

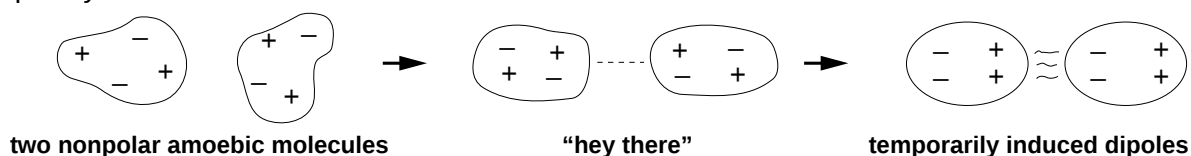
Student Packet: 2.5: Intermolecular Forces: Student Handout AP® Chemistry

Here's a look at intermolecular forces <-- The forces neighboring molecules exert upon one another.

- There are a couple of generalities you can depend on:
 - The higher the melting point and boiling point, the stronger the intermolecular forces
 - Like dissolves like—e.g., things held together by electrostatic attraction (ions, polar molecules) will be soluble in polar solvents

A. Dispersion Forces (Sometimes Called London Forces)

All substances have these weak interactions. They happen because you can induce dipoles in molecules. When two molecules get close to one another, they can influence each other in a local way. The molecules may be neutral or nonpolar, but locally if there is some + charge hangin' around on a spot it will attract some - charge on the other molecule. The dipoles that are induced are temporary.



How strong dispersion forces are depends upon how easily polarized the electrons are in each molecule. Usually the bigger the mass in the nucleus, the farther the electrons are from the nucleus and the easier they are to influence.

large molecule --> large molecular mass --> very polarizable --> stronger dispersion forces.

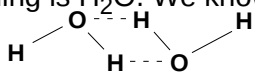
B. Dipole Forces

These are straight-up electrostatic interactions (by the way, electrostatic interactions just means the attraction between opposite charges) between polar molecules. These are weaker than ionic forces because dipoles are only partial charges whereas ions have full charges.

C. Hydrogen Bonding

This is a special case of dipole forces in which the molecule is very polar (large electronegativity difference between bonded atoms in the molecule) and the molecules are constructed so they can get close to each other.

The classic example of hydrogen bonding is H_2O . We know water is a very polar molecule and it also fits together with itself very well.

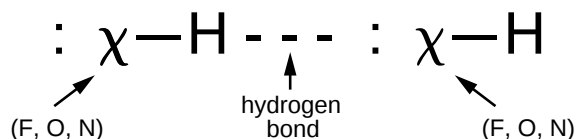


Because of water's polarity, all the H's and O's have strong electrostatic attractions. On top of that, the molecule fits together with itself very well.

Only a few molecules can hydrogen bond; you can tell from their properties because they will have abnormally high boiling points and melting points. --> You sort of expect these things (B.P and M.P.) to increase with molecular weight, so as you go down a group (V, VI, and VII) and look at the B.P. and M.P. of the hydrides you expect them to increase. But right at the beginning of the groups, NH_3 , H_2O , HF the properties are way-high because of hydrogen bonding. CH_4 doesn't hydrogen bond so the properties of the Group IVA hydrides simply increase with molecular size.

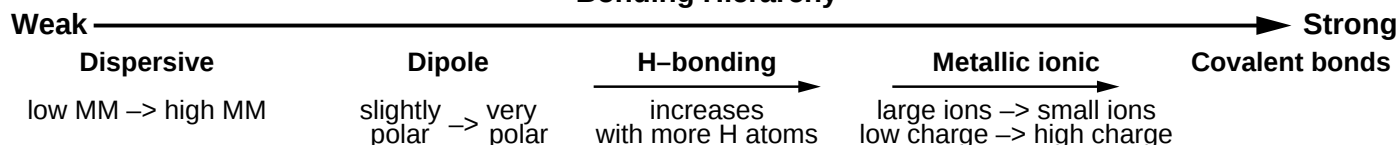
Also use these rules to determine if hydrogen bonding will occur:

- H has to be bonded to F, O, N (big electronegativity differences induce molecular polarity).
- The positive and negative poles on the molecule, have to be able to get close together.
- There must also be a lone pair on the central atom (F, O_2 , or N) in the molecule under consideration.



Type of Substance	Structural Unit	Force between Units	Properties	Example
Ionic	ions $\begin{array}{cccc} m^+ & x^- & m^+ & x^- \\ x^- & m^+ & x^- & m^+ \\ m^+ & x^- & m^+ & x^- \\ x^- & m^+ & x^- & m^+ \end{array}$	Ionic Bonding (strong)	• High melting point • Conducts electricity only when melted or dissolved • Usually water soluble • Insoluble in nonpolar solvents ("like dissolves like")	NaCl MgO
Molecular	a) nonpolar molecules } covalent bonds b) polar molecules }	Dispersion Forces (weak)	• Low melting point and boiling point • Nonconducting, insoluble in H₂O • Soluble in nonpolar solvents	H ₂ CCl ₄
	$\begin{array}{ccc} x-x & x-x & x-x \\ x-x & x-x & x-x \\ x-x & x-x & x-x \\ x-x & x-x & x-x \end{array}$	Dispersion Forces Dipole Hydrogen Bonding (Intermediate)	• Higher melting point and boiling (higher than non-polar covalent solids) • Nonconducting • Likely to be soluble in H₂O	HCl NH ₃ H ₂ O
Covalent Network Solids	atoms $\begin{array}{cccc} & & & \\ -x-x-x-x- \\ & & & \\ -x-x-x-x- \\ & & & \\ -x-x-x-x- \\ & & & \end{array}$	Covalent Bond (strong)	• Hard, solid • VERY high melting point • Nonconductors • Insoluble in common solvents	C (diamond) SiO ₂ (glass sand quartz) Si SiC
Metallic	cations and mobile electrons $\begin{array}{cccc} m^+ & e^- & m^+ & e^- \\ e^- & m^+ & e^- & m^+ \\ m^+ & e^- & m^+ & e^- \\ e^- & m^+ & e^- & m^+ \end{array}$	Metallic Bond	• Variable melting points (Hg is liquid at room temp. vs. Mg that melts at ~650°C) • Insoluble in common solvents • Malleable, ductile • Good conductors • May react with H₂O	Na Hg Mg Fe

Bonding Hierarchy

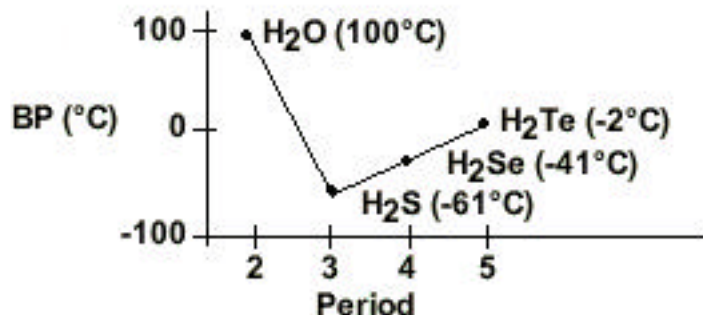


Student Packet: 2.5: Intermolecular Forces: AssessMe questions

- 1) In which of the following processes are covalent bonds broken?
- A) melting benzene
 - B) melting quartz
 - C) boiling $\text{C}_2\text{H}_5\text{OH}$
 - D) evaporating water
 - E) I'm clueless
- 2) Which of the following molecules is not capable of hydrogen bonding?
- A) H_2NCN B) H_2O_2 C) H_2F^+ D) $[\text{NH}_3\text{F}]^+$ E) I'm clueless
- 3) Which of the following compounds contains a double bond?
- A) C_3H_8 B) C_2H_6 C) C_2H_4 D) $\text{C}_2\text{H}_6\text{O}$ E) I'm clueless
- 4) What is the probable shape of RnCl_3^+ ?
- A) Trigonal planar
 - B) T-shaped
 - C) Trigonal bipyramidal
 - D) Square pyramidal
 - E) I'm clueless
- 5) Which of the following will have the highest melting point?
- A) naphthalene, C_{10}H_8
 - B) methane CH_4
 - C) Hg
 - D) SiO_2
 - E) I'm clueless
- 6) Which of the following will have the lowest melting point?
- A) iron B) BaCl_2 C) Cl_2 D) water E) I'm clueless

Student Packet: 2.5: Intermolecular Forces: ShowMe questions

- 1) Boiling points typically increase down a group with increasing atomic mass. The following chart shows the boiling points of Group 6A hydrides:



Why is the boiling point of H₂O so unexpectedly high?

- 2) The boiling point of benzene is 80°C, while that of naphthalene is 218°C. Rationalize the difference between the two values.



- 3) Automobile wax consists of a mixture of hydrocarbons (molecules containing hydrogen and carbon). Why does water bead on a freshly waxed car?

- 4) The following table shows the freezing points of the Group 8A elements (the noble gases):

Element	FP (°C)
He	-269.7
Ne	-248.6
Ar	-189.4
Kr	-157.3
Xe	-111.9

Explain the trend in freezing points in terms of intermolecular forces.

Student Packet: 2.5: Intermolecular Forces: TestMe questions

1) Arrange the following intermolecular forces in order of increasing strength:

- I. Dipole-dipole interactions
- II. Hydrogen bonding
- III. Electrostatic interactions
- IV. London dispersion forces

A) $I < II < III < IV$ B) $IV < II < I < III$ C) $I < III < IV < II$ D) $III < II < I < IV$ E) $IV < I < II < III$

2) Of the group 7A acids, which has the highest boiling point?

A) HF B) HCl C) HBr D) HI E) All are exactly the same

3) Arrange the following compounds in order of increasing melting point based on the relative strength of their intermolecular forces:



- A) $\text{NaCl} < \text{MgCl}_2 < \text{AlCl}_3 < \text{SiCl}_4 < \text{Cl}_2$
- B) $\text{MgCl}_2 < \text{SiCl}_4 < \text{Cl}_2 < \text{NaCl} < \text{AlCl}_3$
- C) $\text{Cl}_2 < \text{SiCl}_4 < \text{AlCl}_3 < \text{MgCl}_2 < \text{NaCl}$
- D) $\text{Cl}_2 < \text{AlCl}_3 < \text{SiCl}_4 < \text{NaCl} < \text{MgCl}_2$
- E) $\text{MgCl}_2 < \text{AlCl}_3 < \text{SiCl}_4 < \text{NaCl} < \text{Cl}_2$

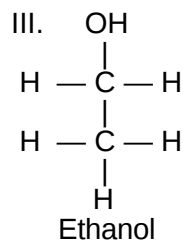
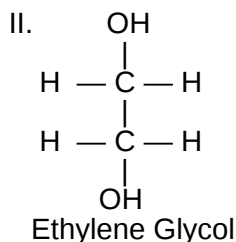
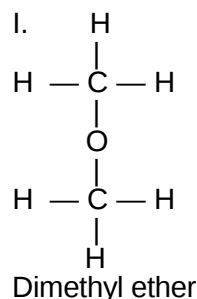
4) Glass is composed primarily of SiO_2 . Two possible shapes of the meniscus of liquids in a glass tube are shown below:



Consider adding mercury and water to two separate glass tubes. Which of the following statements is true?

- A) Hg and H_2O both exhibit meniscus shape I.
- B) Hg and H_2O both exhibit meniscus shape II.
- C) Hg exhibits meniscus shape I, while H_2O exhibits meniscus shape II.
- D) Hg exhibits meniscus shape II, while H_2O exhibits meniscus shape I.
- E) Neither Hg nor H_2O has a meniscus.

5) Arrange the following molecules in order of increasing boiling point:



A) $I < II < III$ B) $I < III < II$ C) $II < I < III$ D) $II < III < I$ E) $III < I < II$