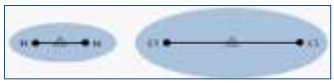
Polar Molecules

Chapter 4.4

Electronegativity

- Polarity refers to a separation of positive and negative charge. In a nonpolar bond, the bonding electrons are shared equally:

H_2, Cl_2:

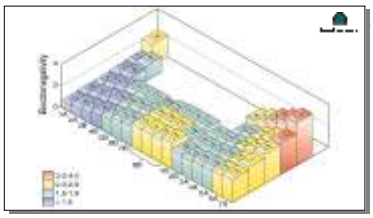


- In a polar bond, electrons are shared unequally because of the difference in Z_{eff}.

HCl:

Electronegativity

- Electronegativity refers to the ability of an atom in a molecule to attract shared electrons.
- The Pauling scale of



Bond Polarity

A polar bond can be pictured using partial charges:

$\overset{\delta^+}{H}\!-\!\overset{\delta^-}{Cl}$ (2.1 — 3.0) $\Delta\delta = 0.9$

Electronegativity Difference	Bond Type
0 - 0.5	Nonpolar
0.5 - 2.0	Polar
2.0 ↑	Ionic

Polar Covalent HCl

$^{\delta+}H-Cl^{\delta-}$

[H :Cl]

A polar covalent bond.

The bonding electrons are attracted more strongly by Cl than by H.

"Polar" vs. "Non-Polar"

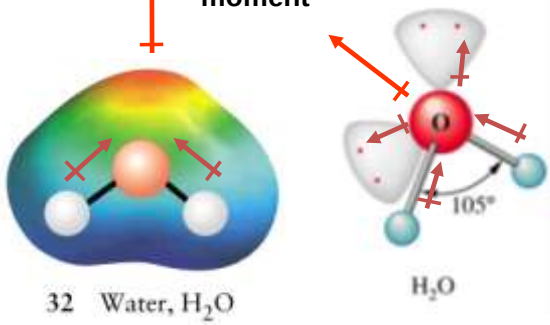
- A molecule is considered "polar" if it has a net "dipole moment". A molecule is "non-polar" if it has no net dipole moment (or if the dipole moment is negligibly small)
- Characteristics of a polar molecule:
  - **Polar covalent bond(s)**
  - **Molecular geometry that gives rise to a net dipole moment**

TABLE 3.1 Dipole Moments of Selected Molecules

Molecule	Dipole moment, D	Molecule	Dipole moment, D
HF	1.91	PH_3	0.58
HCl	1.08	AsH_3	0.20
HBr	0.80	SbH_3	0.12
HI	0.42	O_3	0.53
CO	0.12	CO_2	0
ClF	0.88	BF_3	0
NaCl*	9.00	CH_4	0
CsCl*	10.42	*cis*-CHCl=CHCl	1.90
H_2O	1.85	*trans*-CHCl=CHCl	0
NH_3	1.47		

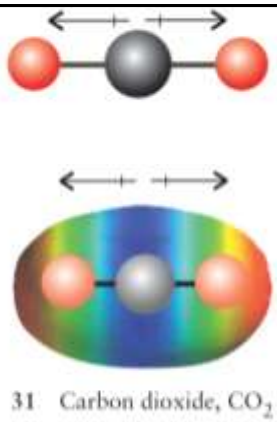
* The species consists of pairs of ions in the gas phase.

Dipoles do not cancel; thus, there is a net dipole moment



32 Water, H_2O

Dipoles cancel; thus, there is no net dipole moment



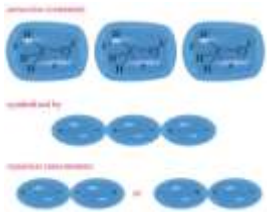
31 Carbon dioxide, CO_2

Intermolecular Forces

- Strength of attractions between molecules
- Influence physical properties (bp, solubility)
- Classification depends on structure
  - Molecular polarity
    - Dipole-dipole interactions
    - Hydrogen bonding
    - London dispersions

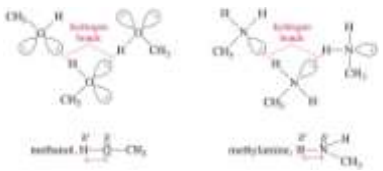
Dipole-Dipole Forces

- Between polar molecules
- Positive end of one molecule aligns with negative end of another molecule
- Lower energy than repulsions
- Larger dipoles cause higher boiling points



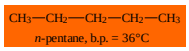
Hydrogen Bonding

- Strongest dipole-dipole attraction
- Organic molecule must have N-H or O-H
- The hydrogen from one molecule is strongly attracted to a lone pair of electrons on the other molecule
- H-bonded molecules have higher boiling points

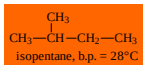


London Dispersion Forces

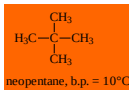
- van der Waals forces
- Between nonpolar molecules
- Temporary dipole-dipole interactions
- Molecules with more surface area have stronger dispersion forces and higher boiling points
  - Larger molecules
  - Unbranched molecules



n-pentane, b.p. = 36°C

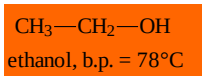


isopentane, b.p. = 28°C

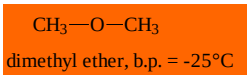


neopentane, b.p. = 10°C

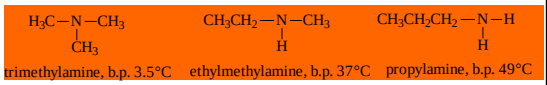
Boiling Points and Intermolecular Forces



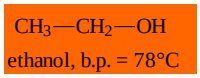
ethanol, b.p. = 78°C



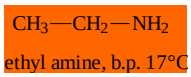
dimethyl ether, b.p. = -25°C



trimethylamine, b.p. 3.5°C ethylmethylamine, b.p. 37°C propylamine, b.p. 49°C



ethanol, b.p. = 78°C



ethyl amine, b.p. 17°C

Solubility and Intermolecular Forces

- Like dissolves like
  - Polar solutes dissolve in polar solvents
  - Nonpolar solutes dissolve in nonpolar solvents
- Molecules with similar intermolecular forces will mix freely