Bonding

What's the big attraction?

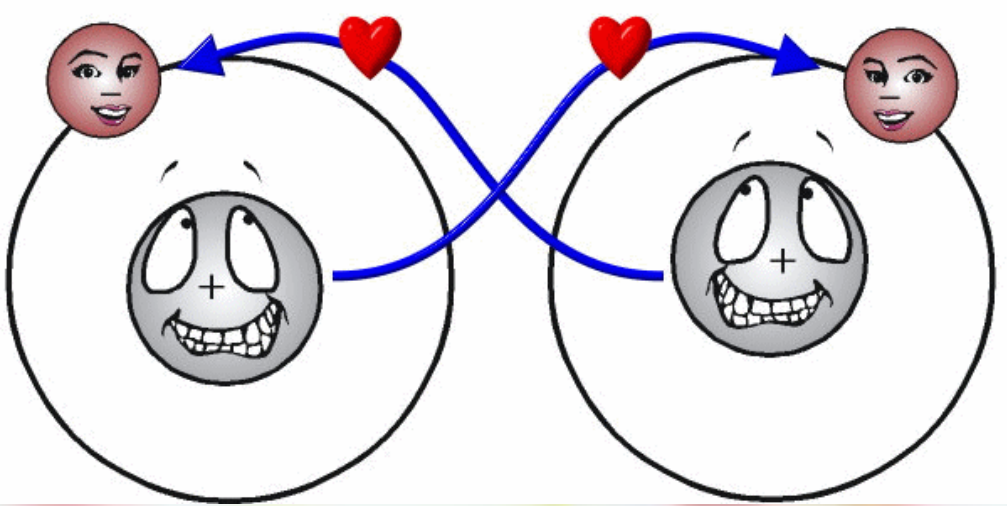
The Nature of Bonding

- A *chemical bond* is the force of attraction between the atoms of a compound.

  … but what causes the attraction?
- Consider the charges of the subatomic particles:
  - Electrons? Negative
  - Protons? Positive
  - Neutrons? Neutral
- So, which part of one atom is attracted to which part of another atom?

Tug of War

- The electrons of one atom are attracted to the protons of another.



- When atoms combine, there is a tug of war over the *valence* electrons.
  - Valence electrons = outer electrons

Who Wins??

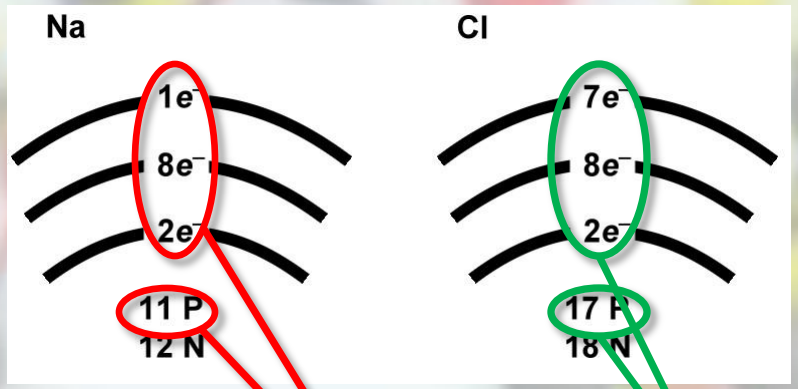
- The outcome of a tug of war depends upon the contestants:
  - If one team pulls hard and the other does not, the team that pulls hard wins.
  - If both teams pull equally, you have a stalemate where both teams end up holding on to the same rope.
- The result is similar with a tug of war over electrons:
  - If one atom has a strong pull on electrons and the other has a weak pull on electrons, the atom with the strong pull gains electrons, and the one with the weak pull loses.
  - If two atoms pull hard on the same electrons, and neither lets go, they end up sharing those electrons.

An Example of Unequal Pulls

- Imagine a tug of war between sodium and chlorine. Note their locations on the *Periodic Table*.
  - How is sodium classified? Metal
  - How is chlorine classified? Nonmetal
  - What would happen during a tug of war over valence electrons between sodium and chlorine?
    Sodium would lose its valence electron, and chlorine would gain.

Delving Deeper

- Draw Bohr-Rutherford diagrams of sodium and chlorine.

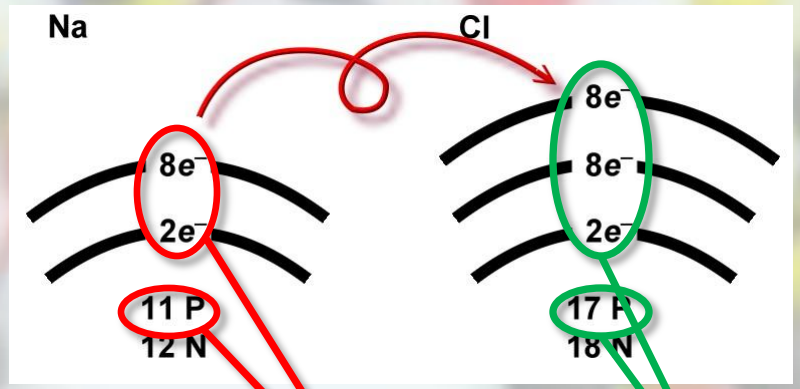


- Fill in the table below:

Element	Sodium	Chlorine
Nuclear Charge	+11	+17
Charge on Electrons	-11	-17
Total Charge	0	0

Continuing . . .

- Now draw Bohr-Rutherford diagrams of sodium and chlorine after the electron transfer.



- Fill in the table below:

Element	Sodium	Chlorine
Nuclear Charge	+11	+17
Charge on Electrons	-10	-18
Total Charge	+1	-1

and the Bond is . . .

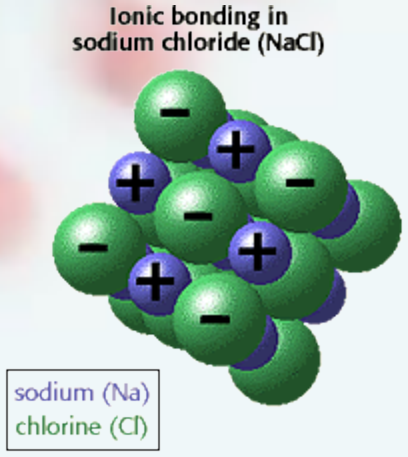
- As a result of transferring electrons, the charge on the sodium becomes +1 while the charge on the chlorine becomes −1

  Na^+ and Cl^-

- These charged particles are called . . . ions.
- The ions become bonded because . . . they are oppositely charged.
- The attraction between oppositely charged ions is called an **Ionic Bond**.

Sodium Chloride: An Example

- The electron configurations of sodium and chlorine change when they combine:
  - **Na:** 2-8-1 + **Cl:** 2-8-7 → **Na^+:** 2-8 + **Cl^-:** 2-8-8
- The charges of sodium and chlorine change when they combine:
  - $Na^0 + Cl^0 \rightarrow Na^{+1} + Cl^{-1}$
    - The charge on the ion is the same as its oxidation state or valence.
    - The sodium and chlorine are attracted because they are oppositely charged.
    - The charge on the compound is zero.



Summary of Ionic Bonding

- The electrons of one atom are attracted to the protons of another.
- Metals hold onto electrons loosely while nonmetals hold onto electrons tightly.
- Metals lose electrons and nonmetals gain electrons in such a way that they complete their outer shells.
  - Atoms that gain or lose electrons become electrically charged.
  - Charged atoms are called ions.
  - Metals become positively charged ions called ***cations*** by losing electrons.
  - Nonmetals become negatively charged ions called ***anions*** by gaining electrons.
- Metal cations and nonmetal anions become bonded because they are oppositely charged.

An Example of Equal Pulls

- Imagine a tug of war between two hydrogen atoms to form a diatomic molecule of hydrogen (H_2)
  - How does the pull of one hydrogen atom on electrons compare to the pull of another hydrogen atom on electrons? It is the same.
  - What would happen during a tug of war over valence electrons between two hydrogen atoms?

    Neither would let go. They would share.

Delving Deeper

- Sharing valence electrons is called ***covalent bonding***.
- When it comes to covalent bonding, "sharing is pairing."
  - Unpaired electrons pair in such a way that each atom completes its outer shell.
- Draw electron dot diagrams for each of the hydrogen atoms in the hydrogen molecule.
  - How many electrons does each hydrogen need to complete its outer shell? Two

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H· ·H

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H:H

- The hydrogens are bonded because they are holding on to the same electrons.

Determining Bond Type

- It is obvious that sodium and chlorine bond ionically, because sodium is a very active metal, and chlorine is a very active nonmetal.
- It is obvious that diatomic molecules such as H_2 contain covalent bonds because the two identical atoms have the same pull on electrons.
- But what type of bond is found between hydrogen and oxygen in water?
  - Oxygen is a nonmetal.
  - Hydrogen, being at the top of the family, is a metalloid.
  - They are not as different as sodium and chlorine, nor are they as similar as two hydrogens.
- Some measure is needed to show how different atoms' pulls on electrons are. It is electronegativity.

Electronegativity

- *Metals have low electronegativities.*
- *Nonmetals have high electronegativities.*
- *Electronegativity difference is a good indicator of how different the pull on electrons is.*

- The most metallic element is . . . francium.
  - Its electronegativity is . . . 0.7, the lowest.
- The most nonmetallic element is . . .flourine.
  - Its electronegativity is . . . 4.0, the highest.
- The electronegativity difference is . . . **3.3**

THIS IS THE LARGEST ELECTRONEGATIVITY DIFFERENCE POSSIBLE.

Electronegativity Difference

- The largest electronegativity difference possible is that between francium and fluorine. It is 3.3
  - This represents the greatest ionic character.
- The smallest electronegativity possible is that found within diatomic molecules or between other very similar atoms. It is 0
  - This represents the least ionic character.
- The midpoint is about …1.7
  - This represents 50 percent ionic character.
  - It is the dividing line between ionic and covalent.
  - An electronegativity difference of 1.7 or more represents an ionic bond. Less than 1.7 is covalent.

Back to Water

- Fill in the table below to determine the bond type in water:

Element	Electronegativity
Oxygen	3.4
Hydrogen	2.1
Electronegativity Difference	1.3

- The electronegativity difference is less than 1.7
- The bonds between hydrogen and oxygen are covalent.

Comparing Covalent Bonds

- Not all covalent bonds are created equal.
  - In the bond between chlorine atoms in a chlorine molecule (Cl_2), the electronegativity difference is 0.0, and the atoms share equally.
  - In a hydrogen chloride (HCl) molecule, the electronegativity difference is ***not*** 0.0, and the atoms don't share equally. Fill in the table below:

Element	Electronegativity
Chlorine	3.2
Hydrogen	2.1
Electronegativity Difference	1.1

- The bond is covalent, but the atoms don't share equally. Chlorine is more electronegative. It has a stronger pull on electrons.
  - The shared electrons will be displaced closer to the chlorine.
  - This will make the charge on the chlorine side of the bond slightly negative, and on the hydrogen side of the bond slightly positive.

Types of Covalent Bonds

- In hydrogen chloride the hydrogen side of the bond is slightly positive, and the chloride side of the bond is slightly negative.

$$^{+}H\text{–}Cl^{-}$$

- The earth has opposite ends just like the hydrogen chloride molecule. The opposite ends of the earth are called . . . poles.

- The adjective used to describe the bears living at the poles is . . . polar.
- Bonds with oppositely charged ends are also called polar.

Classifying Bonds

- There are three types of chemical bonds:
  - ionic,
  - polar covalent, and
  - nonpolar covalent
- Bond type is determined by electronegativity difference.