States of Matter and IMF

AP Chemistry – Unit 7

Learning Goals

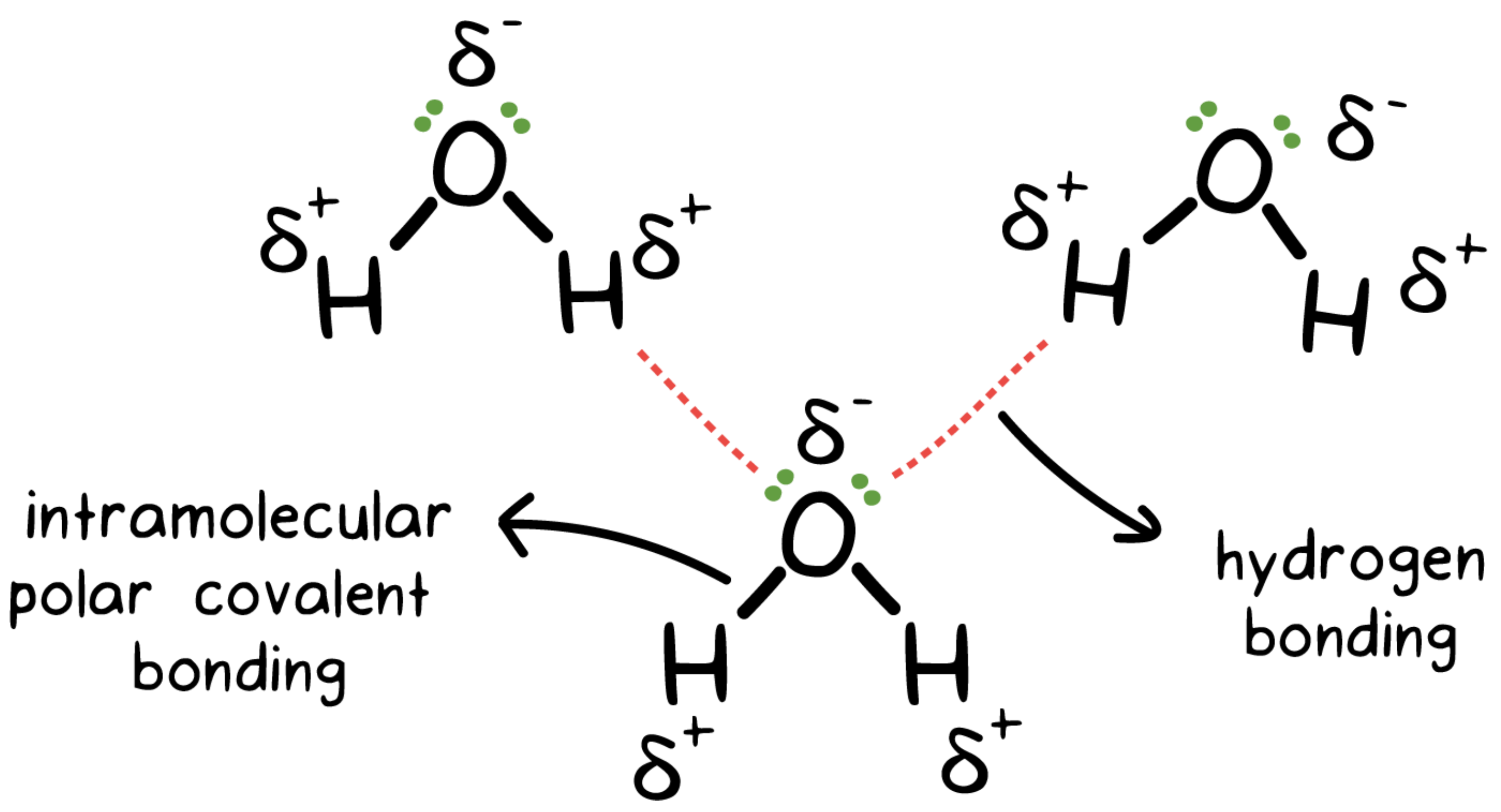
- Utilize particulate diagrams to identify different states of matter and determine type(s) of intermolecular forces of attraction
- Identify intramolecular attractions (bond type), polarity of molecules and intermolecular attractions making use of Coulomb’s law to determine strength
- Apply knowledge of bonding and intermolecular attractive forces to explain physical properties such as evaporation, solubility, melting points, boiling points, vapor pressures and physical states of matter.
- Identify intramolecular attractions (bond type), polarity of molecules and intermolecular attractions making use of Coulomb’s law to determine strength
- Apply knowledge of bonding and intermolecular attractive forces to explain physical properties such as evaporation, solubility, melting points, boiling points, vapor pressures and physical states of matter
- Explain whether changes are physical or chemical according to types of attractive forces (intramolecular or intermolecular) that must be overcome
- Use separation techniques in the laboratory explaining results using intermolecular attractive forces

Intermolecular Forces

Intramolecular Forces vs. Intermolecular Forces

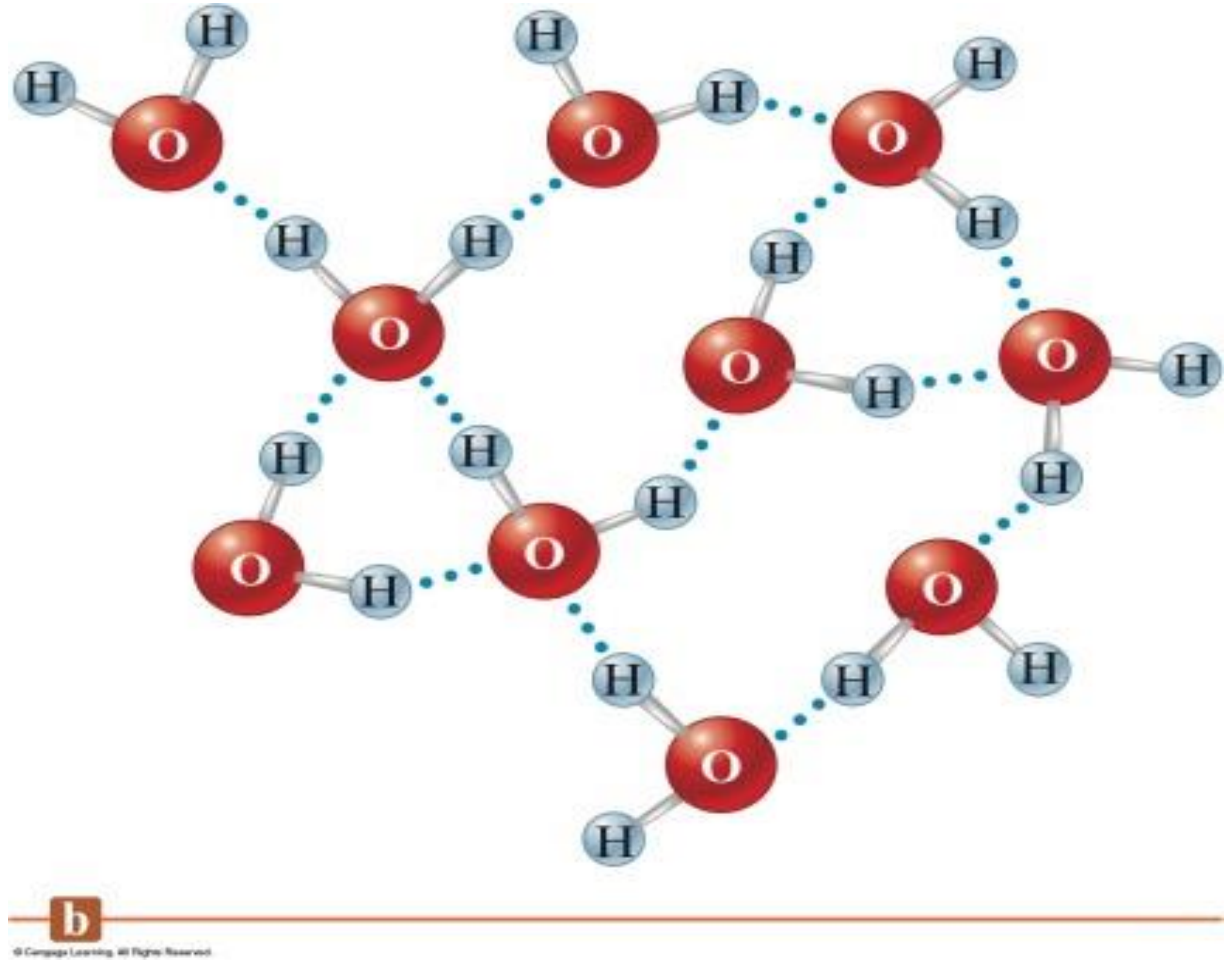
- **Intramolecular Forces**
  - Within the molecule
  - Molecules are formed by sharing or transfer of electrons between the atoms

- **Intermolecular Forces** – forces that hold one molecule to another molecule
  - These forces arise from the **unequal distribution of the electrons** in the molecule and the **electrostatic attraction between oppositely charged portions of a molecule**
  - Between molecules
    - Dipole-Dipole
    - Hydrogen Bonding
    - London Dispersion Forces



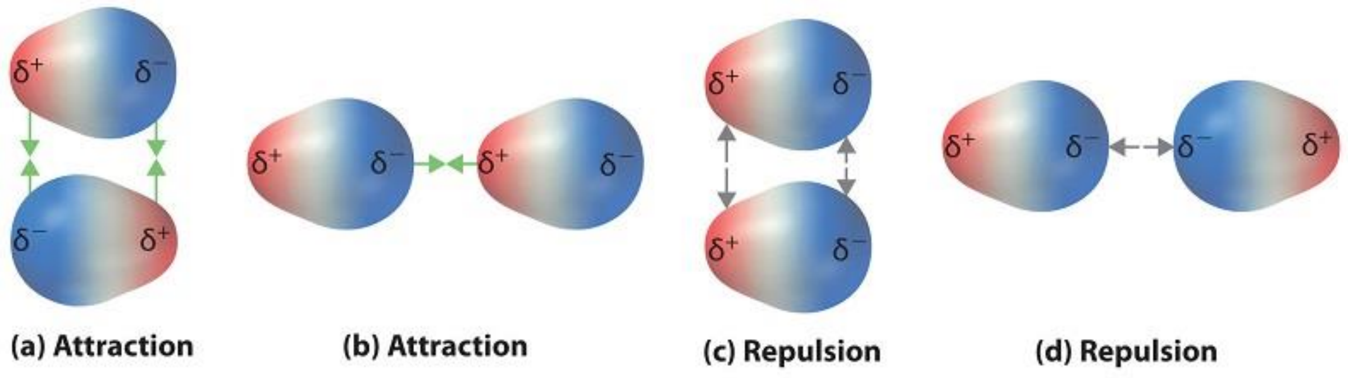
Intramolecular forces are stronger than intermolecular forces!

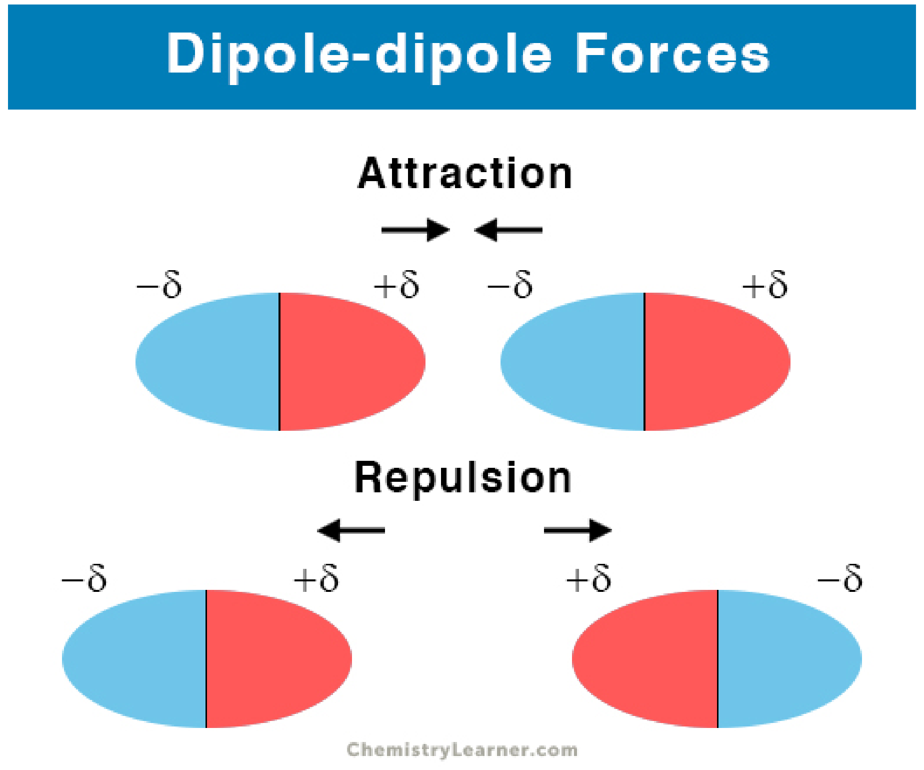
Dotted lines are the IMFs between the water molecules



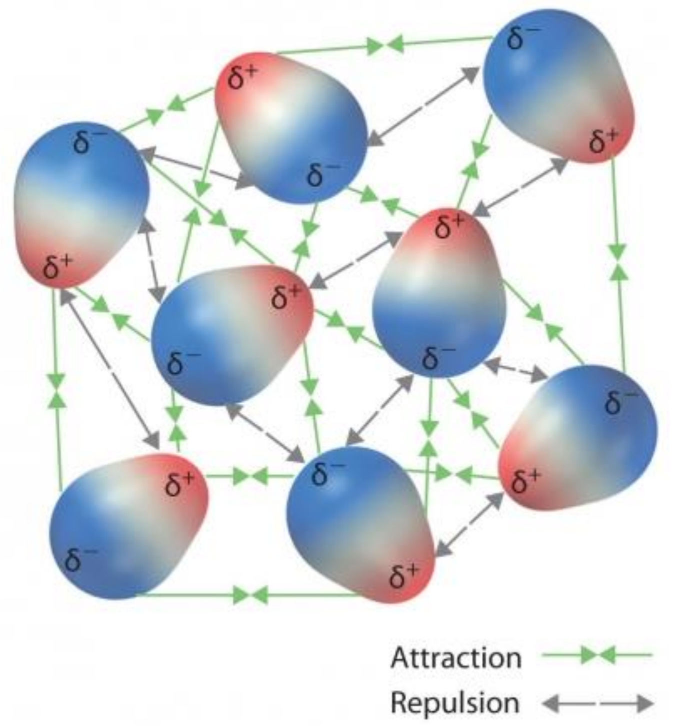
Intermolecular Forces

1. Dipole-Dipole Forces

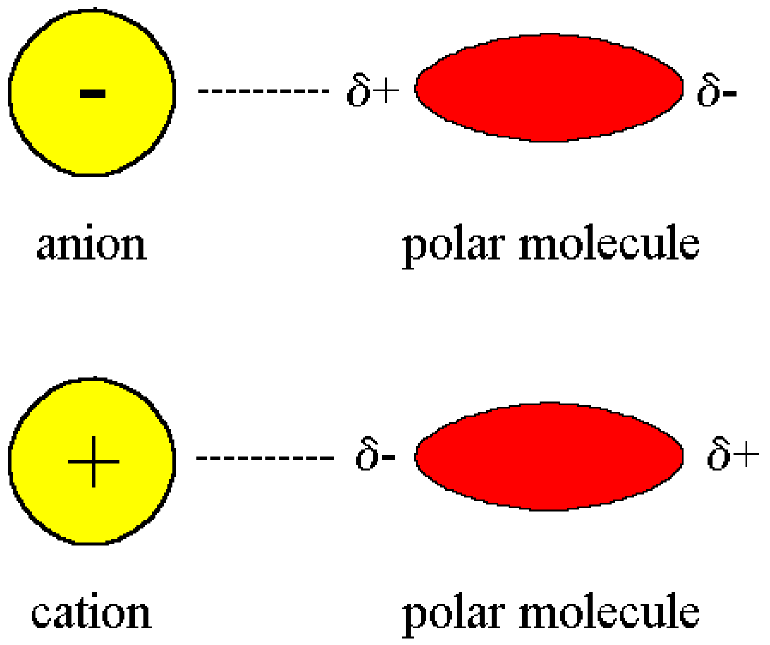




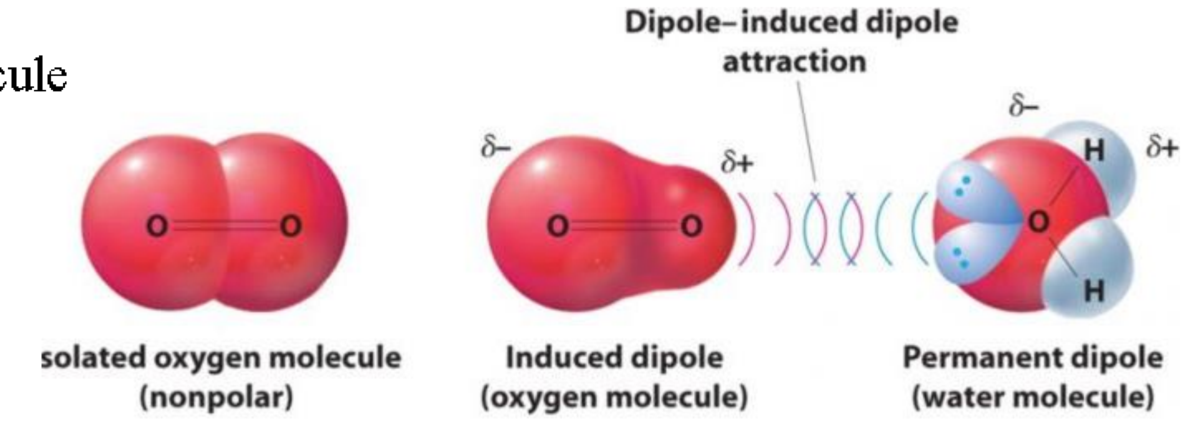
- **Dipole-Dipole**
  - Attractive forces between the **positive end of one polar molecule** and the **negative end of another polar molecule.**
  - They are much weaker than ionic or covalent bonds and have a significant effect only when the molecules involved are close together (touching or almost touching).
  - Molecules can attract each other electrostatically, lining up so that the positive and negative ends are close to each other
  - Only ~1% as strong as covalent or ionic bonds



- **Ion-induced dipole**
  - The attraction force between an **charged ion** and a **nonpolar molecule**
  - The ion induces the electron cloud of the nonpolar molecule and polarizes, forming a temporary dipole

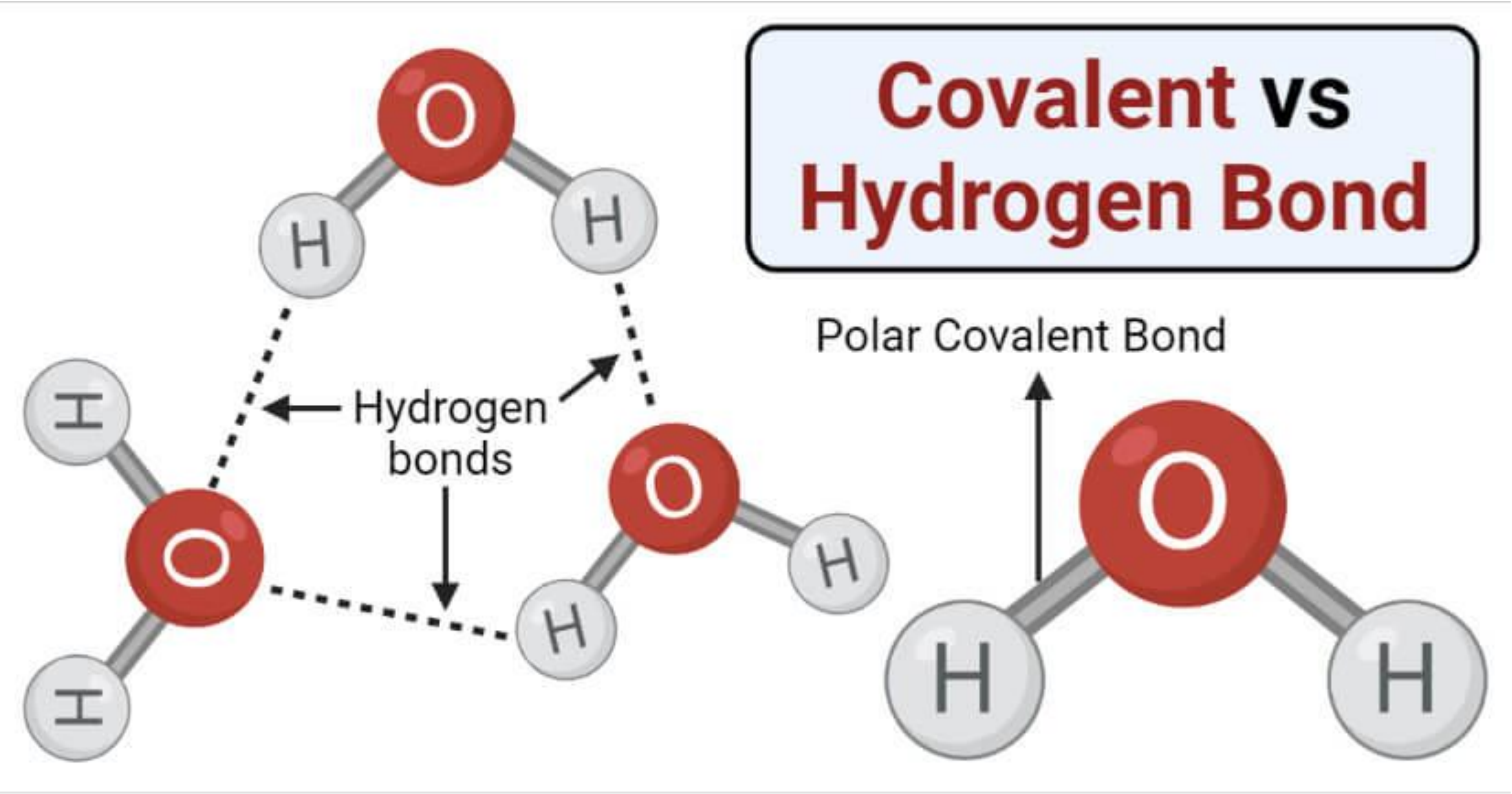


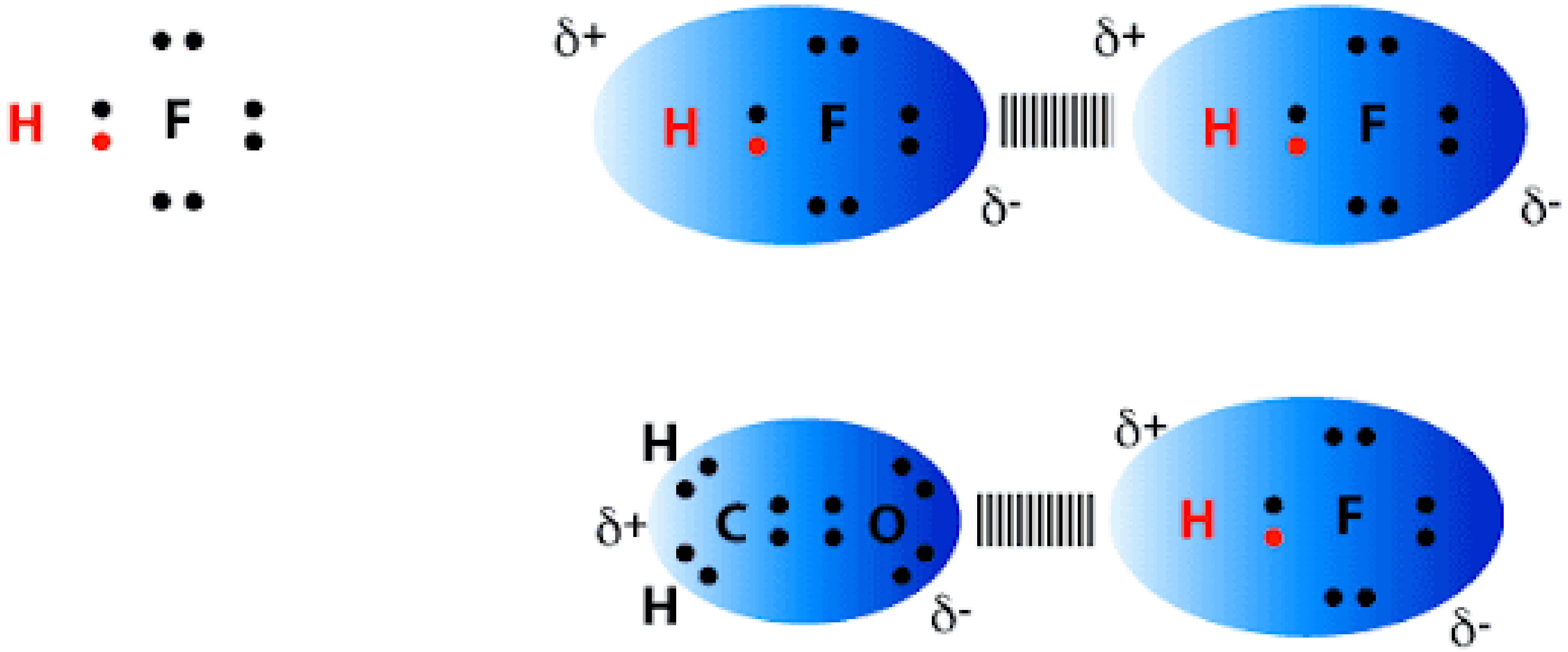
- **Dipole – Induced Dipole**
  - The attraction between a **polar molecule** and a **nonpolar molecule**
  - Large molecules are more polarizable than smaller molecules since they contain more electrons!



2. Hydrogen Bonding

- The force of **attraction between the hydrogen atom** of one molecules and an **unshared electron pair of electrons** F, O, or N of a neighboring molecule
- Strongest IMF
- Hydrogen is then electrostatically attracted to a lone pair on the electronegative atom or adjacent molecules



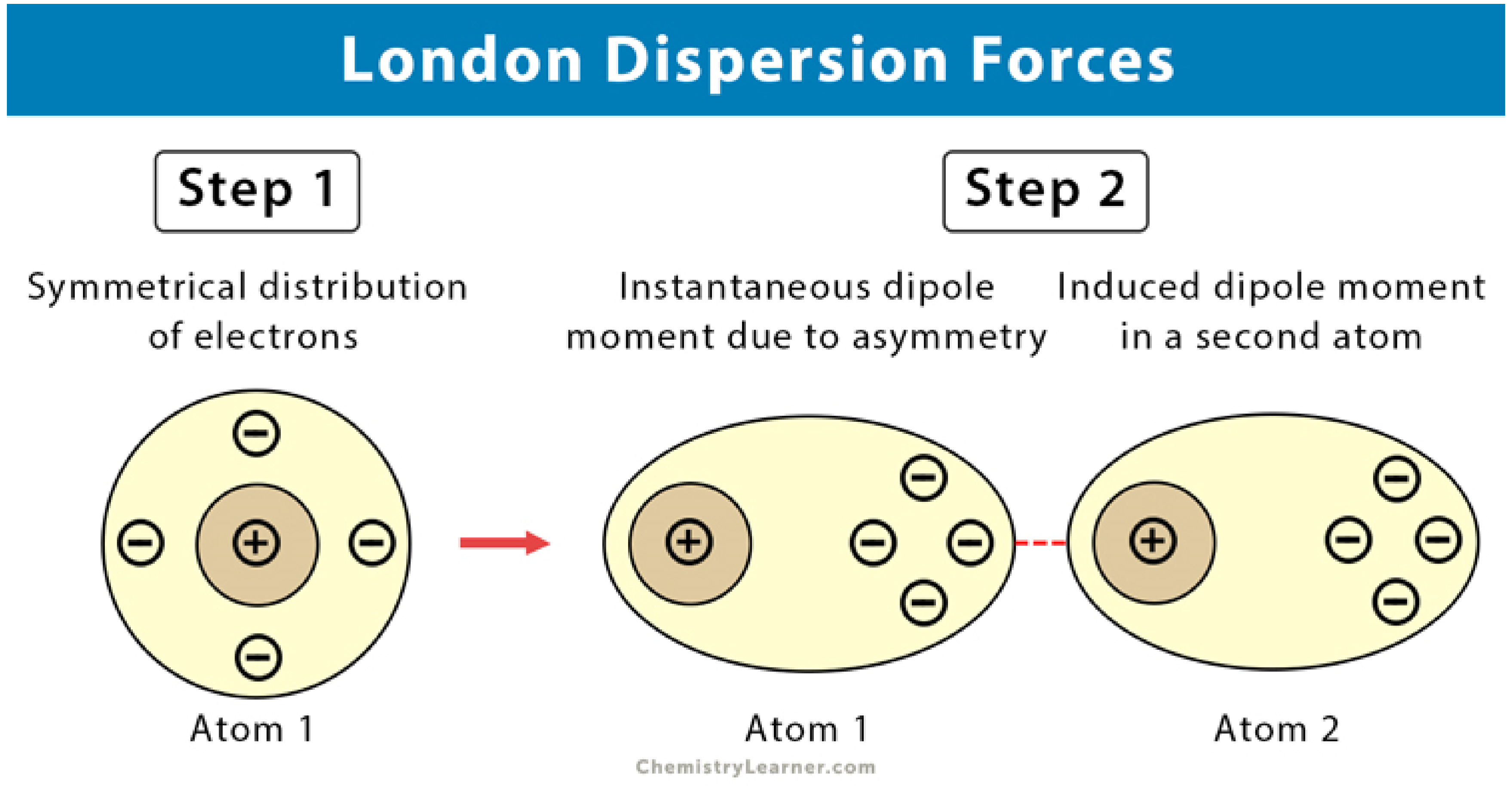


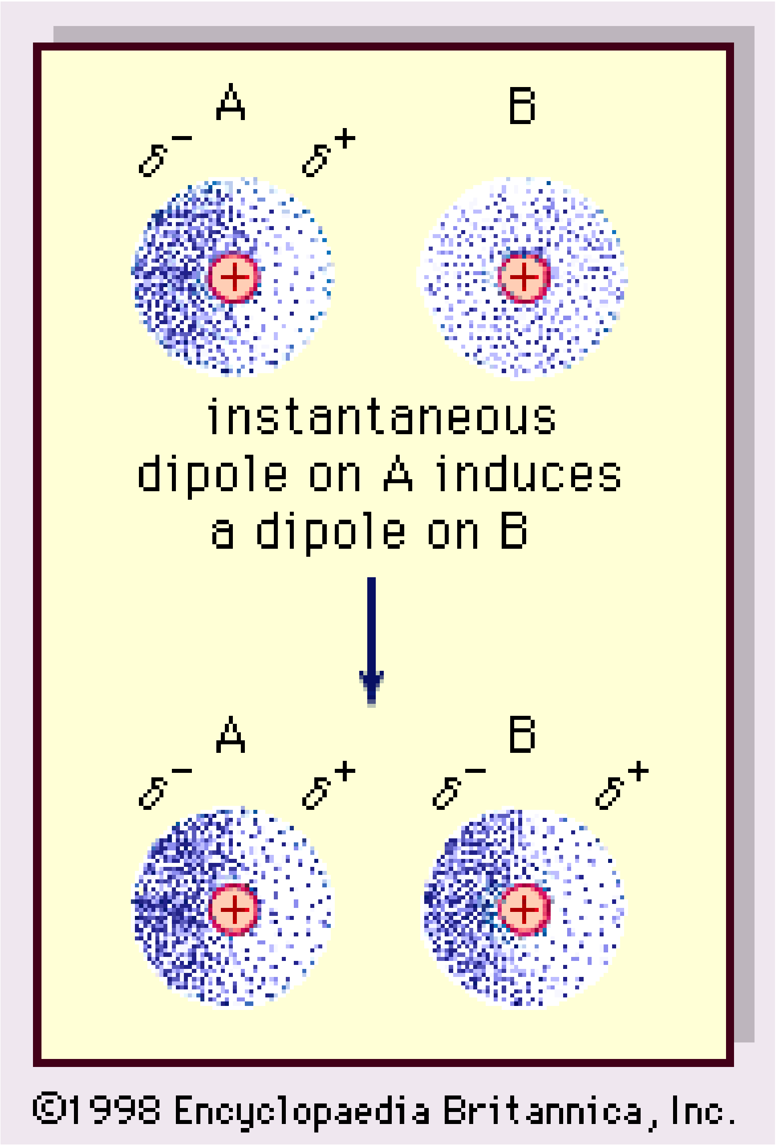
Intermolecular Forces

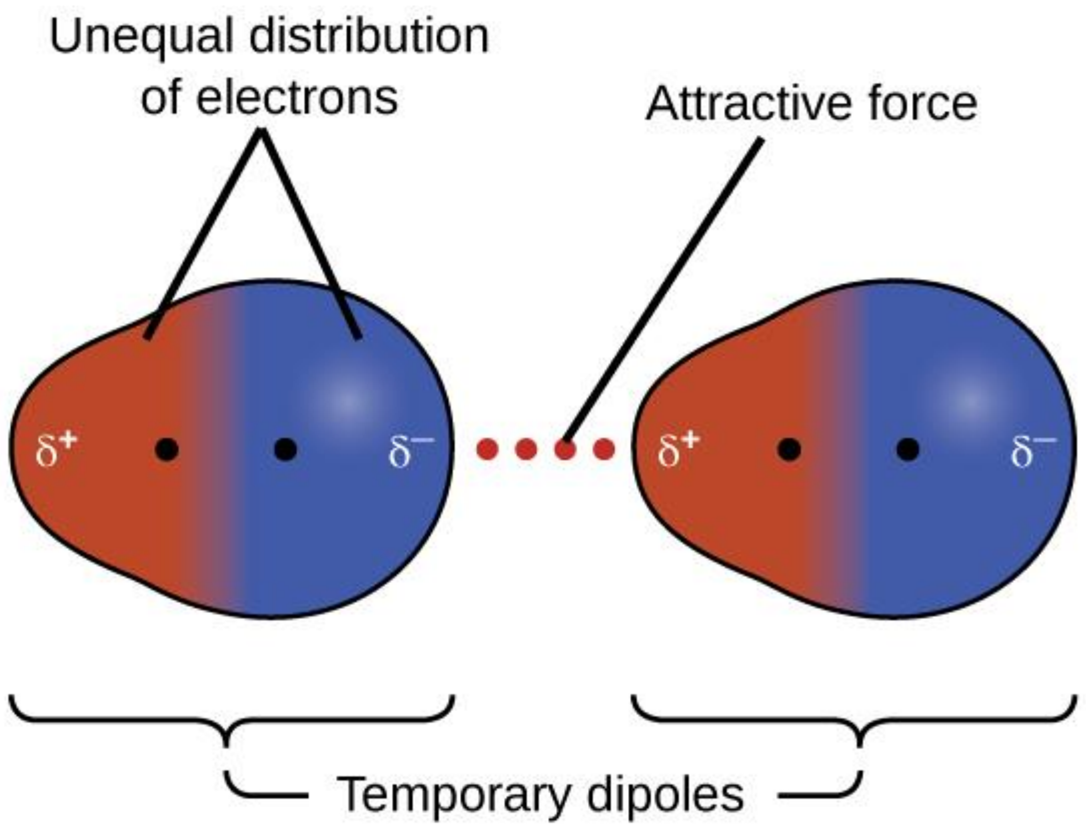
3. London Dispersion Forces – aka Van der Waal Forces

- Instantaneous dipole moments resulting from the motion of electrons inside an atom or molecule
- **ALL** atoms and molecules possess LDF
- LDF increases with the number of elections in the molecule
- Significant in large atoms/molecules
- Occurs in all molecules, including nonpolar
  - Primary force in nonpolar molecules

- **London dispersion forces** are due to the formation of **instantaneous dipole moments** in polar or nonpolar molecules as a result of short-lived fluctuations of electron charge distribution





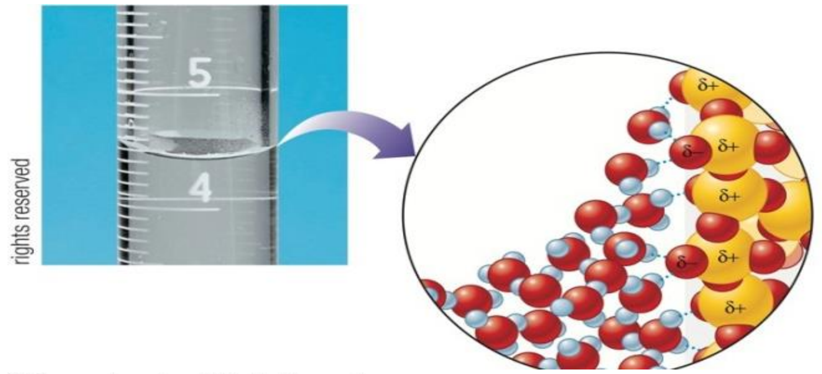


Summary of Intermolecular Forces

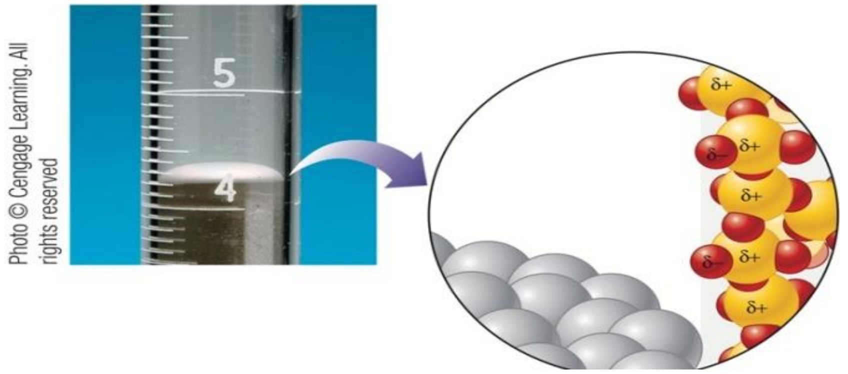
Force	Model	Basis of Attraction	Energy (kJ/mol)	Example
Nonbonding (Intermolecular)				
Ion-dipole		Ion charge–dipole charge	40–600	$Na^{+}\cdots O$(H)(H)
H bond	$\overset{\delta^-}{-A}-\overset{\delta^+}{H}\cdots\cdots:\overset{\delta^-}{B}-$	Polar bond to H–dipole charge (high EN of N, O, F)	10–40	:Ö(H)—H····:Ö(H)—H
Dipole-dipole		Dipole charges	5–25	I—Cl····I—Cl
Ion–induced dipole		Ion charge–polarizable e^- cloud	3–15	$Fe^{2+}\cdots O_2$
Dipole–induced dipole		Dipole charge–polarizable e^- cloud	2–10	H—Cl····Cl—Cl
Dispersion (London)		Polarizable e^- clouds	0.05–40	F—F····F—F

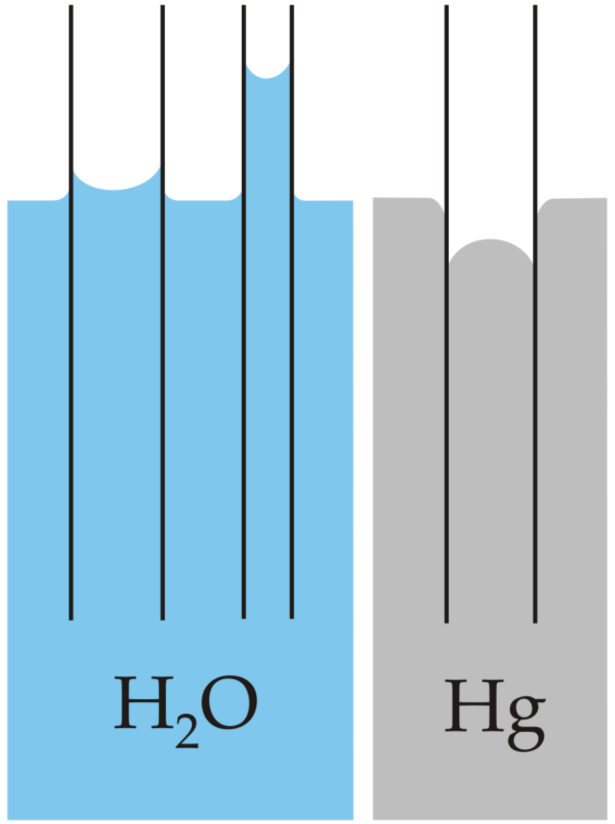
Liquid State - IMF

Concave Meniscus Formed
By Polar water molecules



Convex Meniscus Formed
By Nonpolar Liquid Mercury

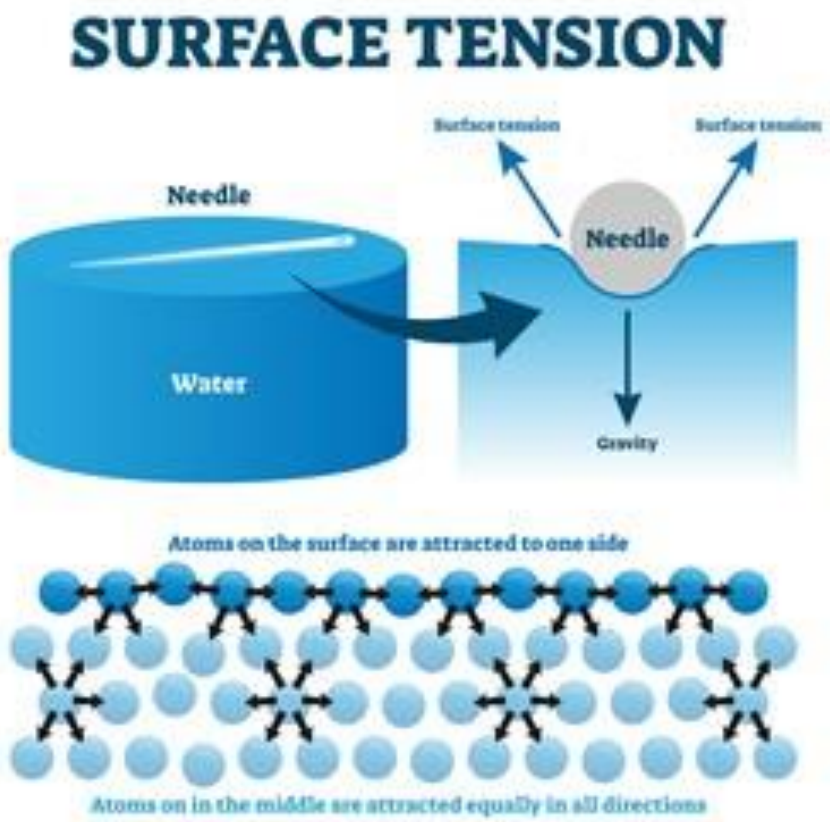




Liquids

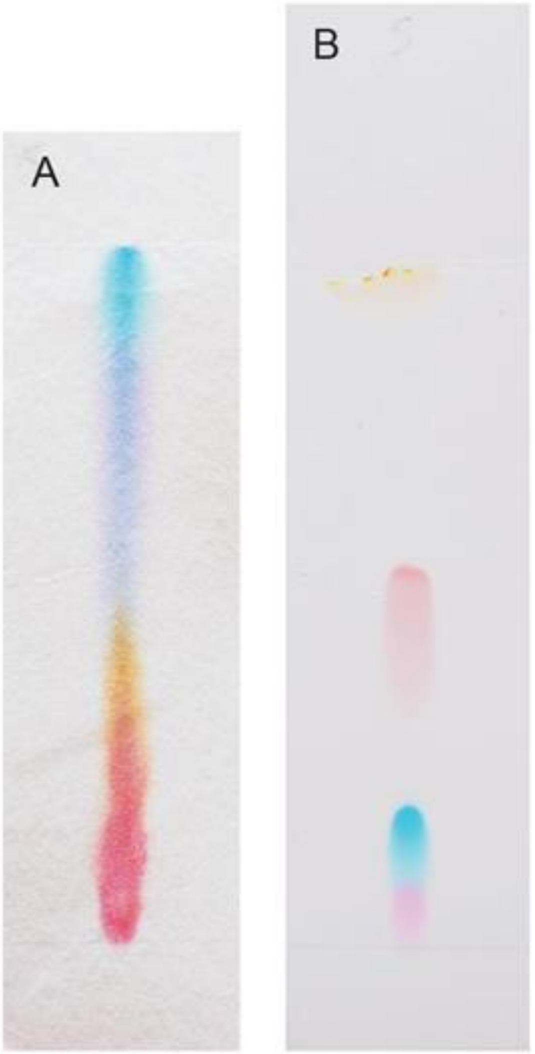
- Low compressibility, lack of rigidity, and high density compared with gases.

All Three properties are GREATER for liquids composed of polar molecules since their IMF's are greater than nonpolar molecules



- **Surface tension** – resistance of a liquid to an increase in its surface area
  - Liquids with large intermolecular forces tend to have high surface tensions.

- **Capillary action** – spontaneous rising of a liquid in a narrow tube:
  - Cohesive forces – IMF among the molecules of the liquid.
  - Adhesive forces – IMF between the liquid molecules and their container.
  - Used in Chromatography



- **Viscosity** – measure of a liquid's resistance to flow:
  - Liquids with large intermolecular forces or molecular complexity tend to be highly viscous.

Molecular Size affect on IMF

London Dispersion forces are present between **all** molecules, whether they are polar or nonpolar

- Larger and heavier atoms and molecules exhibit stronger dispersion forces than smaller and lighter ones.
- In a larger atom or molecule, the valence electrons are, on average, farther from the nuclei than in a smaller atom or molecule. They are less tightly held and can more easily form temporary dipoles.
- The ease with which the electron distribution around an atom or molecule can be distorted is called the ***polarizability***.

London dispersion forces tend to be:

- stronger between molecules that are easily polarized

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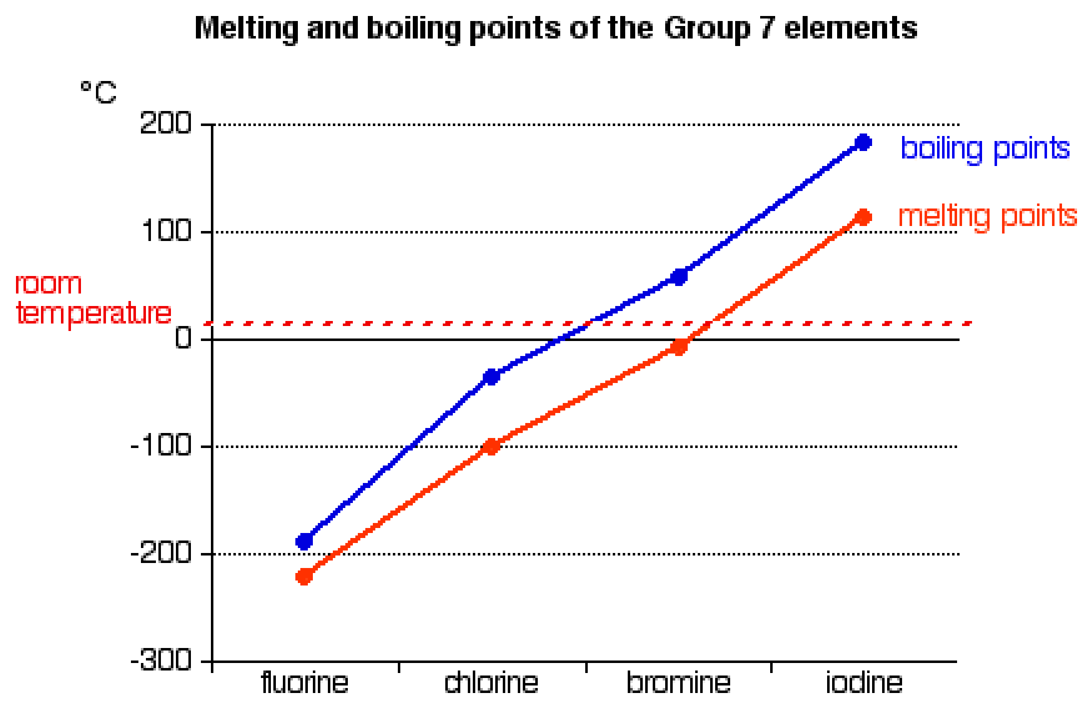
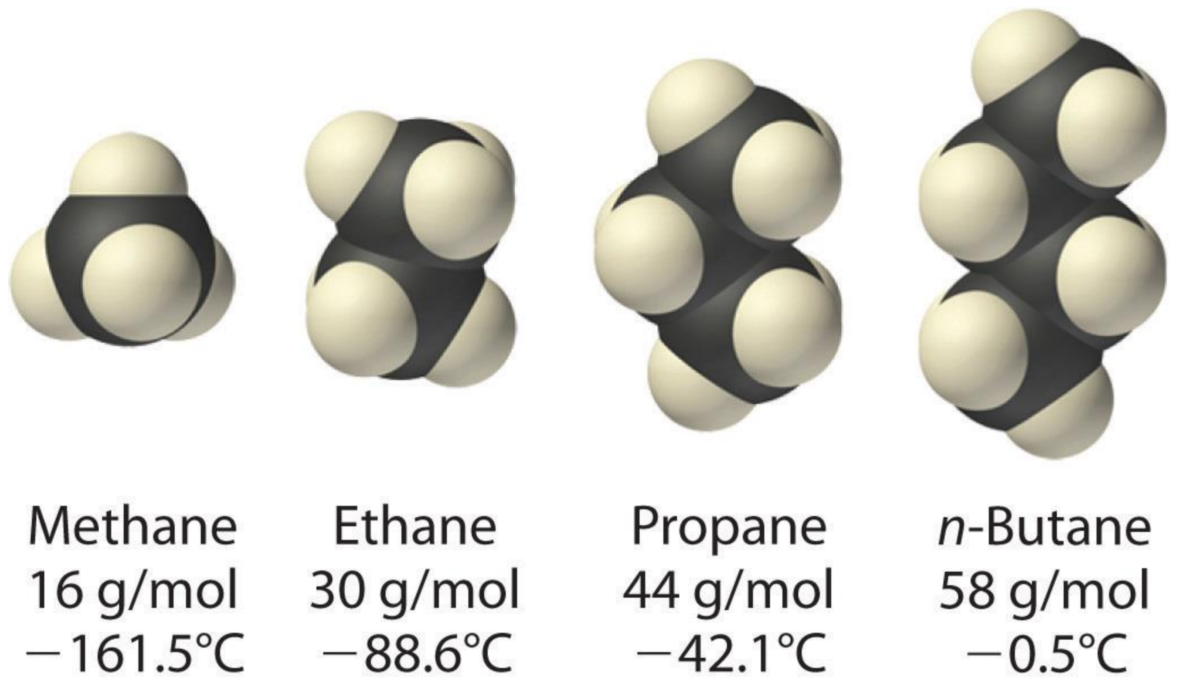
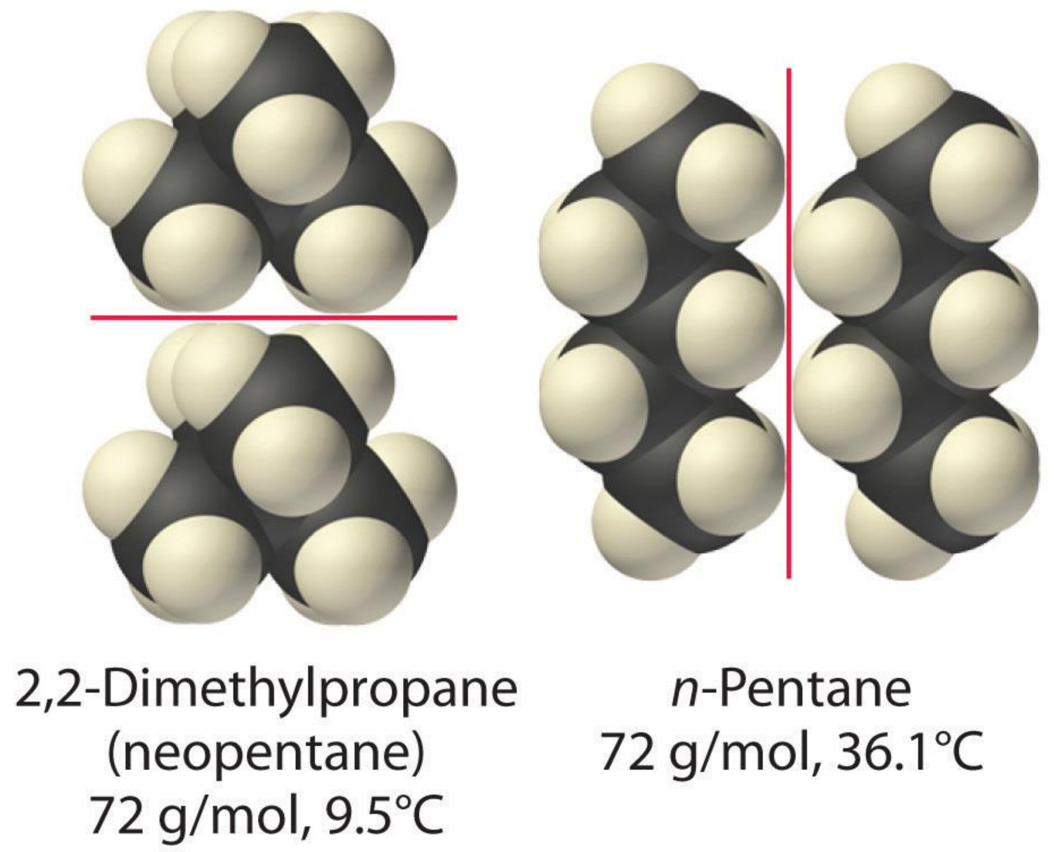
- weaker between molecules that are not easily polarized





(a) Increasing mass and boiling point

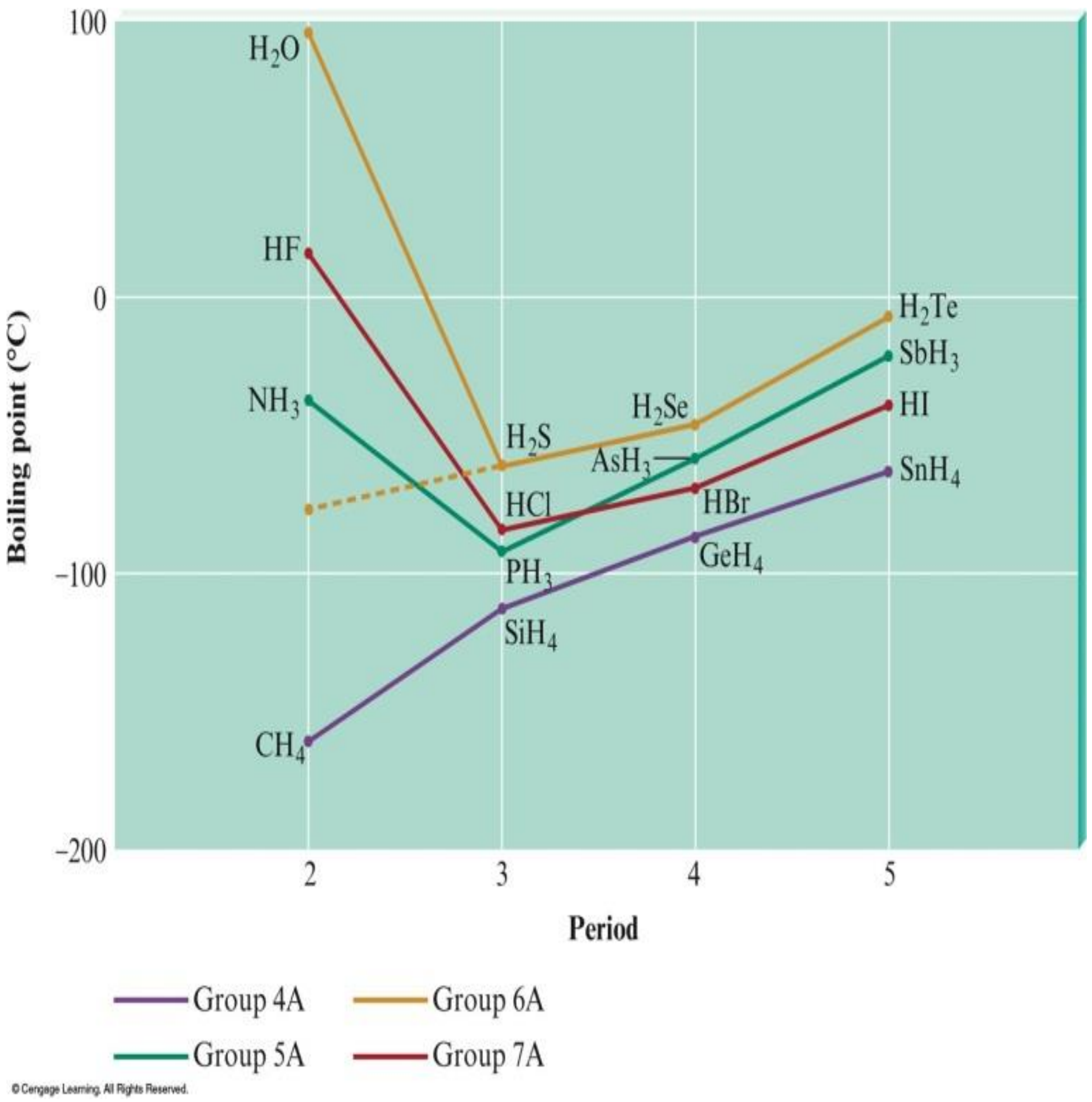


(b) Increasing surface area and boiling point

Melting & Boiling Points - IMF

Melting and Boling Points

- In General, the stronger the IMF, the higher the melting and boiling points
- The Boiling points of covalent hydrides of the elements in groups 4A, 5A, 6A, an 7A in graph

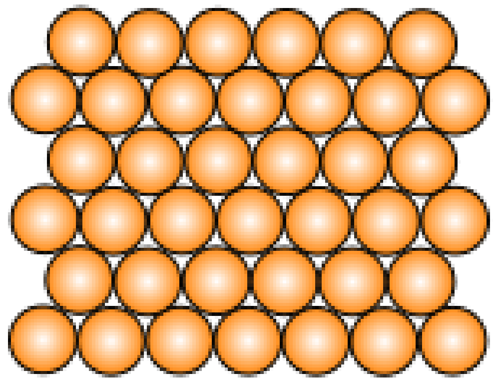
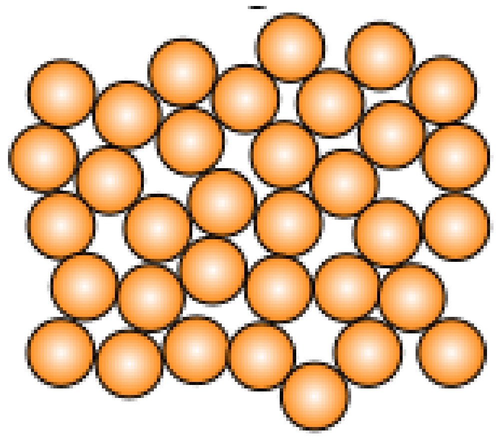


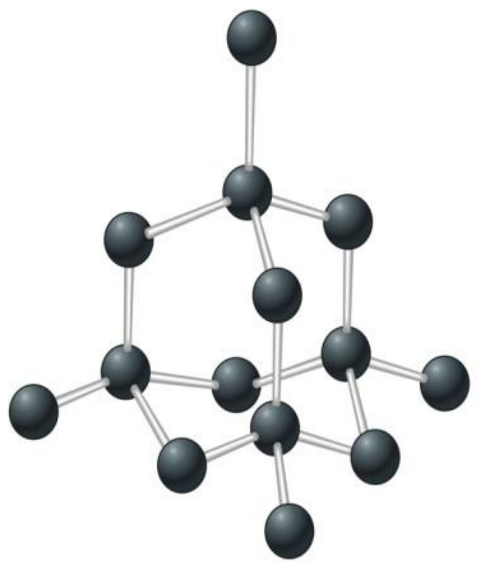
Solids

Solids

1. **Amorphous Solids:**
   - Disorder in the structures
   - Glass

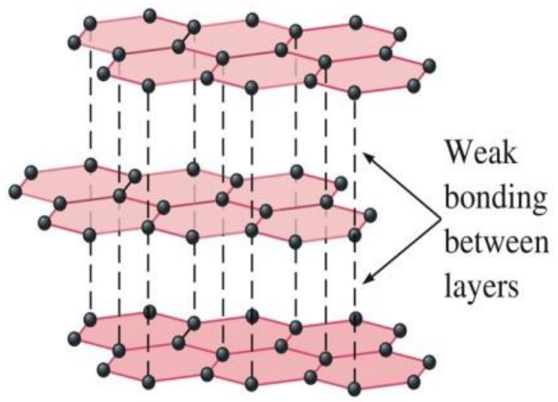
2. **Crystalline Solids:**
   - Ordered Structures
   - Unit Cells
   - Examples of Three Types of Crystalline Solids

Crystalline forms	Non-crystalline forms (amorphous forms)
1. A crystalline form has regular arrangement of atoms.	A non-crystalline form irregular arrangement of atoms.
2. Structure of crystalline form: 	Structure of non-crystalline form: 
2. They have a definite geometrical shape.	They have irregular shapes.
3. They have sharp melting points.	They melt over a range of temperature.
4. Carbon exists in three crystalline forms which are diamond, graphite and fullerene.	Carbon exists in three amorphous forms which are coal, charcoal and coke.



a

Diamond



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Graphite

Alloys

Two Types of Alloys

- **Substitutional alloy** - some of the host metal atoms are *replaced* by other metal atoms of similar size.
  - Brass
- **Interstitial alloy** - some of the holes in the closest packed metal structure are occupied by small atoms.
  - Steel