KIM

INTERMOLECULAR FORCES: THE FORCE BEHIND VARIOUS PROPERTIES

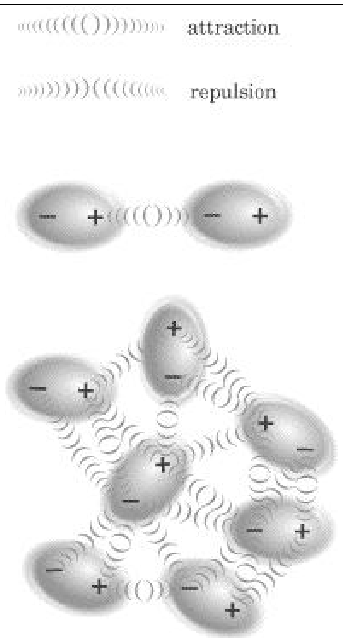
WHY?

Intermolecular forces are largely responsible for the properties of affinity, solubility, volatility, melting/ boiling point, and viscosity. Intermolecular forces explain why Teflon is non-stick, why maple syrup flows slowly, how proteins fold and interact with other molecules, and why certain substances are gases, liquids, or solids.

LEARNING OBJECTIVES:

- **Define** and understand what an intermolecular force (IMF) is
- **Observe and connect** how the strength of an IMF is related to changes in variables in Coulomb's law
- **Define** and understand what affinity/ solubility, boiling point/ volatility, viscosity are
- **Observe and connect** how molecular polarity, IMF strength, and aforementioned properties are related
- **Explain** how molecular polarity, IMF strength, and the aforementioned properties are related

MODEL 1: Introduction to Intermolecular Forces



- The term "**INTER**molecular forces" is used to describe the forces of **attraction BETWEEN** atoms, molecules, and ions when they are placed close to each other (This is different from intramolecular forces, which is another word for covalent bonds **inside** molecules).

- When two particles experience an intermolecular force, a positive (+) charge on one particle is attracted to a negative (-) charge on the other particle.

- When intermolecular forces are **strong**, the atoms, molecules, or ions are strongly attracted to each other, and draw **closer** together.

- When intermolecular forces are **weak**, the atoms, molecules, or ions do not attract each other strongly, and move **far apart**.

Key Questions:

1. What is the difference between inter- and intra- molecular forces (in 10 words or less)?

2. What is the minimum number of molecules (or atoms, ions) needed for an intermolecular force?

3. When two particles experience an intermolecular force, how are the two particles attracted to each other?

4. Draw two CO molecules. Indicate how they would line up, and draw the intermolecular force as a dashed line.

5. What would be easier to separate two molecules experiencing a strong intermolecular attraction or two molecules experiencing a weak intermolecular attraction? Answer in a complete sentence.

Exercises:

6. What law governs the magnitude of the force of attraction between two oppositely charged substances?

7. According to this law, as the magnitude of charges increases, what happens to the strength of attraction?

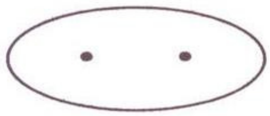
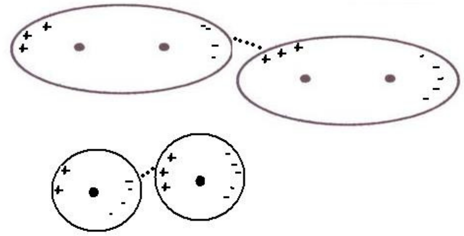
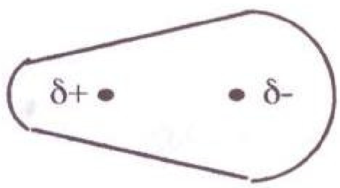
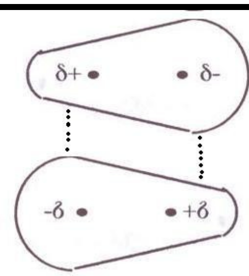
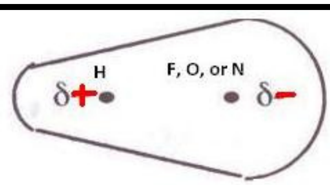
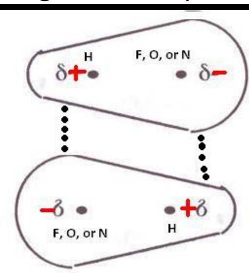
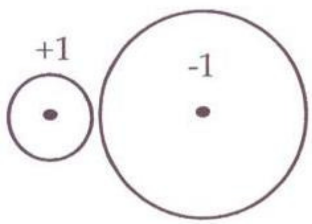
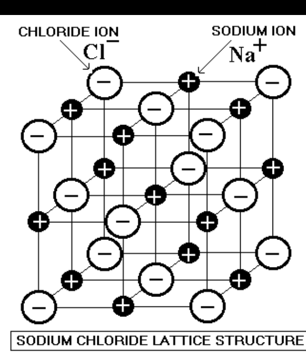
8. What has a stronger force of attraction—ionic bonds or the intermolecular forces between two polar molecules? **EXPLAIN WHY.**

9. According to this law, as the distance between charges increases, what happens to the strength of attraction?

10. When two polar molecules are moved far apart from each other, what happens to the intermolecular force between them? **EXPLAIN WHY.**

11. Intermolecular forces are nearly negligible in the gas phase. **EXPLAIN WHY** this is true.

MODEL 2: Different types of particles → Different strength intermolecular forces

Van der Waals Forces	 Covalently bonded **NONPOLAR** molecule	 BULKIER substances with larger electron clouds can make these temporary dipoles more easily (i.e they are more ***polarizeable***). Strength of LDF increases when two molecules can polarize each other over a great surface area.	**LONDON DISPERSION FORCES (LDF)** occur for **ALL** substances with electrons, but are the **only** force acting on nonpolar particles. LDF is the name of the weakest type of IMF that results from random or induced electron fluctuations, which create very small, **temporary** dipoles.
	 **Covalently bonded POLAR molecule**	 Dipole-dipole forces are stronger than LDF, and their strength is proportional to the charges of the dipoles involved.	**DIPOLE-DIPOLE FORCES** occur when two polar molecules are attracted to each other. The dipoles in polar molecules range are **permanent.**
	 **Covalently bonded POLAR molecule with an H-F, H-O, or H-N bond in it**	 Hydrogen bonds are much stronger than other dipole dipole forces because the high polarity of the molecules.	**HYDROGEN BONDS** are a special subset of dipole-dipole forces. Hydrogen bonds involve molecules with large electronegativity differences (those that have H-F, H-O, or H-N bonds), which leads to dipoles with large partial charges.
Ionic Bonding			**IONIC BONDS** are technically NOT an intermolecular force, but they have similar features.

Key Questions:

12. What is the same about all intermolecular forces? What is different?

13. What is the collective term for the intermolecular forces that affect neutral (non-charged) substances?

14. How do temporary, weak dipoles form in atoms and molecules that aren't polar?

15. Compare the strength of these dipoles formed to those in polar molecules:

16. What type of molecule has a permanent dipole?

17. Would CO_2 have dipole-dipole forces? Why or why not?

18. Why do polar compounds with H-F, H-O, and H-N bonds produce the strongest van der Waals forces?

Exercises:

19. Why are dipole-dipole forces typically stronger than London dispersion forces?

20. Why are dipole-dipole forces only about 1% the strength of ionic bonds?

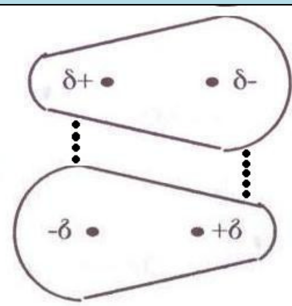
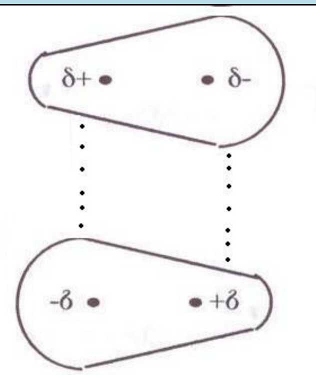
21. Which substance would have greater London dispersion forces—F_2 or I_2? EXPLAIN.

22. What happens to the strength of intermolecular forces as polarity increases? EXPLAIN WHY.

23. Draw two H_2O molecules. Indicate how they would line up, and draw the intermolecular force as a dashed line. Is this attractive force stronger or weaker than the attraction between two CO molecules?

24. Rank the strength of the hydrogen bonds between HF, H_2O, and NH_3. Explain why you ranked them this way.

MODEL 3: Properties dependent upon intermolecular forces

Property	**Strong IMF**	**Weak IMF**
		
Distance between molecules	SMALL	LARGE
Energy it take to separate molecules	LARGE	SMALL
Affinity for other molecules like itself		
Volatility		
Boiling/ melting point		
Viscosity		

Key Questions:

25. What is the difference, on a molecular level, between a gas, liquid, and solid?

26. Rank gas, liquid, and solid in order of increasing intermolecular forces.

27. To go from a liquid to a gas, then, what must happen?

28. To go from a liquid to a solid, then, what must happen?

29. If there are many intermolecular forces, does the total energy required to disrupt them increase or decrease?

Exercises:

30. Give the following definitions for the properties, fill in the rest of the table with large/ small or low/ high.
    •Affinity-attraction
    •Volatility-is the ease with something becomes a gas
    •Boiling point-is the temperature at which liquid turns to the gas
    •Melting point-is the temperature at which liquid turns to a solid
    •Viscosity-resistance to flow.

31. Rank the boiling points of HF, H_2O, and NH_3 from lowest to highest. Explain.

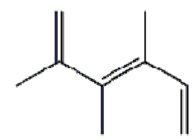
32. Would you want a perfume to have high or low intermolecular forces? Why or why not?

33. A textbook states: "Most substances consisting of small molecules are gases at normal temperatures and pressures. Examples are O_2, N_2, CH_4, and CO_2. A notable exception to this rule is water." Using the examples, explain how the physical state observed is related to the intermolecular forces of attraction in each compound.

34. Pancake syrup is highly viscous. What does this say about the type of intermolecular forces it has—are they strong or weak? What could you do to make it flow better (simple kitchen trick)?

35. Gasoline is very volatile. What does this say about the type of intermolecular forces it has? What kind of compound (polar, nonpolar, etc.) make up gasoline?

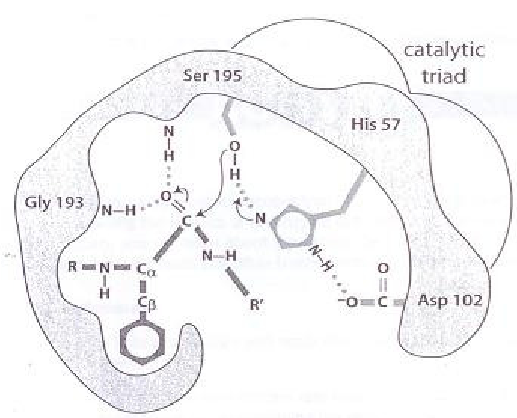
Problems:



36. It was mentioned before that the strength of LDF is related to the surface area of the points of contact between two molecules. Would a linear or branched alkane have greater LDF? Which would have a higher melting point?

37. Teflon's major component is a polymer of linked CF_4 units—what feature of fluorine makes even London dispersion forces between Teflon and anything else very, very weak? (Note: A gecko can't "stick" to Teflon!)

38. Hydrogen bonds help dictate the way that proteins, such as enzymes fold, and also sometimes play a significant role in the way proteins interact with other substances (e.g. enzymes with substrates). In the diagram to the right, what would happen to the active site of chymotrypsin if His 57 were replaced by an amino acid with a nonpolar amino acid residue?



A diagram of the enzyme active site for chymotrypsin is shown. The amino acids Gly 193, Ser 195, His 57 and Asp 102 form part of the active site. A portion of a natural peptide substrate from R to R' is depicted with the residue phenylalanine occupying the hydrophobic pocket of the enzyme.