

# Exercise 6.5e

## Intermolecular Forces

Name: \_\_\_\_\_

Date: \_\_\_\_\_ Per: \_\_\_\_\_

The forces that hold atoms together to form compounds are *intramolecular* forces. They include ionic, covalent, and metallic bonds. Their formation creates new substances with properties unlike those of the atoms that comprise them.

The forces that occur between substances that result in their physical properties (melting point, boiling point, solubility, density, etc.) are *intermolecular forces*. They do not result in the formation of new substances, they only affect the degree of compaction and mobility of the particles.

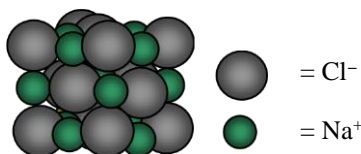
*Intermolecular forces* (IMF) can be ranked qualitatively using Coulomb's Law: Force  $\propto \frac{Q_1 Q_2}{r}$

where  $Q_1$  and  $Q_2$  are the magnitudes of the charges and  $r$  is the distance between the charges

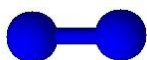
Coulomb's Law indicates that:

- the larger the charge, the stronger the attraction
- the closer the charges, the stronger the interaction.

**DIRECTIONS:** Use the diagrams and boiling point information below to answer the questions.



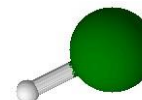
NaCl = 1413°C



N<sub>2</sub> = -192°C



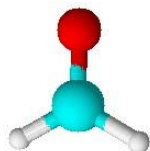
CO<sub>2</sub> = -57°C



HBr = -66°C



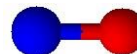
H<sub>2</sub>O = 100°C



CH<sub>2</sub>O = -21°C



NH<sub>3</sub> = -33°C



NO = -150°C



HF = 19°C

- Which species has the **highest** boiling point? \_\_\_\_\_ (This indicates the **strongest IMF**s.)
  - How does it differ from the other compounds? \_\_\_\_\_
  - What are the charges on each of the particles in this compound?  
 $Q_1$  (positive charge) = \_\_\_\_\_ :  $Q_2$  (negative charge) = \_\_\_\_\_  
 The attraction between these particles is called an \_\_\_\_\_. (Full positive and negative charges).
- Compare the boiling points and structures of N<sub>2</sub> and NO. Which has stronger IMF based on boiling points? \_\_\_\_\_
  - How do these compounds differ from one another? \_\_\_\_\_

There are no ionic charges in these compounds, but there may be **partial charges**, due to **electronegativity differences** between bonded atoms. The three most electronegative elements are **F, O** and **N**, followed by the **halogens** (Cl > Br > I). These will carry partial negative charges ( $\delta^-$ ) when bonded to **other** elements and the atom they are bonded to will carry a partial positive charge ( $\delta^+$ ).

- Label the partial charges ( $\delta^?$ ) in these two compounds.



- Which substance exhibits partial charges? \_\_\_\_\_ Which does not? \_\_\_\_\_
- How would the strength of the partial charges compare to the strength of full charges according to Coulomb's Law?  
 \_\_\_\_\_

The separation of charges within a molecule is called a **dipole moment**. Attraction between these partial charges on adjacent molecules is called a \_\_\_\_\_ interaction (Partial positive and negative charges).

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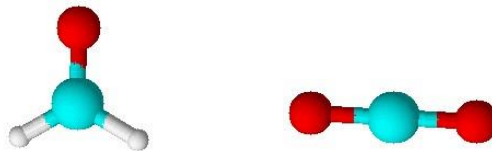
## Intermolecular Forces

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3. Compare the boiling points and structures of CO<sub>2</sub> and CH<sub>2</sub>O. Which has stronger IMF based on boiling points? \_\_\_\_\_.

- a. Label the partial positive and negative charges. Draw vectors ( $\oplus \rightarrow$ ) indicating the direction of the charge separation with the arrow head pointing to the negative charge.



- b. Explain the difference in boiling point based on the partial **charges** and **molecular shape**. \_\_\_\_\_

4. Identify the two compounds that do not possess **dipole moments**. \_\_\_\_\_

- a. What appears to determine their relative boiling points? \_\_\_\_\_

All atoms and molecules possess **instantaneous dipole moments**, due to the movement of the electrons in their structures. At any given instant, the electrons might all be on one side of the nucleus, giving rise to a separation of charge within the atom. These are called **London Dispersion Forces (LDF)** and increase in strength with the number of electrons in the system.

5. Compare HBr and HF. Both possess polar bonds and permanent dipole moments. Both also possess LDFs.

- a. Which will have the larger LDF? \_\_\_\_\_

- b. Which has the stronger IMF, based on their boiling points? \_\_\_\_\_

The difference in the strength of these dipoles is due to *hydrogen bonding* (H-bonding). The three most electronegative elements, **F**, **O** and **N**, when bonded directly to *hydrogen* give rise to especially large dipoles.

The **H<sup>δ+</sup>** bonded to F, O or N is called a *H-bond donor* and is the positive charge in the coulombic equation. The **F<sup>δ-</sup>**, **O<sup>δ-</sup>** and **N<sup>δ-</sup>** are called *H-bond acceptors* and are the negative charges. Label these as **d** (donor) or **a** (acceptor) on the molecules at the top of the sheet if they exhibit H-bonding.

6. Decide if each of the compounds has H-bond donors and/or acceptors

Substance	H-bond donor	H-bond acceptor
NaCl		
N <sub>2</sub>		
CO <sub>2</sub>		
HBr		
H <sub>2</sub> O		

Substance	H-bond donor	H-bond acceptor
CH <sub>2</sub> O		
NH <sub>3</sub>		
NO		
HF		

7. Which of the following pairs of compounds can form H-bonds to each other?

- a. NO and H<sub>2</sub>O \_\_\_\_\_      c. CH<sub>2</sub>O and H<sub>2</sub>O \_\_\_\_\_      e. H<sub>2</sub>O and NH<sub>3</sub> \_\_\_\_\_  
 b. H<sub>2</sub>O and H<sub>2</sub>O \_\_\_\_\_      d. CH<sub>2</sub>O and CH<sub>2</sub>O \_\_\_\_\_      f. NH<sub>3</sub> and NH<sub>3</sub> \_\_\_\_\_

8. What types of IMF will exist between the following pairs of compounds?

- a. CO<sub>2</sub> and CO<sub>2</sub> \_\_\_\_\_      d. CH<sub>2</sub>O and CH<sub>2</sub>O \_\_\_\_\_  
 b. H<sub>2</sub>O and Na<sup>+</sup> \_\_\_\_\_      e. HBr and NH<sub>3</sub> \_\_\_\_\_  
 c. NO and H<sub>2</sub>O \_\_\_\_\_      f. HF and NH<sub>3</sub> \_\_\_\_\_