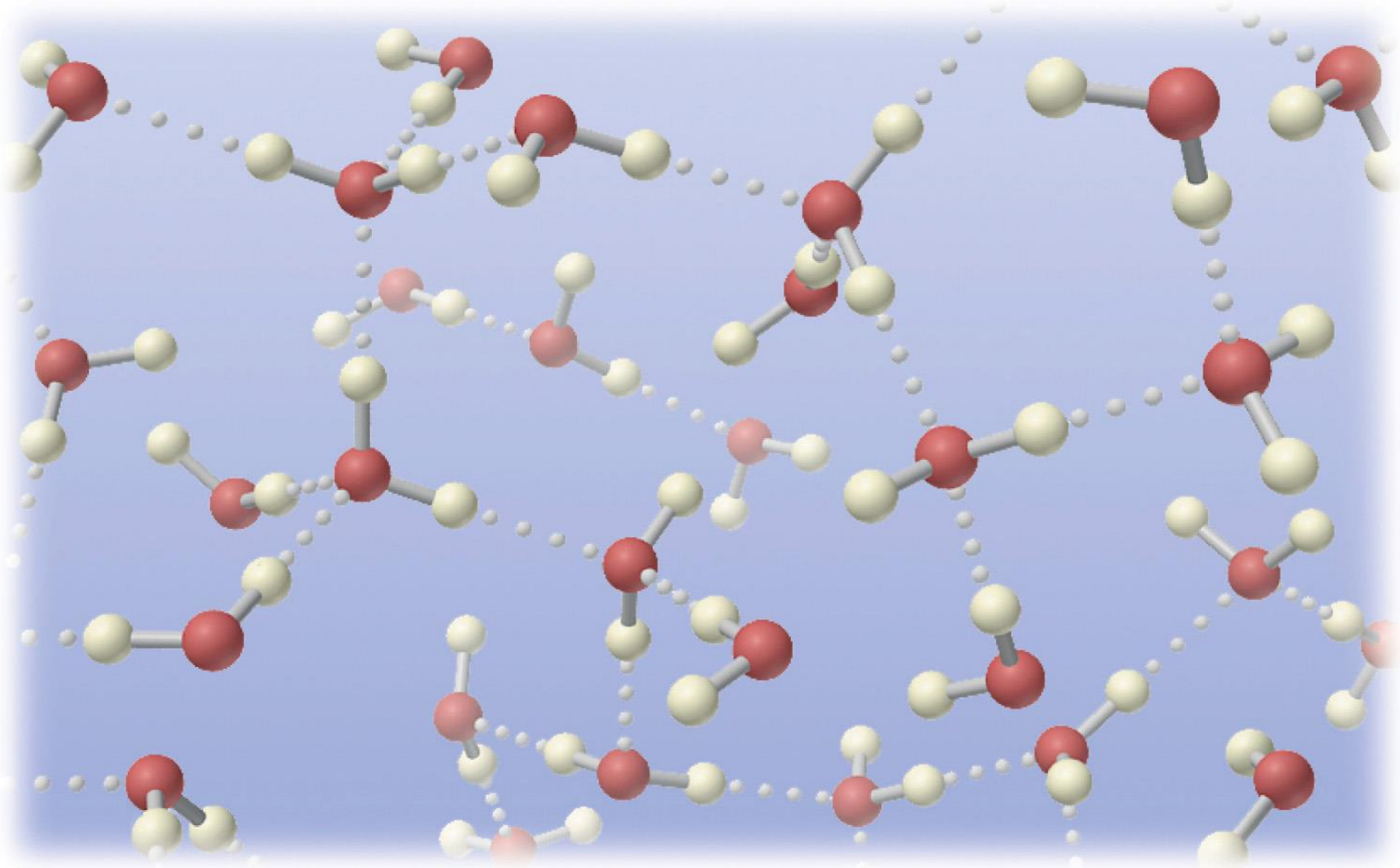
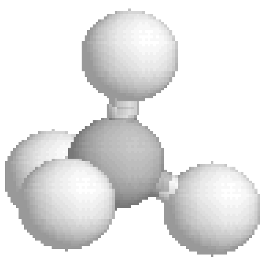
Chapter 10: liquids and solids

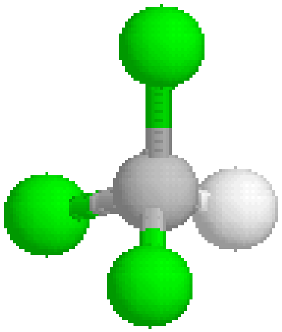


Group Brainstorm Activity

- Come up with *two* molecular level explanations for why the boiling points of these two molecules are so different.

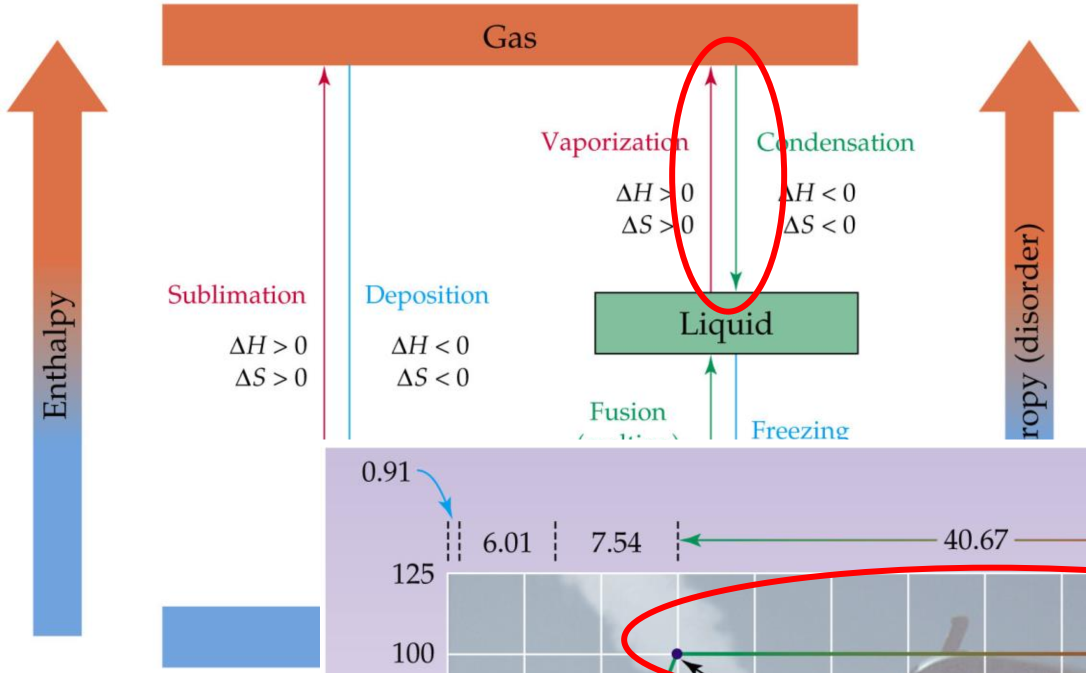


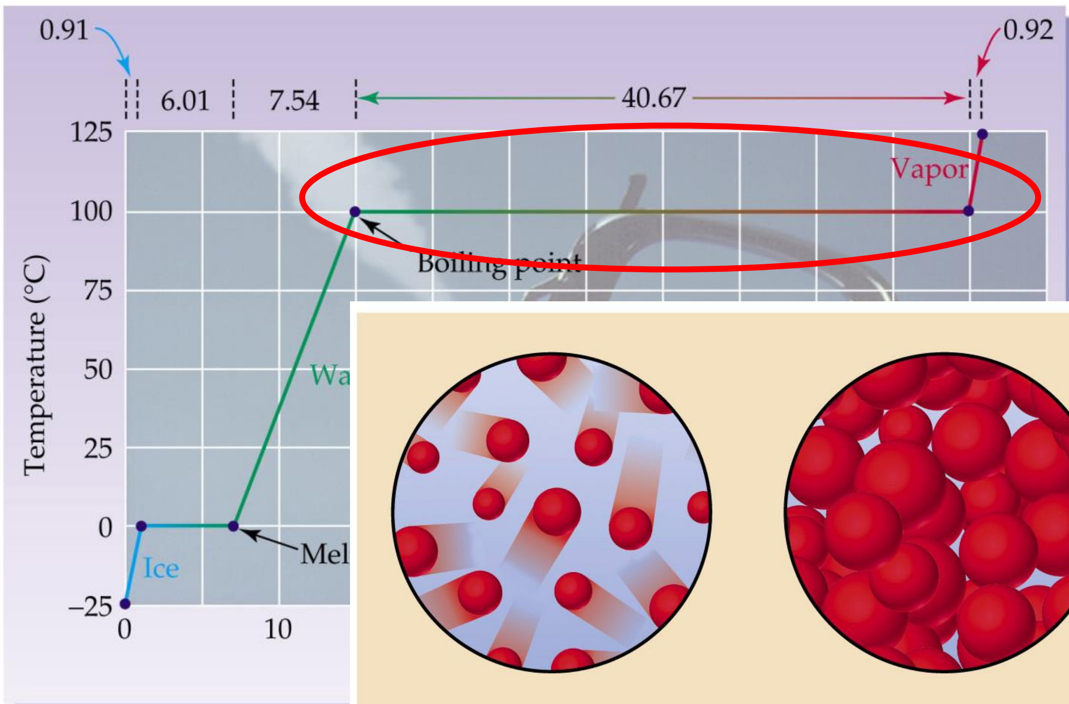
CH_4
$- 161.6°C$

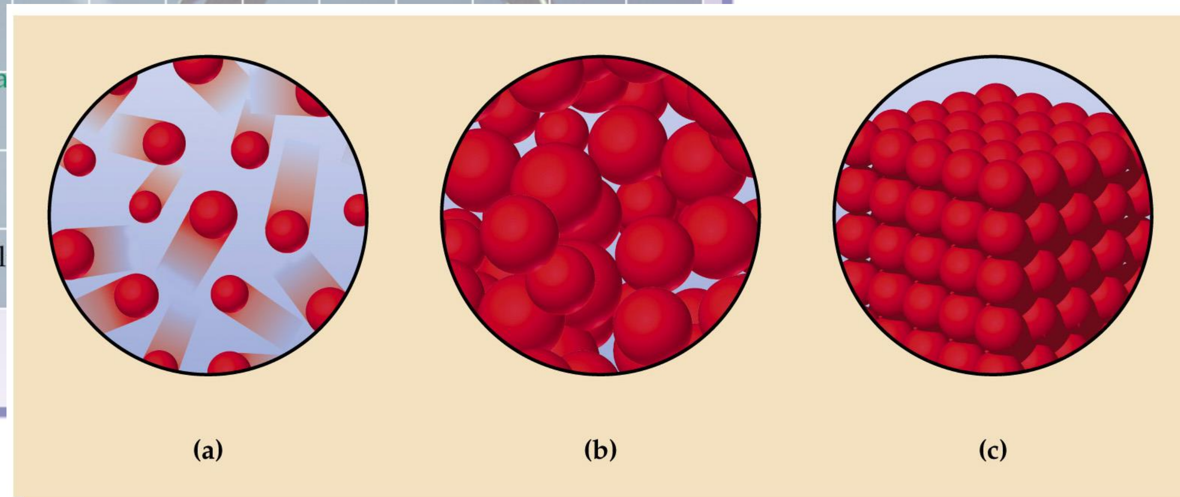


$CHCl_3$
$+ 62.26°C$

Representing Phase Changes







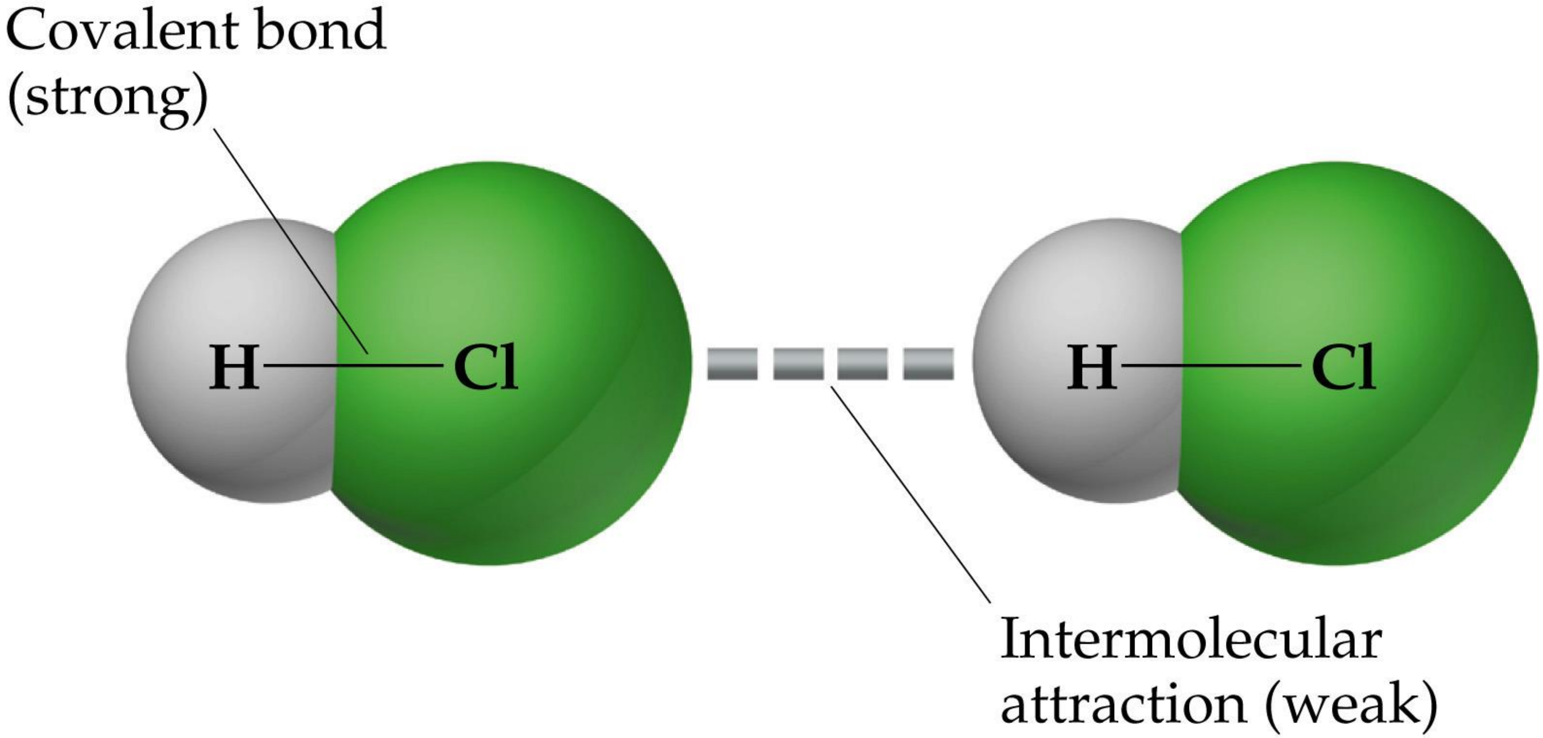
Animation

Animation 2

Practice

- Draw an enthalpy diagram to represent "boiling"
- Draw a heating curve to represent "boiling"
- Use a molecular level representation to explain "boiling"
- Use your bodies to demonstrate why methane boils at a lower temperature than chloroform

Intramolecular and Intermolecular Forces



Intermolecular Forces

- The attractive forces between molecules are called intermolecular forces. There are three types:

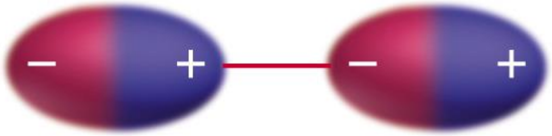
    Dipole-Dipole forces

    London Dispersion forces

    Hydrogen Bonding

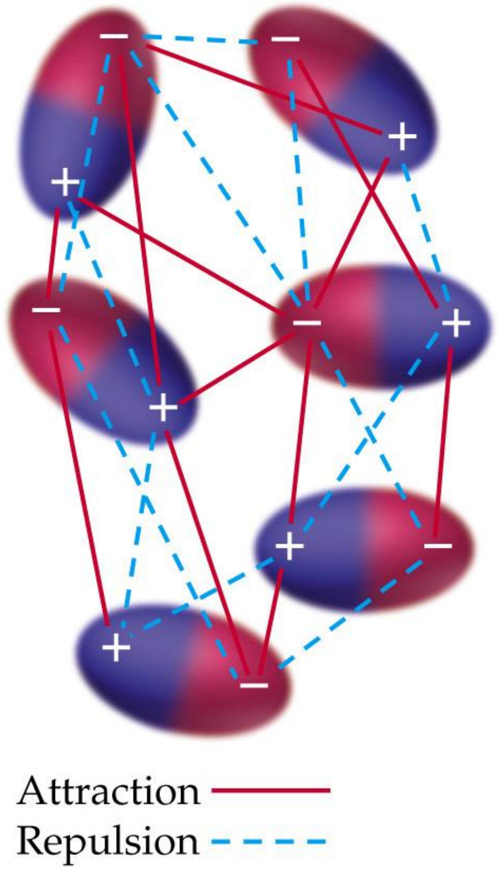
- Often, there is more than one type of force present

Dipole-Dipole Forces



(a)

- Electrostatic interaction of two polar molecules
- Strength of intermolecular forces increase with increasing polarity

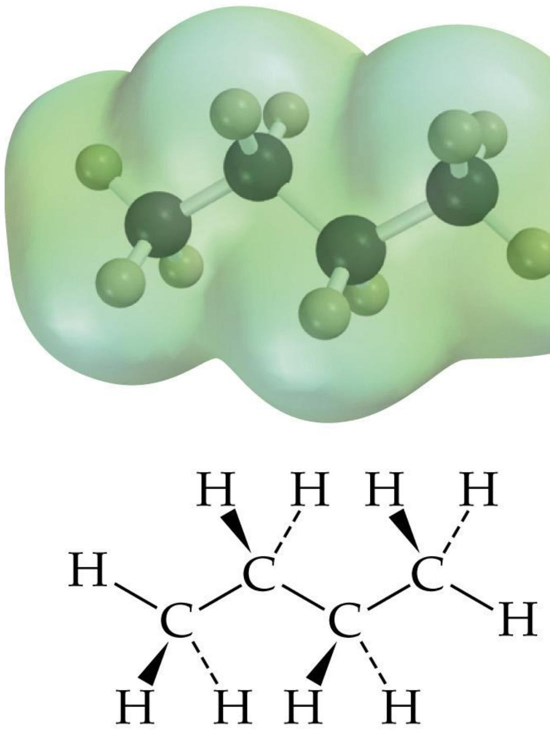


(b)

Dipole-Dipole Forces

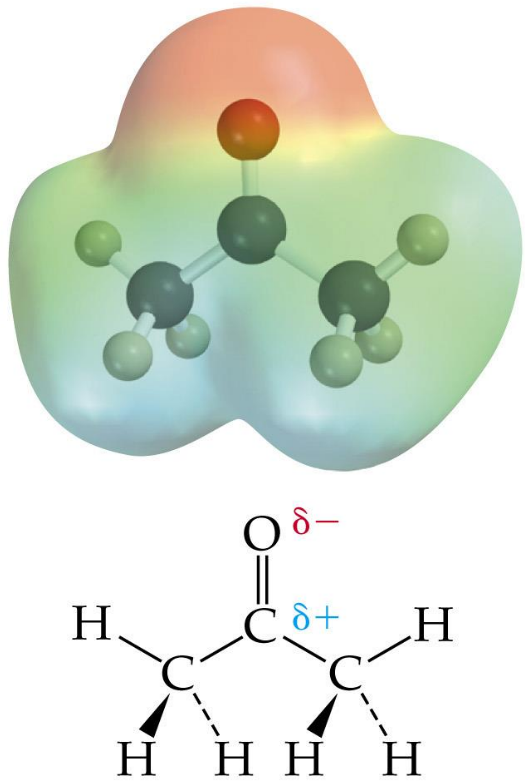
- Use two different representations to illustrate a dipole-dipole interaction between 2 chloroform molecules and share your drawing with your group members.

Why?



Butane (C_4H_{10})

Mol mass = 58 amu
bp = −0.5°C



Acetone (C_3H_6O)

Mol mass = 58 amu
bp = 56.2°C

Simple Organic Substances

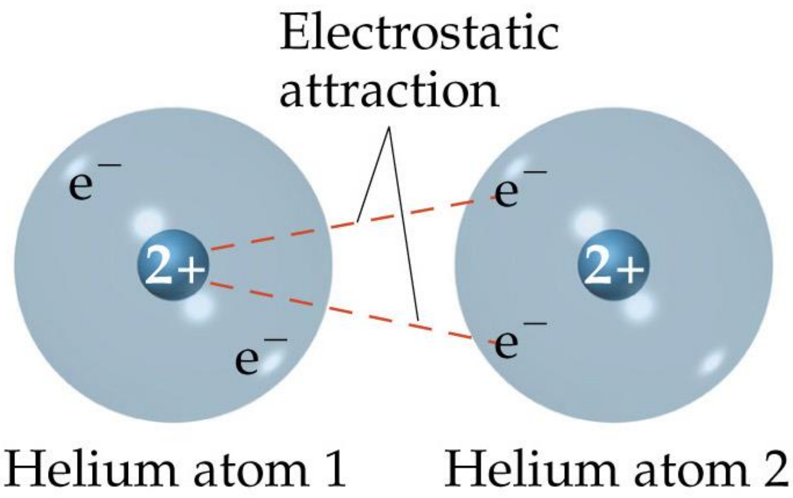
TABLE 11.2 Molecular Weights, Dipole Moments, and Boiling Points of Several Simple Organic Substances

Substance	Molecular Weight (amu)	Dipole Moment μ (D)	Boiling Point (K)
Propane, $CH_3CH_2CH_3$	44	0.1	231
Dimethyl ether, CH_3OCH_3	46	1.3	248
Methyl chloride, CH_3Cl	50	1.9	249
Acetaldehyde, CH_3CHO	44	2.7	294
Acetonitrile, CH_3CN	41	3.9	355

Questions??

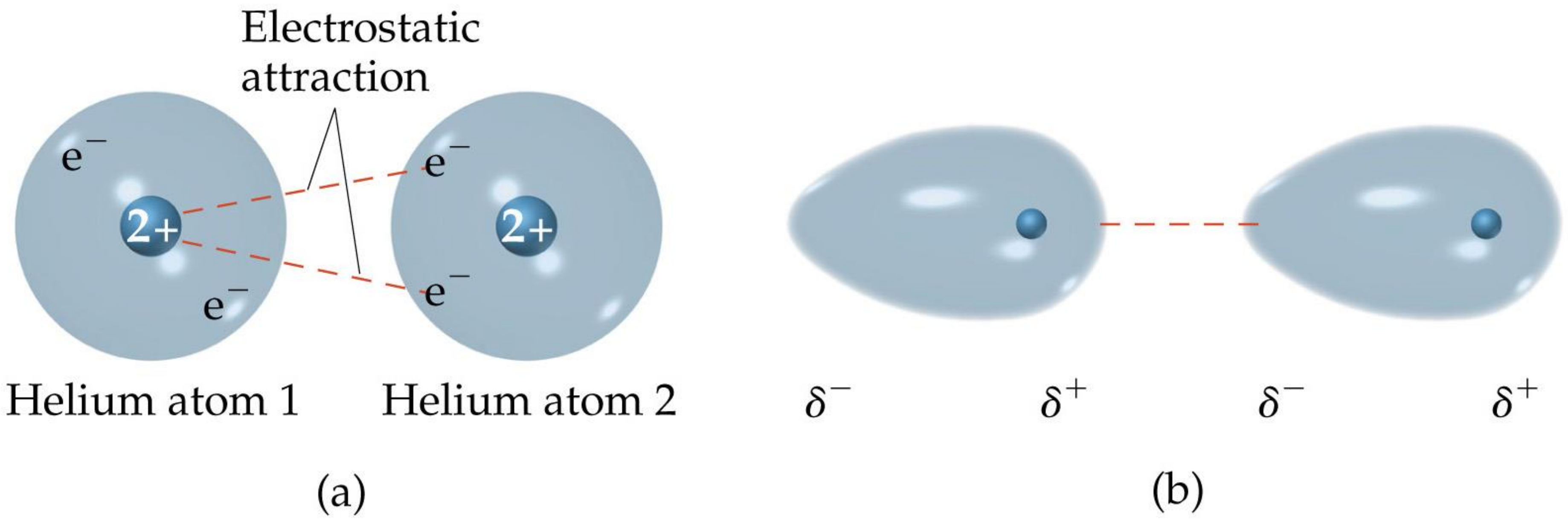
- Do non-polar molecules have attractive forces between molecules?
- How do we account for the fact that non-polar gases can be liquefied and solidified?

London Dispersion Forces



(a)

London Dispersion Forces



London Dispersion Forces

- Can your explain the boiling point data below:

Boiling points (K) of halogens

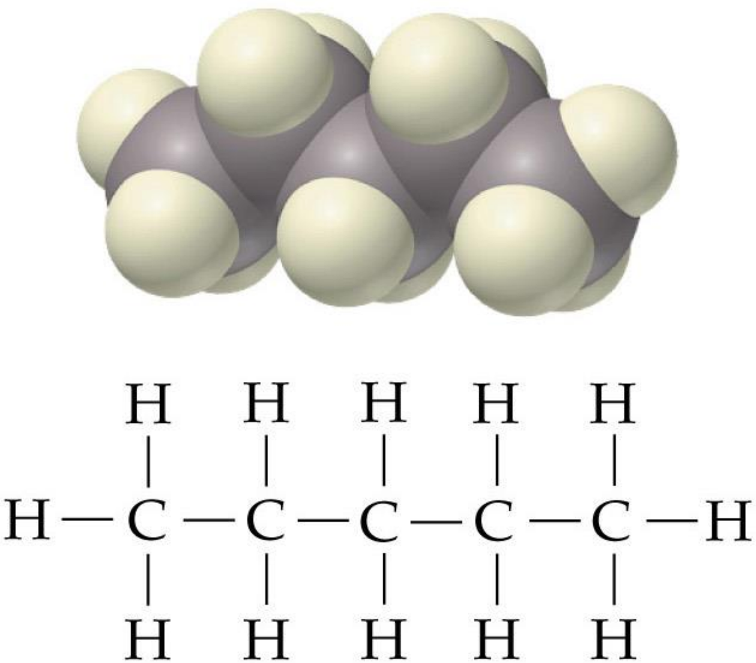
F_2	Cl_2	Br_2	I_2
85.1	238.6	332.0	457.6

Boiling points of Noble gases:

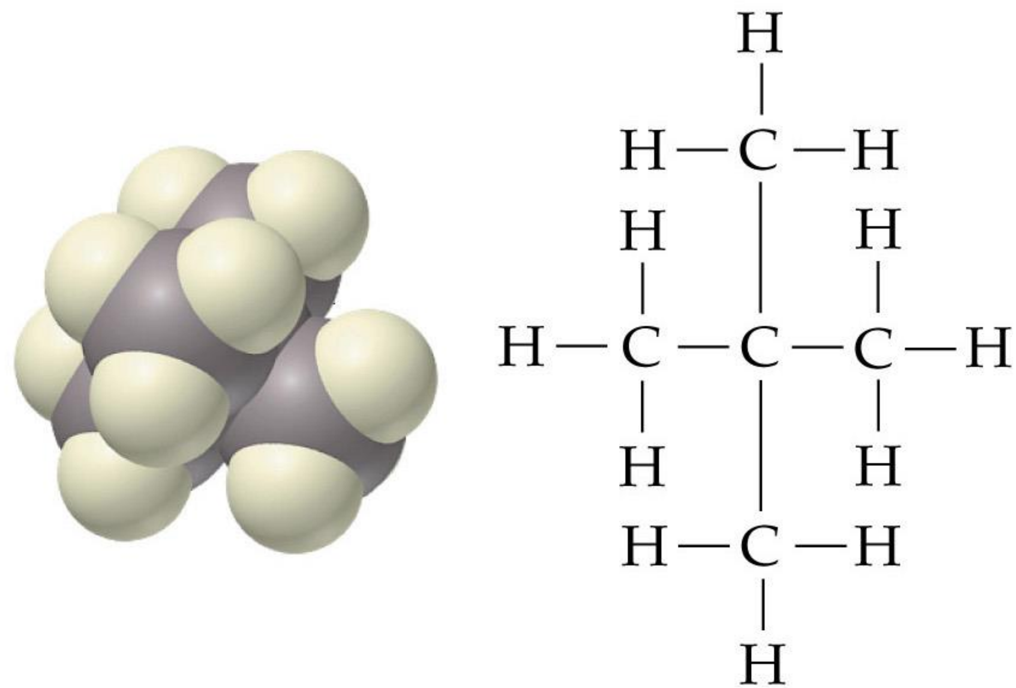
He	Ne	Ar	Kr	Xe
4.6	27.3	87.5	120.9	166.1

London Dispersion Forces

Can you explain the boiling point data below?



(a) Pentane (bp = 309.4 K)



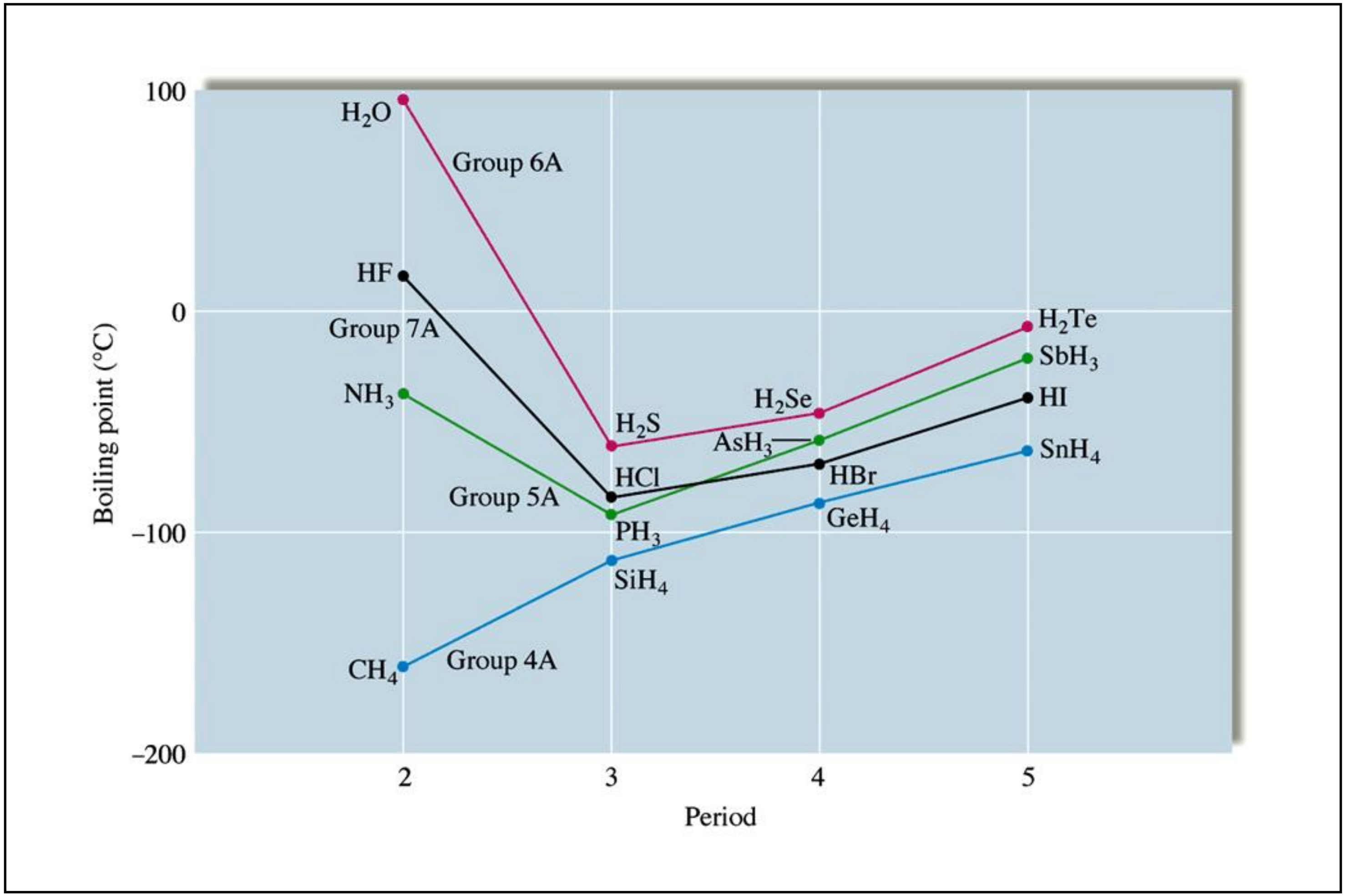
(b) 2,2-Dimethylpropane (bp = 282.7 K)

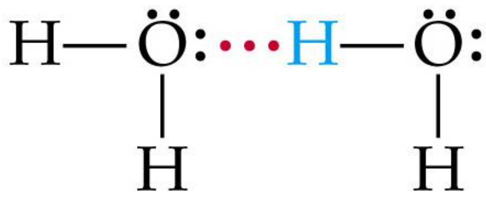
Definitions: Liquid Properties

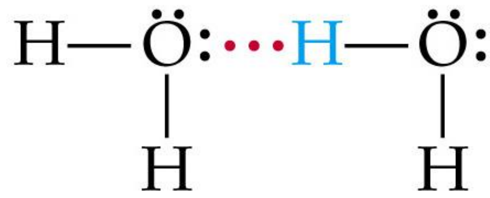
- Surface Tension: The resistance to an increase in its surface area
  - Polar molecules
  - Cohesive forces
- Capillary Action: Spontaneous rising of a liquid in a narrow tube.
  - Adhesive forces
  - Forces between liquid and container
- Viscosity: Resistance to flow
  - strong intermolecular forces.
  - Honey, cold oil, …

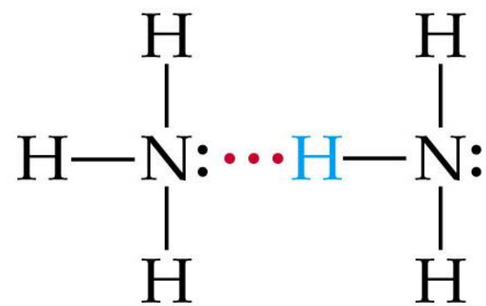
Boiling points of covalent hydrides,

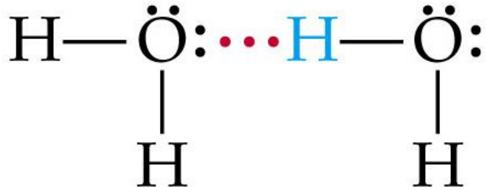
…What's going on with water, HF, and ammonia?

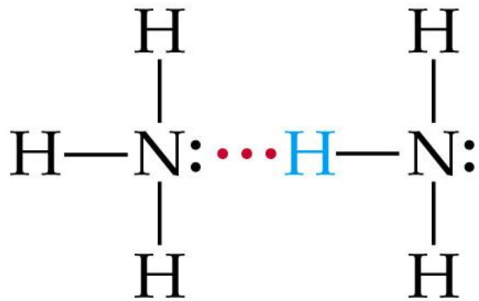


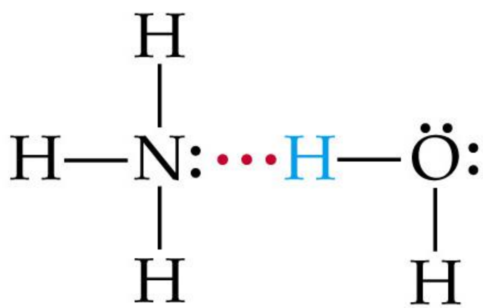


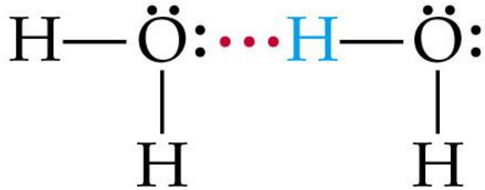


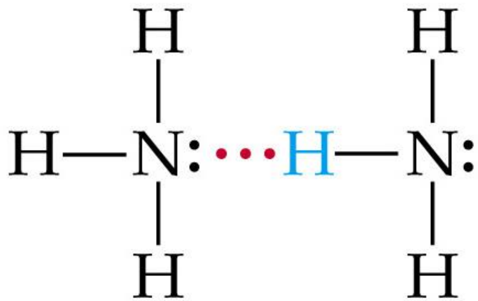


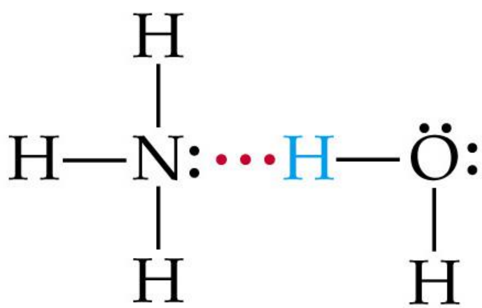


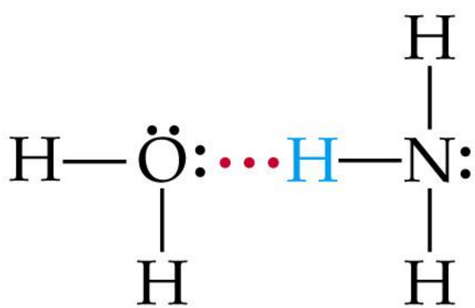






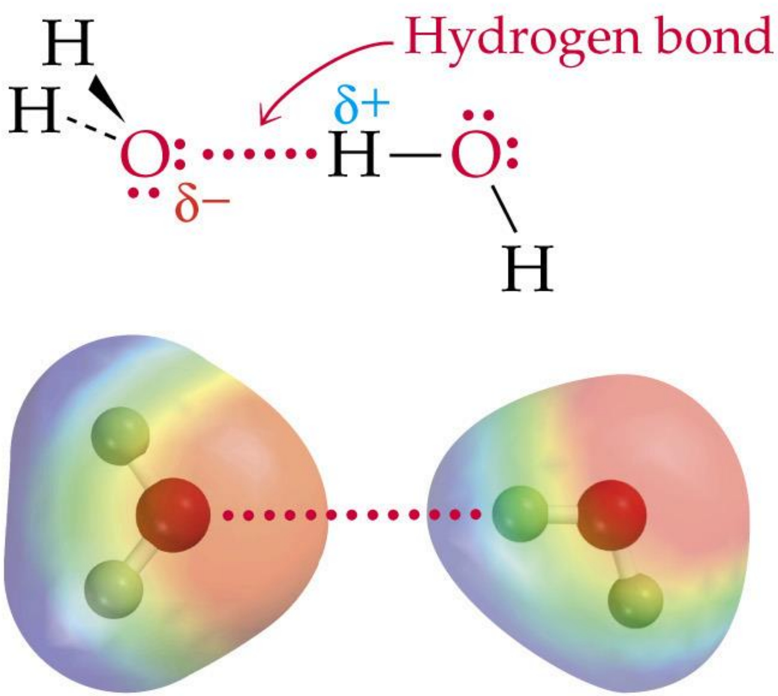


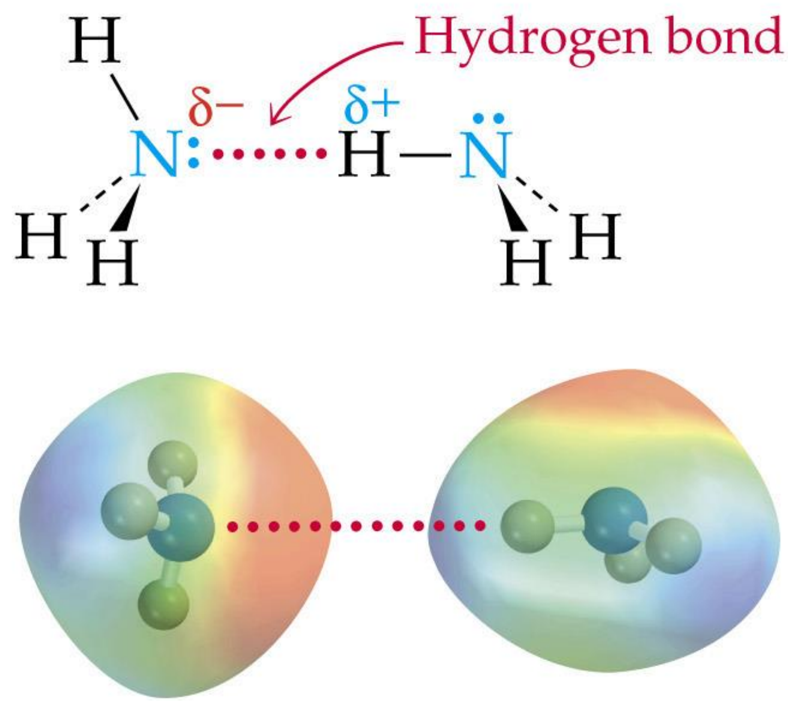




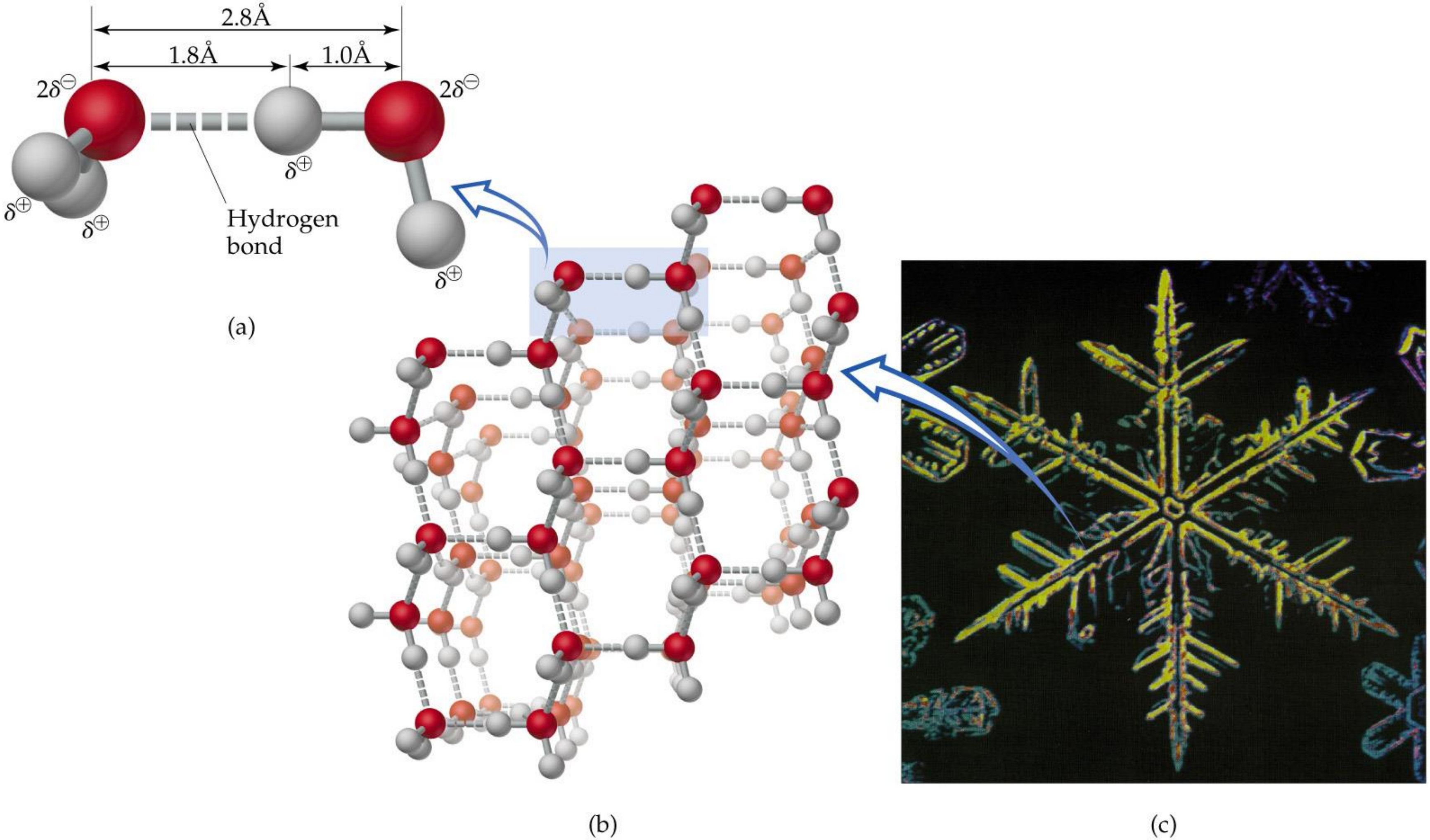
The Hydrogen bond

- A special intermolecular attraction between the H in a polar bond (H-F, H-O or H-N) and an unshared electron pair on a nearby electronegative ion or atom (F, O or N)
- Hydrogen bonds (4 to 25 kJ/mol) are weaker than covalent bonds but stronger than most dipole-dipole or dispersion forces.

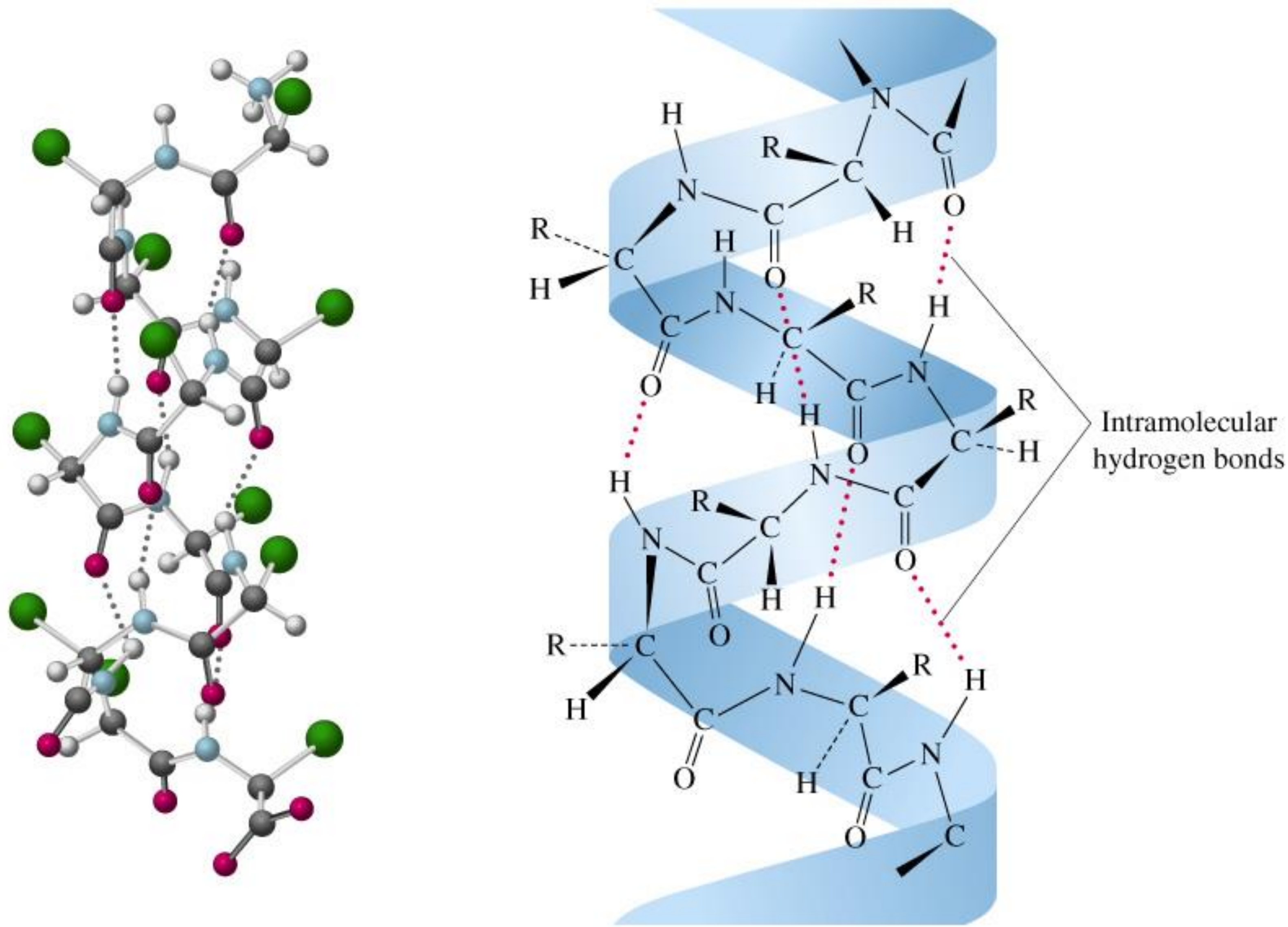

Hydrogen bond
δ+
δ−


Hydrogen bond
δ−
δ+

Hydrogen Bonding in Ice



Room temp - 4 °C	~ 1.0000 g/ml
0- 4 °C	~ 0.9998 g/ml
Ice	~ 0.92000 g/ml



(b)

Conceptual Question

- Name and illustrate the forces present between molecules for each substance below. Also, rank the substances from strongest to weakest intermolecular forces.

1. He NH_3 NF_3 NaCl

2. HF F_2 FCl

Conceptual Question

- In each of the following groups of substances, indicate which has the highest boiling point and explain your answer.

$CH_3CH_2CH_2CH_3$

$CH_3OCH_2CH_3$

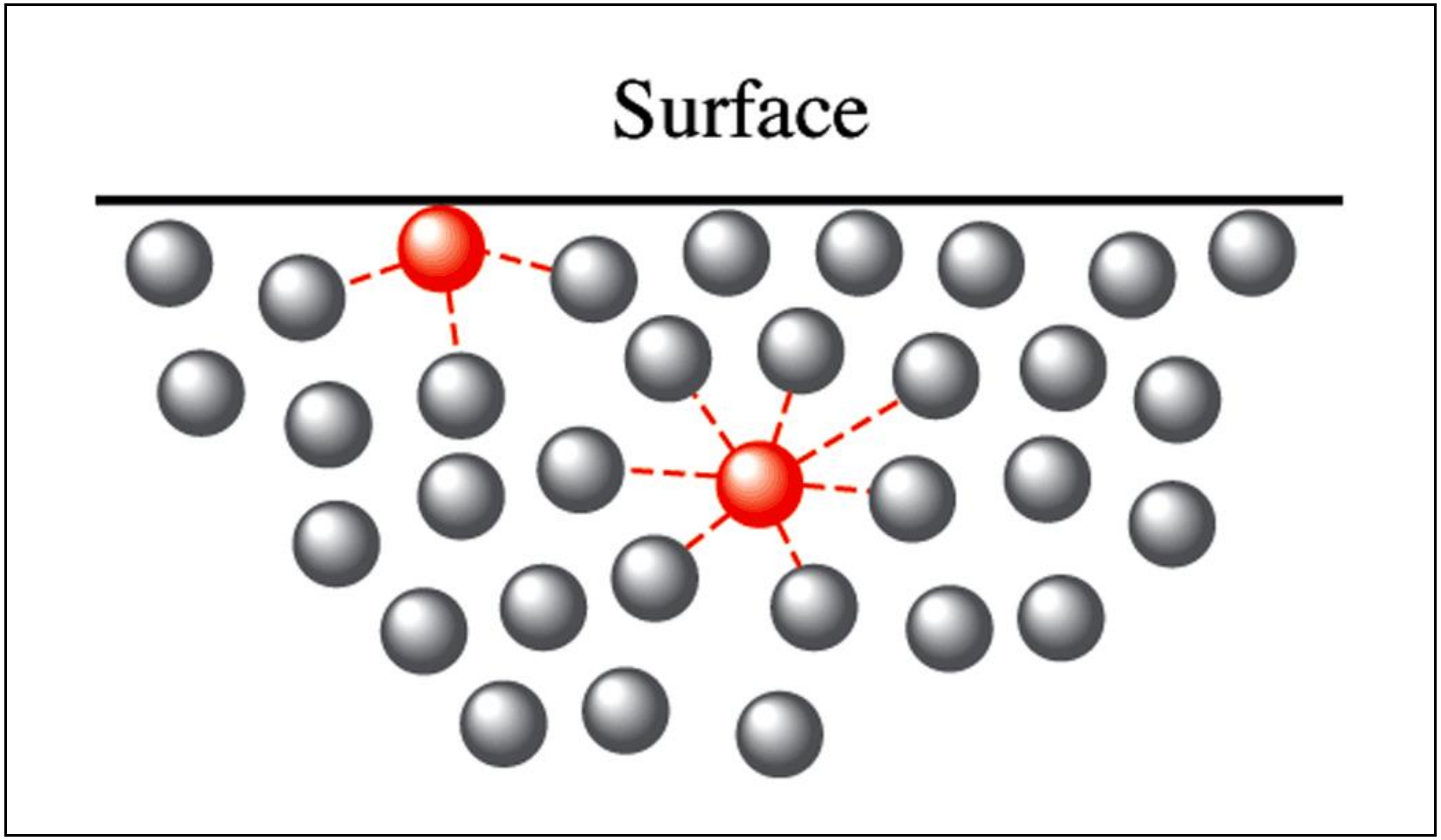
$CH_3CH_2CH_2F$

$CH_3CH_2CH_2NH_2$

$CH_3CH_2N(CH_3)_2$

Intermolecular forces within a liquid: Instantaneous position matters!

Interior molecule attracted by all surrounding, BUT surface molecule attracted only by those below and on each side.



Solids

Representing Components in a Crystalline Solid

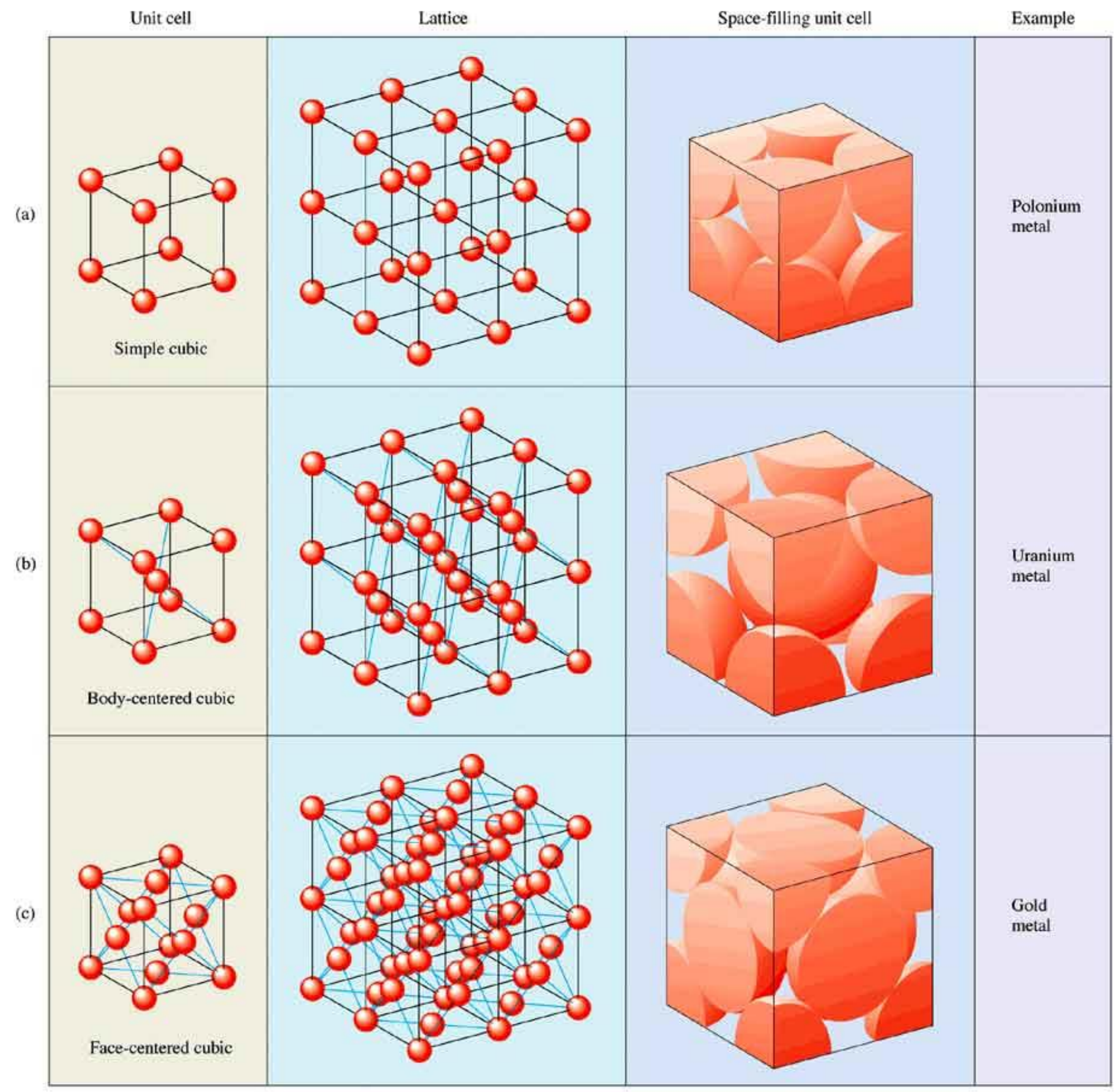
- Unit Cell: The smallest repeating unit of the lattice.

    - simple cubic
    - body-centered cubic
    - face-centered cubic

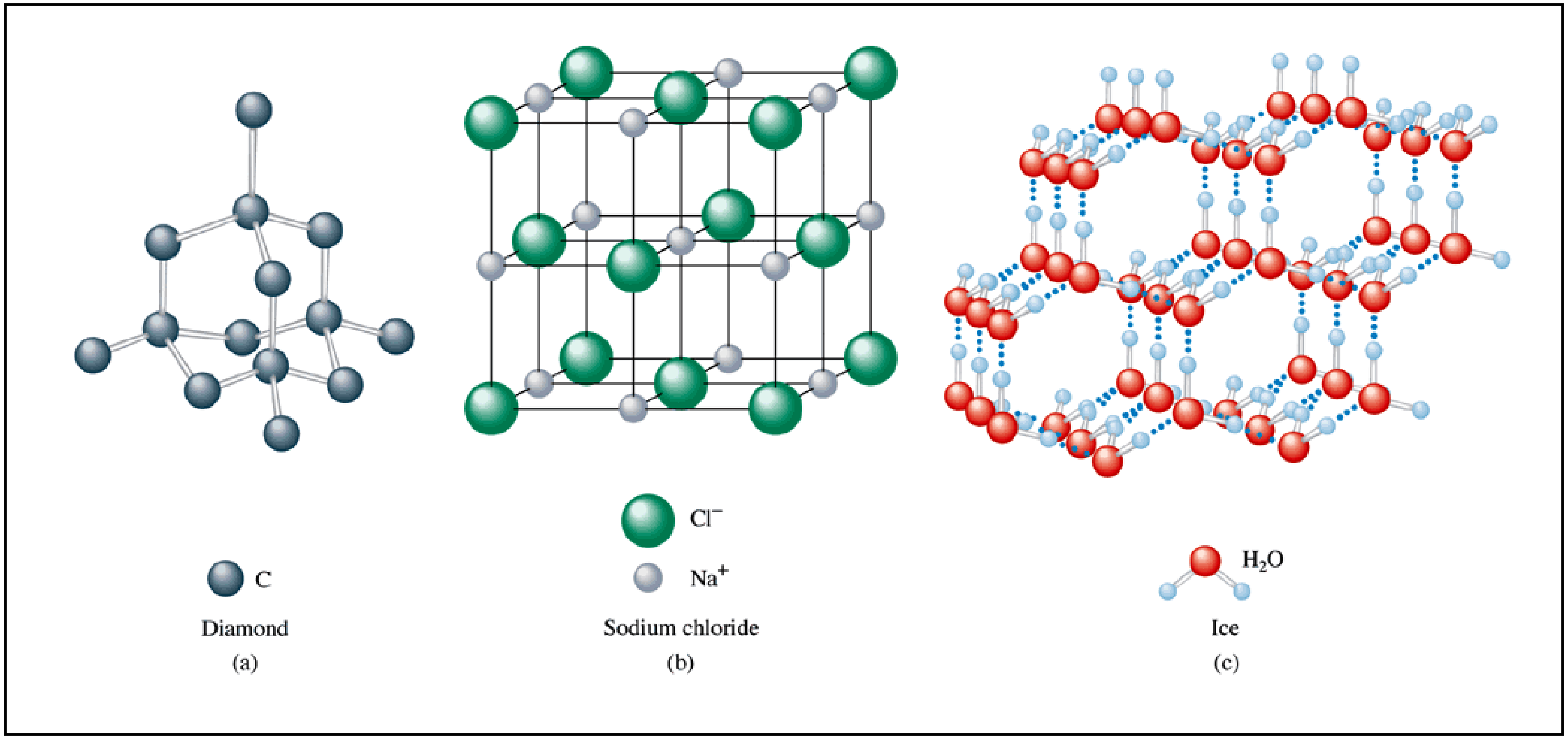
Cubic unit cells

Calc.# atoms per cell

*see pg 464 for density



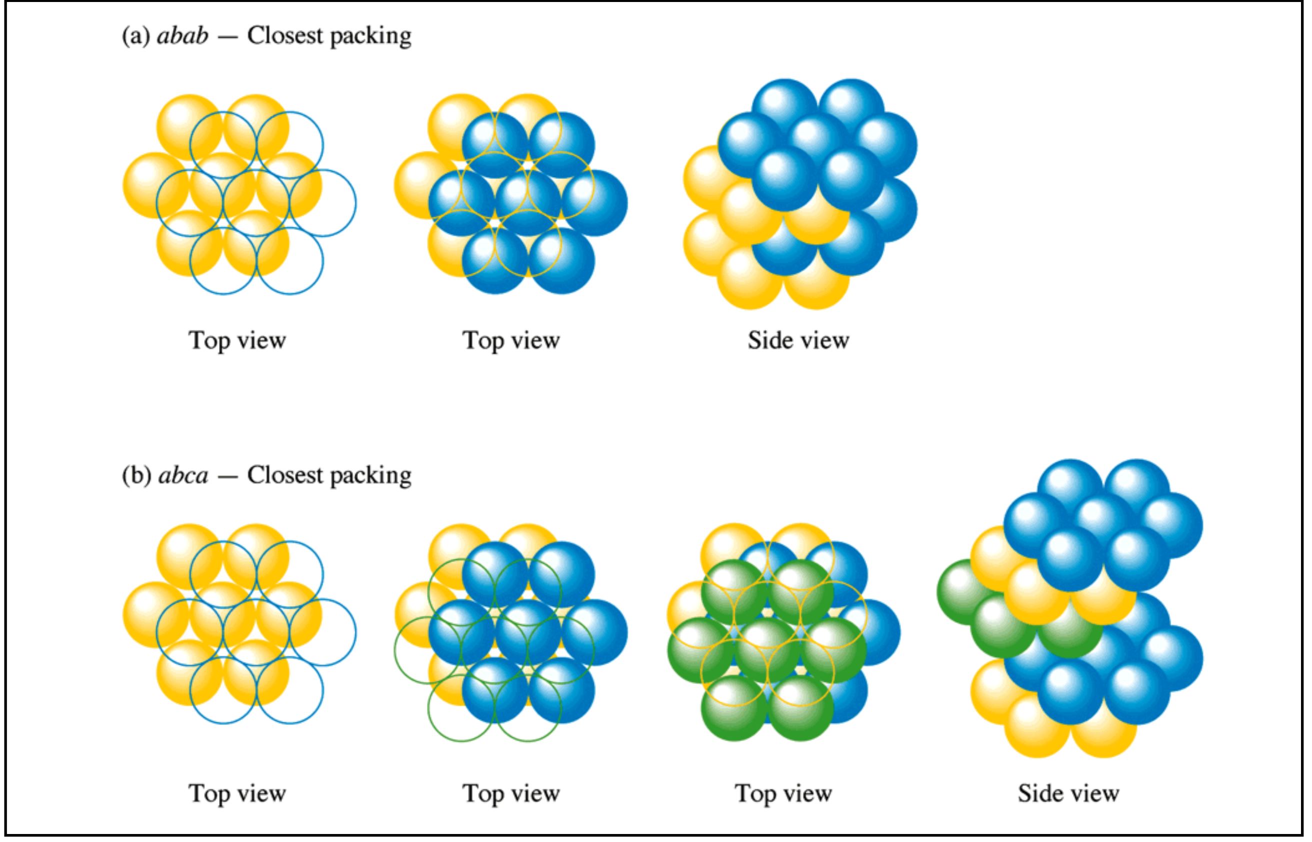
Types of crystalline solids



Atomic　　Ionic　　Molecular

Packing: The closest arrangement of uniform spheres:

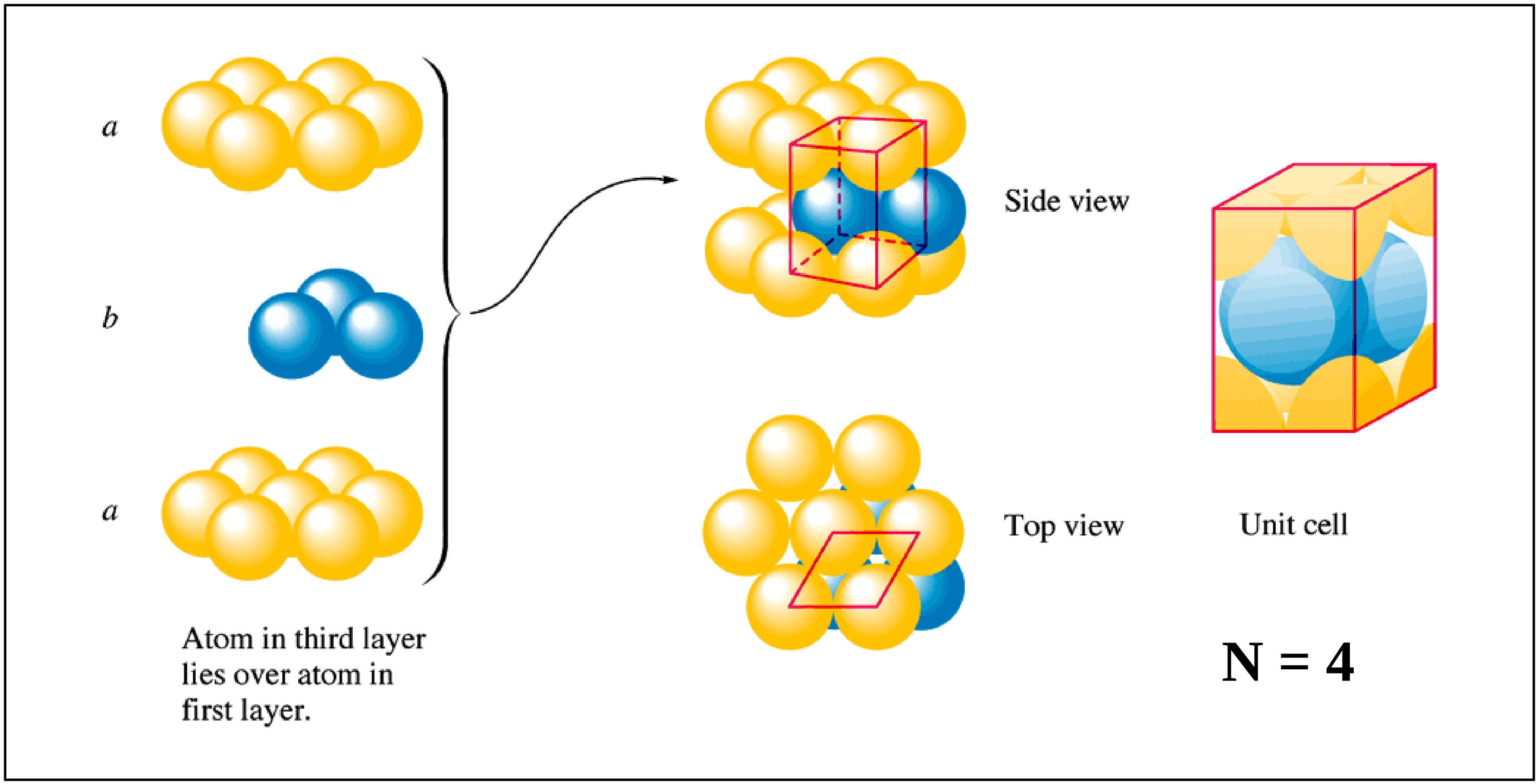
aba & abc packing



Think of oranges and produce in grocery store

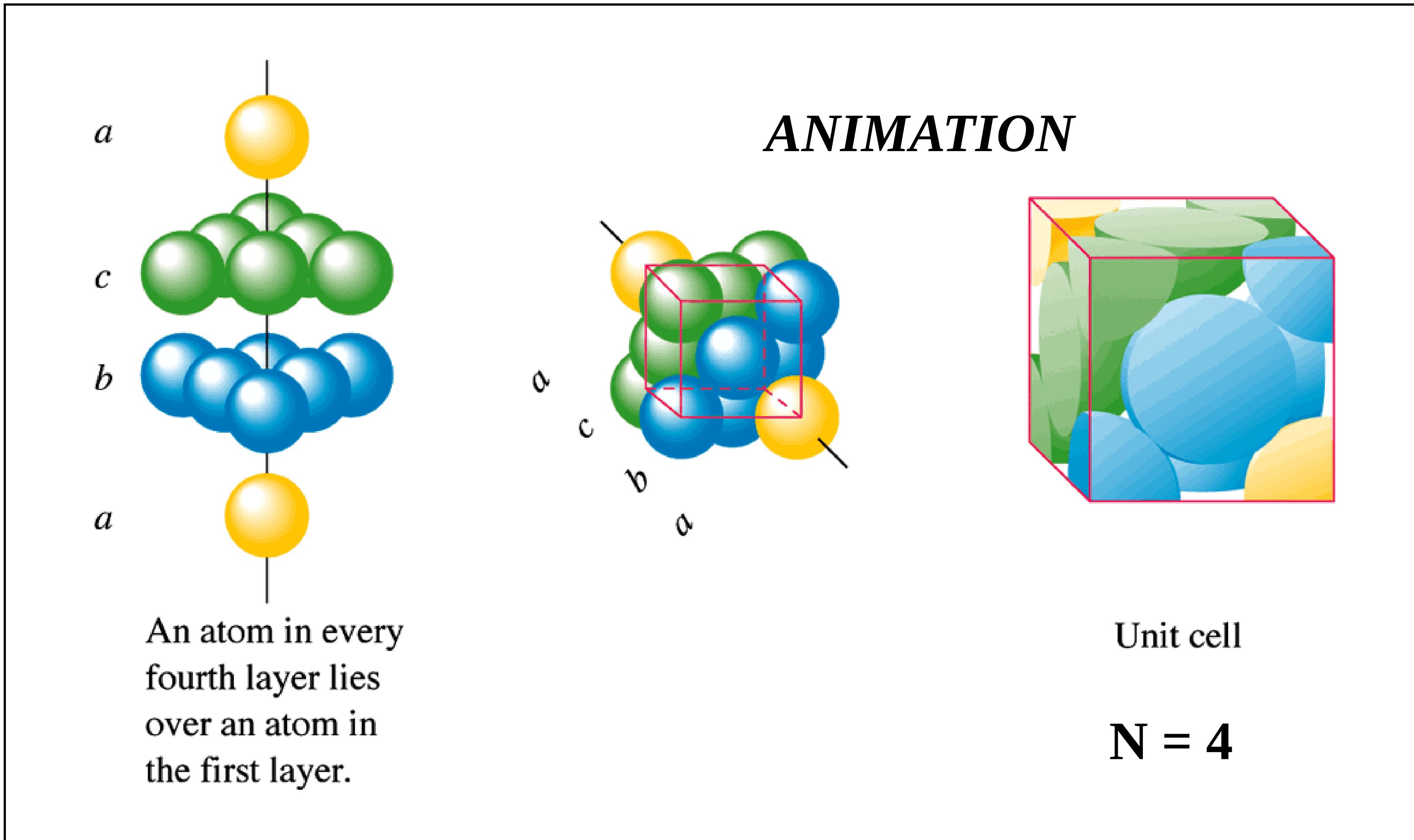
Spheres packed so third layer directly over first layer (aba):

"hexagonal packed" Body Center Cubic



Spheres packed in the (abc) arrangement:

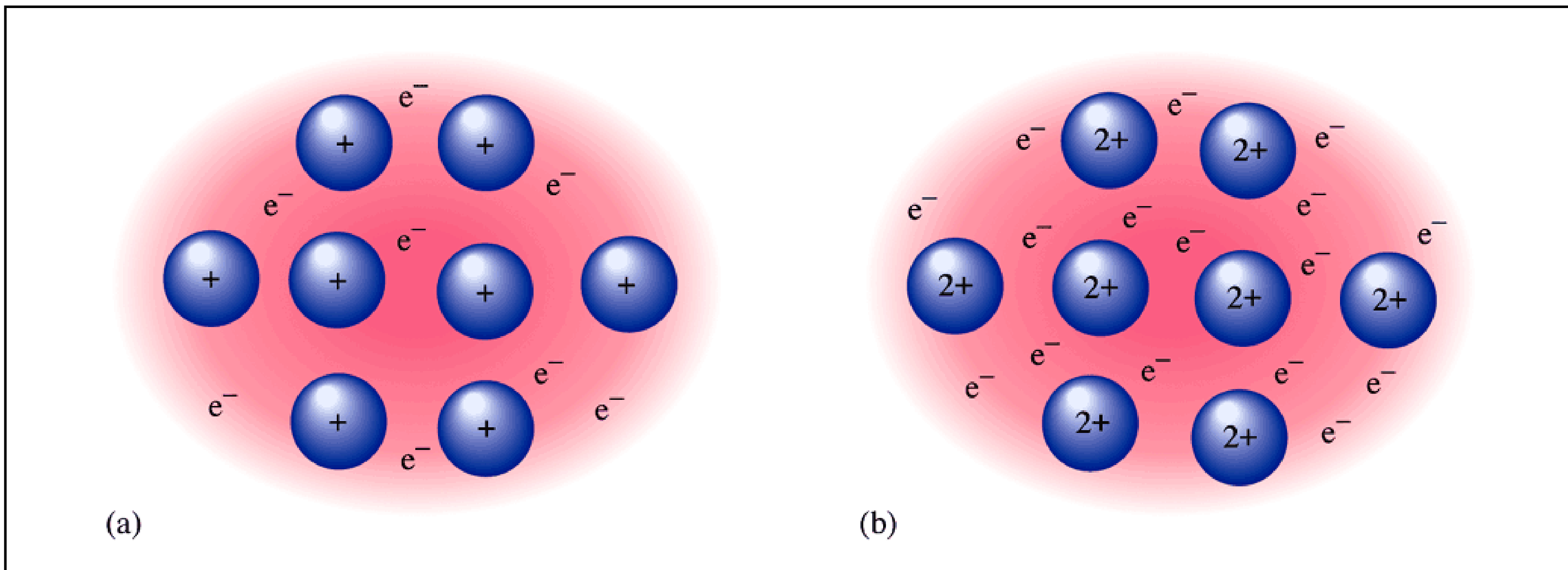
"Face-centered cubic"



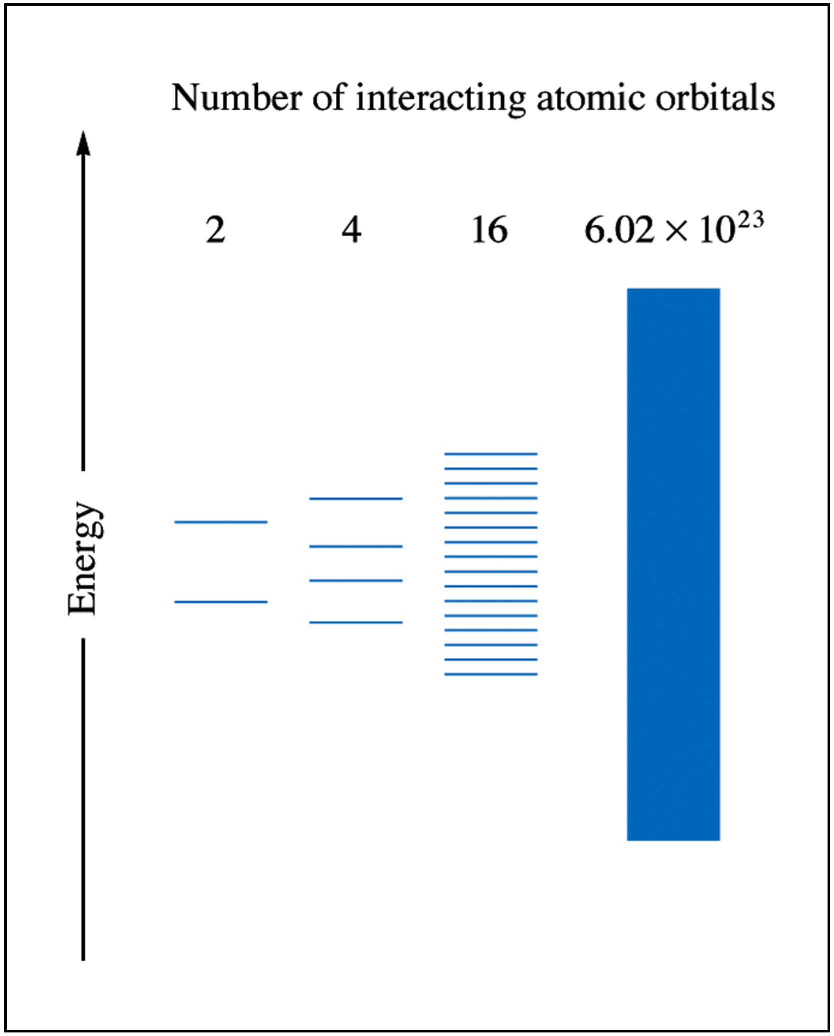
Metals

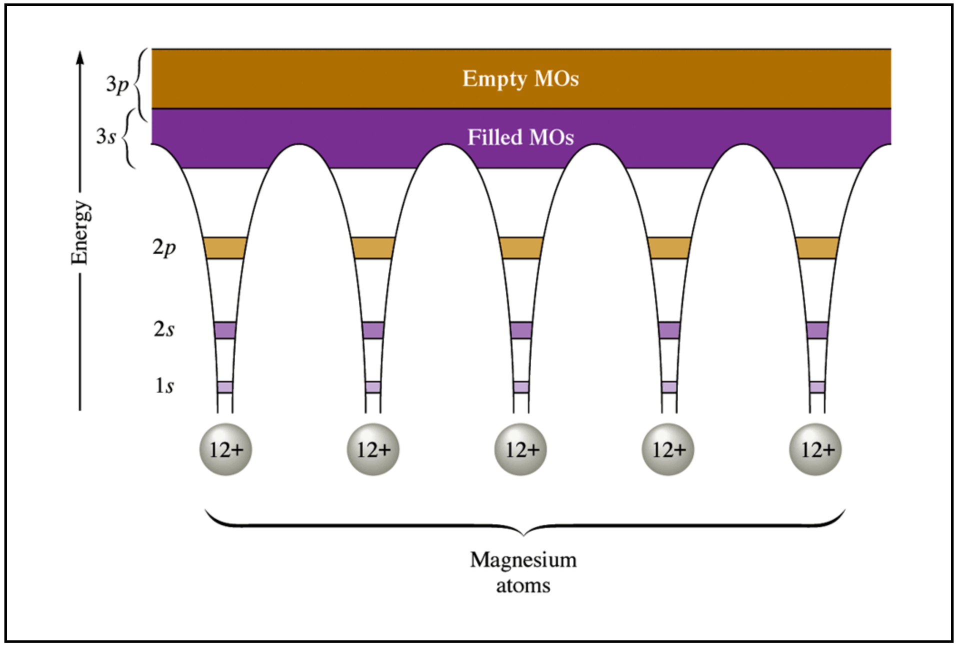
silver

The electron sea model for metals:
a regular array of cations in a "sea" of valence electrons.

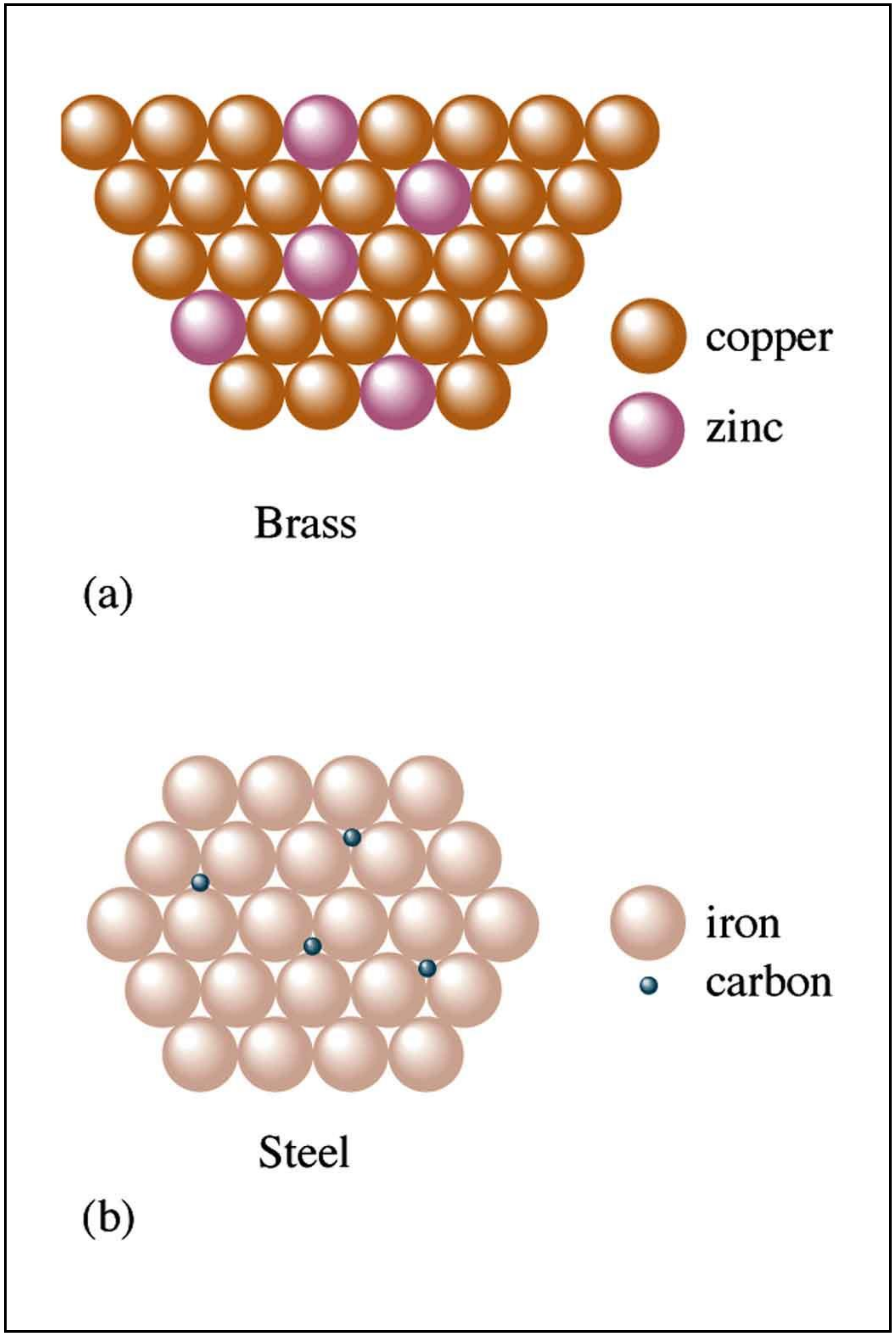


“Band Model” or Molecular Orbital Model



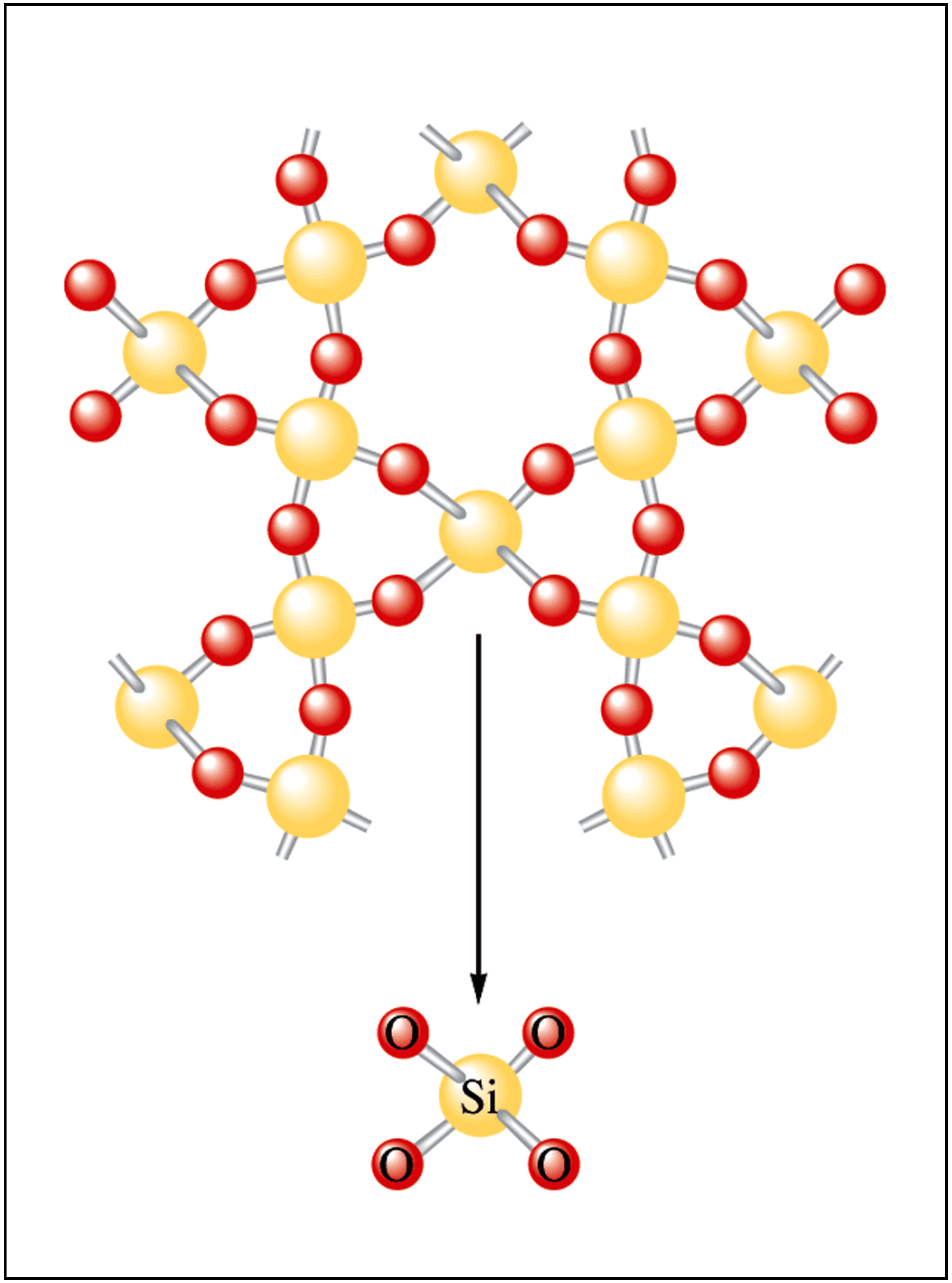


Alloys: mixtures of metals that give unique properties

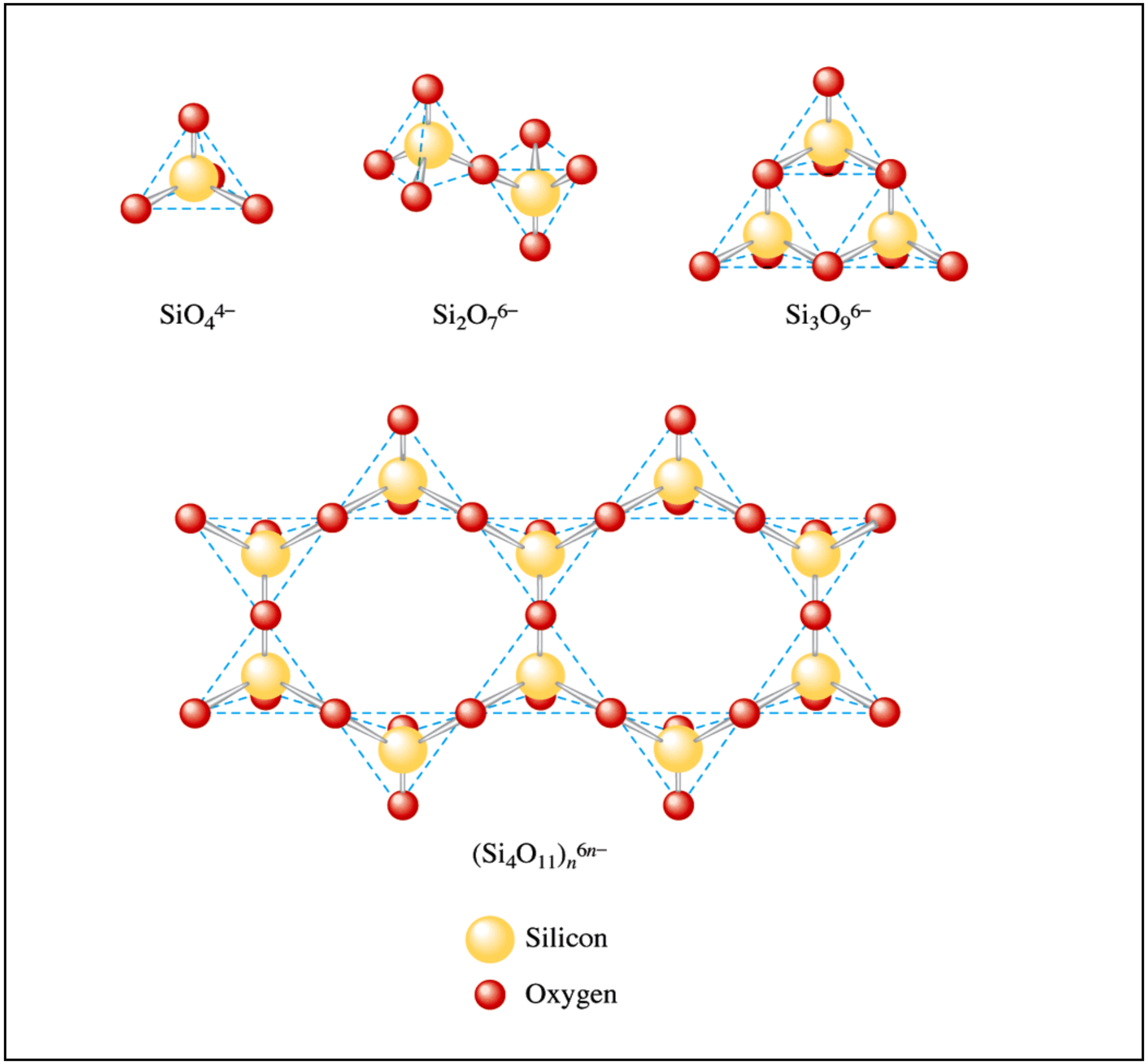


Quartz: (empirical formula SiO_2)

Chains of SiO_4 tetrahedra sharing oxygen atoms



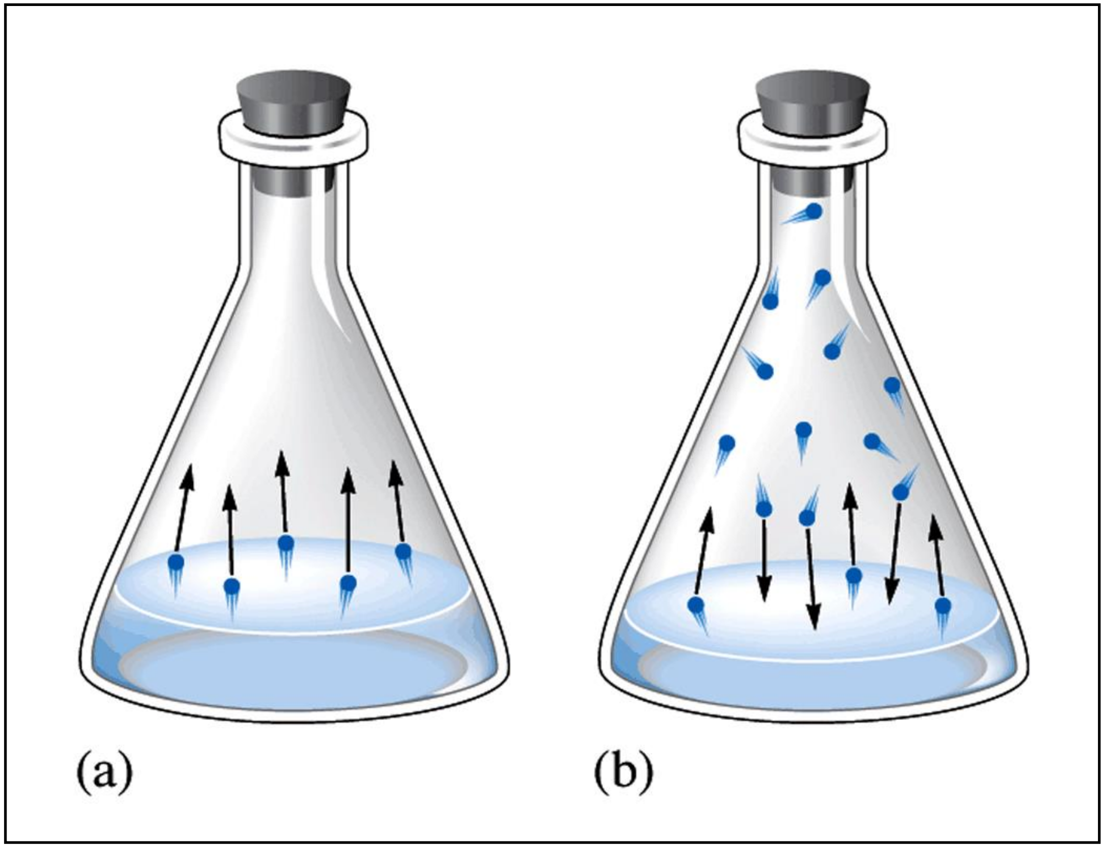
Silicates based on SiO_4 $^{4-}$ tetrahedra



Vapor pressure & changes of state

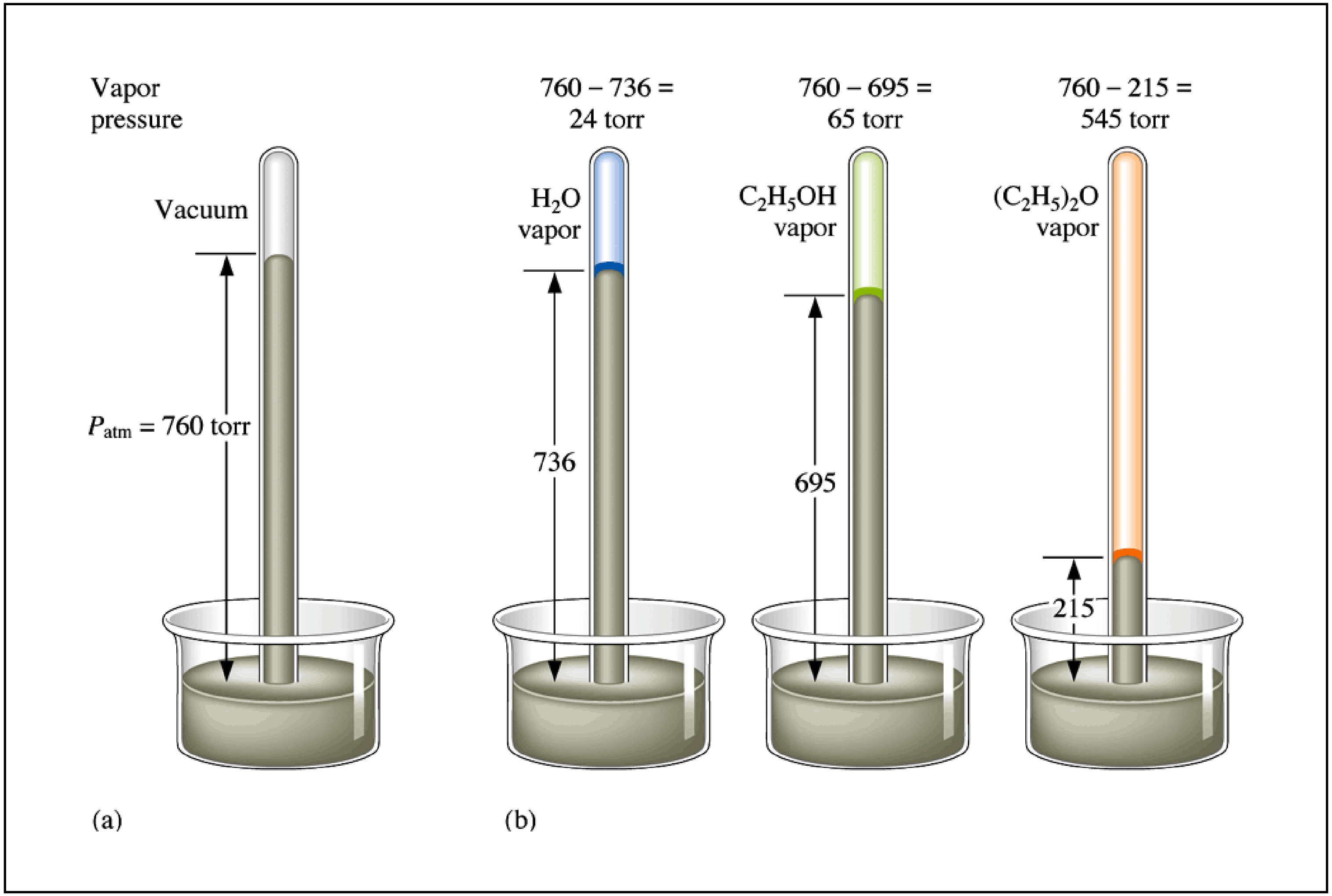
Liquid in a closed container:

What's the difference between (a) and (b)? Discuss…

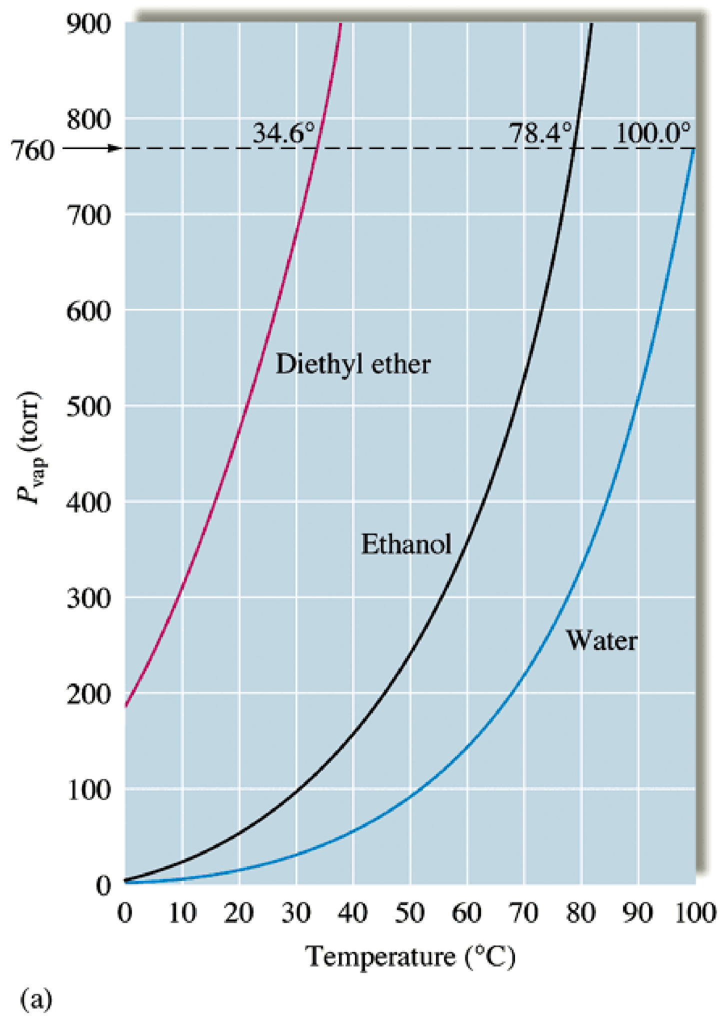


Barometer for vapor pressure:

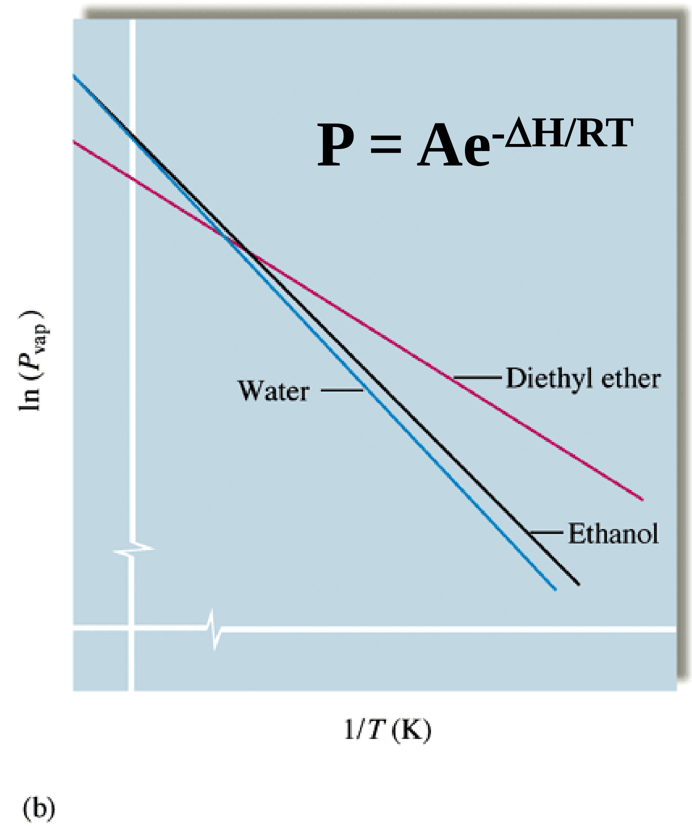
What intermolecular forces are at work to explain these data? Discuss with a friend



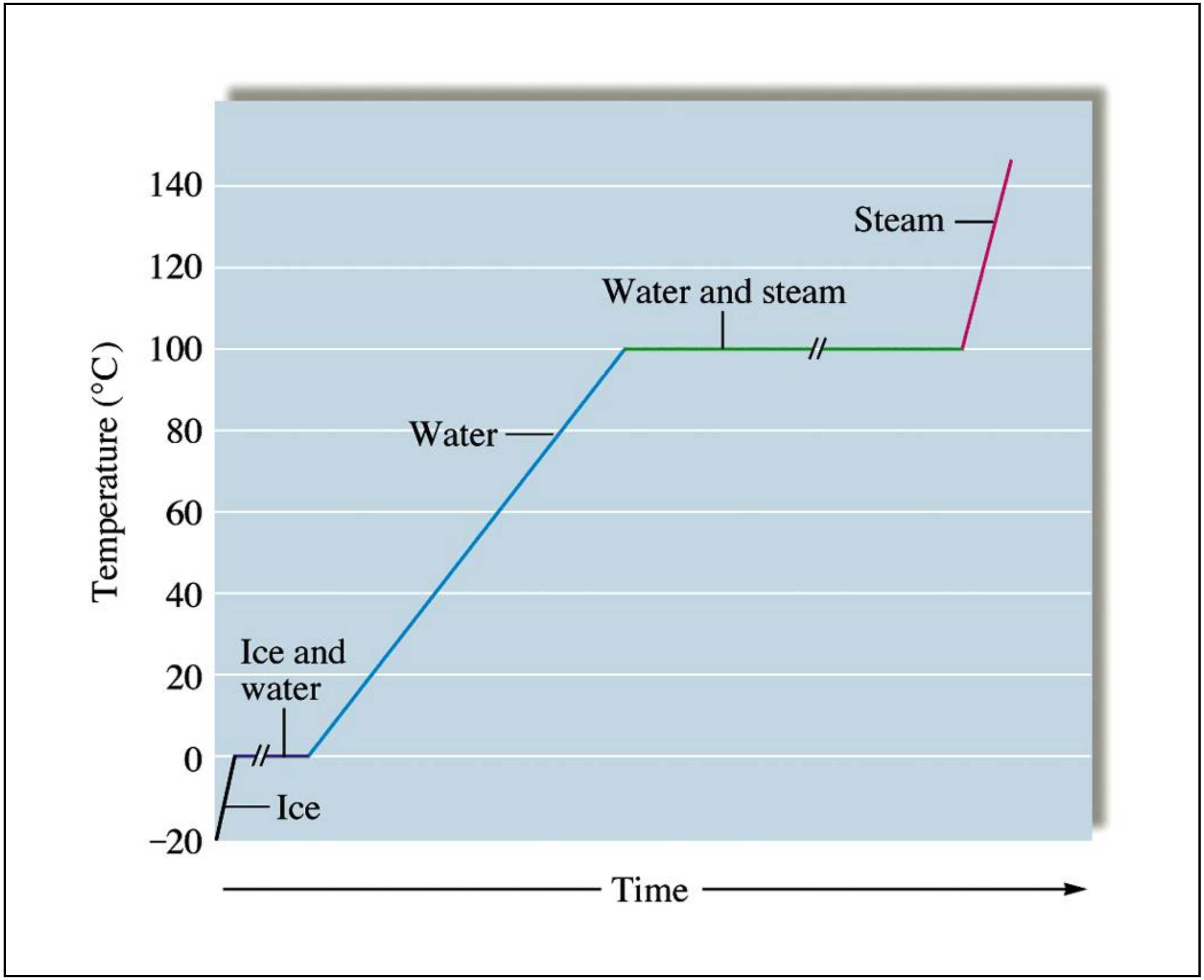
Can we explain these results? Remember Lab?



Can be used for 2 conditions, See pg 487

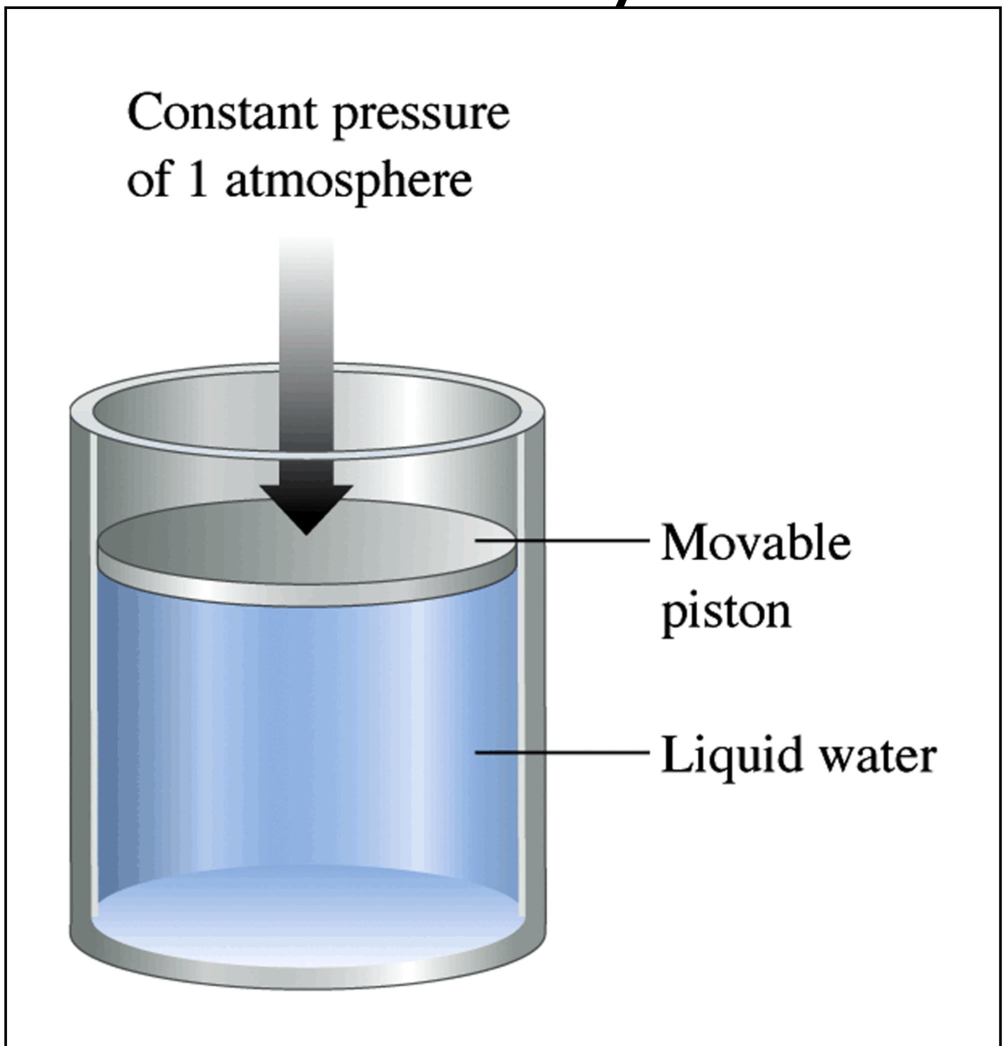


Heating Curves: Remember this from Lab?



What is boiling?

Can bubbles form in the closed system below? Discuss with your friends…



What is Melting?

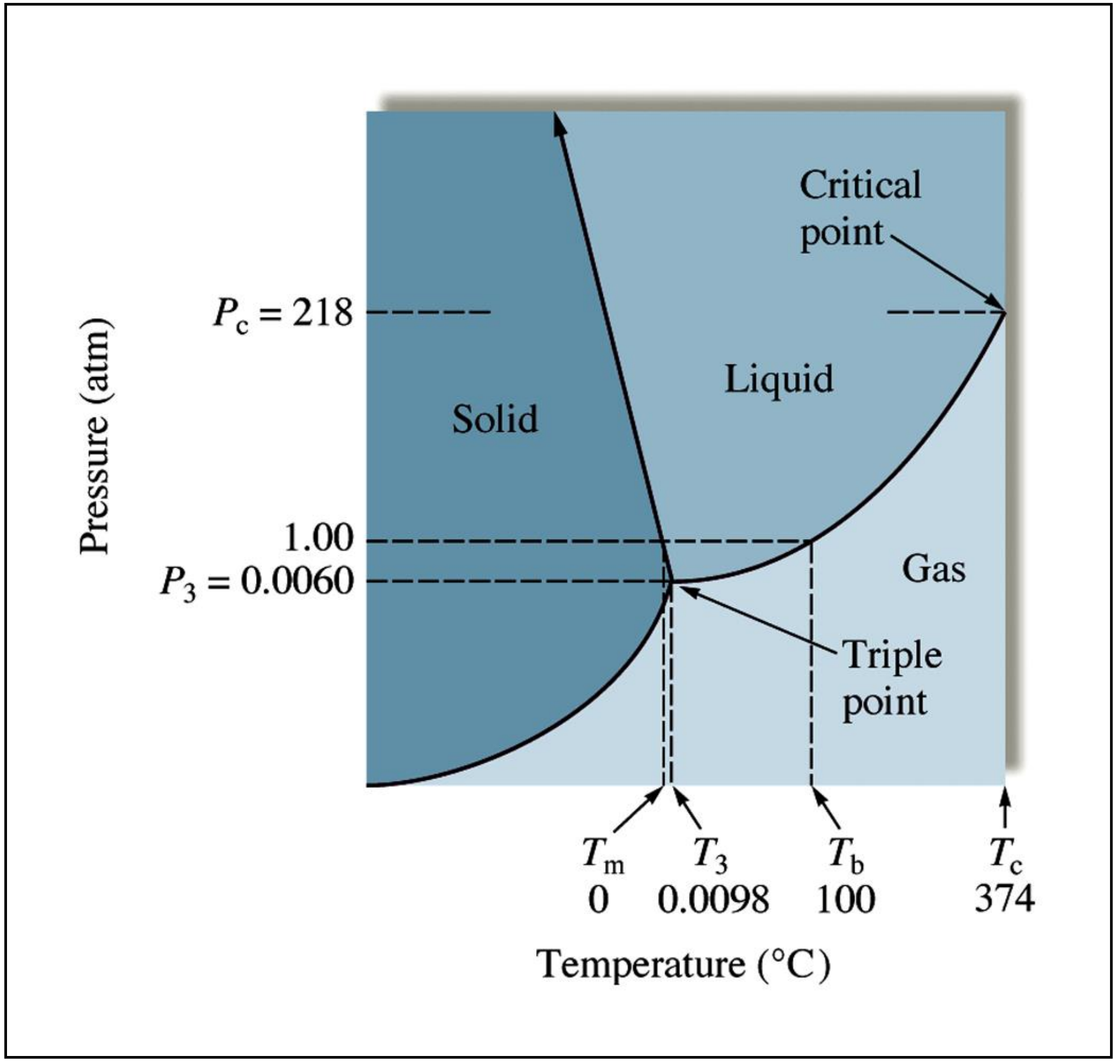
- Molecules break loose from lattice points and solid changes to liquid. (Temperature is constant as melting occurs)
- vapor pressure of solid = vapor pressure of liquid

What is Boiling?

- Constant temperature, added energy is used to vaporize the liquid.

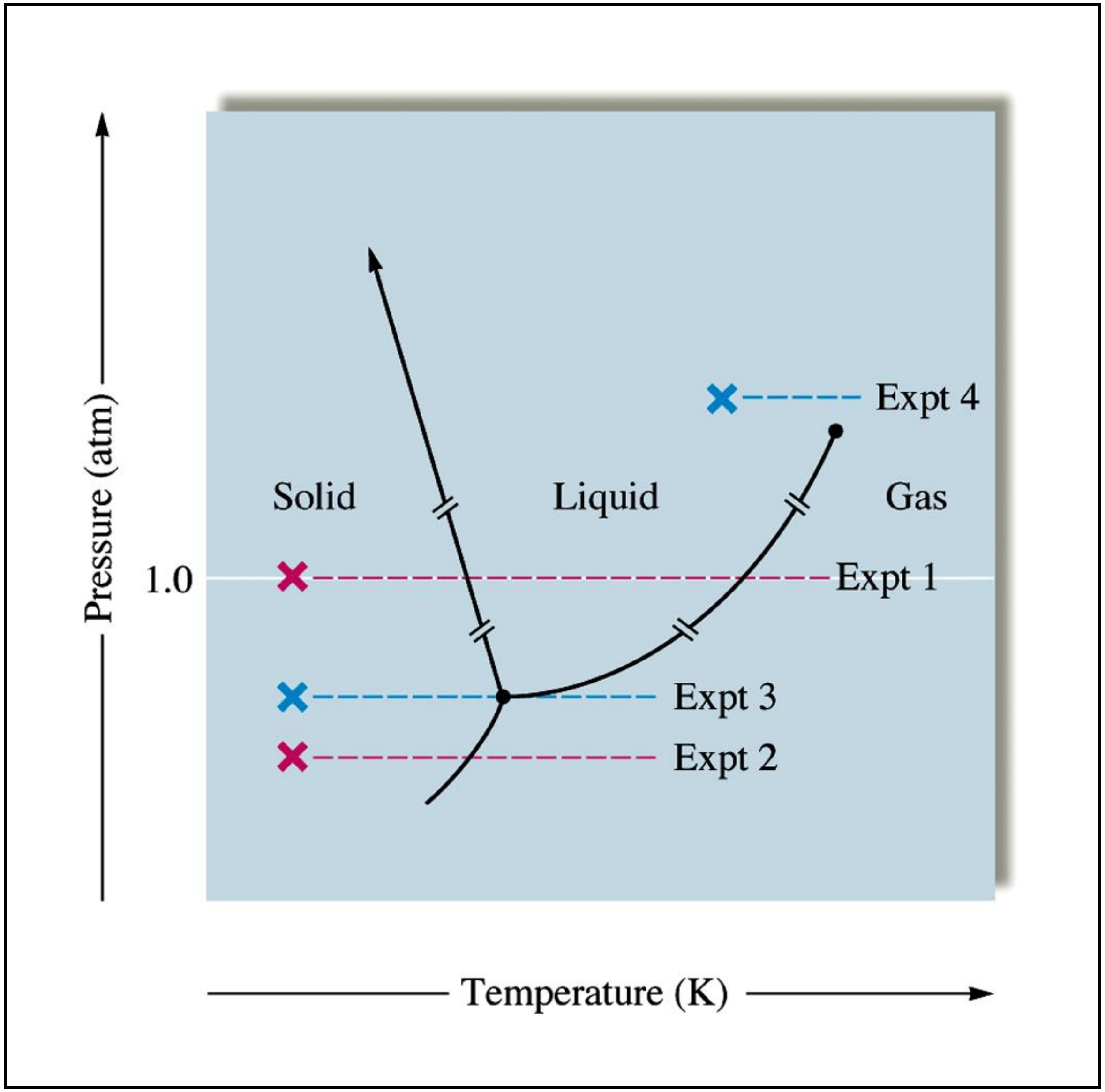
- vapor pressure of liquid = pressure of surrounding atmosphere

The phase diagram for water,…discuss what it shows and what it means…



ANIMATION

What do experiments # 1-4 tell us about water?...discuss



Phase Diagram: Definitions

- Represents phases as a function of temperature and pressure.

- critical temperature: temperature above which the vapor can't be liquefied.

- critical pressure: pressure required to liquefy AT the critical temperature.

- critical point: critical temperature and pressure (for water, T_c = 374°C and 218 atm).

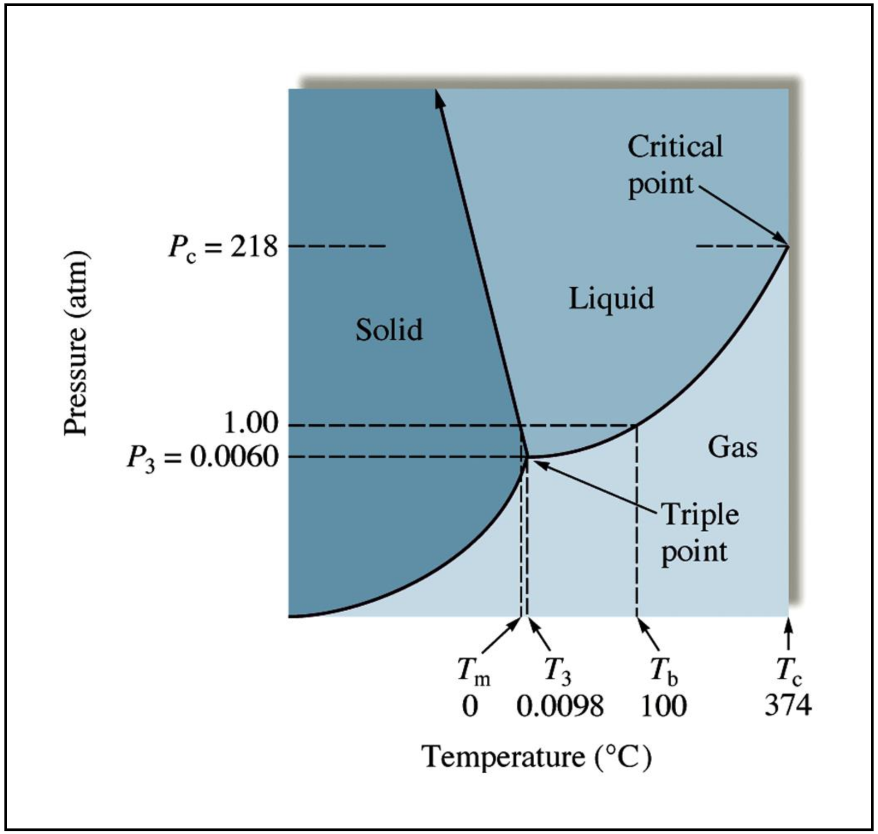
Will boiling water for tea burn your mouth on Mt Everest?

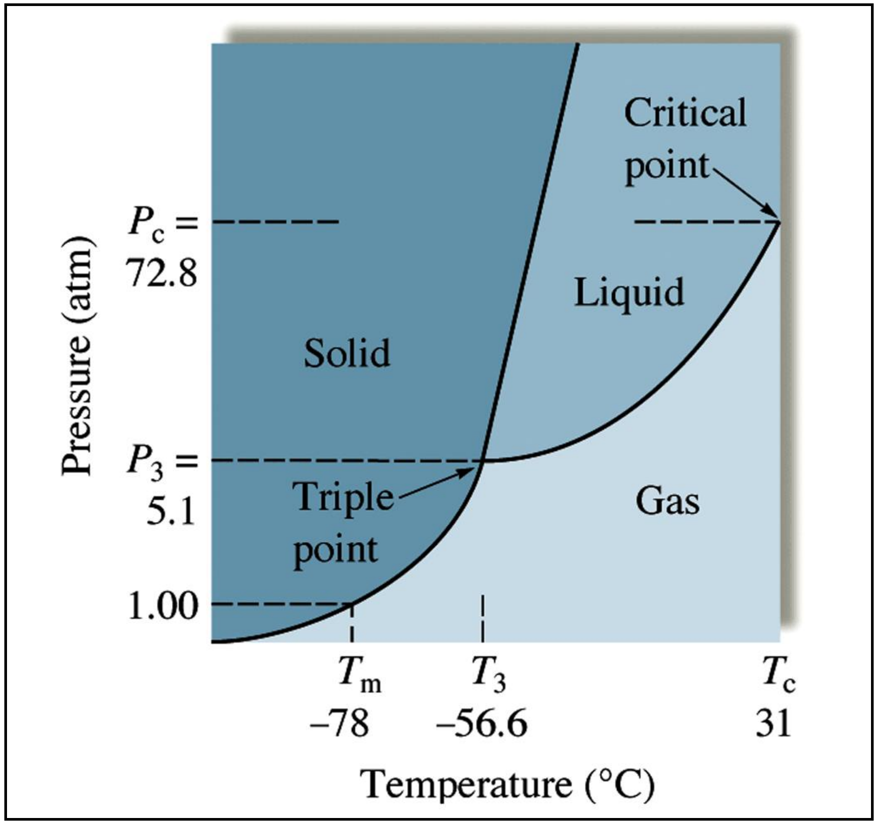
TABLE 10.10 Boiling Point of Water at Various Locations

Location	Feet Above Sea Level	P_{atm} (torr)	Boiling Point (°C)
Top of Mt. Everest, Tibet	29,028	240	70
Top of Mt. McKinley, Alaska	20,320	340	79
Top of Mt. Whitney, Calif.	14,494	430	85
Leadville, Colo.	10,150	510	89
Top of Mt. Washington, N.H.	6,293	590	93
Boulder, Colo.	5,430	610	94
Madison, Wis.	900	730	99
New York City, N.Y.	10	760	100
Death Valley, Calif.	−282	770	100.3

Compare CO2 and water: discuss with a friend,…

- How they are similar & different?
- Can you explain based on molecular structure and intermolecular forces?

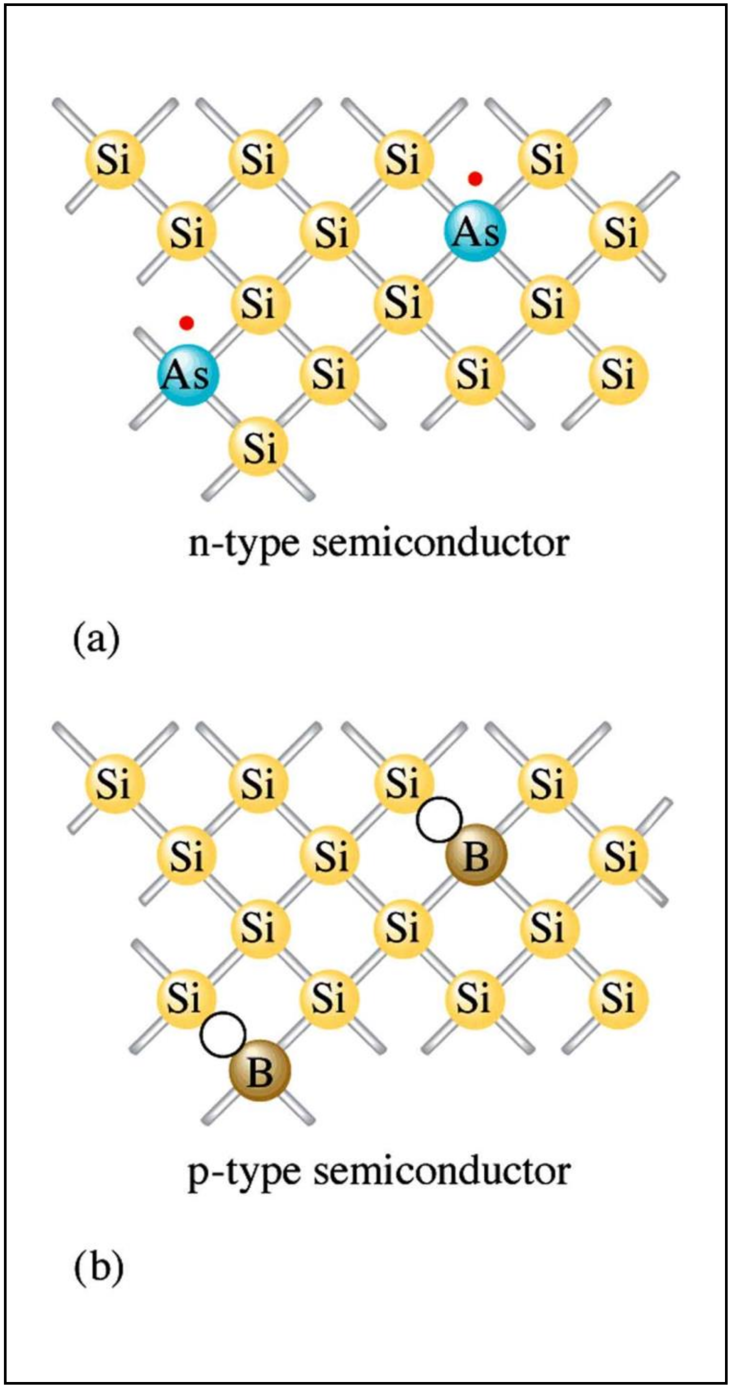




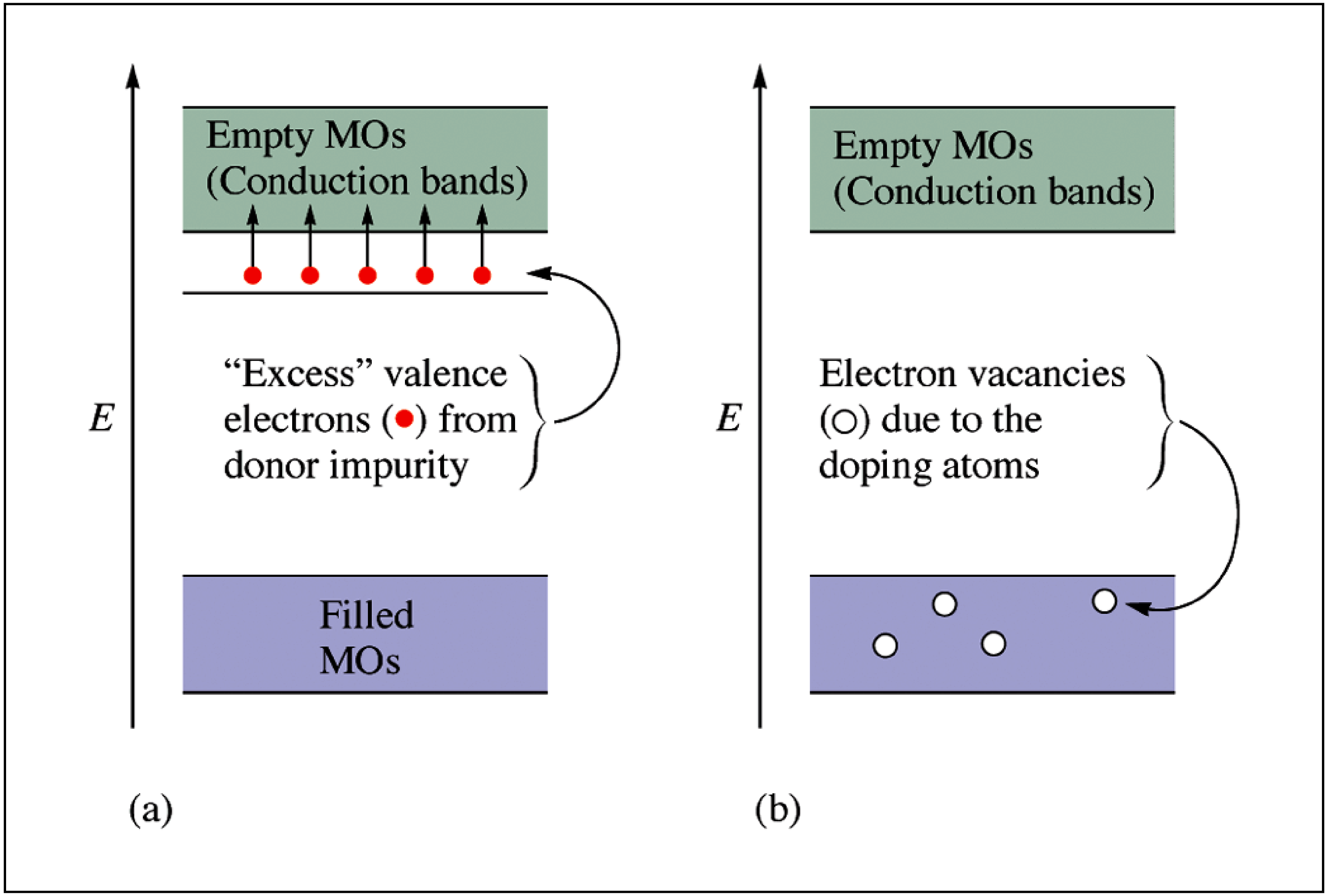
Semiconductors:

n-type: Doping with one <u>more</u> valence electron than silicon. (arsenic)

P-type: Doping with one <u>less</u> electron than silicon. (boron)



Semiconductors



n-type **p-type**

Semiconductors

The p-n junction

contact between p-type and n-type