

CHEM 206 section 01

LECTURE #6

Wed. Jan.23, 2008

ASSIGNED READINGS:

TODAY'S CLASS: Ch.13.3-13.5

NEXT CLASS: finish Ch.13 to 13.5,
start Ch.14...

(1)

CHAPTER 13 Intermolecular Forces & Liquids

For Chem206,
you are responsible for:

- 13.1 States of matter & the kinetic-molecular theory
- 13.2 Intermolecular forces
- 13.3 Hydrogen bonding
- 13.4 Summary...
- 13.5 Properties of liquids

Chapter Goals:

- Describe intermolecular forces and their effects, and the importance of hydrogen bonding
- Understand the properties of liquids

To learn this: you **must** remember...

- electrostatic (ion-ion) attraction in ionic compounds
- how to use electronegativity to determine polarity of covalent bonds
- how to draw Lewis structures
- how to determine polarity of molecules

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13.1 States of matter & the kinetic-molecular theory

- Particles (atoms, ions, molecules) of matter are in **CONSTANT MOTION**
- Kinetic energy proportional to temperature
- If forces between particles are **weak**:
 - particles' kinetic energy overcomes attractions
 - ⇒ **GASEOUS STATE**
- If forces between particles are **strong**:
 - keeps particles closer together
 - ...& their motion is limited
 - ⇒ **SOLID or LIQUID STATE**

Must understand **NATURE OF INTERACTIONS** between particles to understand:

- melting points, boiling points...*etc.*
- solubility
- how biological molecules maintain shape/function

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13.2 Intermolecular Forces = forces between molecules

MUCH WEAKER THAN **INTRAMOLECULAR FORCES**
= forces within molecules = covalent bonds = **STRONG**

3 main types of INTERmolecular forces:

- 1.) dipole-dipole interactions
 - 2.) hydrogen bonding
 - 3.) London dispersion forces
"van der Waals forces"
"induced-dipole / induced-dipole interactions"
- } **relatively strong**
(but < covalent bonds)
- } very weak

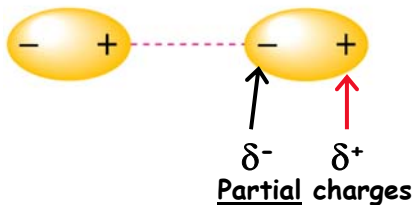
Also: dipole-ion interactions...

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Dipole-dipole interactions

Zumdahl's Figure 10.2
see also K&T's Figure 13.3

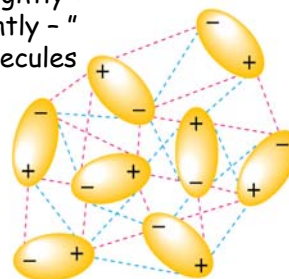
= Interactions between molecules with permanent dipoles



Electrostatic attraction between "slightly +" and "slightly -" areas of molecules

Attraction

Repulsion



DIPOLE-DIPOLE interactions = relatively strong forces between POLAR molecules

THUS: Polar substances...

- require more E to separate molecules than nonpolar substances
→ higher boiling points & melting points
- dissolve well in other polar substances

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Recall: polarity can be quantified by measuring interaction with electric field

Table 9.8

Molecule (AB)	Moment (μ , D)
HF	1.78
HCl	1.07
HBr	0.79
HI	0.38
H ₂	0

LINEAR MOLECULES

Molecule (AB ₂)	Moment (μ , D)
H ₂ O	1.85
H ₂ S	0.95
SO ₂	1.62
CO ₂	0

BENT or LINEAR

Molecule (AB ₃)	Moment (μ , D)
NH ₃	1.47
NF ₃	0.23
BF ₃	0

TRIGONAL PYRAMIDAL or PLANAR

Molecule (AB ₄)	Moment (μ , D)
CH ₄	0
CH ₃ Cl	1.92
CH ₂ Cl ₂	1.60
CHCl ₃	1.04
CCl ₄	0

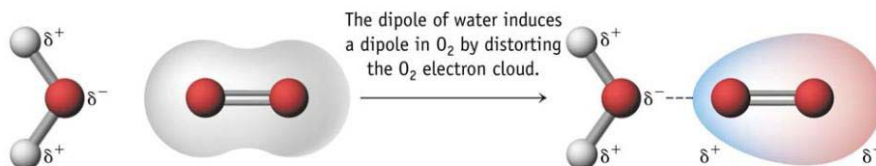
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Dipole / induced-dipole interactions K&T Fig. 13.6

- relatively **weak** forces between POLAR & NONPOLAR molecules
- involve interaction between **permanent dipoles** & **transiently induced dipoles**

How oxygen can dissolve in water:



→ molecules approach each other
 → δ^- end of polar molecule
 repels e^- s in nonpolar molecule

(OR: δ^+ end of polar molecule
 attracts e^- s in nonpolar molecule)

→ e^- distribution in nonpolar
 molecule becomes asymmetric

i.e., a small dipole
 has been "induced"

But not permanently...
"transient dipole"

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Distortion of e^- cloud is called "polarization"

- "POLARIZABILITY"
 describes how easily an atom's electron cloud can be distorted
(which induces a dipole...)



Small atoms

→ e^- s in small orbitals
 → held tightly by nucleus

Compare
 F_2 vs. I_2

Large atoms

→ e^- s in larger orbitals
 → held less tightly by nucleus

Small molecules

→ few atoms
 → few e^- clouds can
 be distorted

Compare
 CH_4 vs. C_4H_{10}

Large molecules

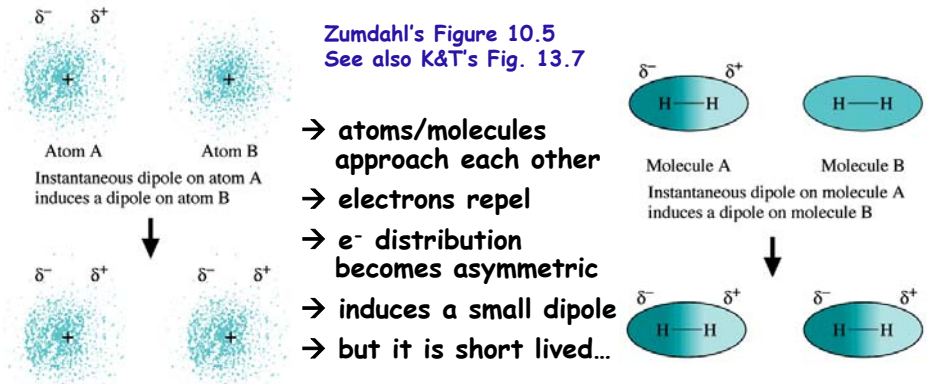
→ many atoms
 → more e^- clouds can be
 distorted

OBSERVATION: $O_2(g)$ is much more soluble in 293K water than $H_2(g)$
EXPLANATION: easier to induce dipoles in O_2 molecule (larger atoms)

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London Dispersion Forces (or "van der Waals forces")
 = induced-dipole / induced-dipole interactions

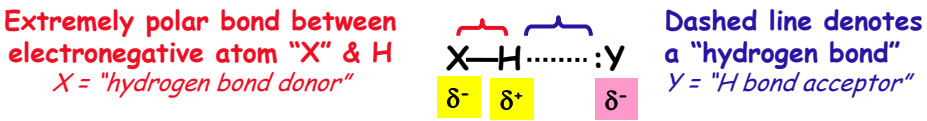
- **weakest** intermolecular forces, involving transient dipoles
- occur between molecules of ALL substances, but most important for **nonpolar** molecules (since no other forces)



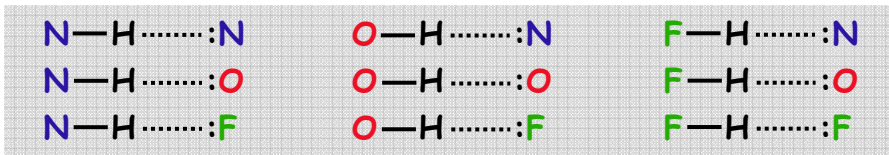
OBSERVATION: I₂ (nonpolar) is a solid at room temperature
EXPLANATION: London dispersion forces can be quite significant!
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13.3 Hydrogen bonding: X—H.....:Y where X&Y = N,O,F

Hydrogen bonds are strong intermolecular forces (10-40 kJ/mol)
 BUT: much weaker than ion-ion interactions (100's of kJ/mol)
 and covalent bonds! (100's of kJ/mol)



These X-H bonds are sufficiently polar to yield H-bonds (...):

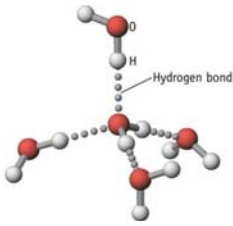


NOTE: research still ongoing to fully understand hydrogen bonding...
 H-bonds have mostly electrostatic character (dipole-dipole δ⁺H ↔ δ⁻Y),
 but some covalent character too (i.e., orbital overlap H 1s ↔ Y 2s^mpⁿ)
 ⇒ HOWEVER, they are NOT full bonds, just interactions

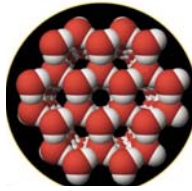
Hydrogen bonds are strong intermolecular forces (10-40 kJ/mol)
 ...stronger than "regular" dipole-dipole interactions...
 BUT: much weaker than ion-ion interactions (100's of kJ/mol)
 and covalent bonds! (100's of kJ/mol)

WHY ARE HYDROGEN BONDS SUCH STRONG INTERACTIONS?

- ⇒ CAUSE: larger-than-usual partial charge δ^+ on H due to large electronegativity differences in: **H-F H-OR H-NR₂**
- ⇒ EFFECT: strong interaction (electrostatic AND orbital overlap) to small, δ^- , lone-pair bearing atoms (F, O or N *only*)



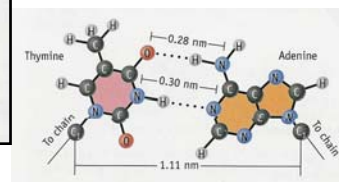
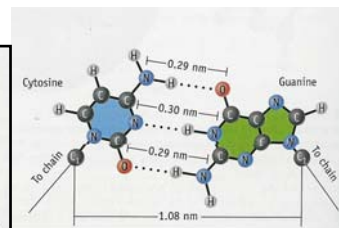
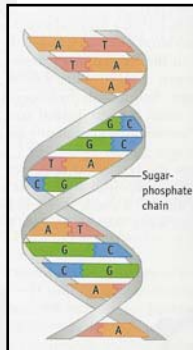
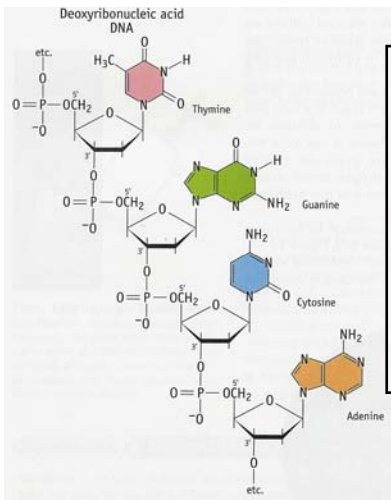
K&T Fig. 13.10: water ice
 → Regular arrangement enforced by Td geometry of O atoms



K&T Fig. 13.9
 solid acetic acid

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For your interest only: The net "cohesive" effect of hundreds of H-bonds is what holds DNA & proteins in their correct shapes! see "A Closer Look" p.520 K&T 5th Ed.



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ASSIGNED READINGS:

BEFORE NEXT CLASS:

Read: Ch.13.1-13.5
+ WORK ON problems

Review: molarity (Ch.5), mass % (Ch.1 & 3)

Next class: Ch.14...