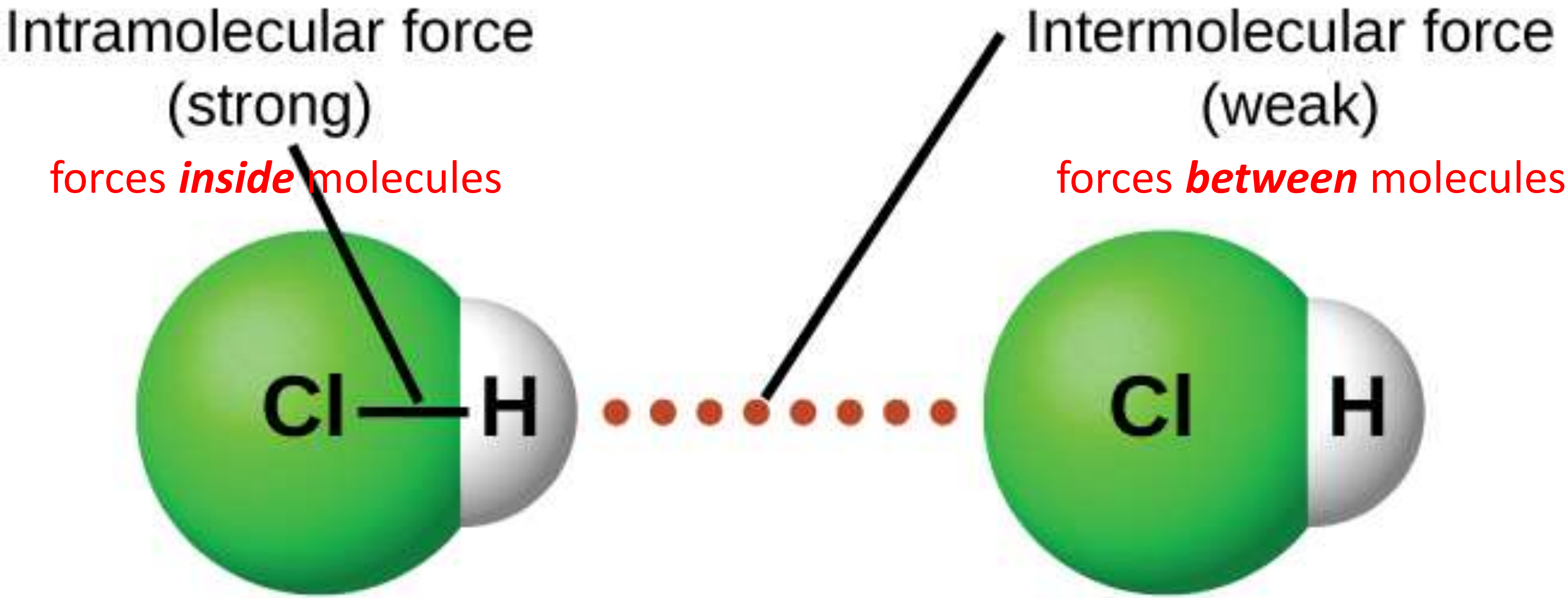
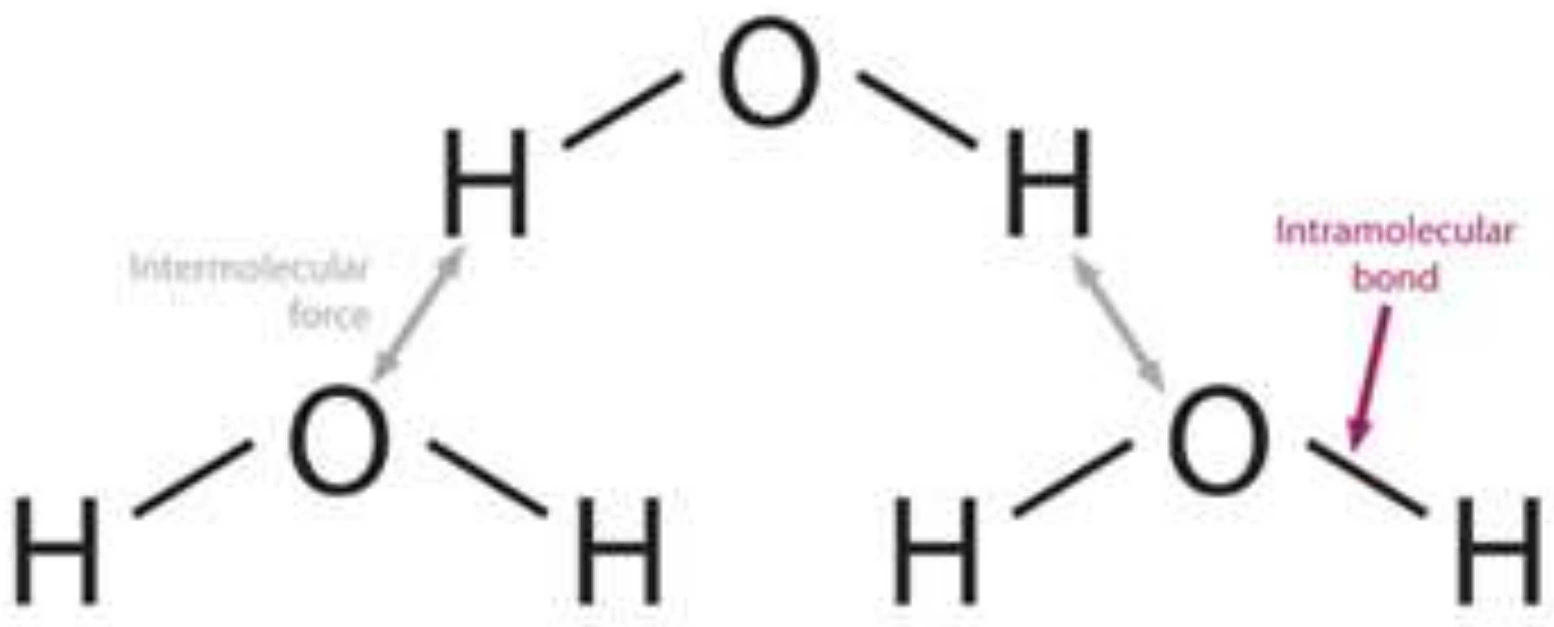
INTERMOLECULAR FORCES AND POLARITY

INTRA- VS. INTERMOLECULAR FORCES



INTRAMOLECULAR FORCES

- Forces of electrostatic attraction within a molecule
- Occurs between the nuclei of atoms & their electrons making up the molecule (i.e. covalent bonds)
- Must be broken by chemical means
- Form new substances when broken



INTERMOLECULAR FORCES

- Forces of attraction between two molecules

  Ex: - London dispersion

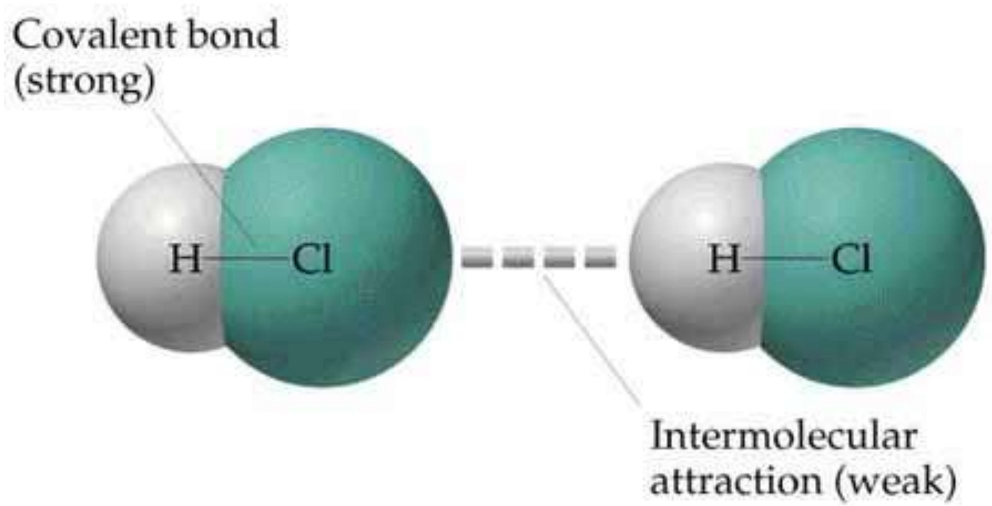
  - Dipole-dipole

  - Hydrogen bonds

- Much weaker than intramolecular forces so much easier to break

- Physical changes break or weaken these forces

- Do not form new substances when broken

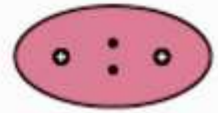
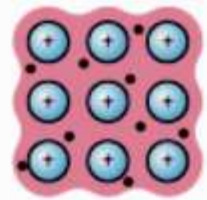


TYPES OF INTERMOLECULAR FORCES

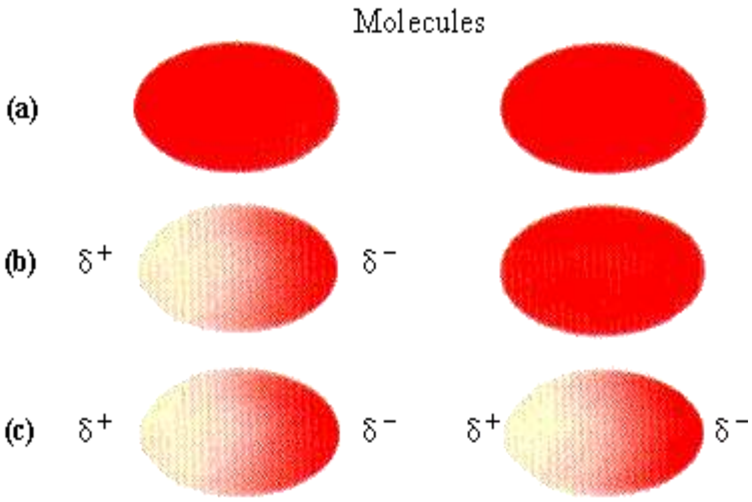
INCREASING STRENGTH

Intramolecular

Intermolecular

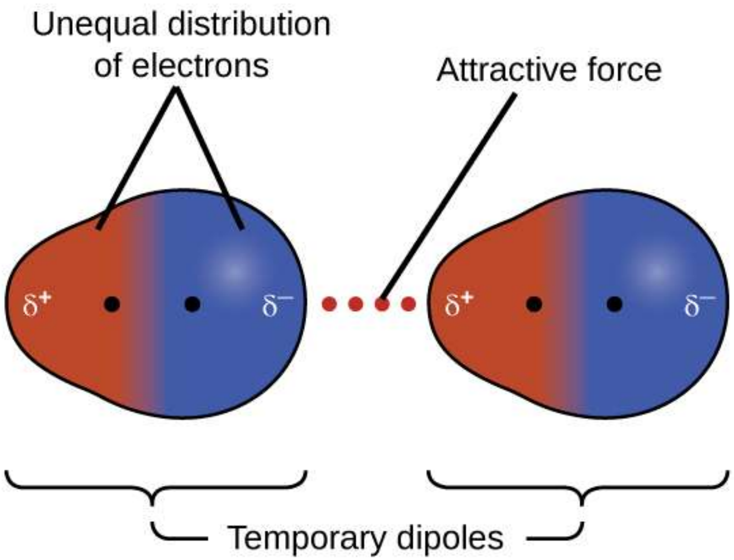
	Force	Model	Nature of Attraction	Energy (kJ/mol)	Example
Intramolecular	ionic		cation-anion	400–4000	NaCl
	covalent		nuclei-shared electron pair	150–1100	H—H
	metallic		cations-delocalized electrons	75–1000	Fe
Intermolecular	ion-dipole		ion charge-dipole charge	40-600	Na^+----OH_2
	hydrogen bond	δ^- δ^+ δ^- —A—H·······:B—	polar bond to hydrogen-dipole charge (lone pair, high *EN* of N, O, F)	10–40	:Ö(H)—H----:Ö(H)—H
	dipole-dipole		dipole charges	5–25	I—Cl----I—Cl
	ion-induced dipole		ion charge-polarizable electrons	3–15	Fe^{2+}----O_2
	dipole-induced dipole		dipole charge-polarizable electrons	2–10	H—Cl----Cl—Cl
	dispersion (London)		polarizable electrons	0.05–40	F—F----F—F

1. LONDON DISPERSION FORCES

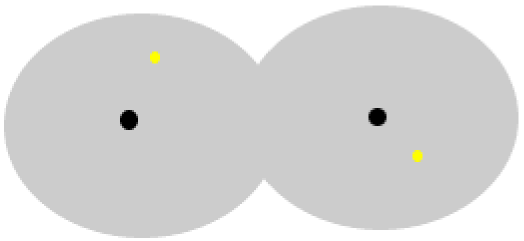


- Attraction between nonpolar molecules

- Attraction comes from temporary dipoles produced from the *random* movement of electrons

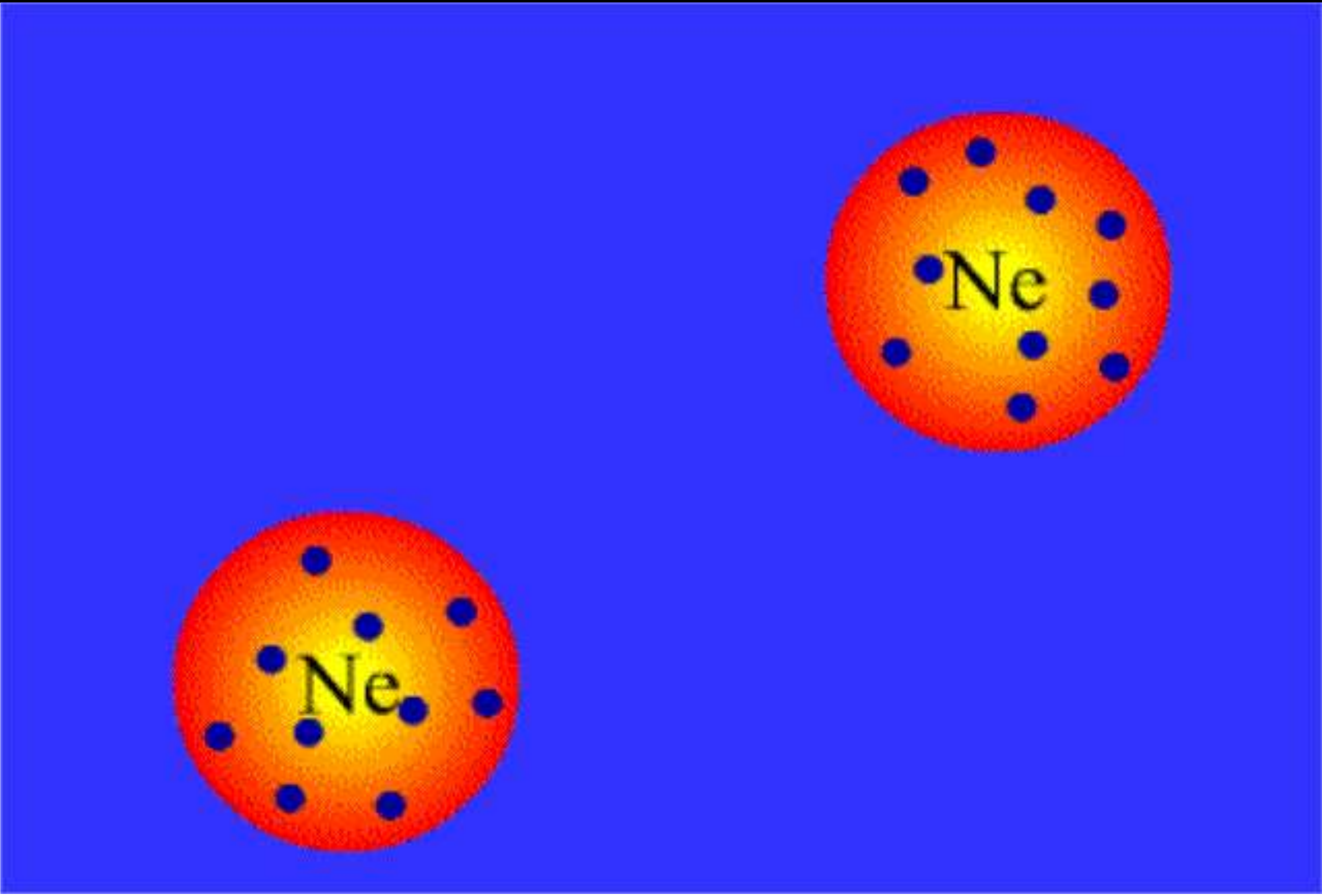


By chance, electrons will disperse unevenly and generate a temporary dipole in the molecule.



-A temporary dipole can induce a temporary dipole in a neighbouring molecule

1. LONDON DISPERSION FORCES



1. LONDON DISPERSION FORCES

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Strength of LDF depends on:

-The size of the atoms

-The number of electrons

-Molecule size

1. LONDON DISPERSION FORCES

Strength of LDF depends on:

The size of the atoms

- The larger an atom, the more loosely held are its outer electrons, and the more readily will the electron cloud will polarize.

The number of electrons

- Larger atoms have more electrons to disperse, creating stronger temporary dipoles when the electron cloud is polarized

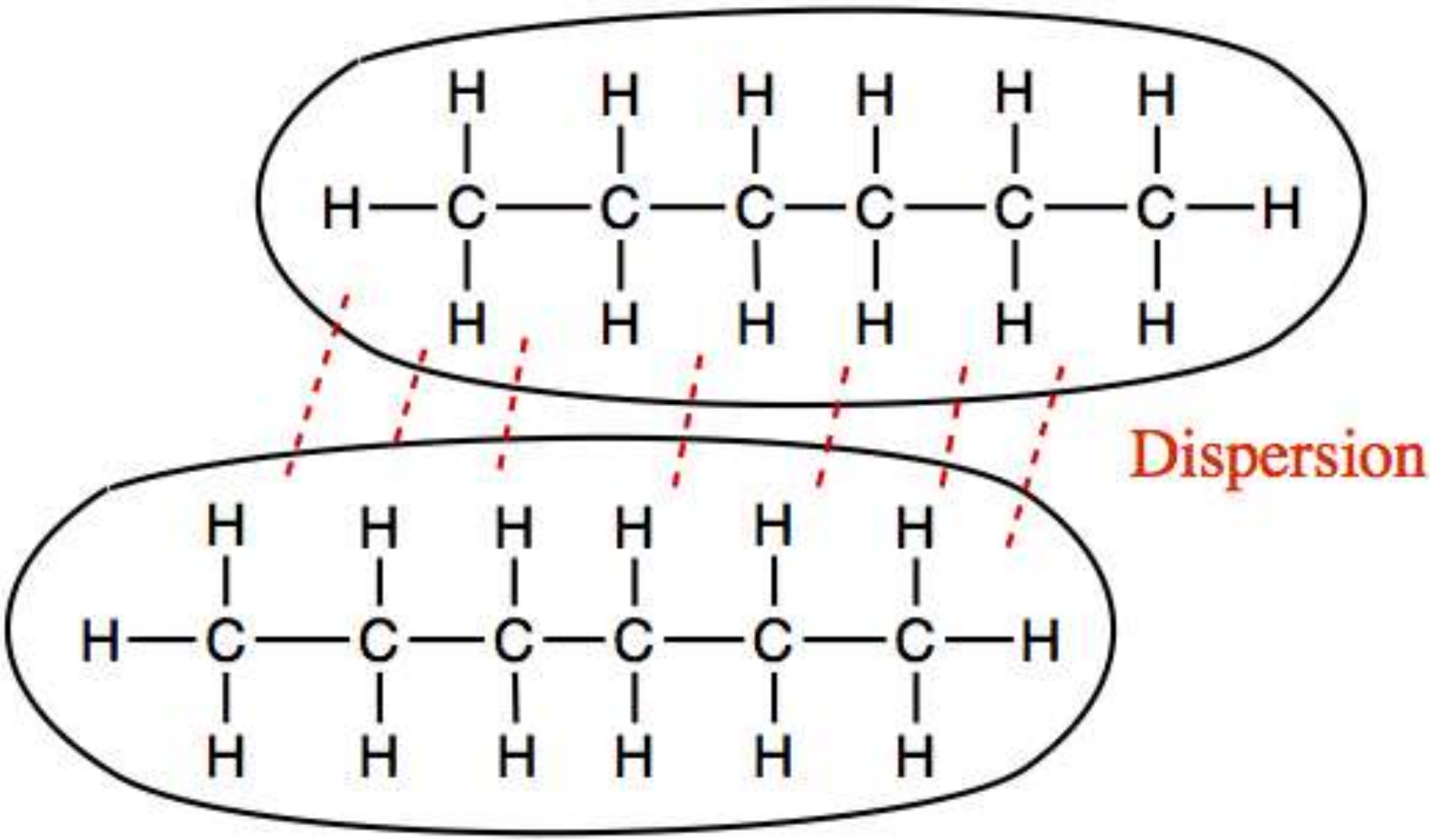
Halogen	Molecular Weight (amu)	Boiling Point (K)	Noble Gas	Molecular Weight (amu)	Boiling Point (K)
F_2	38.0	85.1	He	4.0	4.6
Cl_2	71.0	238.6	Ne	20.2	27.3
Br_2	159.8	332.0	Ar	39.9	87.5
I_2	253.8	457.6	Kr	83.8	120.9
			Xe	131.3	166.1

1. LONDON DISPERSION FORCES

Strength of LDF depends on:

Molecule size:

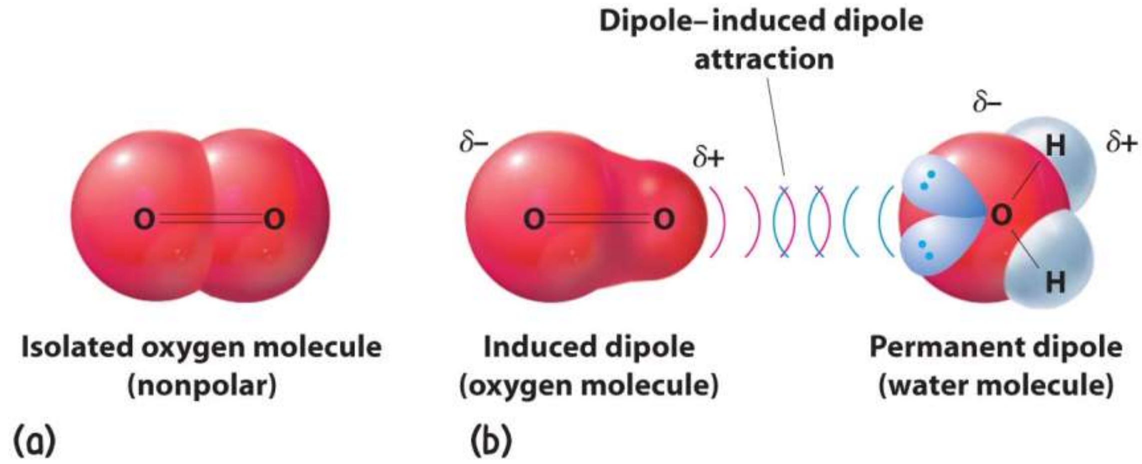
- Dispersion force attractions exist all along the regions where two elongated molecules are close (the forces are additive)



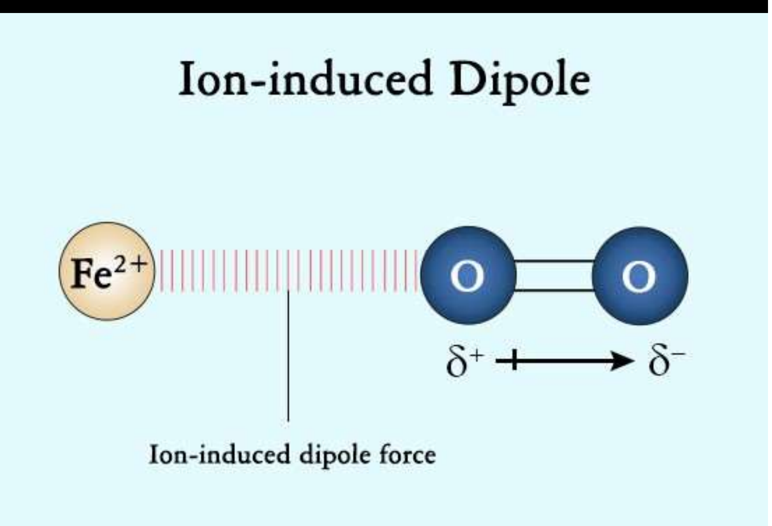
2. DIPOLE-INDUCED DIPOLE FORCES

- Attraction between a polar and a non-polar molecule

- Attraction comes from a *permanent* dipole inducing a *temporary* dipole in a neighbouring non-polar molecule



3. ION-INDUCED DIPOLE FORCES



- Attraction between an ion and a non-polar molecule

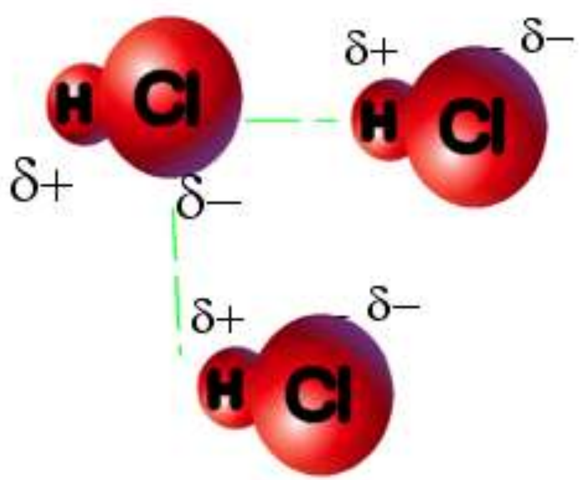
- Attraction comes from a *charged molecule* inducing a *temporary* dipole in a neighbouring non-polar molecule

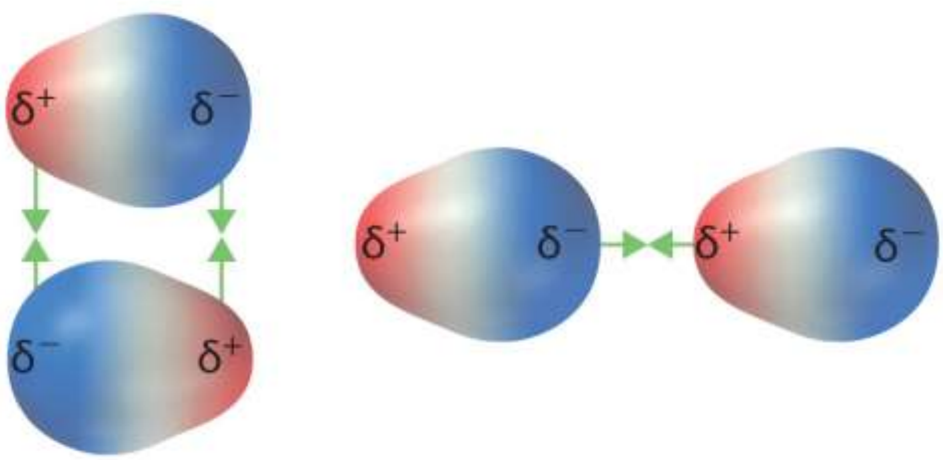
4. DIPOLE-DIPOLE FORCES

- Attraction between polar molecules

- Molecules with dipoles are characterized by oppositely charged ends that are due to an unequal distribution of charge on the molecule

•Polarity is determined by both the polarity of the bond & the shape of the molecule





(a) Attraction (b) Attraction

4. DIPOLE-DIPOLE FORCES

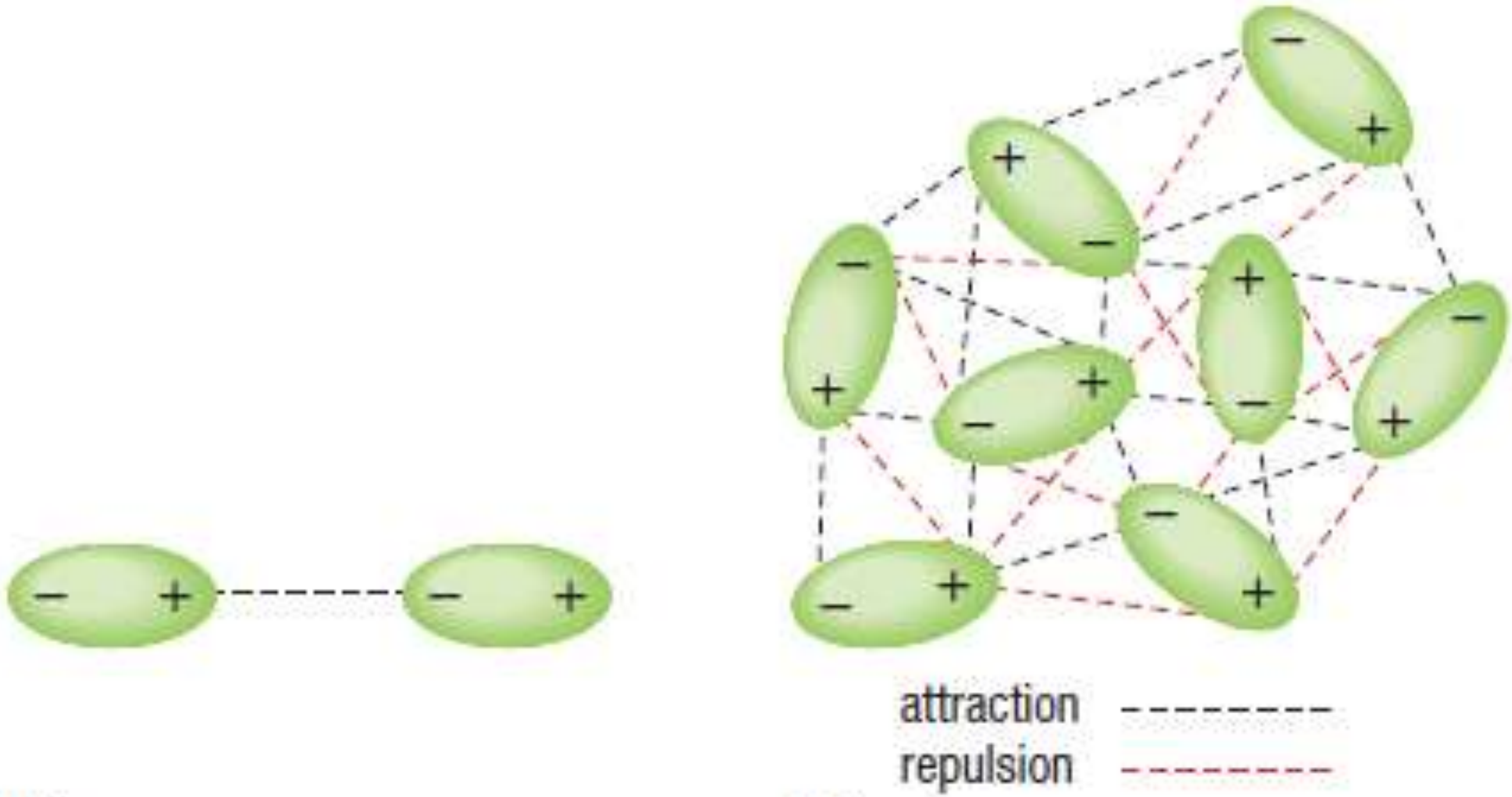
- Based on the simultaneous attraction of the electrons of one dipole by the dipoles of neighbouring molecules

- Strength of the force is related to polarity of the given molecule

Which molecule will make stronger dipole-dipole forces?

I—Cl	I—F
2.5 3.0	2.5 4.0
ΔEN = 0.5	ΔEN = 1.5

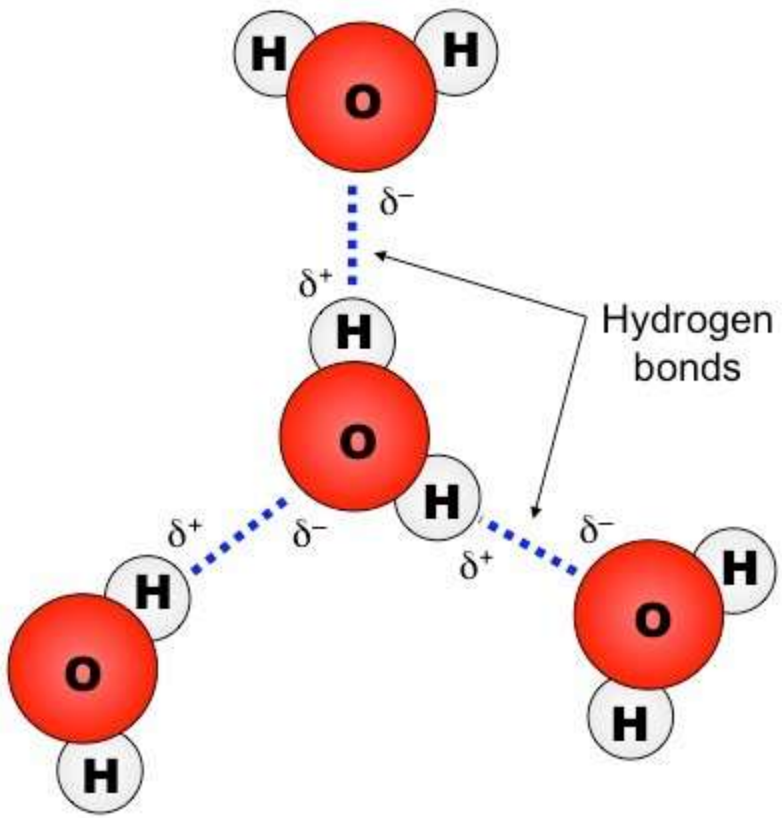
4. DIPOLE-DIPOLE FORCES

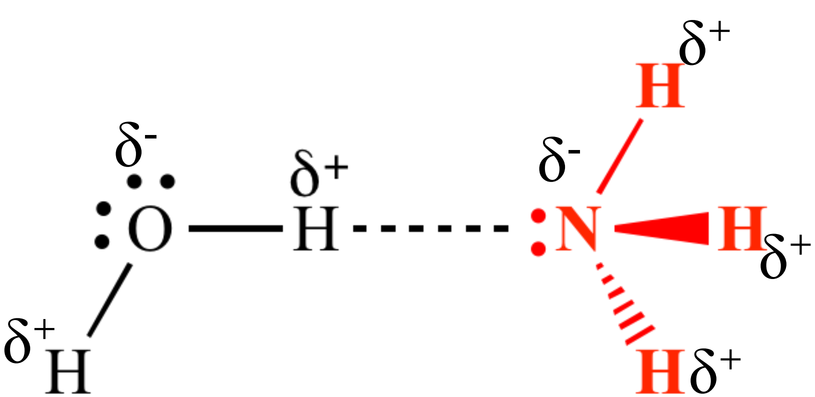


(a)

(b)

5. HYDROGEN BONDS





- strong dipole-dipole bonds

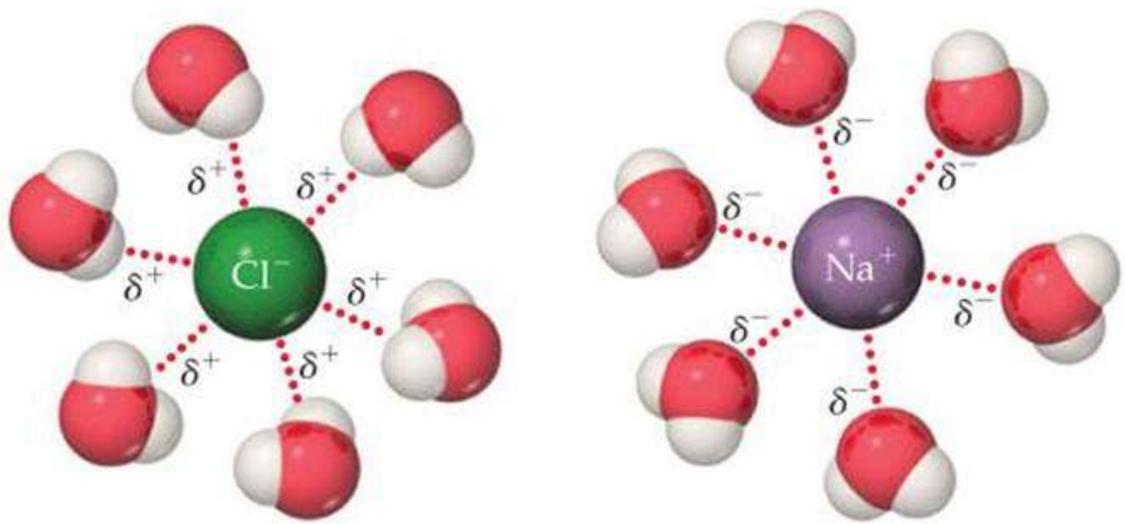
- exist between molecules with oxygen, nitrogen, and/or fluorine bound to hydrogen.

-O, N, and F are very electronegative and pull electrons shared with hydrogen towards themselves, producing an unusually strong dipole.

6. DIPOLE-ION BONDS

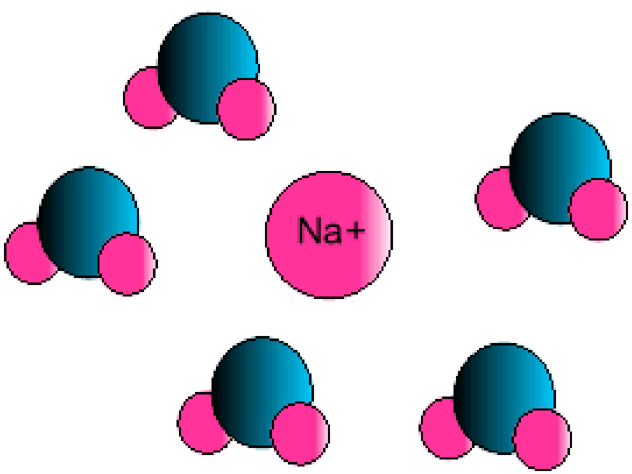
- attraction between an ion and a polar molecule

- the partial charges (dipoles) of polar molecules exert attraction for charged particles



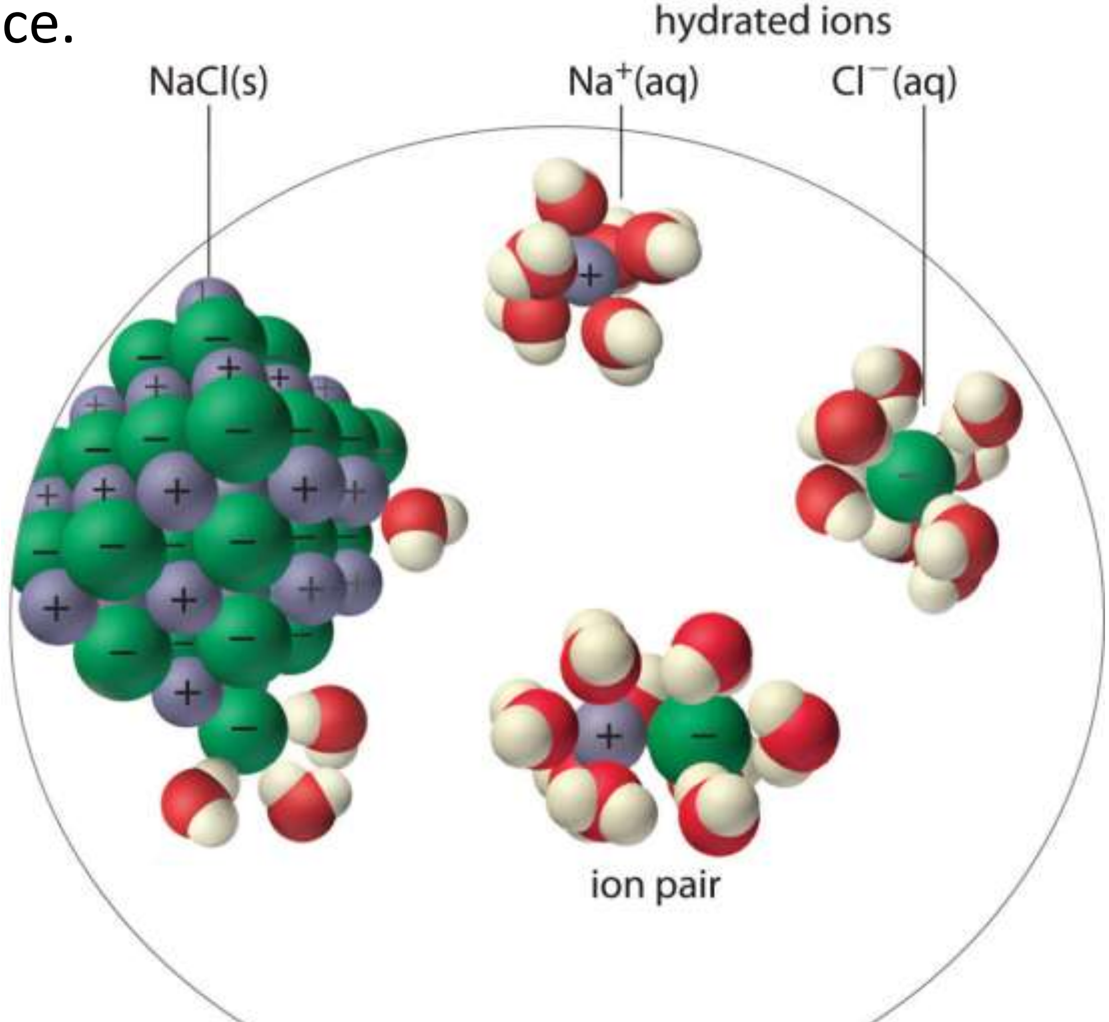
Positive ends of polar molecules are oriented toward negatively charged anion

Negative ends of polar molecules are oriented toward positively charged cation

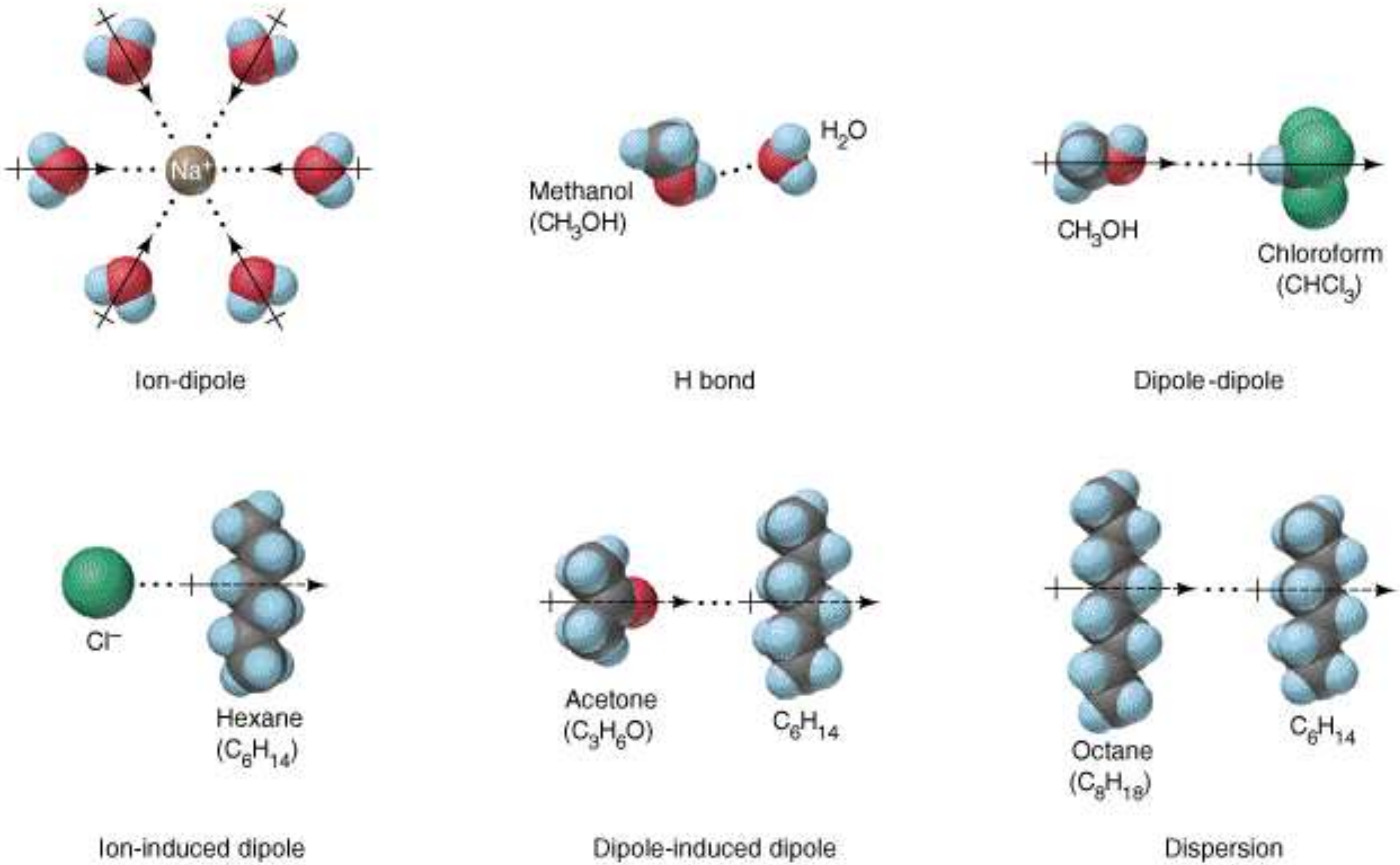


6. DIPOLE-ION BONDS

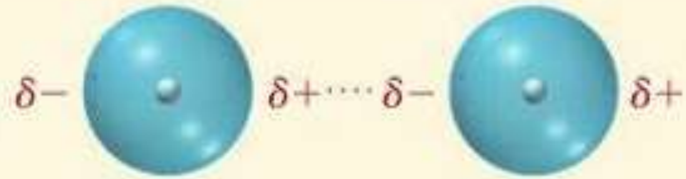
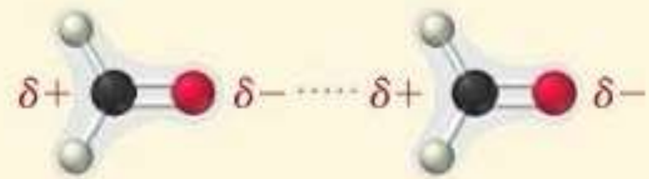
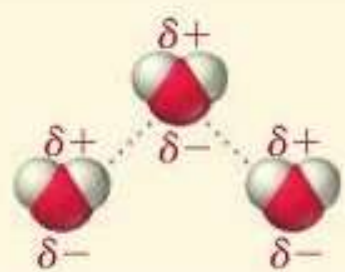
The strength and number of ion-dipole bonds determines if they can overcome the stronger ionic attraction between the positive and negative ions, and determine if an ionic compound is soluble in the polar substance.



SUMMARY OF INTERMOLECULAR FORCES



SUMMARY OF INTERMOLECULAR FORCES

Type	Present in	Molecular perspective	Strength
Dispersion	All molecules and atoms		
Dipole–dipole	Polar molecules		
Hydrogen bonding	Molecules containing H bonded to F, O, or N		

PROPERTIES BASED ON INTERMOLECULAR FORCES

Intermolecular forces affect:

- Melting point
- Boiling point
- Capillary action
- Surface tension
- Solubility

PREDICTING BOILING POINTS

- Molecules that are isoelectronic (same # of electrons) have the same strength of London dispersion forces

- More polar molecules have stronger dipole – dipole interaction → Higher melting & boiling points

- The more electrons per molecule, the stronger the London forces & the higher the melting & boiling point

Boiling points of hydrides

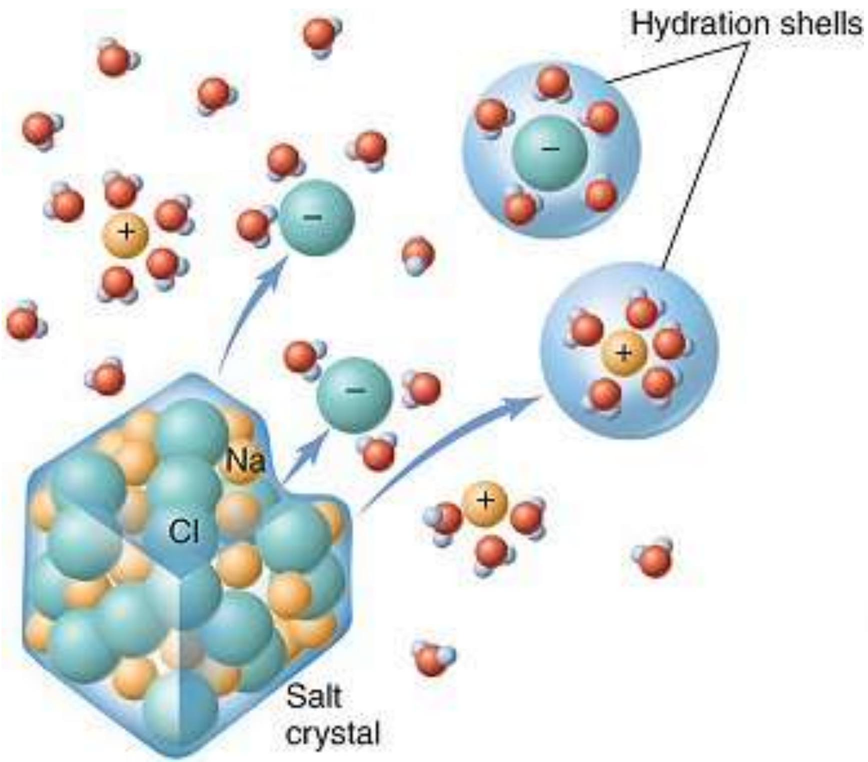
Those in red illustrate hydrogen bonding

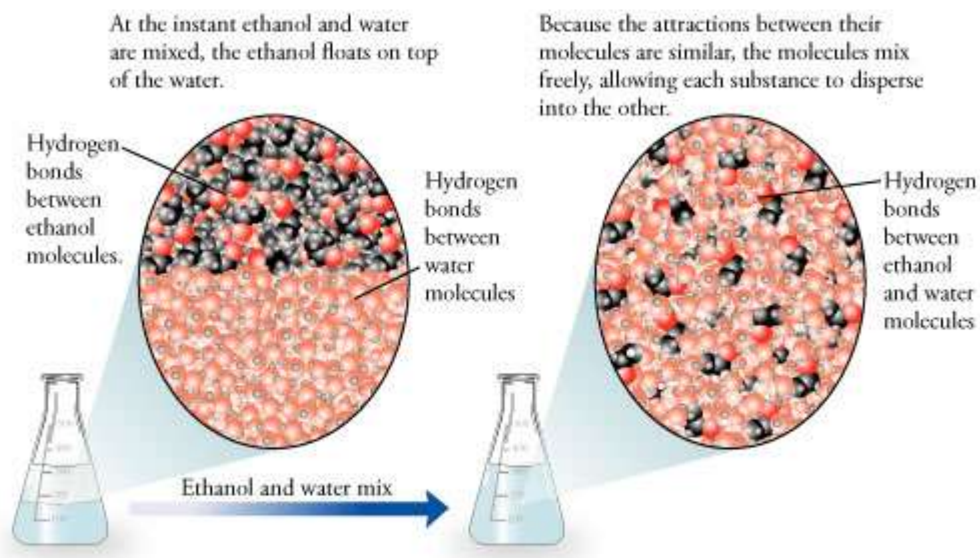
	Mr	°C
CH_4	16	-161
SiH_4	32	-117
GeH_4	77	-90
SnH_4	123	-50
NH_3	17	-33
PH_3	34	-90
AsH_3	78	-55
SbH_3	125	-17

	Mr	°C
H_2O	18	+100
H_2S	34	-61
H_2Se	81	-40
H_2Te	130	-2
HF	20	+20
HCl	36.5	-85
HBr	81	-69
HI	128	-35

POLARITY AND SOLUBILITY

- Solution is formed when a solute dissolves in solvent
- Solution formation is independent on the intermolecular forces of all molecules involved
- Remember: ‘Like Dissolves Like’

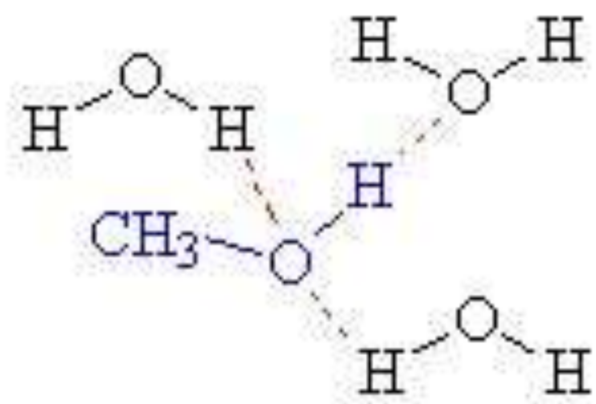




SOLUBILITY: COVALENT MOLECULES

- Polar liquids dissolve in other polar liquids
  - Share same type of intermolecular forces

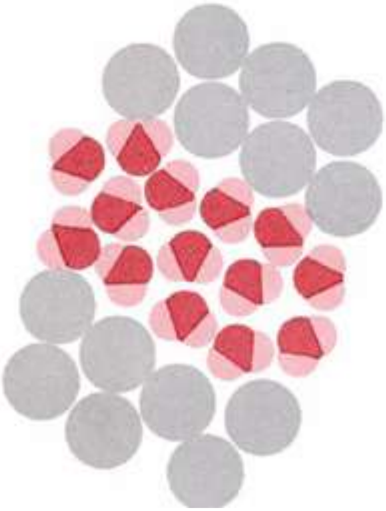
- Example: methanol in water
  - Both have hydrogen bonds between each



Methanol (in blue) is attracted to the water molecules (black) through hydrogen bonds (red).

SOLUBILITY: COVALENT MOLECULES

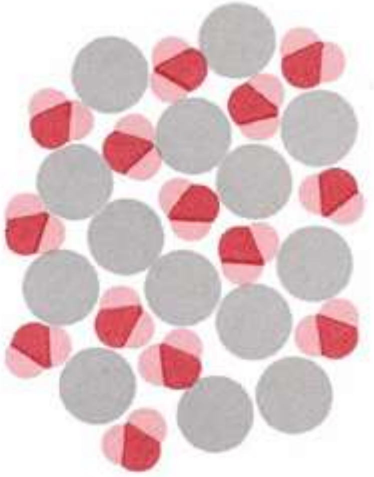
- Example: carbon tetrachloride in water
  - Will not dissolve as it is nonpolar & does not contain the same intermolecular forces



CCl_4 in water

- Solids behave similarly to liquids

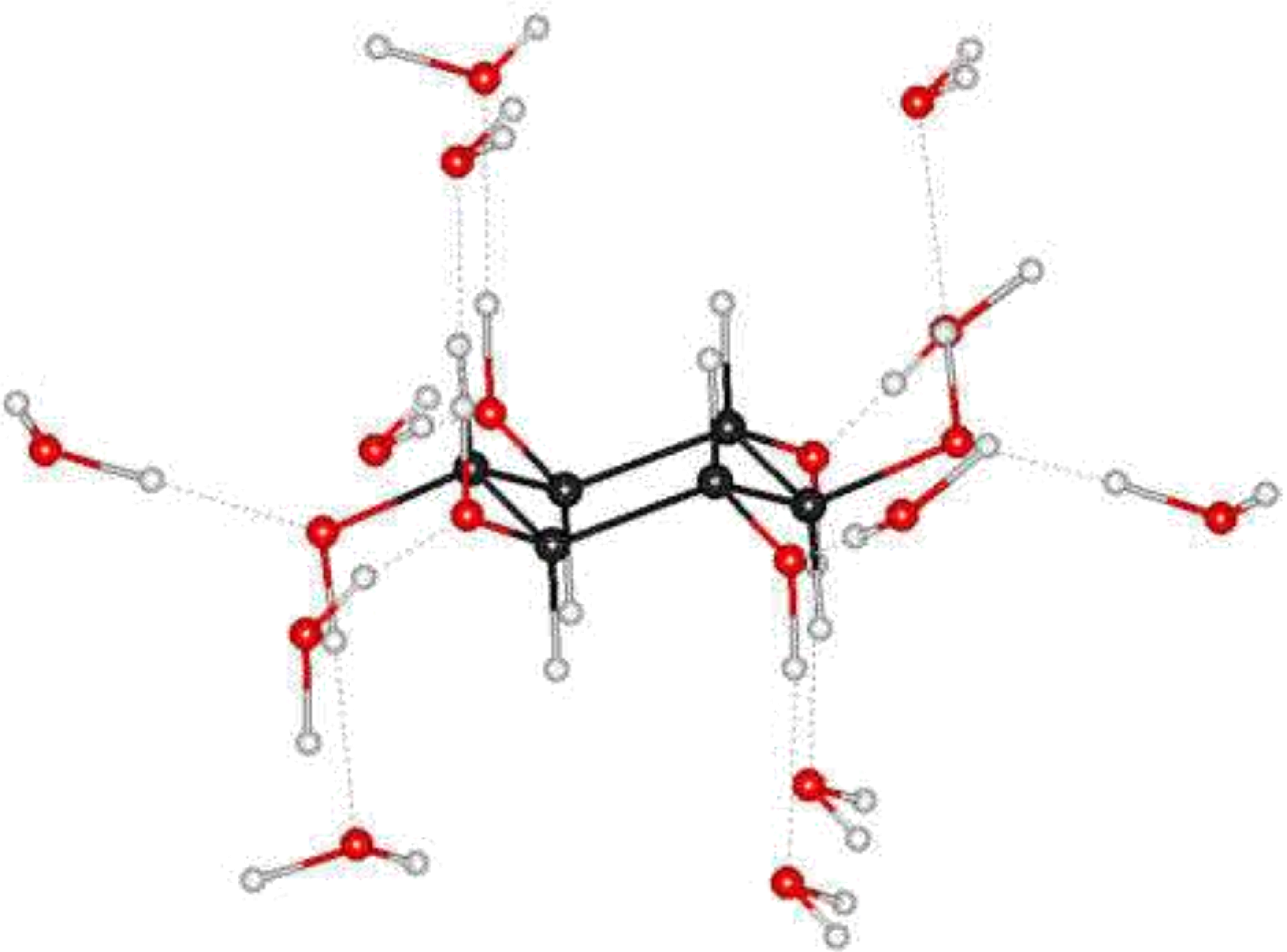
- Example: sugar in water
  - Sugar is slightly polar (H bonds) & dissolves in water (H bonds)



sugar in water

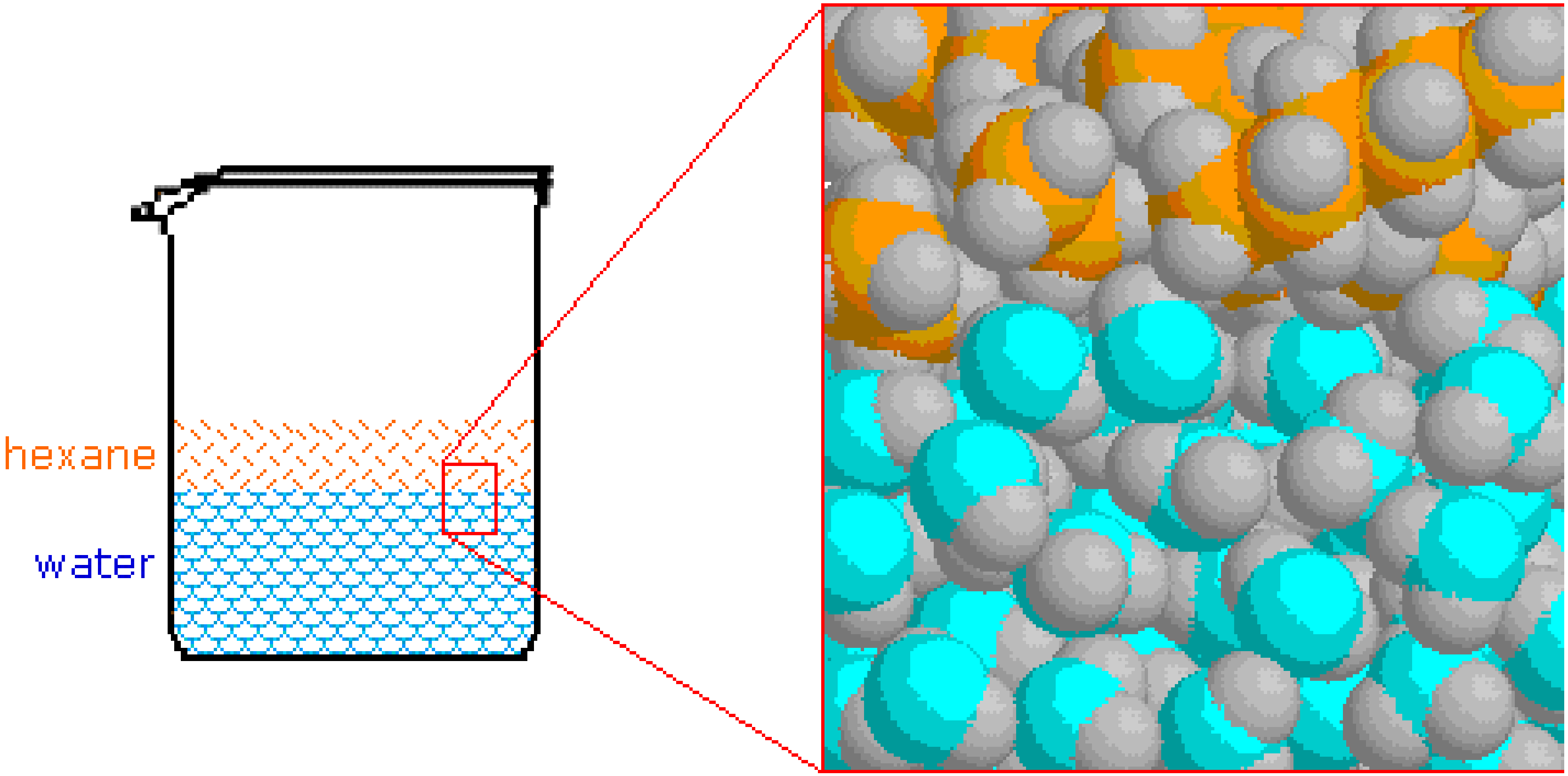
SOLUBILITY: COVALENT MOLECULES

Soluble: Sugar (glucose) in water



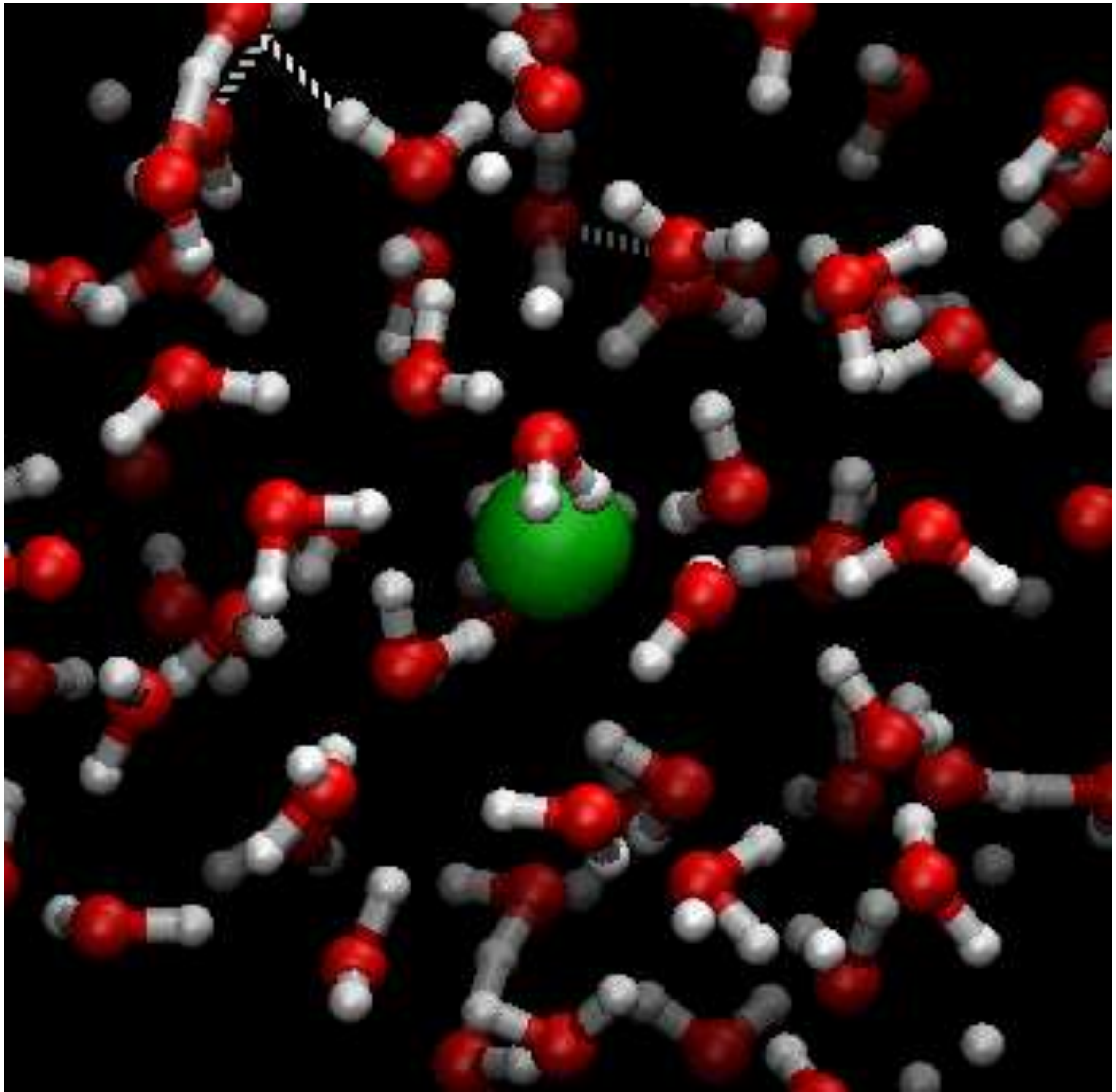
SOLUBILITY: COVALENT MOLECULES

Insoluble: Hexane in water



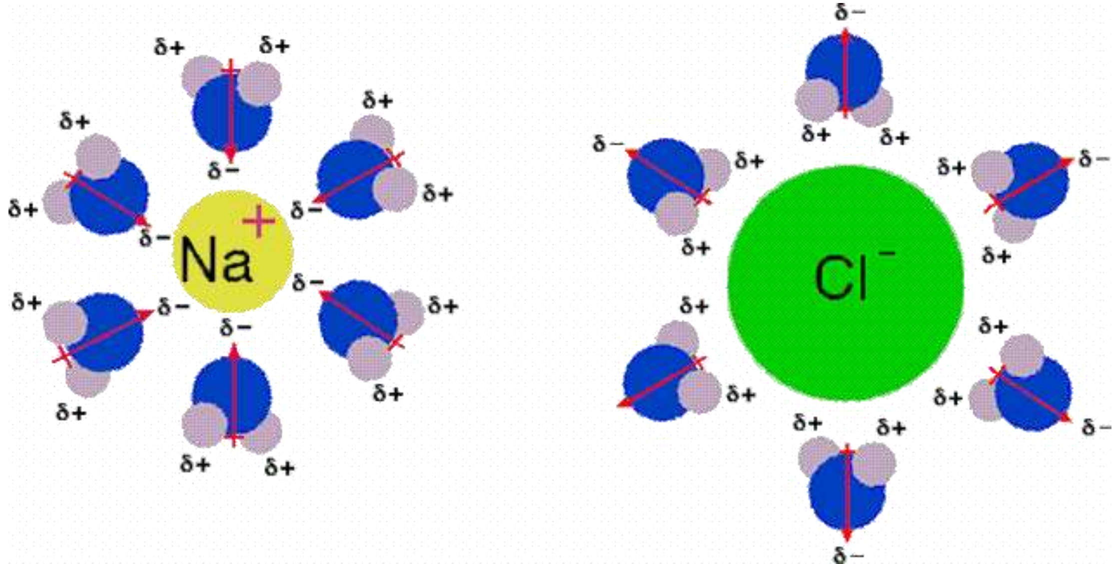
SOLUBILITY: COVALENT MOLECULES

Water preferentially forms H-bonds with other water molecules than induced-dipole forces with non-polar molecules.

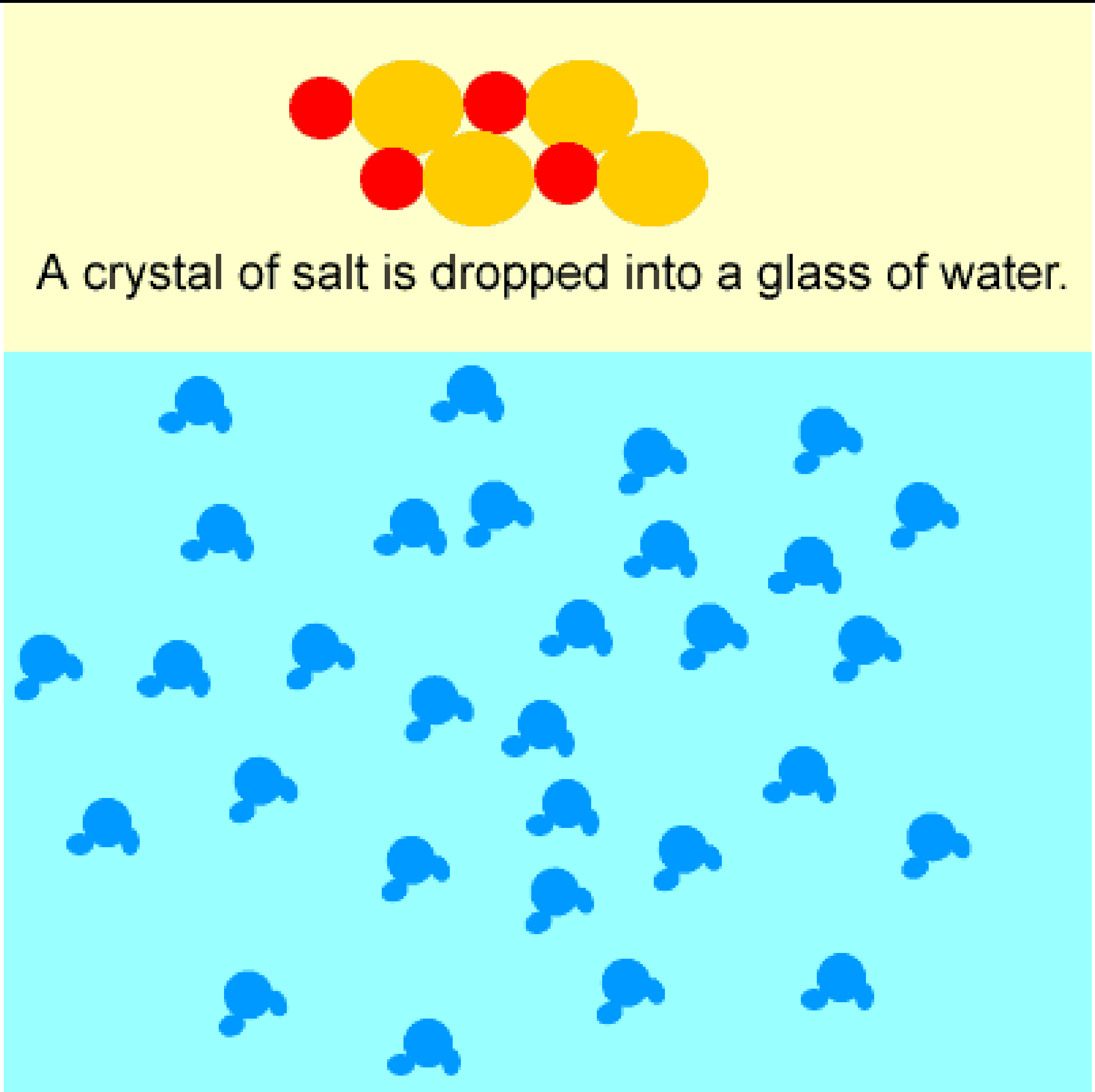


SOLUBILITY: IONIC MOLECULES

- Rarely soluble in nonpolar or low polar solvents
- Sometimes soluble in water
- Example: NaCl
  - Consists of Na+ & Cl- ions
  - When placed in water the partial negative charges from O in the water are attracted to the Na+
  - Partial positive charge from H is attracted to Cl-



SOLUBILITY: IONIC MOLECULES

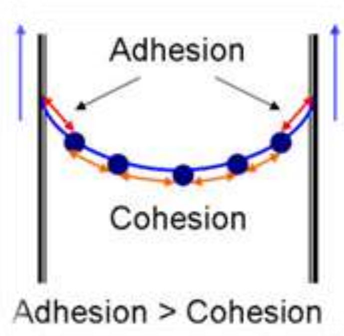


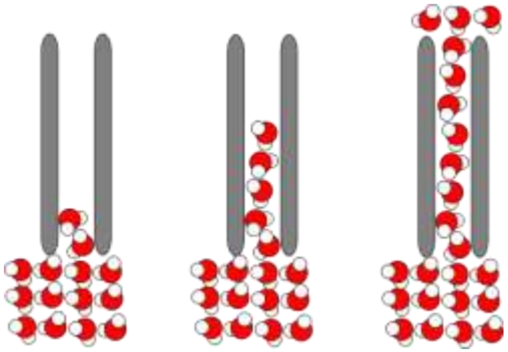
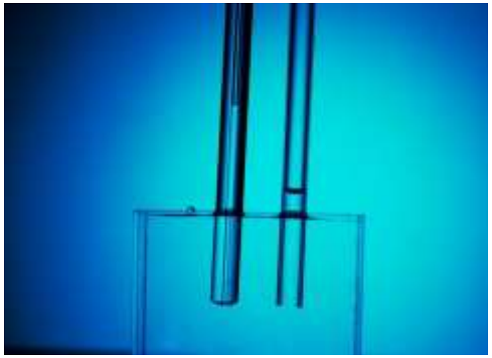
OTHER PHYSICAL PROPERTIES

- Surface tension

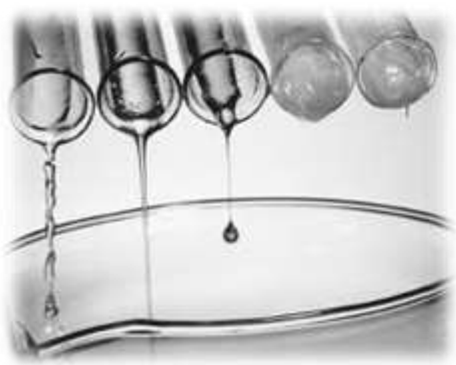


- Capillary action



- Viscosity



Homework

- Page 247 #1 – 8
- Complete pre-lab for access to lab tomorrow