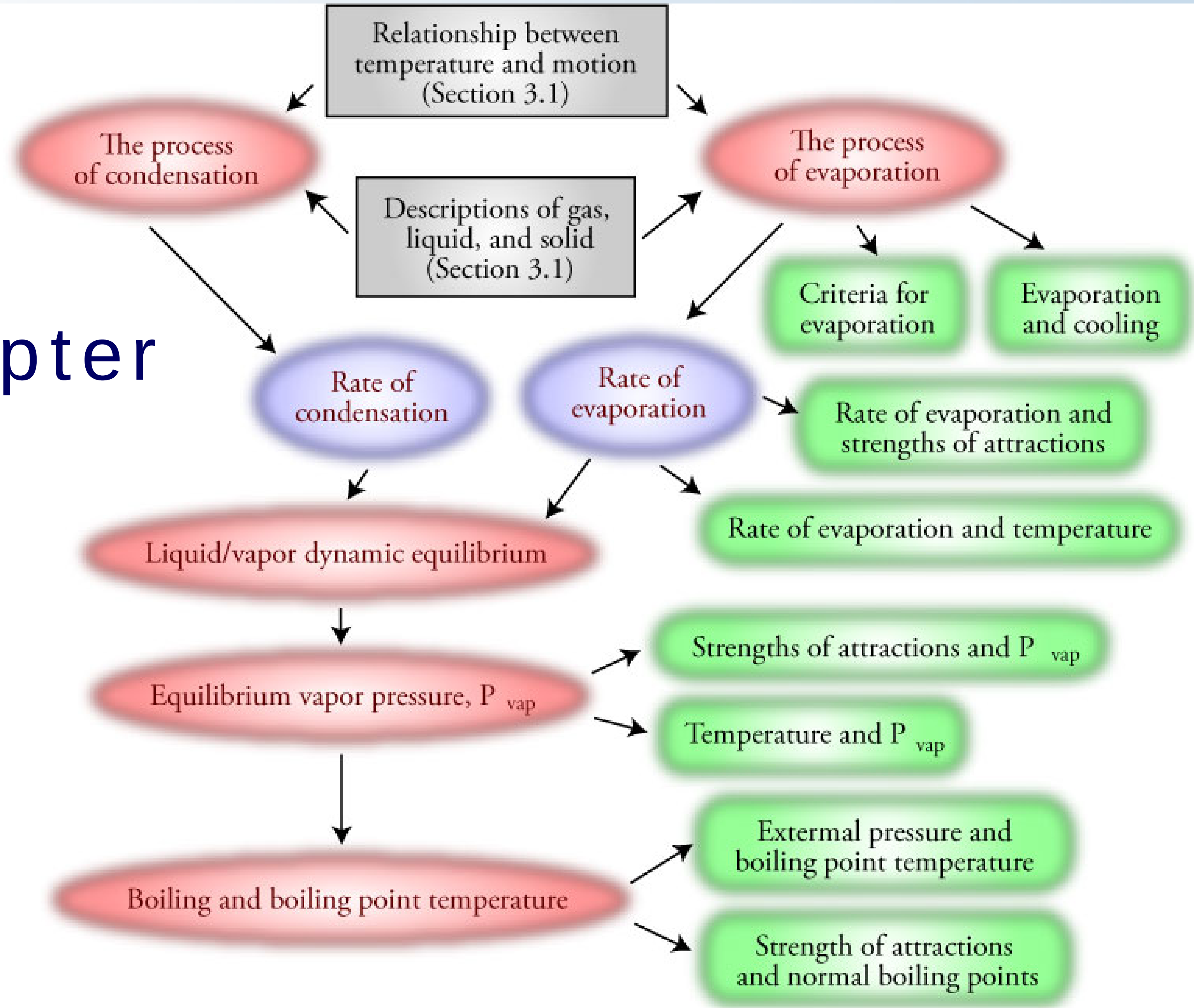
Chapter 14

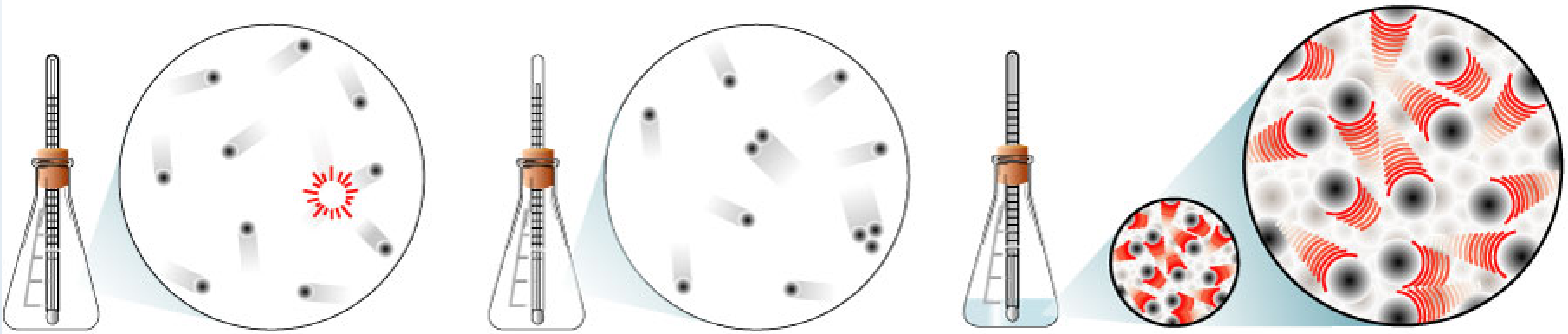
Liquids: Condensation, Evaporation, and Dynamic Equilibrium

Chapter Map



Relationship between temperature and motion (Section 3.1)
The process of condensation
The process of evaporation
Descriptions of gas, liquid, and solid (Section 3.1)
Criteria for evaporation
Evaporation and cooling
Rate of condensation
Rate of evaporation
Rate of evaporation and strengths of attractions
Rate of evaporation and temperature
Liquid/vapor dynamic equilibrium
Strengths of attractions and P vap
Equilibrium vapor pressure, P vap
Temperature and P vap
Extermal pressure and boiling point temperature
Boiling and boiling point temperature
Strength of attractions and normal boiling points

Condensation (Gas to Liquid)

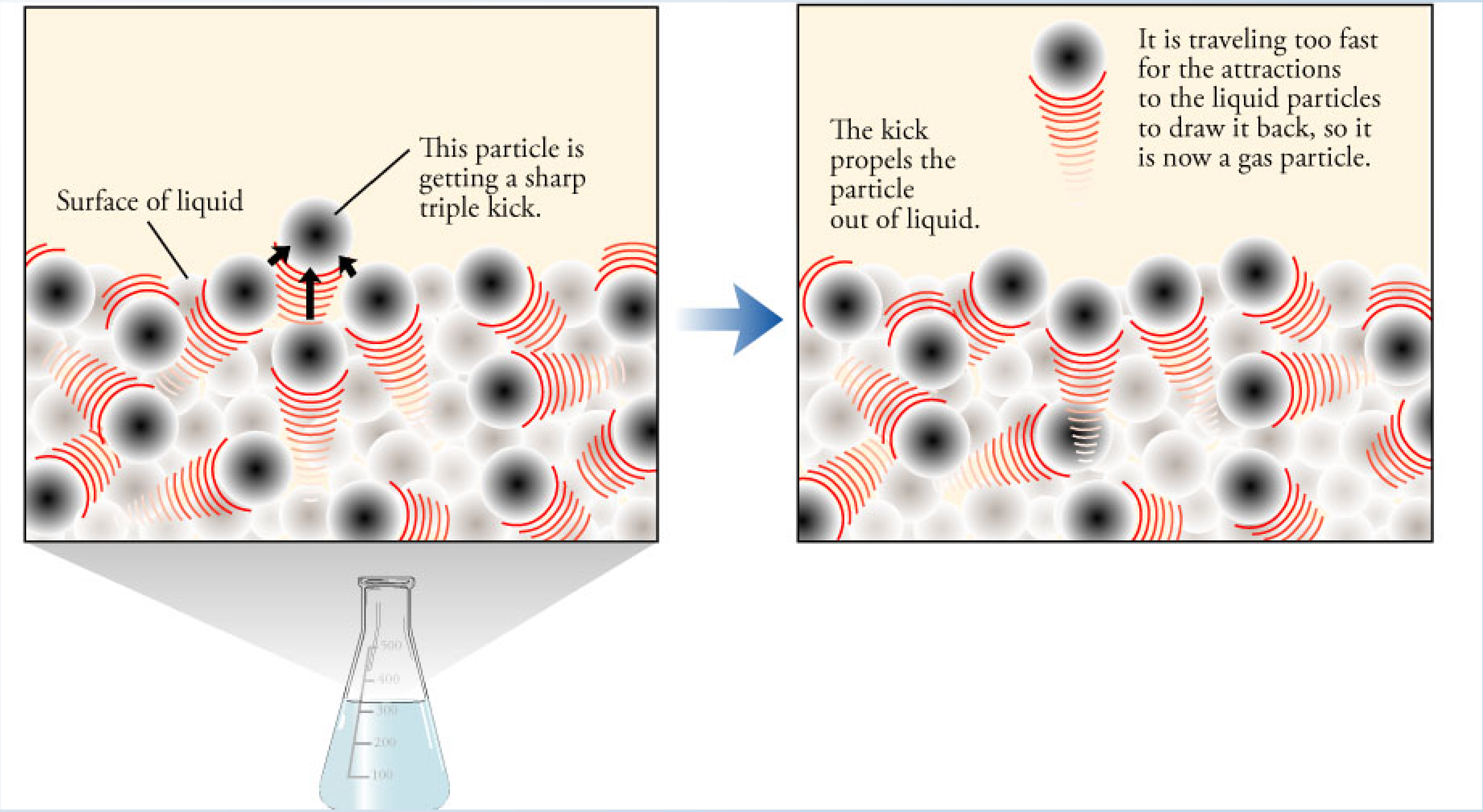


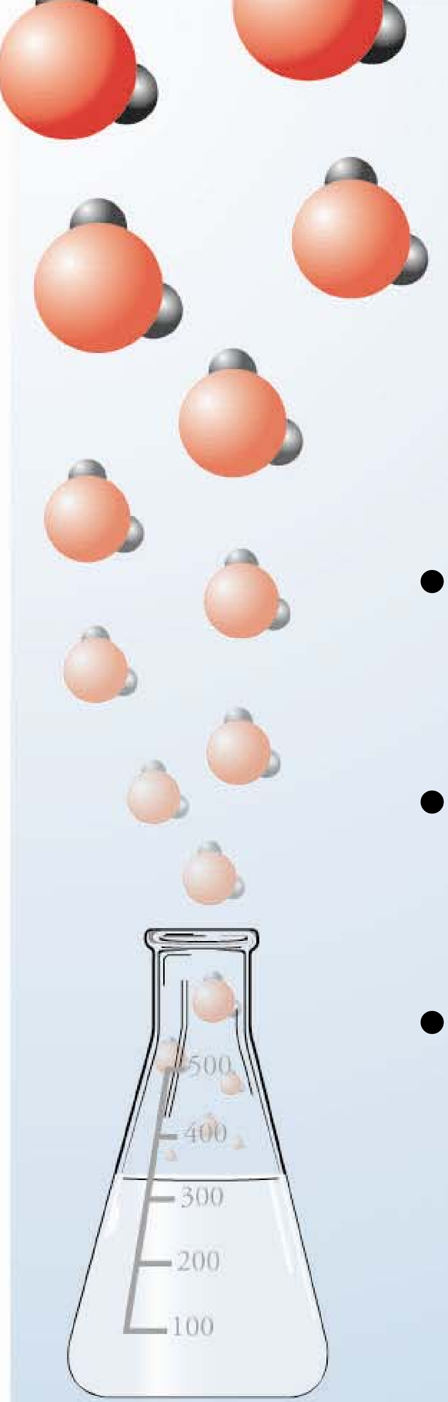
At a high temperature, there are no significant attractions between the particles.

As the temperature is lowered, attractions between particles lead to the formation of very small clusters that remain in the gas phase.

As the temperature is lowered further, the particles move slowly enough to form clusters so large that they drop to the bottom of the container and combine to form a liquid.

Evaporation

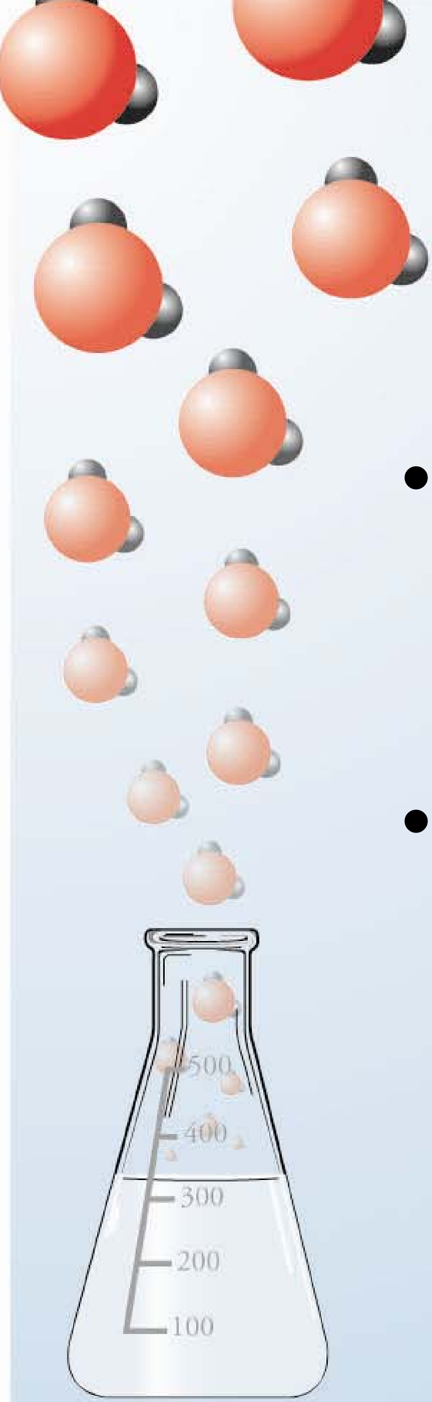




For a particle to escape from the surface of the liquid, it must meet the following criteria.

- The particle must be at the liquid's surface.
- Its direction of motion must take it beyond the liquid's surface.
- Its momentum must be great enough to take it beyond the backward pull of the other particles at the surface.

Rate of Evaporation



- The rate of evaporation is the number of particles moving from liquid to gas per second.
- It is dependent on the following:
  - Surface area of the liquid
  - Strength of attractions between the particles in the liquid
  - Temperature

Relative Rates of Evaporation

Weaker attractions between particles

↓

Lower momentum necessary for particles to escape the liquid

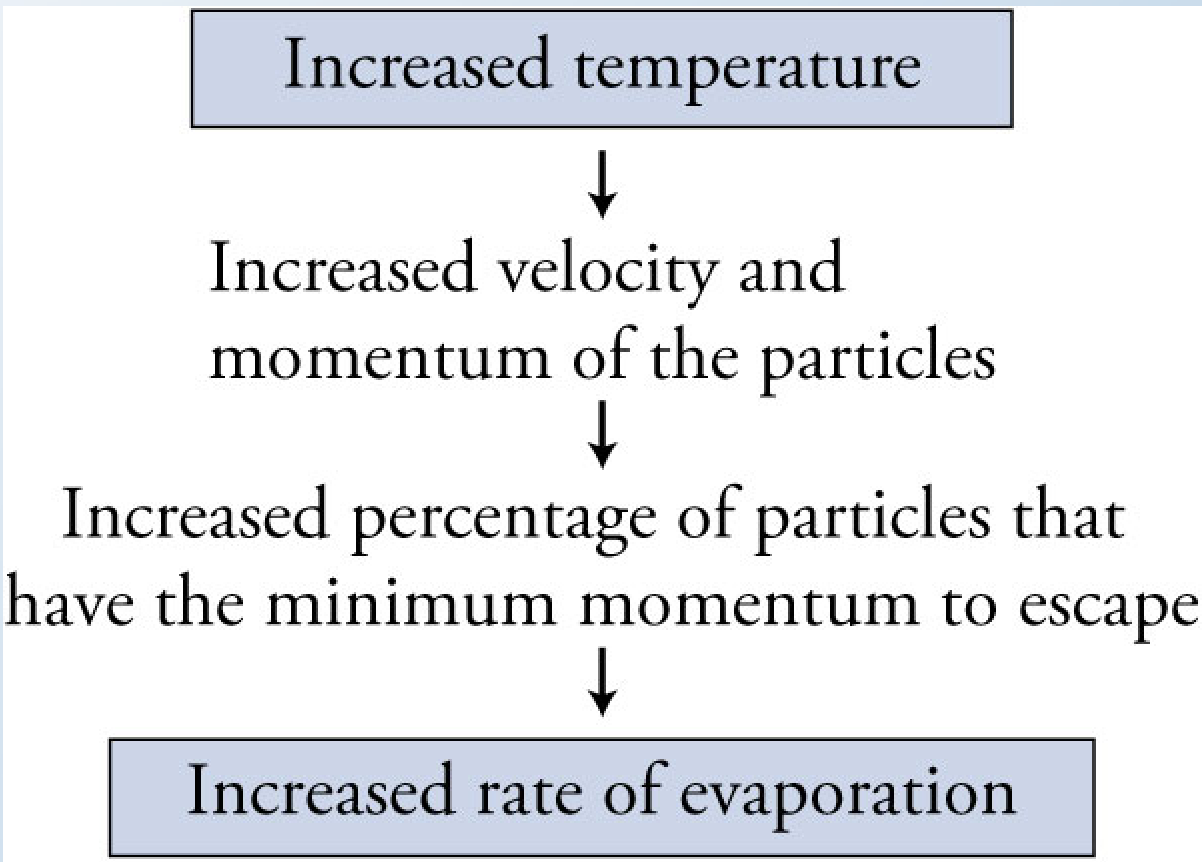
↓

At a constant temperature, a greater percentage of particles that have the momentum necessary to escape

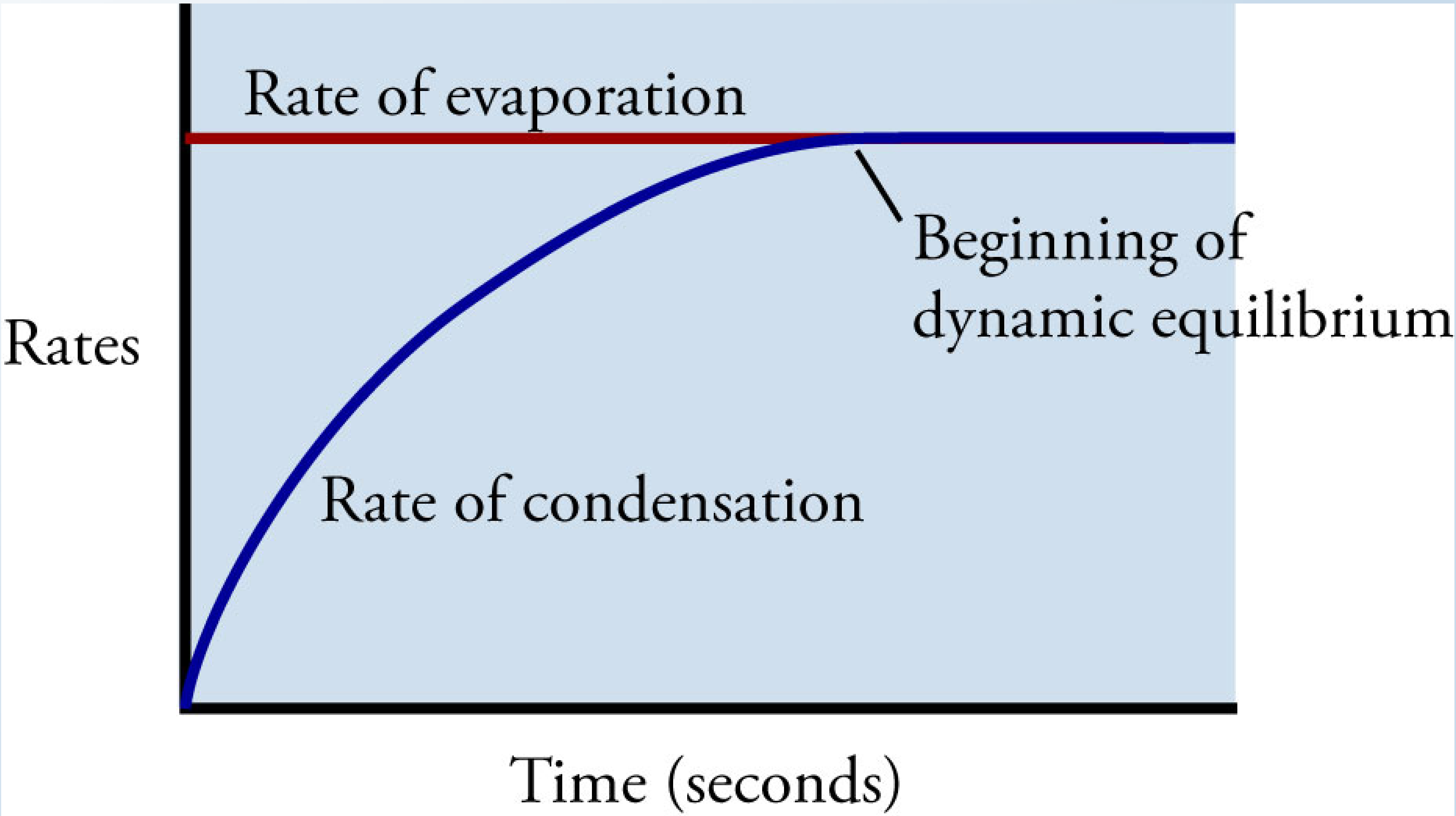
↓

Higher rate of evaporation

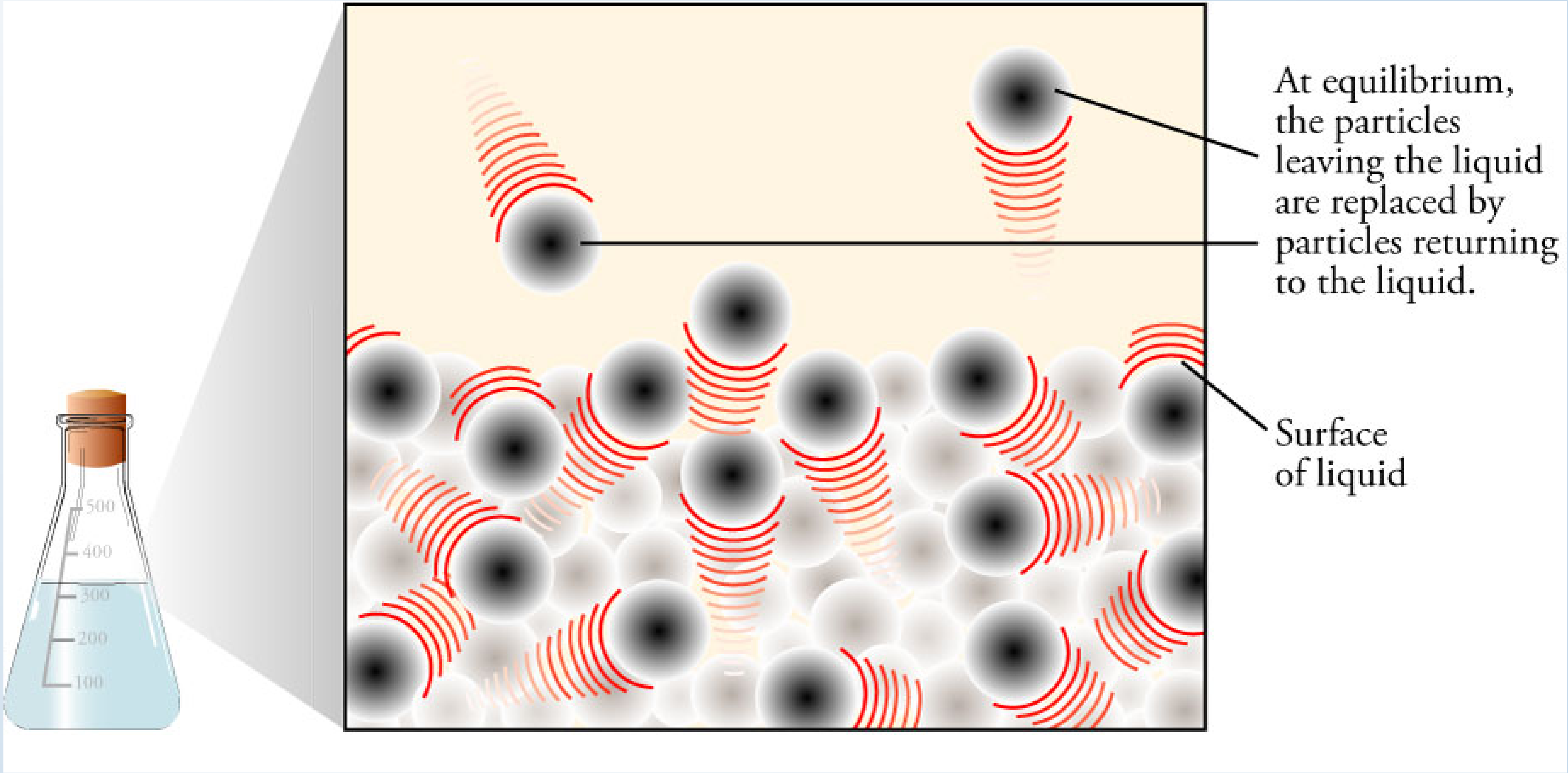
Temperature and Rate of Evaporation



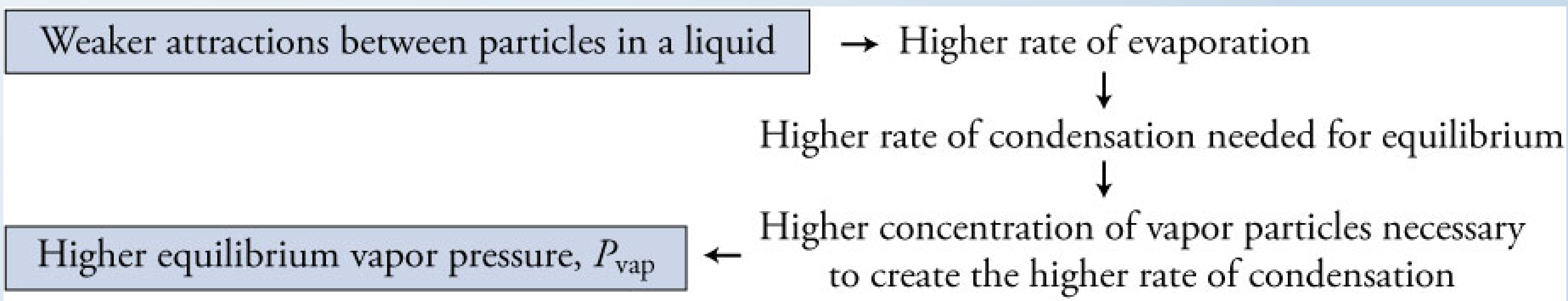
Dynamic Equilibrium and Rates of Evaporation and Condensation



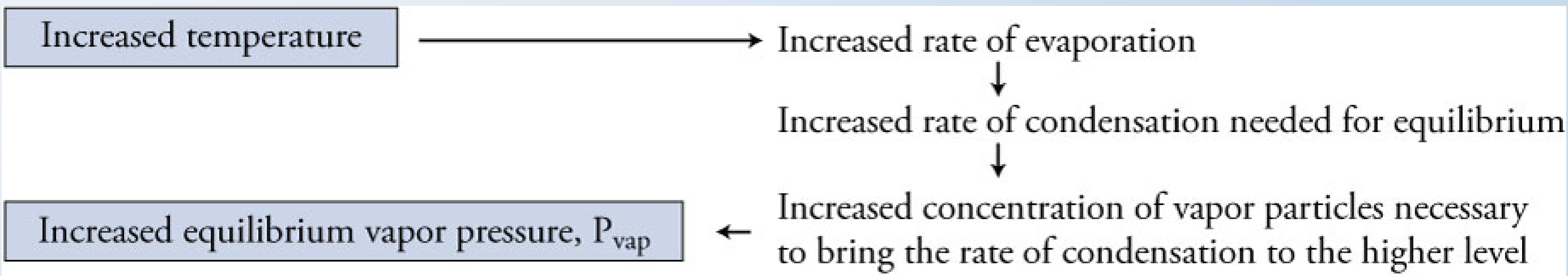
Liquid-Vapor Equilibrium



Relative Equilibrium Vapor Pressures

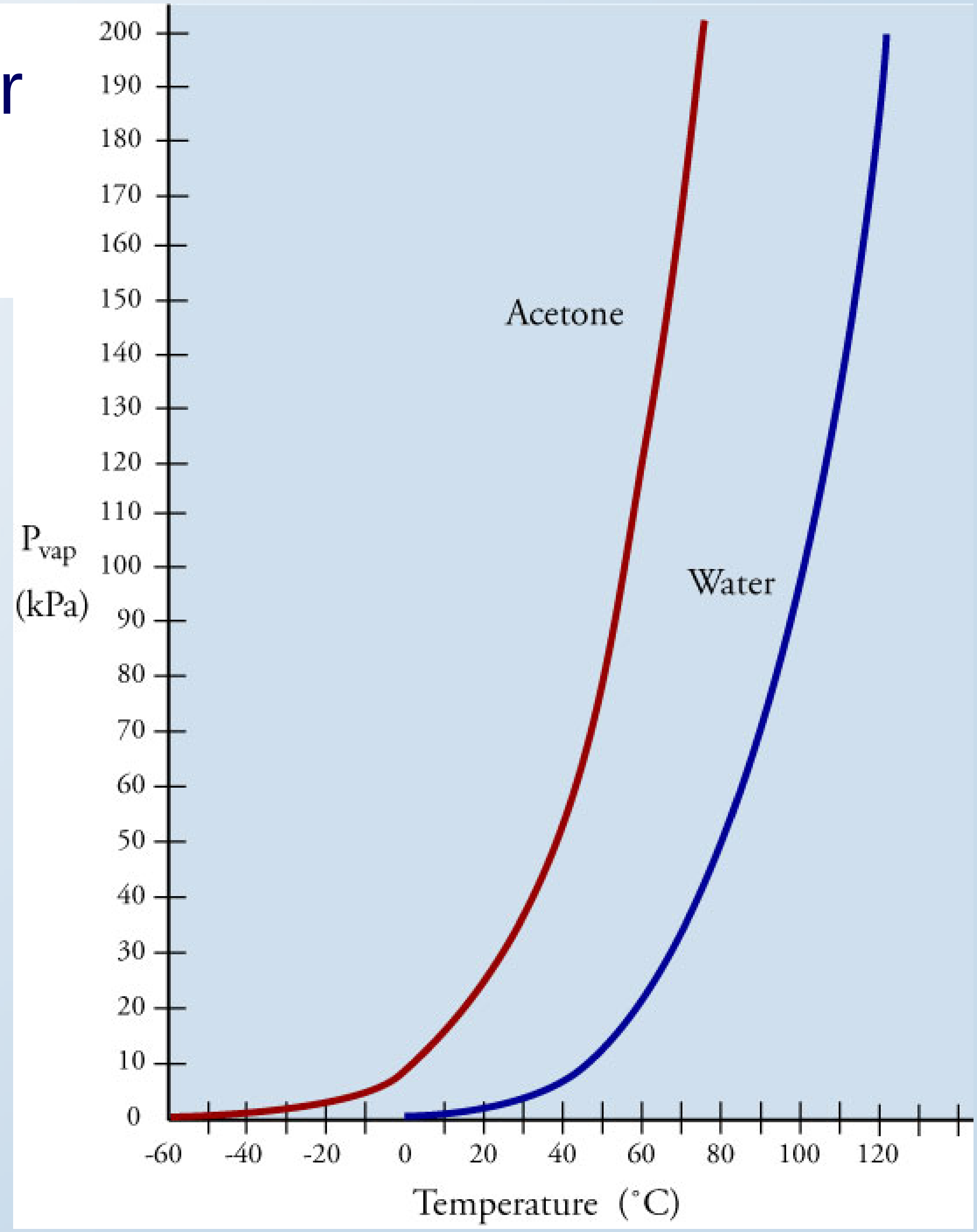


Temperature Effect On Equilibrium Vapor Pressure

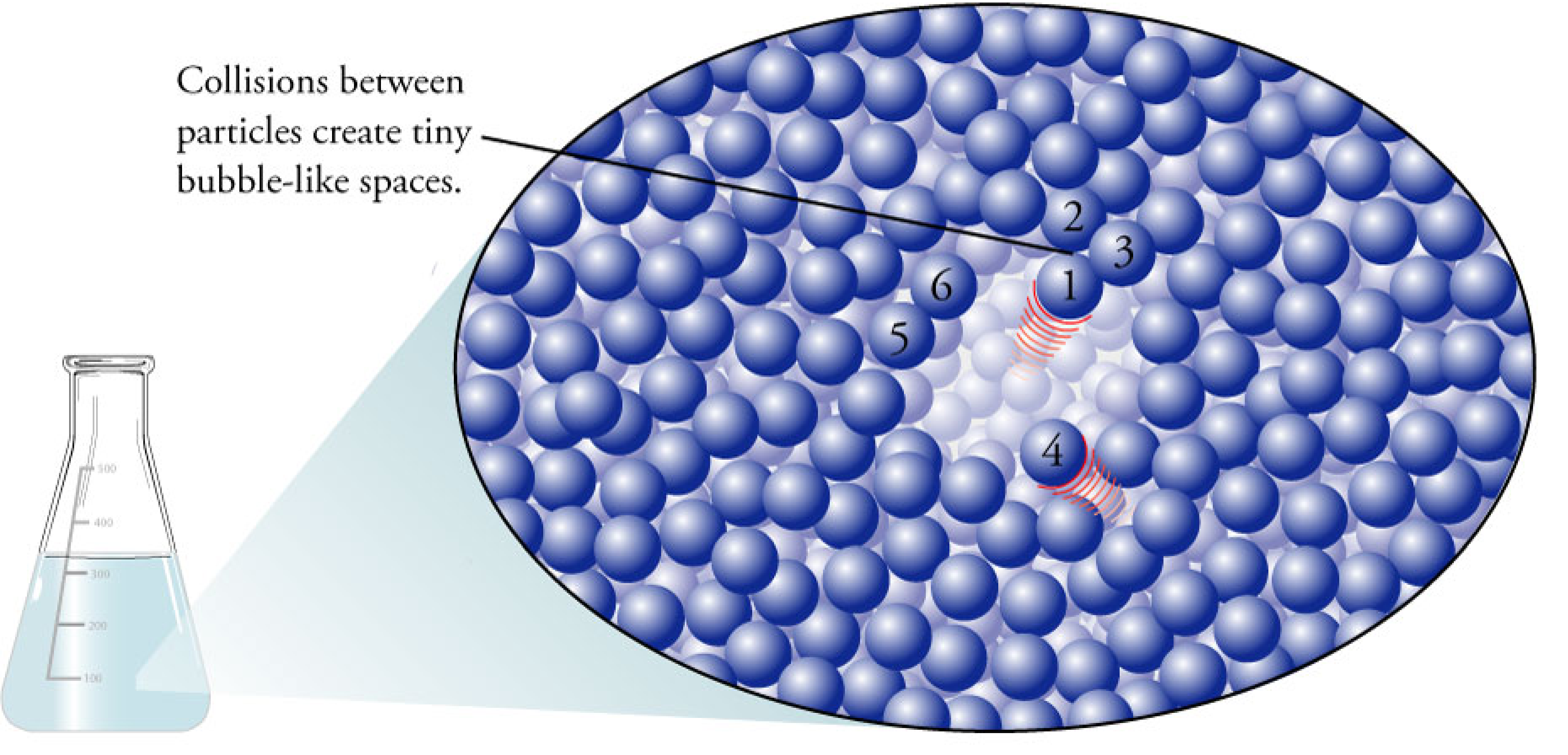


Acetone/Water

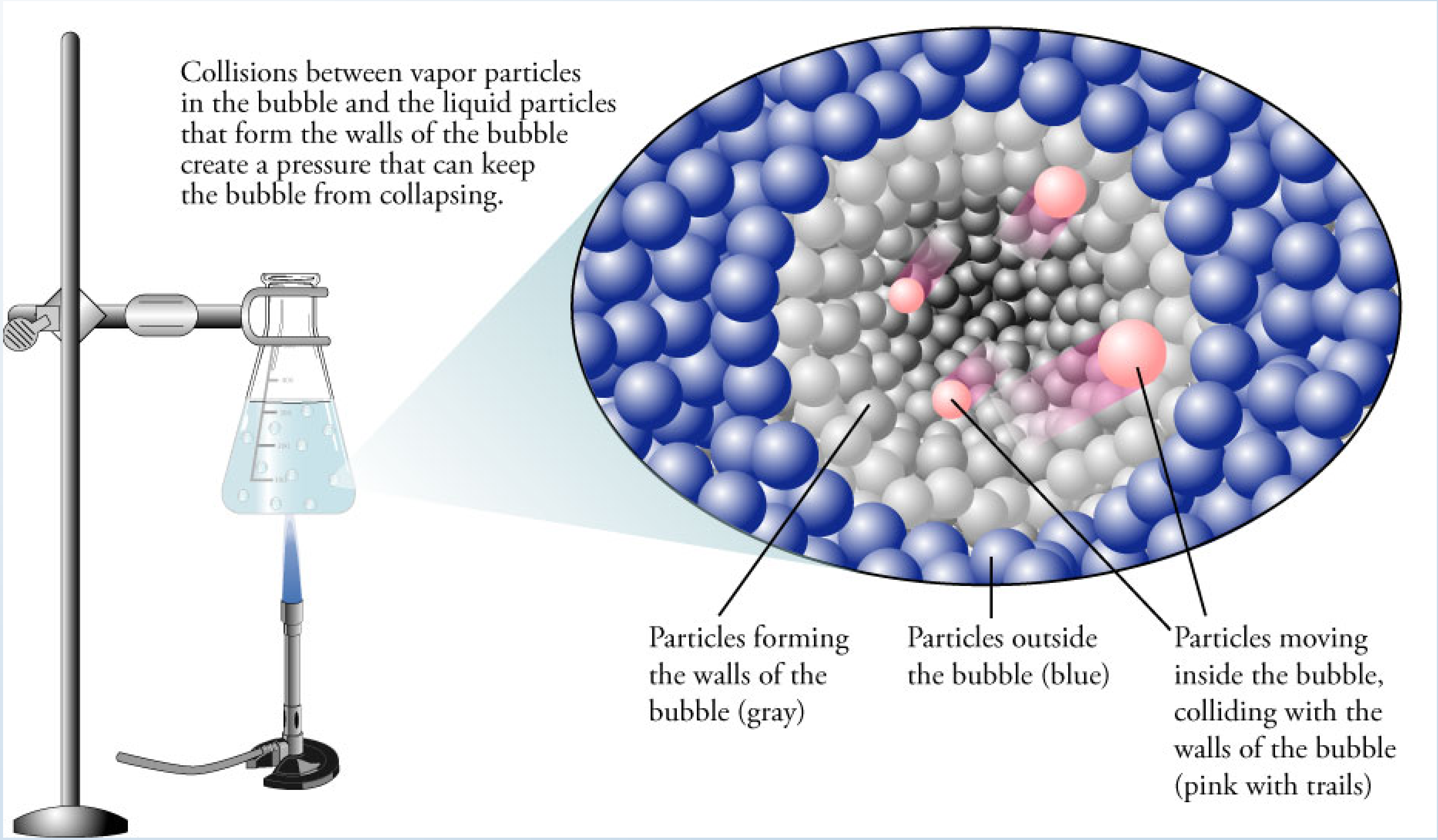
P_{vap} vs. T



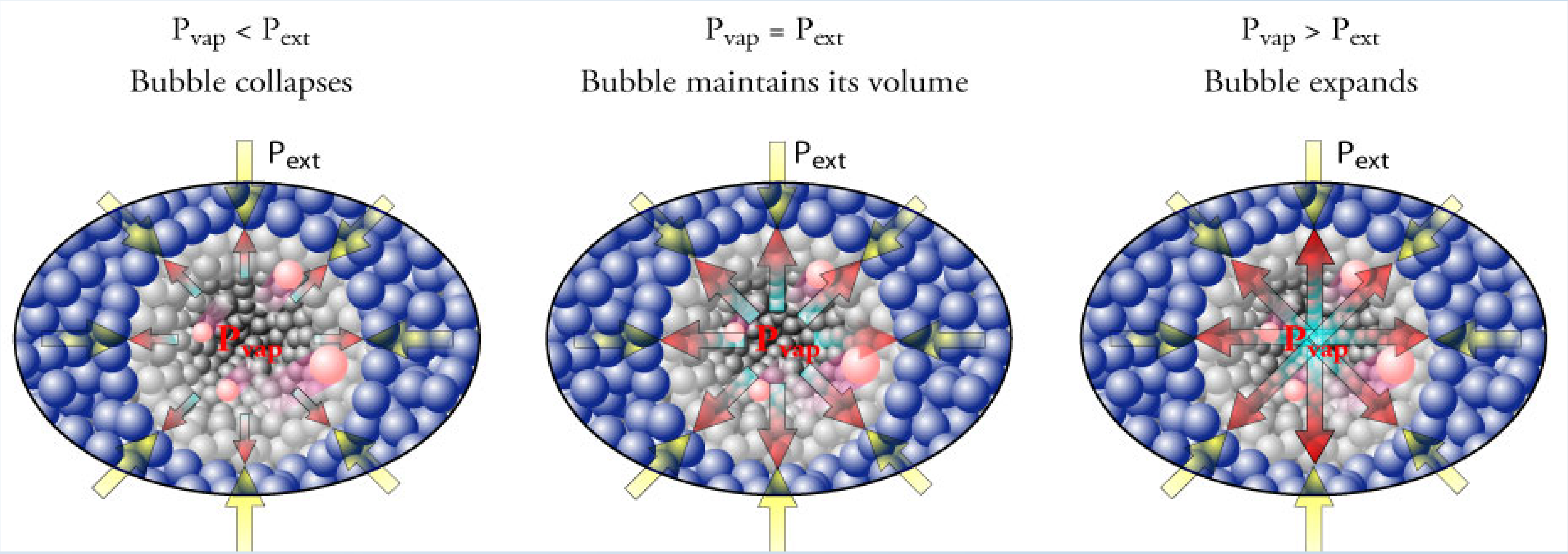
Spaces in Liquids



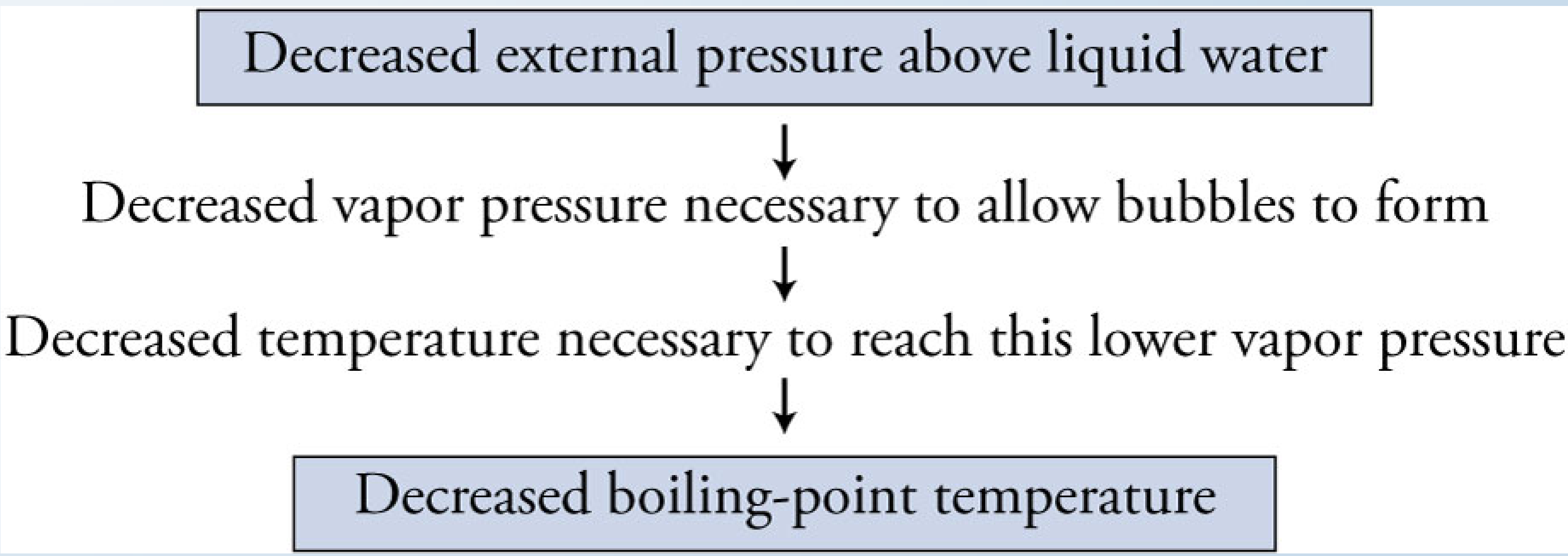
Bubble in Liquid



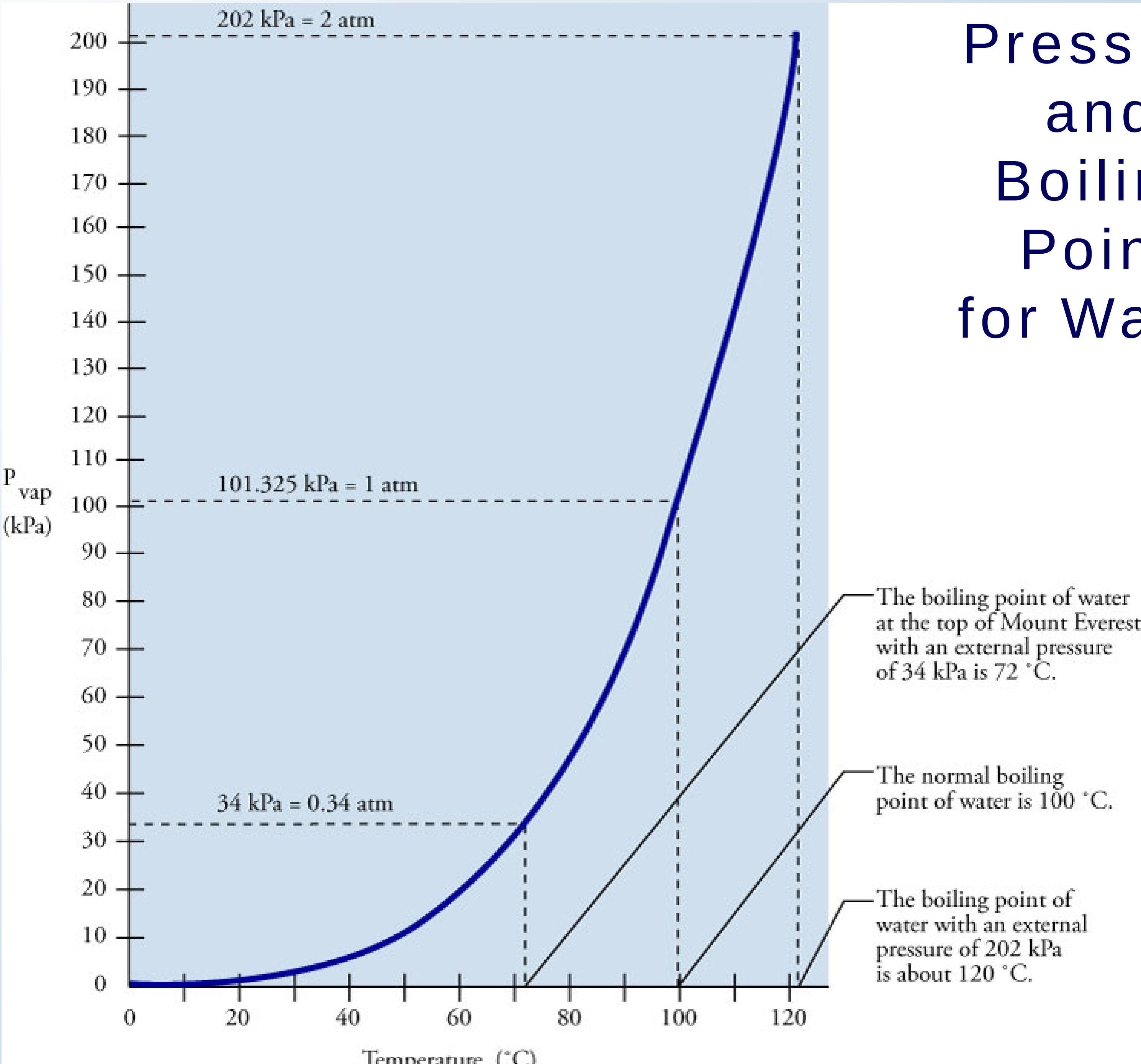
Bubble Formation



Pressure and Boiling Points



Pressure and Boiling Point for Water



Strengths of Attractions and Boiling Point

Increased strength of attractions

↓

Decreased rate of evaporation

↓

Decreased rate of condensation at equilibrium

↓

Lower concentration of vapor necessary to reach lower rate of condensation

↓

Lower vapor pressure at any given temperature

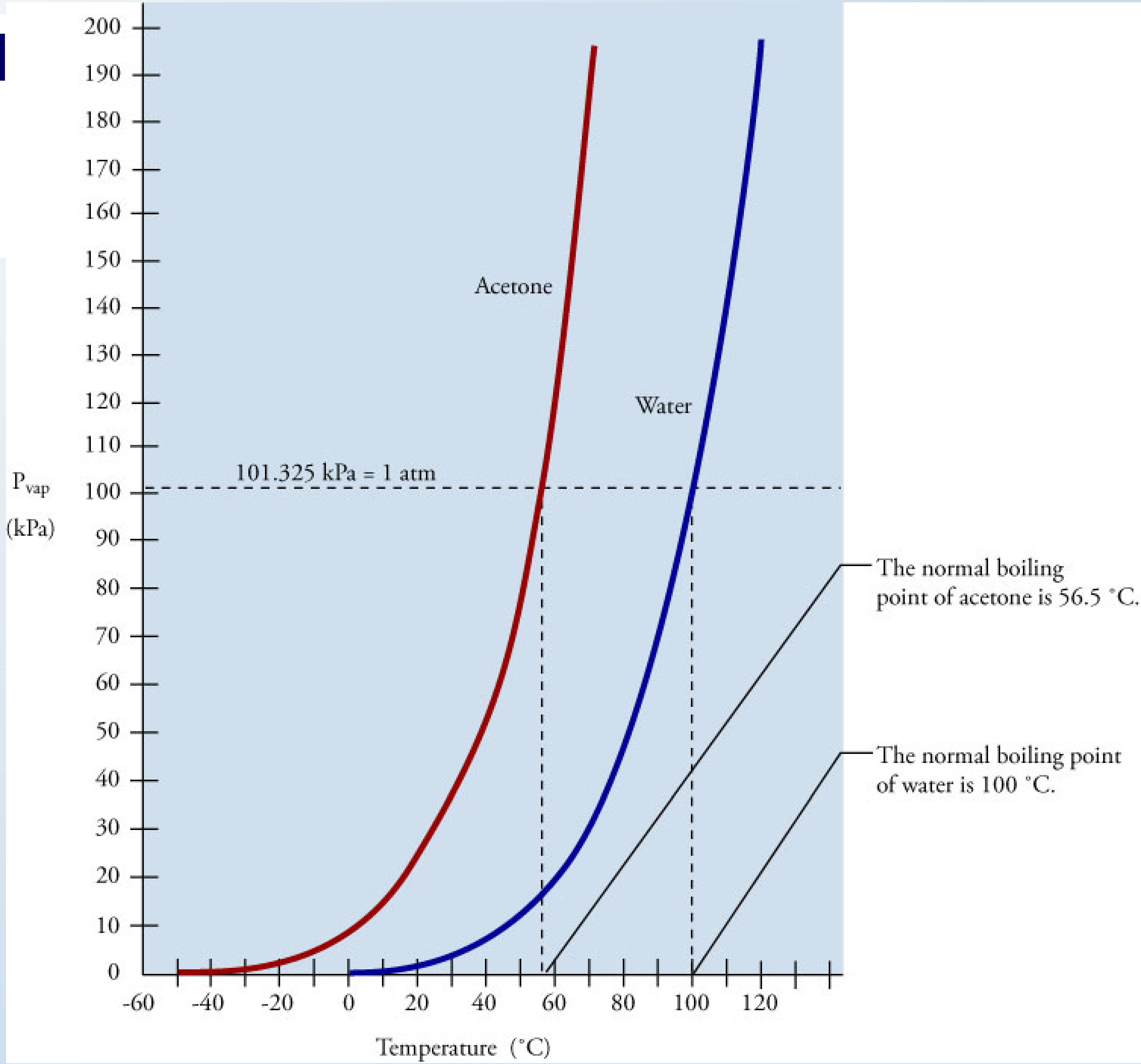
↓

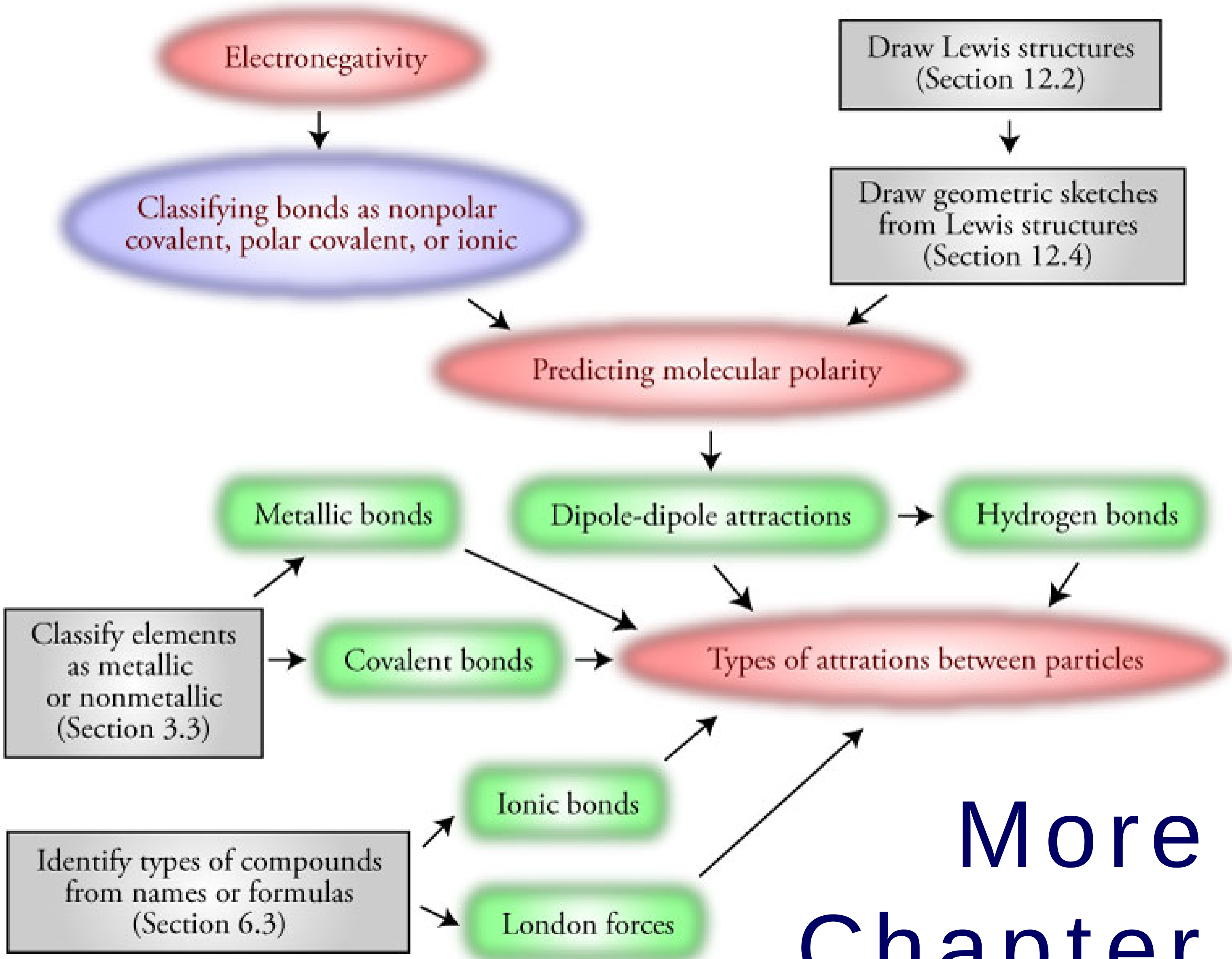
Higher temperature necessary to bring the vapor pressure to the external pressure

↓

Increased boiling-point temperature

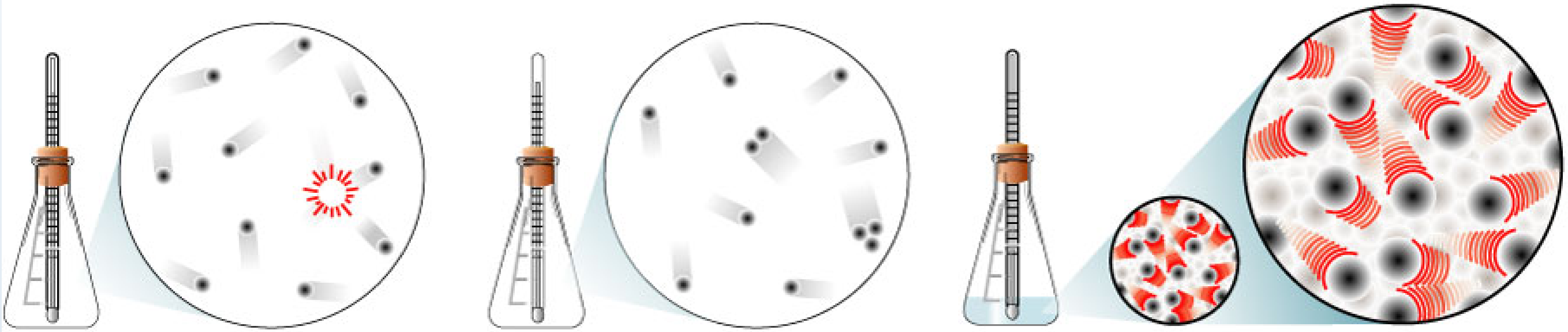
Normal Boiling Points





More Chapter 14

Condensation (Gas to Liquid)



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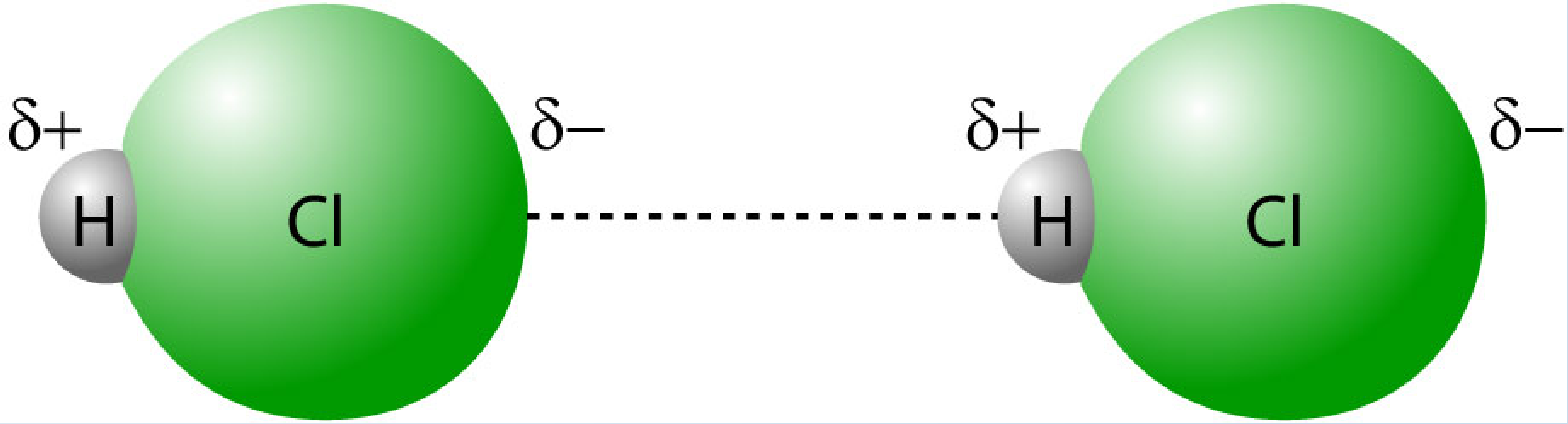
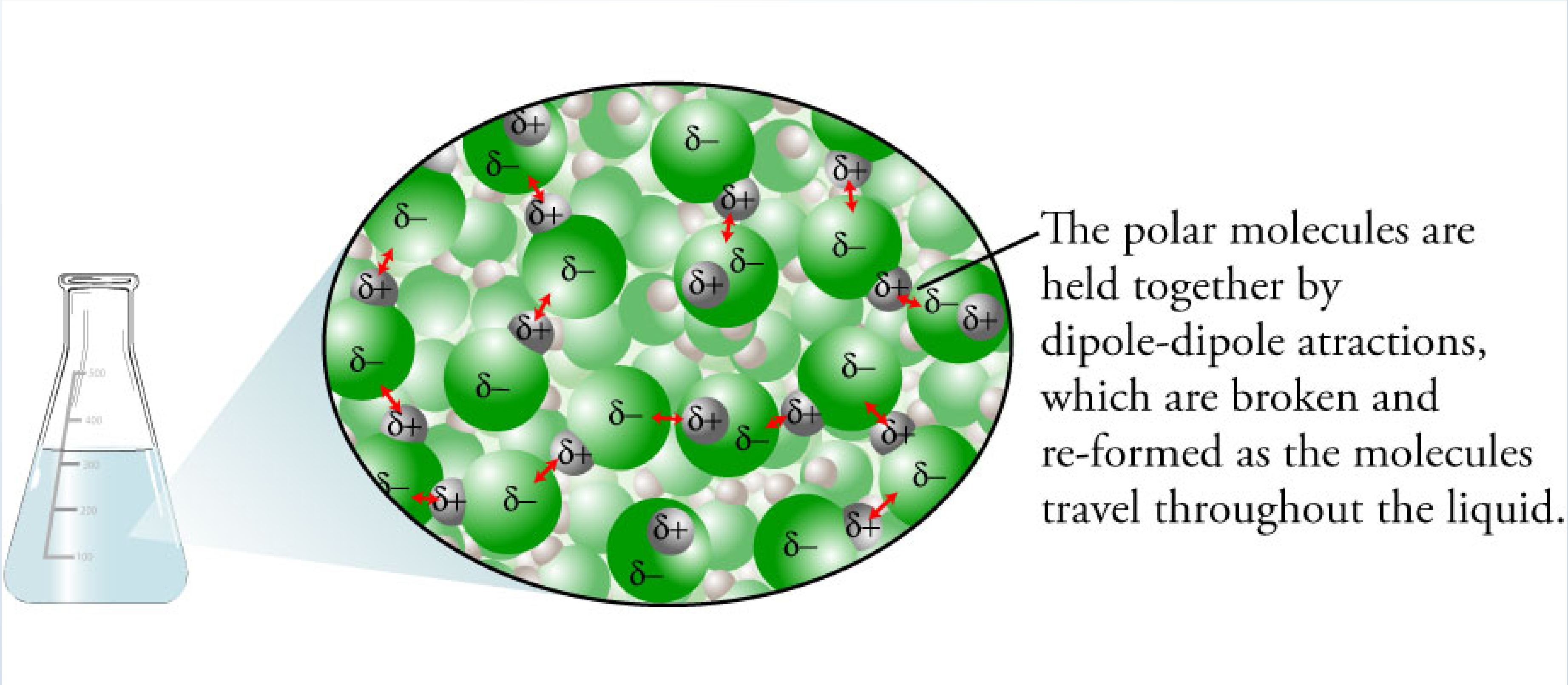
Dipole-Dipole Attractions

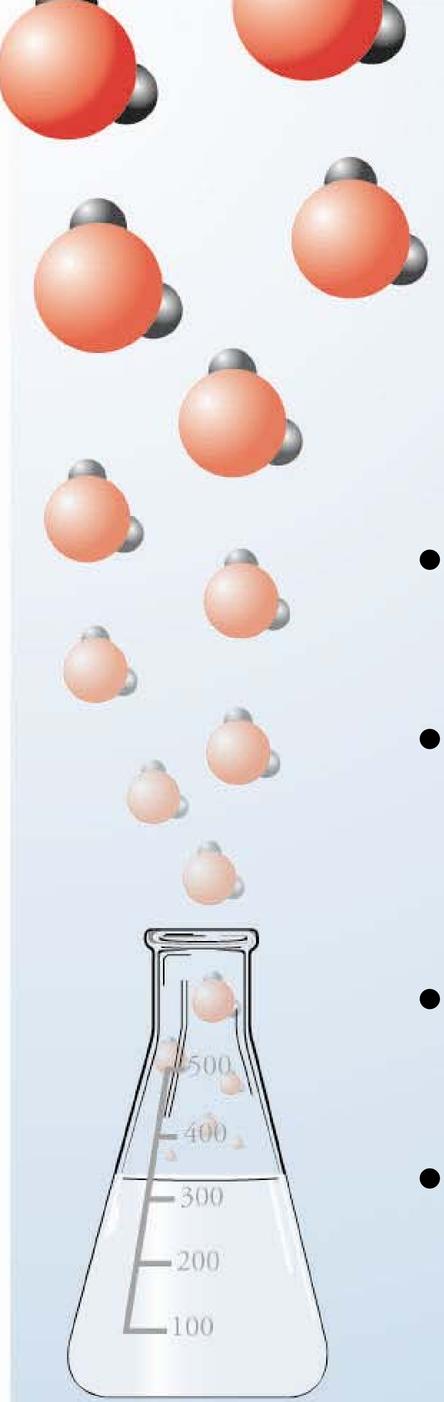


Dipole-Dipole Attractions in a Liquid



Electronegativities

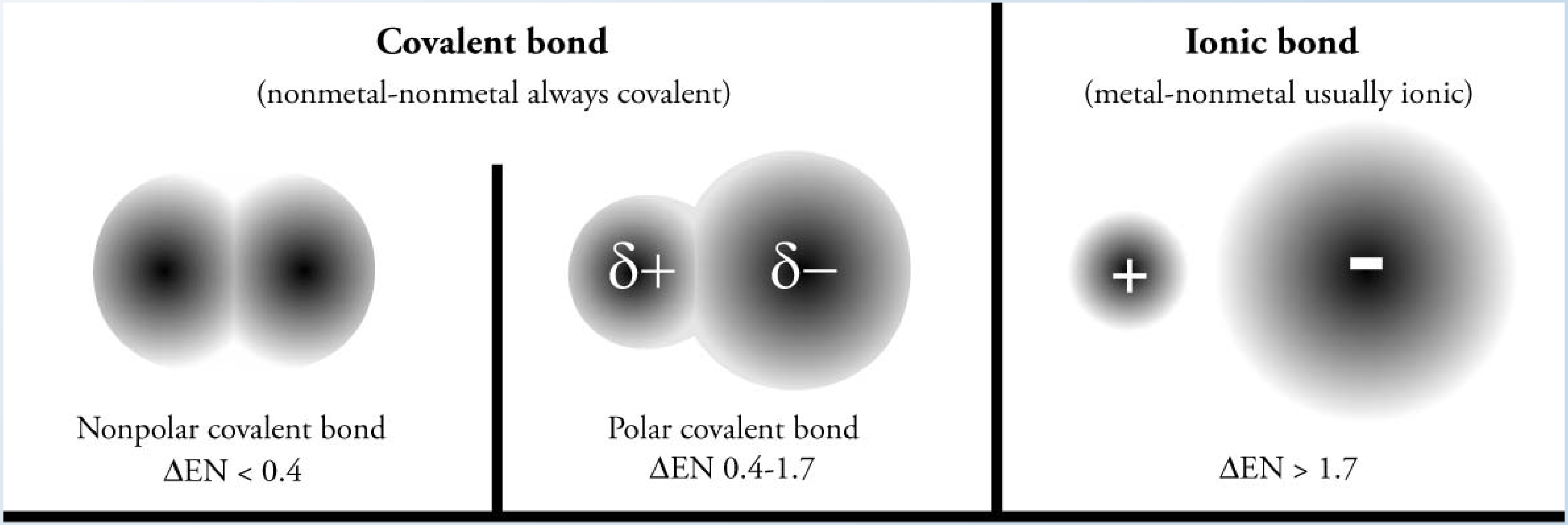
Period	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	2.20 H																	
2	0.98 Li	1.57 Be											2.04 B	2.55 C	3.04 N	3.44 O	3.98 F	
3	0.93 Na	1.31 Mg											1.61 Al	1.90 Si	2.19 P	2.58 S	3.16 Cl	
4	0.82 K	1.00 Ca	1.36 Sc	1.54 Ti	1.63 V	1.66 Cr	1.55 Mn	1.83 Fe	1.88 Co	1.91 Ni	1.90 Cu	1.65 Zn	1.81 Ga	2.01 Ge	2.18 As	2.55 Se	2.96 Br	3.00 Kr
5	0.82 Rb	0.95 Sr	1.22 Y	1.33 Zr	1.6 Nb	2.16 Mo	1.9 Tc	2.2 Ru	2.28 Rh	2.20 Pd	1.93 Ag	1.69 Cd	1.78 In	1.96 Sn	2.05 Sb	2.1 Te	2.66 I	2.6 Xe
6	0.79 Cs	0.89 Ba	1.27 Lu	1.3 Hf	1.5 Ta	2.36 W	1.9 Re	2.2 Os	2.20 Ir	2.28 Pt	2.54 Au	2.00 Hg	1.62 Tl	2.33 Pb	2.02 Bi	2.0 Po	2.2 At	
7	0.7 Fr	0.9 Ra																



Electronegativity, a measure of the electron attracting ability of atoms in chemical bonds is used to predict.

- whether a chemical bond is nonpolar covalent, polar covalent, or ionic.
- which atom in a polar covalent bond is partial negative and which is partial positive.
- which atom in an ionic bond forms the cation and which forms the anion.
- which of two covalent bonds are more polar.

Bond Types


Covalent bond
(nonmetal-nonmetal always covalent)
Ionic bond
(metal-nonmetal usually ionic)
δ+
δ−
+
-
Nonpolar covalent bond
ΔEN < 0.4
Polar covalent bond
ΔEN 0.4-1.7
ΔEN > 1.7

Which atom in a polar covalent bond is partially negative and which is partially positive?

higher electronegativity

↓

partial negative charge

lower electronegativity

↓

partial positive charge

Which of two bonds is more polar?

The greater the ΔEN is, the more polar the bond.

Predicting Molecular Polarity

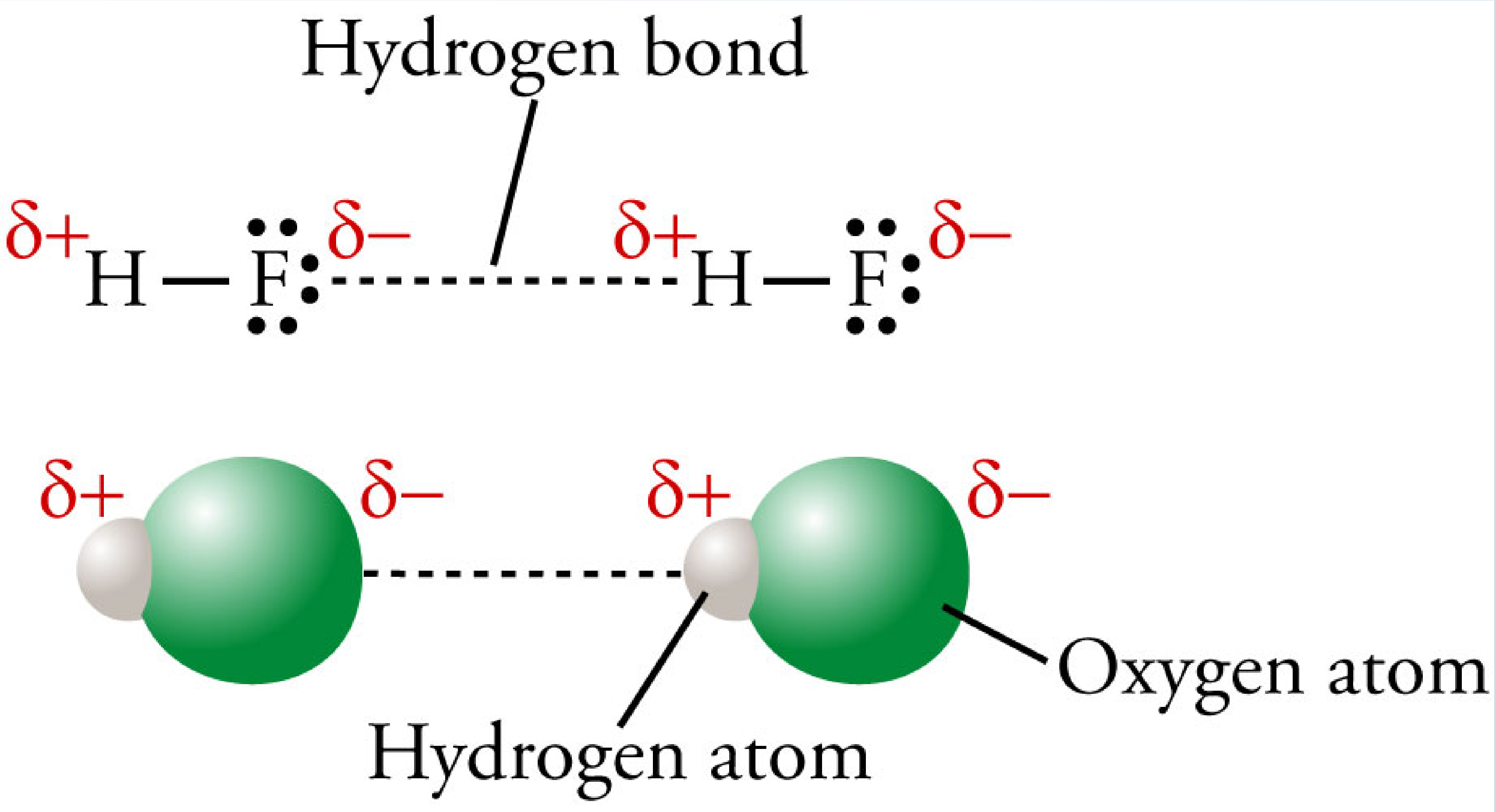
- Three questions will help you predict whether substances are composed of polar or nonpolar molecules.
  - Is the substance molecular?
  - If the substance is molecular, do the molecules contain polar covalent bonds?
  - If the molecules contain polar covalent bonds, are these bonds asymmetrically arranged?

Examples of Polar and Nonpolar Molecules

- Polar
  - H_2O, NH_3
  - Oxyacids
  - Hydrogen halides: HF, HCl, HBr, and HI
  - Alcohols: CH_3OH, C_2H_5OH
- Nonpolar
  - Elements composed of molecules: H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2, P_4, S_8, Se_8
  - CO_2
  - Hydrocarbons, C_aH_b

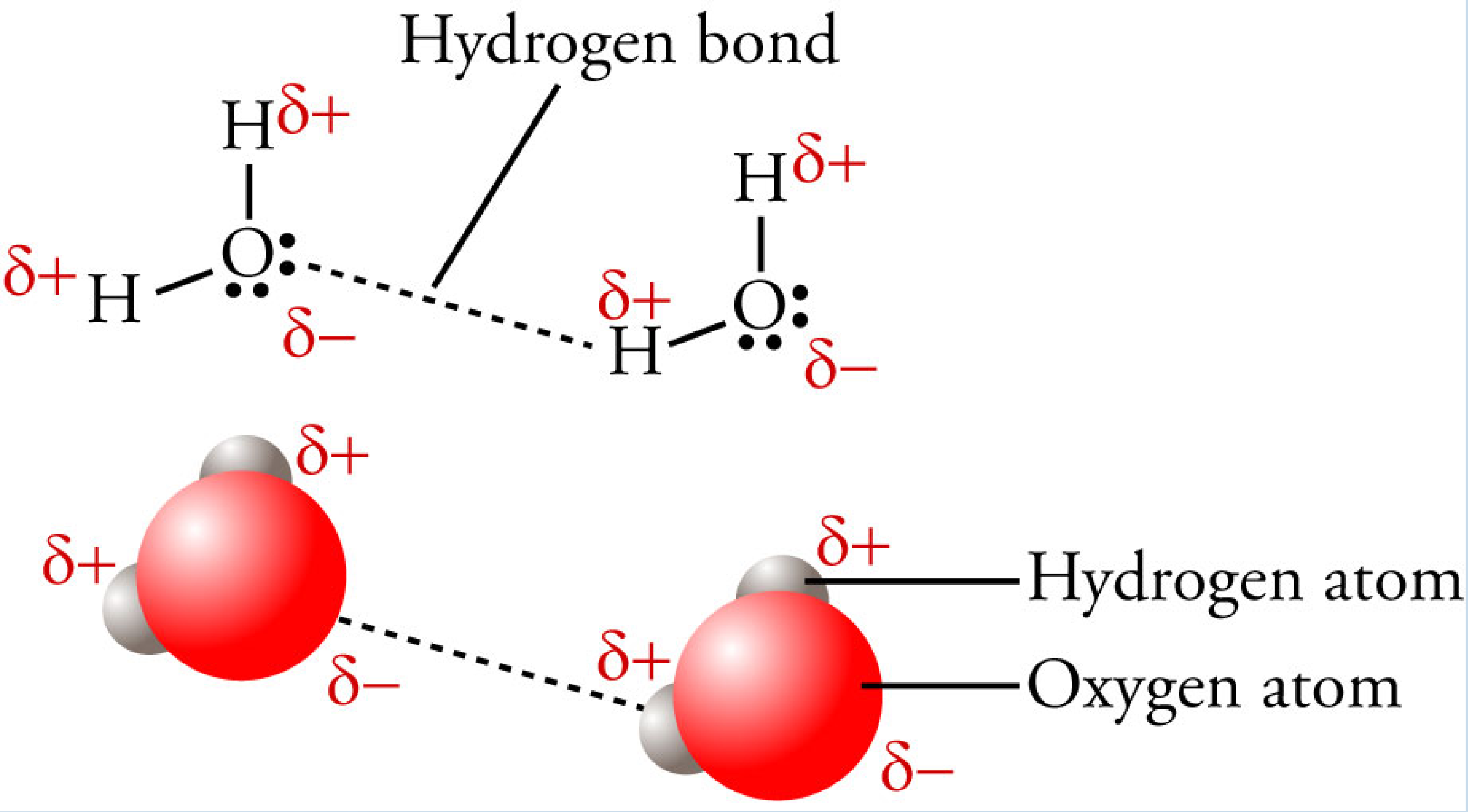
Hydrogen Bonds in HF

In HF, the hydrogen bond is between the partial positive H of one HF molecule and the partial negative F of another HF molecule.

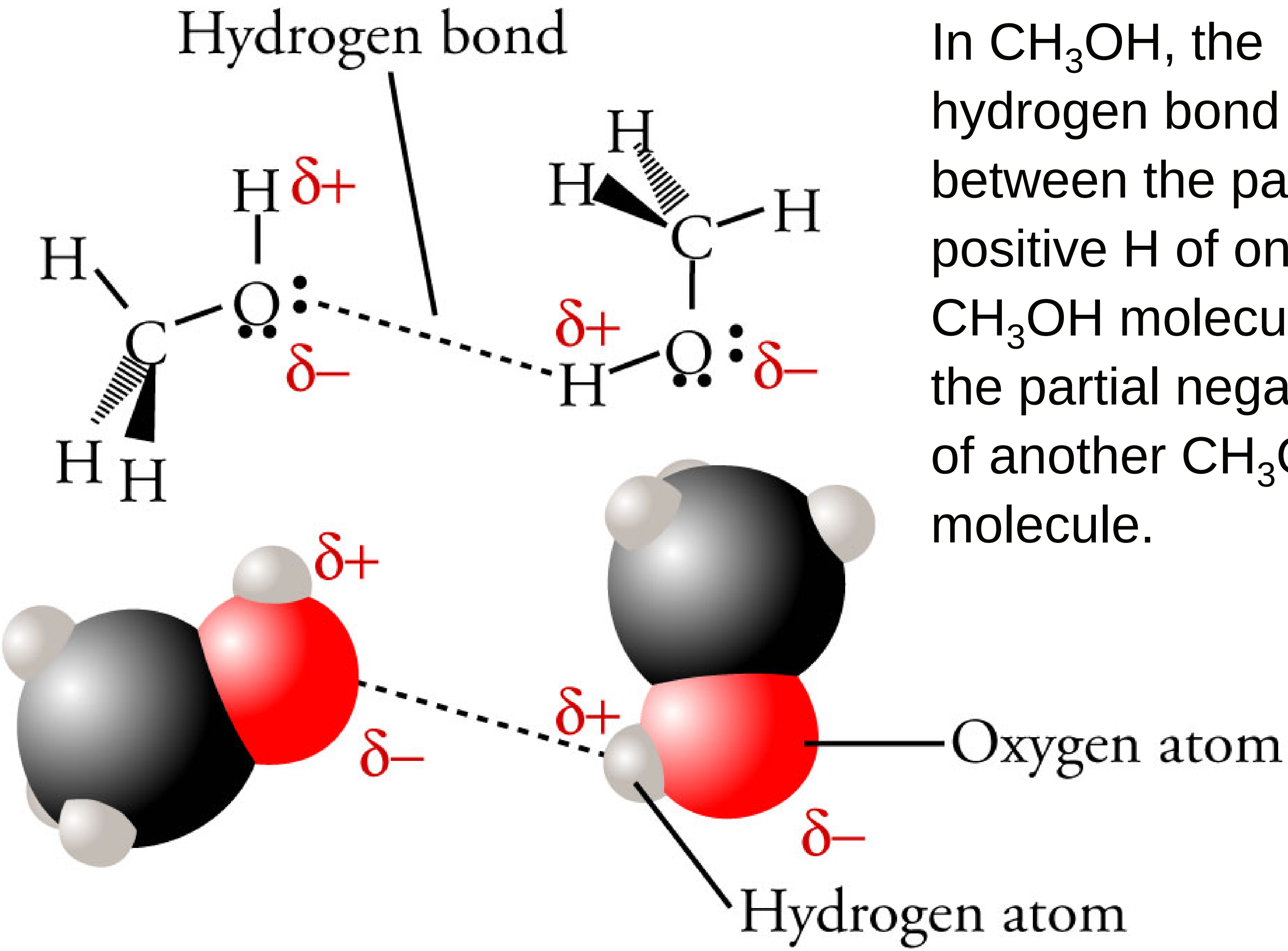


Hydrogen Bonds in Water

In H_2O, the hydrogen bond is between the partial positive H of one H_2O molecule and the partial negative O of another H_2O molecule.



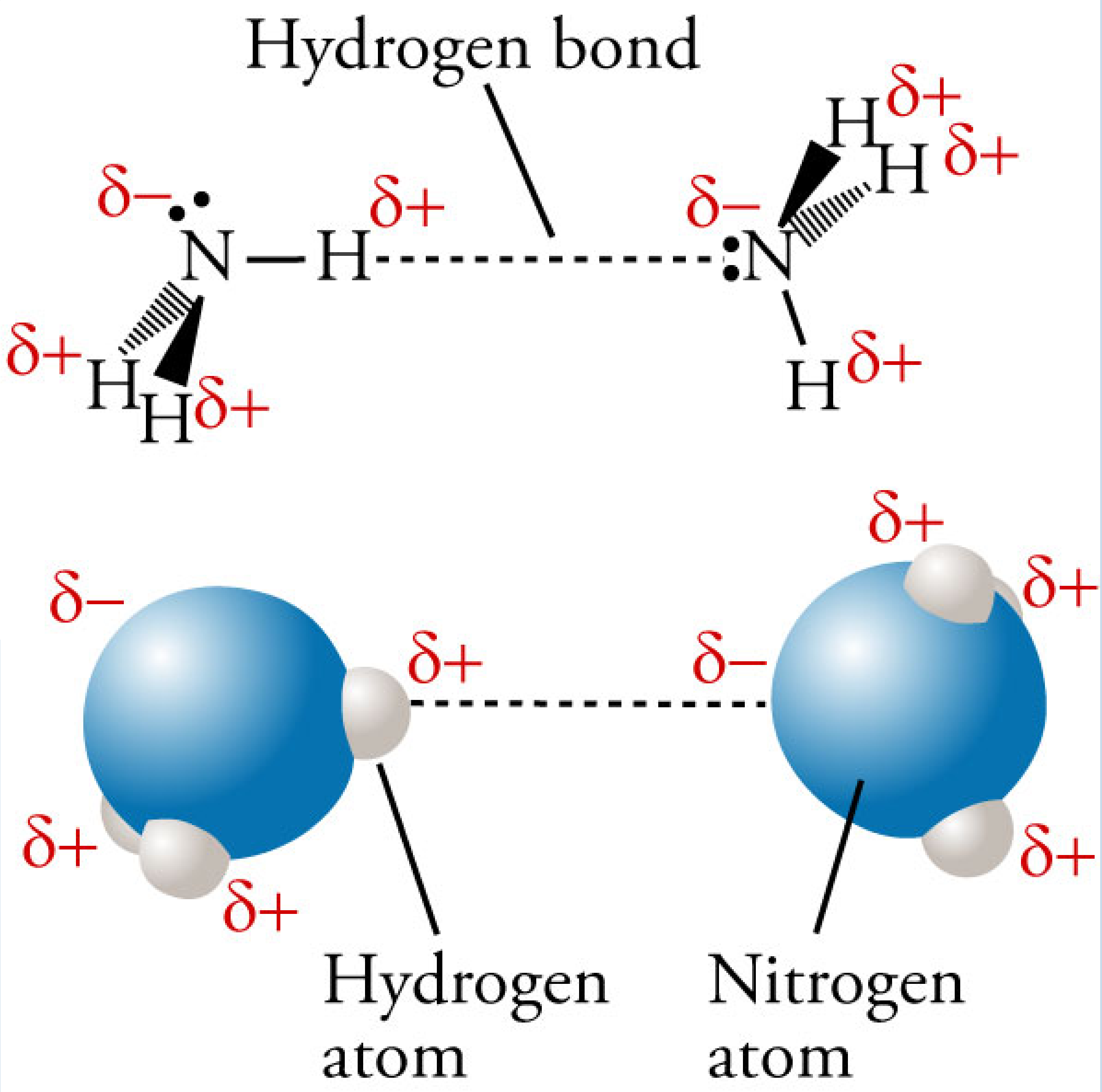
Hydrogen Bonds in Methanol



In CH_3OH, the hydrogen bond is between the partial positive H of one CH_3OH molecule and the partial negative O of another CH_3OH molecule.

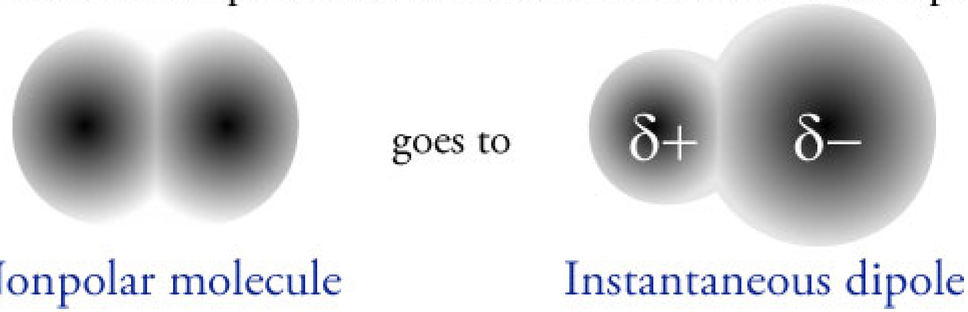
Hydrogen Bonds in Ammonia

In NH_3, the hydrogen bond is between the partial positive H of one NH_3 molecule and the partial negative N of another NH_3 molecule.



London Forces

1. Chance or collisions cause nonpolar molecules to form instantaneous dipoles.

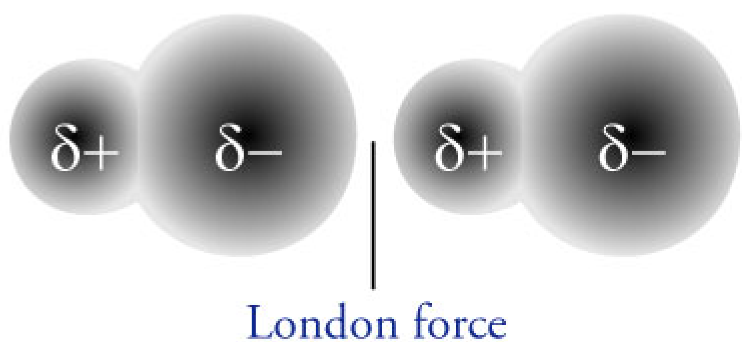


2. Instantaneous dipoles induce dipoles in other nonpolar molecules.

Repulsion between the partial negative charge of the instantaneous dipole and the negative charge of the electrons in the nonpolar molecule pushes the electrons in the nonpolar molecule to the right, forming an induced dipole.

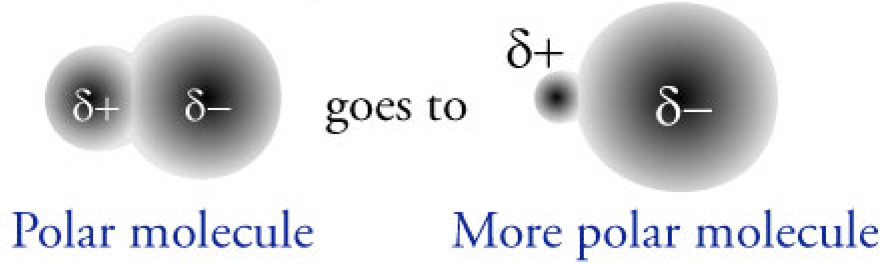
Induced dipole

3. Induced dipoles can induce dipoles in other nonpolar molecules, resulting in many molecules with partial charges. London forces are the attractions between the partial positive and partial negative charges in these instantaneous and induced dipoles.

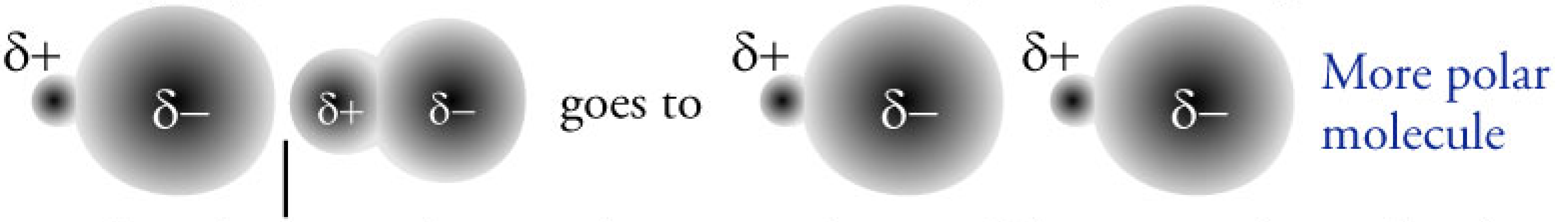


London Forces in Polar Molecules

1. Chance or collisions cause polar molecules to become more polar.

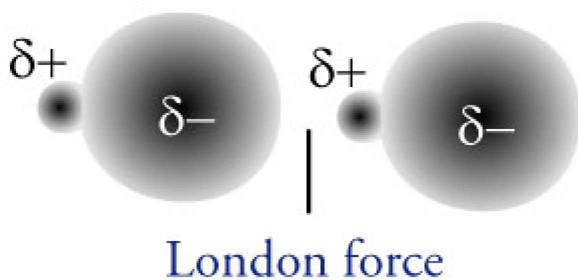


2. More highly polar molecules induce increases in polarity in less polar molecules.

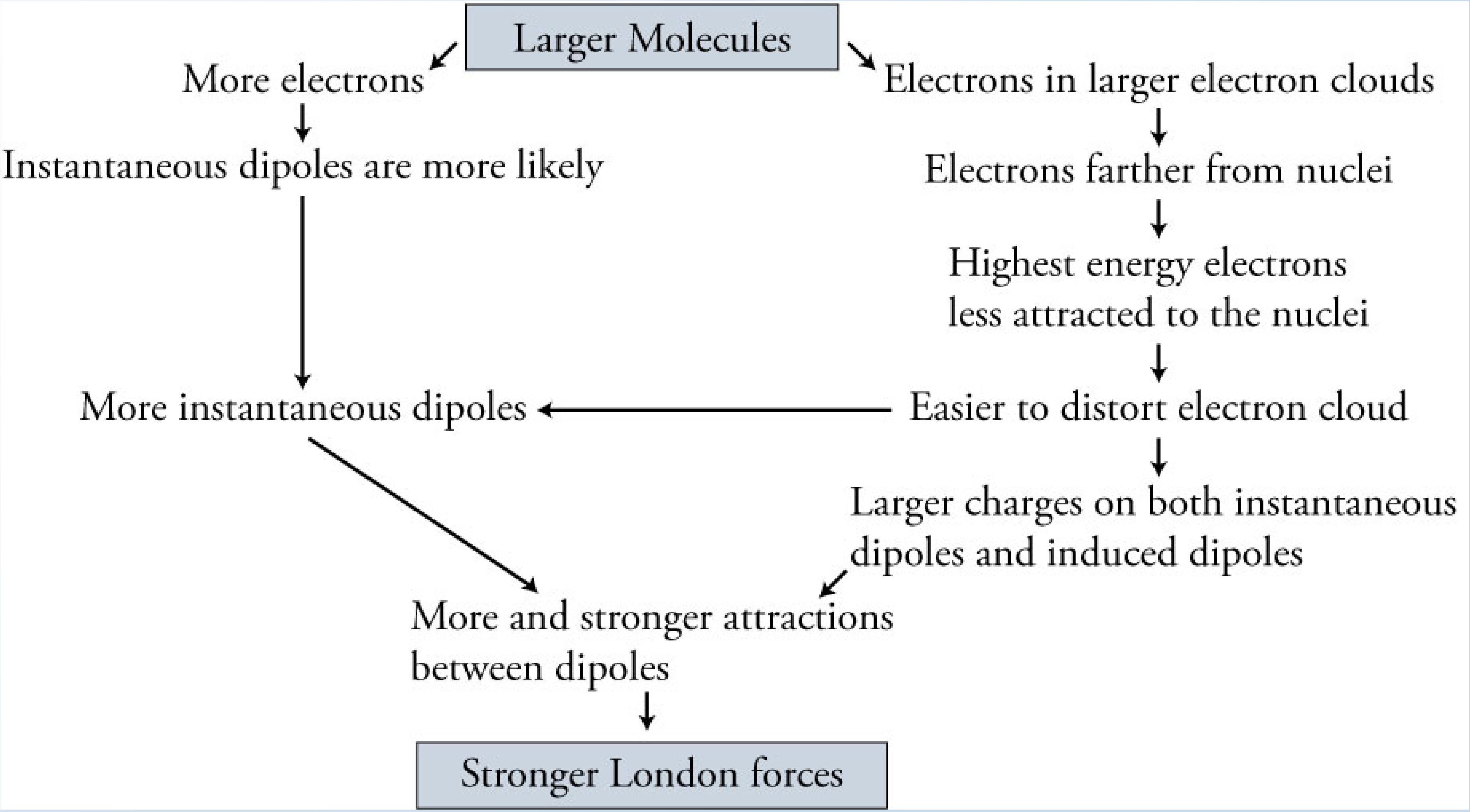


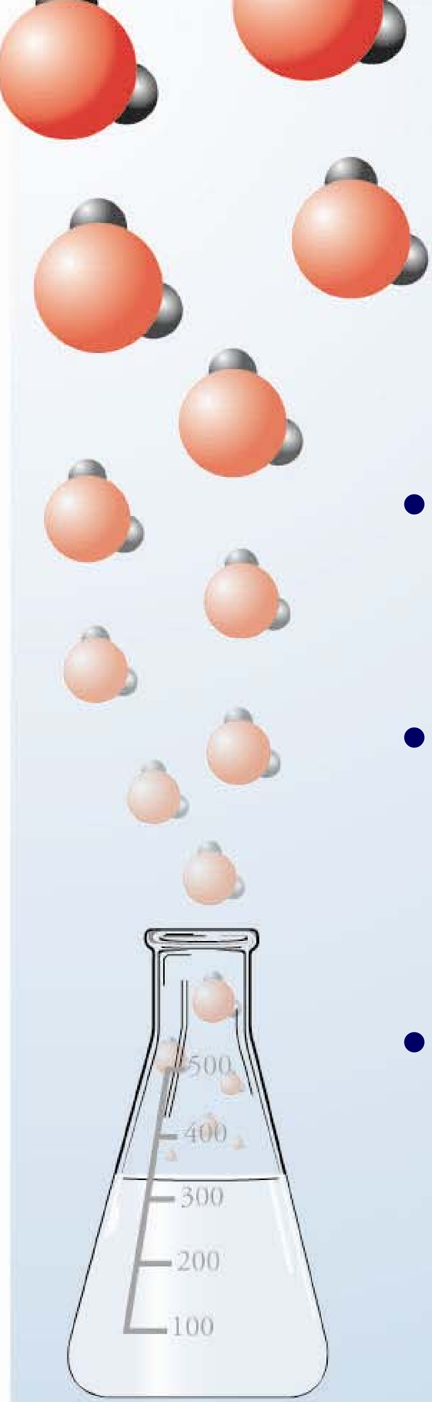
Repulsion between the partial negative charge of the more polar molecule and the negative charge of the electrons in the less polar molecule pushes the electrons in the less polar molecule to the right, leading to an induced increase in polarity.

3. The more polar molecules can induce increases in polarity in other less polar molecules, resulting in many molecules with larger partial charges. London forces are the attractions between the partial positive and partial negative charges in these instantaneously increased dipoles and induced increases in dipoles.



Why Larger Molecules Have Stronger London Forces

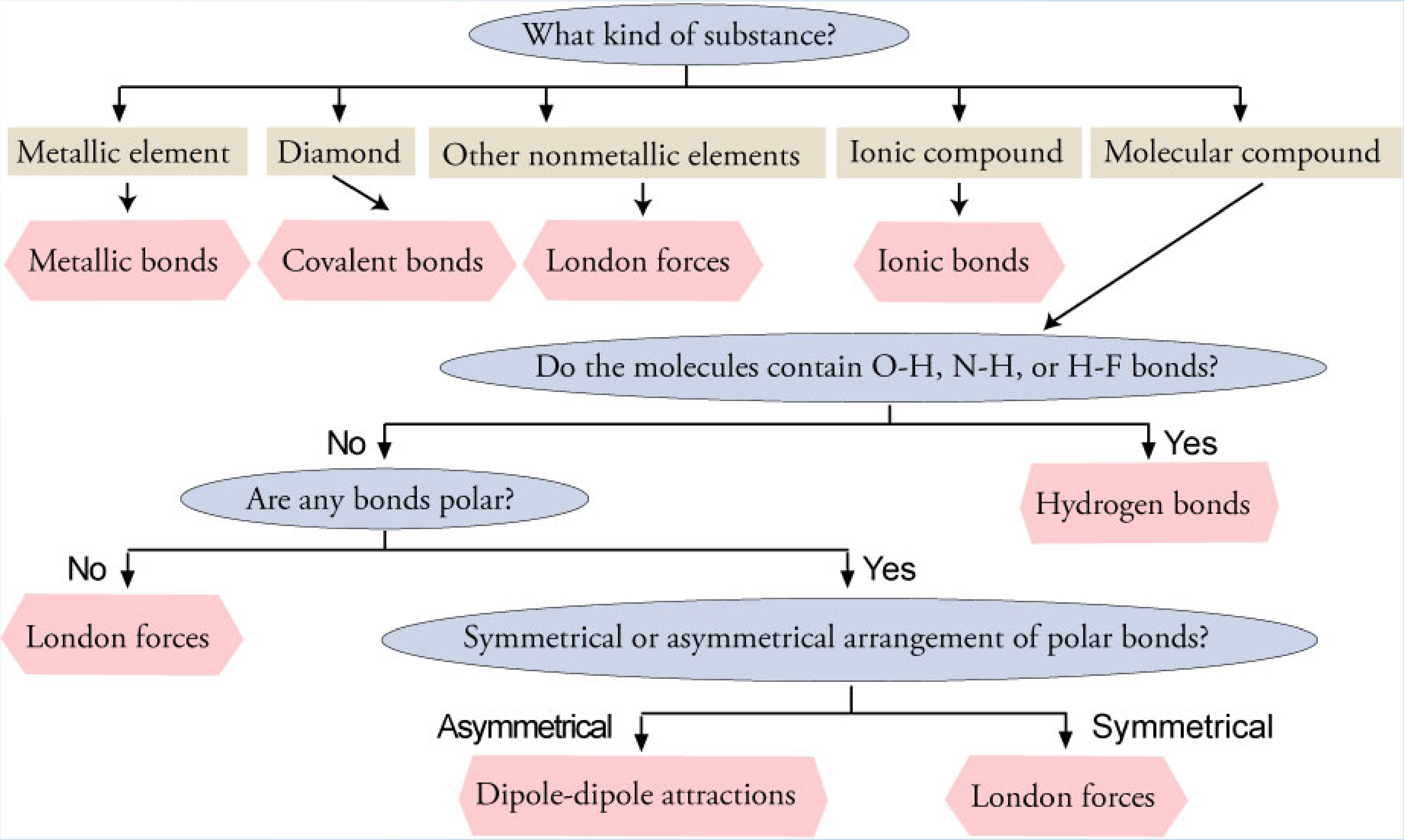




Types of Attractions – Carbon

- **Diamond -** Carbons atoms held together by covalent bonds, forming huge 3-dimensional molecules.
- **Graphite -** Carbons atoms held together by covalent bonds, forming huge 2-dimensional molecules held together by London forces.
- **Fullerenes -** Carbons atoms held together by covalent bonds, forming 3-dimensional molecules held together by London forces.

Predicting Types of Attractions

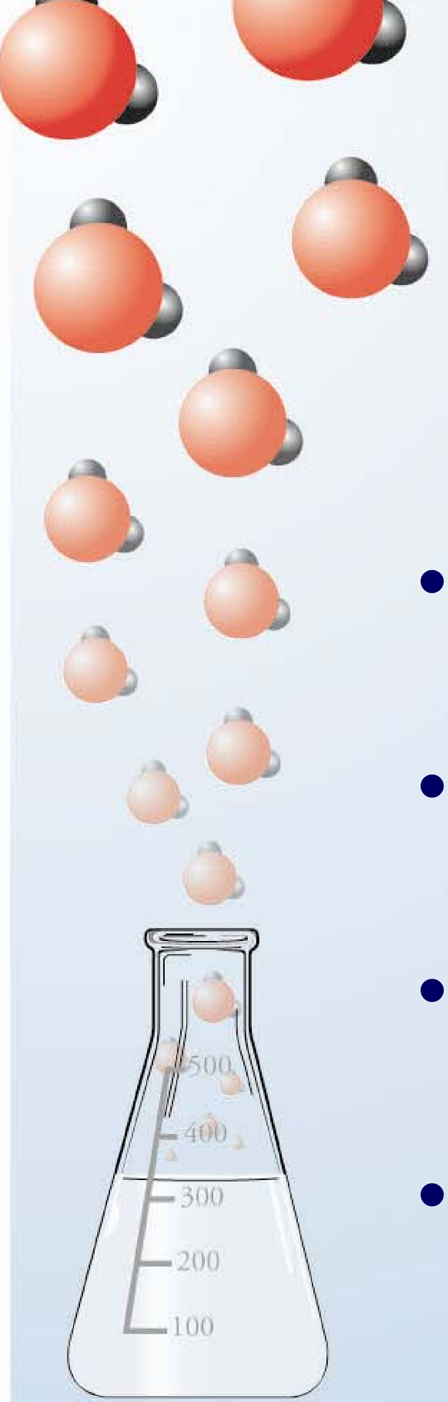


Types of Particles and Attractions - Elements

Type of element	Particles to visualize	Examples	Type of Attraction
metals	cations in a sea of electrons	gold, Au	metallic bonds
noble gases	atoms	xenon, Xe	London forces
carbon (diamond)	atoms	C(dia)	covalent bonds
other nonmetallic elements	molecules	H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2, S_8, Se_8, P_4	London forces

Types of Particles and Attractions - Compounds

Type of compound	Particles to visualize	Examples	Type of Attraction
ionic	cations and anions	NaCl	ionic bonds
nonpolar molecular	molecules	hydrocarbons	London forces
polar molecular w/out H-F, O-H, or N-H	molecules	HCl	dipole-dipole
polar molecular with H-F, O-H, or N-H	molecules	HF, H_2O, NH_3, alcohols	hydrogen bonds



Particles and Types of Attractions for the Elements

- **Metals –** cations in a sea of electrons, metallic bonds
- **Noble gases –** atoms, London forces
- **Carbon (diamond) –** atoms, covalent bonds
- **Other nonmetallic elements –** molecules, London forces

Particles and Types of Attractions for the Compounds

- **Ionic –** cations and anions, ionic bonds
- **Molecular**
  - – Nonpolar – molecules, London forces
  - – Polar without H-F, O-H, or N-H – molecules, dipole-dipole attractions
  - – Polar with H-F, O-H, or N-H – molecules, hydrogen bonds