Hewitt/Suchocki/Hewitt

Conceptual Physical Science

Fourth Edition

Chapter 15:

HOW ATOMS BOND AND MOLECULES ATTRACT

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This lecture will help you understand:

- Electron-Dot Structures
- The Formation of Ions
- Ionic Bonds
- Metallic Bonds
- Covalent Bonds
- Polar Covalent Bonds
- Molecular Polarity
- Molecular Attractions

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Electron-Dot Structures

- Atoms bond together through their electrons. To learn about bonding, therefore, we need to know something about how the electrons within an atom are organized.
- Electrons behave as though they are contained within a series of seven concentric shells.

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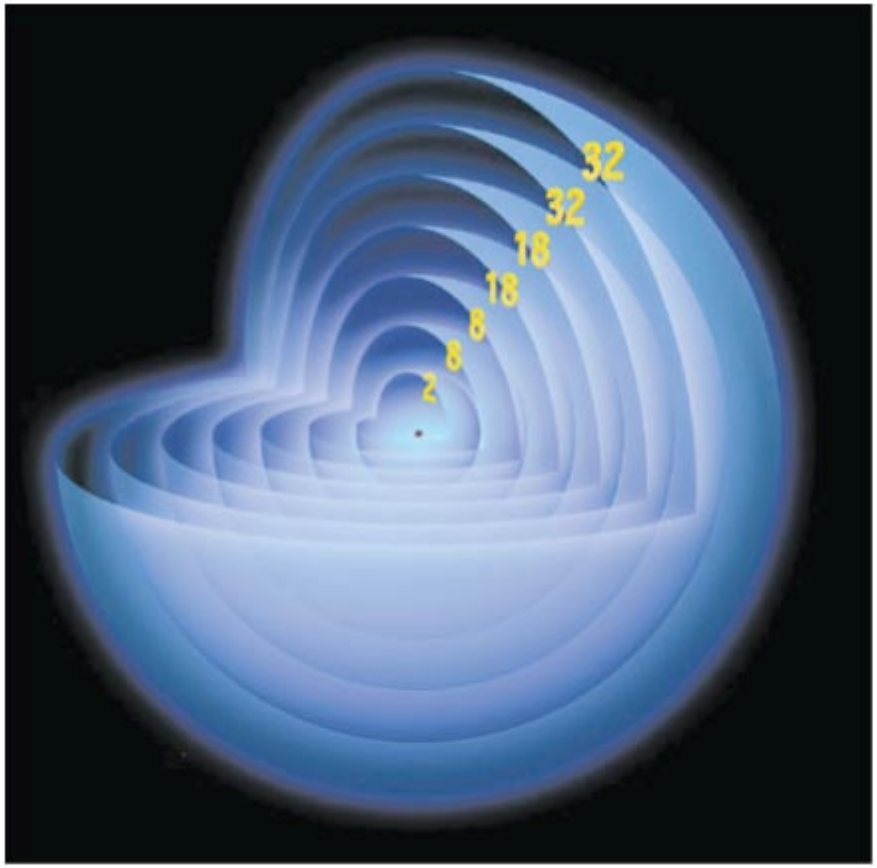
Electron-Dot Structures

The numbers indicate the maximum number of electrons each shell may contain.

Note:

This is a “conceptual model” and not a representation of what an atom “looks like.”

Rather, it helps us to understand how the electrons within atoms *behave*.



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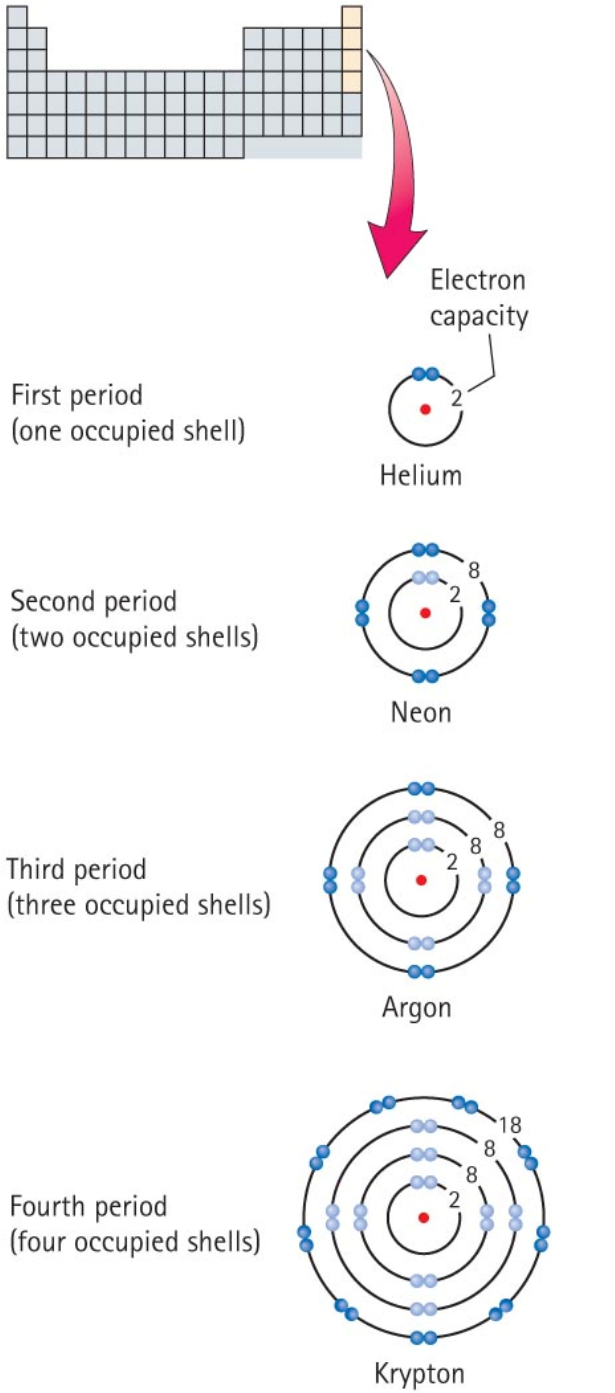
The shells are more easily drawn in two dimensions.

Each atom has its own configuration of electrons. Elements in the same group have similar configurations, which is why they have similar properties.



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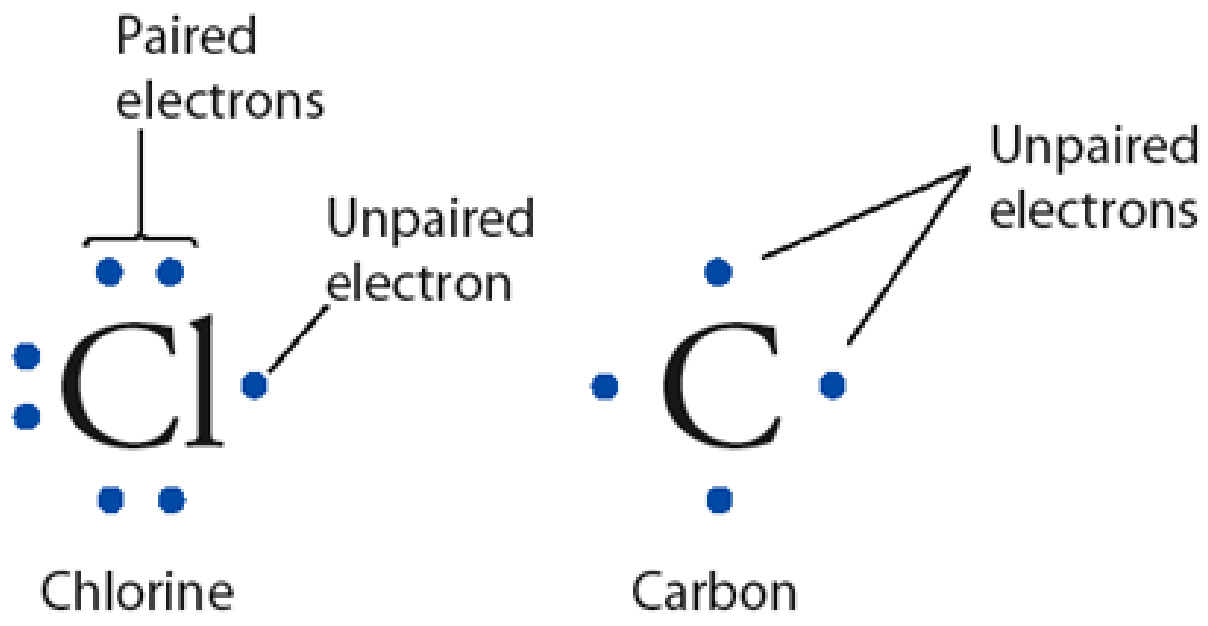
Electron-Dot Structures

- Valence electrons: Electrons in the outermost shell of an atom. These are the ones that can participate in chemical bonding.
- Electron-dot structure: A notation showing the valence electrons surrounding the atomic symbol.



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In class activity 1

- Draw the dot diagram for sodium and chlorine ATOMS

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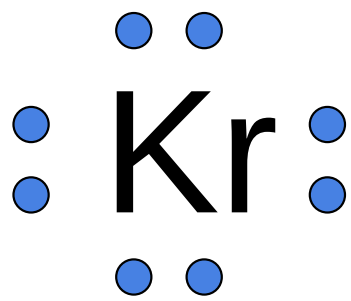
Special Note

For heavier atoms, some valence electrons are more available than others. Krypton, for example, has 18 valence electrons, but only eight of these are typically shown within an electron-dot structure. These are the eight that extend farthest away from the nucleus.



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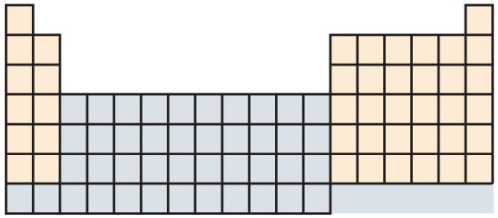
Electron-Dot Structures



1	2	13	14	15	16	17	18
H·							He:
Li·	·Be·	·B·	·C·	·N·	:O·	:F·	:Ne:
Na·	·Mg·	·Al·	·Si·	·P·	:S·	:Cl·	:Ar:
K·	·Ca·	·Ga·	·Ge·	·As·	:Se·	:Br·	:Kr:
Rb·	·Sr·	·In·	·Sn·	·Sb·	:Te·	:I·	:Xe:
Cs·	·Ba·	·Tl·	·Pb·	·Bi·	:Po·	:At·	:Rn:

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Note that elements within the same group have the same electron-dot structure.

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Electron-Dot Structures
CHECK YOUR ANSWER

Sodium, Na, atomic number 11, has only one valence electron. Upon losing this electron, what other atom in the periodic table does the sodium thus resemble?

A. **Neon, Ne, atomic number 10**
B. Magnesium, Mg, atomic number 12
C. Lithium, Li, atomic number 3
D. Sodium can only resemble sodium.

Explanation:
With 10 electrons, the sodium has enough electrons to fill the first and second shells, just like neon, Ne.

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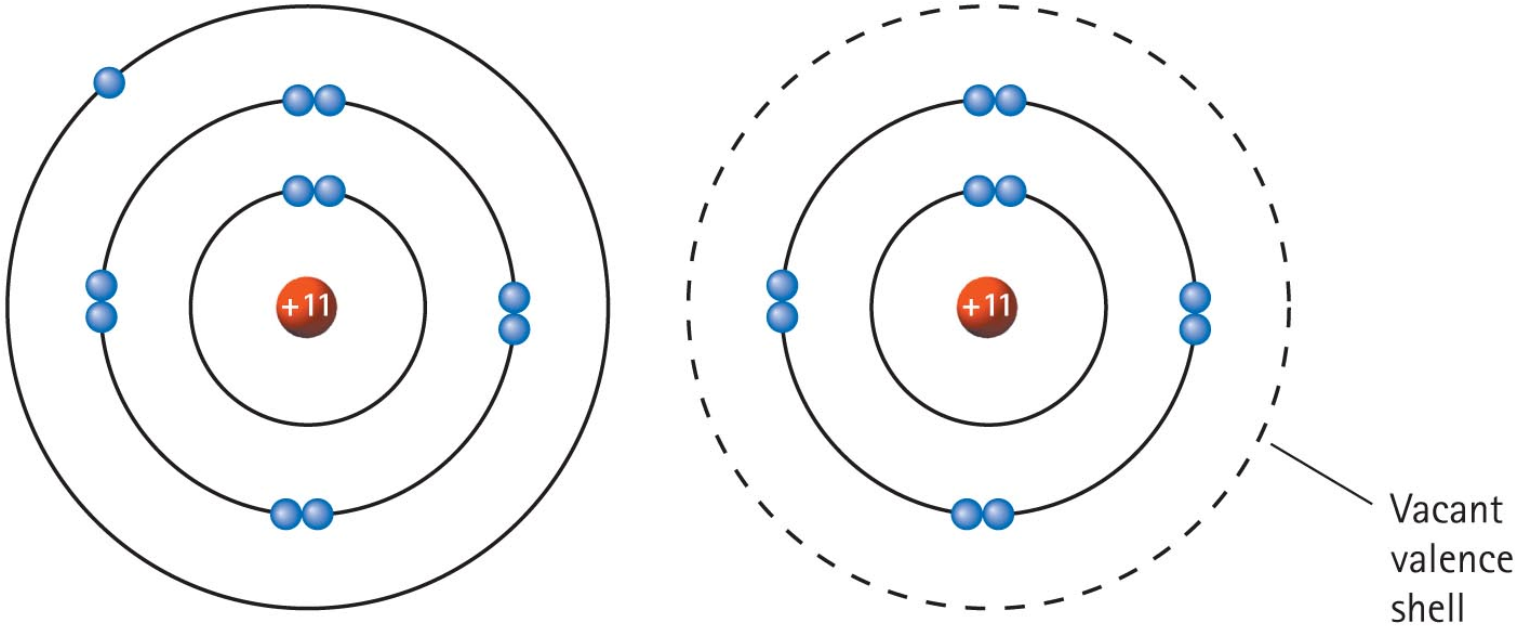
The Formation of Ions

- Ion: An atom that has lost or gained one or more electrons.



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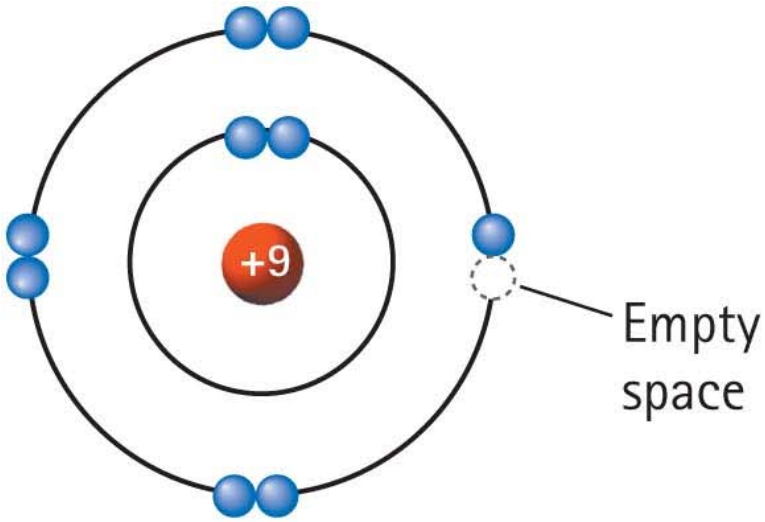
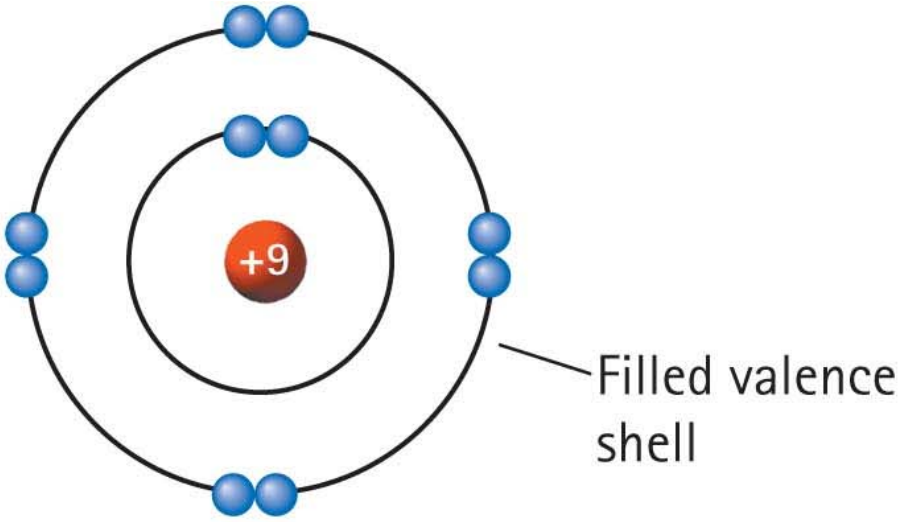


F

9 protons
9 electrons

0 net charge



F^{1-} (negative ion)

9 protons
10 electrons

−1 net charge

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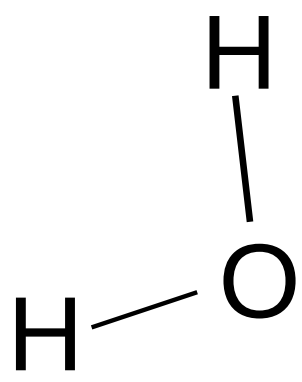
The Formation of Ions



Water

H^+

Hydrogen ion

- Molecular ion: Typically formed by the loss or gain of a hydrogen ion, H^+.

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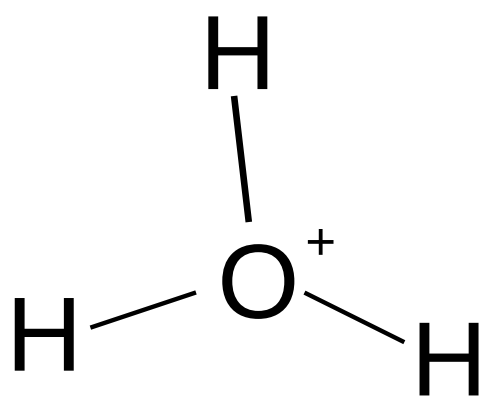
The Formation of Ions



Hydronium ion, H_3O^+

- Molecular ion: Typically formed by the loss or gain of a hydrogen ion, H^+.

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Ionic Bonds

- Ion: An atom that has lost or gained one or more electrons.

- Ionic Bond: The electrical force of attraction between oppositely charged ions.

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In class activity 2

- What is the charge of an ion that is formed from a magnesium atom?

- Why does it have this sign and amount of charge?

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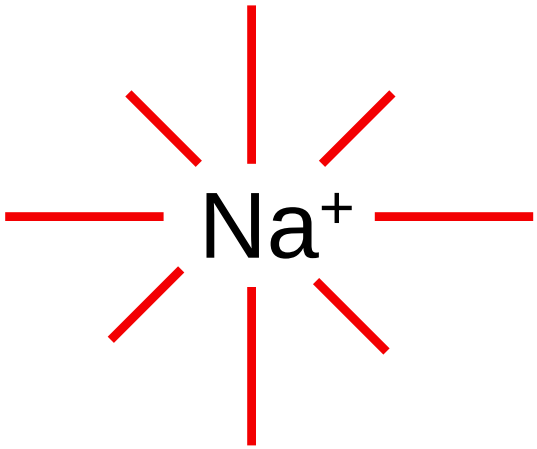
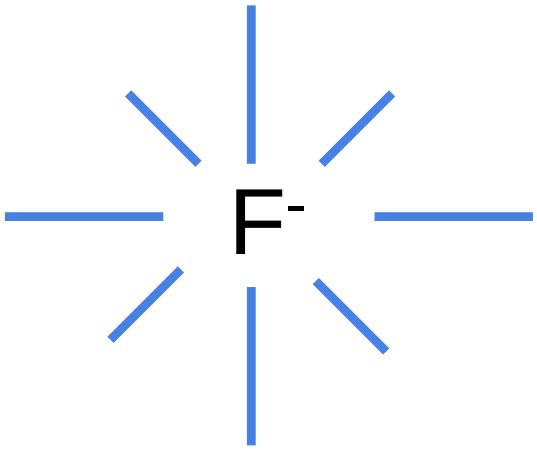
Ionic Bonds

- Ion: An atom that has lost or gained one or more electrons.

- Ionic Bond: The electrical force of attraction between oppositely charged ions.





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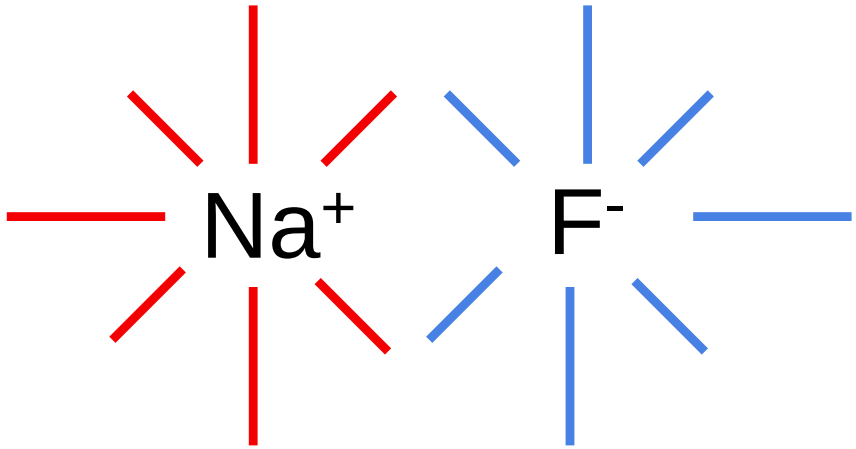

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In class activity 3

- Draw the dot diagrams of sodium and chlorine IONS

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Ionic Bonds
CHECK YOUR ANSWER

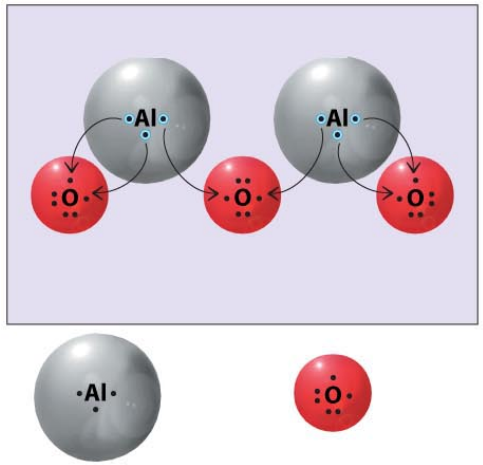
What is the chemical formula for a compound made of aluminum ions, Al^{3+}, and oxygen ions, O^{2-}?

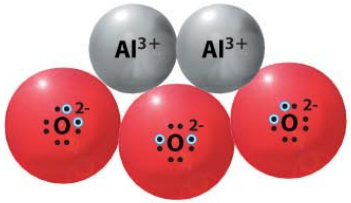
A. AlO

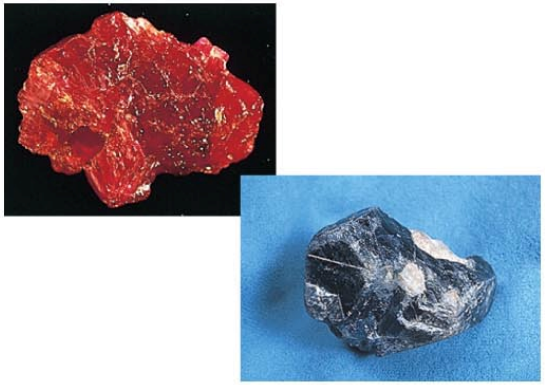
B. Al_3O_2

C. Al_2O_3

D. Al_6O_6







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Ionic Bonds
CHECK YOUR ANSWER

What is the chemical formula for a compound made of magnesium ions, Mg^{2+}, and oxygen ions, O^{2-}?

A. MgO

B. Mg_2O_2

C. Mg_4O_4

D. Any of the above

Explanation:
The chemical formula is used to show the ratio by which atoms combine. By convention, the lowest numbers are preferred, so 1:1 is used rather than 2:2. The numeral 1, however, is implied when no subscript is written.

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In class activity 4

- Is the change from sodium and chlorine a physical or a chemical change?

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In class activity 5

- Write the chemical formula of the ionic compound calcium fluoride

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Metallic Bonds

- Outer electrons in metal atoms are held only weakly by the nucleus.
- This weak attraction allows the electrons to move about quite freely.
- This mobility of electrons accounts for many metallic properties.

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Metallic Bonds

- An alloy is a mixture of metallic elements.

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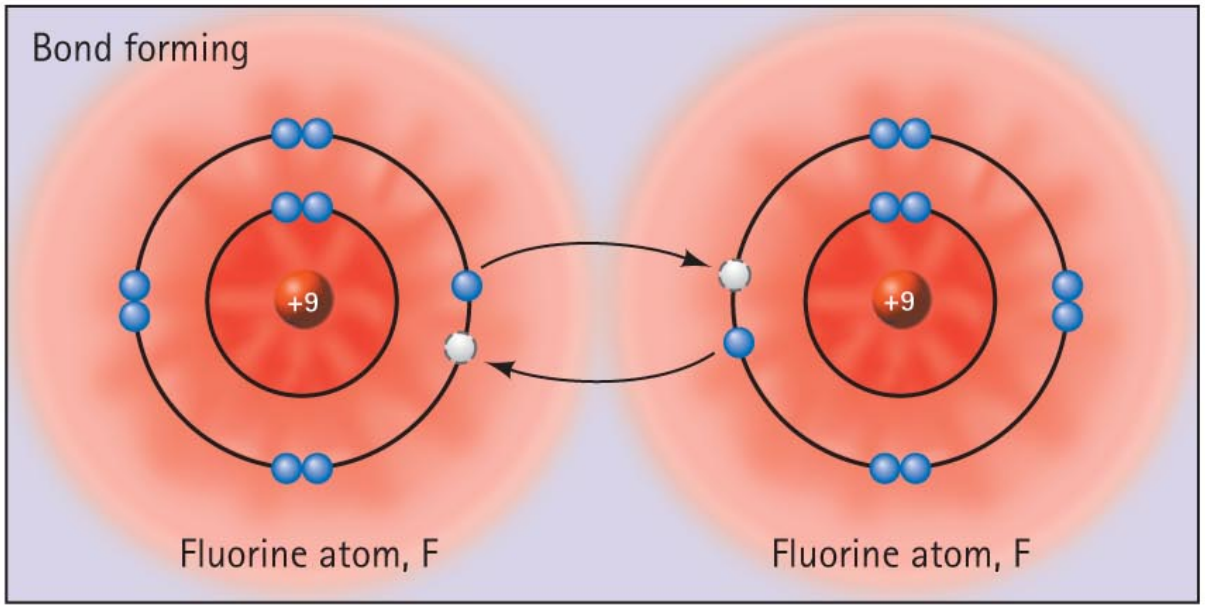
Covalent Bonds

- The type of electrical attraction in which atoms are held together by their mutual attraction for shared electrons.



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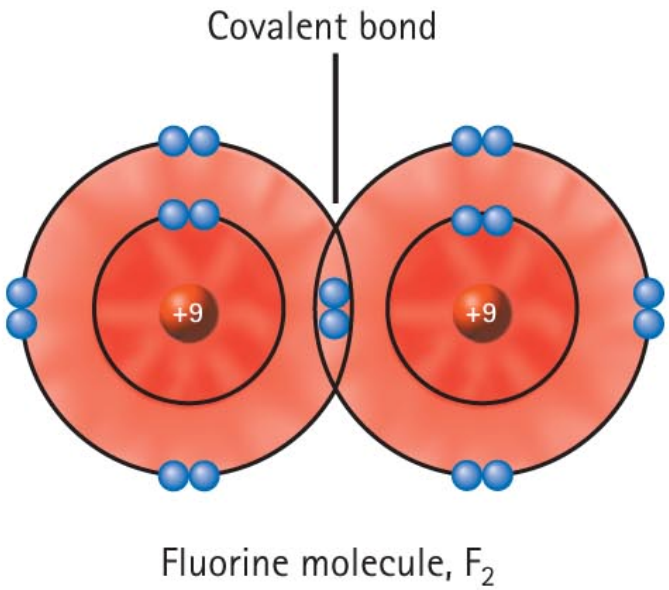

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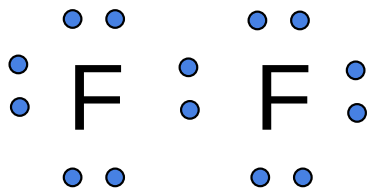
Covalent Bonds

- The type of electrical attraction in which atoms are held together by their mutual attraction for shared electrons.
- There are two electrons within a single covalent bond.
- The covalent bond is represented using a straight line.



F — F

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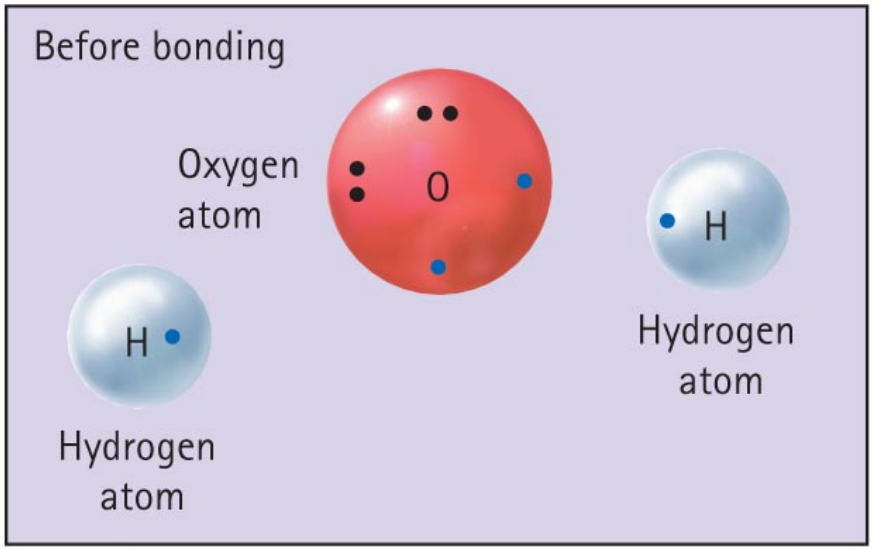
Covalent Bonds

- The number of covalent bonds an atom can form equals its number of unpaired valence electrons.



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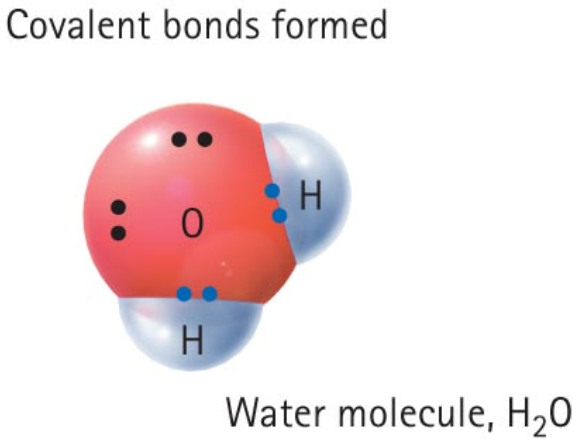

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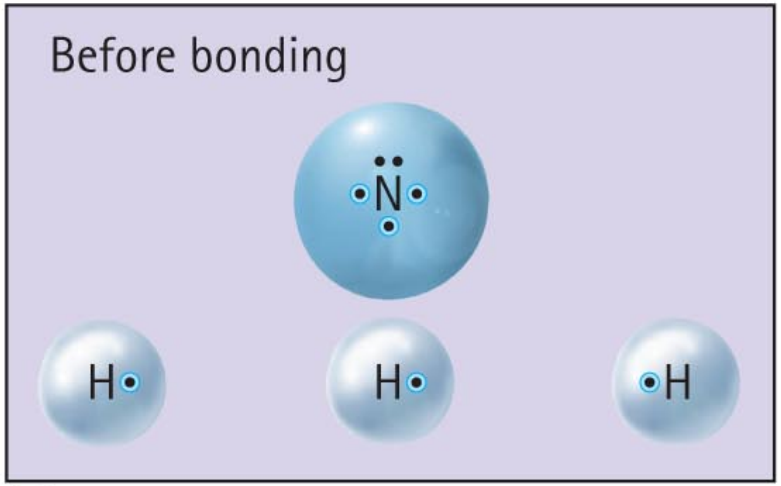

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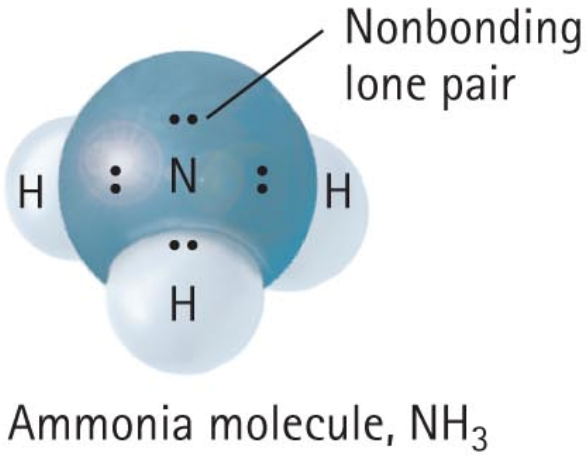

Ammonia molecule, NH_3

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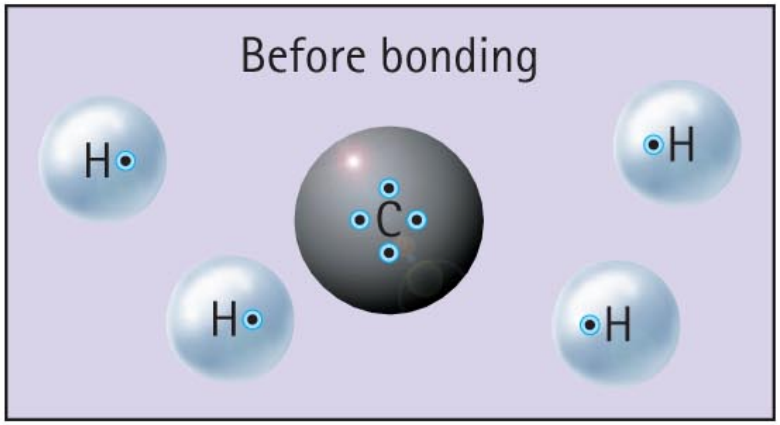

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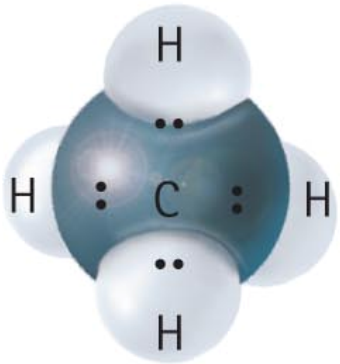

Methane molecule, CH_4

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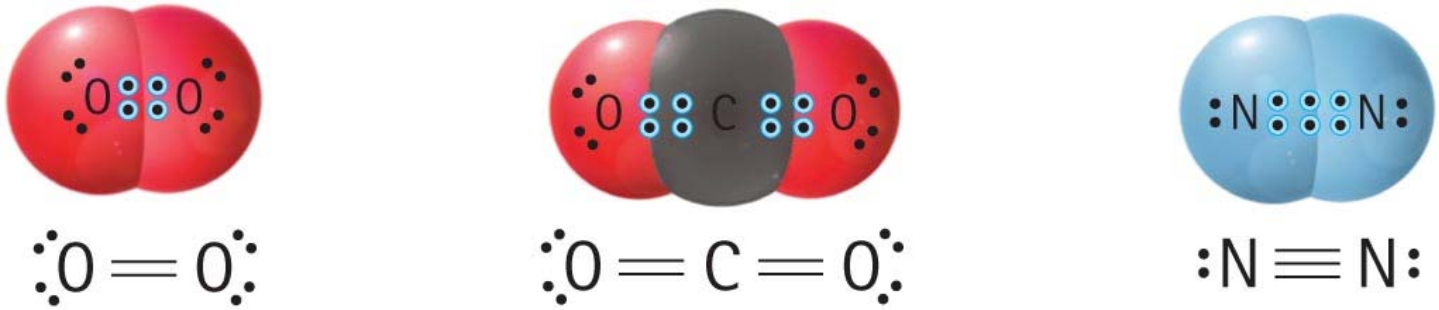
Covalent Bonds

- The number of covalent bonds an atom can form equals its number of unpaired valence electrons.

- Multiple covalent bonds are possible.



Oxygen, O_2 Carbon dioxide, CO_2 Nitrogen, N_2

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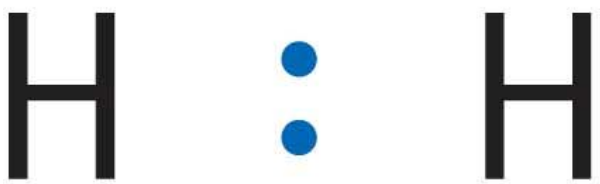
Non-polar Covalent Bonds

- Electrons within a covalent bond are shared evenly when the two atoms are the same.



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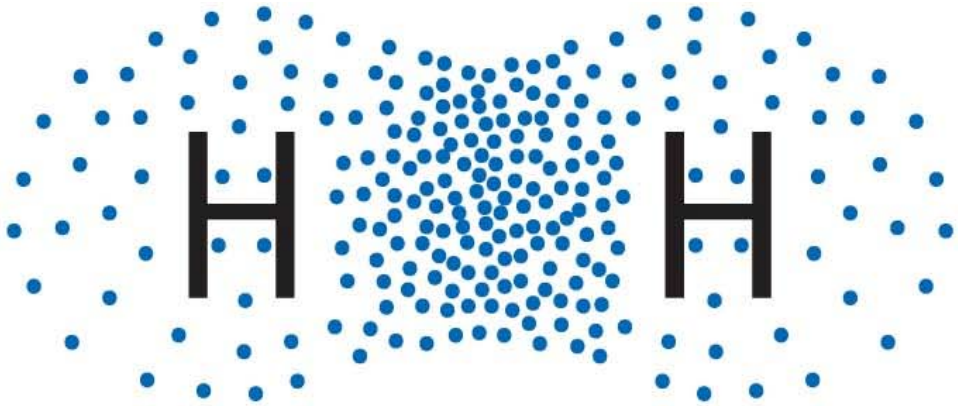

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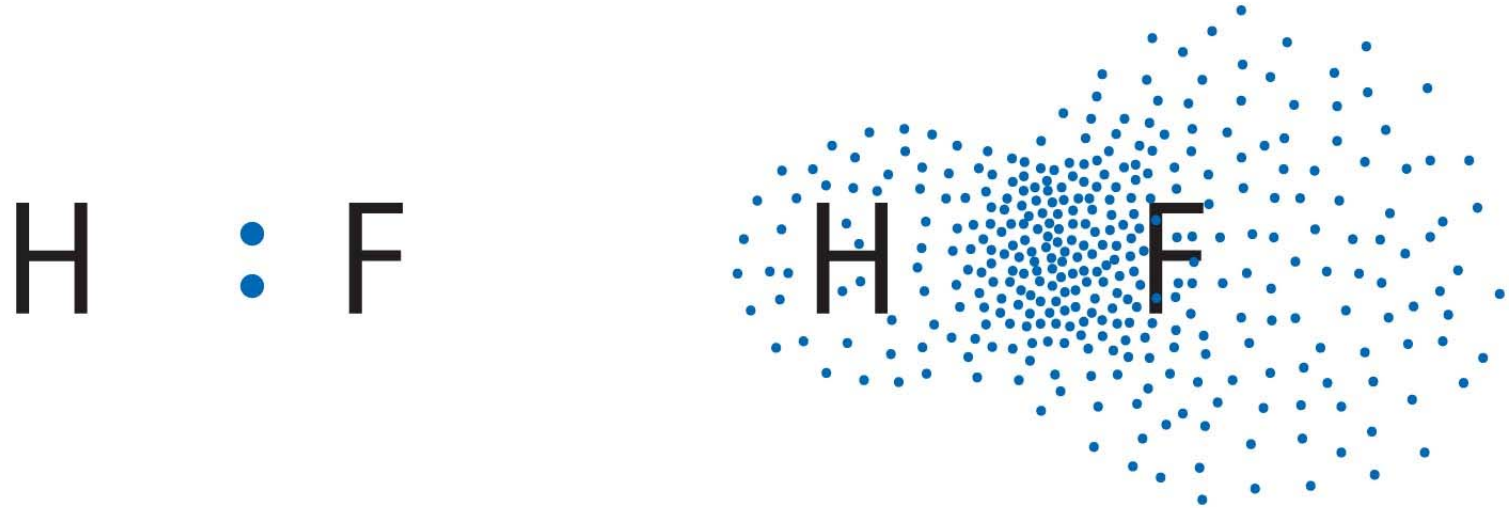
Polar Covalent Bonds

- Electrons within a covalent bond are shared evenly when the two atoms are the same.

- They may be shared *unevenly*, however, when the bonded atoms are different.



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Polar Covalent Bonds

- Electrons within a covalent bond are shared evenly when the two atoms are the same.
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- Electronegativity: The ability of a bonded atom to pull on shared electrons. Greater electronegativity means greater “pulling power.”

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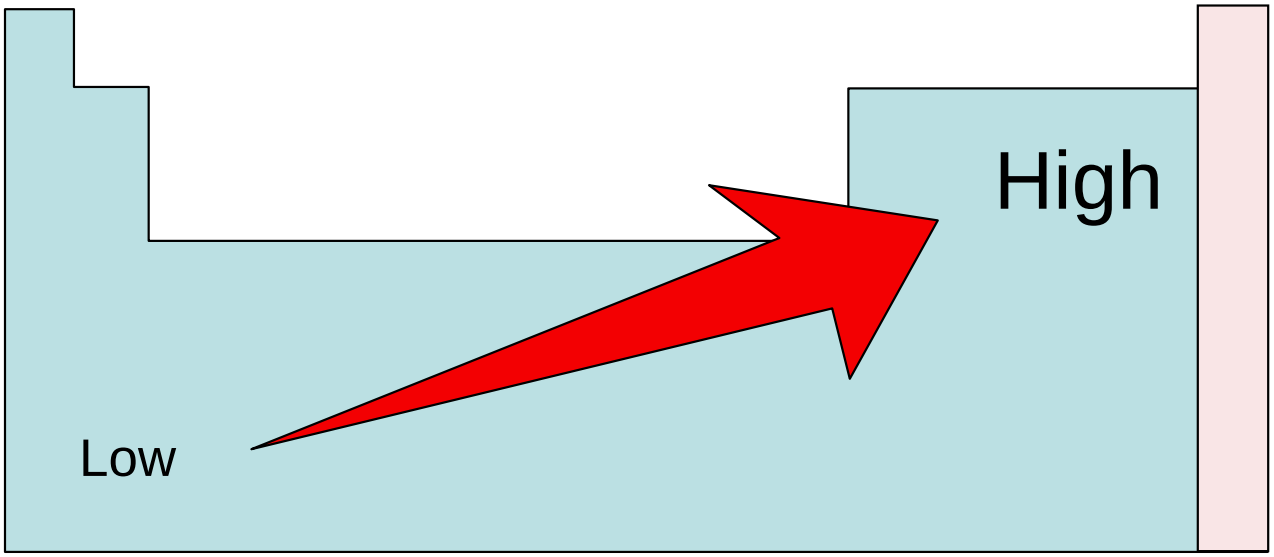

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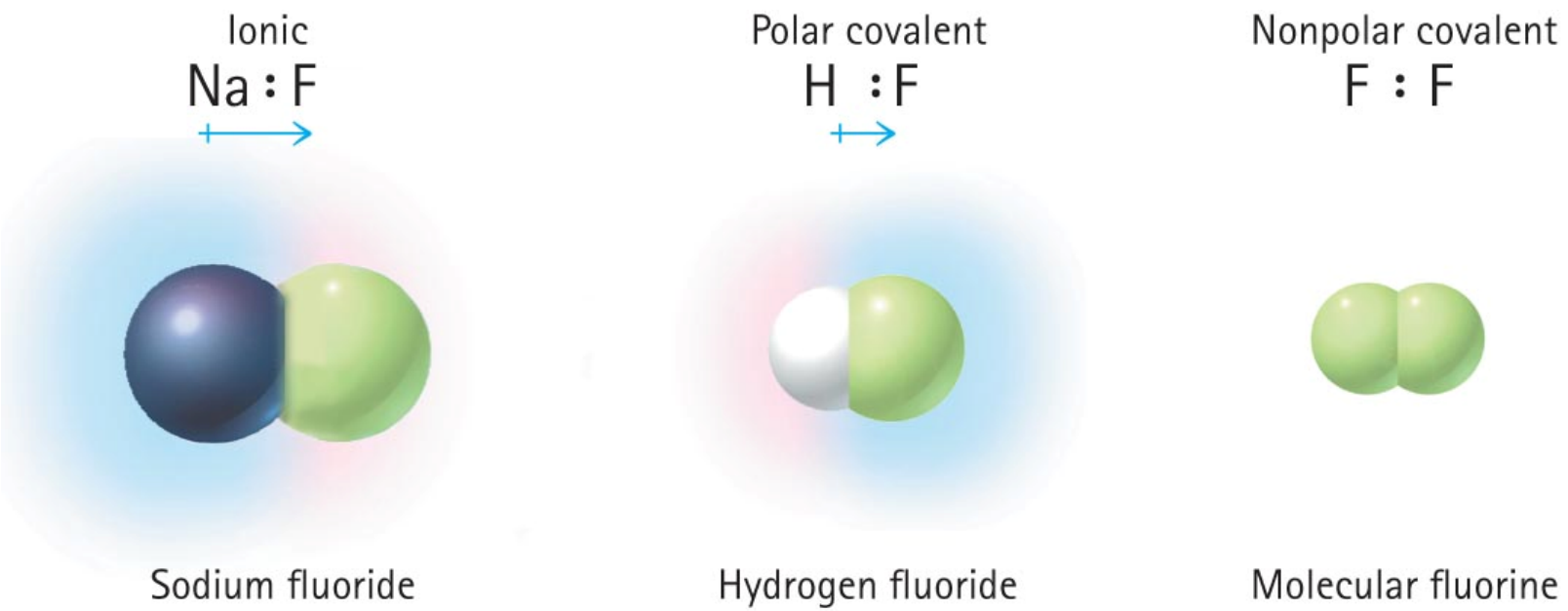

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Polar Covalent Bonds
CHECK YOUR ANSWER

Which is heavier: carbon dioxide, CO_2, or water, H_2O?

A. **Carbon dioxide is heavier.**
B. Water is heavier.
C. They both have the same number of atoms so they weigh the same.
D. It depends.

Explanation:
Look to the Periodic Table and add up the masses of the atoms within each of these substances. Carbon dioxide adds up to 44 amu, while water is only 18 amu. So, carbon dioxide is more than twice as heavy. At room temperature, carbon dioxide is a gas because it is nonpolar.

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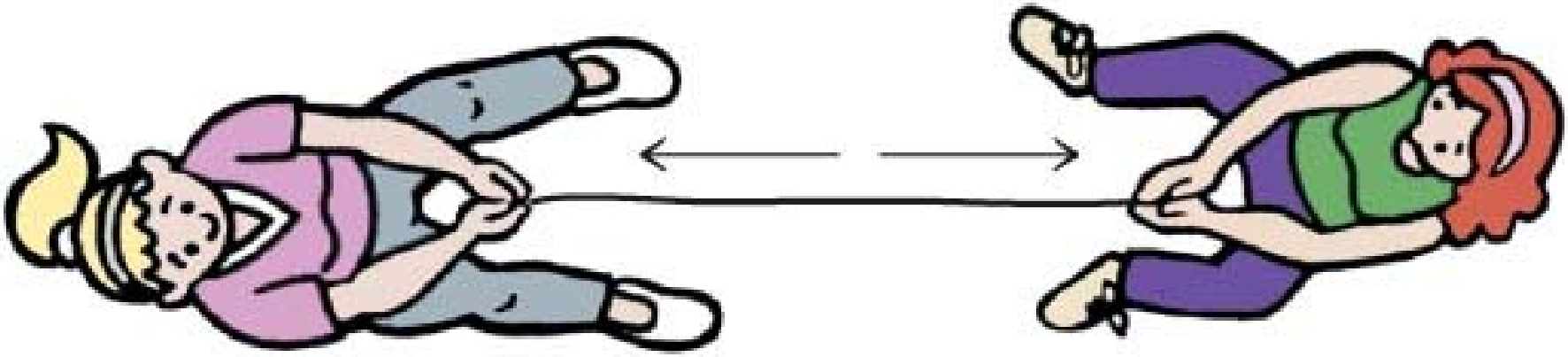
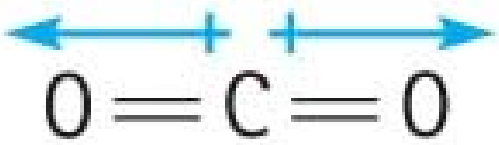
Molecular Polarity

- But if polar bonds within a molecule are facing in equal and opposite directions…





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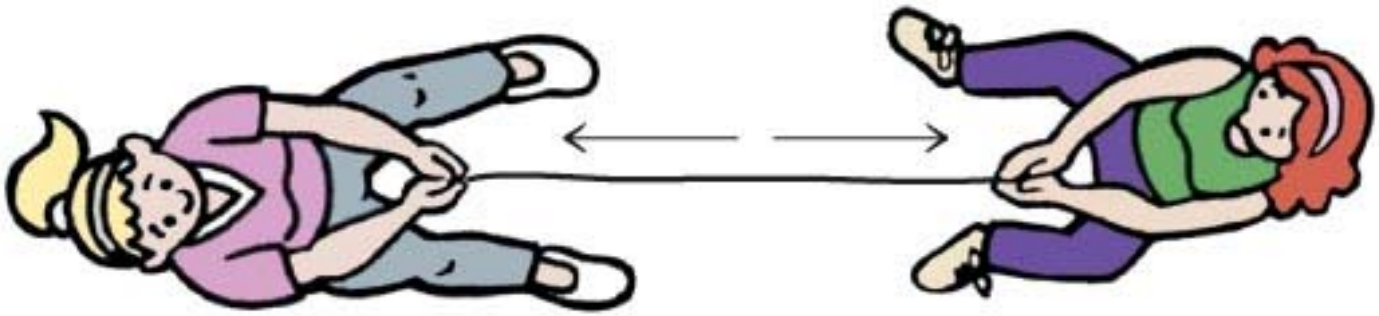
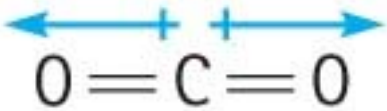
Molecular Polarity

- But if polar bonds within a molecule are facing in equal and opposite directions…

…then the polarity may cancel itself out.





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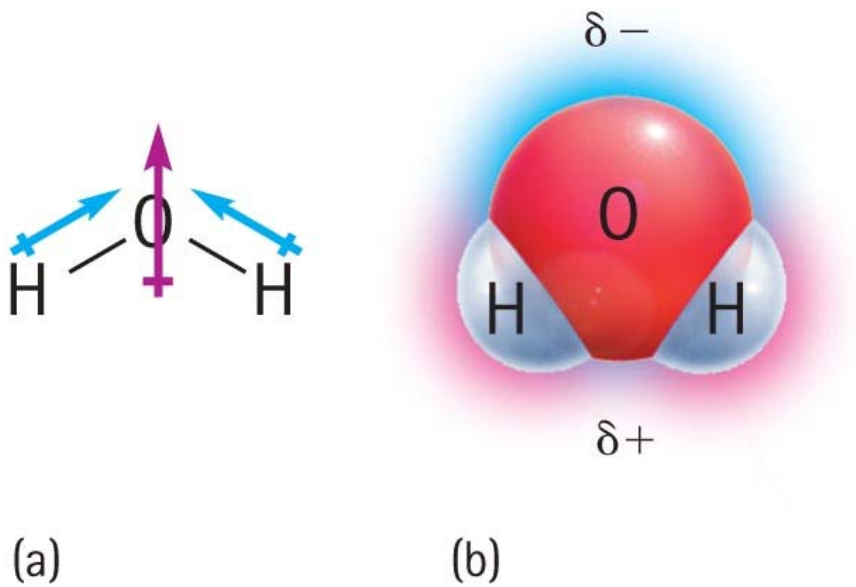

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…or not!

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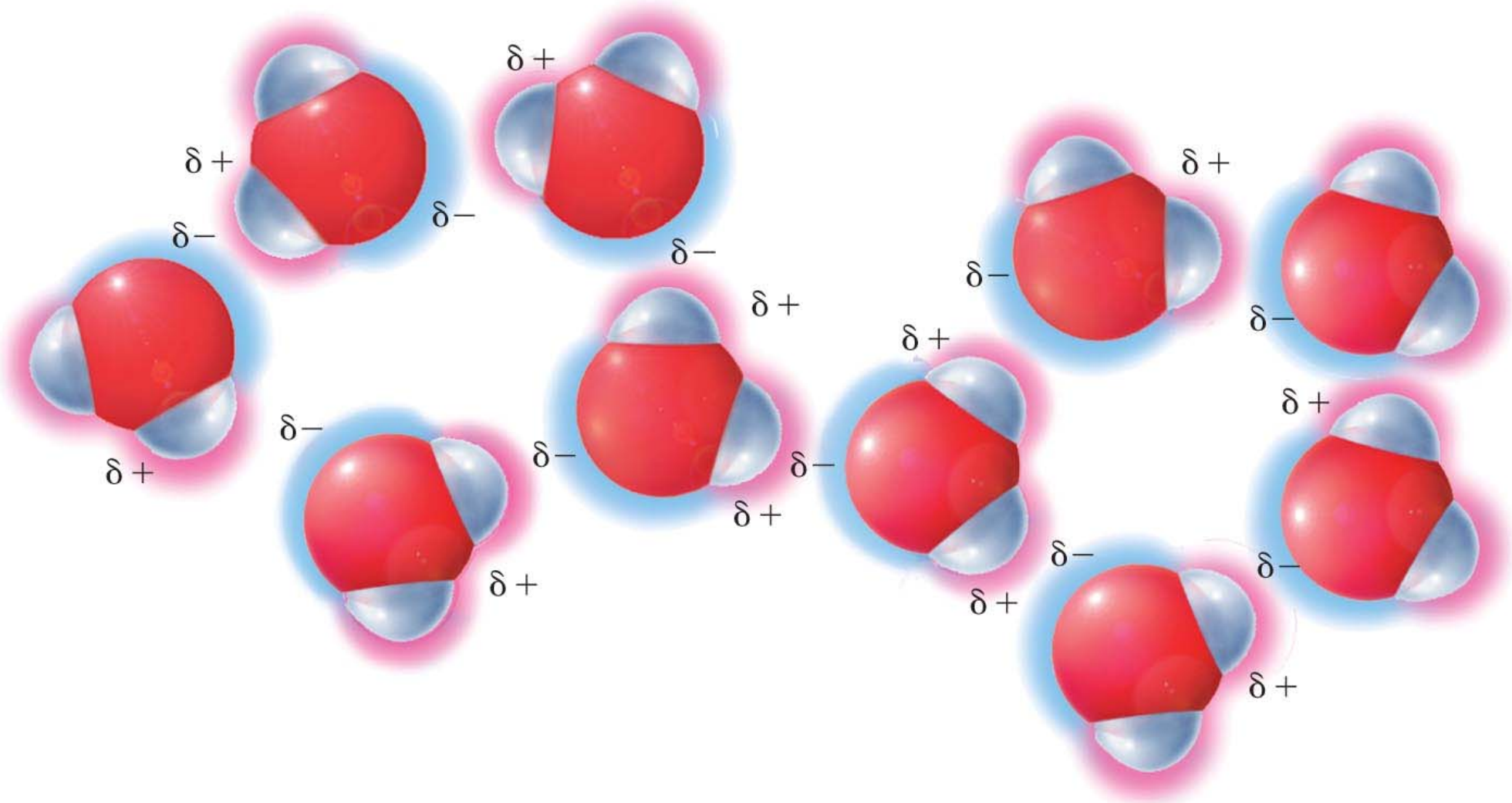
Molecular Polarity



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Molecular Polarity
CHECK YOUR NEIGHBOR

Water has such a relatively high boiling point because water

A. is such a heavy substance.
B. is transparent so that heat passes right through it.
C. contains three atoms per molecule.
D. molecules are so sticky.

Explanation:
The slightly negative end of one water molecule holds onto the slightly positive end of another water molecule. This force of attraction must be overcome before the liquid water can transform into the gaseous phase.

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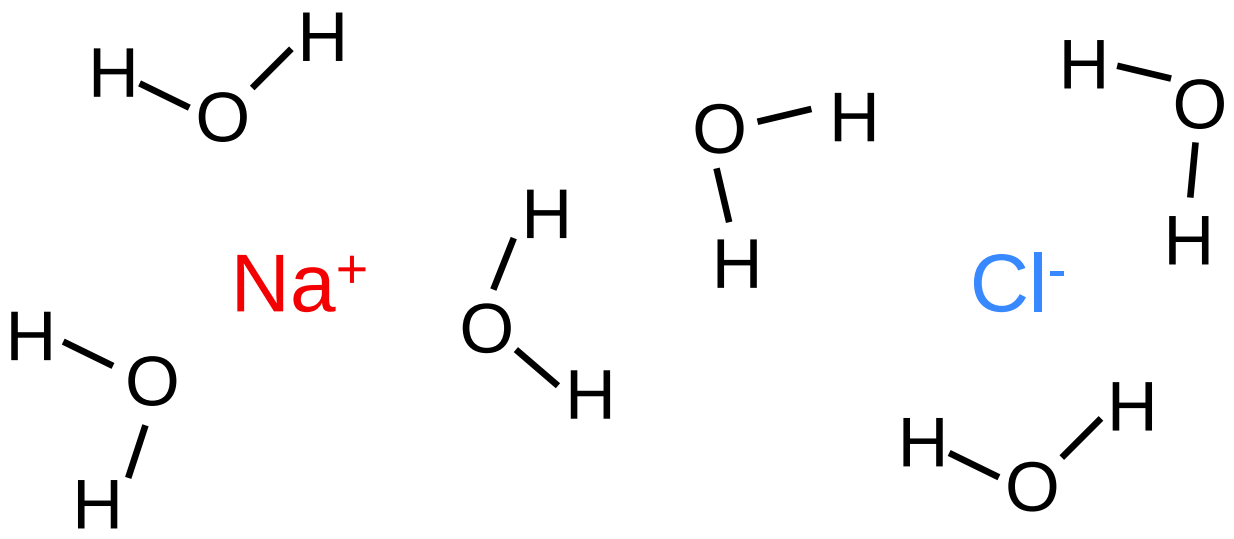
Molecular Attractions

- *Ion–dipole*

  The attraction between an ion and a dipole. Example: NaCl in water.



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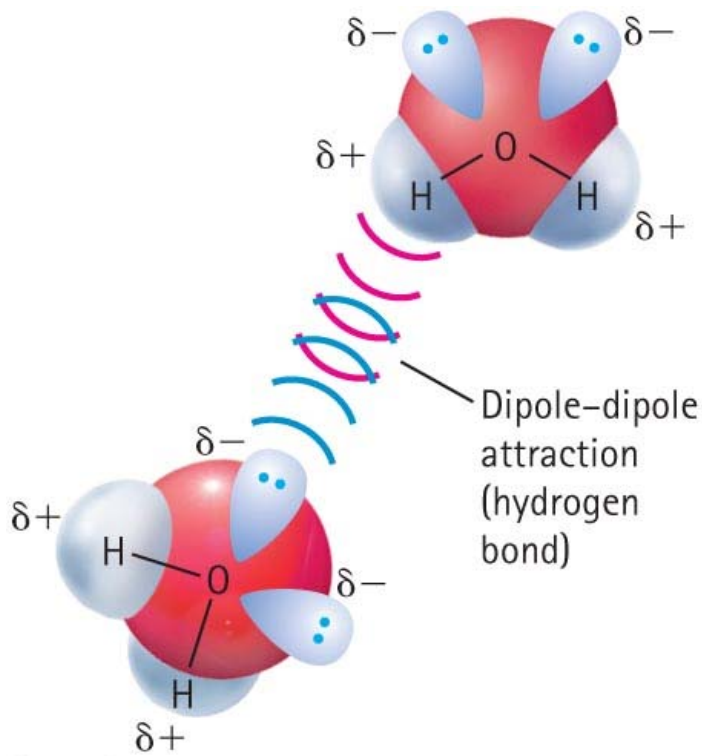
Molecular Attractions

- *Ion–dipole*

  The attraction between an ion and a dipole. Example: NaCl in water.

- *Dipole–dipole*

  The attraction between two dipoles. Example: cohesive forces within water.



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Molecular Attractions

- *Ion–dipole*

  The attraction between an ion and a dipole. Example: NaCl in water.

- *Dipole–dipole*

  The attraction between two dipoles. Example: cohesive forces within water.

- *Dipole–induced dipole*

  The attraction between a dipole and an induced dipole.

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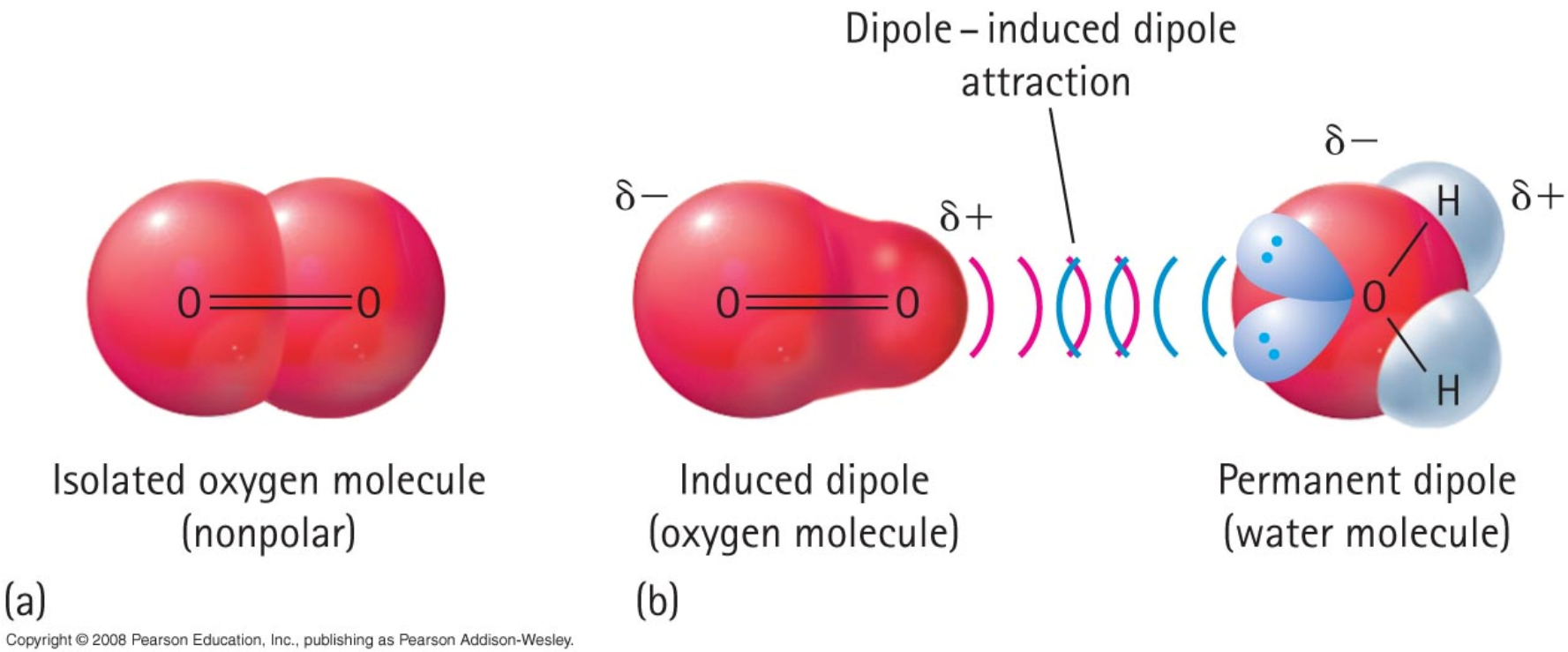
Molecular Attractions



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- *Dipole–induced dipole*

  The attraction between a dipole and an induced dipole.

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Molecular Attractions
CHECK YOUR ANSWER

A nonpolar material, such as oxygen, O_2, is soluble in a polar material, such as water, H_2O, by way of

A. ion–dipole attractions.
B. dipole–dipole attractions.
C. dipole–induced dipole attractions.
D. All of the above.

Explanation:
This is a relatively weak force of attraction, which explains why not much oxygen dissolves in the water. There is enough, however, to allow fish to live.

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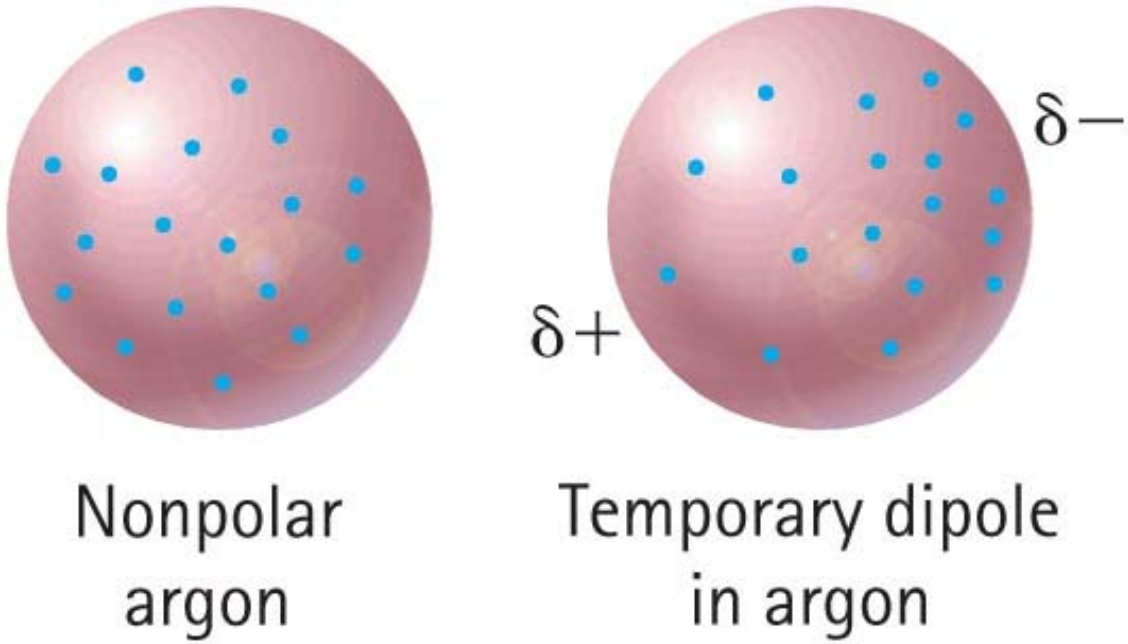
Molecular Attractions

A fourth molecular attraction is the *induced dipole-induced dipole*, which occurs between nonpolar molecules.



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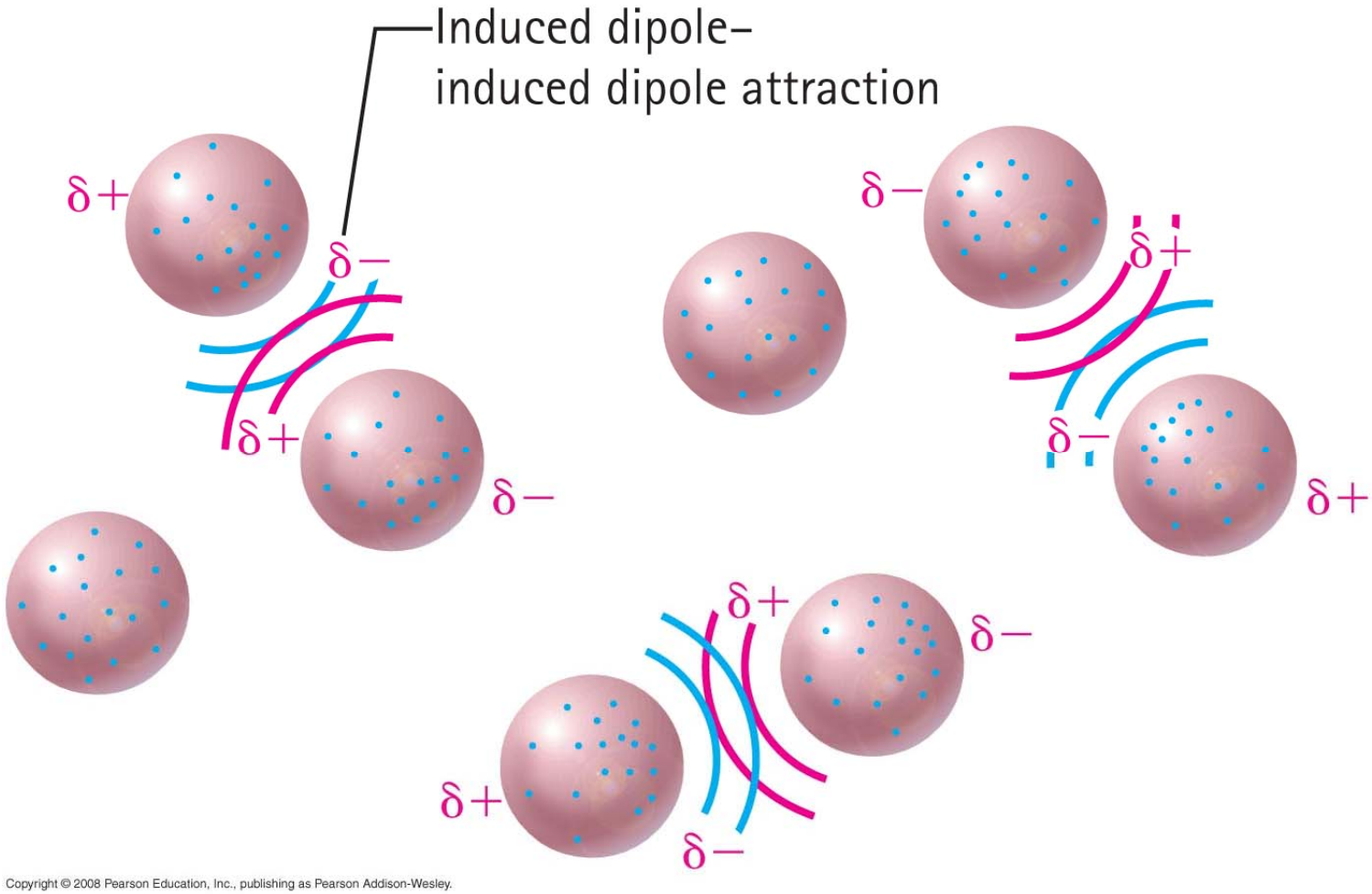
Molecular Attractions



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Nonpolar atoms are attracted to each other by these “momentary” dipoles,

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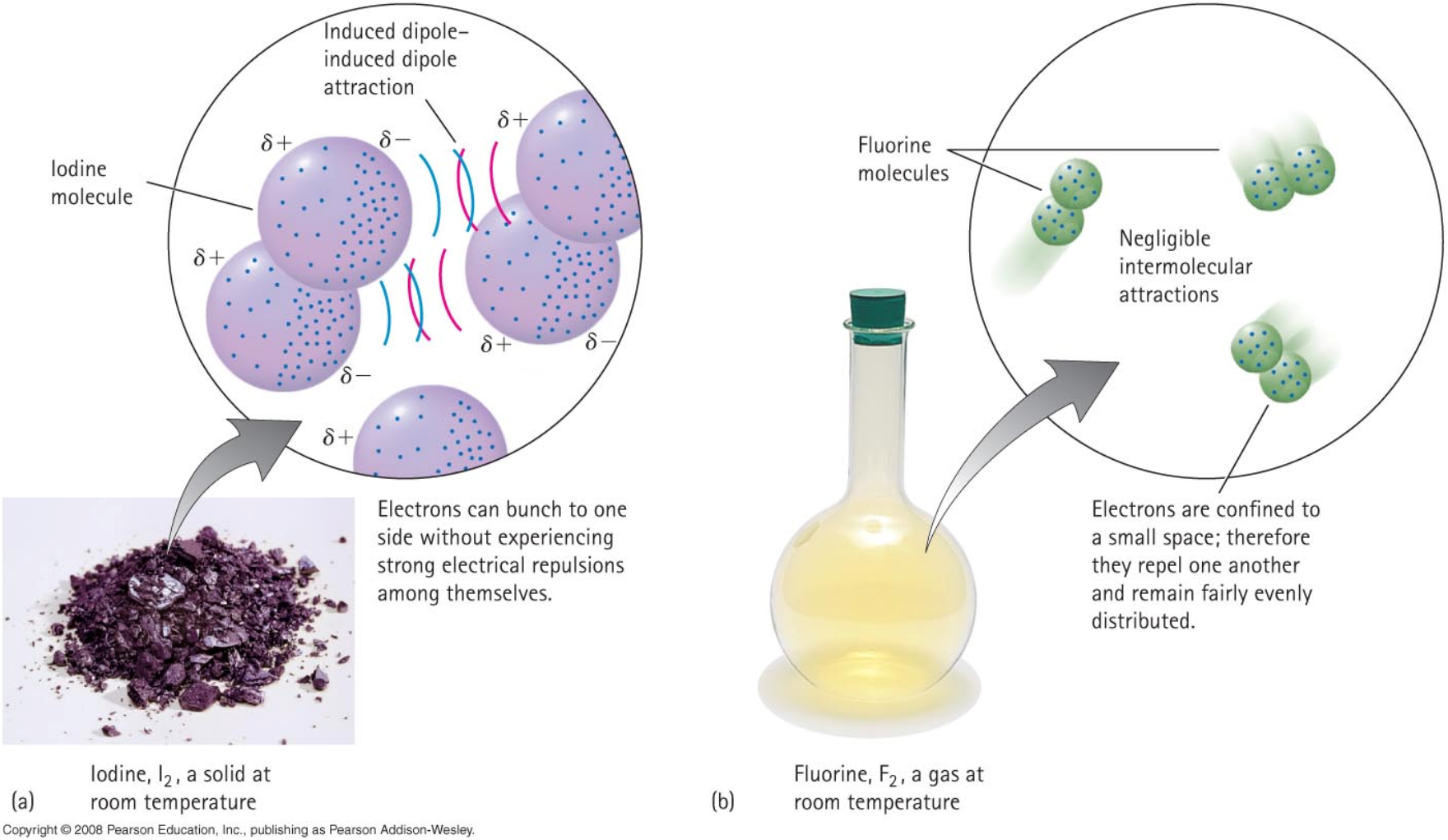
Molecular Attractions



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The larger the atom, the stronger the “momentary” dipole.

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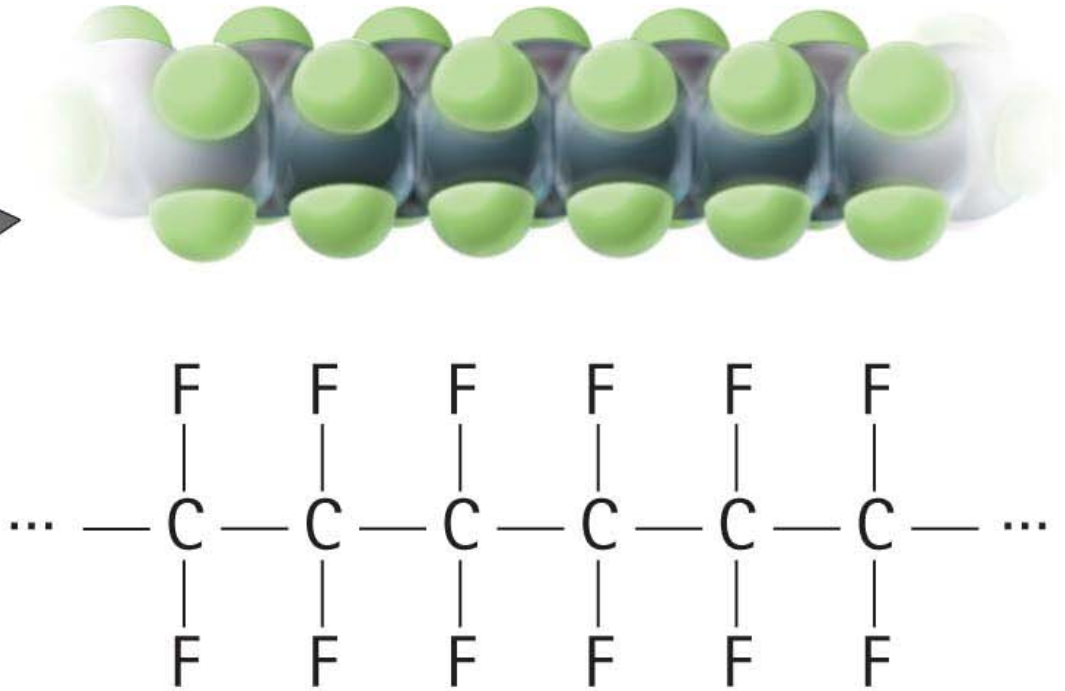
Molecular Attractions



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The tiny nonpolar fluorine atoms within Teflon provide very weak attractions, which is why Teflon provides a “non-stick” surface.

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Molecular Attractions

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So how do the gecko's sticky feet stay so clean?

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Molecular Attractions
CHECK YOUR ANSWER

Which type of molecular attraction takes the least amount of energy to break apart?

A. ion–dipole attractions.
B. dipole–dipole attractions.
C. dipole–induced dipole attractions.
D. induced dipole-induced dipole attractions.

Explanation:
The induced dipole-induced dipole attraction is the weakest of these four, but only on a molecule-to-molecule basis.

Remember, each hook on a strip of Velcro may be weak, but all the tiny hooks working together can provide for a significant holding power.

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