

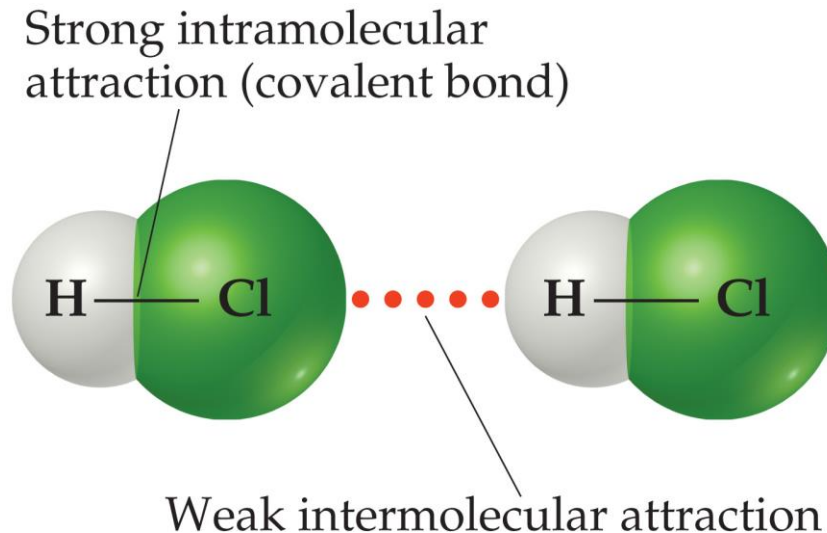


Intermolecular Forces

Chapter 4
AS

TYPES OF INTERMOLECULAR FORCE

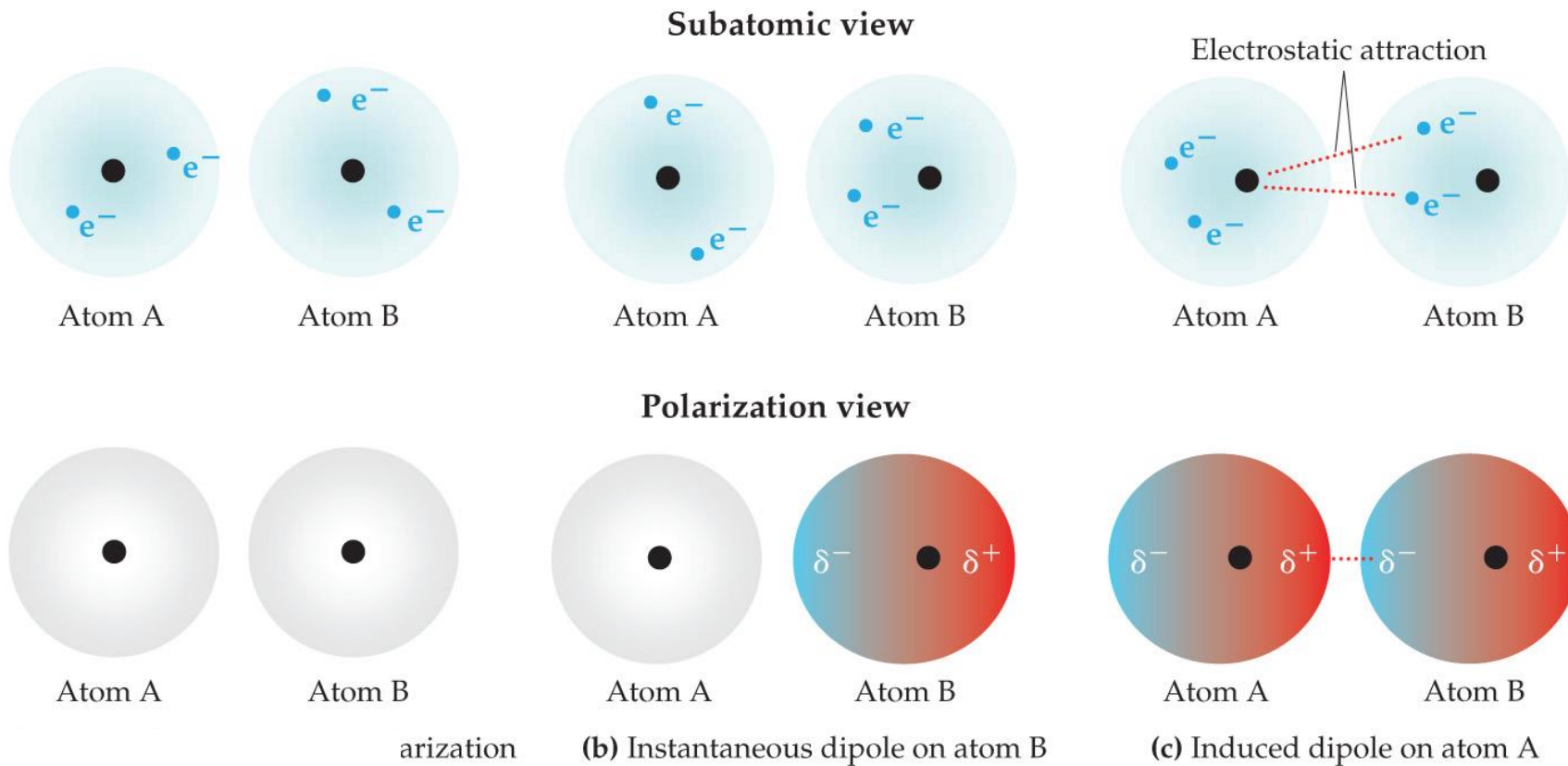
- van der Waals' forces (which are also called dispersion forces and temporary dipole–induced dipole forces)
- permanent dipole–dipole forces
- hydrogen bonding.



- The attractions between molecules are not nearly as strong as the intramolecular attractions (bonds) that hold compounds together.
- Many physical properties reflect intermolecular forces, like boiling points, melting points, viscosity, surface tension, and capillary action.

DISPERSION FORCES

- The figure below shows how a nonpolar particle (in this case a helium atom) can be temporarily polarized to allow dispersion force to form.
- The tendency of an electron cloud to distort is called its **polarizability**.



FACTORS WHICH AFFECT AMOUNT OF DISPERSION FORCE IN A MOLECULE

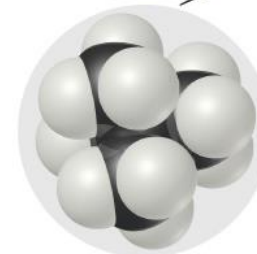
- number of electrons in an atom (more electrons, more dispersion force)
- size of atom or molecule/molecular weight
- shape of molecules with similar masses (more compact, less dispersion force)

Linear molecule—larger surface area enhances intermolecular contact and increases dispersion force



n-Pentane (C_5H_{12})
bp = 309.4 K

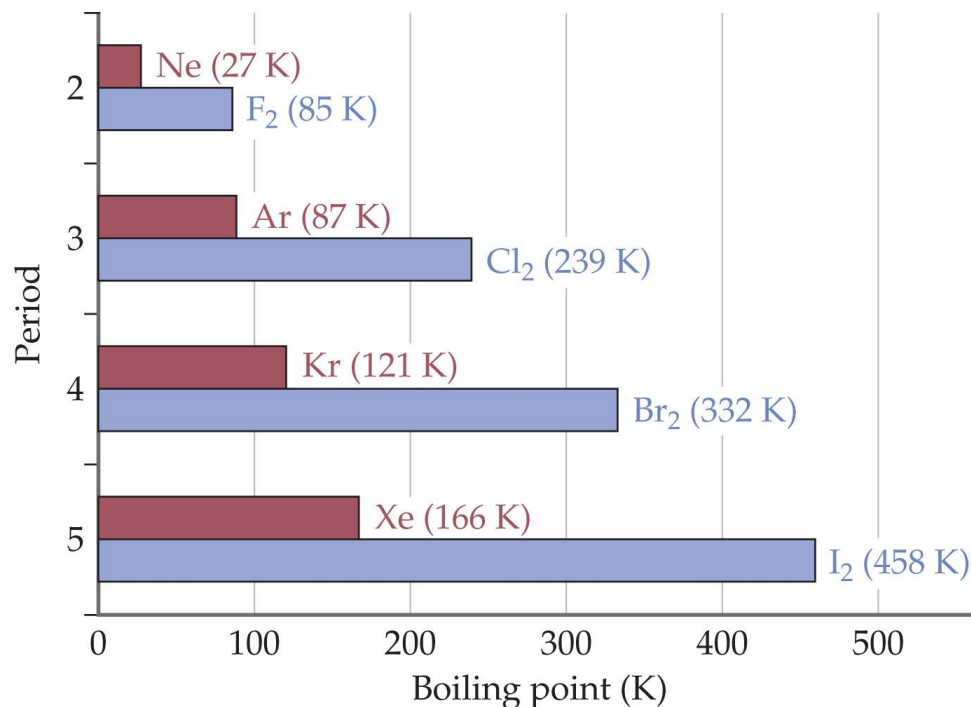
Spherical molecule—smaller surface area diminishes intermolecular contact and decreases dispersion force



Neopentane (C_5H_{12})
bp = 282.7 K

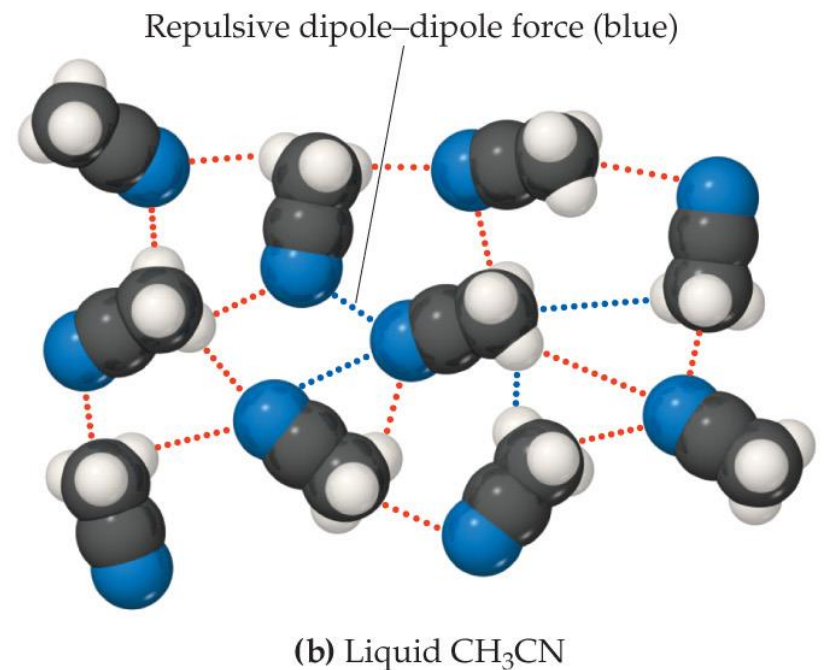
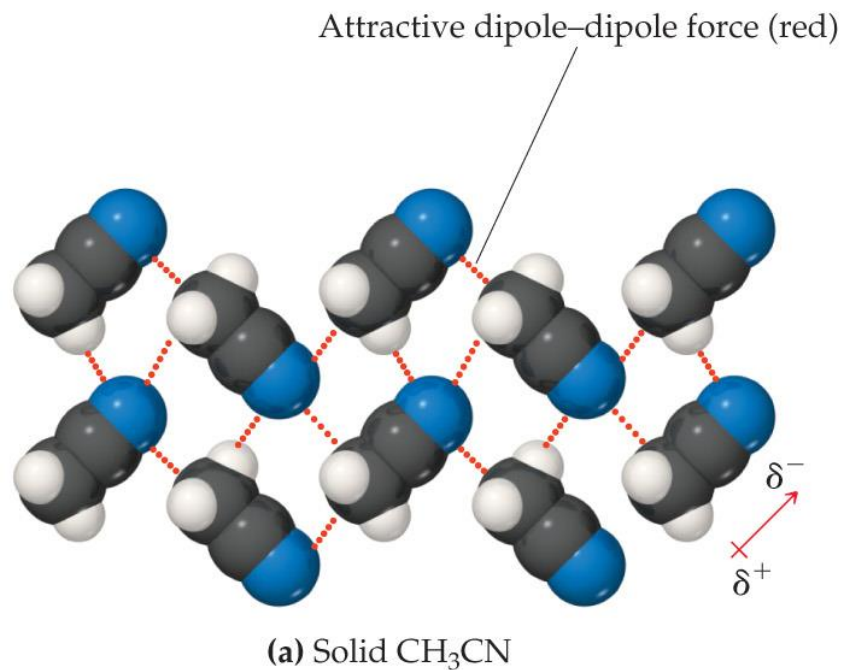
POLARIZABILITY & BOILING POINT

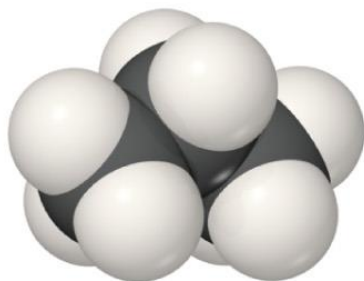
- If something is easier to polarize, it has a *lower* boiling point.
- Remember: This means *less* intermolecular force (smaller molecule: lower molecular weight, fewer electrons).



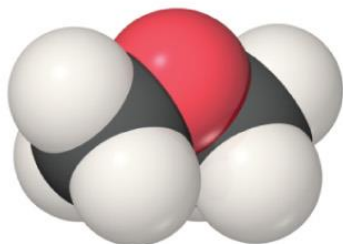
DIPOLE-DIPOLE INTERACTIONS

- Polar molecules have a more positive and a more negative end—a dipole (two poles, δ^+ and δ^-).
- The oppositely charged ends attract each other.

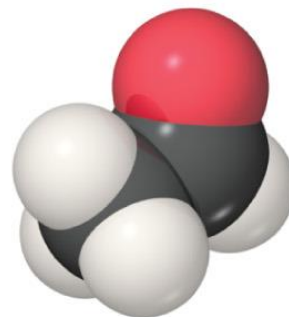




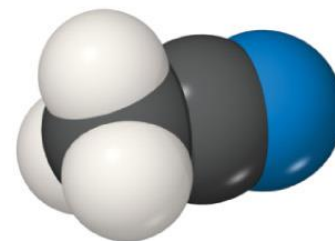
Propane
 $\text{CH}_3\text{CH}_2\text{CH}_3$
MW = 44 amu
 $\mu = 0.1 \text{ D}$
bp = 231 K



Dimethyl ether
 CH_3OCH_3
MW = 46 amu
 $\mu = 1.3 \text{ D}$
bp = 248 K



Acetaldehyde
 CH_3CHO
MW = 44 amu
 $\mu = 2.7 \text{ D}$
bp = 294 K



Acetonitrile
 CH_3CN
MW = 41 amu
 $\mu = 3.9 \text{ D}$
bp = 355 K

Increasing polarity
Increasing strength of dipole-dipole forces

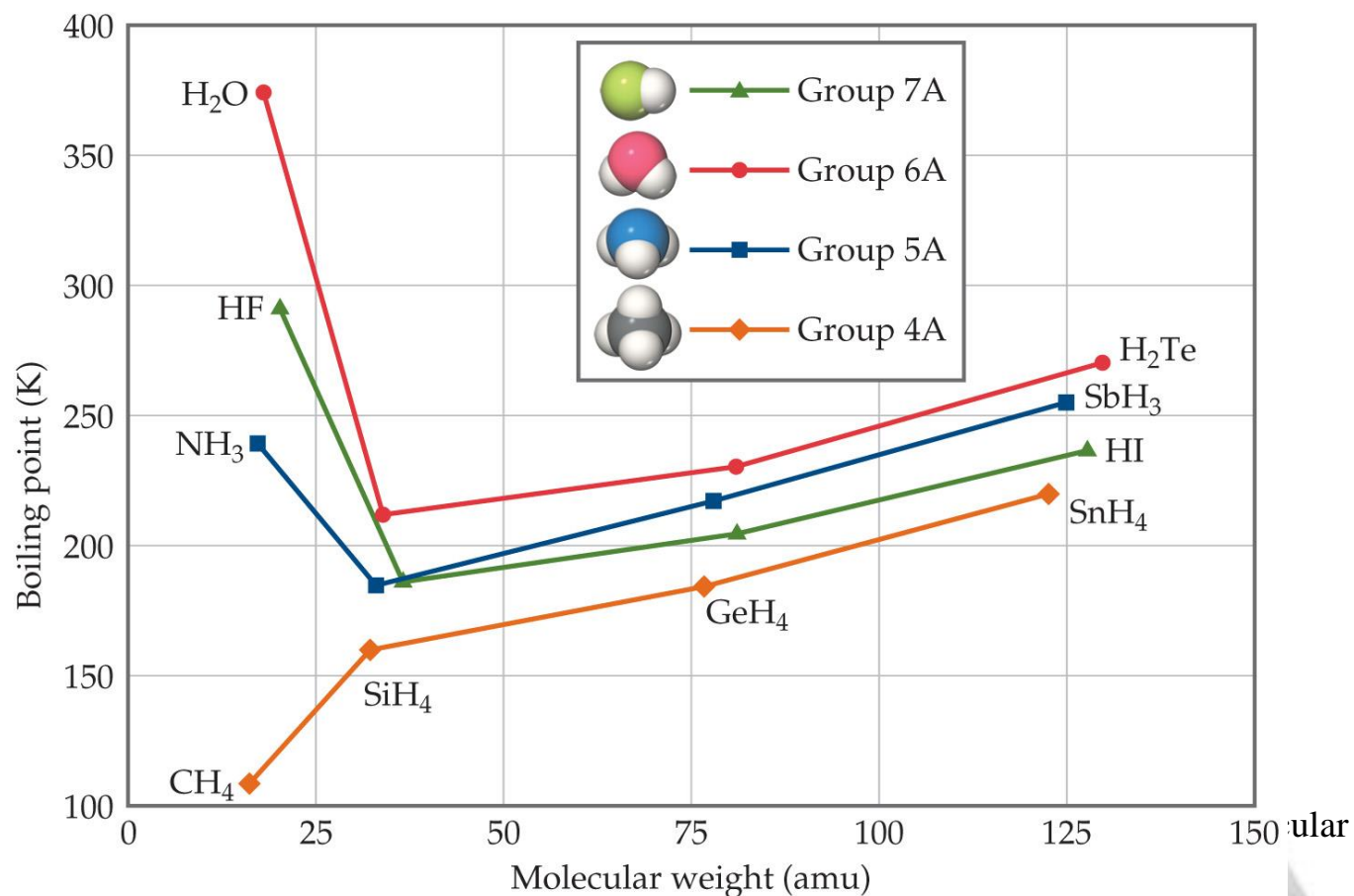
For molecules of approximately equal mass and size, the more polar the molecule, the higher its boiling point.

WHICH HAVE A GREATER EFFECT: DIPOLE–DIPOLE INTERACTIONS OR DISPERSION FORCES?

- If two molecules are of comparable size and shape, dipole–dipole interactions will likely be the dominating force.
- If one molecule is much larger than another, dispersion forces will likely determine its physical properties.

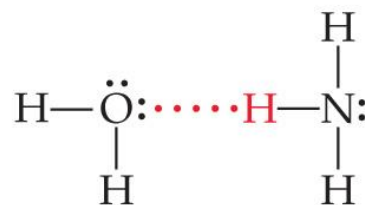
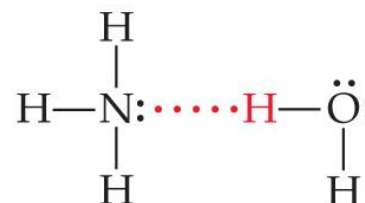
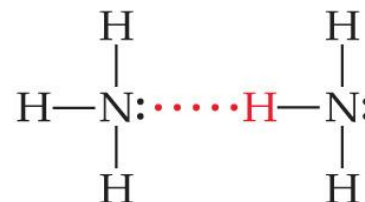
WHAT DOES THIS GRAPH SHOW US?

- In a group, the period 3/4/5 elements have higher boiling points as the group member gets larger.
- What happens with the period 2 elements?
- For group 4A, the trend is continued. What about for the other groups?



- The dipole–dipole interactions experienced when H is bonded to N, O, or F are unusually strong.
- We call these interactions **hydrogen bonds**.
- A hydrogen bond is an attraction between a hydrogen atom attached to a highly electronegative atom and a nearby small electronegative atom in another molecule or chemical group.

Covalent bond, *intramolecular* Hydrogen bond, *intermolecular*

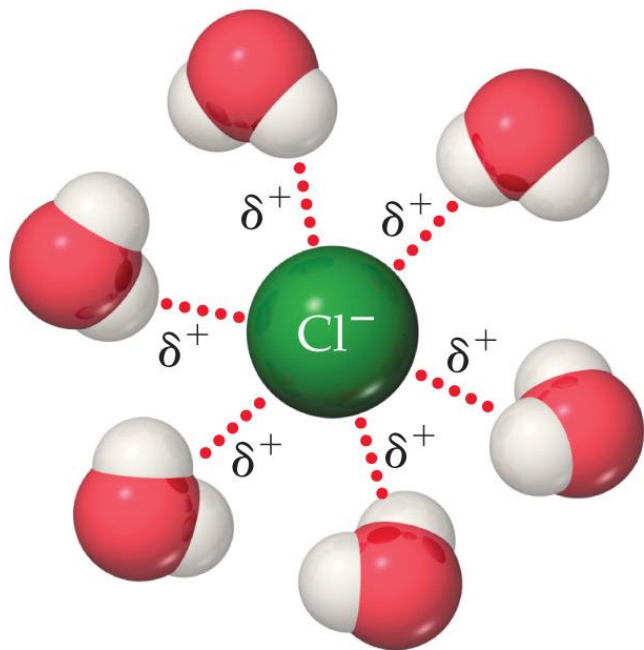


WHAT FORMS HYDROGEN BONDS?

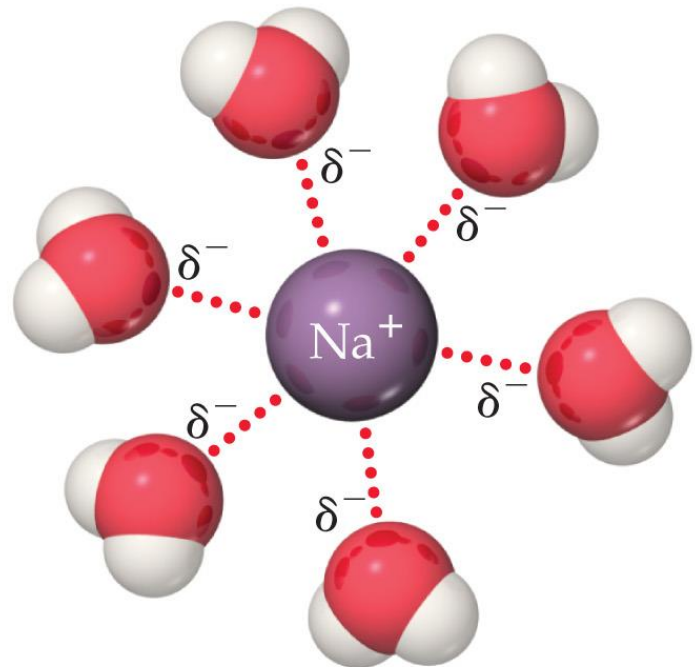
- Hydrogen bonding arises in part from the high electronegativity of nitrogen, oxygen, and fluorine.
- These atoms interact with a nearly bare nucleus (which contains one proton).



- Ion–dipole interactions are found in solutions of ions.
- The strength of these forces is what makes it possible for ionic substances to dissolve in polar solvents.

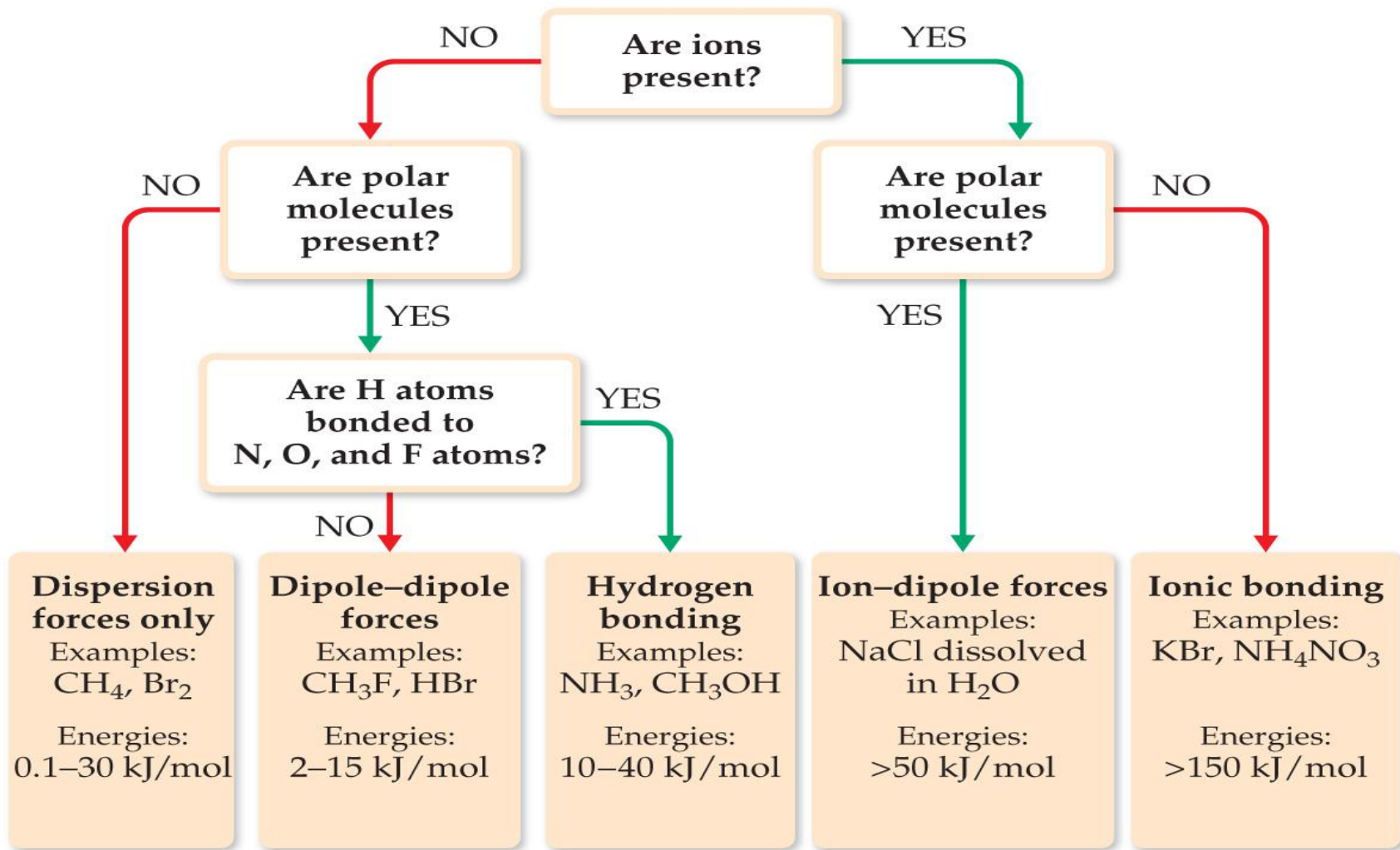


Positive ends of polar molecules are oriented toward negatively charged anion



Negative ends of polar molecules are oriented toward positively charged cation

SUMMARIZING INTERMOLECULAR FORCES



van der Waals forces

Increasing interaction strength

LIQUID PROPERTIES AFFECTED BY INTERMOLECULAR FORCES

- boiling point (previously discussed) and melting point
- viscosity
- surface tension
- capillary action

- Resistance of a liquid to flow is called **viscosity**.
- It is related to the ease with which molecules can move past each other.
- Viscosity increases with stronger intermolecular forces and decreases with higher temperature.



SAE 40
higher number
higher viscosity
slower pouring

SAE 10
lower number
lower viscosity
faster pouring

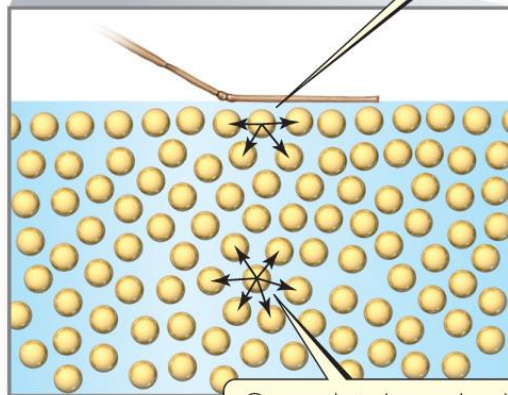
Table 11.5 Viscosities of a Series of Hydrocarbons at 20 °C

Substance	Formula	Viscosity (kg/m-s)
Hexane	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	3.26×10^{-4}
Heptane	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	4.09×10^{-4}
Octane	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	5.42×10^{-4}
Nonane	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	7.11×10^{-4}
Decane	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$	1.42×10^{-3}

Intermolecular
Forces



On any surface molecule, there is no upward force to cancel the downward force, which means each surface molecule "feels" a net downward pull



On any interior molecule, each force is balanced by a force pulling in the opposite direction, which means that interior molecules "feel" no net pull in any direction

- Water acts as if it has a "skin" on it due to extra inward forces on its surface. Those forces are called the **surface tension**.