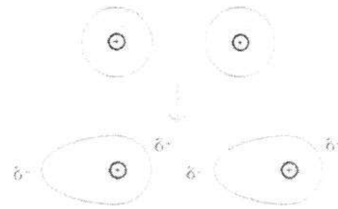
<u>A Closer Look at London Dispersion Forces (LDFs):</u> Induced Dipole – Induced Dipole Attraction

LDFs are determined by the __polarizability__ of a molecule (i.e. how much the electron cloud can temporarily be shifted)

➔ an electron cloud, even in a nonpolar molecule, can __temporarily__ shift, causing one side of the molecule to be more negative than another

➔ this temporary dipole can __induce__ (cause) a temporary dipole on a neighboring molecule (hence the name "induced dipole")

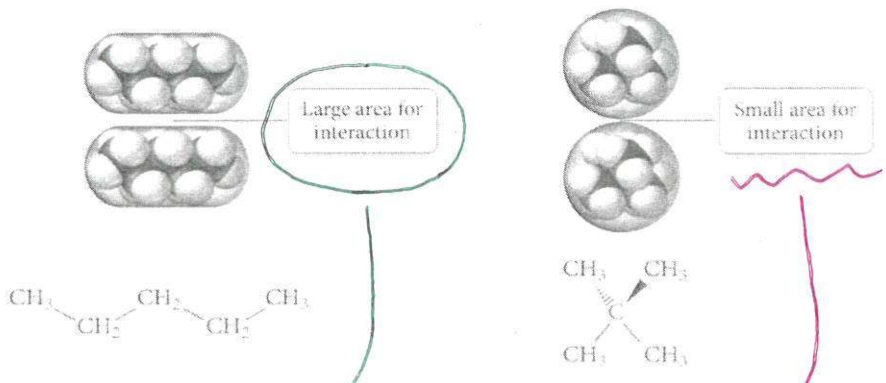


What can increase LDFs?

1. Greater electron cloud (more electrons): molecule is __more__ polarizable = __↑__ LDFs
2. Increase in molar mass (implies more electrons): molecule is __more__ polarizable = __↑__ LDFs
3. Increase in surface-to-surface contact area: __↑__ induced dipole = __↑__ LDFs

Both molecules are pentane!

C_5H_{12}



(a) *n*-Pentane (b) Neopentane

Boiling point: 36.1°C Boiling point: 10.0°C

Be careful!

- When non-polar substances with __only__ London dispersion forces have a considerably __larger__ (and thus very polarizable) electron cloud than the polar molecules, the LDFs can be quite substantial and be **STRONGER** than hydrogen bonding forces or dipole-dipole forces (!!) ✓ ← heavily AP-tested

Example: Cl_2 has a higher boiling point that HCl. Explain.

Although Cl_2 is non-polar + only has LDFs, the large # of e^- in Cl compared to H causes Cl's LDFs to be stronger than the combo of dipole-dipole attractions + LDFs exhibited by HCl.

Let's Practice!

1. Rank the following in order of increasing LDFs: CH_3CH_3, CH_4, $CH_3CH_2CH_3$

   CH_4, CH_3CH_3, $CH_3CH_2CH_3$

2. Rank the following in order of increasing LDFs: Br_2, F_2, Cl_2, I_2

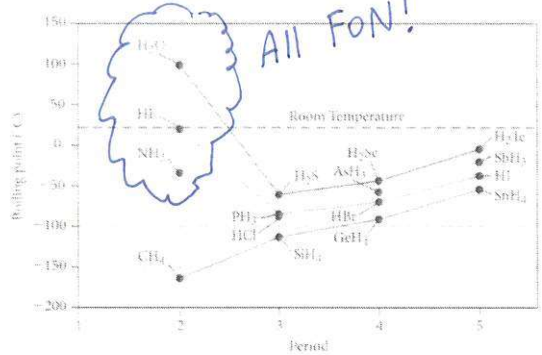
   F_2, Cl_2, Br_2, I_2

A Closer Look at Hydrogen Bonding Attractive Forces

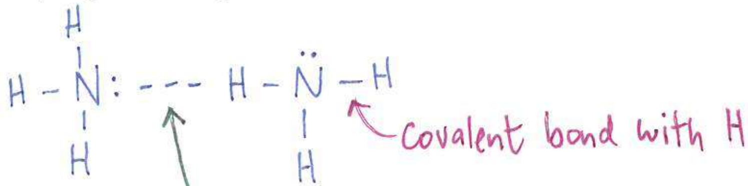
Note: Hydrogen "bonds" are NOT actual bonds (intramolecular forces), and thus the name is very misleading!

Hydrogen "Bonding": force of attraction between hydrogen atom bonded to a small highly electronegative atom (F, O, and N) and the unshared electron pair on another electronegative atom of F, O, or N.

- Hydrogen "bonding" is F-O-N! ☺
- Hydrogen "bonding" is usually depicted with a dotted or dashed line.
- Hydrogen "bonding" is responsible for some of the unique properties of water, including its relatively high boiling point.



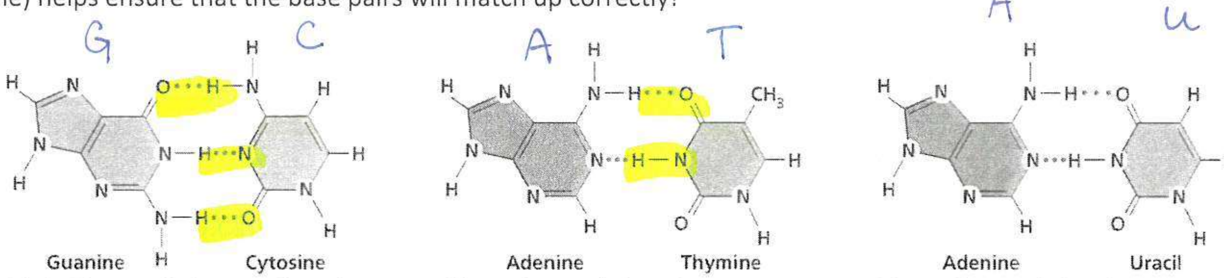
How do you represent Hydrogen Bonding? Let's look at NH_3.



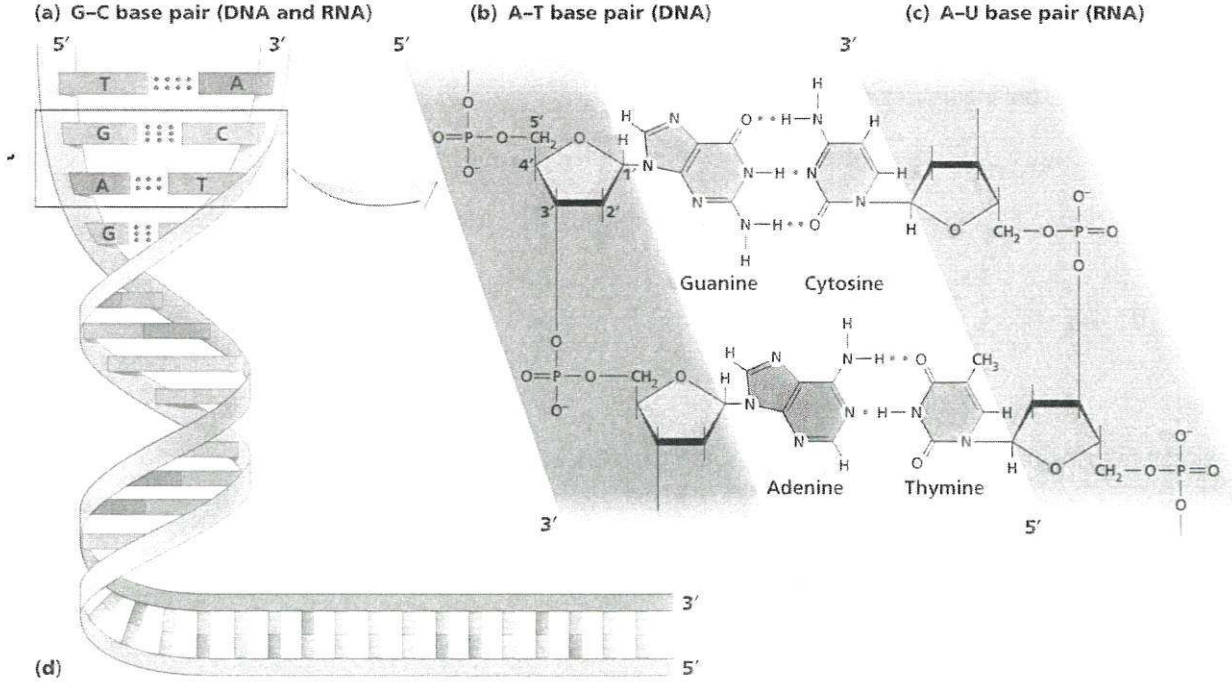
hydrogen bonding attractive force (aka hydrogen bond)

Hydrogen Bonding: It's in Your DNA!

The different number of hydrogen bonds in each complementary base pair (adenine and thymine vs cytosine and guanine) helps ensure that the base pairs will match up correctly!



(a) G–C base pair (DNA and RNA) **(b) A–T base pair (DNA)** **(c) A–U base pair (RNA)**

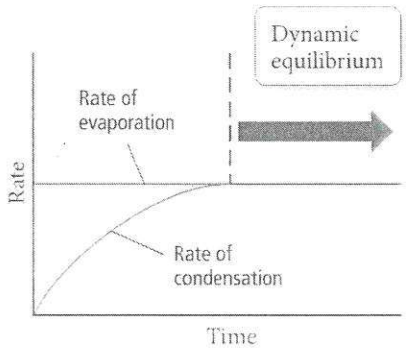


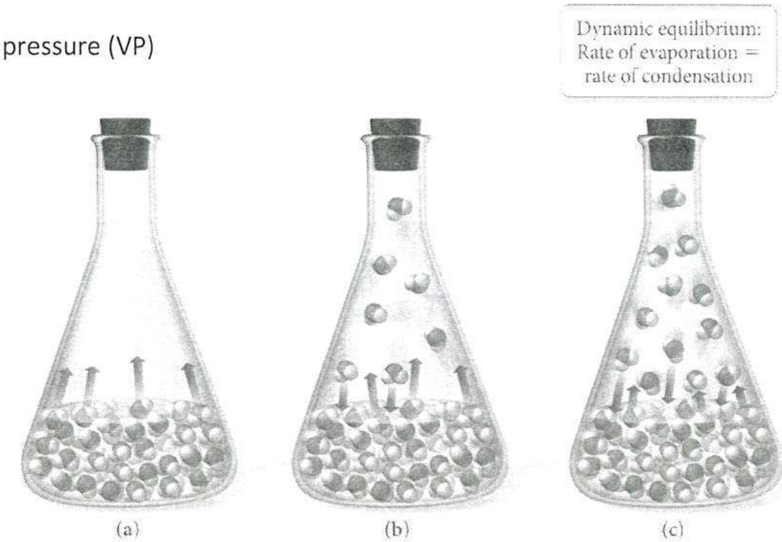
IMFs in Action

Measure of Intermolecular Forces

inverse

1. Vapor Pressure: the pressure exerted by a gas (vapor) when it is in dynamic equilibrium with its liquid (must be in Sealed container!)
   a. The weaker the attractive forces between the molecules, the more molecules will be in vapor (and vice versa).
   b. Thus, $\downarrow$ IMFs = $\uparrow$ vapor pressure (VP)

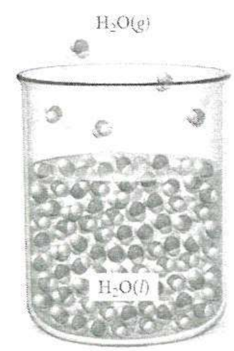




(a) (b) (c)

inverse

2. Volatility: how quickly a substance evaporates.
   a. The weaker the attractive forces between the molecules, the more quickly and easily molecules will separate from each other and enter the gas phase.
   b. Thus, $\downarrow$ IMFs = $\uparrow$ volatility



direct

3. Boiling point: the temperature at which molecules separate from each other in the liquid phase and enter the gas phase.
4. Melting point: temperature at which molecules of a solid have enough thermal energy to overcome IMFs and become a liquid
   a. Thus, $\uparrow$ IMFs = $\uparrow$ melting point (MP) = $\uparrow$ boiling point (BP)
5. Solubility in water: amount of a given substance that will dissolve in water
   a. Strong interactions form between polar/ionic solute particles and polar solvent molecules as they mix → energetically favorable!
   b. Thus, $\uparrow$ IMFs = $\uparrow$ solubility in water

Other Properties You Must be able to Explain with IMFs: The **Higher** these are, the **Stronger** the IMFs!

direct

1. Surface tension: energy required to increase the surface area of a liquid
2. Capillary action: spontaneous rising of a liquid in a narrow tube
3. Viscosity: resistance to flow

***Note: Only Vapor Pressure and Volatility have an Inverse Relationship with IMF strength!**