

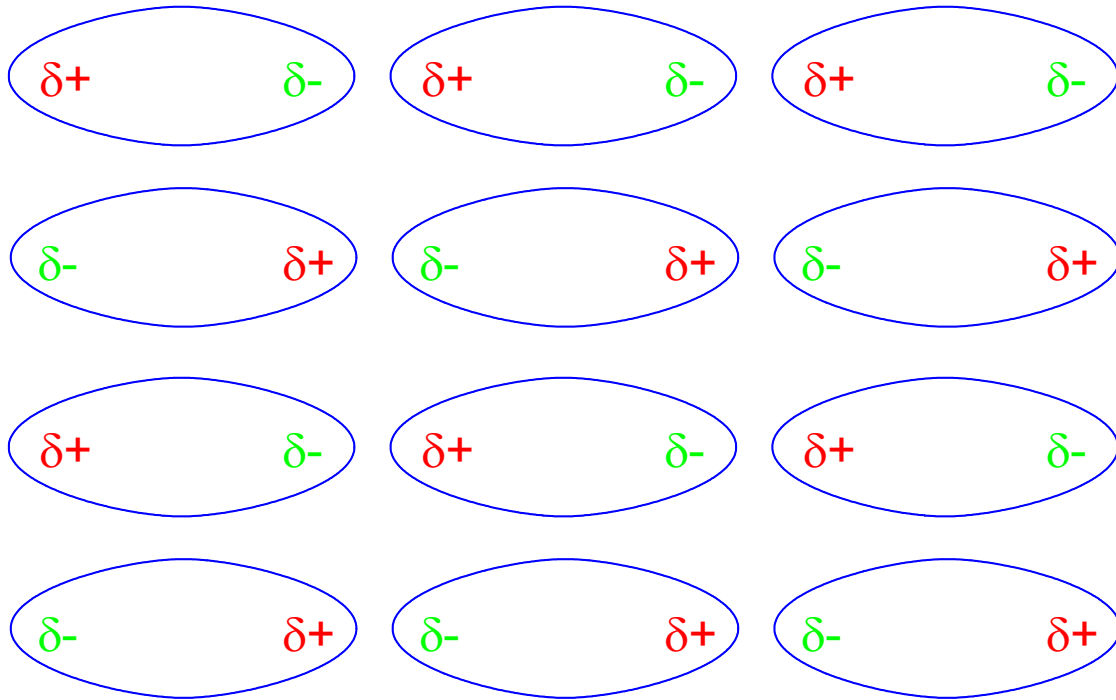
Types of Intermolecular Forces

- van der Waals forces:
 - dipole-dipole
 - London dispersion
 - Hydrogen bonding
- ☞ Molecules can have one, two, or all three kinds of intermolecular forces, but all have London dispersion forces.
- ☞ Substances with stronger overall intermolecular forces, whatever their types, are more likely to have:
- higher melting points (m.p.)
 - higher boiling points (b.p.)
 - higher enthalpies of vaporization (ΔH_{vap})
 - lower vapor pressures (v.p.)
 - a condensed phase (solid or liquid) at room temperature
- ☞ Typical intermolecular forces tend to be weaker than typical covalent bond strengths.
- Covalent bonds: $\approx 50 - 950 \text{ kJ/mol}$
 - Intermolecular forces: $\approx 1 - 50 \text{ kJ/mol}$

Dipole-Dipole Attractions Between Polar Molecules

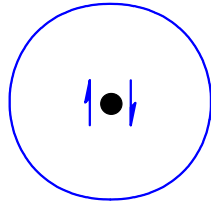
Permanent Dipole Moments

$$D \approx 1 - 10 \text{ kJ/mol}$$

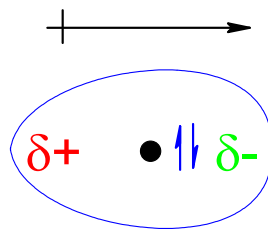


London Dispersion Forces Transitory Dipole Moments

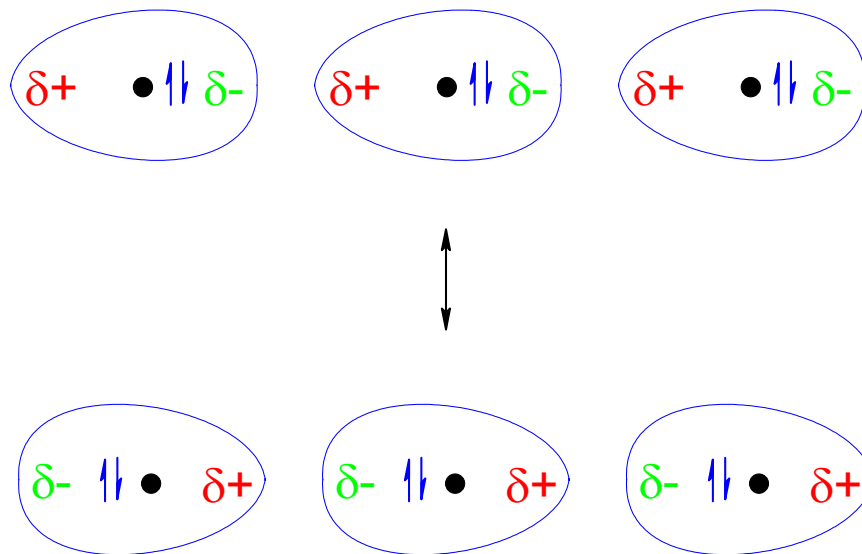
Average Electron Distribution
No Polarity



Momentary Electron Distribution
Temporary Polarity



London Dispersion Forces Induced Transitory Dipole Moments



- ☞ London dispersion forces arise from changing electron distributions.
- ☞ All molecules have electrons, so all have London dispersion forces, regardless of whether they are polar or non-polar.
- ☞ **Polarizability** - Molecules with higher molecular weights have more electrons, generally more loosely held, resulting in electron distributions that are more susceptible to deformation from adjacent charges.
- ☞ **Heavier molecules have higher London dispersion forces.**

Effects of London Dispersion Forces on Properties

Group VI Hydrides, H₂X

Compound	H ₂ S	H ₂ Se	H ₂ Te
b.p. (°C)	-60.33	-41.3	-2

Halogens, X₂

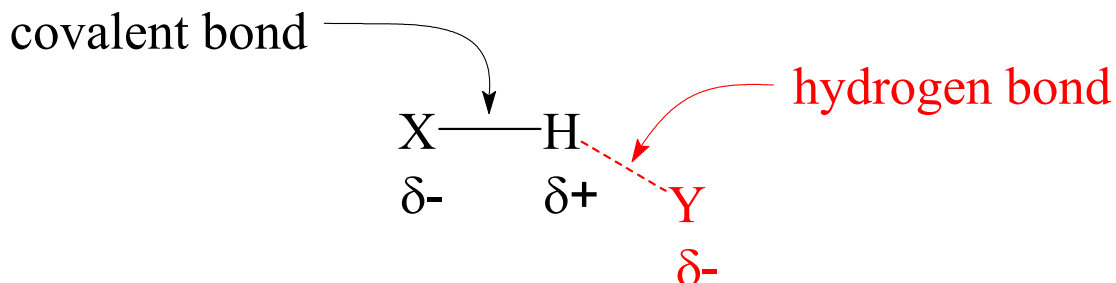
Element	F ₂	Cl ₂	Br ₂	I ₂
m.p. (°C)	-220	-101	-7.3	114
b.p. (°C)	-188	-34	58.8	184
At 25 °C	gas	gas	liquid	solid

Alkanes (C_nH_{2n+2}) at Room Temperature

<i>n</i>	Phase	Examples
1 - 4	gas	methane, ethane, propane, butane
5 - 17	liquid	pentane, hexane, heptane, octane, ...
18 - ∞	solid	paraffin waxes

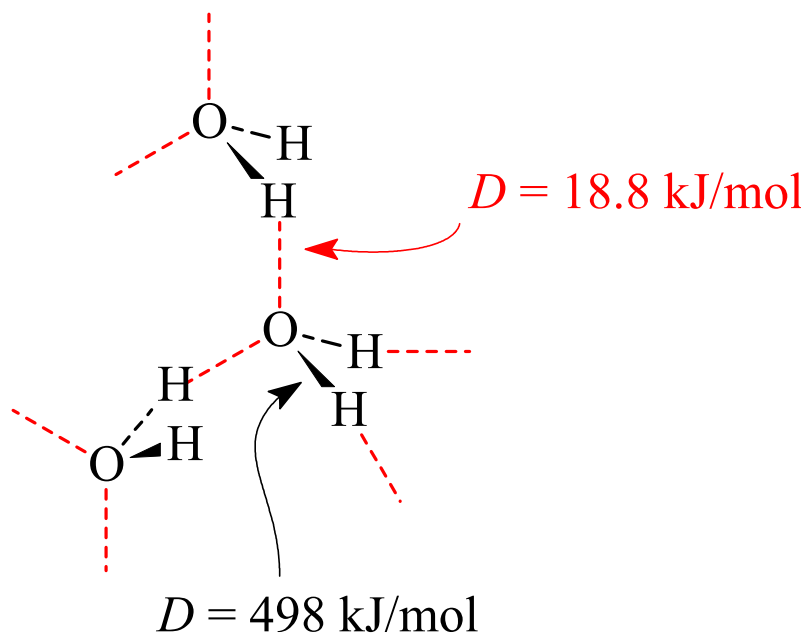
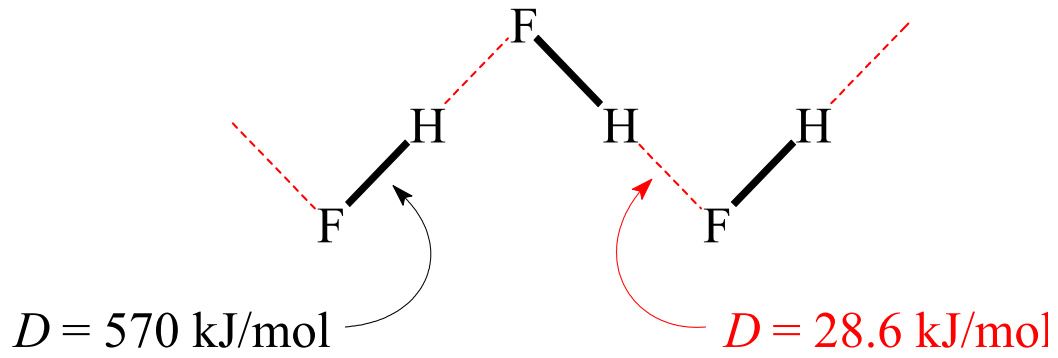
Hydrogen Bonding

- ☞ A hydrogen bond is a non-covalent attraction between a hydrogen that is covalently bonded to a very electronegative atom (X) and another very electronegative atom (Y), most often on an adjacent molecule. (X and Y may be the same or different elements.)

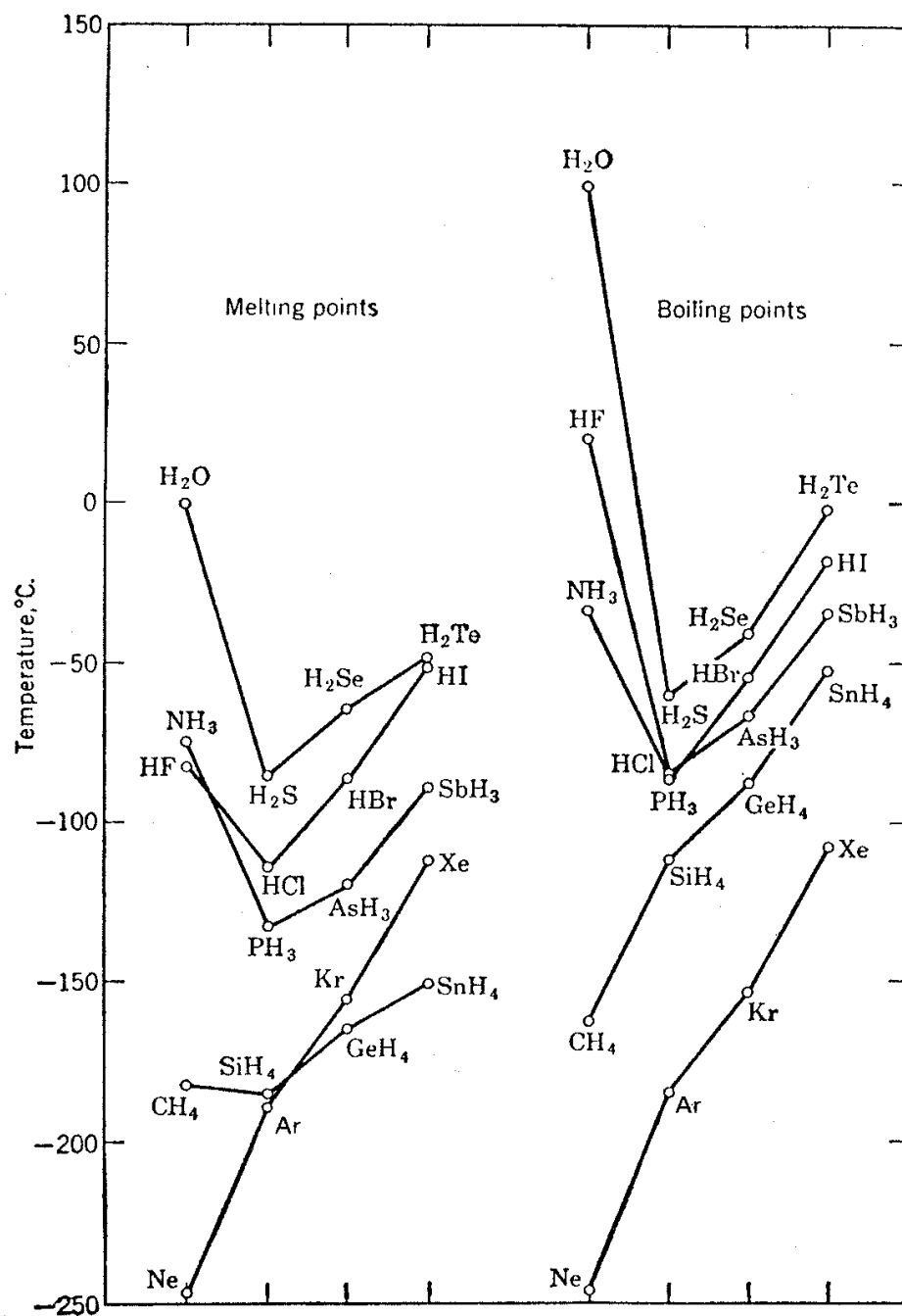


- X and Y are typically O, N, or F.
- The X–H covalent bond must be very polar.
- The hydrogen bond H \cdots Y is mainly electrostatic.
- Hydrogen bond strengths typically are in the range 4 - 46 kJ/mol.

Hydrogen Bonding in Solid HF and H₂O



Melting Points and Boiling Points of Hydrides, XH_n ($n = 1, 2, 3, 4$)



Structure of Ice

