalent Molecules

- In a **polar molecule**, there is a separation of positive and negative charge within the molecule.



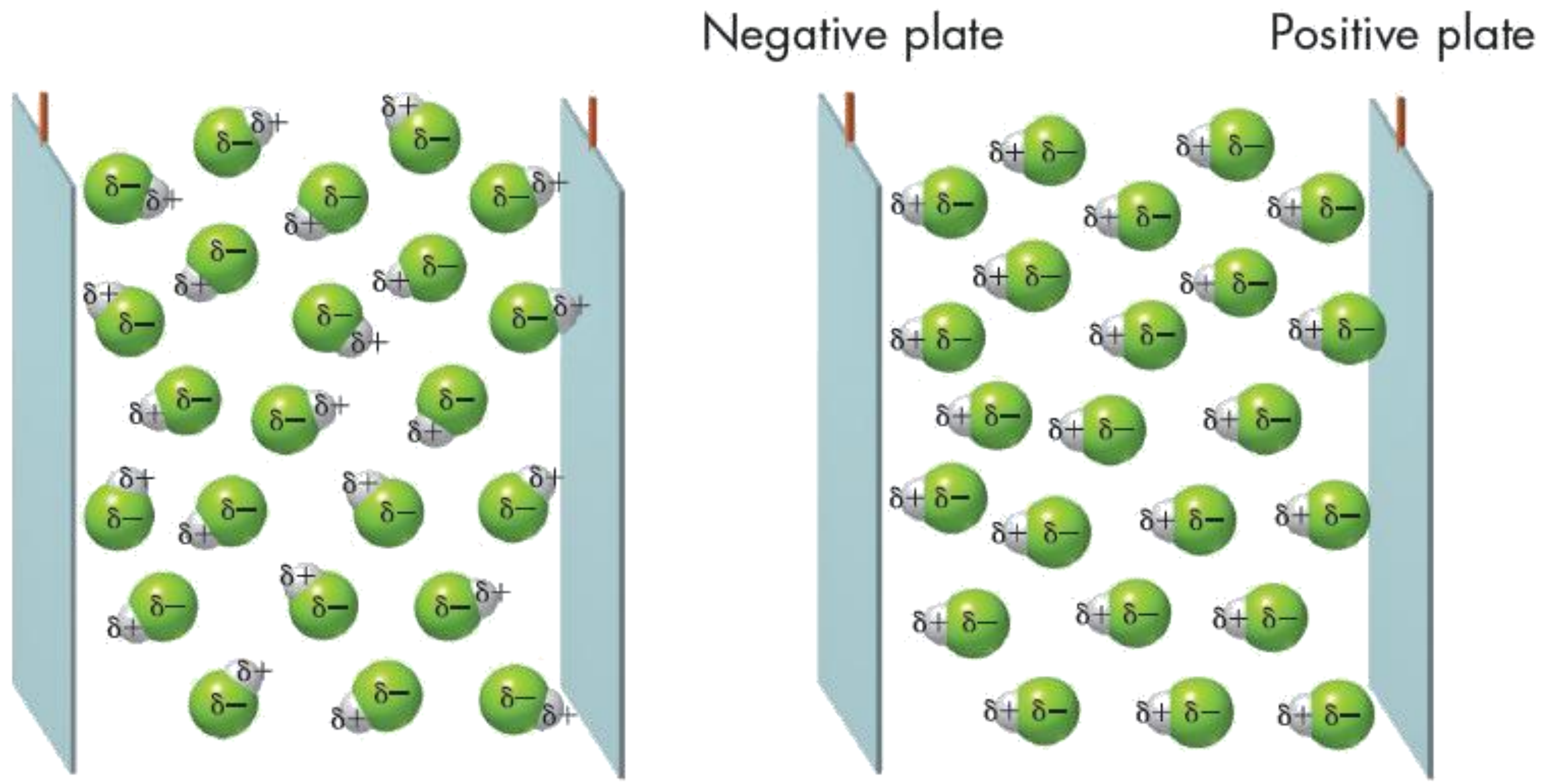
- The bonds between the atoms are POLAR and the molecule itself is polar (not symmetrical).



ENRICHMENT

Molecular Polarity

Polar molecules (“dipoles”) align themselves based on their polarity.

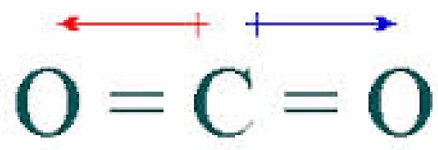


Electric field is absent.
Polar molecules orient randomly.

Electric field is on.
Polar molecules line up.

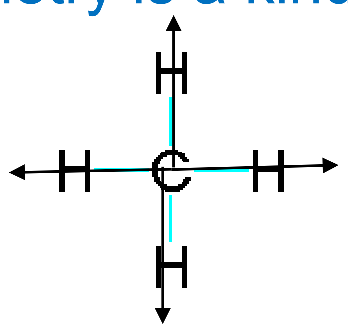
Distinguishing Polarity in Covalent Molecules

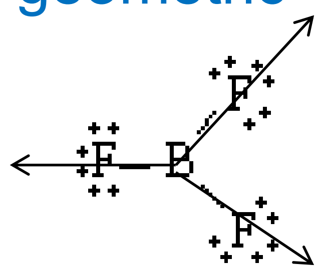
- A molecule may be **non-polar** and contain **POLAR bonds** if geometric **SYMMETRY** exists for that molecule.
  - A CO_2 molecule has two polar bonds and is linear. The bond polarity cancels, but the molecule is nonpolar.

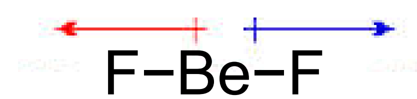


➢ Symmetry means that if any plane is cut down the center, the resulting planes are identical

➢ Symmetry is a kind of geometric “balance” of molecules on all sides.

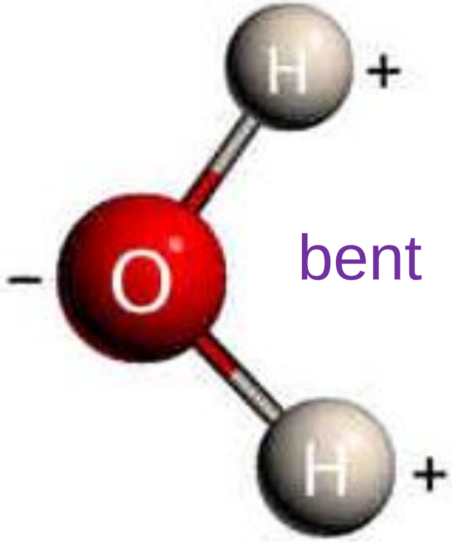




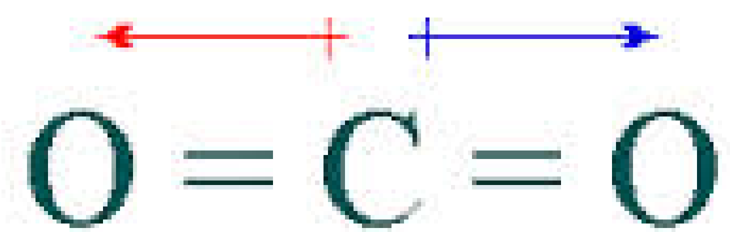


Distinguishing Polarity in Covalent Molecules

- The water molecule, just like carbon dioxide, has two polar bonds.
- Therefore, the water molecule is “bent” rather than linear and is a is polar molecule. Water’s bond polarities do not cancel (as in CO_2).



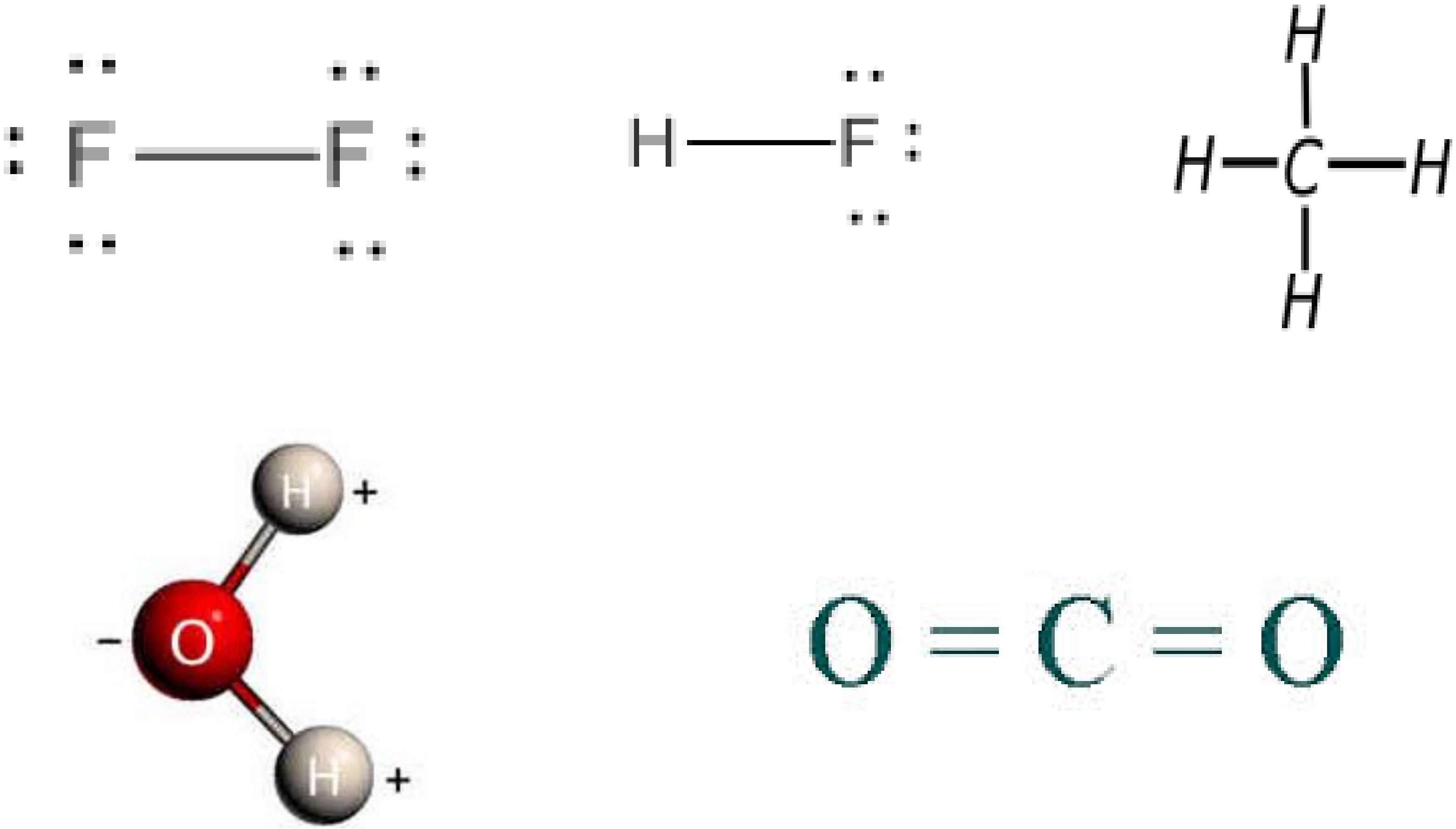
bent



linear

Bond Polarity & Molecular Polarity

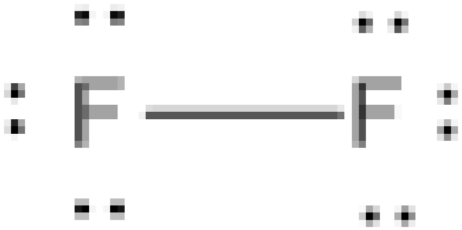
- Look at the molecules below and determine the types of bonds and the types of molecules:



Bond Polarity & Molecular Polarity

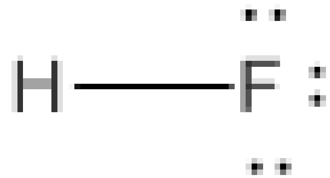
QUICK CHECK

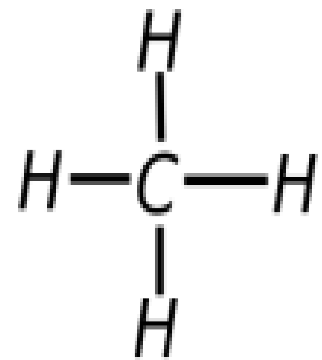
- Look at the molecules below and determine the types of bonds and the types of molecules:



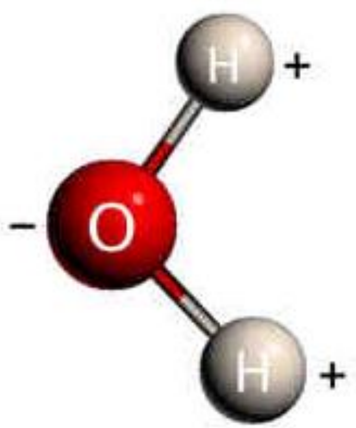
non-polar bond &
non-polar molecule

polar bond &
polar molecule

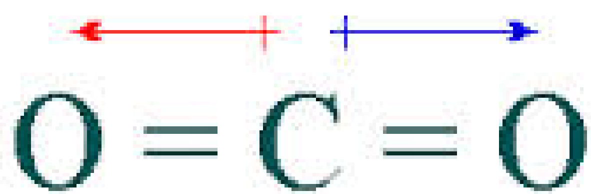




polar bonds,
non-polar molecule



polar bond & polar molecule



polar bonds,
non-polar molecule

Identify the Ions of Elements & Stability.

What is the charge of each ion?

A lithium ion has a charge of ____.

A calcium ion has a charge of ____.

An aluminum ion has a charge of ____.

A fluorine ion has a charge of ____.

An oxygen ion has a charge of ____.

A phosphorus ion has a charge of ____.

A Selenium ion has a charge of ____.

An krypton ion has a charge of ____.

A Gallium ion has a charge of ____.

When is an atom stable?

a. when its electrons are evenly distributed through its energy levels
b. when its lowest occupied energy level is filled with electrons
c. when its highest unoccupied energy level is filled with electrons
d. when its highest occupied energy level is filled with electrons

Which description applies to an element that has two valence electrons?

a. reactive metal
b. nonreactive metal
c. reactive nonmetal
d. nonreactive nonmetal

Identify the Ions of Elements & Stability.

What is the charge of each ion?

A lithium ion has a charge of +1.

A calcium ion has a charge of +2.

An aluminum ion has a charge of +3.

A fluorine ion has a charge of -1.

An oxygen ion has a charge of -2.

A phosphorus ion has a charge of -3.

A Selenium ion has a charge of -2.

An krypton ion has a charge of 0.

A Gallium ion has a charge of +3.

When is an atom stable?

a. when its electrons are evenly distributed through its energy levels
b. when its lowest occupied energy level is filled with electrons
c. when its highest unoccupied energy level is filled with electrons
d. when its highest occupied energy level is filled with electrons

Which description applies to an element that has two valence electrons?

a. reactive metal
b. nonreactive metal
c. reactive nonmetal
d. nonreactive nonmetal

Explain How Ionic Bonds Form.

How and why do ionic bonds form? Check all that apply.

[ ] Ionic bonds form between metal atoms and other metal atoms.

[ ] Ionic bonds form between metal atoms and nonmetal atoms.

[ ] The atoms with lower ionization energy transfer one or more electrons to the atom with higher ionization energy.

[ ] The atoms with higher ionization energy transfer one or more electrons to the atom with lower ionization energy.

[ ] The metal atom forms a cation and the nonmetal atom forms an anion.

[ ] The metal atom forms a anion and the nonmetal atom forms an cation.

[ ] The attraction between ions with the same charge forms an ionic bond.

[ ] The attraction between ions with an opposite charge forms an ionic bond.

[ ] Positive ions are called cations and negative ions are called anions.

[ ] Negative ions are called cations and positive ions are called anions.

Explain How Ionic Bonds Form

How and why do ionic bonds form? Check all that apply.

[x] Ionic bonds form between metal atoms and nonmetal atoms.

[x] The atoms with lower ionization energy (metal) transfer one or more electrons to the atom with higher ionization energy (non-metal).

[x] The metal atom forms a cation and the nonmetal atom forms an anion.

[x] The attraction between ions with an opposite charge forms an ionic bond.

[x] Positive ions are called cations and negative ions are called anions.

Distinguishing Properties of Compounds.

Why does water have a much higher boiling point than methane?

a. Methane molecules are more polar, so its molecules have stronger attractive forces.
b. Partial charges on the polar water molecules increase attractive forces between molecules.
c. A water molecule has much more mass than a methane molecule, so water has a higher boiling point.
d. Water has a higher boiling point because its molecules do not contain carbon atoms.

Why do ionic compounds tend to have high melting points?

a. Ionic compounds contain more than one element, which causes a high melting point.
b. Ionic compounds cannot absorb energy efficiently because they contain ions.
c. An ionic compound contains metal atoms that raise its melting point.
d. A strong electrical attraction means ions require a lot of energy to move apart.

Distinguishing Properties of Compounds.

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a. Ionic compounds contain more than one element, which causes a high melting point.

b. Ionic compounds cannot absorb energy efficiently because they contain ions.

c. An ionic compound contains metal atoms that raise its melting point.

d. A strong electrical attraction (in the crystal lattice) means ions require a lot of energy to move apart.

Period	*s*-block 1 IA
1	1.00794 +1 −1 **H** 1 $1s^1$

KEY

Atomic Mass → 12.0111; Selected Oxidation States → −4, +2, +4; Symbol → **C**; Atomic Number → 6; Electron Configuration → $1s^2 2s^2 2p^2$

Relative atomic masses are based on ^{12}C = 12.00000

s-block
GROUP

New Designation
Former Designation
(prior to 1984 IUPAC decision)

d-block
Transition Elements

Period	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	
2	6.941 +1 **Li** 3 $1s^2 2s^1$	9.01218 +2 **Be** 4 $1s^2 2s^2$									
3	22.98977 +1 **Na** 11 $[Ne]3s^1$	24.305 +2 **Mg** 12 $[Ne]3s^2$									
4	39.0983 +1 **K** 19 $[Ar]4s^1$	40.08 +2 **Ca** 20 $[Ar]4s^2$	44.9559 +3 **Sc** 21 $[Ar]3d^1 4s^2$	47.88 +2 +3 +4 **Ti** 22 $[Ar]3d^2 4s^2$	50.9415 +2 +3 +4 +5 **V** 23 $[Ar]3d^3 4s^2$	51.996 +2 +3 +6 **Cr** 24 $[Ar]3d^5 4s^1$	54.9380 +2 +3 +4 +7 **Mn** 25 $[Ar]3d^5 4s^2$	55.847 +2 +3 **Fe** 26 $[Ar]3d^6 4s^2$	58.9332 +2 +3 **Co** 27 $[Ar]3d^7 4s^2$	58.69 +2 +3 **Ni** 28 $[Ar]3d^8 4s^2$	63.546 29 [Ar]3d
5	85.4678 +1 **Rb** 37 $[Kr]5s^1$	87.62 +2 **Sr** 38 $[Kr]5s^2$	88.9059 +3 **Y** 39 $[Kr]4d^1 5s^2$	91.224 +4 **Zr** 40 $[Kr]4d^2 5s^2$	92.9064 +3 +5 **Nb** 41 $[Kr]4d^4 5s^1$	95.94 +3 +6 **Mo** 42 $[Kr]4d^5 5s^1$	(98) +4 +6 +7 **Tc** 43 $[Kr]4d^6 5s^1$	101.07 +3 **Ru** 44 $[Kr]4d^7 5s^1$	102.906 +3 **Rh** 45 $[Kr]4d^8 5s^1$	106.42 +2 +4 **Pd** 46 $[Kr]4d^{10} 5s^0$	107.86 47 [Kr]4d
6	132.905 +1 **Cs** 55 $[Xe]6s^1$	137.33 +2 **Ba** 56 $[Xe]6s^2$	**La-Lu** 57 71	178.49 +4 **Hf** 72 $[Xe]4f^{14}5d^2 6s^2$	180.948 +5 **Ta** 73 $[Xe]4f^{14}5d^3 6s^2$	183.85 +6 **W** 74 $[Xe]4f^{14}5d^4 6s^2$	186.207 +4 +6 +7 **Re** 75 $[Xe]4f^{14}5d^5 6s^2$	190.2 +3 +4 **Os** 76 $[Xe]4f^{14}5d^6 6s^2$	192.22 +3 +4 **Ir** 77 $[Xe]4f^{14}5d^7 6s^2$	195.08 +2 +4 **Pt** 78 $[Xe]4f^{14}5d^9 6s^1$	196.96 79 [Xe]4f
7	(223) +1 **Fr** 87 $[Rn]7s^1$	226.025 +2 **Ra** 88 $[Rn]7s^2$	**Ac-Lr** 89 103	(261) **Unq*** 104	(262) **Unp** 105	(263) **Unh** 106	(262) **Uns** 107	**Uno** 108	**Une** 109		* The sys 103 wil

nasses are
2.00000

ation States

s-block

18 O
4.00260 **He** 2 $1s^2$ (0)

p-block

GROUP

10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 O
			10.81 **B** 5 $1s^22s^22p^1$ (+3)	12.0111 **C** 6 $1s^22s^22p^2$ (−4 +2 +4)	14.0067 **N** 7 $1s^22s^22p^3$ (−3 −2 −1 +1 +2 +3 +4 +5)	15.9994 **O** 8 $1s^22s^22p^4$ (−2)	18.998403 **F** 9 $1s^22s^22p^5$ (−1)	20.179 **Ne** 10 $1s^22s^22p^6$ (0)
			26.98154 **Al** 13 [Ne]$3s^23p^1$ (+3)	28.0855 **Si** 14 [Ne]$3s^23p^2$ (−4 +2 +4)	30.97376 **P** 15 [Ne]$3s^23p^3$ (−3 +3 +5)	32.06 **S** 16 [Ne]$3s^23p^4$ (−2 +4 +6)	35.453 **Cl** 17 [Ne]$3s^23p^5$ (−1 +1 +3 +5 +7)	39.948 **Ar** 18 [Ne]$3s^23p^6$ (0)
58.69 **Ni** 28 [Ar]$3d^84s^2$ (+2 +3)	63.546 **Cu** 29 [Ar]$3d^{10}4s^1$ (+1 +2)	65.39 **Zn** 30 [Ar]$3d^{10}4s^2$ (+2)	69.72 **Ga** 31 [Ar]$3d^{10}4s^24p^1$ (+3)	72.59 **Ge** 32 [Ar]$3d^{10}4s^24p^2$ (−4 +2 +4)	74.9216 **As** 33 [Ar]$3d^{10}4s^24p^3$ (−3 +3 +5)	78.96 **Se** 34 [Ar]$3d^{10}4s^24p^4$ (−2 +4 +6)	79.904 **Br** 35 [Ar]$3d^{10}4s^24p^5$ (−1 +1 +5)	83.80 **Kr** 36 [Ar]$3d^{10}4s^24p^6$ (0 +2)
106.42 **Pd** 46 [Kr]$4d^{10}5s^0$ (+2 +4)	107.868 **Ag** 47 [Kr]$4d^{10}5s^1$ (+1)	112.41 **Cd** 48 [Kr]$4d^{10}5s^2$ (+2)	114.82 **In** 49 [Kr]$4d^{10}5s^25p^1$ (+3)	118.71 **Sn** 50 [Kr]$4d^{10}5s^25p^2$ (+2 +4)	121.75 **Sb** 51 [Kr]$4d^{10}5s^25p^3$ (−3 +3 +5)	127.60 **Te** 52 [Kr]$4d^{10}5s^25p^4$ (−2 +4 +6)	126.905 **I** 53 [Kr]$4d^{10}5s^25p^5$ (−1 +1 +5 +7)	131.29 **Xe** 54 [Kr]$4d^{10}5s^25p^6$ (0 +2 +4 +6)
195.08 **Pt** 78 [Xe]$4f^{14}5d^96s^1$ (+2 +4)	196.967 **Au** 79 [Xe]$4f^{14}5d^{10}6s^1$ (+1 +3)	200.59 **Hg** 80 [Xe]$4f^{14}5d^{10}6s^2$ (+1 +2)	204.383 **Tl** 81 [Xe]$4f^{14}5d^{10}6s^26p^1$ (+1 +3)	207.2 **Pb** 82 [Xe]$4f^{14}5d^{10}6s^26p^2$ (+2 +4)	208.980 **Bi** 83 [Xe]$4f^{14}5d^{10}6s^26p^3$ (+3 +5)	(209) **Po** 84 [Xe]$4f^{14}5d^{10}6s^26p^4$ (+2 +4)	(210) **At** 85 [Xe]$4f^{14}5d^{10}6s^26p^5$	(222) **Rn** 86 [Xe]$4f^{14}5d^{10}6s^26p^6$ (0)