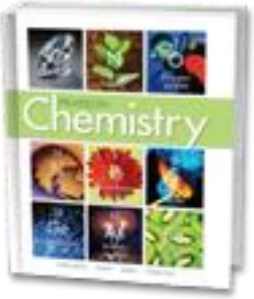


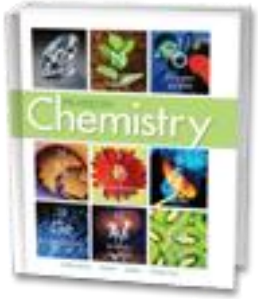
Chapter 8
Covalent Bonding

Polar Bonds and Molecules

Molecular Compounds

The Nature of Covalent Bonding

Bonding Theories



COVALENT BONDING CHAPTER 8A

Topics:

1. Covalent Bonding

Objectives:

1. Explain covalent bonding in terms of bonds (nonpolar, polar, and coordinate covalent) and molecules (nonpolar & polar).
2. Define and recognize polyatomic ions.
3. Understanding how to represent molecules, compounds and types of covalent bonds (single, double, triple) in various ways (molecular & structural formulas, Lewis structures).

Identify Electrons Available for Bonding

For each of the following elements, identify: (1) the "A" Group, (2) the number of valence electrons available for bonding, and (3) how the atom would behave according to the Octet Rule (gain/lose e-, how many e-?), (4) cation or anion? Use your Periodic Table.

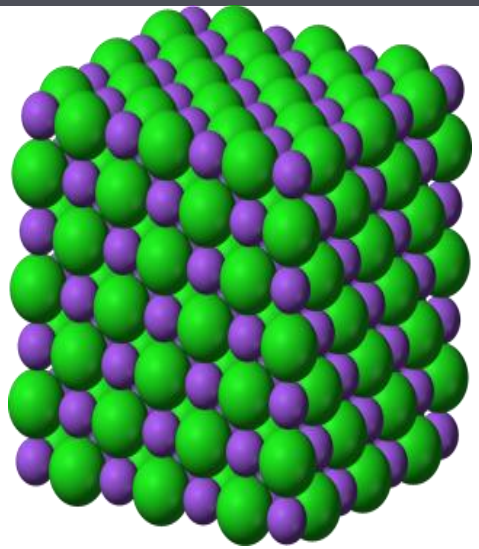
- C
- H
- N
- Al
- Ne
- O
- P
- Cl
- Mg

Identify Electrons Available for Bonding

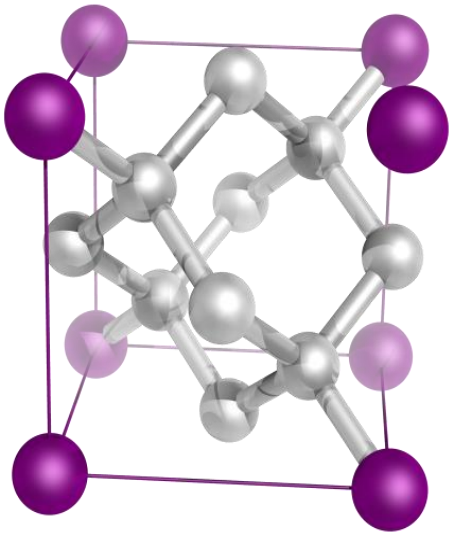
For each of the following elements, identify: (1) the "A" Group, (2) the number of valence electrons available for bonding, and (3) how the atom would behave according to the Octet Rule (gain/lose e-, how many e-?), (4) cation or anion? Use your Periodic Table.

- C … IVA, 4 e-, gain or lose 4 e-, ±4
- H^{+} … IA, 1 e-, lose 1 e-, +1 cation
- N^{-3} … VA, 5 e-, gain 3 e-, -3 anion
- Al^{+3} … IIIA, 3 e-, lose 3 e-, +3 cation
- Ne^{0} … VIIIA, 8 e-, no bond, 0
- O^{-2} … VIA, 6 e-, gain 2 e-, -2 anion
- P^{-3} … VA, 5 e-, gain 3 e-, -3 anion
- Cl^{-1} … VIIA, 7 e-, gain 1 e-, -1 anion
- Mg^{+2} … IIA, 2 e-, lose 2 e-, +2 cation

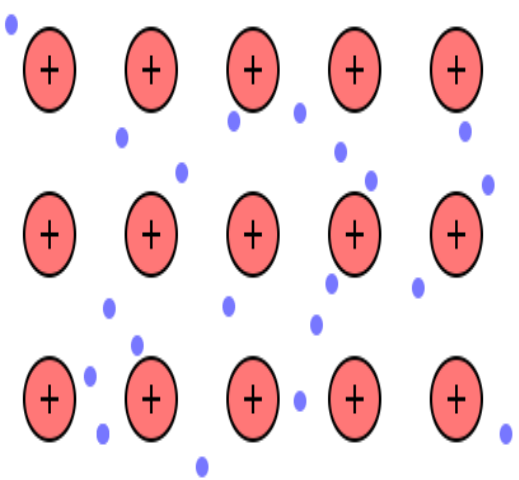
There are three main ways that elements can come together to form bonds.



Ionic



Covalent



Metallic

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

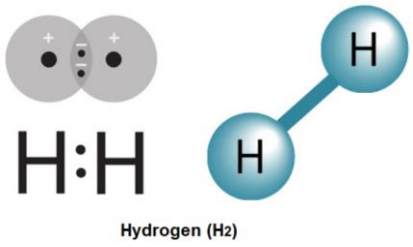
Bonding type between atoms depends upon electronegativity differences (END) → electron attracting power

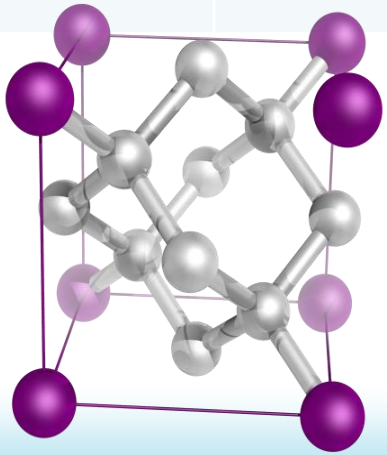
- If the END is < 1.7 expect covalent bonds (e- sharing) between atoms
- If the END is > 1.7 expect ionic bonds (e- transfer)

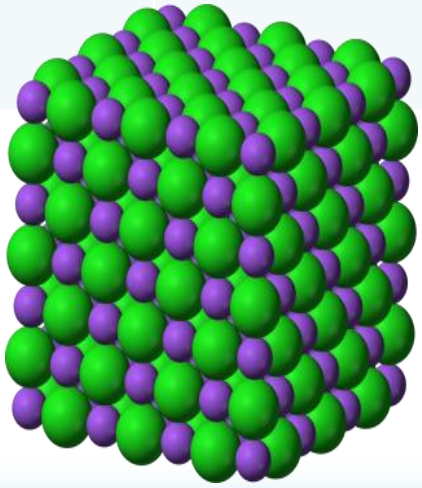
8.1 Molecular Compounds > Bonding & END

- In real life, bonds usually possess both covalent and ionic character

END →	0	0.94	1.67	2.54	3.30
% ionic	0 %	20 %	50 %	80%	90 %
% covalent	100%	80%	50 %	20 %	10 %
Examples	H_2 O_2 F_2 Br_2 I_2 N_2 Cl_2 Non-polar Organic Molecules	Al_2Se_3	CaS	AlF_3	FrF CsF



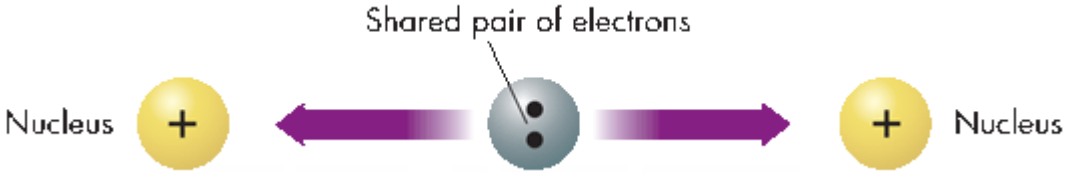


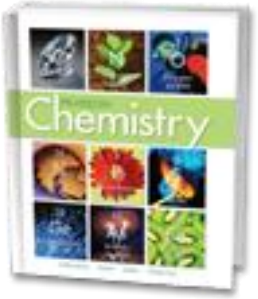


A covalent bond is formed when two or more atoms SHARE electrons [END < 1.7] ... but we need to focus on HOW the electrons are shared.

There are three types of covalent bonds:

1. Non-polar covalent
2. Polar covalent
3. Coordinate covalent





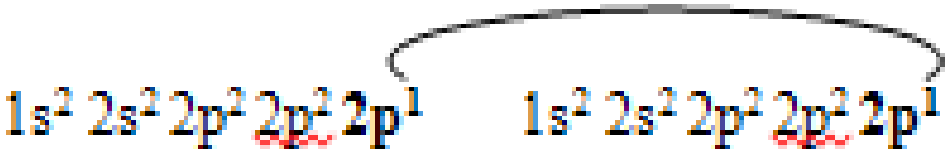
Covalent Bonds (Polar & Non-Polar) Notes (5:53)

https://screencast-o-matic.com/watch/cF6nINY67j

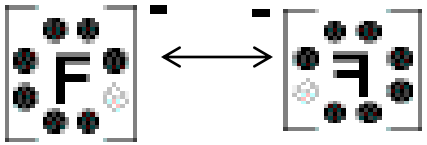
Recap Notes (4:13) using Molecular Models

https://screencast-o-matic.com/watch/cF6hDuYoAV

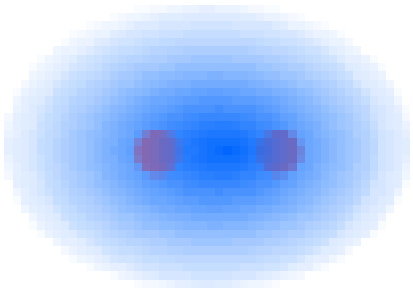
Non-Polar bonds mean that **Electrons** are **shared EQUALLY** between atoms of EQUAL electronegativity



- Electron configuration of F_2
- Electron dot diagram of F_2



- Symbol of bond F–F
- END 4.0 – 4.0 = 0
- Electron cloud graphic →

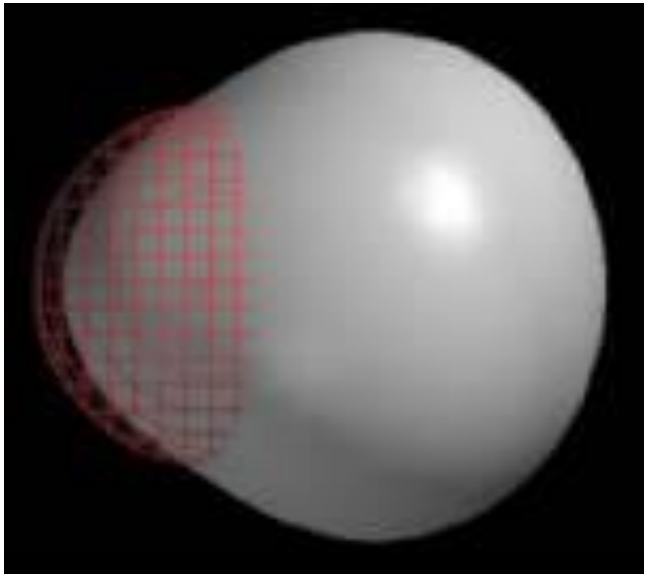


Polar Covalent Bonds [END > 0 < 1.7]

- When **electrons** are **shared UNEQUALLY** between atoms of unequal electronegativity

δ+ δ–

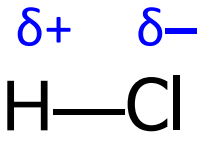
H—Cl



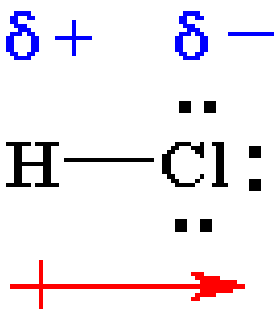
Polar Covalent Bonds [END > 0 < 1.7]

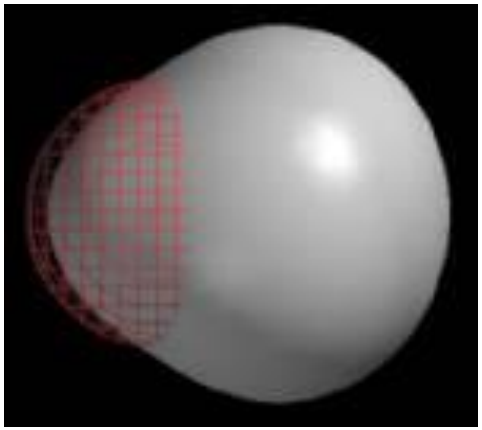
- When electrons are shared UNEQUALLY between atoms of unequal electronegativity

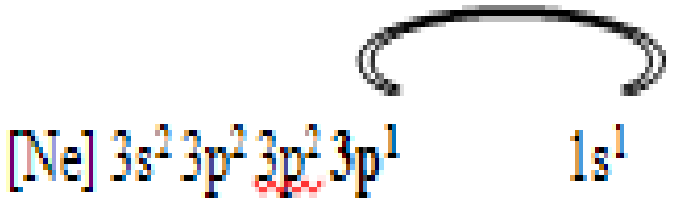
- Formation of HCl [END 1.0]



  - Chlorine [3.2] – Hydrogen [2.2] electronegativities
  - The chlorine atom [*higher electronegativity*] acquires a partial negative charge, **pulling the electrons closer to its nucleus**.
  - The hydrogen atom acquires a slightly positive charge.







There is no sharp boundary between ionic and covalent bonds.

As the electronegativity difference between two atoms increases, the polarity of the bond increases, meaning the electrons are pulled more strongly to the more electronegative atom.

Electronegativity Differences and Bond Types

Electronegativity difference range	Most probable type of bond	Example
0.0 – 0.4	Nonpolar covalent	H—H (0.0)
0.4 – 1.0	Moderately polar covalent	$\overset{\delta+}{H}—\overset{\delta-}{Cl}$ (1.0)
1.0 – 1.7	Very polar covalent; 50% ionic	$\overset{\delta+}{H}—\overset{\delta-}{F}$ (1.8) *[borderline]*
> 1.7 – 3.3	Ionic (*electrostatic attraction*)	Na^+Cl^- (2.1)

QUICK CHECK

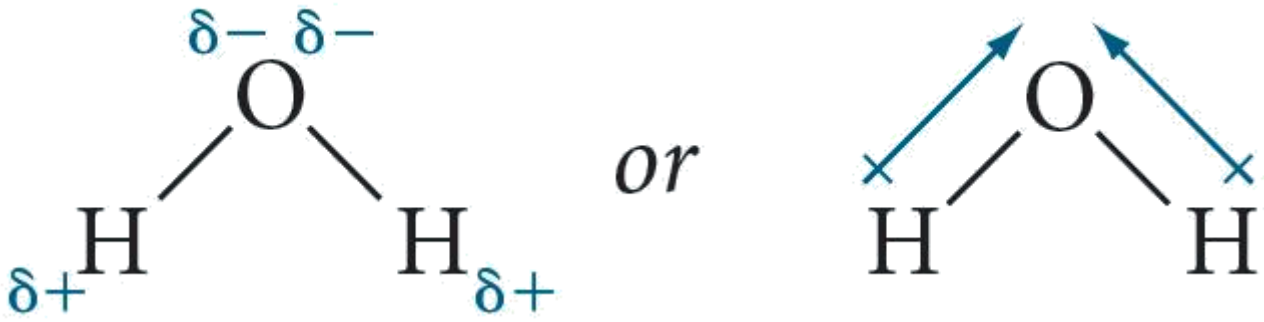
Based on the electronegativity difference, determine the bond type. *Use the Reference Table.*

N – H

F – F

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

Al – Cl



QUICK CHECK

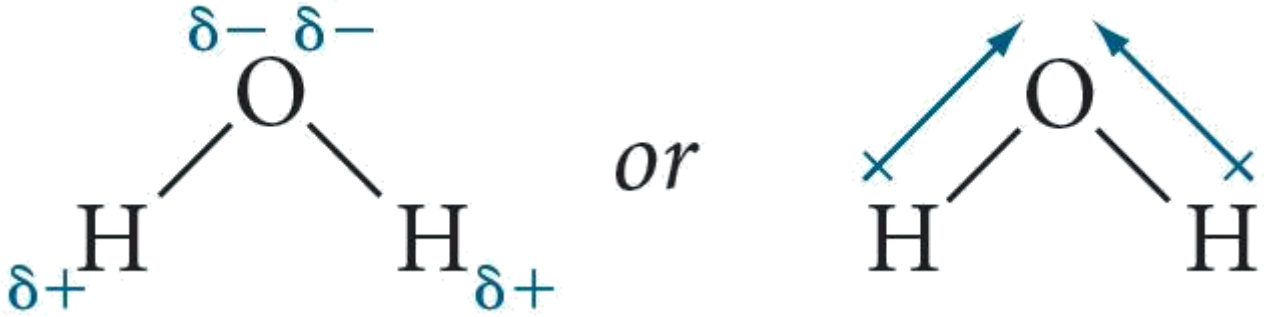
Based on the electronegativity difference, determine the bond type.

N(3.1), H(2.2); 0.9; moderately polar covalent

F(4.0), F(4.0); 0.0; nonpolar covalent

Ca^{+2}(1.0), Cl^{-1}(3.2); 2.2; ionic

Al(1.5), Cl(3.2); 1.7; strongly polar covalent/ionic



O(3.5), H(2.2); 1.3; moderately polar covalent

Na_2SO_4 ??

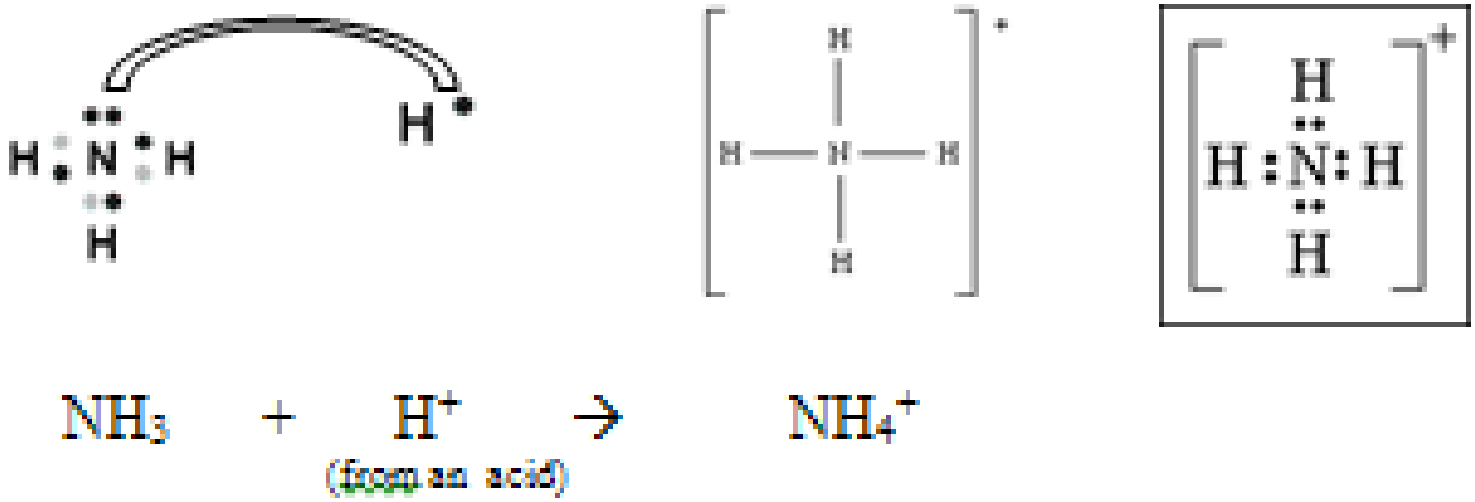
Coordinate Covalent Bonds form when the **electrons** being shared between two atoms are **both donated by the same atom.**

- [*e.g. similar to borrowing/renting books or videos ... the books are given to you and you treat them essentially as if they belonged to you; yet at the same time the books are counted as being part of the library collection or rental store.*]

Coordinate Covalent Bonds

Coordinate Covalent Bonds form when the electrons being shared between two atoms are **both donated by the same atom.**

- Coordinate covalent bonds occur when the donating atom has an unbonded electron pair in its valence



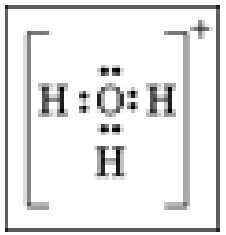
$$NH_3 + H^+ \rightarrow NH_4^+$$

(from an acid)

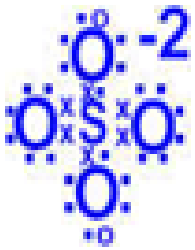
Once coordinate covalent bonds are formed, they are no different than ordinary covalent bonds

Polyatomic Ions often have coordinate covalent bonds as well as covalent bonds.

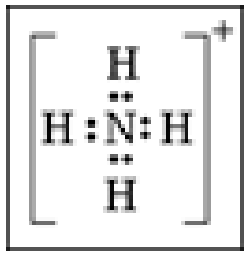
- They are composed of many atoms, but act as ONE ion.
- Compounds containing polyatomic ions include both **ionic** and **covalent** bonding.



H_3O^+



SO_4^{-2}

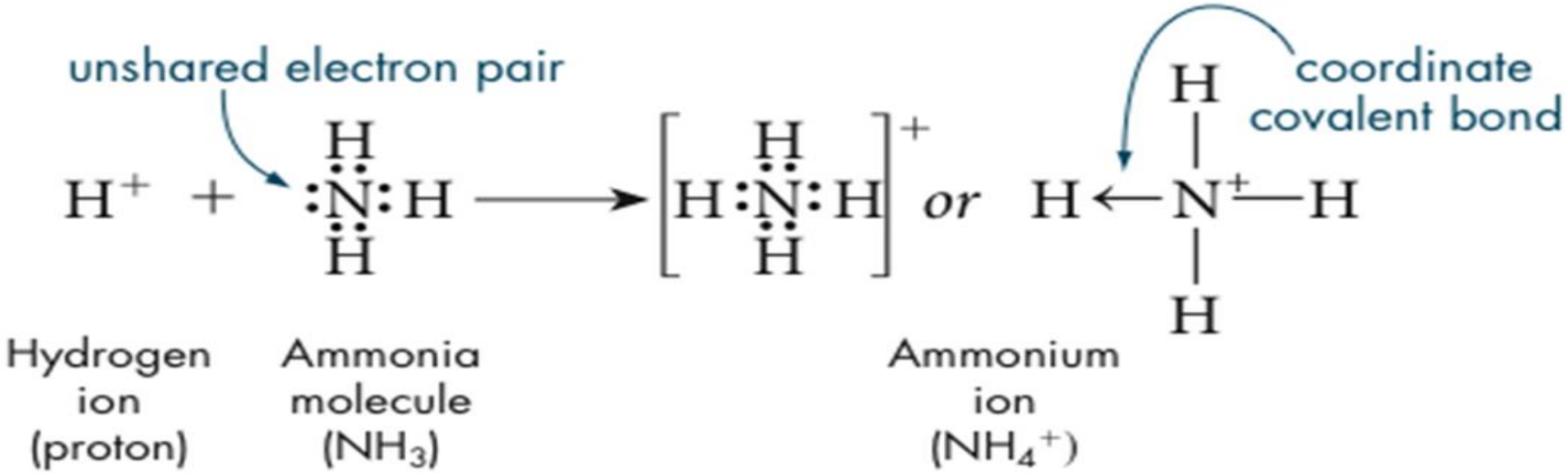


NH_4^+

Polyatomic Ions

Name	Formula	Name	Formula
perPhosphate	$(PO_5)^{-3}$	perCarbonate	$(CO_4)^{-2}$
Phosphate	$(PO_4)^{-3}$	**Carbonate**	$(CO_3)^{-2}$
Phosphite	$(PO_3)^{-3}$	Carbonite	$(CO_2)^{-2}$
hypoPhosphite	$(PO_2)^{-3}$	hypocarbonite	$(CO)^{-2}$
perChlorate	$(ClO_4)^{-1}$	perNitrate	$(NO_4)^{-}$
Chlorate	$(ClO_3)^{-1}$	**Nitrate**	$(NO_3)^{-}$
Chlorite	$(ClO_2)^{-1}$	Nitrite	$(NO_2)^{-}$
hypoChlorite	$(ClO)^{-1}$	Hyponitrite	$(NO)^{-}$
perSulfate	$(SO_5)^{-2}$	perChromate	$(CrO_5)^{-2}$
Sulfate	$(SO_4)^{-2}$	**Chromate**	$(CrO_4)^{-2}$
Sulfite	$(SO_3)^{-2}$	Chromite	$(CrO_3)^{-2}$
hyposulfite	$(SO_2)^{-2}$	Hypochromite	$(CrO_2)^{-2}$
Acetate	$(C_2H_3O_2)^{-1}$	**Cyanide**	$(CN)^{-1}$
Hydroxide	$(OH)^{-1}$	**Manganate**	$(MnO_4)^{-2}$

Ammonium
$(NH_4)^{+1}$



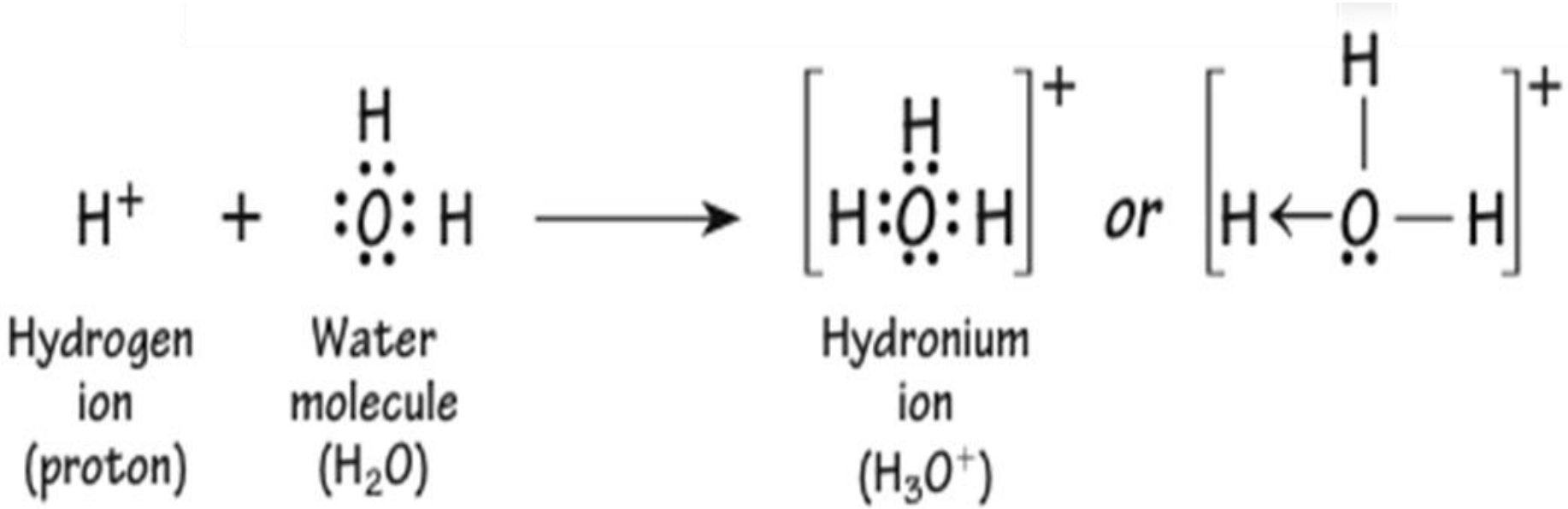
The **ammonium ion (NH_4^+)** forms when a positively charged hydrogen ion (H^+) attaches to the unshared electron pair of an ammonia molecule (NH_3).

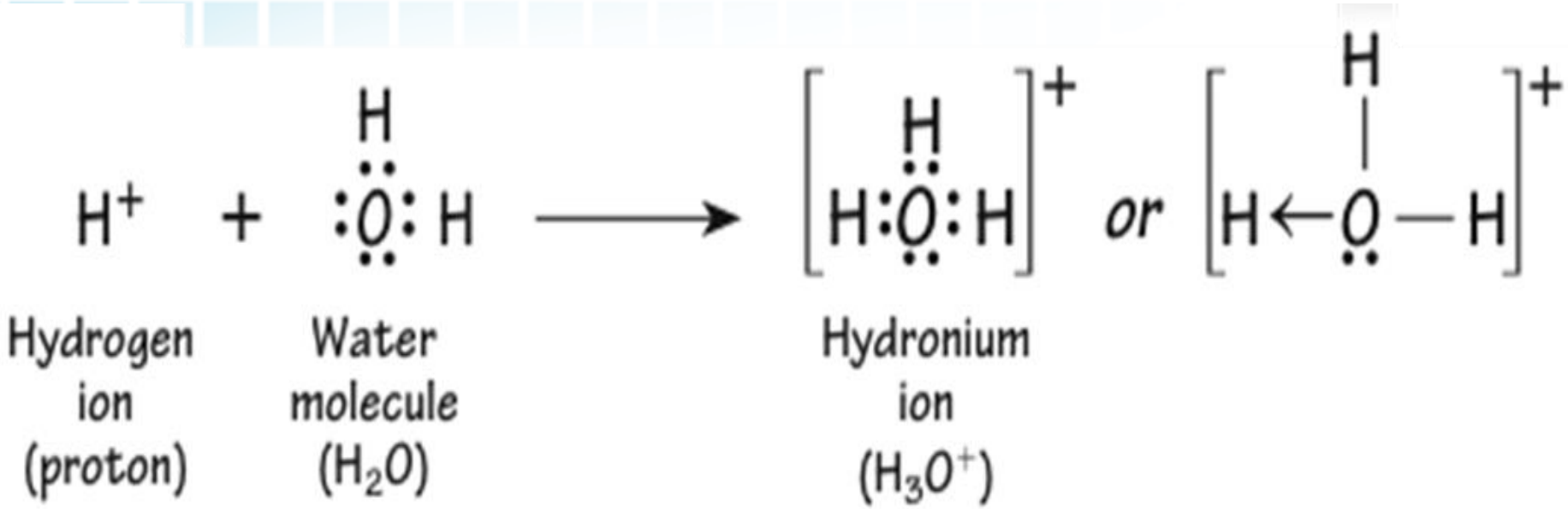
Many ionic compounds (e.g. acids & bases, salts) contain polyatomic ions with covalent & coordinate covalent bonds.

H_2SO_4 HNO_3 H_3PO_4 $HClO_3$

A hydrogen ion (+1 charge) is attracted to an unshared and unbonded electron pair (negative region) in a water molecule.

The H_3O^+ ion (hydronium ion) forms (product) as oxygen shares its UNBONDED pair of electrons with the hydrogen ion to form a **coordinate covalent bond**.





After bonding, the **O** in the H_3O^+ has 8 valence electrons, & each **H** shares 1 valence electron to complete its 1 s sublevel, **satisfying the octet rule for all atoms**. Note, that H_3O^+ has a charge of 1+.

QUICK CHECK

What kind of bonds are represented?

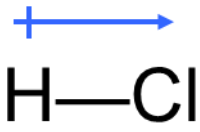
?? bonds A ⟺ B

Equal Distribution of electrons in the bond

?? bonds A ⟹ B A ⟸ B

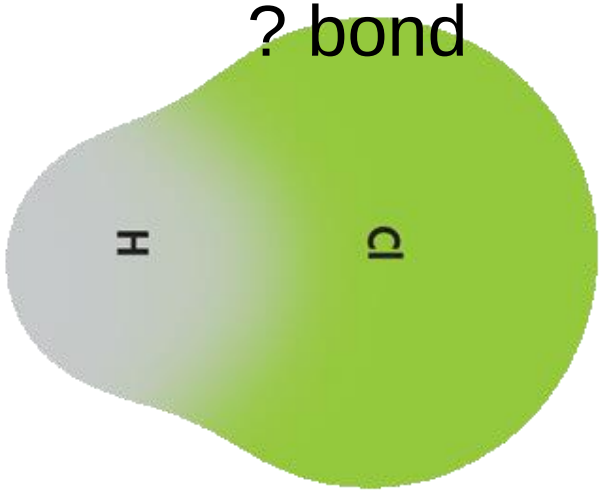
Unequal Distribution of electrons in the bond

Cl – Cl ? bond



? bond

? bond



What happens if atom A or B donates Both of the electrons to make the bond? ? bond

QUICK CHECK

What kind of bonds are represented?

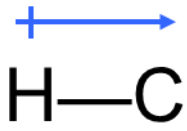
Non-Polar bonds A ⟺ A or B ⟺ B

Equal Distribution of electrons in the bond

Polar Bonds A ⟹ B A ⟸ B

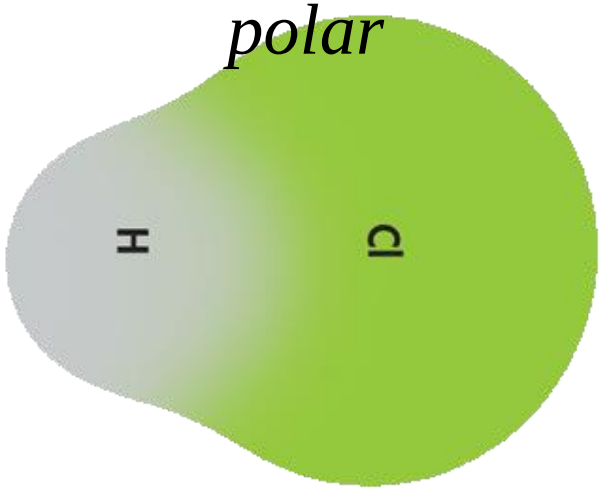
Unequal Distribution of electrons in the bond

Cl – Cl *Non-polar*



polar

polar

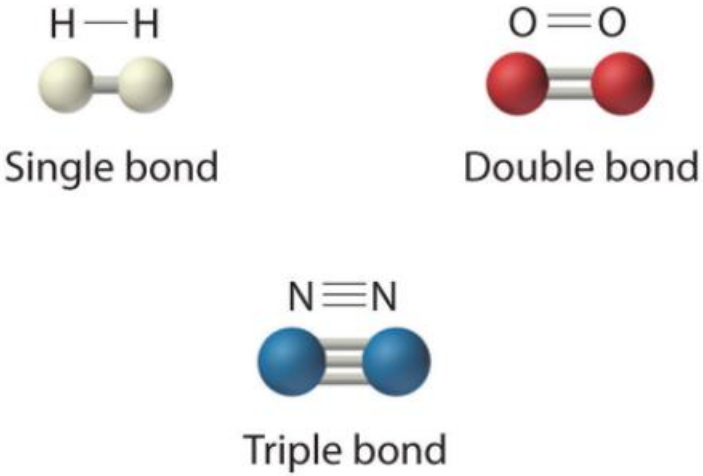


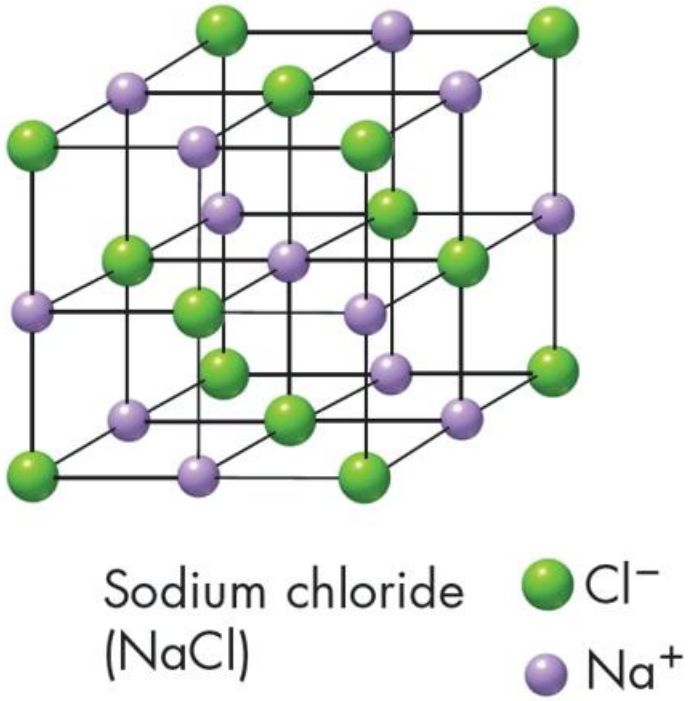
What happens if A or B donates both of the electrons to make the bond? *Coordinate Covalent Bond*

- https://screencast-o-matic.com/watch/cF6nINY67j

Atoms are covalently bonded together to form Covalent **Molecules**

A **molecule** is a discrete, neutral particle which results from covalent bonding as compared to a compound:

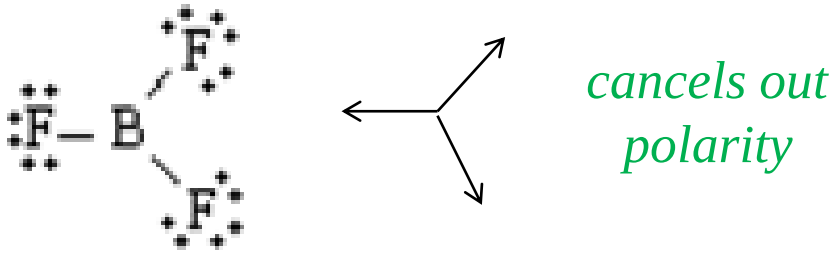




Types of Covalent Molecules

Non-Polar Molecule

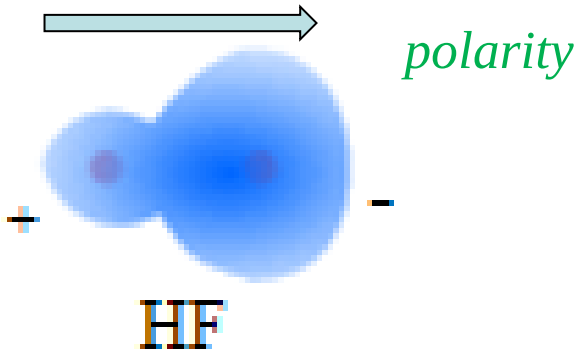
Electrons are shared equally throughout the molecule



cancels out polarity

Polar Molecule

Electrons are shared UNequally throughout the molecule

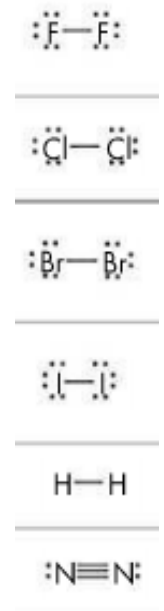


polarity

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 One element are non-polar.



- There are 7 non-polar diatomic molecules:

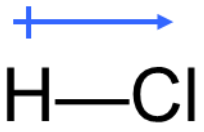
H_2 O_2 F_2 Br_2 I_2 N_2 Cl_2

"Professor *HOFBrINCl*"

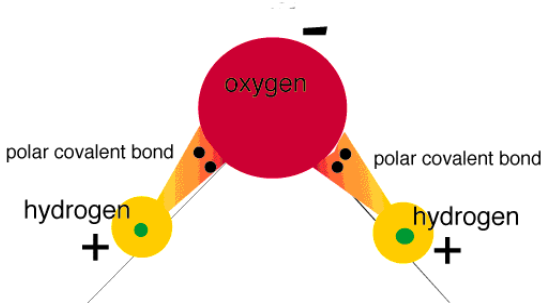
- All other non-polar molecules have at least two different elements. E.g. F−Be−F

Polar Covalent Molecules

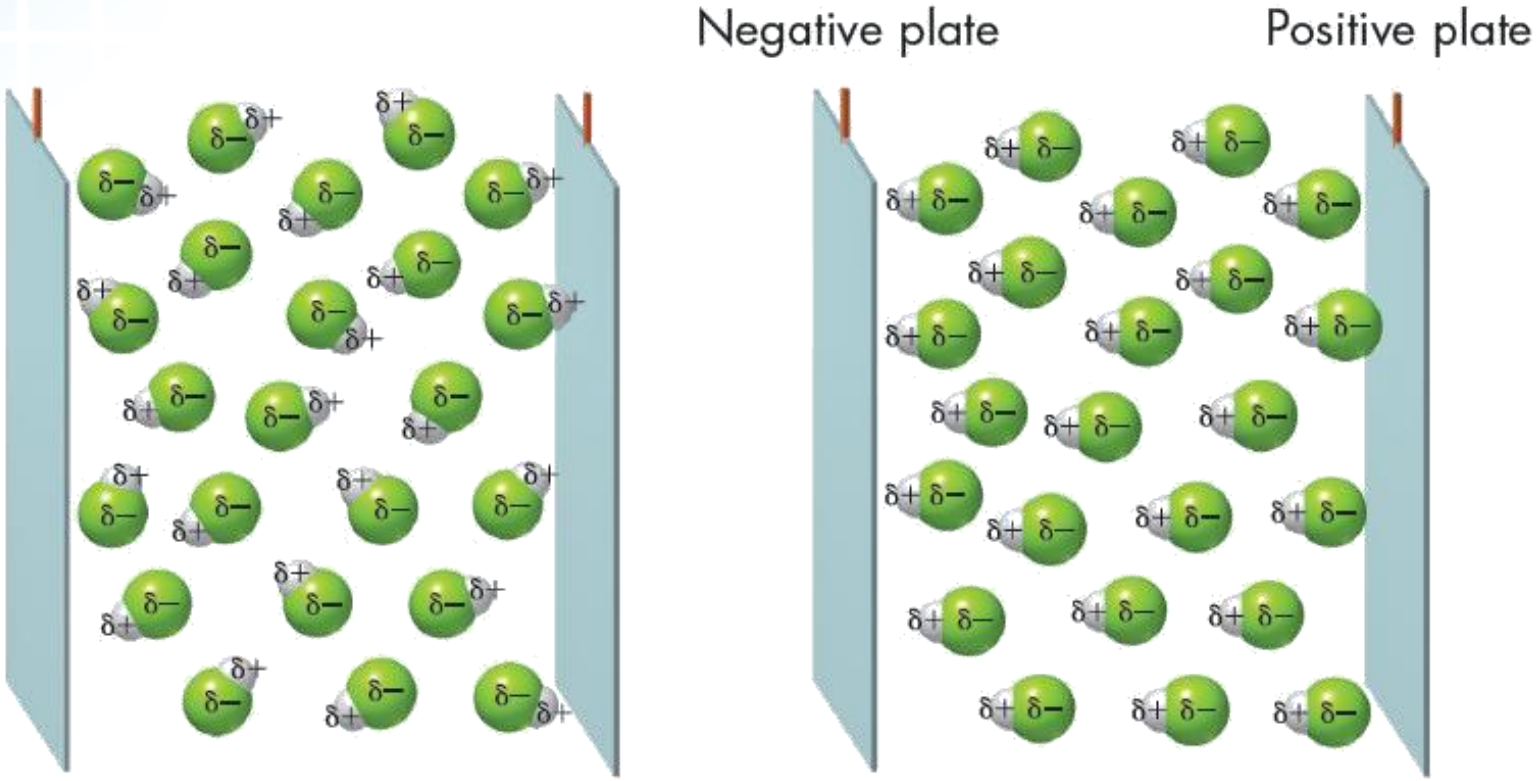
- In a **polar molecule**, there is a separation of positive and negative charge within the molecule.



- "Dipoles" (+ and - ends of a molecule)
- Any **di**atomic molecule made of 2 different elements (*there is an* ***END*** *between the atoms that are covalently bonded*)
- Polyatomic ATOMS are "polar" IF the + and – poles of the molecule are not centered between both atoms → *the negative pole exists closer to one atom(s) and the positive pole exists closer to the other atom(s).*



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

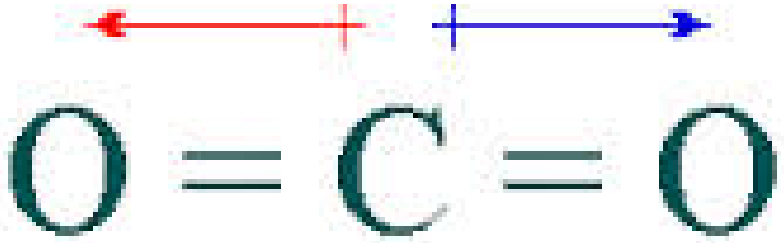


Electric field is absent.
Polar molecules orient randomly.

Electric field is on.
Polar molecules line up.

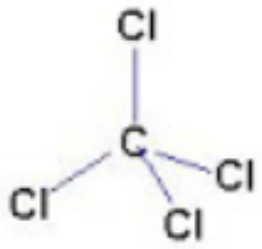
Distinguishing Polarity in Covalent Molecules

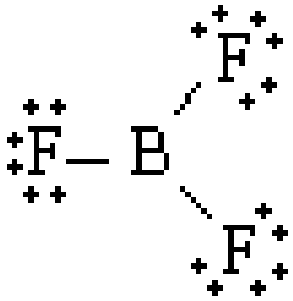
- A **molecule** may be **non-polar** and contain **POLAR bonds** if geometric **SYMMETRY** exists for that molecule.
- A CO_2 molecule has two polar bonds and is linear. The bond polarity cancels, but the molecule is nonpolar.

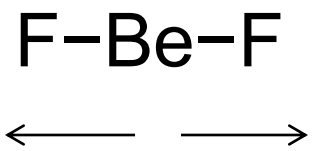


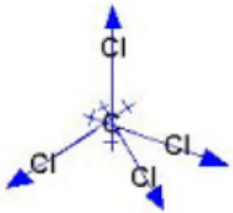
Distinguishing Polarity in Covalent Molecules

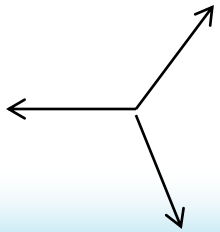
- Symmetry means that if any plane is cut down the center, the resulting planes are identical
- Symmetry is a kind of geometric "Balance" of molecules on all sides.







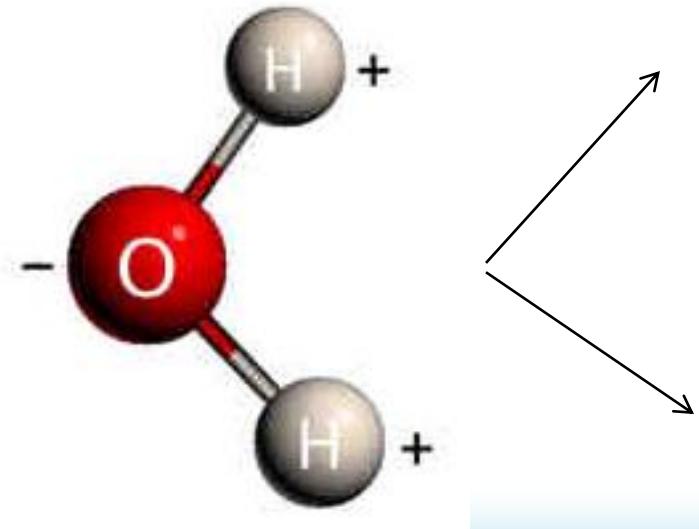




Distinguishing Polarity in Covalent Molecules

- The water molecule, just like carbon dioxide, has two polar bonds.

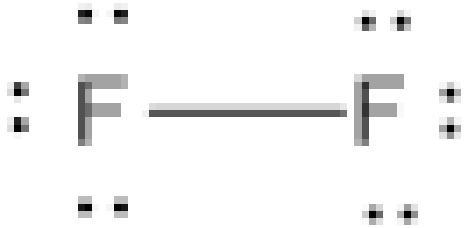
- However, the water molecule is "**bent**" rather than linear. Therefore, the bond polarities do not cancel (as in CO_2) and a water molecule is **polar**.

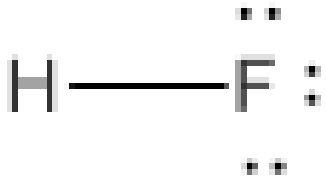


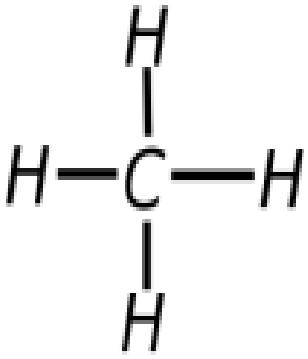
Bond Polarity & Molecular Polarity

QUICK CHECK

- ___ bonds have little or no difference in _____ because they have ____ sharing of _____.
- ____ bonds are formed by atoms that ____ in electronegativity and exhibit _____ sharing of electrons. Therefore, ___ charges develop at opposite ends of the molecule.
- Look at the molecules below and determine the types of bonds and the types of molecules:





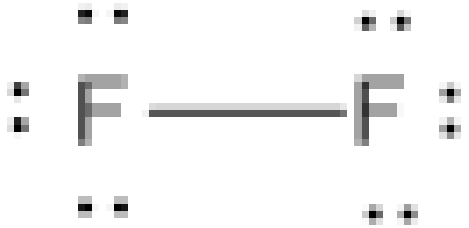


Bond Polarity & Molecular Polarity

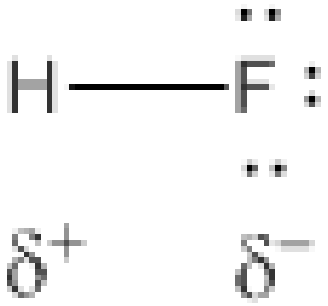
QUICK CHECK

- Nonpolar bonds have little or no difference in electronegativity because they have equal sharing of electrons.
- Polar bonds are formed by atoms that differ in electronegativity and exhibit unequal sharing of electrons. Therefore, partial charges develop at opposite ends of the molecule.
- Look at the molecules below and determine the types of bonds and the types of molecules:

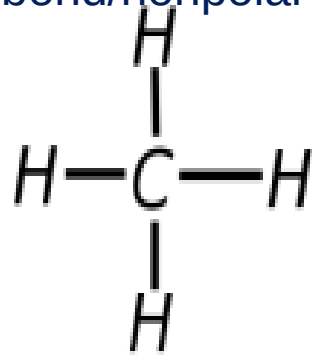
- Non-polar bond/molecule

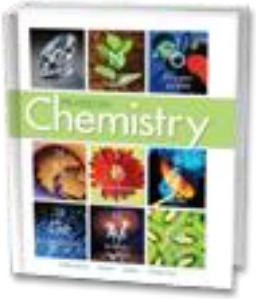


polar bond/molecule



polar bond/nonpolar molecule





Covalent Molecules (Polarity & Geometry) Notes (4:24)

https://screencast-o-matic.com/watch/cF6nFEYXoI

Recap Notes (2:05) using Molecular Models

https://screencast-o-matic.com/watch/cF6hDGYoBr

Representing Molecules

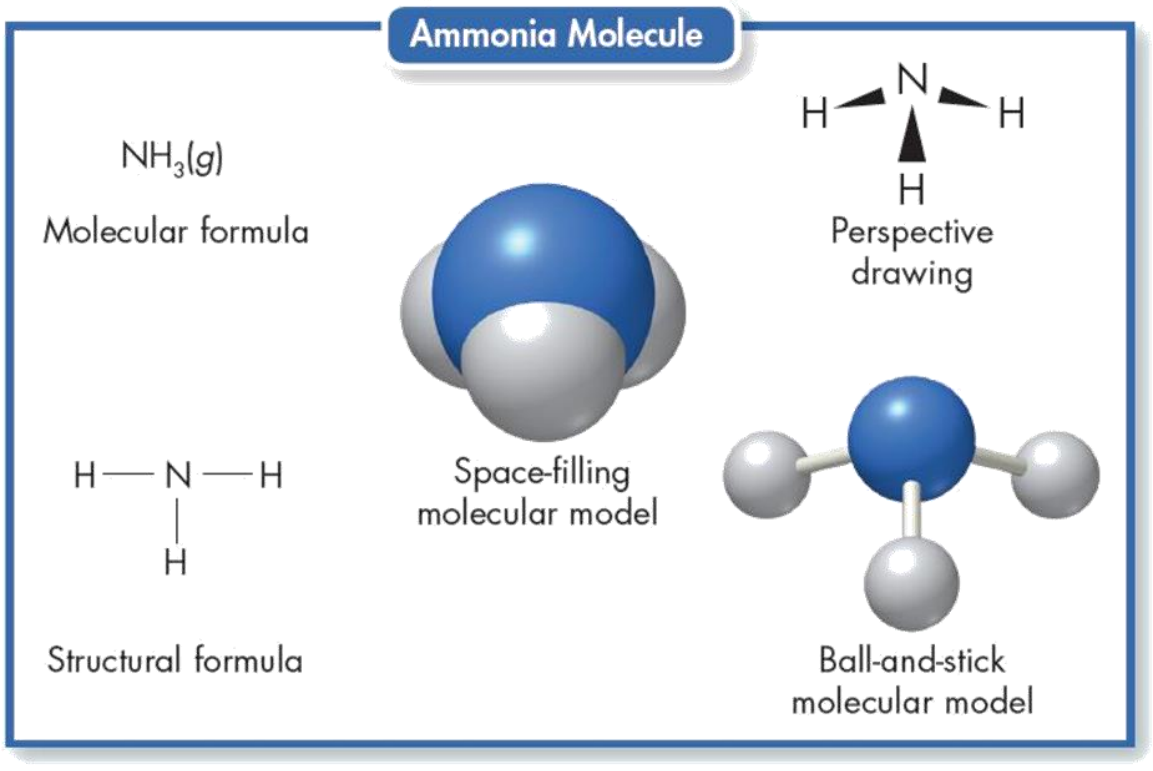
- A **molecular formula** is the chemical formula of a molecular compound. A molecular formula shows how many atoms of each element a substance contains.

E.g. Butane's **molecular formula** (C_4H_{10}) shows 4 carbon atoms & 10 hydrogen atoms.

Empirical Simplest whole number ratio of elements	Molecular Actual whole number ratio Multiple of Empirical
CO_2	CO_2
H_2O	H_2O
NO_2	N_2O_4
P_2O_5	P_4O_{10}
C_5H_{11}	$C_{10}H_{22}$
C_2H_6O	$C_6H_{18}O_3$

Representing Molecules

Molecular Formulas do not show the arrangement of the atoms in space or which atoms are bonded to which. Diagrams, models, and structural formulas can.



Covalent Molecules

- Most molecular compounds are composed of atoms of two or more **nonmetals**.
- The combined atoms usually acquire a total of eight electrons, or an octet, by sharing electrons (octet rule).

Ionic Compounds

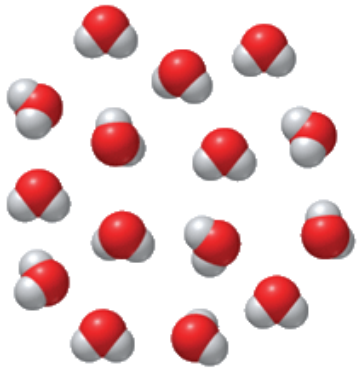
- The smallest representative unit is a **formula unit**, which is the lowest whole-number ratio of ions in an ionic compound.
  - Ionic compounds are formed from a **metal** combined with a **nonmetal**.

Formula Units Vs. Molecules

Molecules

- Discrete unit of atoms
- Molecules collect together

Collection of water molecules



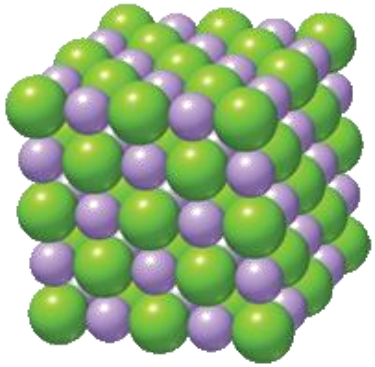
Molecule of water

Chemical formula H_2O

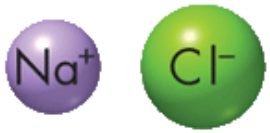
Molecular Formula

Formula units

- No discrete units
- Continuous array of ions.



Array of sodium ions and chloride ions



Formula unit of sodium chloride

NaCl

Chemical formula

Structural Formulas

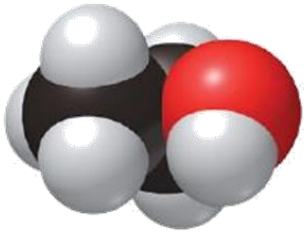
- Show the spatial arrangement of atoms in the molecule of a compound.
- It shows which atom bonds to which atom
- "**DASHES**" represent ONE shared pair of electrons in a covalent bond

CO_2

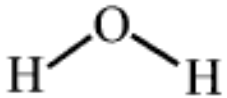
Molecular Formula

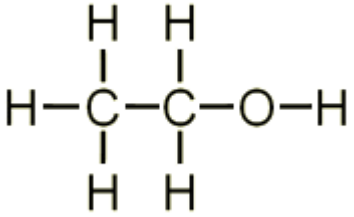
H_2O

Molecular Formula



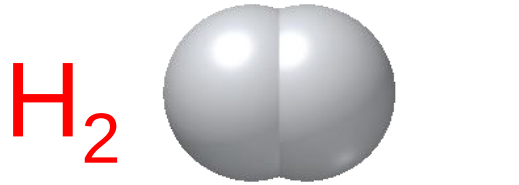
CH_3CH_2OH



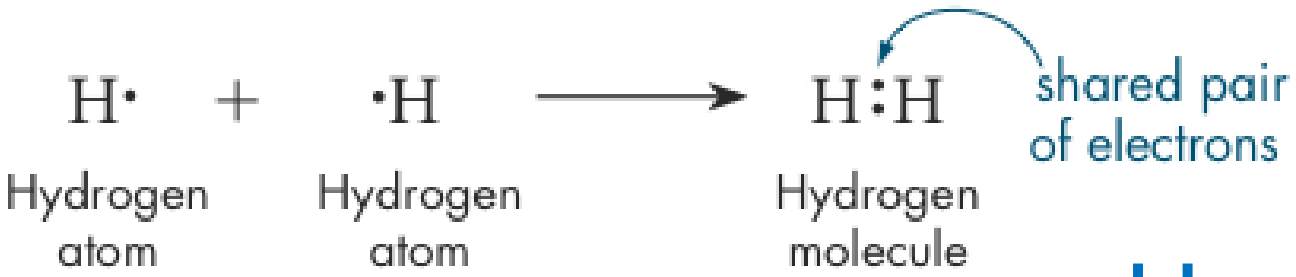


Single Covalent Bonds

- Form from the sharing of ONE pair of electrons between atoms
- E.g. TWO hydrogen atoms are held together mainly by the attraction of the shared electrons to the positive nuclei.
- Hydrogen gas consists of diatomic molecules whose atoms share only one pair of electrons, forming a single covalent bond.



Hydrogen molecule



H—H

Single Covalent Bonds

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.

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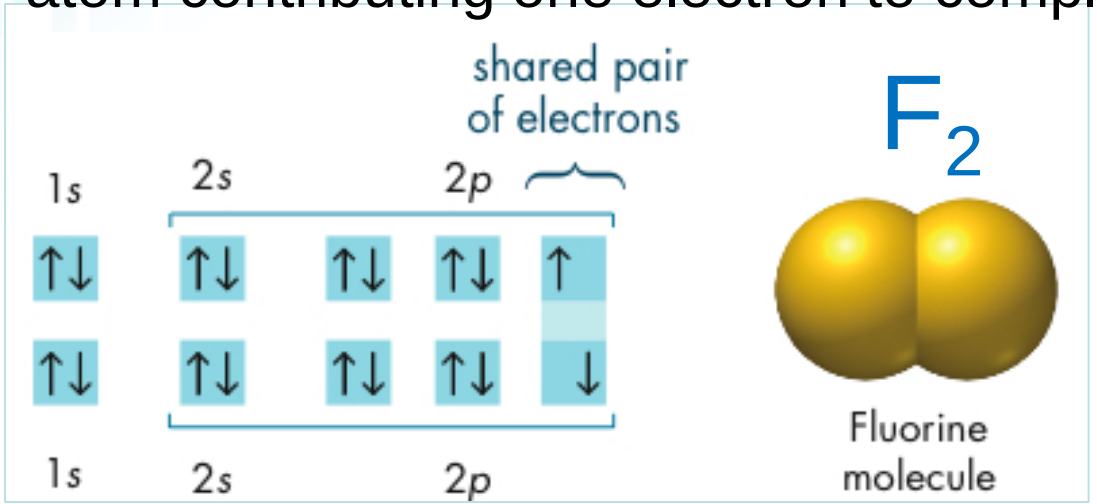
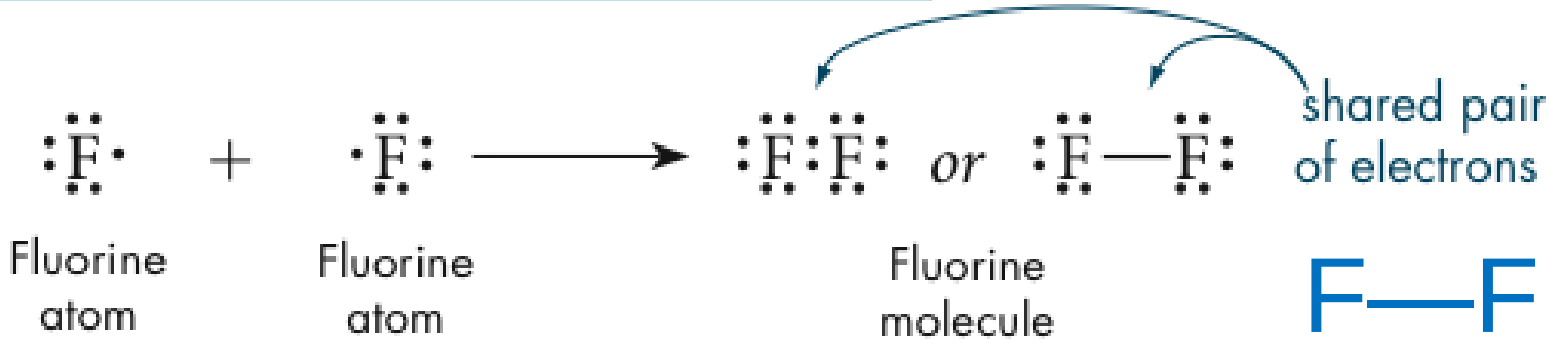
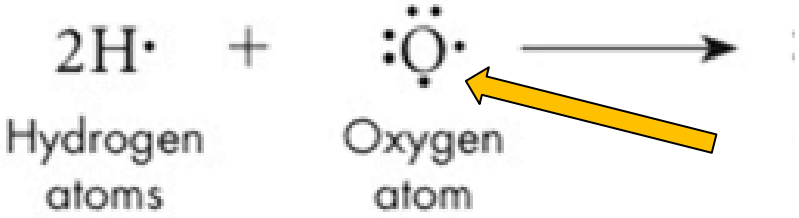


Notice that there are unbonded or unshared pairs of electrons.



The Octet Rule in Covalent Bonding

The oxygen atom in water has two unshared pairs of valence electrons. Once bonded it has a full octet (8 valence e-).



H_2O

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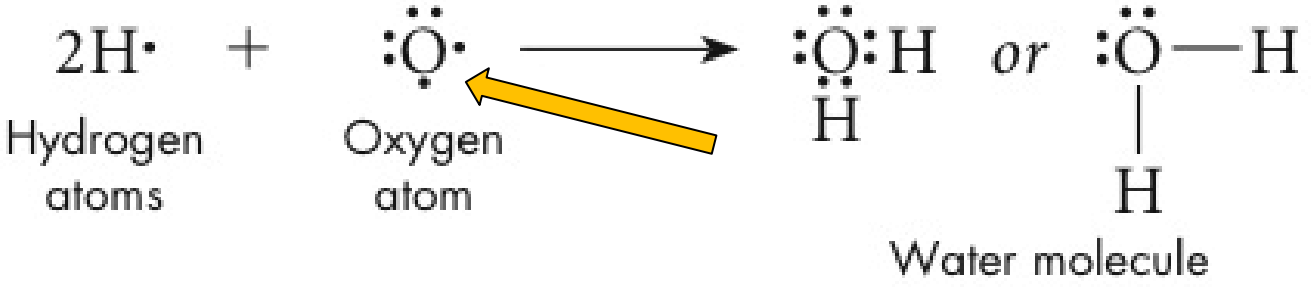
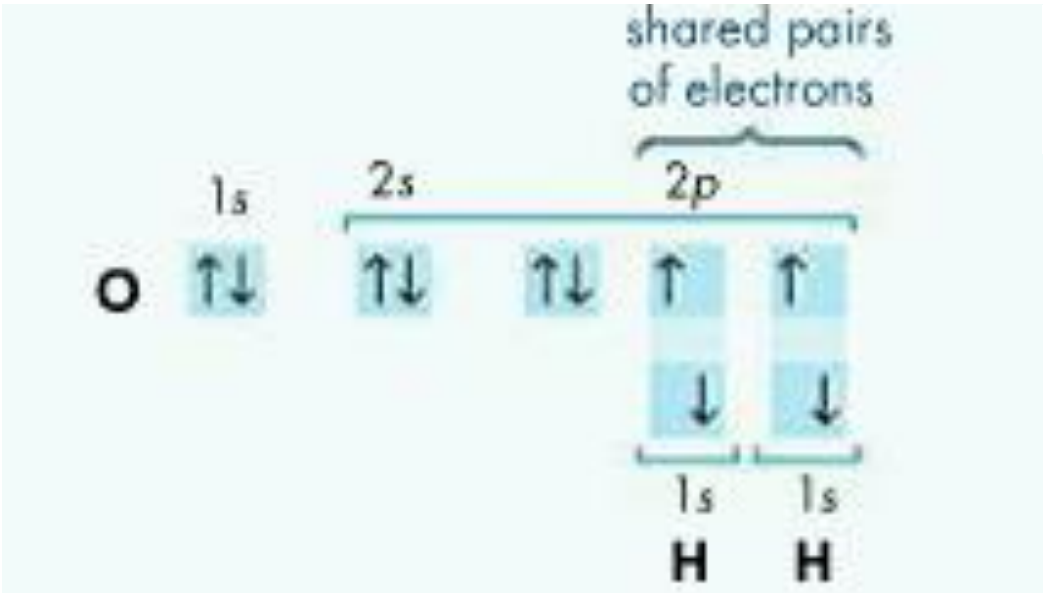


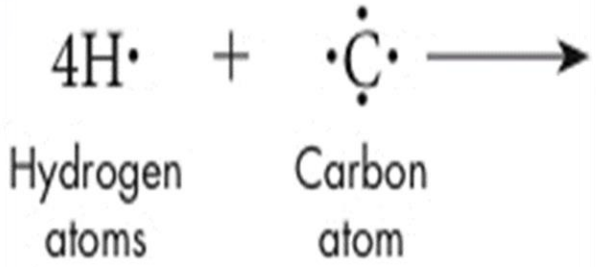
H_2O

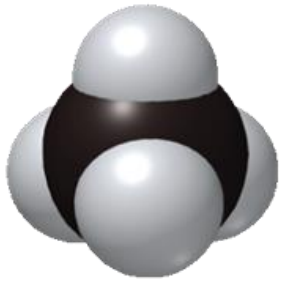
H—O—H



Single Covalent Bond

Methane contains four SINGLE covalent bonds. The carbon atom has four valence electrons and needs four more valence electrons to attain a noble-gas configuration (full octet).





Methane molecule

CH_4

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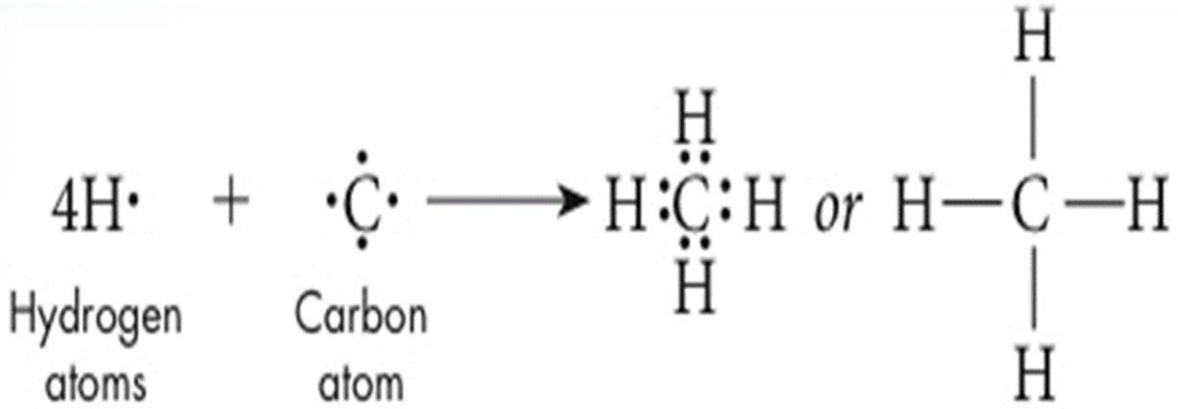

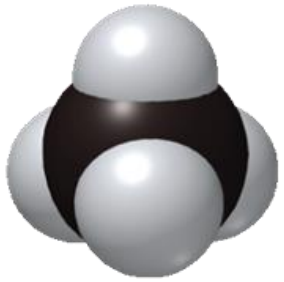

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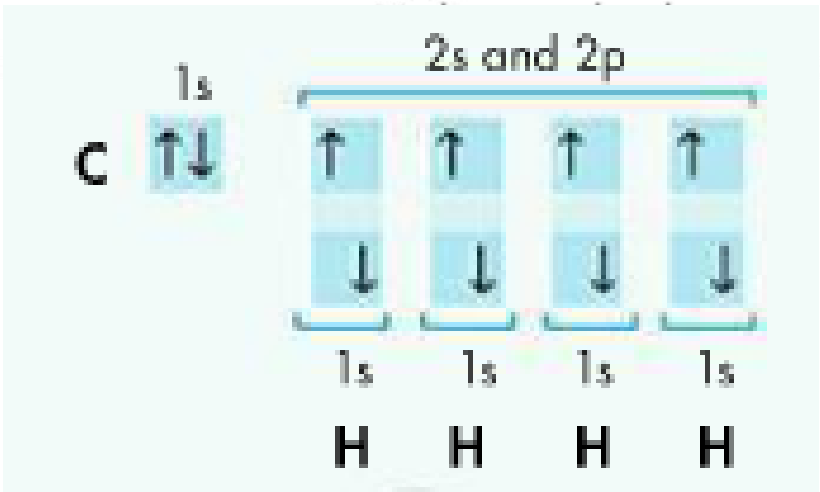
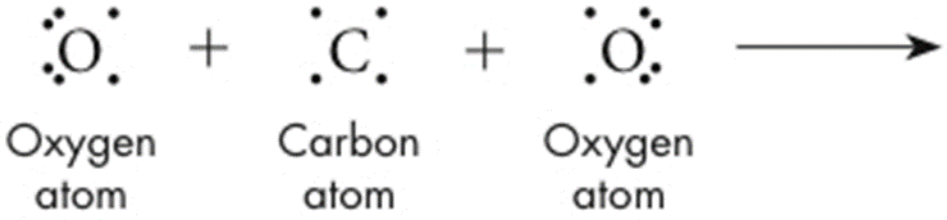


CH_4

Double Covalent Bonds

- A double covalent bond is a bond that involves TWO shared PAIRS of electrons (*4 e- are shared in each C=O bond*).
- Both oxygen atoms in a carbon dioxide (CO_2) molecule share two electrons with carbon to form a total of TWO carbon–oxygen double bonds.



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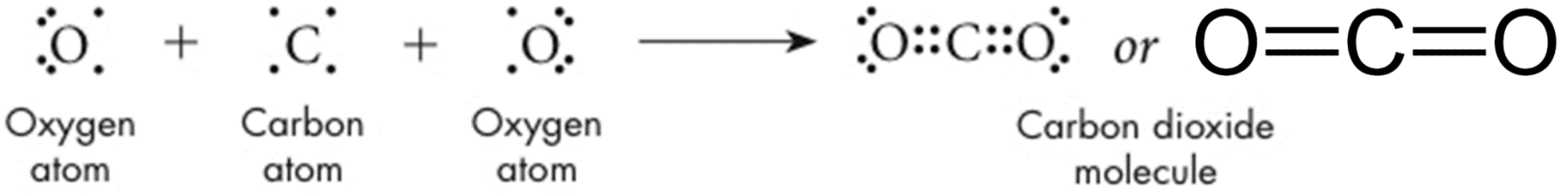
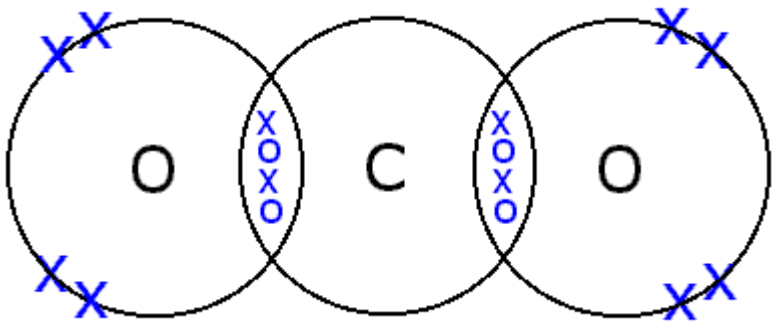
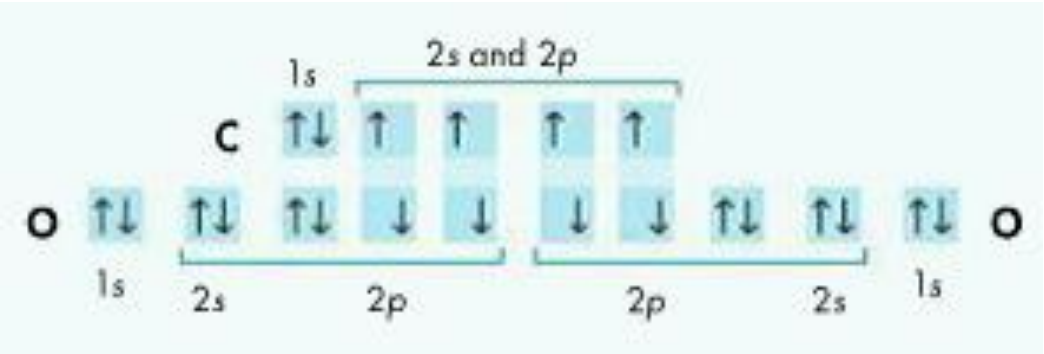
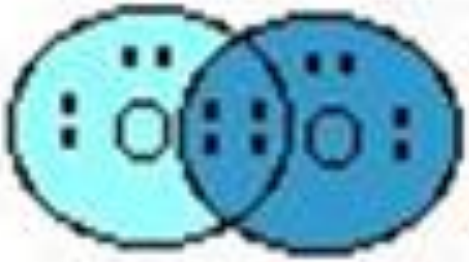


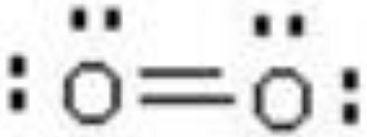


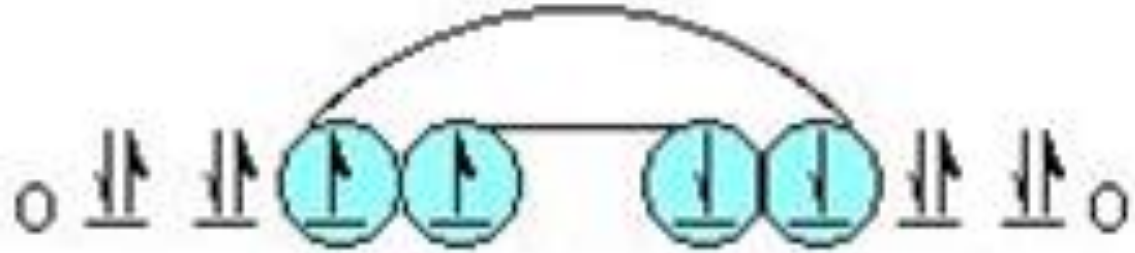


Double Covalent Bonds

- 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-).







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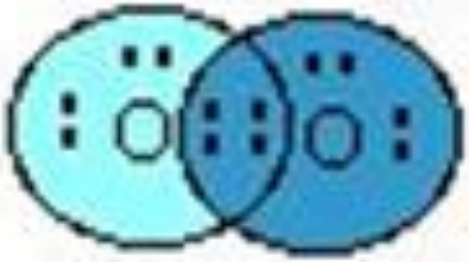
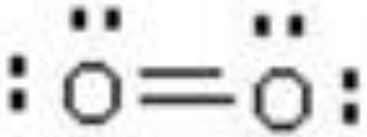
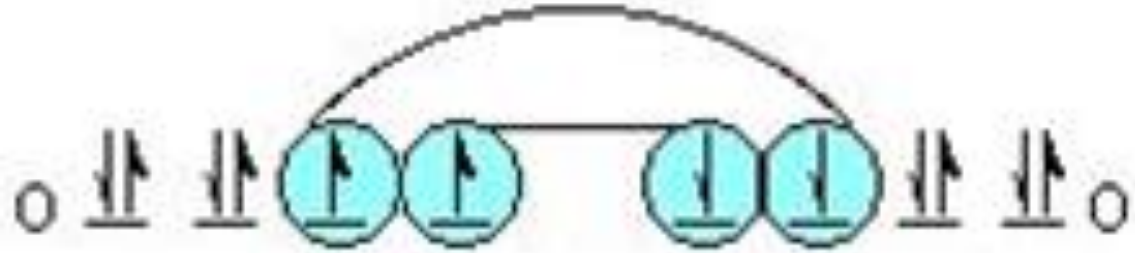
O_2



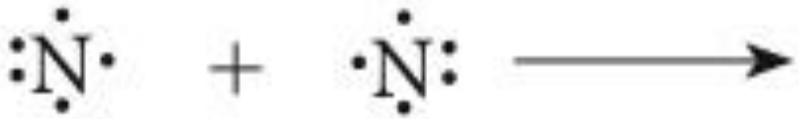




O=O

Triple Covalent Bonds

- A triple covalent bond forms when two atoms share THREE PAIRS of electrons (*6 e- are shared in* N≡N *bond*).



Nitrogen atom + Nitrogen atom

N_2

Triple Covalent Bonds

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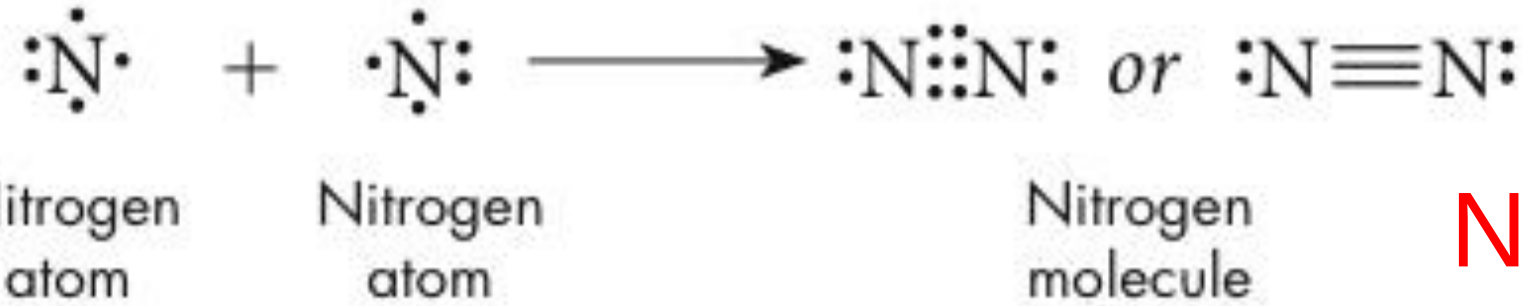
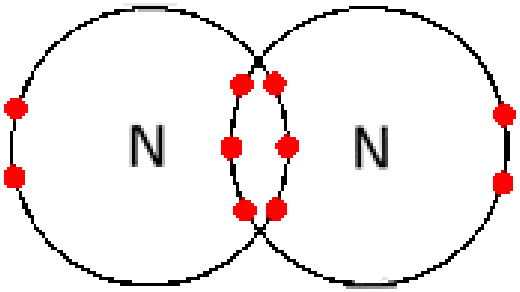
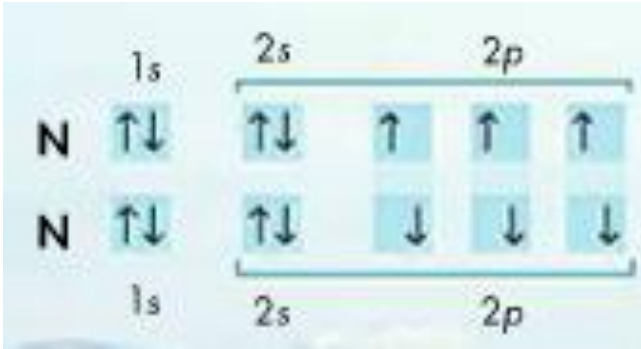


N_2

$N \equiv N$

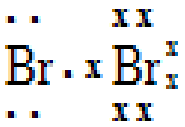
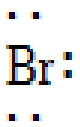
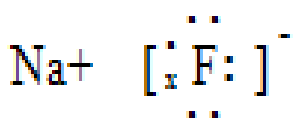




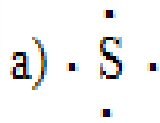
8. 1-3 Review

TRY IT

Which electron dot formula represents a molecule that contains a non-polar covalent bond?

a)  b)  c)  d) 

Which is the correct electron dot representation of an atom of sulfur in the ground state?

a)  b)  c)  d) 

Which electron configuration would most likely represent an atom in the excited state?

a) $1s^2 2s^2 2p^5 3s^1$ b) $1s^2 2s^2 2p^6 3s^2 3p^1$ c) $1s^2 2s^2 2p^6 3s^2 3p^2$ d) $1s^2 2s^2 2p^6 3s^2$

What type of bonding is found in the molecule HBr?

a) ionic b) metallic c) non-polar covalent d) polar covalent

Which formula represents a polar molecule containing polar covalent bonds?

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8. 1-3 Review

TRY IT

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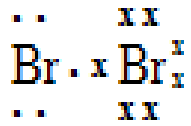
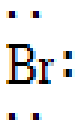
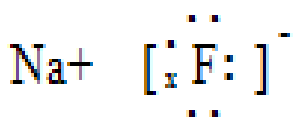
a)  b)  c)  d) 

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8. 1-3 Review

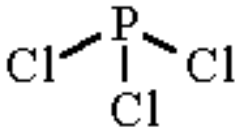
TRY IT

The total number of covalent bonds in a molecule of methane is:

a) 1 b) 2 c) 3 d) 4

The P-Cl bond in a molecule of PCl_3 is:

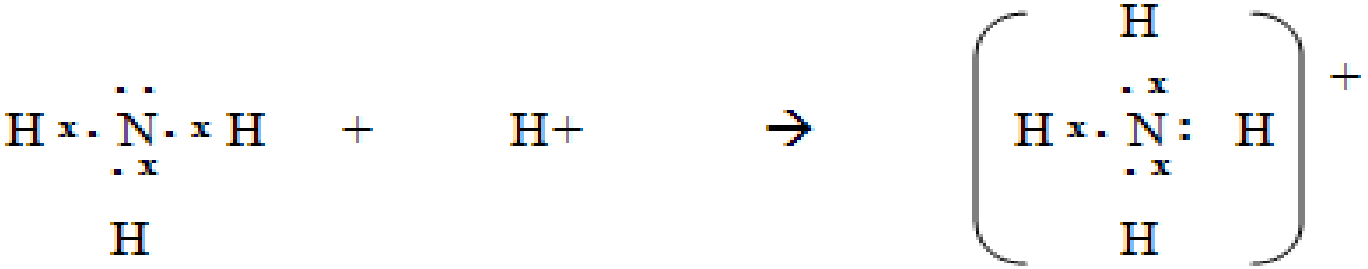
a) non-polar covalent
b) polar covalent
c) coordinate covalent
d) electrovalent



PCl_3 is a(n):

a) non-polar molecule
b) polar molecule
c) ionic compound
d) coordinate covalent molecule

Given the reaction below, the bond formed between NH_3 and the H+ is:



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8. 1-3 Review

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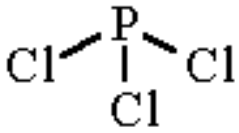

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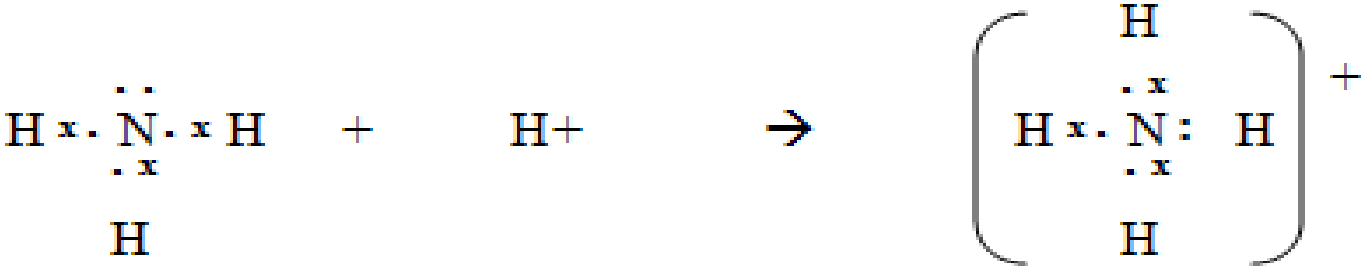

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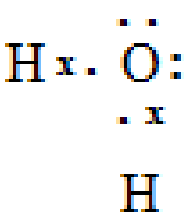
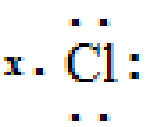
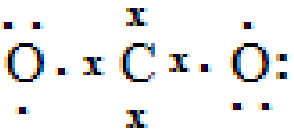
8. 1-3 Review

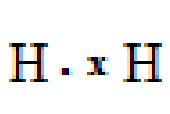
TRY IT

Which molecule is a non-polar molecule with polar bonds?

a) 

b) 

c) 

d) 

Which of the following does not promote an electron being gained by an atom?

a) ionization energy
b) electronegativity
c) non-metallic character
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Which atom has the strongest attraction for electrons?

a) Cl b) F c) Br d) I

Which formula represents a hydrocarbon with a double covalent bond?

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8. 1-3 Review

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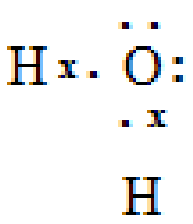
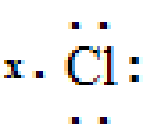
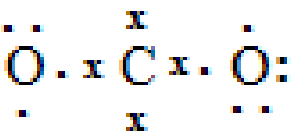
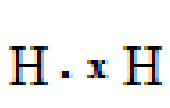
a) 

b) 

c) 

d) 

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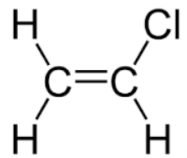

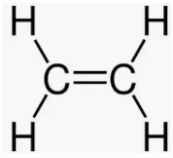

8. 1-3 Review

TRY IT

Show the Lewis structure, electron configuration, the molecular formula, and the structural formula of ammonia (nitrogen bonding with hydrogen).

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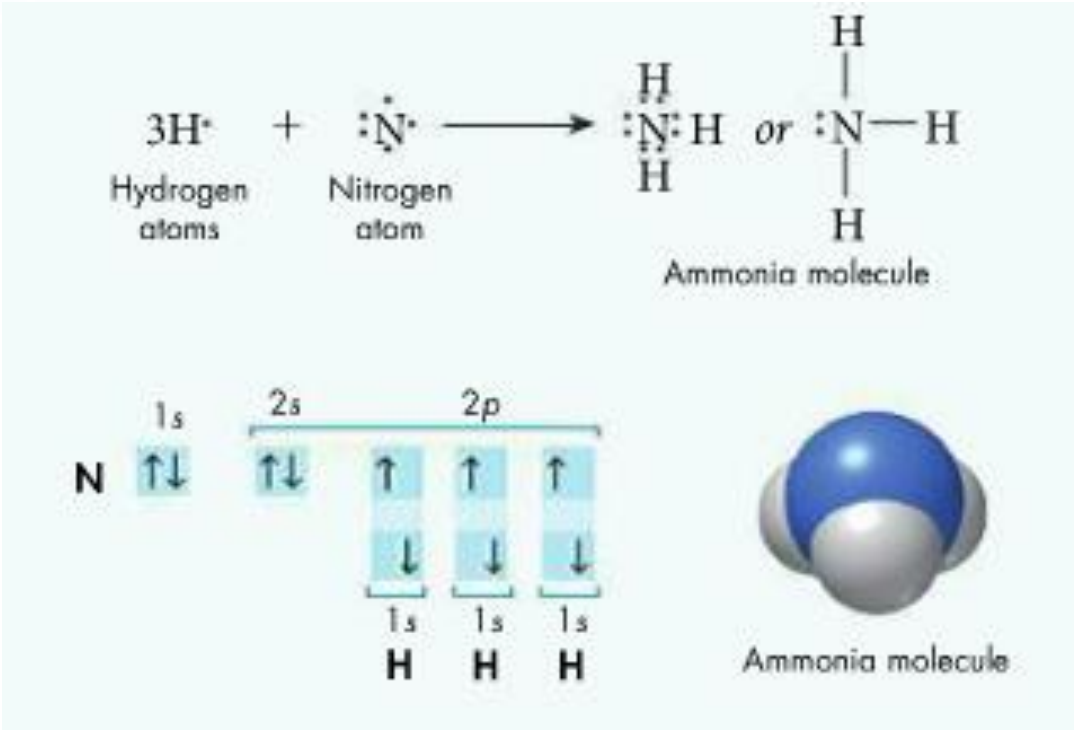
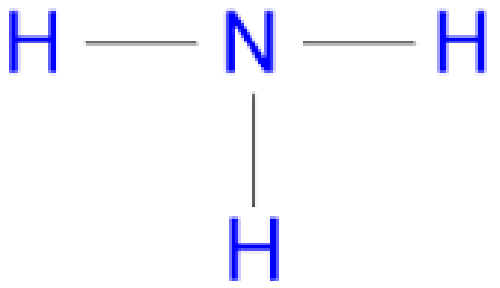
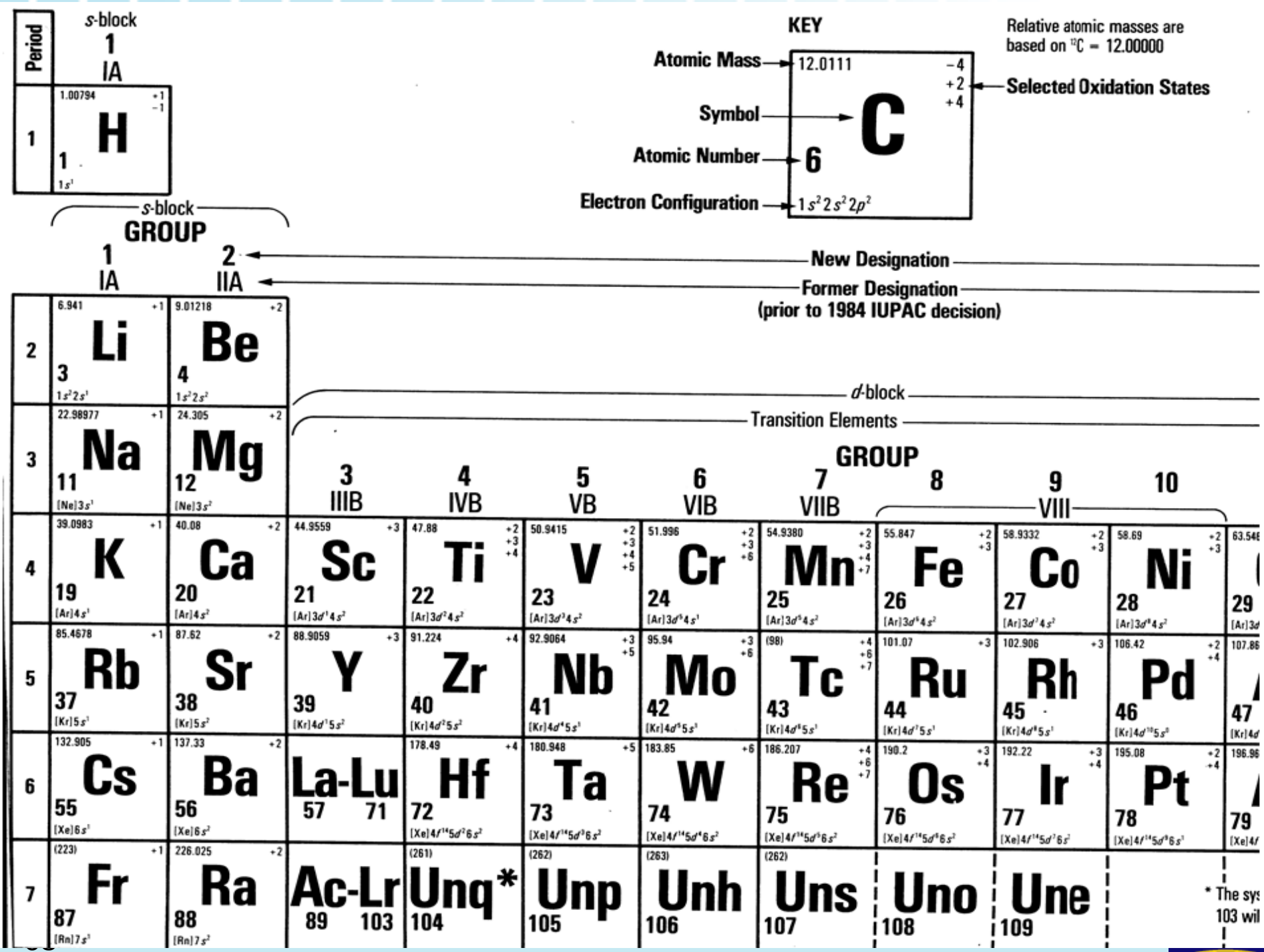


NH_3




Period
s-block
1
IA
1
1.00794
+1
−1
H
1
1s¹
KEY
Atomic Mass
12.0111
−4
+2
+4
Selected Oxidation States
Symbol
C
Atomic Number
6
Electron Configuration
1s²2s²2p²
Relative atomic masses are based on ¹²C = 12.00000
s-block
GROUP
1
IA
2
IIA
New Designation
Former Designation
(prior to 1984 IUPAC decision)
d-block
Transition Elements
GROUP
3
IIIB
4
IVB
5
VB
6
VIB
7
VIIB
8
9
10
VIII
2
6.941
+1
Li
3
1s²2s¹
9.01218
+2
Be
4
1s²2s²
3
22.98977
+1
Na
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[Ne]3s¹
24.305
+2
Mg
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[Ne]3s²
4
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+1
K
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40.08
+2
Ca
20
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+3
Sc
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[Ar]3d¹4s²
47.88
+2
+3
+4
Ti
22
[Ar]3d²4s²
50.9415
+2
+3
+4
+5
V
23
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51.996
+2
+3
+6
Cr
24
[Ar]3d⁵4s¹
54.9380
+2
+3
+4
+7
Mn
25
[Ar]3d⁵4s²
55.847
+2
+3
Fe
26
[Ar]3d⁶4s²
58.9332
+2
+3
Co
27
[Ar]3d⁷4s²
58.69
+2
+3
Ni
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[Ar]3d⁸4s²
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29
[Ar]3d
5
85.4678
+1
Rb
37
[Kr]5s¹
87.62
+2
Sr
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[Kr]5s²
88.9059
+3
Y
39
[Kr]4d¹5s²
91.224
+4
Zr
40
[Kr]4d²5s²
92.9064
+3
+5
Nb
41
[Kr]4d⁴5s¹
95.94
+3
+6
Mo
42
[Kr]4d⁵5s¹
(98)
+4
+6
+7
Tc
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101.07
+3
Ru
44
[Kr]4d⁷5s¹
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+3
Rh
45
[Kr]4d⁸5s¹
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+2
+4
Pd
46
[Kr]4d¹⁰5s⁰
107.86
47
[Kr]4d
6
132.905
+1
Cs
55
[Xe]6s¹
137.33
+2
Ba
56
[Xe]6s²
La-Lu
57
71
178.49
+4
Hf
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+5
Ta
73
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+6
W
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186.207
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+6
+7
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190.2
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Os
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Ir
77
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+2
+4
Pt
78
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79
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7
(223)
+1
Fr
87
[Rn]7s¹
226.025
+2
Ra
88
[Rn]7s²
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

lation States

s-block

p-block

GROUP

10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 0
								4.00260 0 **He** 2 $1s^2$
			10.81 +3 **B** 5 $1s^2 2s^2 2p^1$	12.0111 −4 +2 +4 **C** 6 $1s^2 2s^2 2p^2$	14.0067 −3 −2 −1 +1 +2 +3 +4 +5 **N** 7 $1s^2 2s^2 2p^3$	15.9994 −2 **O** 8 $1s^2 2s^2 2p^4$	18.998403 −1 **F** 9 $1s^2 2s^2 2p^5$	20.179 0 **Ne** 10 $1s^2 2s^2 2p^6$
			26.98154 +3 **Al** 13 [Ne]$3s^2 3p^1$	28.0855 −4 +2 +4 **Si** 14 [Ne]$3s^2 3p^2$	30.97376 −3 +3 +5 **P** 15 [Ne]$3s^2 3p^3$	32.06 −2 +4 +6 **S** 16 [Ne]$3s^2 3p^4$	35.453 −1 +1 +3 +5 +7 **Cl** 17 [Ne]$3s^2 3p^5$	39.948 0 **Ar** 18 [Ne]$3s^2 3p^6$
58.69 +2 +3 **Ni** 28 [Ar]$3d^8 4s^2$	63.546 +1 +2 **Cu** 29 [Ar]$3d^{10} 4s^1$	65.39 +2 **Zn** 30 [Ar]$3d^{10} 4s^2$	69.72 +3 **Ga** 31 [Ar]$3d^{10} 4s^2 4p^1$	72.59 −4 +2 +4 **Ge** 32 [Ar]$3d^{10} 4s^2 4p^2$	74.9216 −3 +3 +5 **As** 33 [Ar]$3d^{10} 4s^2 4p^3$	78.96 −2 +4 +6 **Se** 34 [Ar]$3d^{10} 4s^2 4p^4$	79.904 −1 +1 +5 **Br** 35 [Ar]$3d^{10} 4s^2 4p^5$	83.80 0 +2 **Kr** 36 [Ar]$3d^{10} 4s^2 4p^6$
106.42 +2 +4 **Pd** 46 [Kr]$4d^{10} 5s^0$	107.868 +1 **Ag** 47 [Kr]$4d^{10} 5s^1$	112.41 +2 **Cd** 48 [Kr]$4d^{10} 5s^2$	114.82 +3 **In** 49 [Kr]$4d^{10} 5s^2 5p^1$	118.71 +2 +4 **Sn** 50 [Kr]$4d^{10} 5s^2 5p^2$	121.75 −3 +3 +5 **Sb** 51 [Kr]$4d^{10} 5s^2 5p^3$	127.60 −2 +4 +6 **Te** 52 [Kr]$4d^{10} 5s^2 5p^4$	126.905 −1 +1 +5 +7 **I** 53 [Kr]$4d^{10} 5s^2 5p^5$	131.29 0 +2 +4 +6 **Xe** 54 [Kr]$4d^{10} 5s^2 5p^6$
195.08 +2 +4 **Pt** 78 [Xe]$4f^{14} 5d^9 6s^1$	196.967 +1 +3 **Au** 79 [Xe]$4f^{14} 5d^{10} 6s^1$	200.59 +1 +2 **Hg** 80 [Xe]$4f^{14} 5d^{10} 6s^2$	204.383 +1 +3 **Tl** 81 [Xe]$4f^{14} 5d^{10} 6s^2 6p^1$	207.2 +2 +4 **Pb** 82 [Xe]$4f^{14} 5d^{10} 6s^2 6p^2$	208.980 +3 +5 **Bi** 83 [Xe]$4f^{14} 5d^{10} 6s^2 6p^3$	(209) +2 +4 **Po** 84 [Xe]$4f^{14} 5d^{10} 6s^2 6p^4$	(210) **At** 85 [Xe]$4f^{14} 5d^{10} 6s^2 6p^5$	(222) 0 **Rn** 86 [Xe]$4f^{14} 5d^{10} 6s^2 6p^6$

IONIZATION ENERGIES AND ELECTRONEGATIVITIES

1	2	13	14	15	16	17	18
H 313 / 2.2							He 567
Li 125 / 1.0	Be 215 / 1.5	B 191 / 2.0	C 260 / 2.6	N 336 / 3.1	O 314 / 3.5	F 402 / 4.0	Ne 497
Na 119 / 0.9	Mg 176 / 1.2	Al 138 / 1.5	Si 188 / 1.9	P 242 / 2.2	S 239 / 2.6	Cl 300 / 3.2	Ar 363
K 100 / 0.8	Ca 141 / 1.0	Ga 138 / 1.6	Ge 182 / 1.9	As 226 / 2.0	Se 225 / 2.5	Br 273 / 2.9	Kr 323
Rb 96 / 0.8	Sr 131 / 1.0	In 133 / 1.7	Sn 169 / 1.8	Sb 199 / 2.1	Te 208 / 2.3	I 241 / 2.7	Xe 280
Cs 90 / 0.7	Ba 120 / 0.9	Tl 141 / 1.8	Pb 171 / 1.8	Bi 168 / 1.9	Po 194 / 2.0	At / 2.2	Rn 248
Fr / 0.7	Ra 122 / 0.9						

First Ionization Energy (kcal/mol of atoms)

Electronegativity*

* Arbitrary scale based on fluorine = 4.0

Polyatomic Ions

Name	Formula	Name	Formula
perPhosphate	$(PO_5)^{-3}$	perCarbonate	$(CO_4)^{-2}$
Phosphate	$(PO_4)^{-3}$	**Carbonate**	$(CO_3)^{-2}$
Phosphite	$(PO_3)^{-3}$	Carbonite	$(CO_2)^{-2}$
hypoPhosphite	$(PO_2)^{-3}$	hypocarbonite	$(CO)^{-2}$
perChlorate	$(ClO_4)^{-1}$	perNitrate	$(NO_4)^{-}$
Chlorate	$(ClO_3)^{-1}$	**Nitrate**	$(NO_3)^{-}$
Chlorite	$(ClO_2)^{-1}$	Nitrite	$(NO_2)^{-}$
hypoChlorite	$(ClO)^{-1}$	Hyponitrite	$(NO)^{-}$
perSulfate	$(SO_5)^{-2}$	perChromate	$(CrO_5)^{-2}$
Sulfate	$(SO_4)^{-2}$	**Chromate**	$(CrO_4)^{-2}$
Sulfite	$(SO_3)^{-2}$	Chromite	$(CrO_3)^{-2}$
hyposulfite	$(SO_2)^{-2}$	Hypochromite	$(CrO_2)^{-2}$
Acetate	$(C_2H_3O_2)^{-1}$	**Cyanide**	$(CN)^{-1}$
Hydroxide	$(OH)^{-1}$	**Manganate**	$(MnO_4)^{-2}$

Ammonium $(NH_4)^{+1}$