CHEMICAL BONDS

م.م زينب يحيى كاظم

- Atoms or ions are held together in molecules or compounds by **chemical bonds**.
- The type and number of electrons in the outer electronic shells of atoms or ions are instrumental in how atoms react with each other to form stable chemical bonds.
- Over the last 150 years scientists developed several theories to explain why and how elements combine with each other.

Bonding in Chemistry

- Central theme in chemistry: Why and How atoms attach together
- This will help us understand how to:
  1. Predict the shapes of molecules.
  2. Predict properties of substances.
  3. Design and build molecules with particular sets of chemical and physical properties.

Chemical Bonds

Two of the most common substance on our dining table are salt and granulated sugar

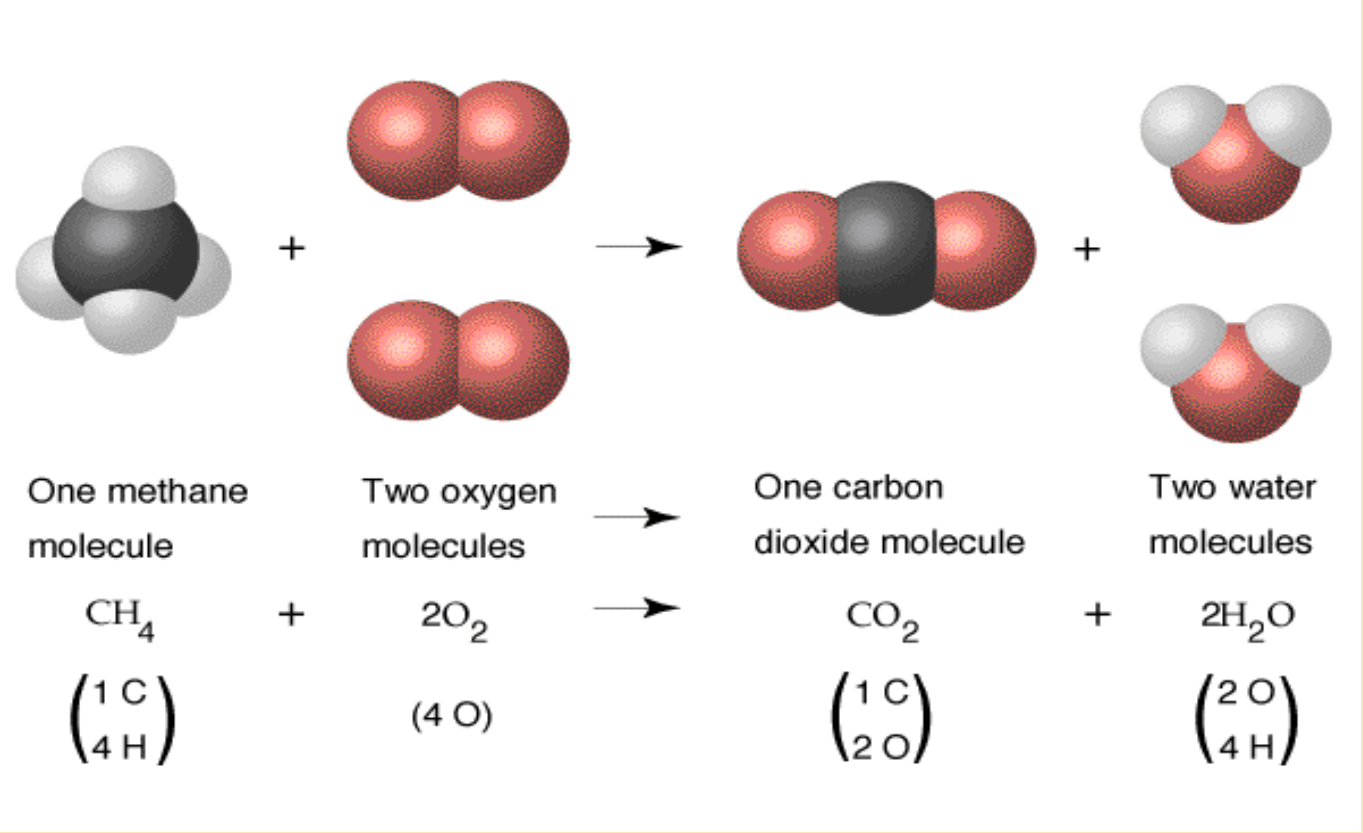
NaCl

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

The properties of substances are determined in large part by the chemical bonds that hold their atoms together

Chemical Bonds

All chemical reactions involve breaking of some bonds and formation of new ones which yield new products with different properties.

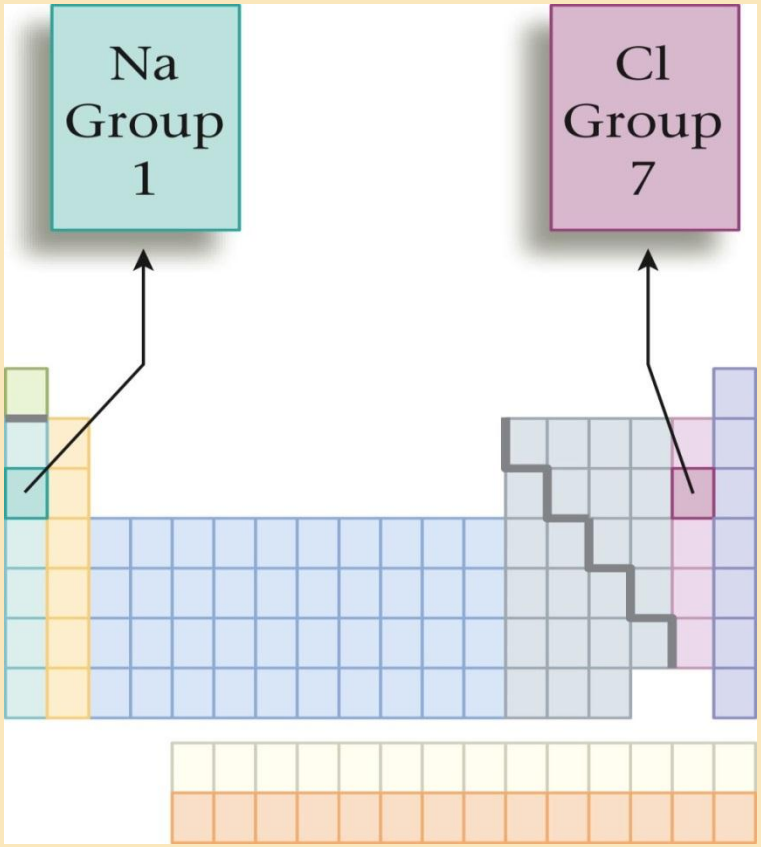


Binary Ionic Compounds

Naming Compounds

- Binary Compounds
  - Composed of two elements
  - Ionic and covalent compounds included
- Binary Ionic Compounds
  - Metal—nonmetal NaCl and $CaCl_2$.
- Binary Covalent Compounds
- Nonmetal—nonmetal such as H_2O and CO_2

- Binary ionic compounds contain positive cations and negative anions.
  - Type I compounds
    - Metal present forms only one cation.
  - Type II compounds
    - Metal present can form 2 or more cations with different charges.



Type I Compounds

Metals (Groups I, II, and III) and Non-Metals

Metal Sodium + Non-Metal Chlorine ide

Sodium Chloride NaCl

Metal Calcium + Non-Metal Bromide ide

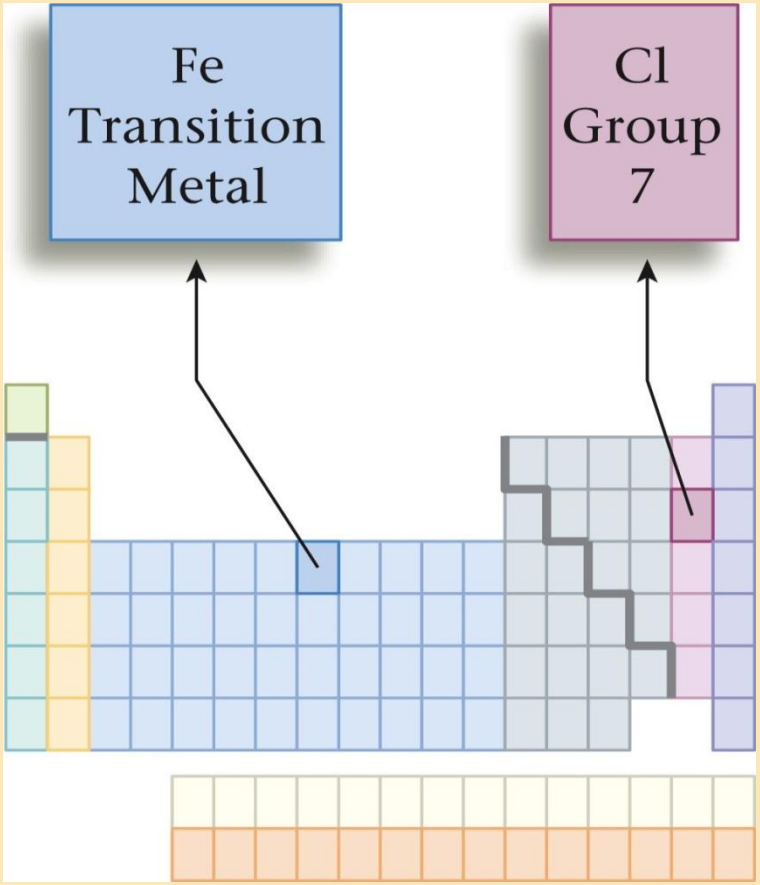
Calcium Bromide $CaBr_2$

Metal Aluminun + Non-Metal Oxide ide

Aluminum Oxide Al_2O_3

Binary Ionic Compounds (Type II) with Transition Metals

- Metals in these compounds can form more than one type of positive charge.
- Charge on the metal ion must be specified.
- Roman numeral indicates the charge of the metal cation.
- Transition metal cations usually require a Roman numeral.



Type II Compounds

Metals (Transition Metals) and Non-Metals

Metal Iron +Roman Numeral (III) + Non-Metal Bromine ide

Iron (III) Bromide $FeBr_3$

Compare with Iron (II) Bromide $FeBr_2$

Metals (Transition Metals) and Non-Metals
Older System

Metal (Latin) Ferrous + ous or ic + Non-Metal Bromine ide

Ferrous Bromide $FeBr_2$

Compare with Ferric Bromide $FeBr_3$

Common Type II Cations

Table 5.2 Common Type II Cations

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

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

Rules for Naming Type II Ionic Compounds

1. The cation is always named first and the anion second.
2. Because the cation can assume more than one charge, the charge is specified by a Roman numeral in parentheses.

$$2(3+) + 3(2-) = 0$$

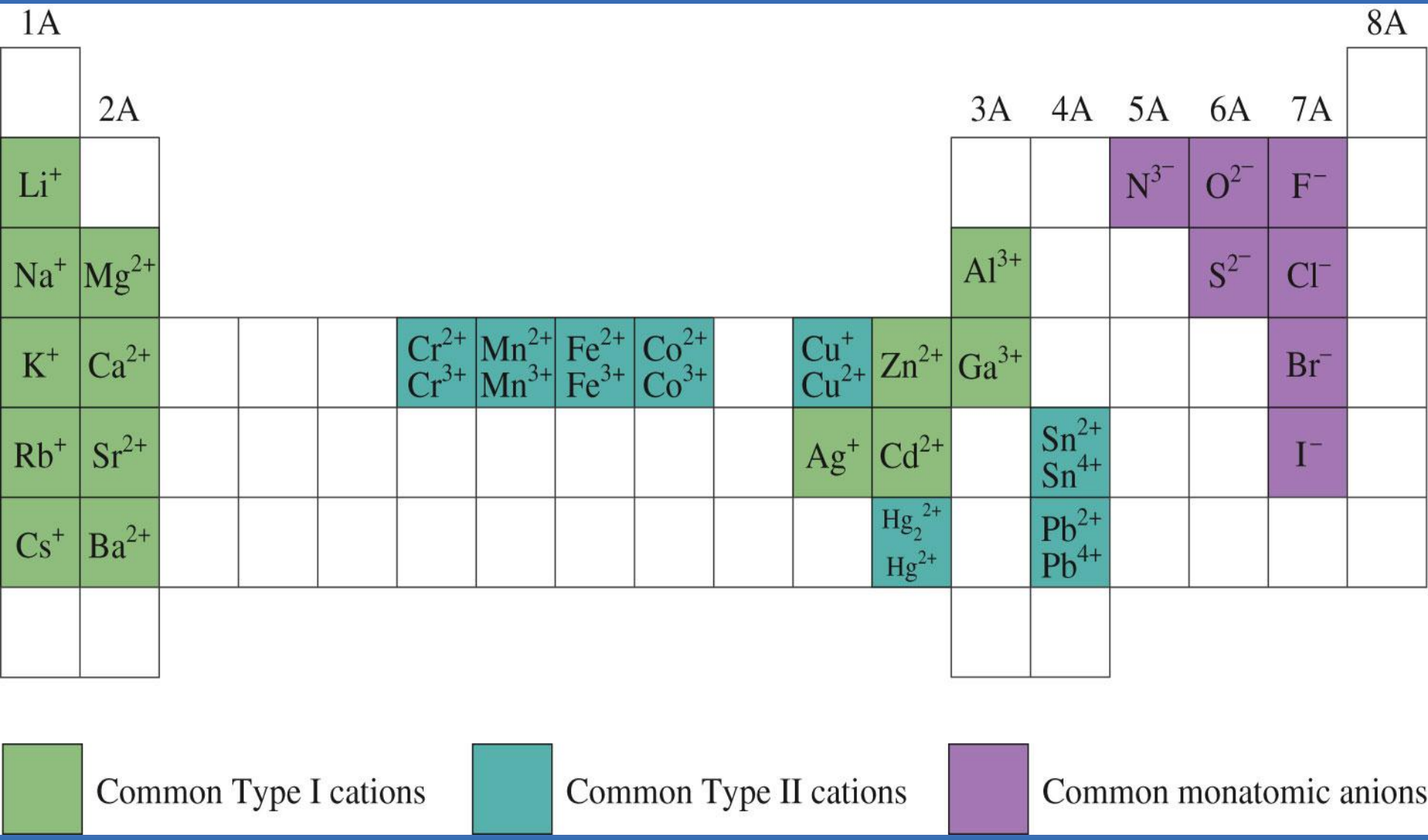
Fe^{3+} O^{2-} Net charge

Compound	Ions Present	Ion Names	Comments
Fe_2O_3 (Cation)	Fe^{3+}	iron(III)	Iron is a transition metal and requires a III to specify the charge on the cation.
Fe_2O_3 (Anion)	O^{2-}	oxide	

Binary Ionic Compounds (Type II)

- Examples:

CuBr	Copper(I) bromide
FeS	Iron(II) sulfide
PbO_2	Lead(IV) oxide


1A
8A
2A
3A
4A
5A
6A
7A
Li+
Na+
Mg2+
K+
Ca2+
Rb+
Sr2+
Cs+
Ba2+
Cr2+ Cr3+
Mn2+ Mn3+
Fe2+ Fe3+
Co2+ Co3+
Cu+ Cu2+
Zn2+
Ag+
Cd2+
Hg2 2+ Hg2+
Al3+
Ga3+
Sn2+ Sn4+
Pb2+ Pb4+
N3−
O2−
F−
S2−
Cl−
Br−
I−
Common Type I cations
Common Type II cations
Common monatomic anions

Properties of Ionic Compounds

- Crystalline structure.
- A regular repeating arrangement of ions in the solid.
- Ions are strongly bonded.
- Structure is rigid.
- High melting points- because of strong forces between ions.

Covalent Compounds

Covalent Compounds

Two nonmetals share electrons so both have 8 valence electrons. Exception: H Neither takes on a charge - no valence. Do not crisscross to determine formula. Must use prefixes in the name. Name tells you the formula. Example: N_2O_4 is di nitrogen tetroxide.

Polyatomic Ions

Polyatomic Ions

A **polyatomic ion** is a group of atoms with an overall ionic charge.

NH_4^+	ammonium	OH^-	hydroxide
NO_3^-	nitrate	NO_2^-	nitrite
CO_3^{2-}	carbonate	PO_4^{3-}	phosphate
HCO_3^-	hydrogen carbonate (or bicarbonate)		

Naming Polyatomic Ions

- The names of the common polyatomic anions end in *ate.*

  NO_3^- nitr**ate** PO_4^{3-} phosph**ate**

- with one oxygen less end in *ite.*

  NO_2^- nitr**ite** PO_3^{3-} phosph**ite**

- with hydrogen use prefix hydrogen (or bi)

  HCO_3^- **hydrogen** carbonate (**bi**carbonate)

  HSO_3^- **hydrogen** sulfite (**bi**sulfite)

Names and Formulas of Common Polyatomic Ions

TABLE 6.7 Names and Formulas of Some Common Polyatomic Ions

Nonmetal	Formula of Ion*	Name of Ion
Hydrogen	OH^-	Hydroxide
Nitrogen	NH_4^+	Ammonium
	NO_3^-	**Nitrate**
	NO_2^-	Nitrite
Chlorine	ClO_4^-	Perchlorate
	ClO_3^-	**Chlorate**
	ClO_2^-	Chlorite
	ClO^-	Hypochlorite
Carbon	**CO_3^{2-}**	**Carbonate**
	HCO_3^-	Hydrogen carbonate (or bicarbonate)
	CN^-	Cyanide
	$C_2H_3O_2^-$	Acetate
	SCN^-	Thiocyanate

Names and Formulas of Common Polyatomic Ions

TABLE 6.7 Names and Formulas of Some Common Polyatomic Ions

Nonmetal	Formula of Ion*	Name of Ion
Sulfur	**SO_4^{2-}**	**Sulfate**
	HSO_4^-	Hydrogen sulfate (or bisulfate)
	SO_3^{2-}	Sulfite
	HSO_3^-	Hydrogen sulfite (or bisulfite)
Phosphorus	**PO_4^{3-}**	**Phosphate**
	HPO_4^{2-}	Hydrogen phosphate
	$H_2PO_4^-$	Dihydrogen phosphate
	PO_3^{3-}	Phosphite
Chromium	**CrO_4^{2-}**	**Chromate**
	$Cr_2O_7^{2-}$	Dichromate
Manganese	MnO_4^-	Permanganate

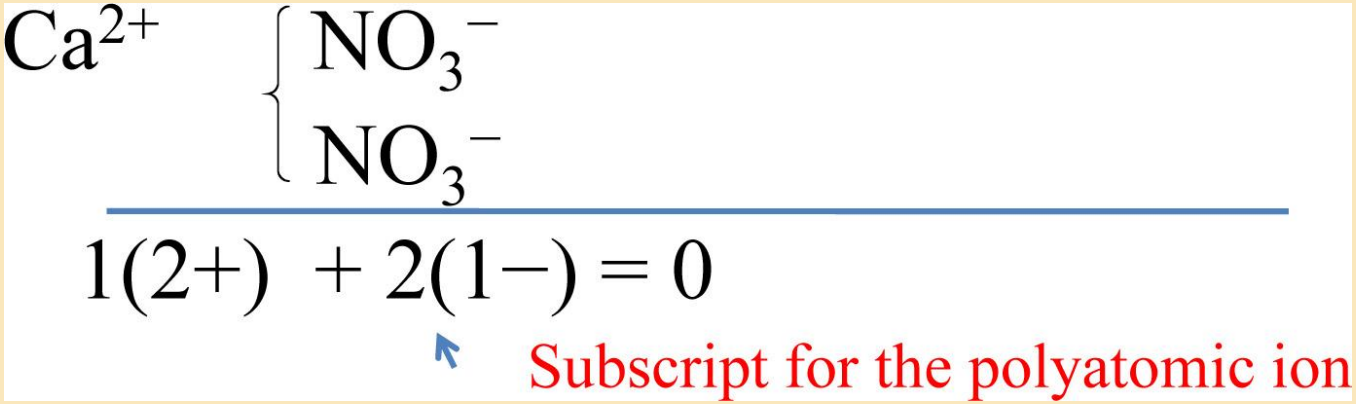
*Formulas and names in bold show the most common polyatomic ion for that element.

Writing Formulas for Compounds with Polyatomic Ions

To write the correct formula for compounds containing polyatomic ions, first determine the ratio of ions using charge balance.

Write the formula for calcium nitrate.

1. The total negative and positive charges must equal zero



Writing Formulas for Compounds with Polyatomic Ions

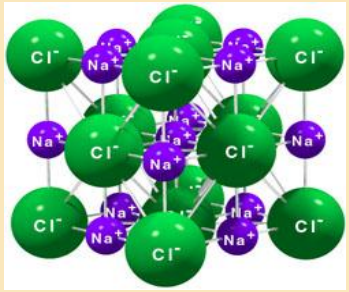
2. When more than one polyatomic ion is needed for charge balance, the subscript is written outside the closing parenthesis of the polyatomic ion.

$$Ca^{2+} + 2\ NO_3^- \rightarrow Ca(NO_3)_2$$

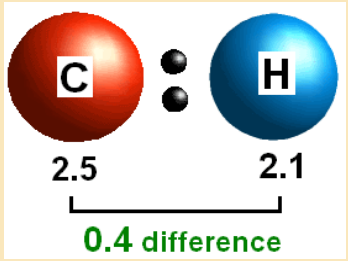
Calcium ion + 2 Nitrate ions **Calcium nitrate**

Types of Chemical Bonds

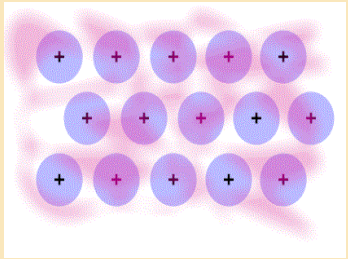
- Ionic bonds



- Covalent bonds



- Metallic bonds



Ionic Bond

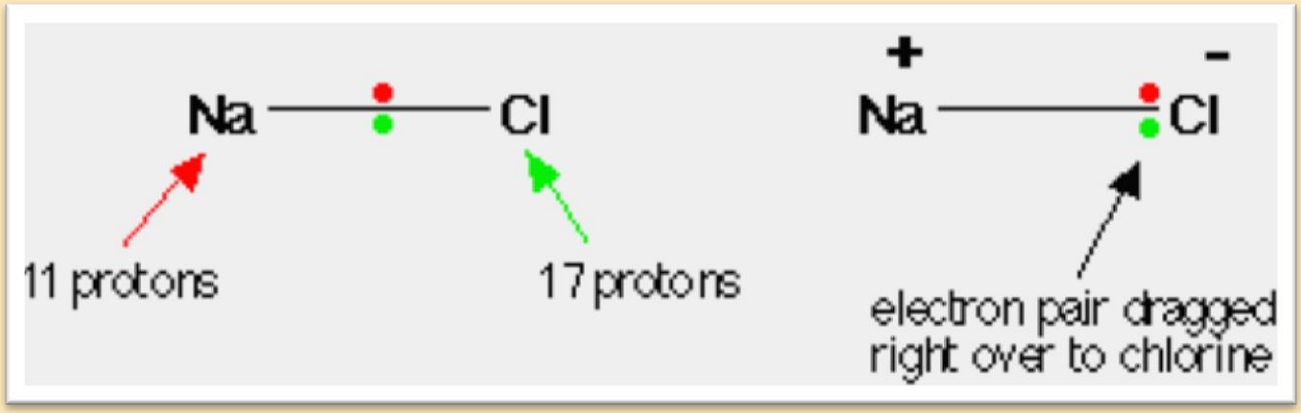
IONIC BOND

bond formed between two ions by the *transfer* of electrons

Ionic bonding

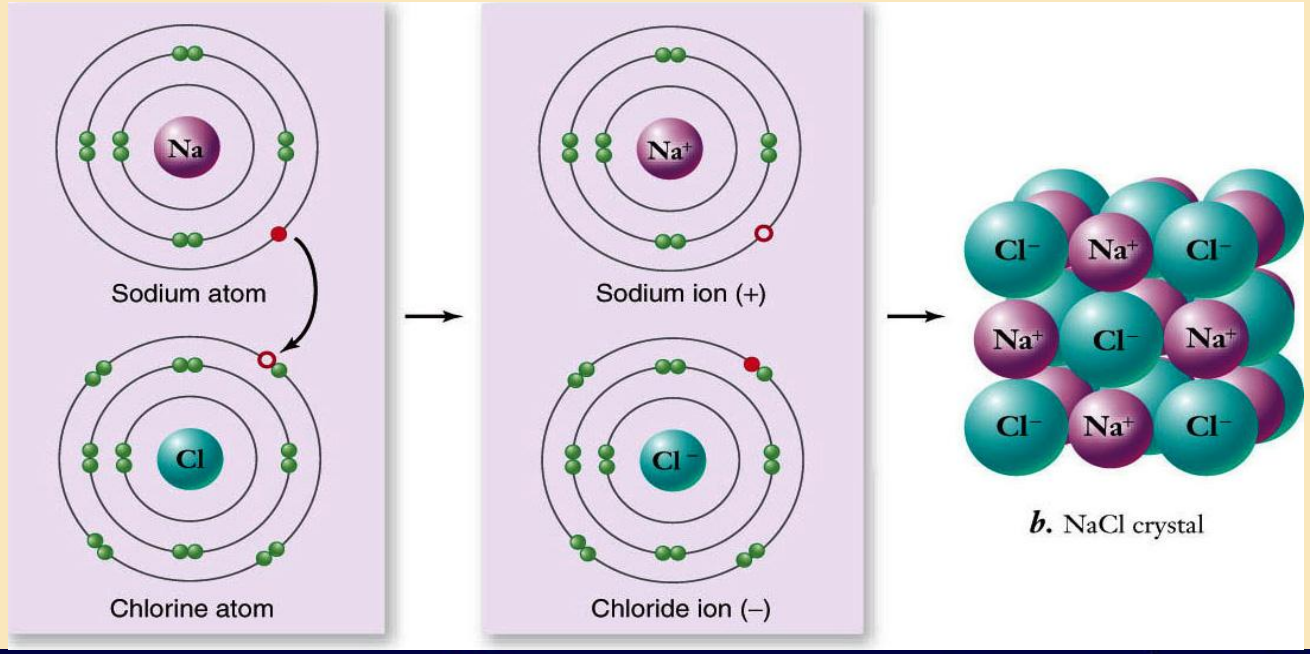
Ionic substances are formed when an atom that loses electrons relatively easily react with an atom that has a high affinity for electrons.

ex. metal-nonmetal compound



Chemical Bonds

Ionic bonds are formed by the attraction of oppositely charged ions.



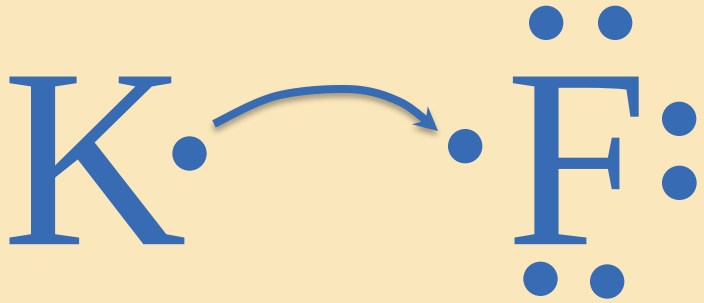
Ionic bonding

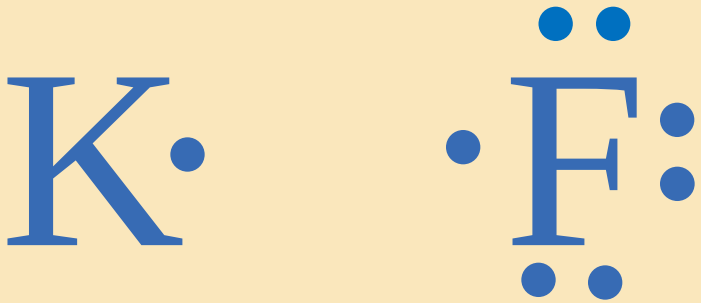
- Between atoms of metals and nonmetals with very different electronegativity
- Bond formed by transfer of electrons
- Produce charged ions all states. Conductors and have high melting point.
- When an atom of a nonmetal takes one or more electrons from an atom of a metal so both atoms end up with eight valence electrons.
- Examples; NaCl, $CaCl_2$, K_2O

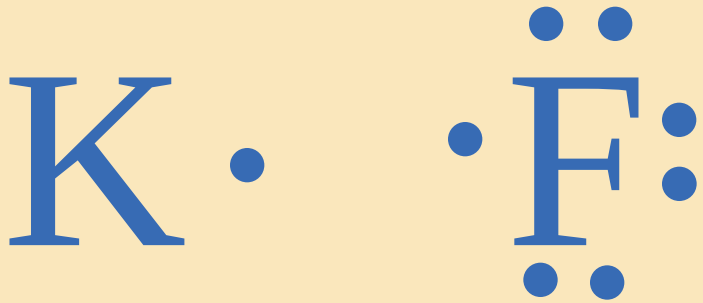
Ionic Bonds

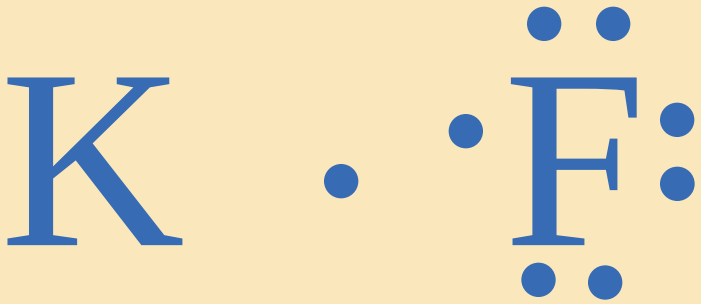
- Metal loses electrons to form cation.
- Nonmetal gains electrons to form anion.
- The electronegativity between the metal and the nonmetal must be > than 2.
- Ionic bond results from + to − attraction.
- Lewis theory allows us to predict the correct formulas of ionic compounds.
- A metal cation and nonmetal anion are joined together by an ionic bond called ***SALT***

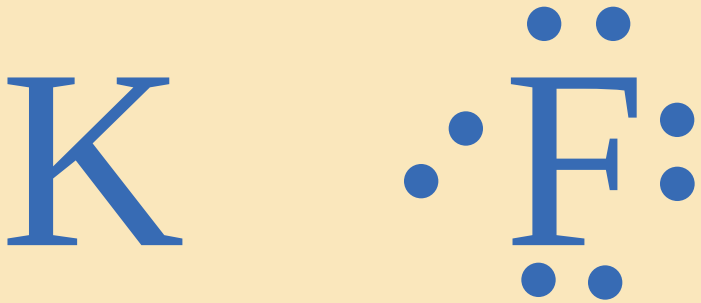
In an **IONIC** bond,
electrons are lost or gained,
resulting in the formation of **IONS**
in ionic compounds.

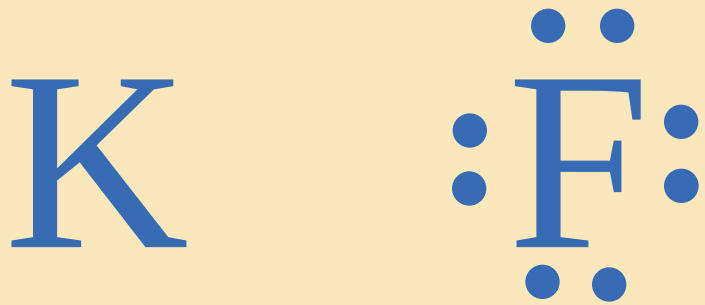


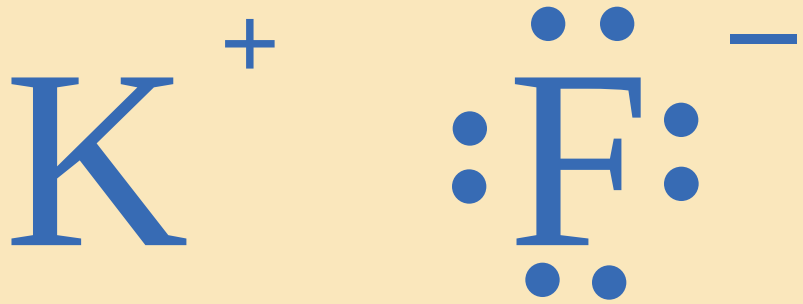

K
F





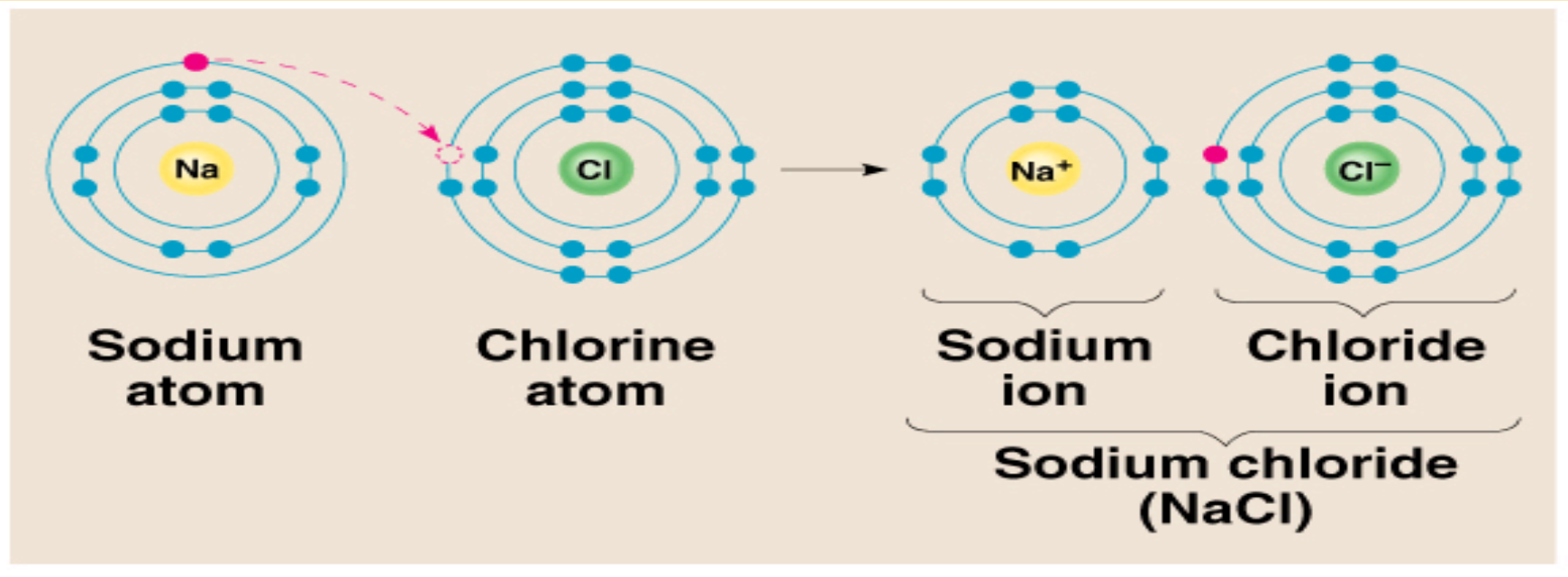

K
F


K
F


K +
F –

The compound potassium fluoride consists of potassium (K^+) ions and fluoride (F^-) ions

The ionic **bond** is the attraction between the positive K^+ ion and the negative F^- ion



Ionic bond – electron from Na is transferred to Cl, this causes a charge imbalance in each atom. The Na becomes (Na^+) and the Cl becomes (Cl^-) , charged particles or ions.

Covalent Bond

COVALENT BOND

bond formed by the *sharing* of electrons

Covalent Bonding

When an atom of one nonmetal shares one or more electrons with an atom of another nonmetal so both atoms end up with eight valence electrons.

Chemical Bonds

Covalent bonds form when atoms share 2 or more valence electrons.

Covalent bond strength depends on the number of electron pairs shared by the atoms.

single bond < double bond < triple bond

Covalent Bond

- Between nonmetallic elements of similar electronegativity.
- Formed by sharing electron pairs
- Lower Melting Points than Ionic Compounds
- Examples; O_2, CO_2, C_2H_6, H_2O, SiC

Covalent Bonds

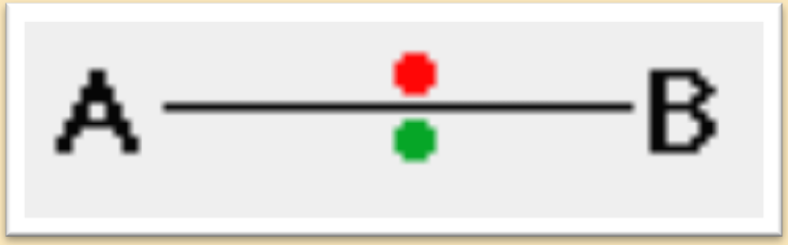
- Often found between two nonmetals.
- Typical of molecular species.
- Atoms share pairs of electrons to attain octets.
- Molecules generally weakly attracted to each other.
  - Observed physical properties of molecular substance due to these attractions.
- A group of atoms joined together by a covalent bond is called ***a Molecule***

The Covalent Bonding

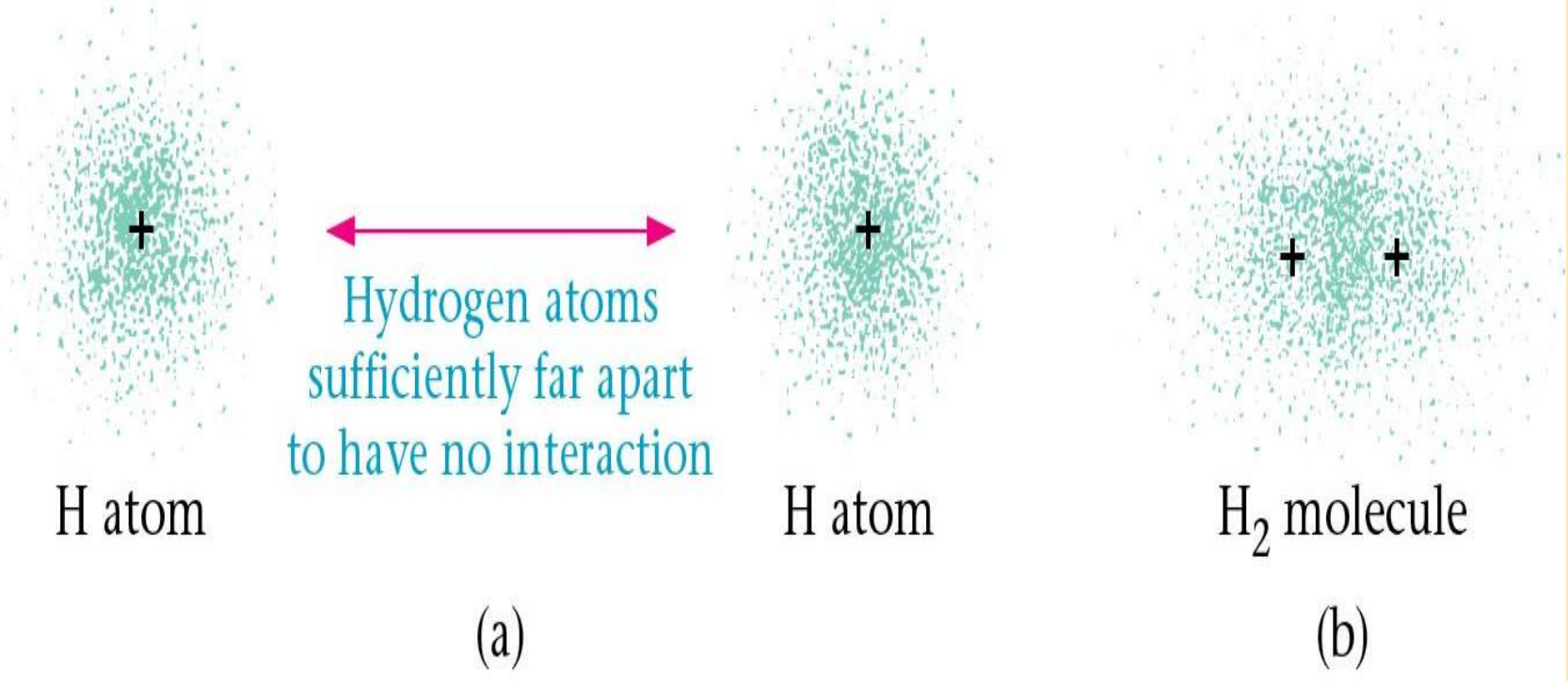
- Shared electrons are attracted to the nuclei of both atoms.
- They move back and forth between the outer energy levels of each atom in the covalent bond.
- So, each atom has a stable outer energy level some of the time.

Covalent Bonding

- Electron are shared by nuclei

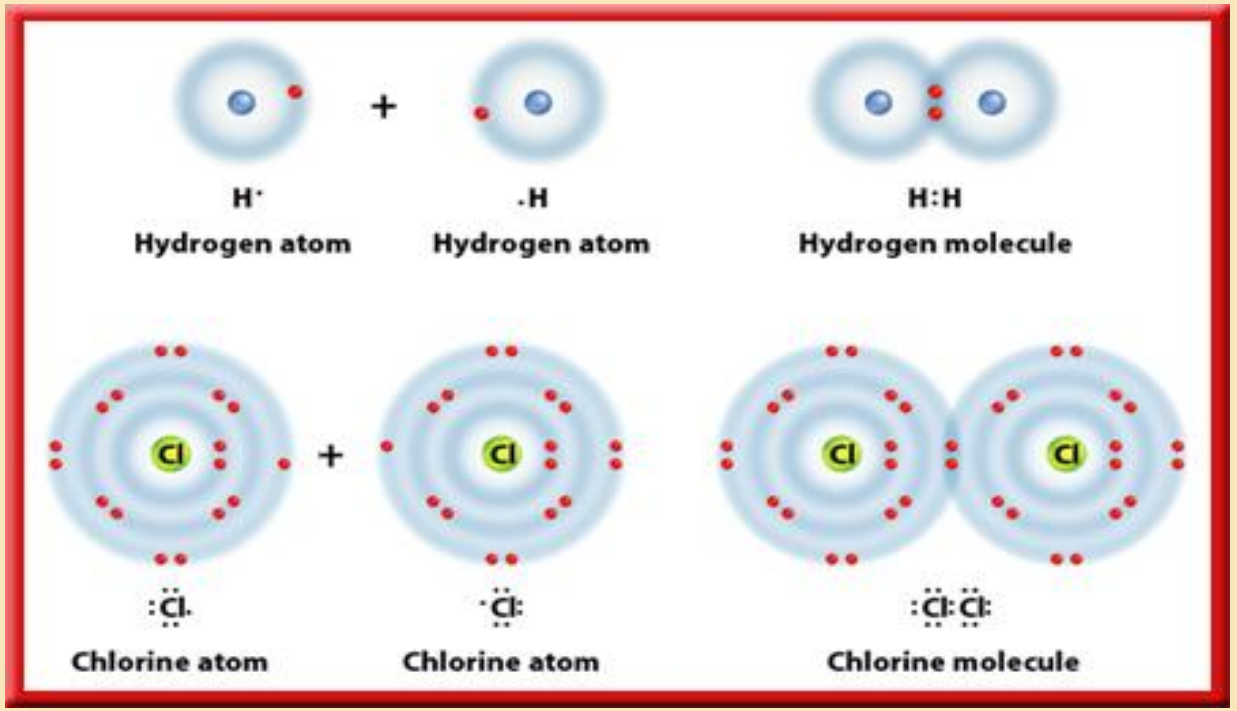


The formation of a bond between two atoms.



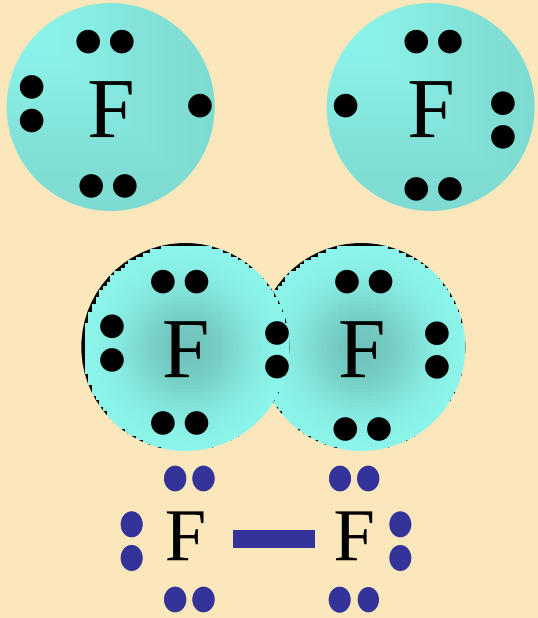
Examples of Convalent Bond

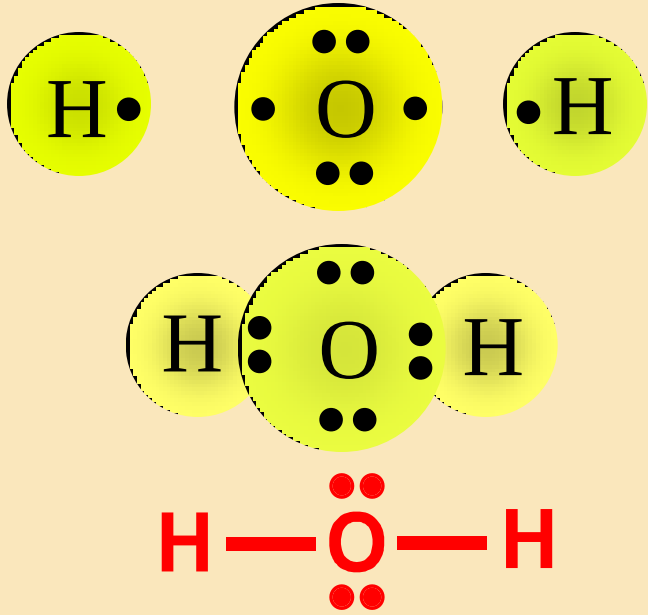
- The neutral particle is formed when atoms share electrons is called a **molecule**



Single Covalent Bonds

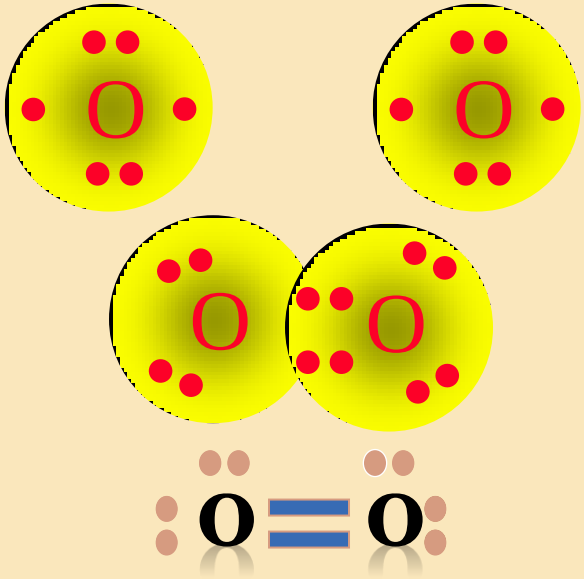
- Two atoms share one pair of electrons.
  - 2 electrons.
- One atom may have more than one single bond.





Double Covalent Bond

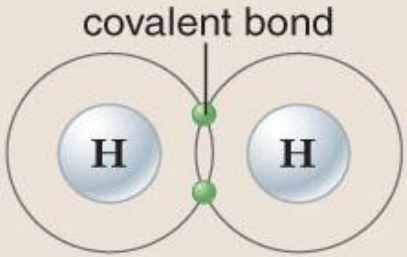
- Two atoms sharing two pairs of electrons.
  - 4 electrons.
- Shorter and stronger than single bond.



Chemical Bonds

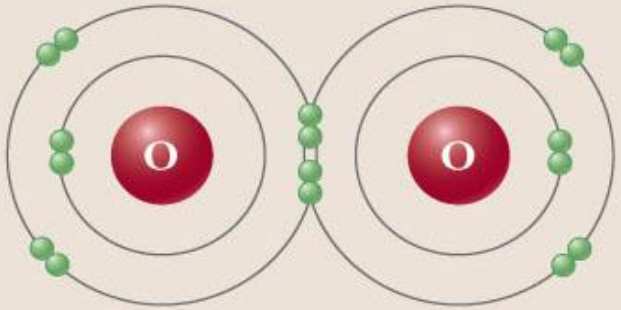
Single covalent bond
hydrogen gas

H—H H_2



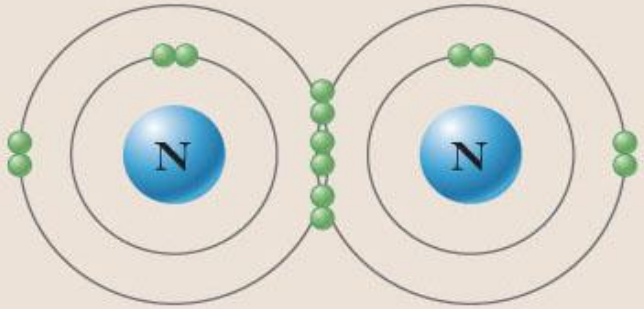
Double covalent bond
oxygen gas

O=O O_2



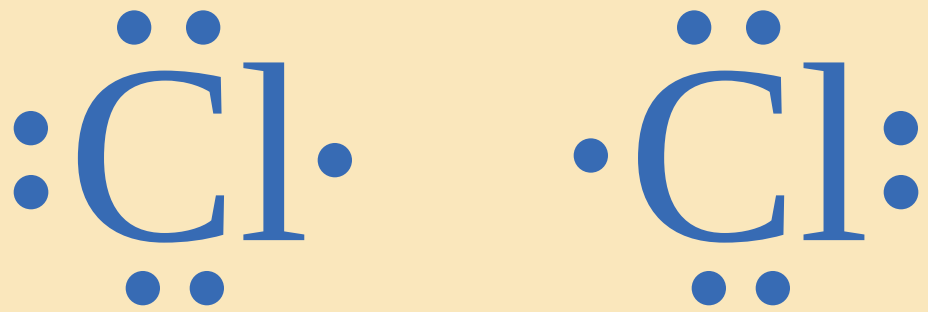
Triple covalent bond
nitrogen gas

N≡N N_2

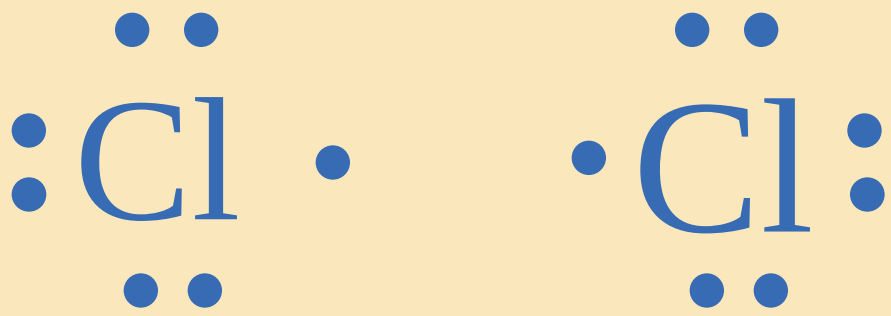


Chlorine forms a covalent bond with itself

Cl_2

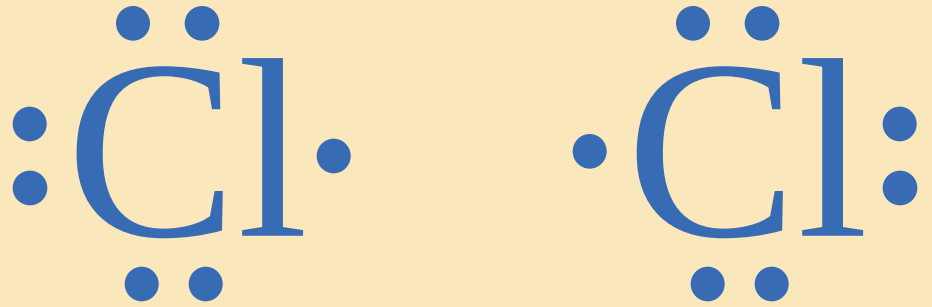


How will two chlorine atoms react?

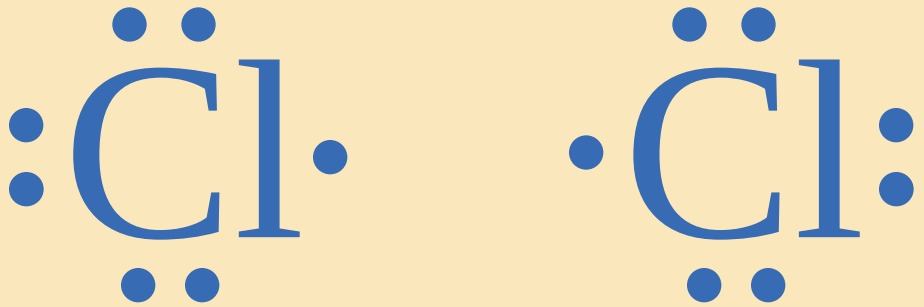


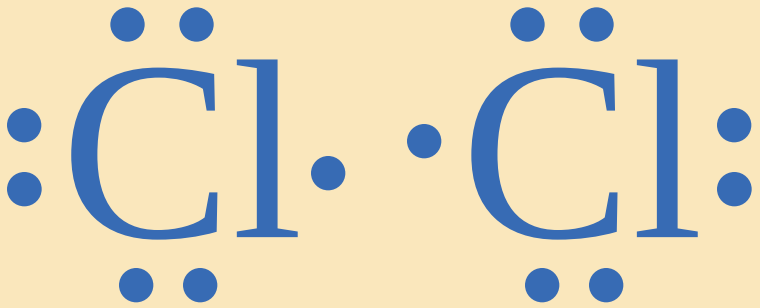
Each chlorine atom wants to

gain one electron to achieve an octet



Neither atom will give up an electron – chlorine is highly electronegative. What's the solution – what can they do to achieve an octet?

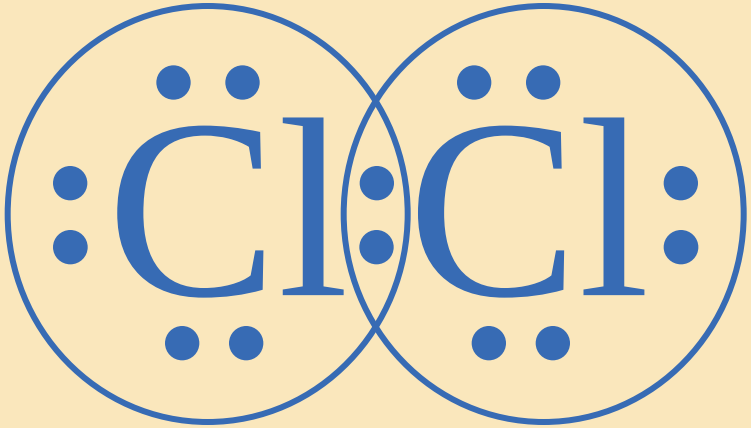




octet

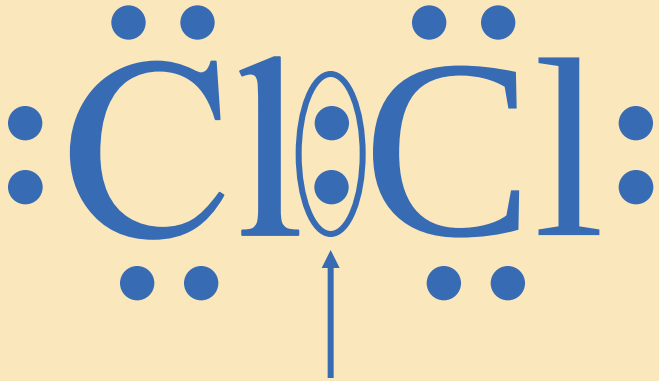
octet

circle the electrons for each atom that completes their octets

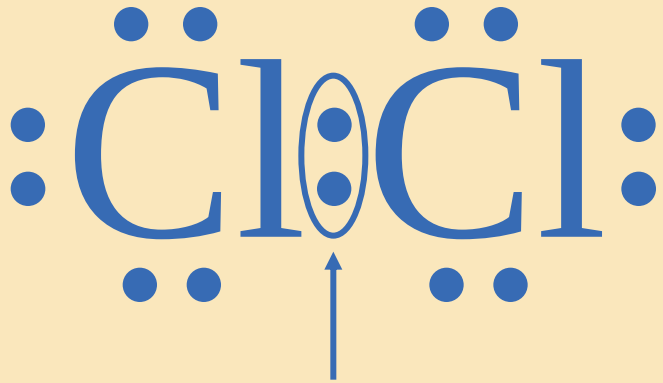


The octet is achieved by each atom sharing the electron pair in the middle

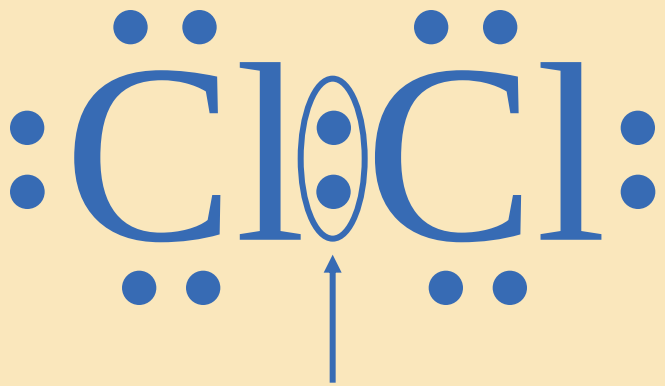
The octet is achieved by each atom sharing the electron pair in the middle



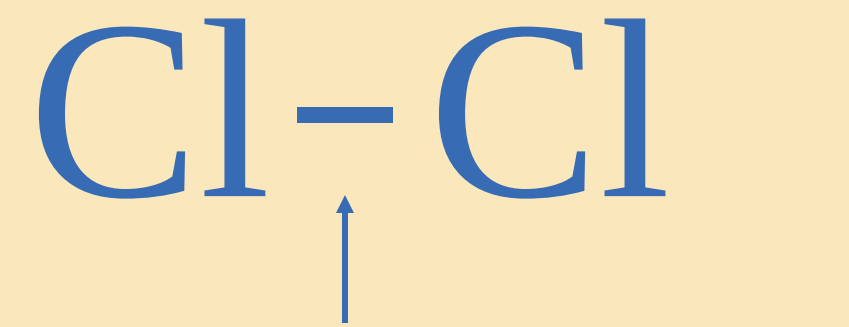
This is the bonding pair



It is a *single* bonding pair



It is called a **SINGLE BOND**



Single bonds are abbreviated with a dash

Cl–Cl

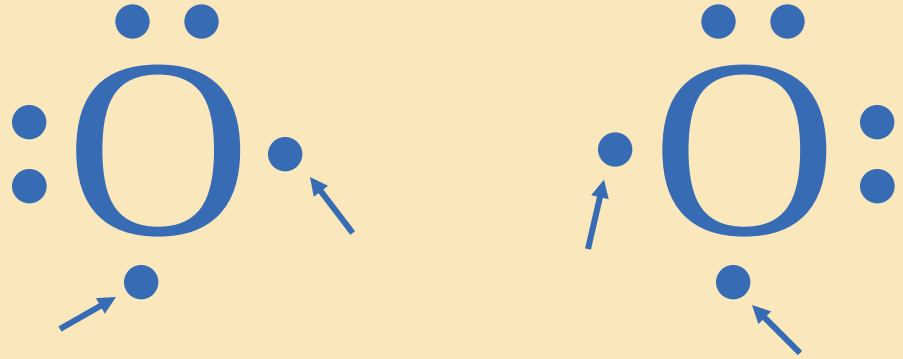
This is the chlorine molecule,

Cl_2

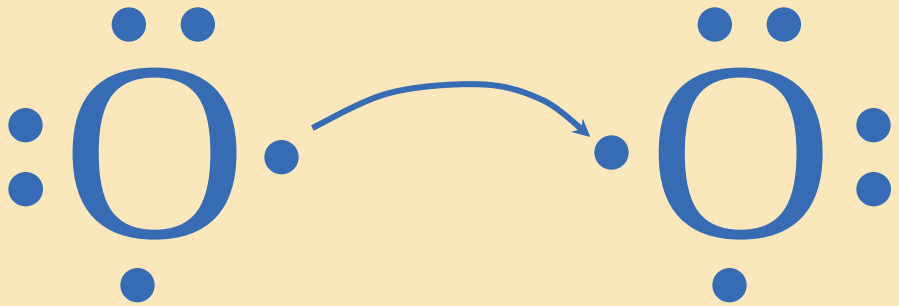
O_2

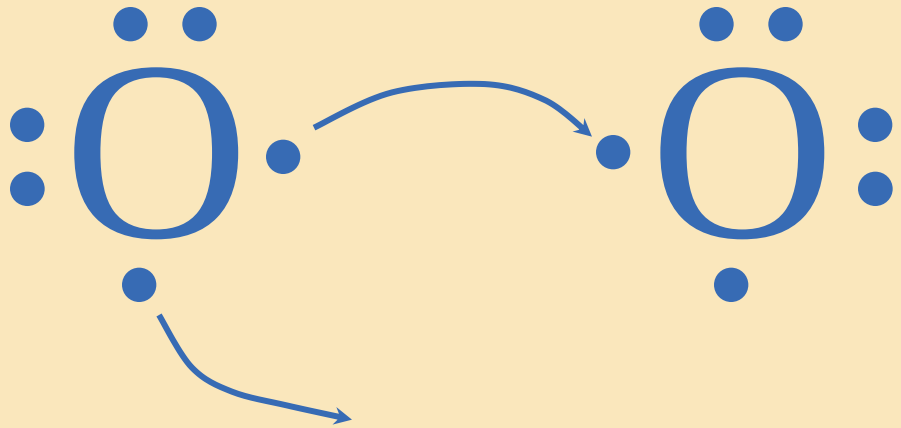
Oxygen is also one of the diatomic molecules

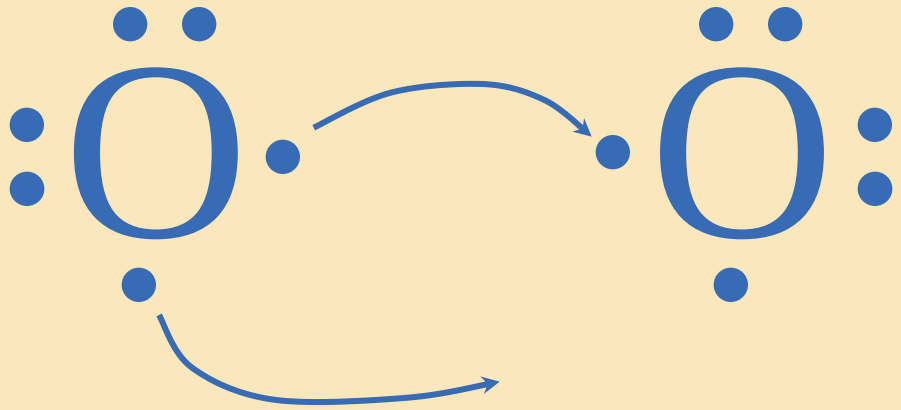
How will two oxygen atoms bond?

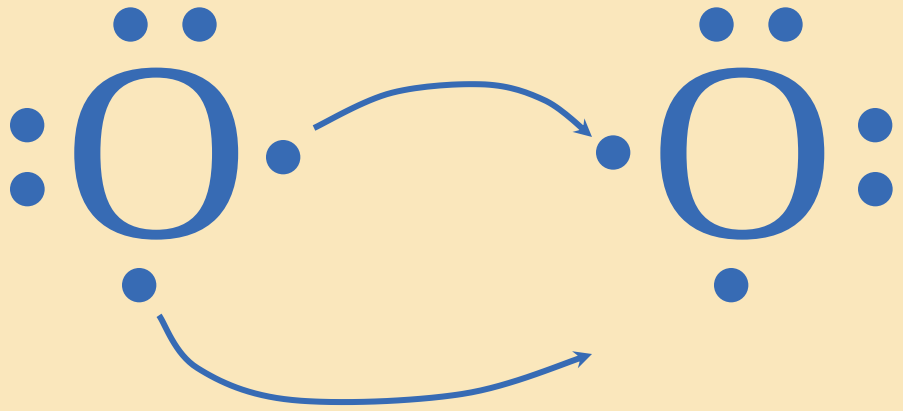


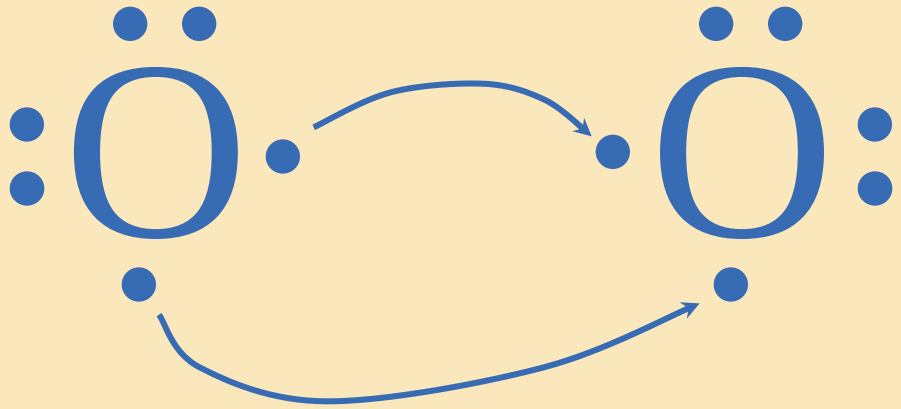
Each atom has two unpaired electrons

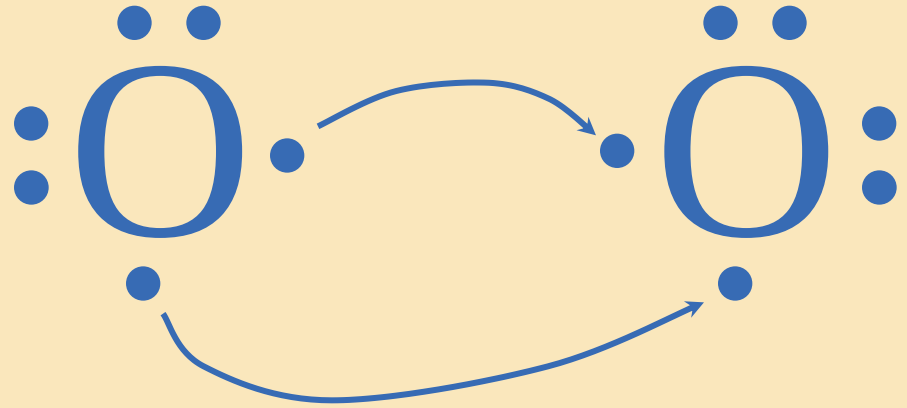






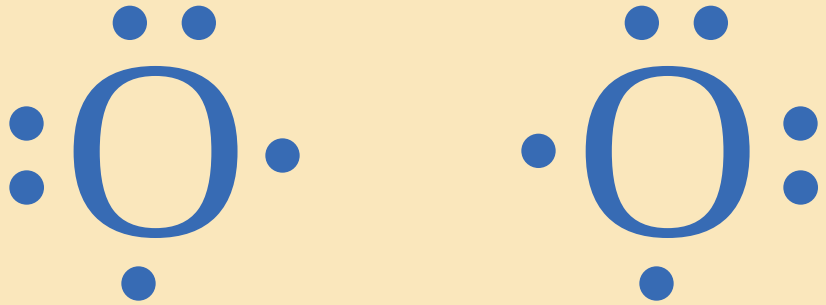


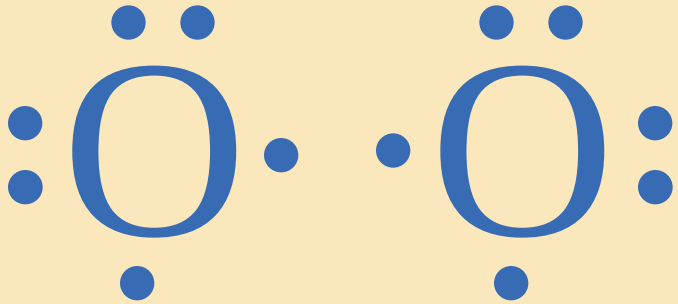


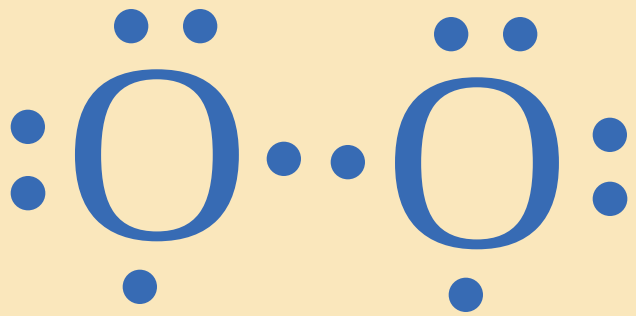


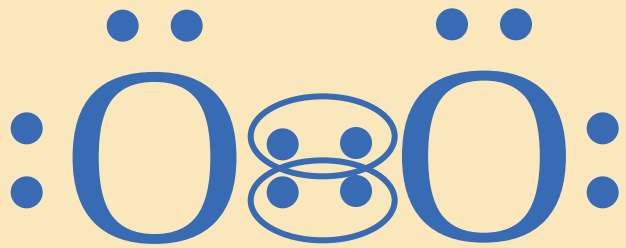
Oxygen atoms are highly electronegative.

So both atoms want to gain two electrons.

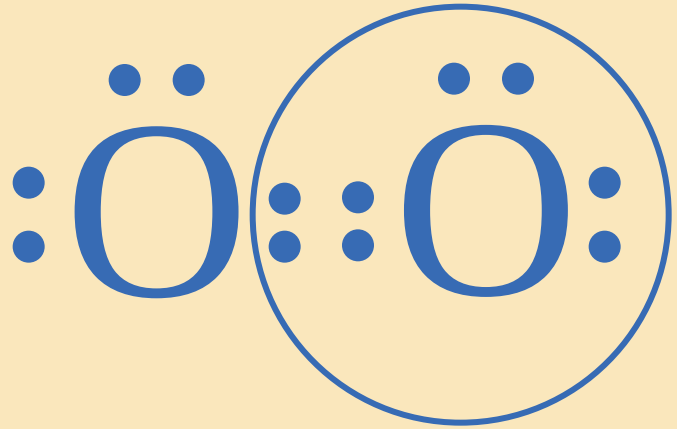








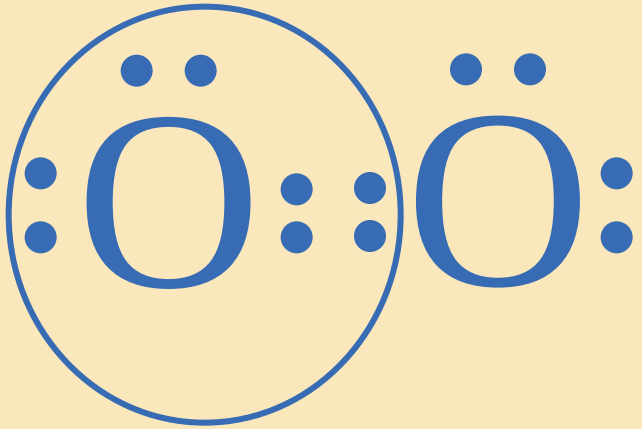
Both electron pairs are shared.



6 valence electrons

plus 2 shared electrons

= full octet



6 valence electrons

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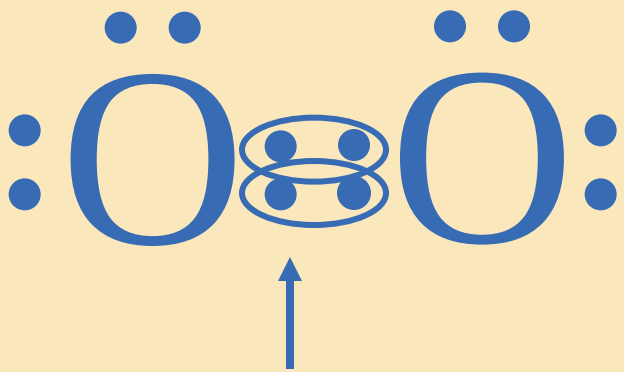
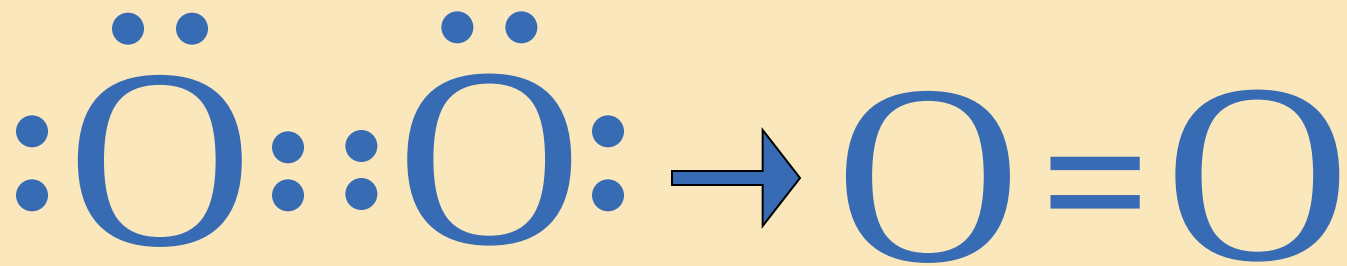


two bonding pairs,

making a ***double bond***



For convenience, the double bond can be shown as two dashes.

Ionic versus Covalent

	IONIC	COVALENT
Bonded Name	Salt	Molecule
Bonding Type	Transfer e^-	Share e^-
Types of Elements	Metal & Nonmetal	Nonmetals
Physical State	Solid	Solid, Liquid, or Gas
Melting Point	High (above 300ºC)	Low (below 300 ºC)
Solubility	Dissolves in Water	Varies
Conductivity	Good	Poor

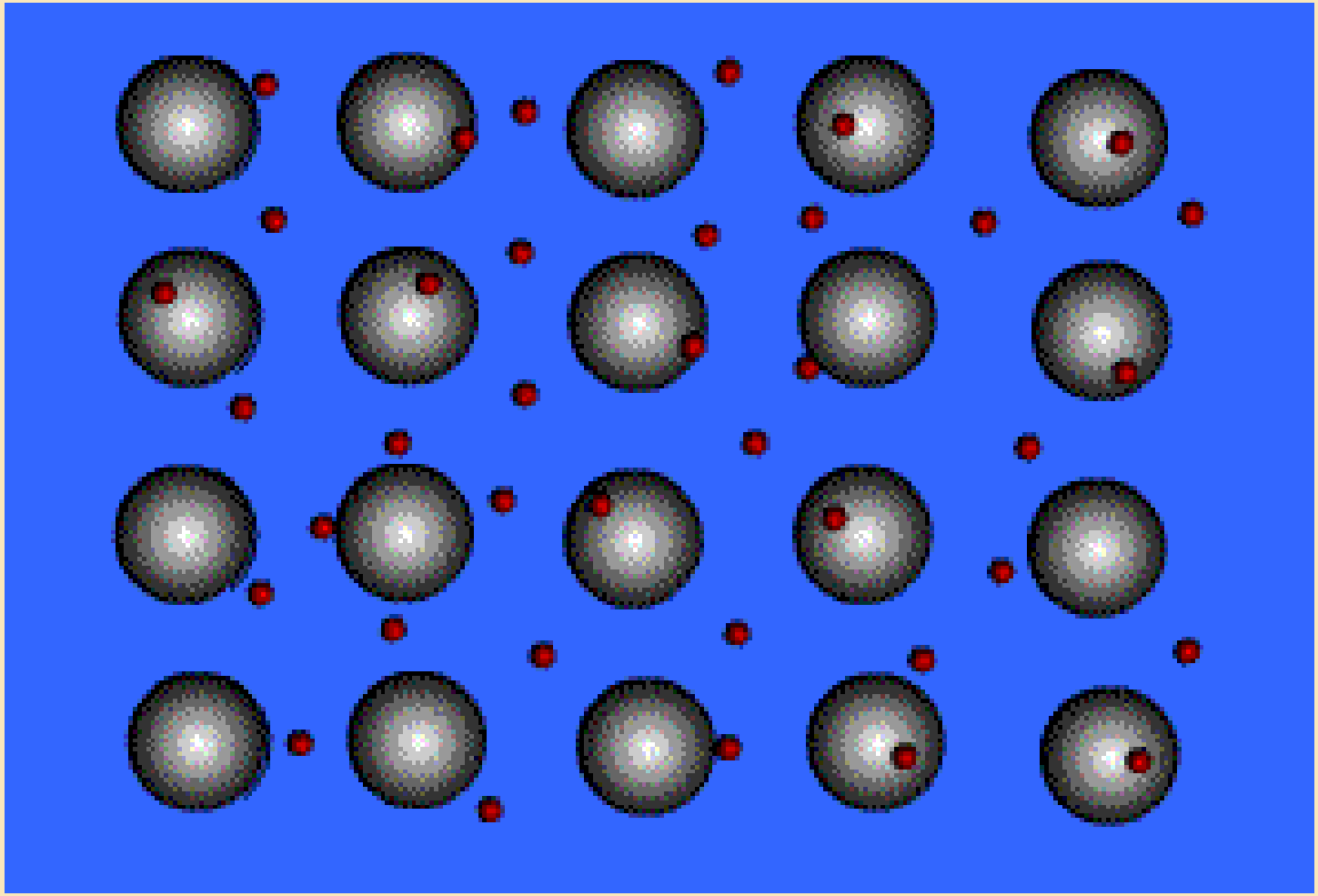
METALLIC BOND

bond found in metals; holds metal atoms together very strongly

Metallic Bond

- Formed between atoms of metallic elements
- Electron cloud around atoms
- Good conductors at all states, lustrous, very high melting points
- Examples; Na, Fe, Al, Au, Co

Ionic Bond, A Sea of Electrons



Thank you