January 18, 2002

- Thanks for the Emails
- *No Class on Monday (MLK Day)!*
- Problem Set #1 solutions will be online next week
- Quiz #1: Next Friday
- Demo(s) next week!

1

Hydrogen Bonding

- **Hydrogen is unusual: its *only* electron is its *valence electron***

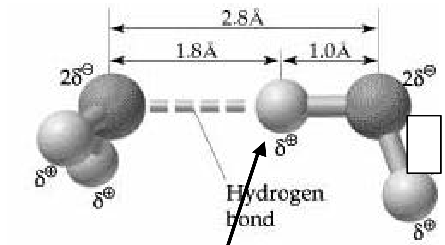
  -if bound to a *very electronegative* element, the unshielded hydrogen nucleus has a significant positive charge

  -the hydrogen is, thus, attracted to the *lone pair electrons* on the *very electronegative* atom of an adjacent molecule

2

H-bonding in Water

- Hydrogen bonding in water is very significant
- Without H-bonding, we would expect water to have a B.P. of about -123 °C



Hydrogen acts as a *bridge* to facilitate electron-sharing between the oxygen atoms on adjacent molecules

Hydride Boiling Points

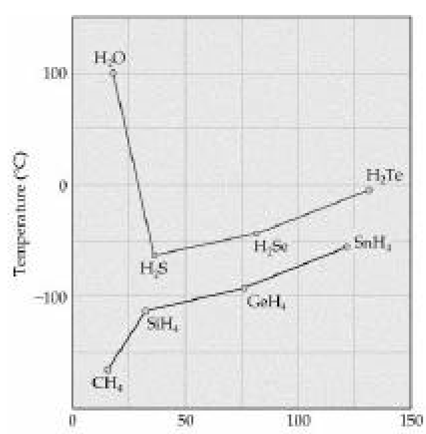
- **Hydrogen bonding results in anomolous behavior:**

  -unusually high B.P. for water

  -same effect observed with other 2nd Period hydrides:

  -$T_b(HF) > T_b(HCl)$

  -$T_b(NH_3) > T_b(PH_3)$



More Hydrogen Bonding

- **Only occurs with Group 5, 6 and 7 hydrides**

  -get biggest dipole if the atom is both *very electronegative* as well as ***small***

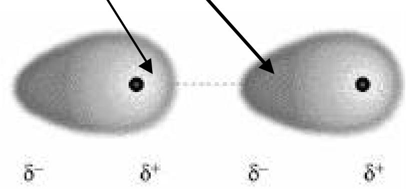
  -so, **N and O and F** hydrides experience this unusually strong *dipole-dipole* interaction

- **Hydrogen "bonds" are the *strongest* intermolecular interaction**

  - typically: 20 - 40 kJ/mol

The London Dispersion Force

- How, can there be *intermolecular attraction* between **nonpolar molecules?**
  - nonpolar species (including ALL atoms) can have an *instantaneous* or *momentary* dipole
  - This can then *induce* a dipole on an adjacent species, resulting in an *electrostatic interaction:*



London Dispersion Forces

- These are usually very weak interactions
  (0.05 - 2 kJ/mol)
- Energy drops off as ***$1/r^6$***
- ALL atoms and molecules will experience *London Dispersion Forces*
- **Magnitude** of force will depend upon how easy it is to distort the electron cloud (*polarize):*

  - favors atoms and molecules that are **LARGE** and have the **greatest surface area**

7

Boiling Point Trends

- The enthalpy change associated with vaporization is due to the ***disruption*** of these intermolecular forces
- The magnitude of ΔH^o_{vap} is reflected in the *boiling point temperature* (T_b) for a compound
- For *polar* molecules:

Substance	Molecular Weight (amu)	Dipole Moment, μ (D)	Boiling Point (K)
Propane, $CH_3CH_2CH_3$	44	0.1	231
Dimethyl ether, CH_3OCH_3	46	1.3	248
Methyl chloride, CH_3Cl	50	1.9	249
Acetaldehyde, CH_3CHO	44	2.7	294
Acetonitrile, CH_3CN	41	3.9	355

8

More BP Trends

- For **NONPOLAR** species:

Halogen	Molecular Weight (amu)	Boiling Point (K)	Noble Gas	Molecular Weight (amu)	Boiling Point (K)
F_2	38.0	85.1	He	4.0	4.6
Cl_2	71.0	238.6	Ne	20.2	27.3
Br_2	159.8	332.0	Ar	39.9	87.5
I_2	253.8	457.6	Kr	83.8	120.9
			Xe	131.3	166.1

increased molar mass = *greater polarizability*

9

Vapor Pressure

- If we put a liquid in a container (and $V_{container} > V_{liquid}$ and $T < T_b$): ***some of the liquid will vaporize***

Why?

➢ If molecules on the *surface* have sufficient Kinetic Energy, they can overcome intermolecular attraction and escape to the gas phase

➢ The **reverse** process can happen too!

➢ Process reaches a *steady state condition* (equilibrium):

X(*l*) X(*g*)

amt in gas phase = ***vapor pressure***

10