Overview of Chapter 13

- Intermolecular Forces
- Liquids and their Properties
- Solids and Their Properties
- Phase diagrams

Questions to consider:

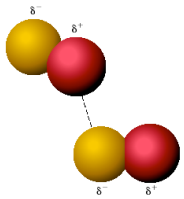
- Why is water usually a liquid?
- Why does water boil at 100°C and not 30°C?
- Why does ice float?
- Do all snowflakes have 6 sides?

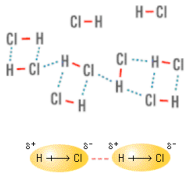
Intermolecular Forces

- Dipole-Dipole
  - Hydrogen bonding
- Dipole-Induced dipole
- Induced dipole-Induced dipole
- Ionic Bonds
- Network Bonds

Dipole-Dipole Forces

Dipole-dipole forces occur between molecules having permanent dipoles.





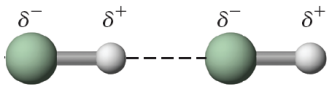
Dipole-Dipole Forces

Influence of dipole-dipole forces is seen in the boiling points of simple molecules.

Compound	Mol. Wt.	Boiling Point
N_2	28	-196°C
CO	28	-192°C
Br_2	160	59°C
ICl	162	97°C

Hydrogen Bonding

A special form of dipole-dipole attraction, which enhances dipole-dipole attractions.



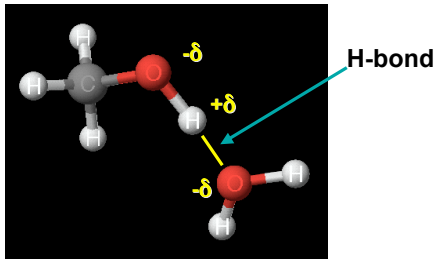
X—H Y—H

Types of Hydrogen Bonds [X—H - - - :Y]

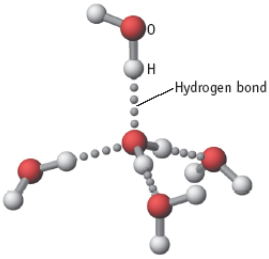
N—H - - - :N—	O—H - - - :N—	F—H - - - :N—
N—H - - - :O—	O—H - - - :O—	F—H - - - :O—
N—H - - - :F—	O—H - - - :F—	F—H - - - :F—

H-bonding is strongest when X and Y are N, O, or F

Hydrogen Bonding Between Methanol and Water



Hydrogen Bonding in H_2O

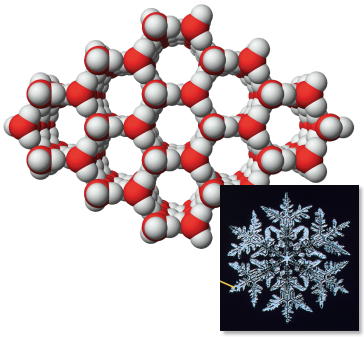


H-bonding is especially strong in water because

- the O—H bond is very polar
- there are 2 lone pairs on the O atom

H-bonding accounts for many of water's unique properties.

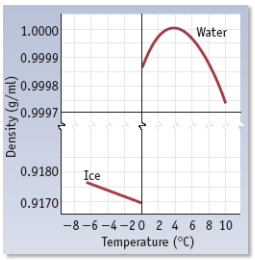
Hydrogen Bonding in H_2O

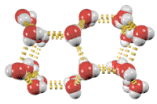


Ice has open lattice-like structure.

Hydrogen Bonding in H_2O

Ice has open lattice-like structure.
Ice density is < liquid, so ice floats on water.

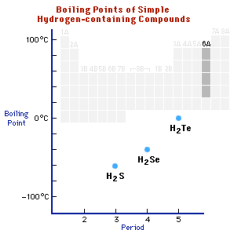


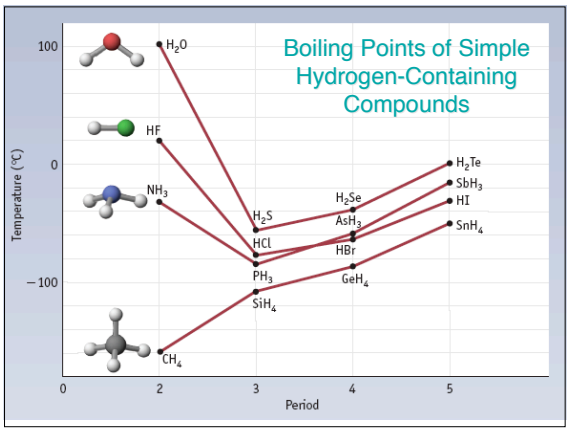


One of the VERY few substances where solid is LESS DENSE than the liquid.

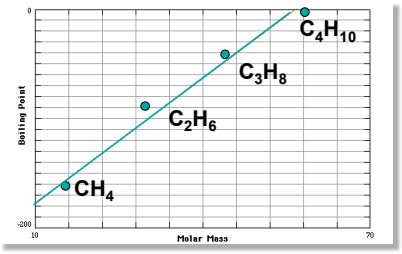
Hydrogen Bonding

Hydrogen bonds leads to abnormally high boiling point of water.





Boiling Points of Hydrocarbons

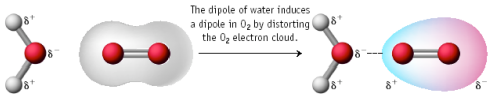


Note linear relation between boiling point and molar mass.

Forces Involving Induced Dipoles

How can non-polar molecules such as O_2 and I_2 dissolve in water?

The water dipole INDUCES a dipole in the O_2 electric cloud.



Dipole-induced dipole

Forces Involving Induced Dipoles

Solubility increases with mass of the gas

Table 13.2 The Solubility of Some Gases in Water*

Gas	Molar Mass (g/mol)	Solubility at 20 °C (g gas/100 g water)†
H_2	2.01	0.000160
N_2	28.0	0.00190
O_2	32.0	0.00434