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
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.
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• 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.
Electron-Dot Structures

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Note:
This is a “conceptual model” and not a representation of what an atom “looks like.”
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**Note:**
Rather, it helps us to understand how the electrons within atoms behave.
The shells are more easily drawn in two dimensions.
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Each atom has its own configuration of electrons. Elements in the same group have similar configurations, which is why they have similar properties.
Electron-Dot Structures

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- Electron-dot structure: A notation showing the valence electrons surrounding the atomic symbol.
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.
Electron-Dot Structures

Note that elements within the same group have the same electron-dot structure.
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.
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Explanation:
With 10 electrons, the sodium has enough electrons to fill the first and second shells, just like neon, Ne.
The Formation of Ions

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

\[
\begin{array}{c|c}
\text{Na} & \text{Na}^{1+} \text{ (positive ion)} \\
\hline
11 \text{ protons} & 11 \text{ protons} \\
11 \text{ electrons} & 10 \text{ electrons} \\
\hline
0 \text{ net charge} & +1 \text{ net charge}
\end{array}
\]
The Formation of Ions

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

**F**

- 9 protons
- 9 electrons
- 0 net charge

**F^1-** (negative ion)

- 9 protons
- 10 electrons
- -1 net charge
The Formation of Ions

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

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The Formation of Ions

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The Formation of Ions

Hydronium ion, $\text{H}_3\text{O}^+$

- **Molecular ion**: Typically formed by the loss or gain of a hydrogen ion, $\text{H}^+$. 
Ionic Bonds

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• Ionic Bond: The electrical force of attraction between oppositely charged ions.
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\[ \text{Na}^+ \quad \text{F}^- \]
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- **Ionic Bond**: The electrical force of attraction between oppositely charged ions.
What is the chemical formula for a compound made of aluminum ions, \( \text{Al}^{3+} \), and oxygen ions, \( \text{O}^{2–} \)?

A. \( \text{AlO} \)
B. \( \text{Al}_3\text{O}_2 \)
C. \( \text{Al}_2\text{O}_3 \)
D. \( \text{Al}_6\text{O}_6 \)
What is the chemical formula for a compound made of aluminum ions, Al$^{3+}$, and oxygen ions, O$^{2-}$?

A. AlO
B. Al$_3$O$_2$
C. Al$_2$O$_3$
D. Al$_6$O$_6$
What is the chemical formula for a compound made of magnesium ions, Mg$^{2+}$, and oxygen ions, O$^{2-}$?

A. MgO  
B. Mg$_2$O$_2$  
C. Mg$_4$O$_4$  
D. Any of the above
What is the chemical formula for a compound made of magnesium ions, $\text{Mg}^{2+}$, and oxygen ions, $\text{O}^{2-}$?

A. $\text{MgO}$  
B. $\text{Mg}_2\text{O}_2$  
C. $\text{Mg}_4\text{O}_4$  
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.
Metallic Bonds

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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.
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• This weak attraction allows the electrons to move about quite freely.
• This mobility of electrons accounts for many metallic properties.
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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• There are two electrons within a single covalent bond.
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\[ F \quad F \]

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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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Before bonding

Oxygen atom

Hydrogen atom

Covalent bonds formed

Water molecule, H₂O
Covalent Bonds

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\[ \text{Oxygen, } O_2 \]
\[ \text{Carbon dioxide, } CO_2 \]
\[ \text{Nitrogen, } N_2 \]
Polar Covalent Bonds

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

 Polar covalent
 H : F

 Nonpolar covalent
 F : F

 Sodium fluoride
 Hydrogen fluoride
 Molecular fluorine
Which is heavier: carbon dioxide, $\text{CO}_2$, or water, $\text{H}_2\text{O}$?

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.
Which is heavier: carbon dioxide, CO$_2$, or water, H$_2$O?

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.
Molecular Polarity

• But if polar bonds within a molecule are facing in equal and opposite directions…
Molecular Polarity

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…then the polarity may cancel itself out.
Molecular Polarity

• But if polar bonds within a molecule are facing in equal and opposite directions...

...then the polarity may cancel itself out.

...or not!

(a) (b)
Molecular Polarity
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.
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*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.
Molecular Attractions

• *Ion–dipole*
  
The attraction between an ion and a dipole. Example: NaCl in water.
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Molecular Attractions

- **Ion–dipole**
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- **Dipole–dipole**
  The attraction between two dipoles. Example: cohesive forces within water.
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• *Dipole–induced dipole*
  The attraction between a dipole and an induced dipole.
• **Dipole–induced dipole**

The attraction between a dipole and an induced dipole.
Is it possible for a fish to drown?

A. No, because fish breathe water.
B. Yes, when the water contains too little oxygen.
C. No, because water is 88.8% oxygen by mass.
D. Yes, when the water is not moving.
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Explanation:
Fish don’t breathe water. Their gills extract the small amounts of dissolved oxygen, $O_2$, which can be found even in water that remains still.
A nonpolar material, such as oxygen, $\text{O}_2$, is soluble in a polar material, such as water, $\text{H}_2\text{O}$, by way of

A. ion–dipole attractions.
B. dipole–dipole attractions.
C. dipole–induced dipole attractions.
D. All of the above.
Molecular Attractions
CHECK YOUR ANSWER

A nonpolar material, such as oxygen, \( \text{O}_2 \), is soluble in a polar material, such as water, \( \text{H}_2\text{O} \), 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.
Molecular Attractions

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

![Diagram of nonpolar argon and temporary dipole in argon](Image)
Molecular Attractions

Induced dipole–induced dipole attraction

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

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

The tiny nonpolar fluorine atoms within Teflon provide very weak attractions, which is why Teflon provides a “non-stick” surface.
So how do the gecko’s sticky feet stay so clean?
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.
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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.