

Comprehensive Study Guide: Intermolecular Forces (IMF)

This study guide provides a detailed overview of intermolecular forces (IMF), their characteristics, and their impact on physical properties based on the principles.

Glossary of Key Terms	
Boiling Point	The temperature at which a liquid turns into a gas; it is highest in substances with strong IMFs and lowest in those with weak IMFs.
Dipole - Dipole	An intermolecular force that exists between polar compounds, such as HBr or HCl.
Dipole - Induced Dipole	A weak attraction that occurs when a polar molecule induces a temporary dipole in a non-polar molecule, such as O ₂ in H ₂ O.
Hydrogen Bonding:	A specific, strong type of dipole-dipole attraction occurring in polar compounds where Hydrogen is bonded to Fluorine, Oxygen, or Nitrogen.
Induced Dipole (Dispersion):	The weakest intermolecular force that occurs between nonpolar compounds and pure elements.
Ion - Dipole:	The interaction between an ion (from an ionic compound) and the partial charges of a polar solvent
Ion - Ion:	The strongest intermolecular force that occurs between ions in ionic compounds like NaCl(s).
Surface Tension:	A property of liquids resulting from intermolecular forces; it is highest in substances with strong IMFs and lowest in those with weak IMFs.
Vapor Pressure:	The pressure exerted by a vapor in equilibrium with its liquid or solid phase; it is highest when IMFs are weak and lowest when IMFs are strong.
Viscosity:	A measure of a fluid's resistance to flow; it is highest in substances with strong IMFs and lowest in those with weak IMFs.

Intermolecular Forces Comparison Table

The following table summarizes the types of intermolecular forces, the compounds involved, and the resulting physical property trends.

IMF Type	Compound Types	Example(s)	Relative Strength	Boiling Point	Vapor Pressure	Viscosity	Surface Tension
Ion - Ion	Ionic compounds	NaCl(s)	Strongest	Highest	Lowest	Highest	Highest
Ion - Dipole	Ionic compounds dissolved in polar solvents	NaCl in H_2O	High	High	Low	High	High
Hydrogen Bonding	Polar compounds with H-F, H-O, and H-N bonds	H_2O or NH_3	Moderate to High	High	Low	High	High
Dipole - Dipole	Polar compounds	HBr(l) or HCl(l)	Moderate	Moderate	Moderate	Moderate	Moderate
Dipole - Induced Dipole	Polar with non-polar compounds	O_2 in H_2O	Low	Low	High	Low	Low
Induced Dipole (Dispersion)	Non-polar compounds & pure elements	$O_2(g)$ or $C_{H4}(l)$	Weakest	Lowest	Highest	Lowest	Lowest

Short-Answer Practice Quiz

Instructions: Answer the following questions using 2–3 sentences.

1. Compare the relative strength of Ion-Ion interactions to Induced Dipole forces.
2. What specific molecular bonds must be present for a polar compound to exhibit Hydrogen Bonding?
3. Explain the relationship between the strength of intermolecular forces and the boiling point of a substance.
4. How does the vapor pressure of a substance change as intermolecular forces become stronger?

5. Identify the types of compounds that typically engage in Dipole-Dipole interactions and provide one example.
6. Under what conditions do Dipole-Induced Dipole interactions occur?
7. Contrast the viscosity of a substance with strong Ion-Ion forces against one with weak dispersion forces.
8. What characterizes the Induced Dipole (Dispersion) force, and in which substances is it found?
9. What type of intermolecular force is created when NaCl is dissolved in H_2O ?
10. Describe the trend of surface tension across the spectrum of intermolecular forces.

Essay Questions

Instructions: Consider the following prompts for more in-depth analysis.

1. **Systematic Comparison of IMFs:** Analyze how the type of compound (ionic, polar, or non-polar) dictates the specific intermolecular force present and how these forces influence the substance's physical state.
2. **The Impact of Polarity on Solution Dynamics:** Discuss the role of Ion-Dipole and Dipole-Induced Dipole forces in the process of mixing different substances, such as gases in liquids or solids in solvents.
3. **Hydrogen Bonding vs. Dipole-Dipole:** Evaluate the structural and chemical differences that allow a molecule like H_2O to form hydrogen bonds. In contrast, a molecule like HCl is limited to dipole-dipole interactions.
4. **The Extremes of IMF Trends:** Contrast the physical properties (Boiling Point, Vapor Pressure, Viscosity, and Surface Tension) of NaCl(s) and $CH_4(l)$, explaining how their respective IMFs account for these differences.
5. **Understanding Vapor Pressure:** Explain why substances with the weakest intermolecular forces possess the highest vapor pressure, incorporating the concept of molecular escape from the liquid phase.

Short Answer Practice Quiz Answer Key

1. Ion-Ion interactions are categorized as the strongest type of intermolecular force, typically found in ionic compounds. In contrast, Induced Dipole (Dispersion) forces are the weakest interactions, occurring in non-polar compounds and pure elements.
2. For Hydrogen Bonding to occur, a polar compound must contain hydrogen atoms directly bonded to highly electronegative elements, specifically Fluorine (F), Oxygen (O), or Nitrogen (N). Examples of substances that meet these criteria include H_2O and NH_3 .
3. There is a direct correlation between intermolecular force strength and boiling point. As the strength of the IMF increases, the boiling point rises, meaning the strongest forces, such as ion-ion interactions, result in the highest boiling points.
4. Vapor pressure is inversely related to the strength of intermolecular forces. Stronger IMFs hold molecules more tightly together, resulting in the lowest vapor pressure, while the weakest forces result in the highest vapor pressure.
5. Dipole-Dipole interactions occur between polar compounds that do not necessarily meet the criteria for hydrogen bonding. Common examples include liquid Hydrogen Bromide (HBr) and Hydrogen Chloride (HCl).
6. Dipole-Induced Dipole interactions occur when a polar compound is mixed with a non-polar compound. A primary example of this interaction is the dissolution of Oxygen (O_2) in Water (H_2O).
7. Substances with strong Ion-Ion forces exhibit the highest viscosity because the particles are strongly attracted to one another. Conversely, substances held together by weak Induced Dipole (Dispersion) forces have the lowest viscosity.
8. Induced Dipole forces, also known as Dispersion forces, are the weakest intermolecular interactions. They are the primary forces found in non-polar compounds and in pure elements, such as $\text{O}_2(\text{g})$ or $\text{CH}_4(\text{l})$.
9. When an ionic compound like NaCl is dissolved in a polar solvent like H_2O , the resulting interaction is known as an Ion-Dipole force. This force is relatively strong, sitting just below Ion-Ion interactions in the hierarchy.
10. Surface tension follows the same trend as boiling point and viscosity; it increases as the strength of the intermolecular force increases. Ion-ion forces produce the highest surface tension, while Induced Dipole forces produce the lowest.

