Exercise 6.5e

Intermolecular Forces – Answers

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.

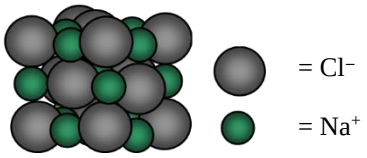
Intermolecular forces (IMF) can be ranked qualitatively using Coulomb's Law: $\text{Force} \propto \frac{Q_1 Q_2}{r}$

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

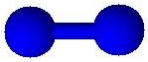
Coulomb's Law indicates that:

a. the larger the charge, the stronger the attraction
b. the closer the charges, the stronger the interaction.

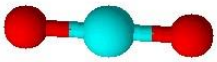
DIRECTIONS: Use the diagrams and boiling point information below to answer the questions.



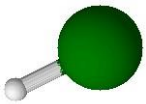
NaCl = 1413°C



N_2 = −192°C

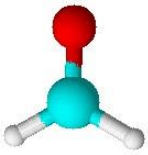


CO_2 = −57°C



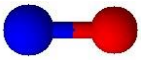
HBr = −66°C

H_2O = 100°C



CH_2O = −21°C

NH_3 = −33°C



NO = −150°C

HF = 19°C

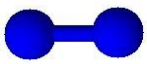
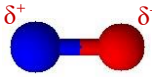
1. Which species has the **highest** boiling point? NaCl *(This indicates the **strongest IMF**s.)*
   a. How does it differ from the other compounds? NaCl is ionic and has full positive & negative charges attracting its particles, whereas the remainder are covalent and have only particle charges attracting their particles
   b. What are the charges on each of the particles in this compound?

   Q_1 (positive charge) = +1 : Q_2 (negative charge) = –1

   The attraction between these particles is called an ionic bond . *(Full positive and negative charges)*.
2. Compare the boiling points and structures of N_2 and NO. Which has stronger IMF based on boiling points? NO
   a. How do these compounds differ from one another? NO is polar covalent and N_2 is non-polar covalent

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 (δ-) when bonded to **other** elements and the atom they are bonded to will carry a partial positive charge (δ+).

   b. Label the partial charges (δ?) in these two compounds.

N_2   NO

   c. Which substance exhibits partial charges? NO Which does not? N_2
   d. How would the strength of the partial charges compare to the strength of full charges according to Coulomb's Law? Partial charges (such as those found in molecules) will be weaker than full charges (found in ionic compounds)

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

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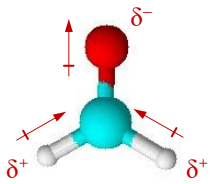
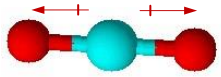
3. Compare the boiling points and structures of CO_2 and CH_2O. Which has stronger IMF based on boiling points? CH_2O .

   a. Label the partial positive and negative charges. Draw vectors (⟶) 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**. CO_2 has polar bonds, but the symmetry of the molecule neutralizes the polarity of the bonds. CH_2O is non-symmetrical and therefore is polar and exhibits greater partial charges at its poles giving it greater intermolecular forces and a higher boiling point.

4. Identify the two compounds that do not possess **dipole moments**. N_2 & CO_2 are not permanent dipoles

   a. What appears to determine their relative boiling points? The size of the molecule (specifically the electron cloud).

> 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? HBr because Br is a larger atom than F and has more electrons that may shift.

   b. Which has the stronger IMF, based on their boiling points? HF

> 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 $\mathbf{H}^{\delta+}$ bonded to F, O or N is called a *H-bond donor* and is the positive charge in the coulombic equation. The $\mathbf{F}^{\delta-}$, $\mathbf{O}^{\delta-}$ and $\mathbf{N}^{\delta-}$ 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	No	No
N_2	No	No
CO_2	No	No
HBr	No	No
H_2O	Yes	Yes

Substance	H-bond donor	H-bond acceptor
CH_2O	No	Yes
NH_3	Yes	Yes
NO	No	Yes
HF	Yes	Yes

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

   a. NO and H_2O Yes
   b. H_2O and H_2O Yes
   c. CH_2O and H_2O Yes
   d. CH_2O and CH_2O No
   e. H_2O and NH_3 Yes
   f. NH_3 and NH_3 Yes

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

   a. CO_2 and CO_2 LDF
   b. H_2O and Na^+ LDF & ion-dipole
   c. NO and H_2O LDF & H-bond
   d. CH_2O and CH_2O LDF & dipole-dipole
   e. HBr and NH_3 LDF & dipole-dipole
   f. HF and NH_3 LDF & H-bond