香港城市大學

CHEM 1300 Chemistry

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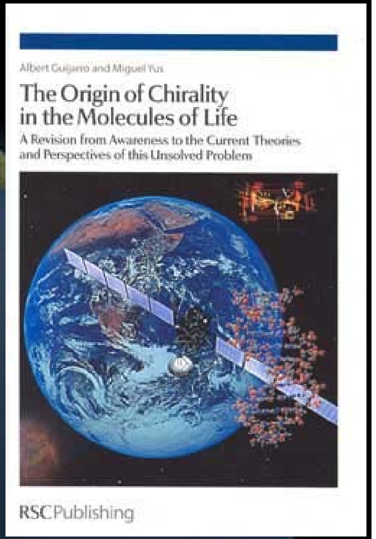
Intro...
(http://www.youtube.com/watch?v=e-QFj59PON4)

Big Bang & Birth of the Earth:
WHERE DID WE COME FROM???
(https://www.youtube.com/watch?v=oeM103KJ5x8, https://www.youtube.com/watch?v=ZSt9tm3RoUU, https://www.youtube.com/watch?v=FnuldVd99x8&feature=youtu.be&utm_source=Newsletter&utm_medium=Newsletter&utm_campaign=CEN)

"Origin of Chirality in the Molecules of Life" by Guijarro and Yus
(search Library for online eBook: http://lib.cityu.edu.hk/)

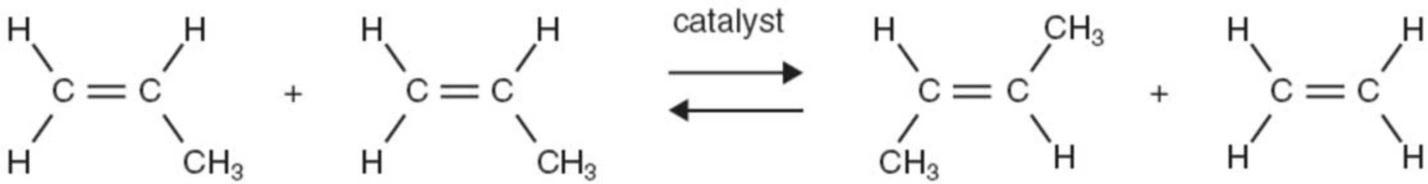


Chemical Origin of Life: Prebiotic Chemistry
(http://www.nature.com/nchem/focus/prebiotic-chemistry/index.html, http://pubs.acs.org/doi/full/10.1021/acscentsci.6b00336)

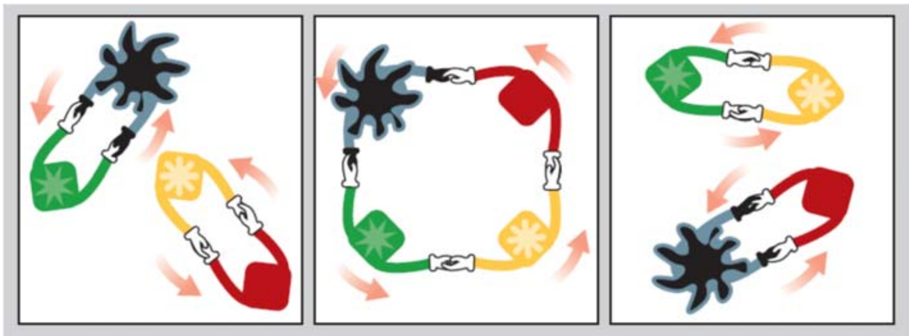
Origin of Chirality on Earth
(http://cshperspectives.cshlp.org/content/2/5/a002147, http://pubs.acs.org/doi/abs/10.1021/ar200316n)

Nobel Prize for Chemistry (2005)

- Y. Chauvin, R. H. Grubbs, R. R. Schrock, for development of the metathesis method in organic synthesis.



- Metathesis: a ‘dance’ of “change-your-partners”:



- **“Green chemistry”:** reduce waste through more efficient production (environmentally friendly).
- Used to develop drugs and advanced materials.


A Periodic Table of Medicines
www.iypt2019.org/
Li
Be
Mg
Na
K
Ca
Sr
Ti
V
Cr
Mn
Fe
Co
Cu
Zn
Ag
Au
Pt
B
Al
C
N
N_2O
O
F
Si
P
S
Cl
Se
Br
Sedormal
I
^{67}Ga
Indium-111 Ox
Sn
As
Sb
^{201}Tl
Bi
^{133}Xe
^{90}Y
Mo
^{99m}Tc
Cs
Ba
^{153}Sm
Gd
La
FOSRENOL
(lanthanum carbonate)
Platinol
Alterne-Cal
TRISENOX
PYLORID
DeWitt's
TWINLAB
TRI-BORON PLUS
COPPER CAPS
SUPER VANADYL FUEL
Manganese
VITAMIN B12
Zinc 50 mg
Bone Special
Alamag Plus
Antacid
CESIUM
Oral-B
Cool, Soothing Antimicrobial Power
Flamazine
DOTAREM
Selenium-ACE
LITH
SODIUM CHLORIDE
Vital K

Why ???

- Why does ice float?
- Why does water expand upon freezing?
- Shape of snowflake ?

Intermolecular Forces

(Chapters 11 and 13)

What's Ahead:

1. States of Matter
2. Polarity of Covalent Bonds and Molecules
3. Types of Intermolecular Forces
4. Applications: Boiling and Melting Points
5. Solutions and Factors affecting Solubility

OBTL Course Intended Learning Outcomes (CILOs)

1. **Describe** the concepts of atoms, molecules, and ions, neutrons, protons and electrons, the periodic table, chemical formula and naming, acids and bases, state of matters, and chemical reactions.

2. **Rationalize** the electronic structures of atoms, ions, and molecules and chemical compounds through the formation of ionic and covalent bonds, and **explain** their physical and chemical properties.

3. **Apply** the principles of stoichiometry and moles, and **relate** these to mass balance, empirical and molecular formula, and chemical equation.

4. **Discuss** the basic principles of chemistry embedded within current real-world issues, such as quality of air and water, global warming, acid rain, energy resources, plastics, foods and drugs.

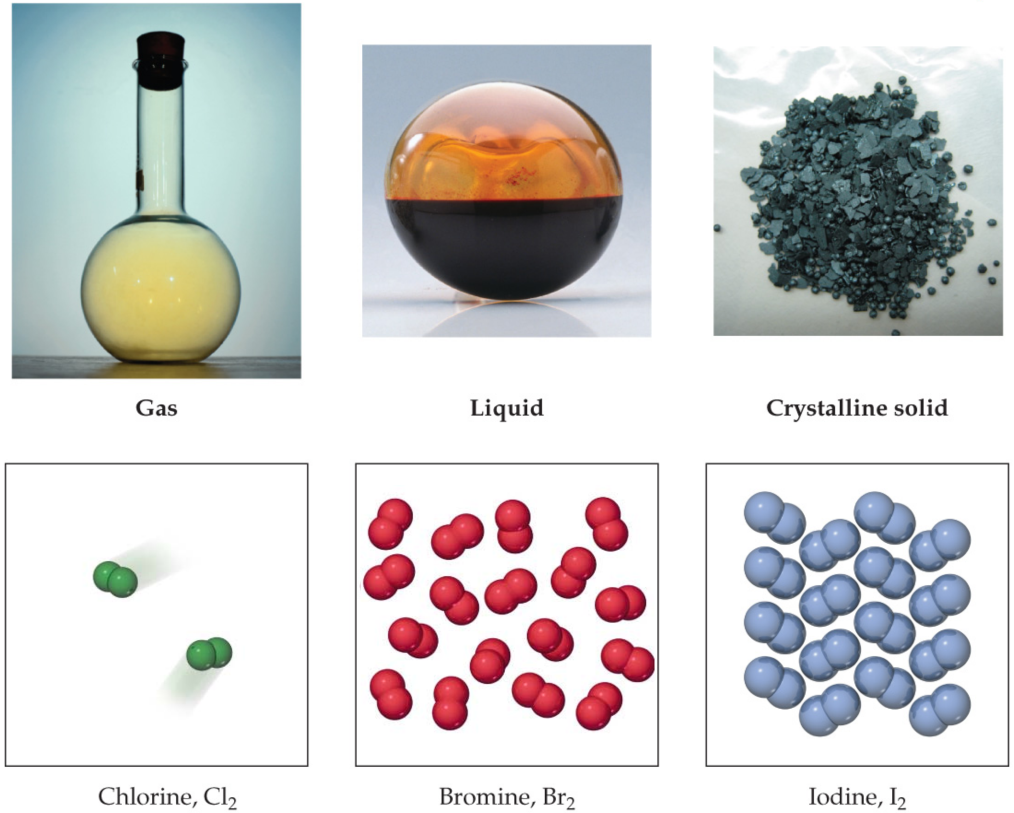
5. **Discover** real-life examples and applications related to the basic principles of chemistry.

Aims: stimulate interest; encourage curiosity; have fun!

States of Matter: At the Molecular Level

For group 7A molecules at room temp and standard p...

[different states?]

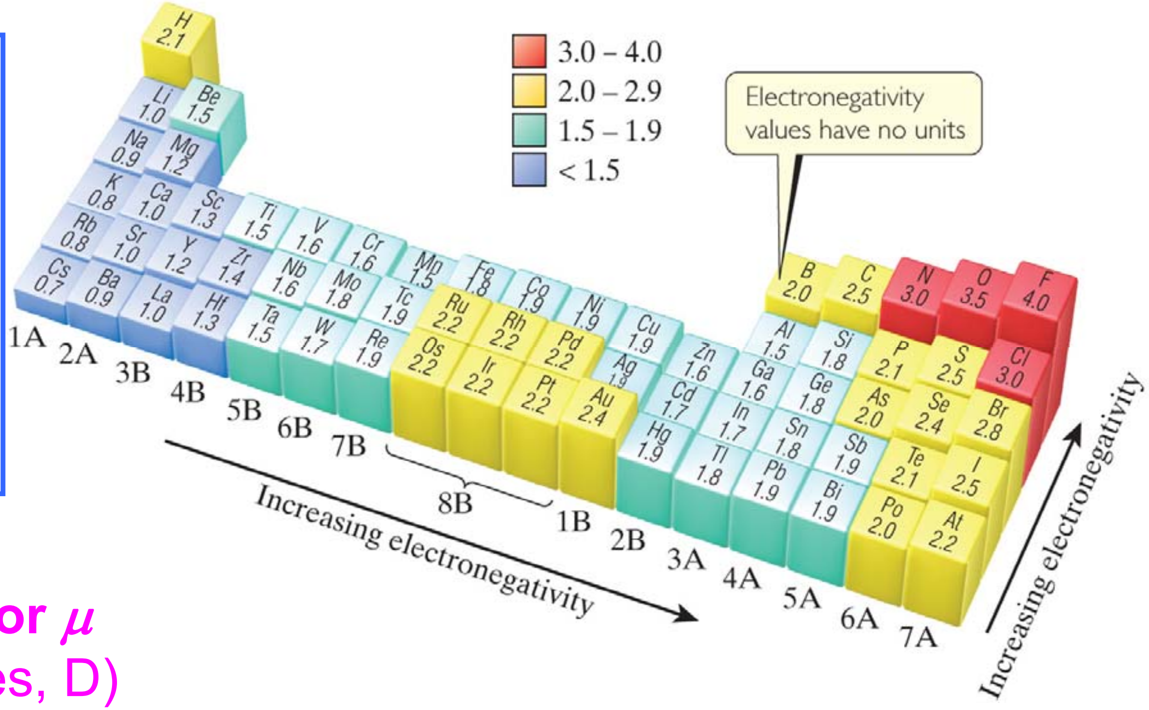


(answers provided at end)

- Motion of molecules ?
- Nature and strength of bonding between molecules ?

Covalent Bonds: Electronegativity (EN) and Dipole Moments

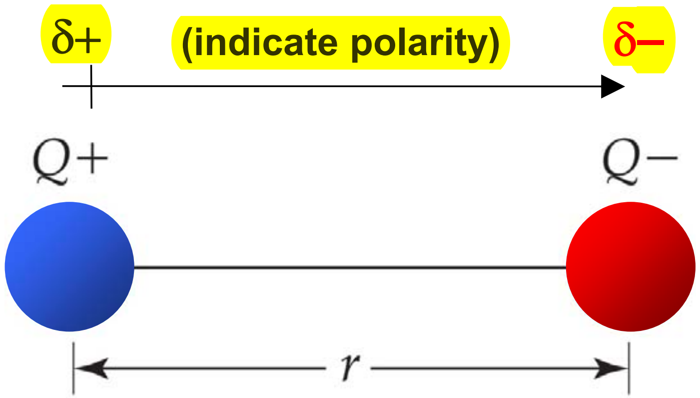
Bond	Dipole Moment (Debye, D)	Bond Description
H–F	1.91	Highly polar
H–Cl	1.08	Polar
H–Br	0.80	Polar
H–O	1.5	Polar
H–N	1.3	Polar
C–H	0.4	Weakly polar
C–Cl	0.5	Weakly polar
C–Br	0.4	Weakly polar
C–O	0.7	Weakly polar
C–N	0.2	Nonpolar



("bond polarity")

Dipole moment, DM or μ

$= Q\,r$ (in debyes, D)

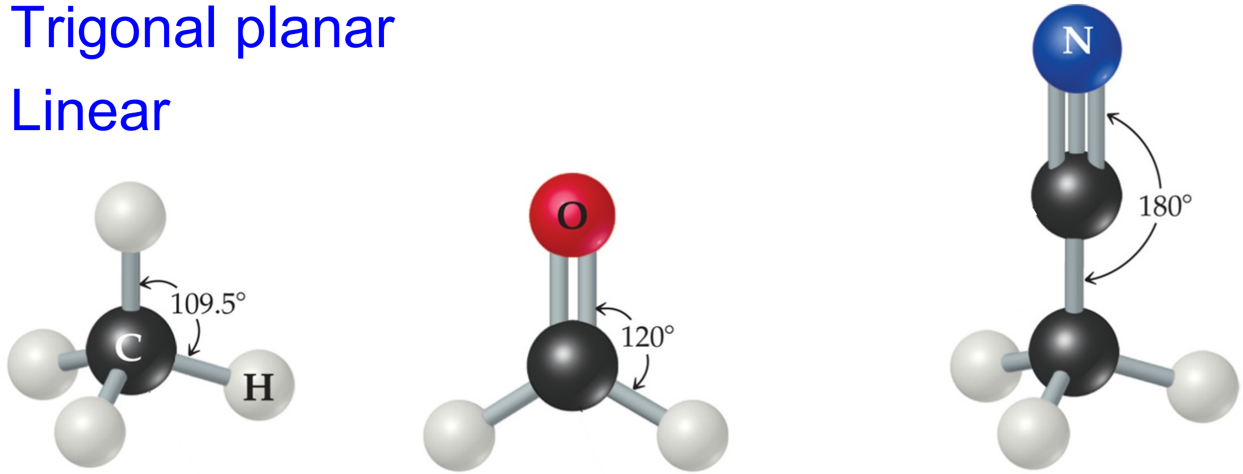


- Ability of atoms **in a molecule** to attract electrons to itself; related to **(but not same as)** high ionization energy and –ve electron affinity (for isolated atoms).
- Use EN to estimate bond polarity: greater ΔEN between 2 atoms, **more polar the bond.**

(Question)

Structure of Organic Compounds

- There are three common geometries in organic compounds:
  - ➢ Tetrahedral
  - ➢ Trigonal planar
  - ➢ Linear

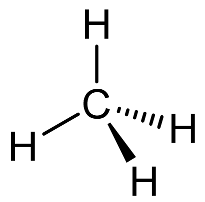


(a) Tetrahedral (b) Trigonal planar (c) Linear

(a) Tetrahedral C is bonded to 4 atoms; (b) trigonal planar C bonded to 3 atoms; (c) linear C bonded to 2 atoms.

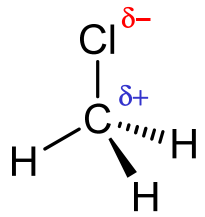
Polarity of Molecules

Methane
CH_4

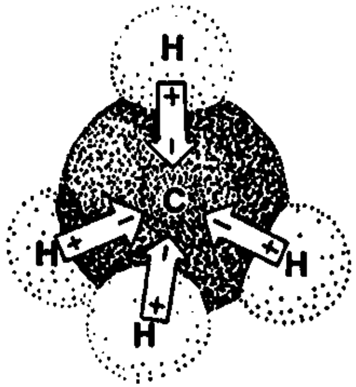


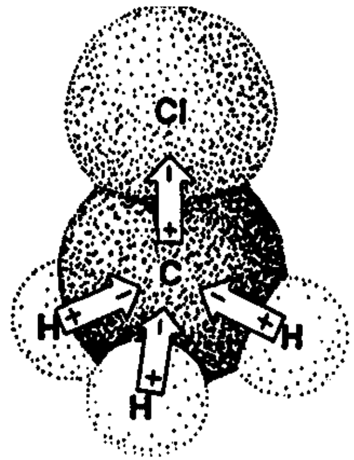
N.B.
tetrahedral!

Chloromethane
CH_3Cl



Draw arrow (vector)
along bond
to show polarity
(direction of
electron flow)

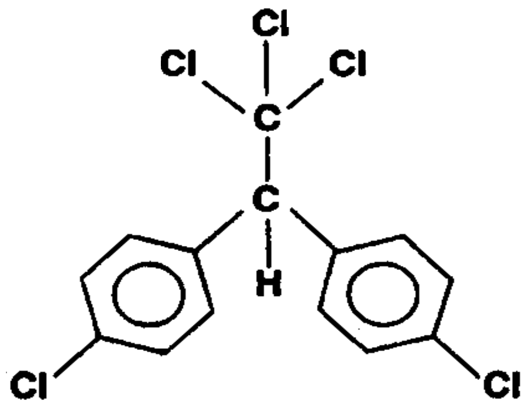




polar?

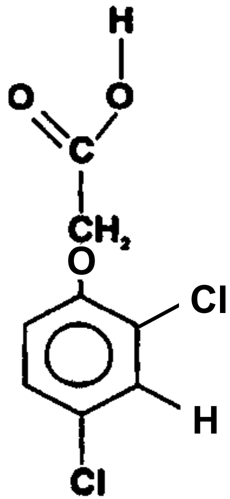
Polarity of Molecules (Pollutants) in the Environment

DDT



Herbicide 2,4-D

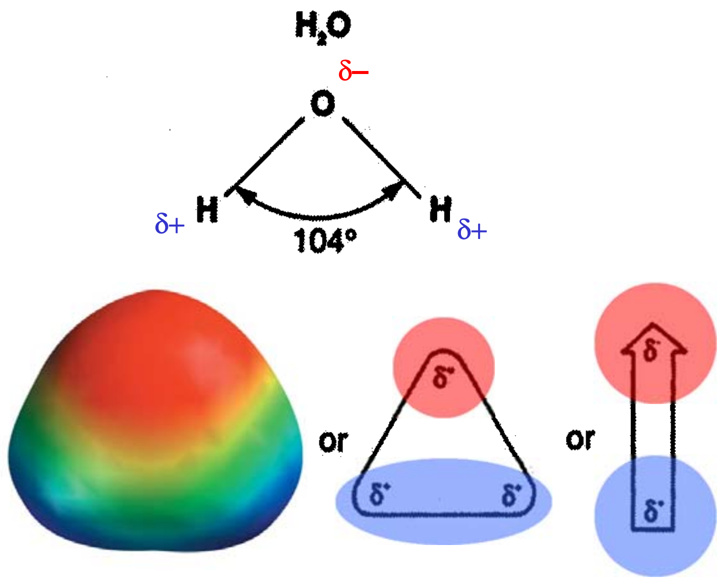
(2,4 - dichlorophenoxy acetic acid)



polar?

direction of dipoles?

Polarity of Molecules



Polarity of Common Groupings in Organic Molecules

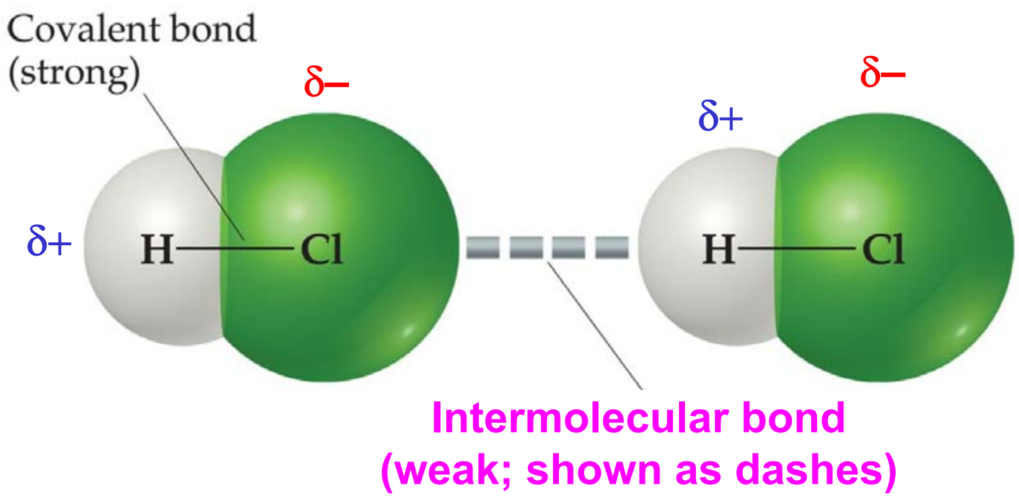
Highly Polar	Polar	Weakly Polar	Nonpolar
$-COO^-$	$-O-H$	$>C-Cl$	$-CH_3$
$-O^-$	$-COOH$	$>C-Br$	$-CH_2CH_3$
$-NH_3^+$	$-NH_2$	$>C-H$	
	$>C=O$		

- H_2O is a very important substance and plays major role in the environment.
- DM of each O-H is 1.5 D; overall dipole moment of 1.85 D.

  ∴ H_2O is a polar molecule and excellent solvent.

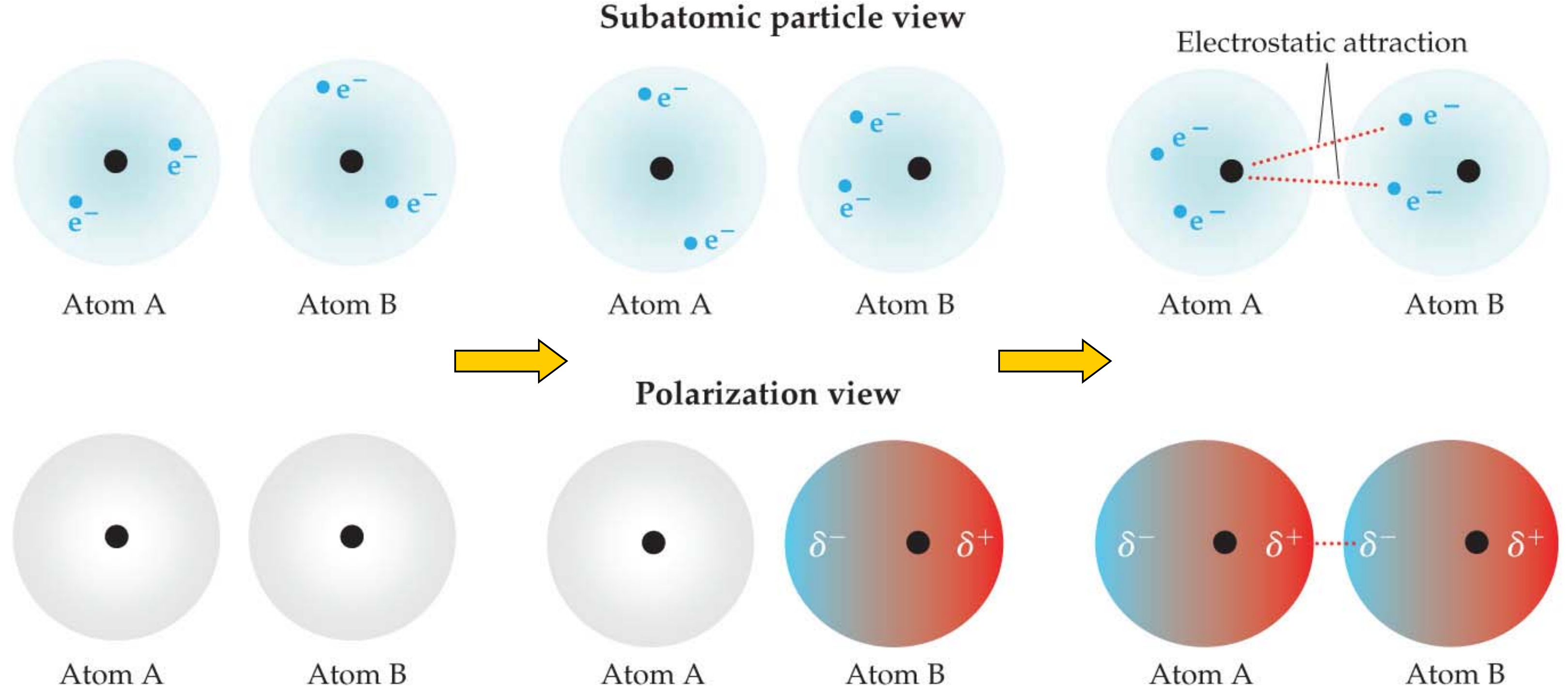
(Summary)

Intermolecular Forces: Interactions between Molecules



- Attractions between molecules are much **weaker** than **intra**molecular bonds that hold molecules together.
- However, they **control physical and chemical properties**, such as boiling and melting points, and solubility.

Intermolecular Forces: 1. Dispersion Forces

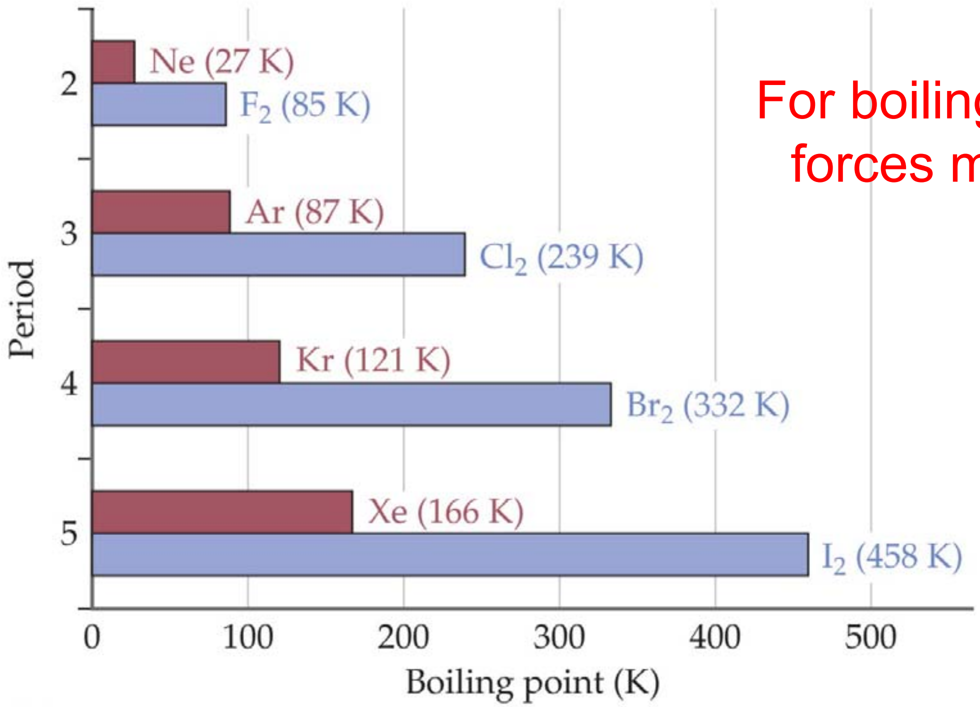


(a) Two helium atoms, no polarization (b) Instantaneous dipole on atom B (c) Induced dipole on atom A

- Instantaneous non-spherical distribution of electrons; results in temporary dipole, which repels electrons and induces dipole in adjacent atom.
- Short-range attraction between **instantaneous** and **induced dipoles**.
- Present in **ALL** molecules, polar and **non-polar** (e.g. aromatic).

  [anything containing electrons!]

Factors Affecting Dispersion Forces (and Consequences)



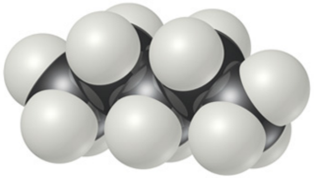
For boiling, intermolecular forces must be broken!

- The strength of dispersion forces generally increase with **larger molecular weight**.

(can distort more easily ➞ temporary dipole)

- WHY? Larger atoms and molecules are **more polarizable** (more "squashable") because there are **more electrons** (which are further from nucleus).

Factors Affecting Dispersion Forces (and Consequences)



n-Pentane
(bp = ?

Neopentane
(bp = ?

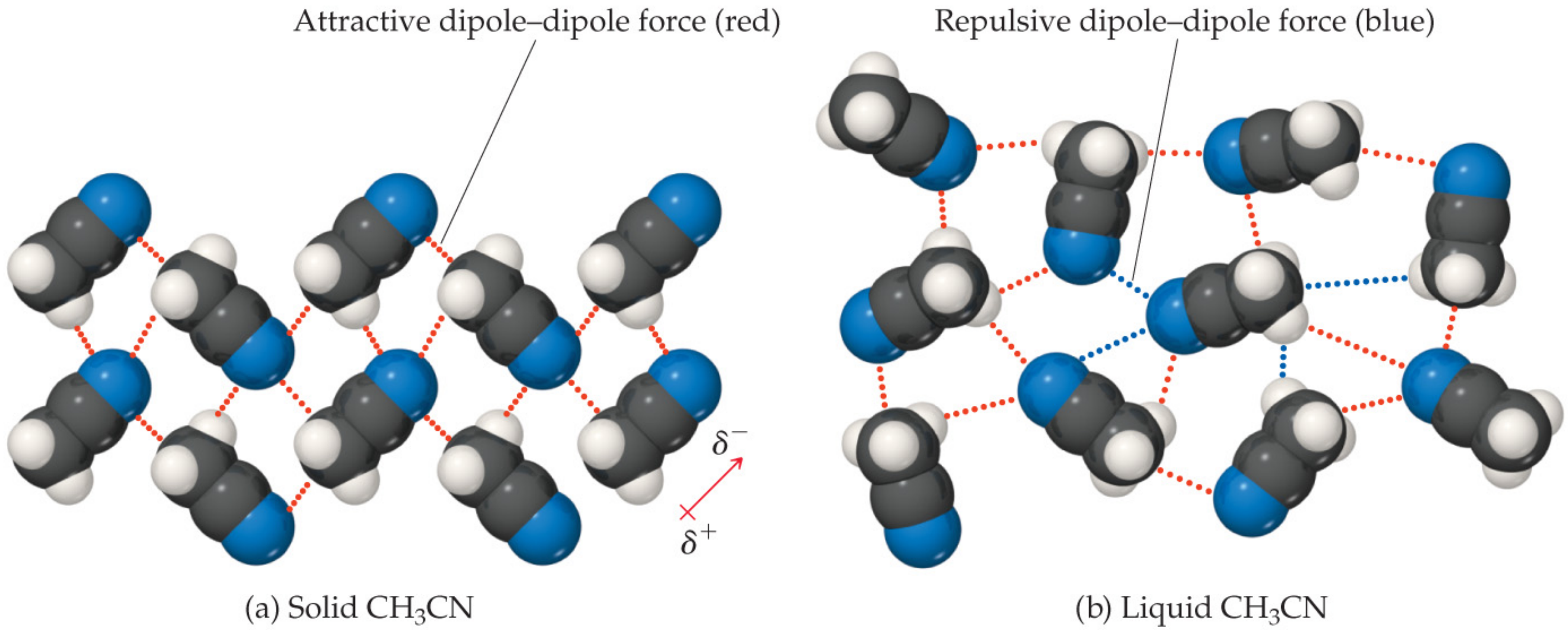
- **Molecular shape** affects the strength of dispersion forces.
- Long, ‘skinny’ molecules (like *n*-pentane) tend to have dispersion forces than short, ‘fat’ molecules (like neopentane).
- This is due to for *n*-pentane molecules and between them...

Intermolecular Forces

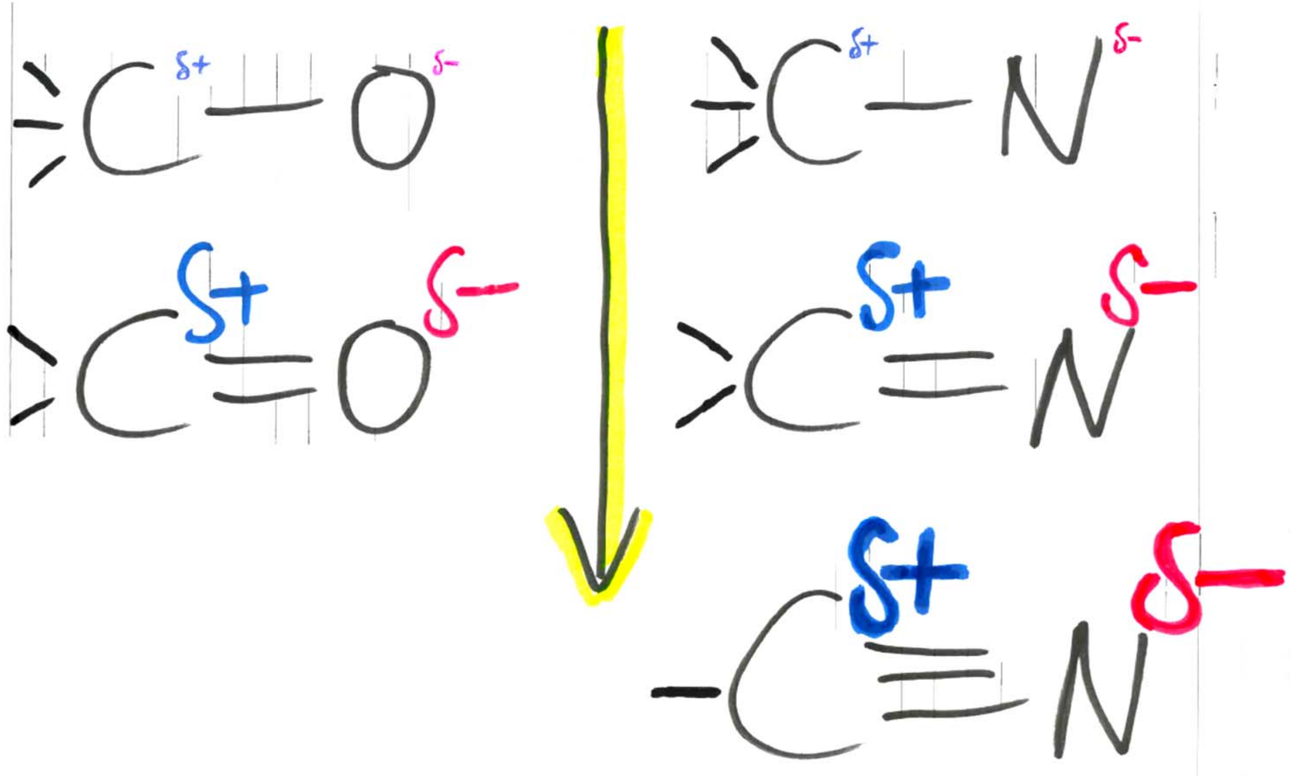
Intermolecular Forces: 2. Dipole-Dipole Interactions

Polar molecules that have permanent dipoles are attracted to each other.

- Both attraction and repulsion occur, but **attractive orientations and attractive forces dominate.**
- Only important when molecules are **close to each other.**

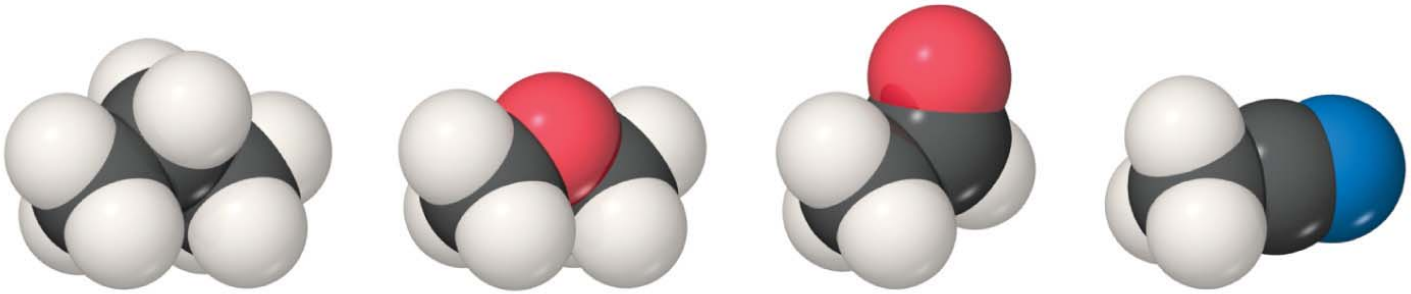


less polar



more polar

Dipole Moment and Boiling Point



Propane	Dimethyl ether	Acetaldehyde	Acetonitrile
$CH_3CH_2CH_3$	CH_3OCH_3	CH_3CHO	CH_3CN
MW = 44 amu	MW = 46 amu	MW = 44 amu	MW = 41 amu
μ =	μ =	μ =	μ =
bp =	bp =	bp =	bp =

strength of interactions?

- Intermolecular forces control boiling pt, vapor p etc.
- Boiling & melting pts are influenced by (a) dipole moment (dipole-dipole interactions), (b) molecular size & shape (dispersion forces).

Which effect is more dominant:

Dipole-Dipole or Dispersion Forces?

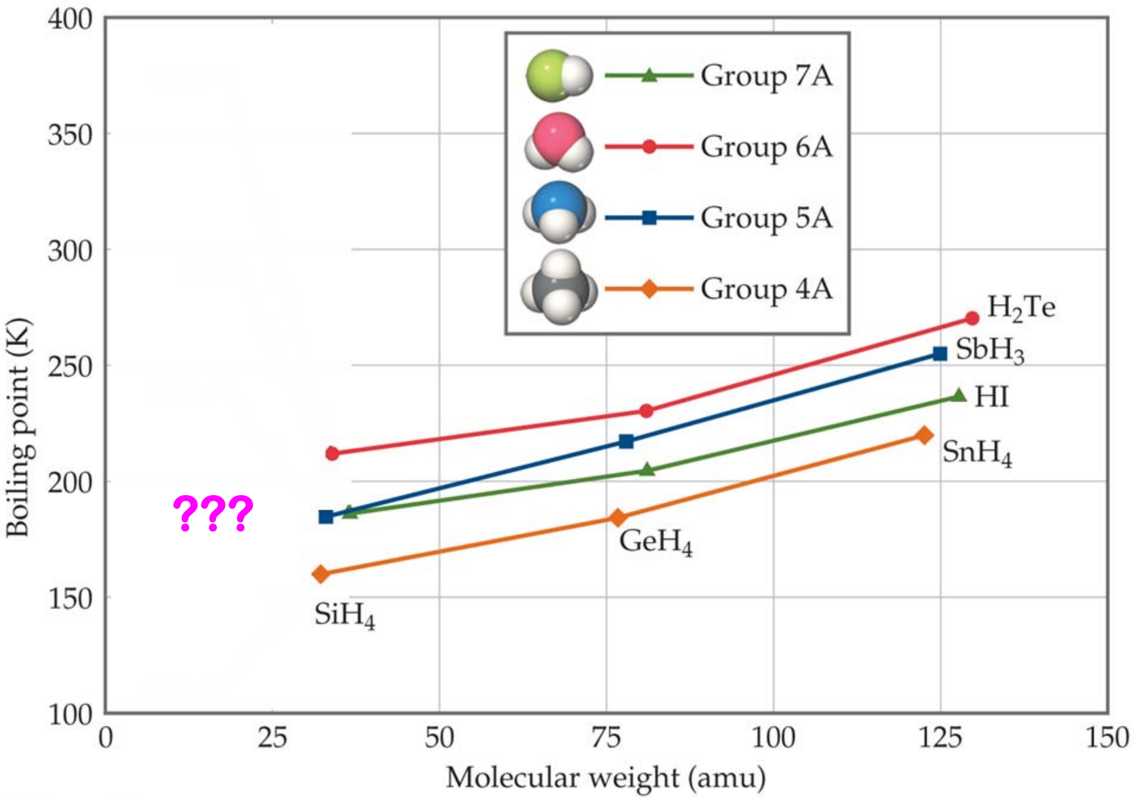
(which force is stronger?)

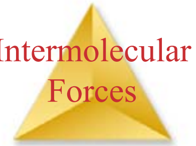
- If two molecules are of comparable size and shape, dipole-dipole interactions will likely be the dominating force.

- If one molecule is much larger in size/molecular weight, dispersion forces can become more dominant and determine the physical properties.

Intermolecular Forces

Question: Can you predict boiling point for next hydride (in 2nd row) of each series?



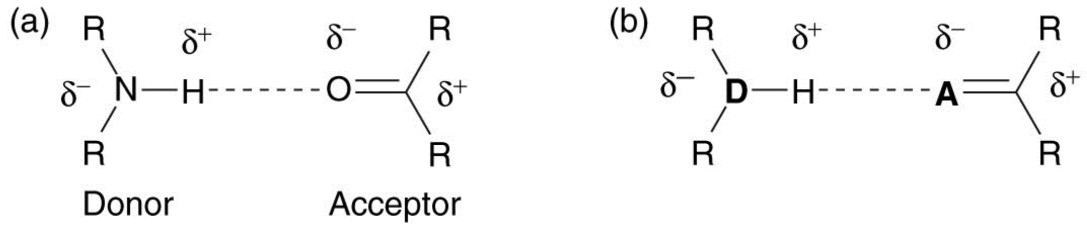


E.g. For group 4A, b.pt. of CH_4 = ?

Boiling Points

- Controlled by intermolecular forces...

Dipole-Dipole Interactions: 3. Hydrogen Bonding



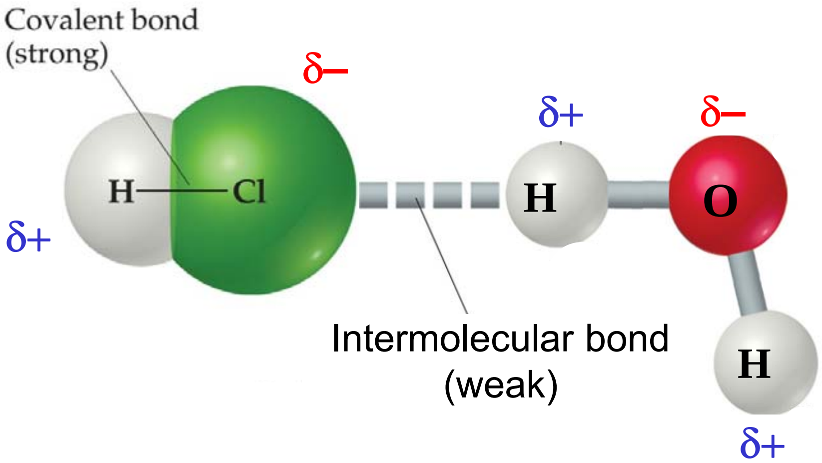
A carbonyl accepting a hydrogen bond from a secondary amine donor (a) and (b) the standard way of expressing donor and acceptor atoms (D, donor atom; A, acceptor atom).

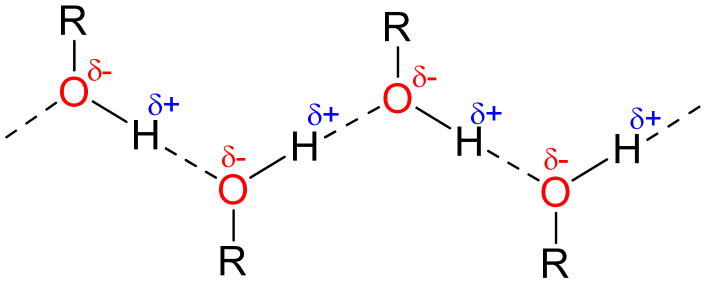
- Observed between **H atom in polar bond** and free electron pair of small, highly electronegative **N**, **O**, or **F** atom in adjacent molecule.

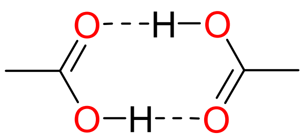
WHY?

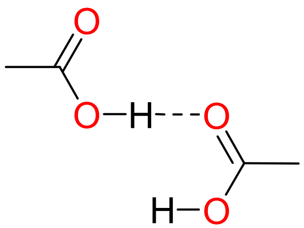
- In polar bond, H atom does not have…

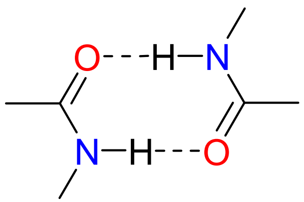
Hydrogen Bonding

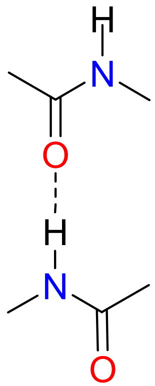












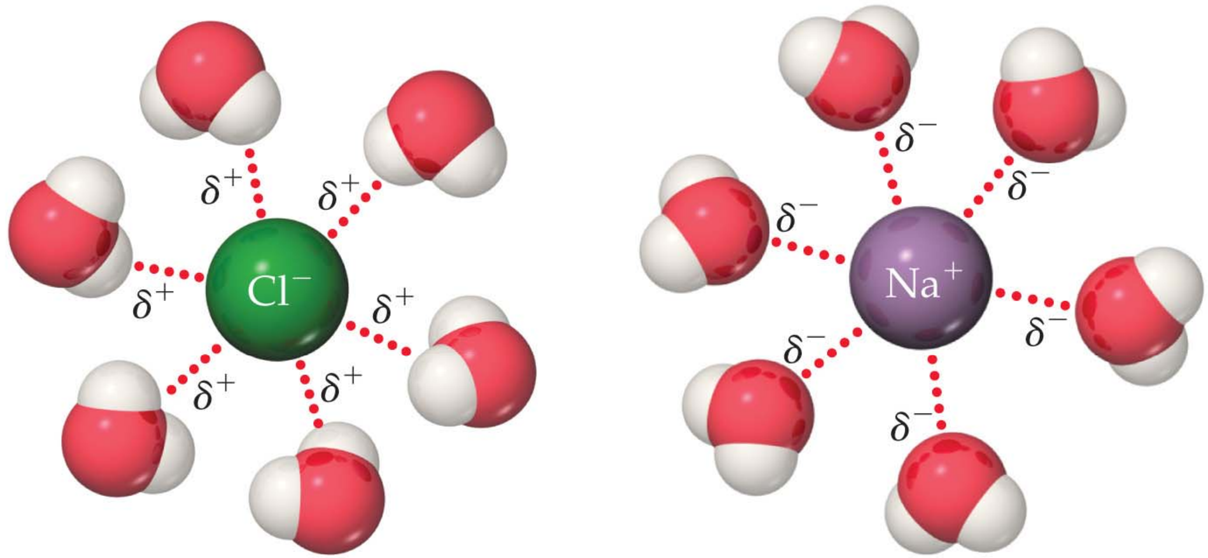
- Unusually strong intermolecular interactions **(N.B. highly directional)**.
- Important in natural building blocks **(amino acids, nucleobases)**.

Densities of Water and Ice

- At 0 °C, density of **solid** ice (0.917 g ml^{-1}) is **less than** that of **liquid** water (1.000 g ml^{-1}), so ice floats on liquid water. Water expands upon freezing. **WHY ?** Shape of snowflake ?
- Hydrogen bonding in ice gives structure with arrangement of H_2O molecules and
- Hydrogen bonding is critical for aquatic life and biological systems.

Intermolecular Forces: 4. Ion-Dipole Interactions

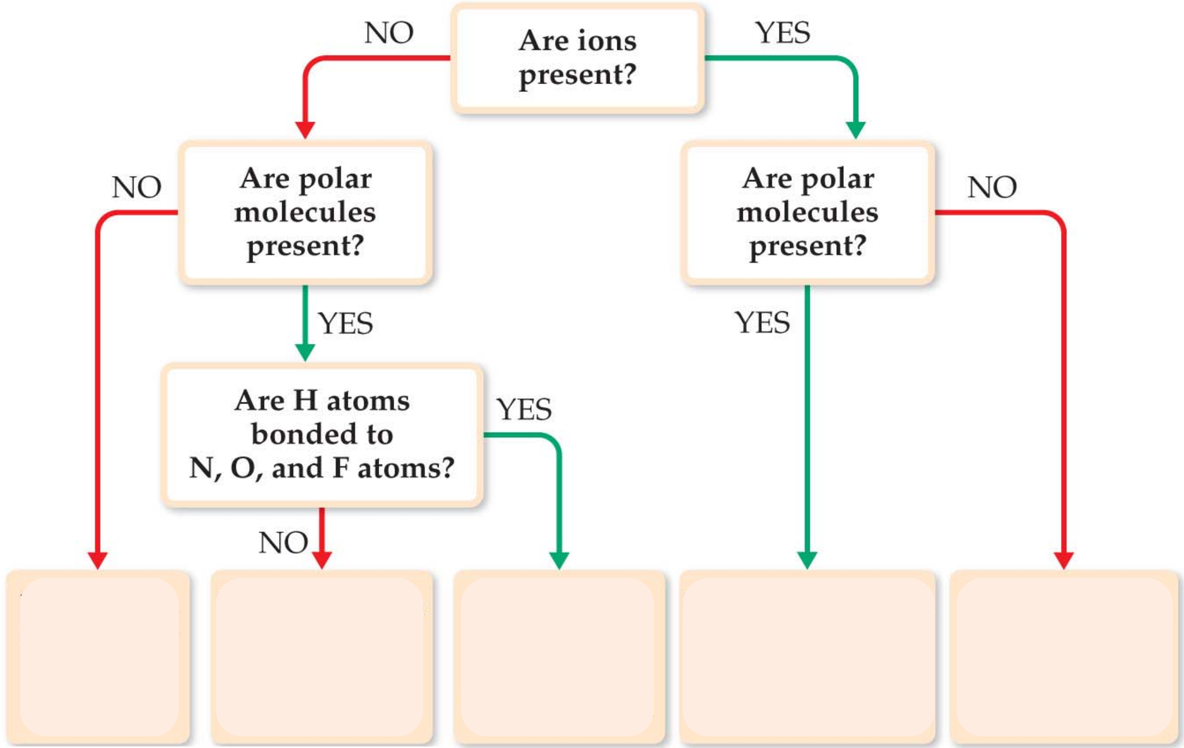
- Important force in solutions of ions and polar molecules (**note orientations to neutralize charge**); stronger than dipole-dipole forces.
- Their **strength** allows ionic substances to dissolve in polar solvents (see 'Solubility').



Positive ends of polar molecules are oriented toward negatively charged anion

Negative ends of polar molecules are oriented toward positively charged cation

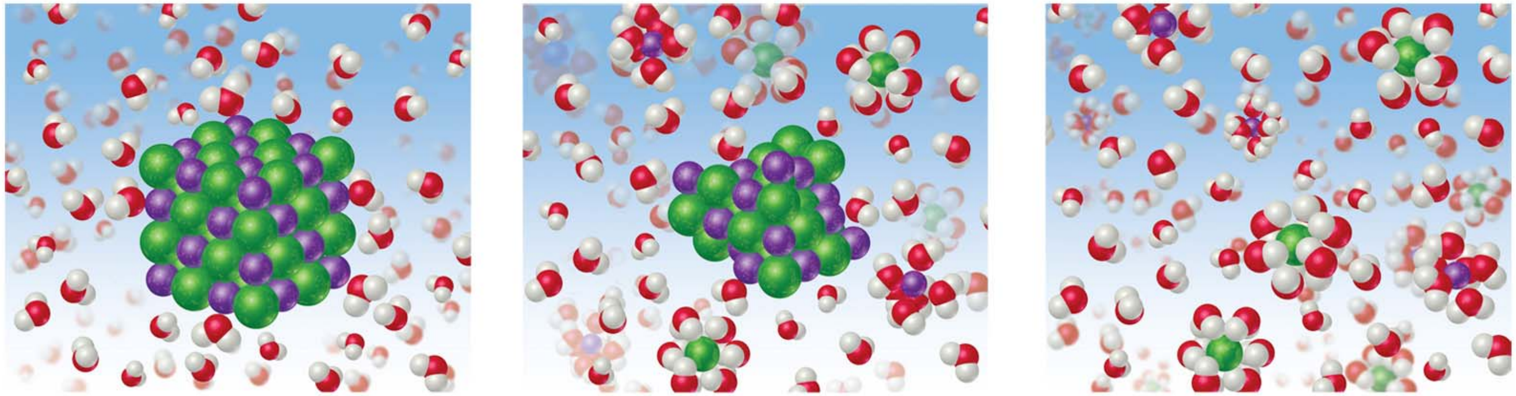
Determining Intermolecular Forces



strength of interactions?

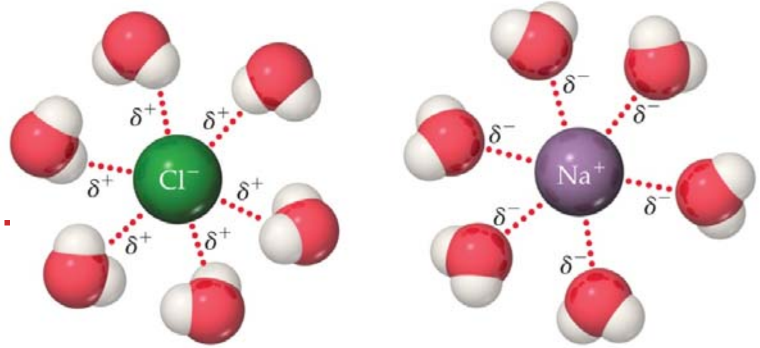
- **REMINDER:** Dispersion force present for….

APPLICATION: Solubility of Ionic and Polar Compounds



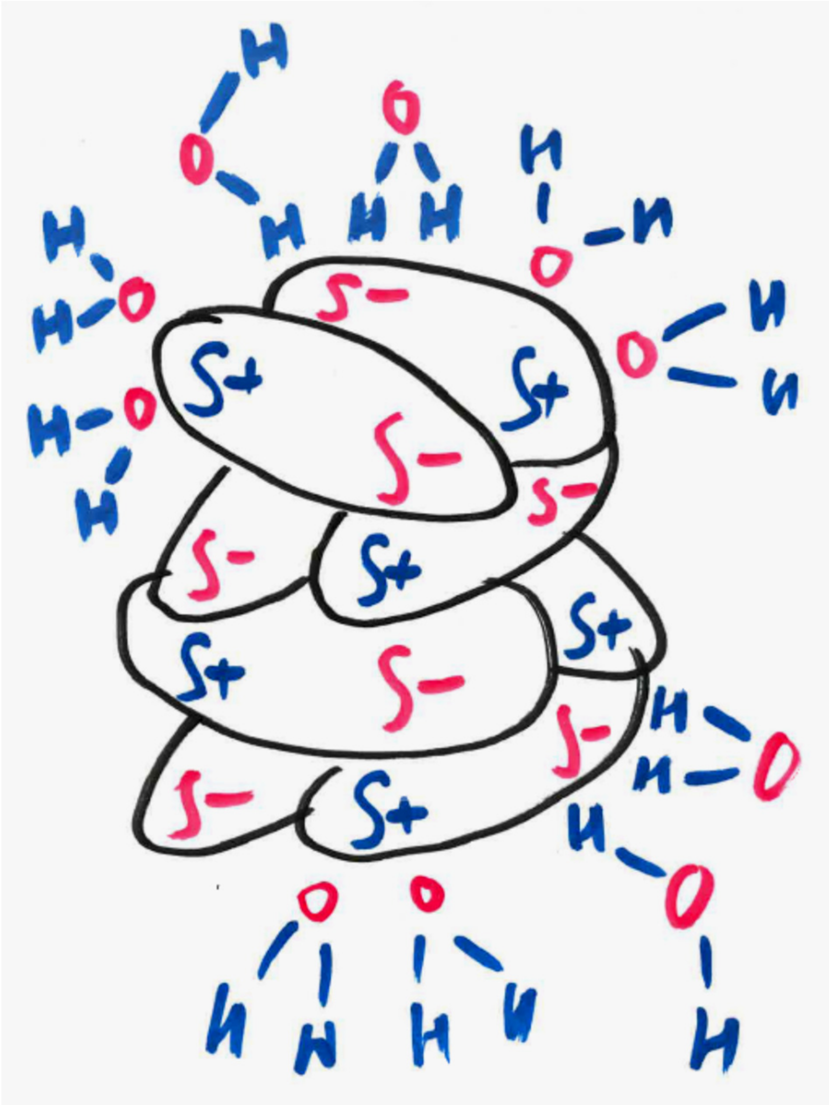
- Dissolution of ionic solid (NaCl) in water: solvent **(H_2O)** molecules surrounds and **orientates** around crystal/ions; this PROCESS is called **SOLVATION** **(HYDRATION for water)**.
- This gives **interactions** which are sufficiently strong to **overcome the "lattice energy"** of the crystal and separate the ions…

Hydrated Na^+ and Cl^- ions:



- Similar for polar covalent compounds.

Similar for polar covalent compounds:



Energy Changes During Solution Process

Introduce: HEAT and HEAT CHANGE

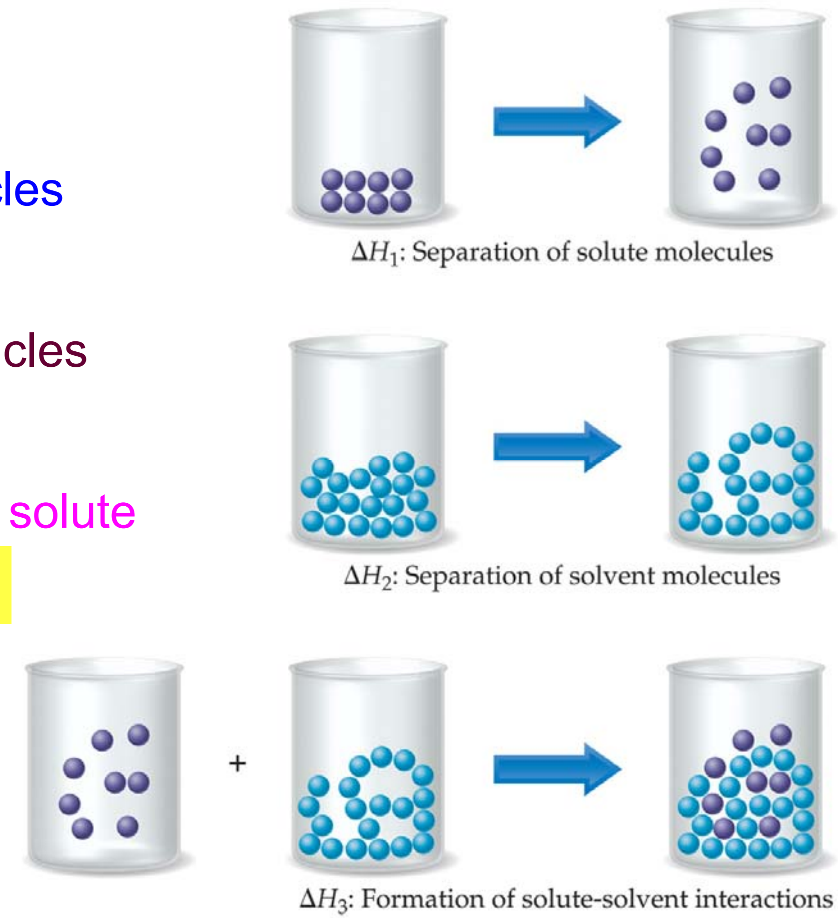
- "Heat content" of a chemical system is called the *enthalpy* (symbol: *H*)
- Enthalpy change (ΔH) is the amount of heat released or absorbed when a chemical reaction occurs (at constant pressure).
- $\Delta H = H_{products} - H_{reactants}$ [enthalpy of products minus enthalpy of reactants]

	EXOTHERMIC Reaction = **favorable**	**ENDOTHERMIC** Reaction = **unfavorable**
Energy absorbed or released	Energy is released. Reaction vessel becomes warmer.	Energy is absorbed. Reaction vessel becomes cooler (or requires heating).
Sign of ΔH	ΔH = negative (–)	ΔH = positive (+)

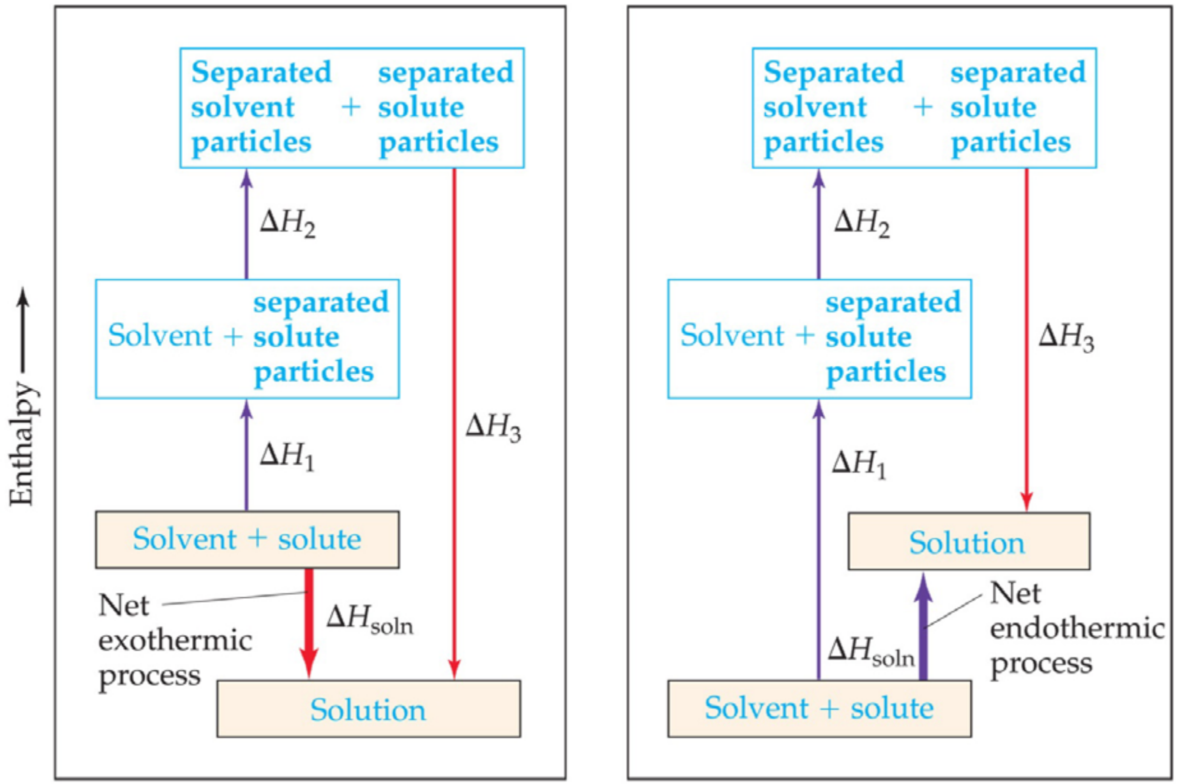
[For details, see "Physical" classes]

Energy Changes During Solution Process

- 3 processes affect the energetics of solubility:
  - ➢ Separation of solute particles
  - ➢ Separation of solvent particles
  - ➢ New interactions between solute and solvent

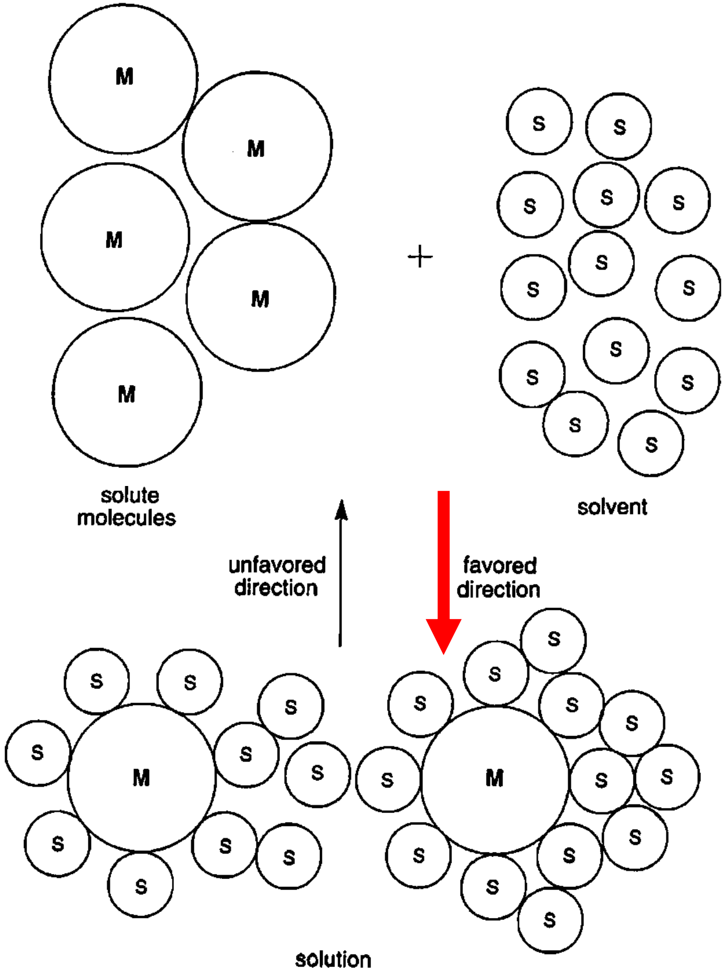


Energy Changes During Solution Process



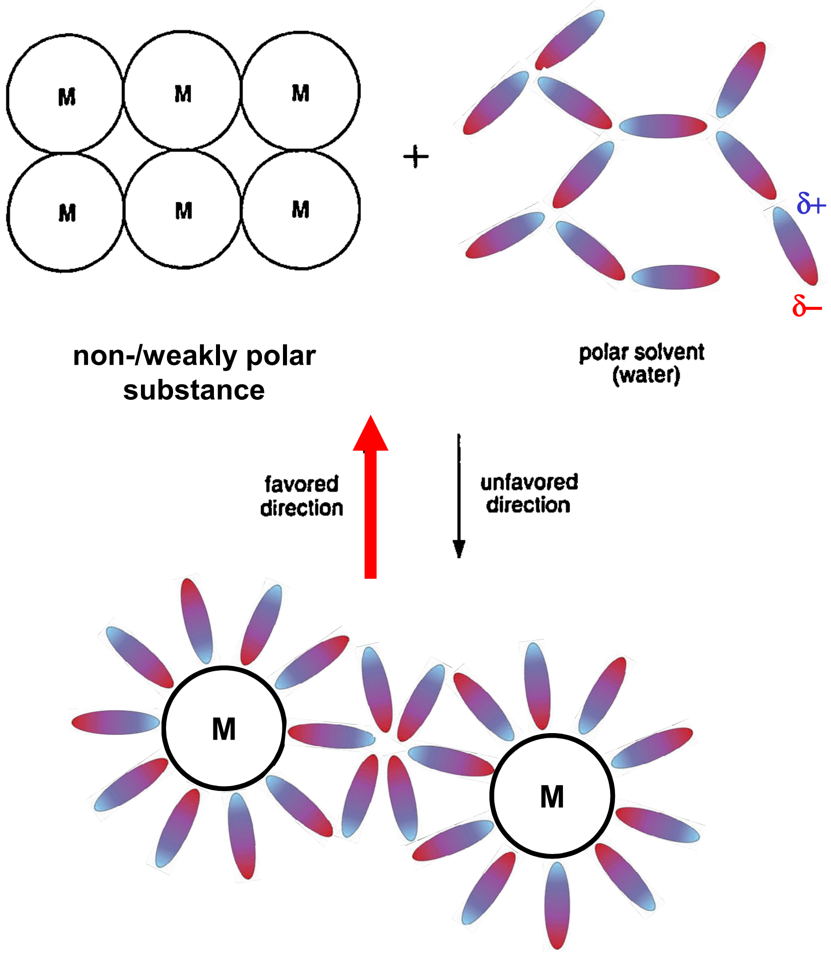
Enthalpy change of the overall solution process depends on sum of ΔH for these 3 steps.

APPLICATION: Solubility (General)

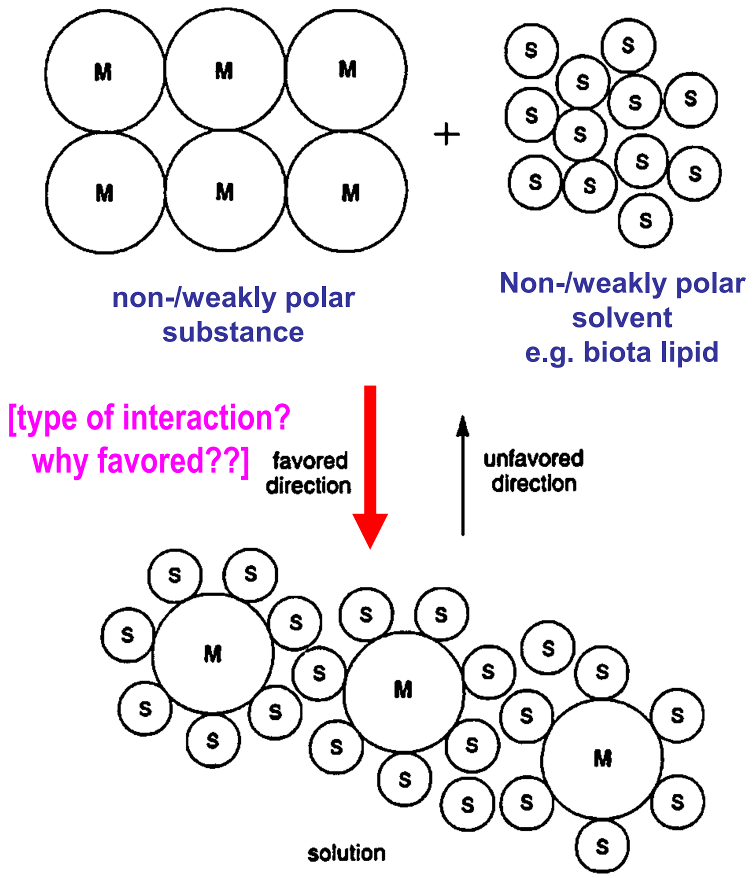


- For a substance to dissolve, solvent molecules must form **intermolecular bonds** with solute molecules,* which **in total** are **stronger than or at least comparable to** solute-solute and solvent-solvent interactions.

Solubility of Non-/Weakly Polar Compounds



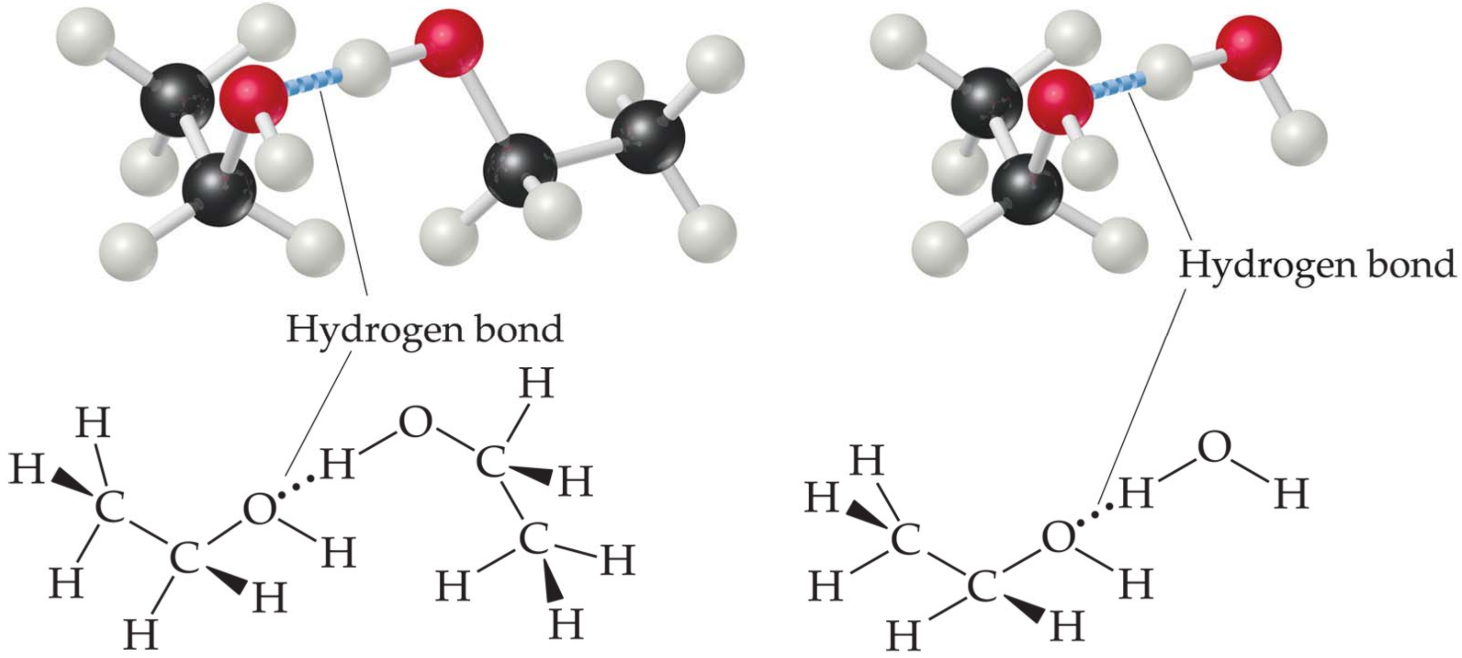
"Unfavorable" intermolecular bonds; variable/random orientation of dipoles



"Like dissolves like",

e.g. DDT is lipophilic and can penetrate biological membranes.

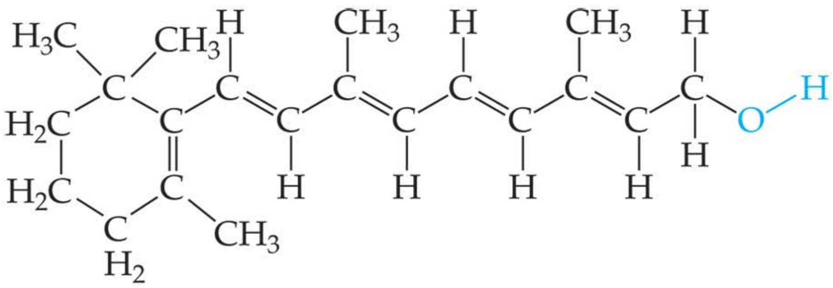
Factors Affecting Solubility in H_2O

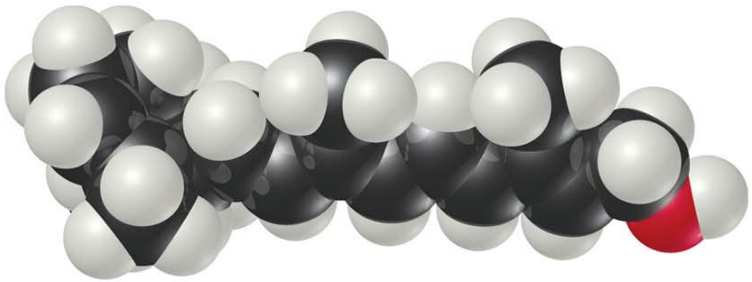


- **Polar molecules, especially those that can form hydrogen bonds, tend to be soluble in water.**
- **Increase number of polar groups to enhance aqueous solubility.**

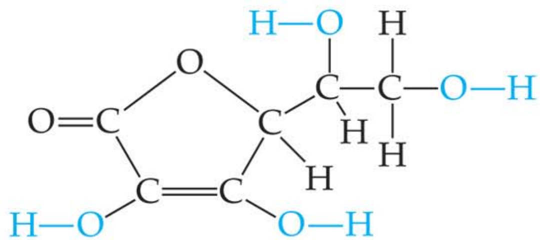
Chemistry and Life: Do you need regular intake of…

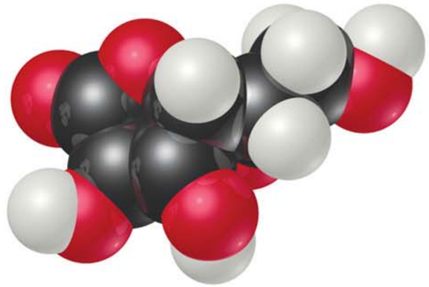
Vitamin A





Vitamin C



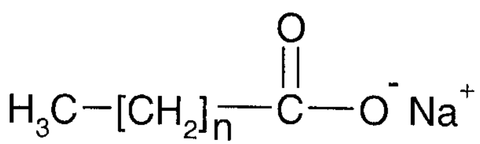


Chemistry and Life: Soaps and Detergents

[*emulsify*: to combine two liquids that normally do not combine easily]

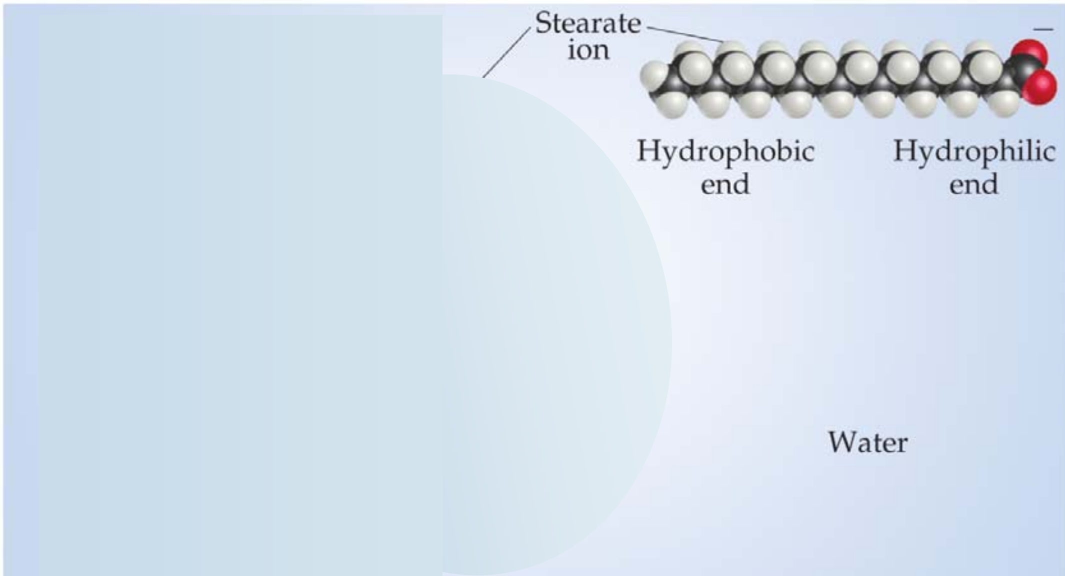
These molecules can aid in emulsification and removal of fats and oils in aqueous solutions…

At high concentration in water:



Fatty Acids

n = 16:
(sodium stearate)



GIVE IT SOME THOUGHT

Why don't oil drops stabilized by sodium stearate coagulate to form larger oil drops?

A. The stearate ion helps the oil droplets bind to the container walls.

B. The smaller droplets are separated from one another by stearate micelles.

C. The smaller droplets carry negative charges because of the embedded stearate ions and thus repel one another.

D. The sodium stearate causes the oil particles to decompose very slowly.