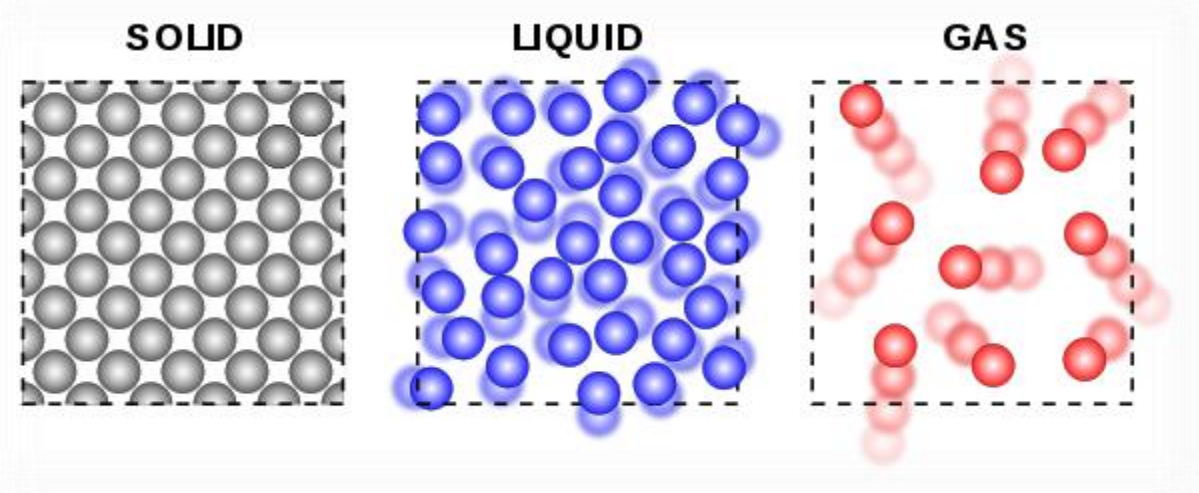
Gases, Liquids, and Solids

Learning Outcomes

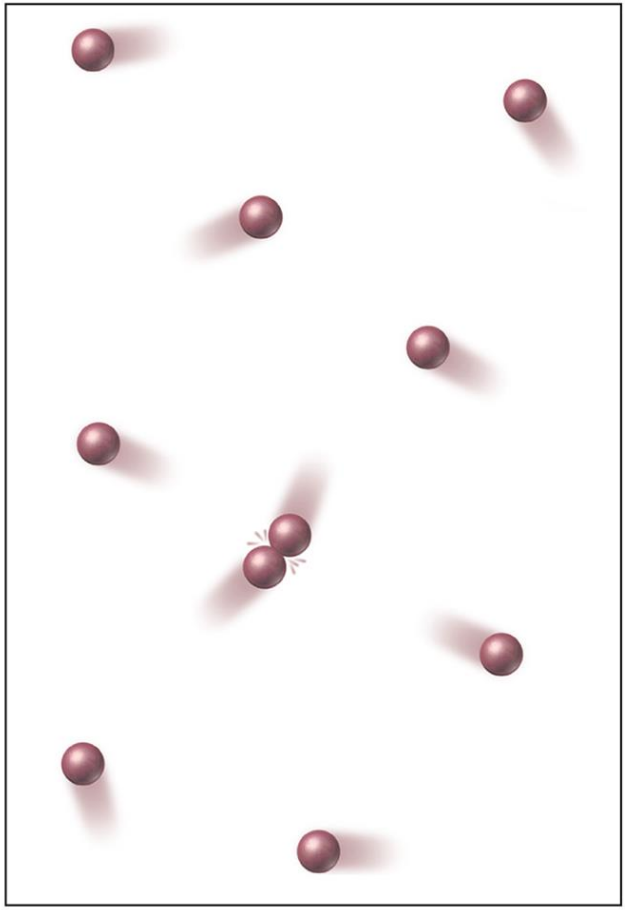
1. Explain why the following proportionalities hold: 1) $V \propto 1/P$, 2) $V \propto T$, and 3) $V \propto n$ based on the kinetic molecular theory of gases.

2. **Chemical Connections: Blood pressure measurement**

States of Matter Review



Kinetic Molecular Theory



1. Collection of particles in constant motion
2. No attractions or repulsions between particles; collisions like billiard ball collisions
3. A lot of space between the particles compared to the size of the particles themselves
4. The speed of the particles increases with increasing temperature

Pressure

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$P = \frac{F}{A}$$

Term	Symbol	SI Unit	SI Base Unit
Pressure	P	Pa	$\frac{\text{kg}}{\text{m}\cdot\text{s}^2}$
Force	F	N	$\frac{\text{kg}\cdot\text{m}}{\text{s}^2}$
Area	A	m^2	m^2

Think-Pair Share

What do you think happens to the ***volume*** of a balloon when the following happens?

1) The temperature increases
2) More air is added to the balloon
3) The outside pressure decreases

Gas Laws

Gas Law	Proportionality
Boyle's Law	$V \propto \frac{1}{P}$
Charles's Law	$V \propto T$
Avogadro's Law	$V \propto n$

Blood Pressure

https://www.youtube.com/watch?v=Ab9OZsDECZw

mmHg is a Unit of Pressure

https://www.youtube.com/watch?v=EkDhIzA-lwI

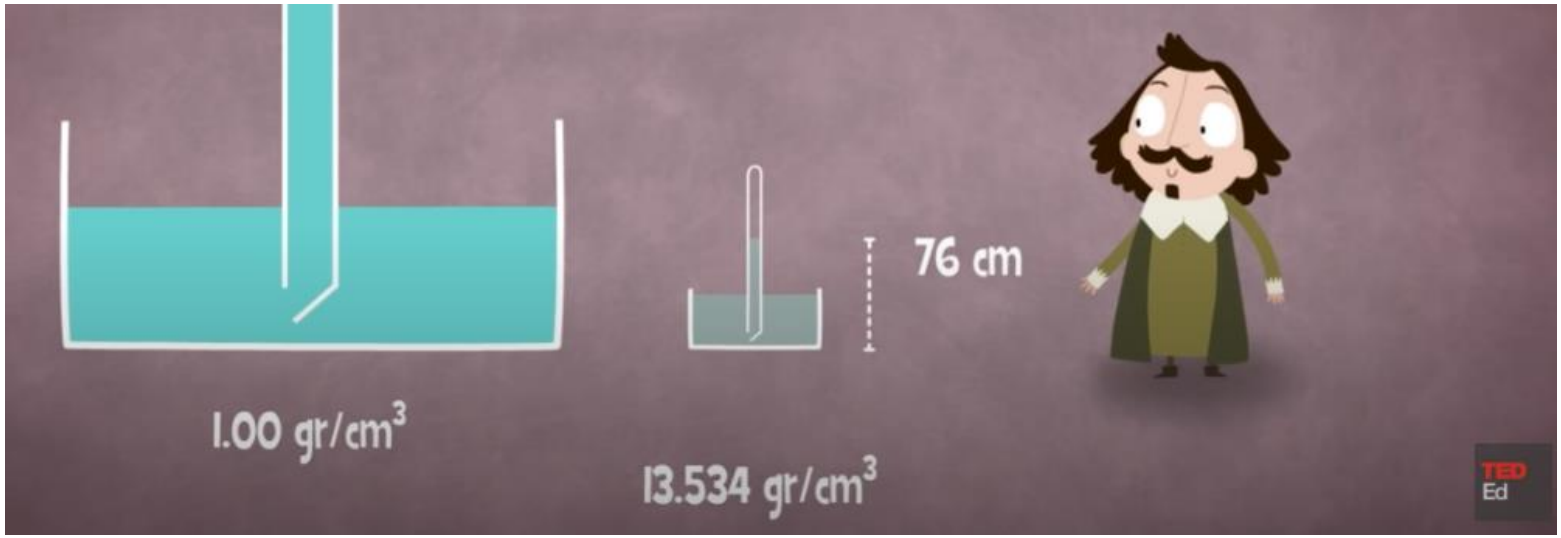
Length Conversion:

$$L = 76\ \text{cm} \times \frac{1\ \text{m}}{100\ \text{cm}} \times \frac{1000\ \text{mm}}{1\ \text{m}}$$

$$L = 760\ \text{mm}$$

Pressure Conversion:

$$P_{\text{atm}} = 76\ \text{cm Hg} = 760\ \text{mm Hg}$$



Sphygmomanometer

Learning Objectives

1. Describe, at the atomic/molecular level, the following processes: boiling, condensation, melting, and freezing.

2. Compare and contrast four types of intermolecular forces: dispersion, dipole–dipole, hydrogen bonds, and ion–dipole.

3. Determine the types of intermolecular forces in compounds.

4. Use intermolecular forces to determine relative boiling points.

Problem 1

What terms do we have for the following phase transformations?

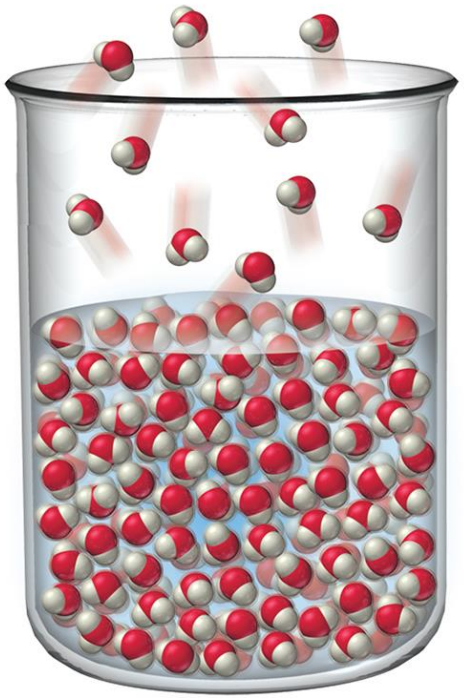
(a) H_2O (l) → H_2O (g)

(b) H_2O (s) → H_2O (l)

(c) H_2O (l) → H_2O (s)

Evaporation: A Molecular Explanation

Molecules on the surface are held less tightly than those in the interior so the most energetic can break away into the gas state.



Why? This will be answered a little later in the chapter!

Problem 2

When poll is active, respond at **PollEv.com/matthewfonta586**

Text **MATTHEWFONTA586** to **22333** once to join

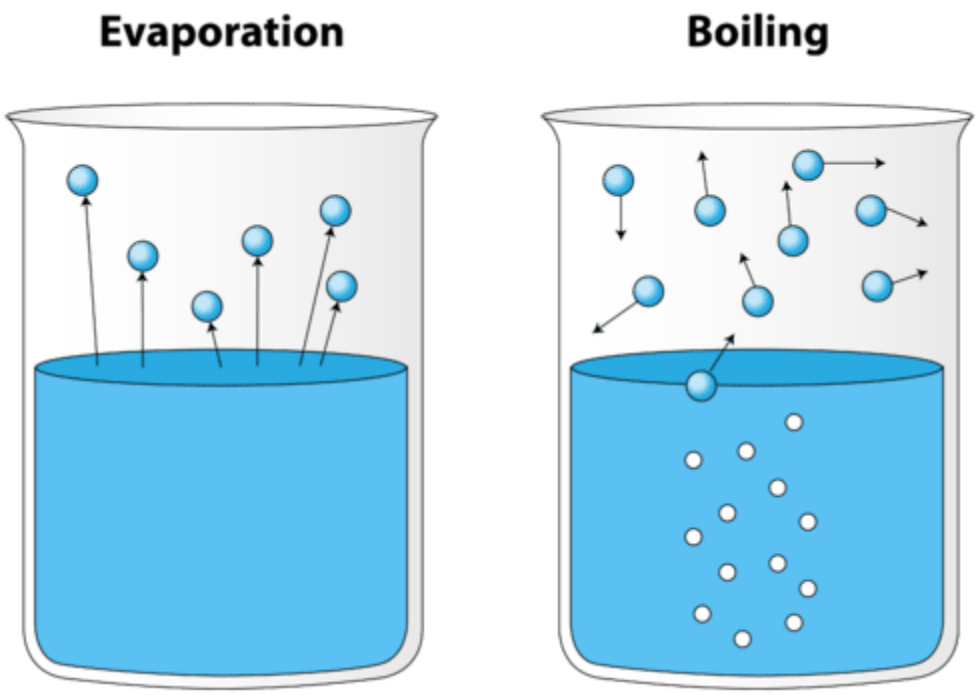
What is the difference between evaporation and boiling?

No responses received yet. They will appear here...

Poll Everywhere

Answers to this poll are anonymous

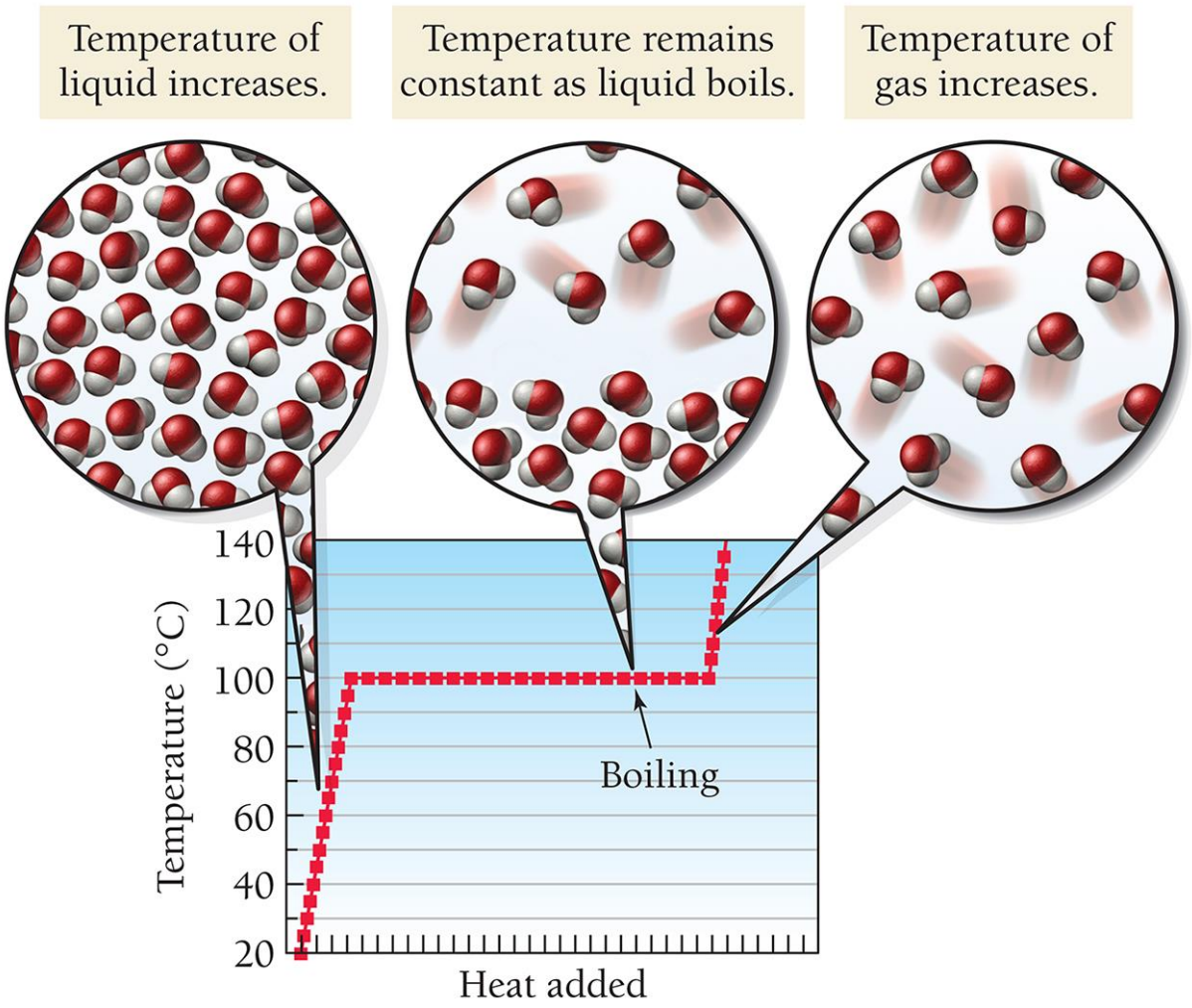
In Boiling, Bubbles Form and Rise



No Bubbles

Bubbles

Boiling Curve of Water



Sublimation

Sublimation is a direct phase transition between the solid phase and gas phase.

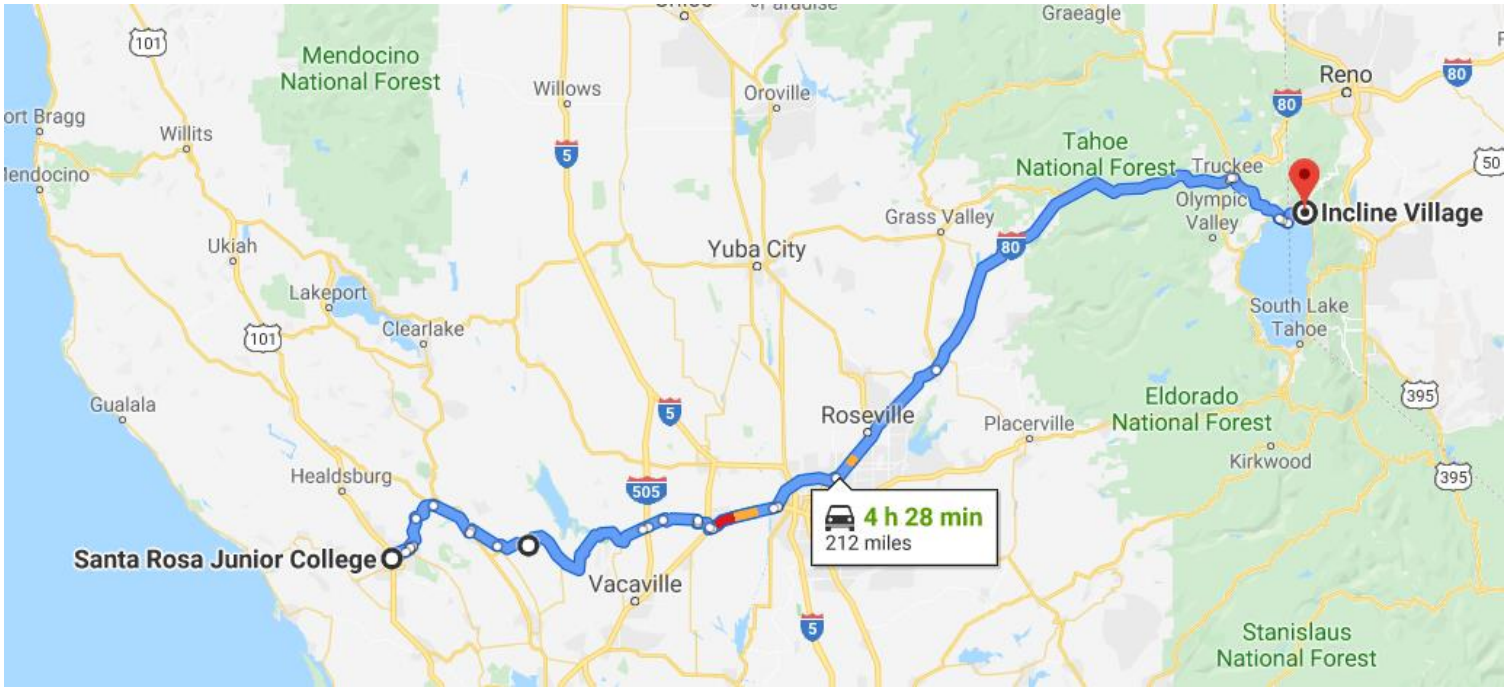
Example: Dry Ice

$$CO_2(s) \rightarrow CO_2(g)$$

Inter-

Interstate (between two states)

Interstate commerce (commerce between two states)



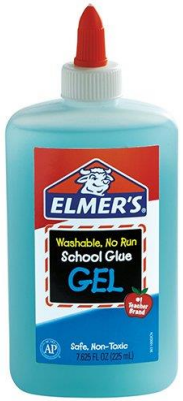
Intermolecular Forces (IMFs)

Intermolecular (between two molecules)

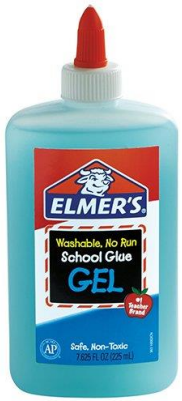
Intermolecular forces (forces between two molecules)

Intermolecular Forces Keep Molecules Together

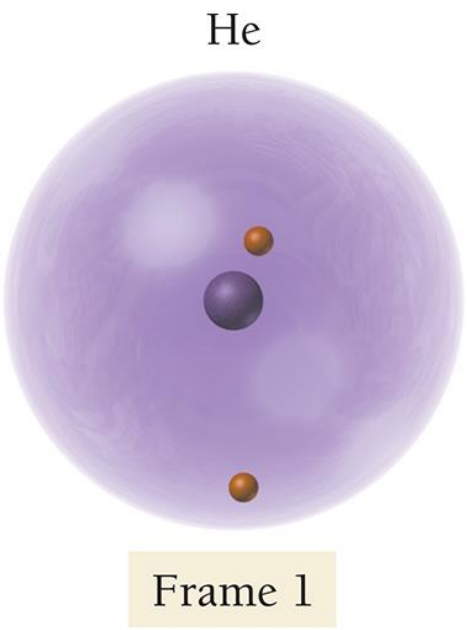
Intermolecular Forces (IMFs)



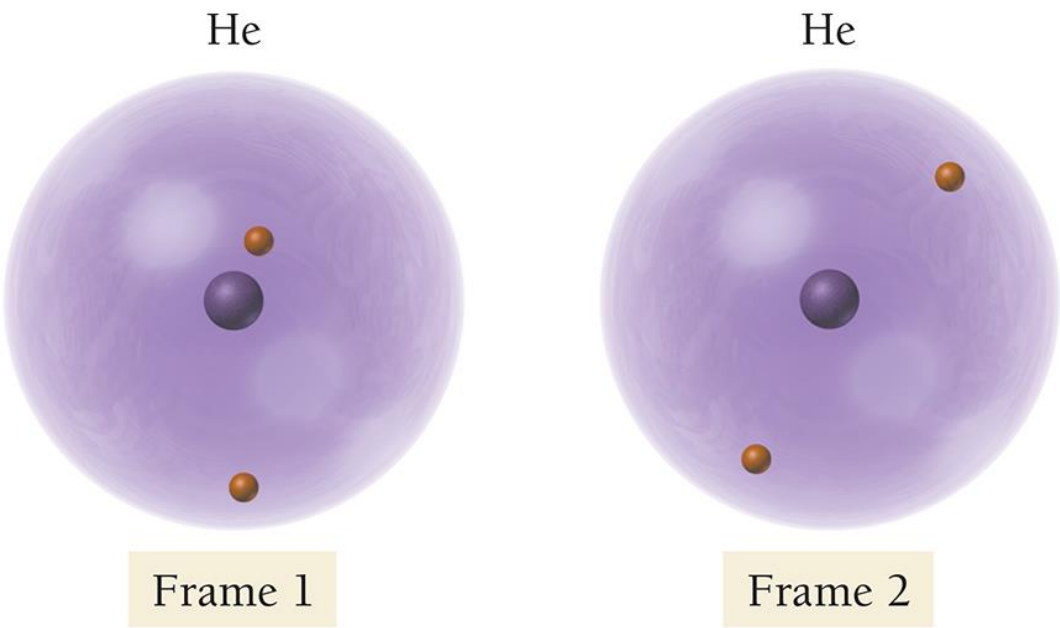
Higher Boiling Points



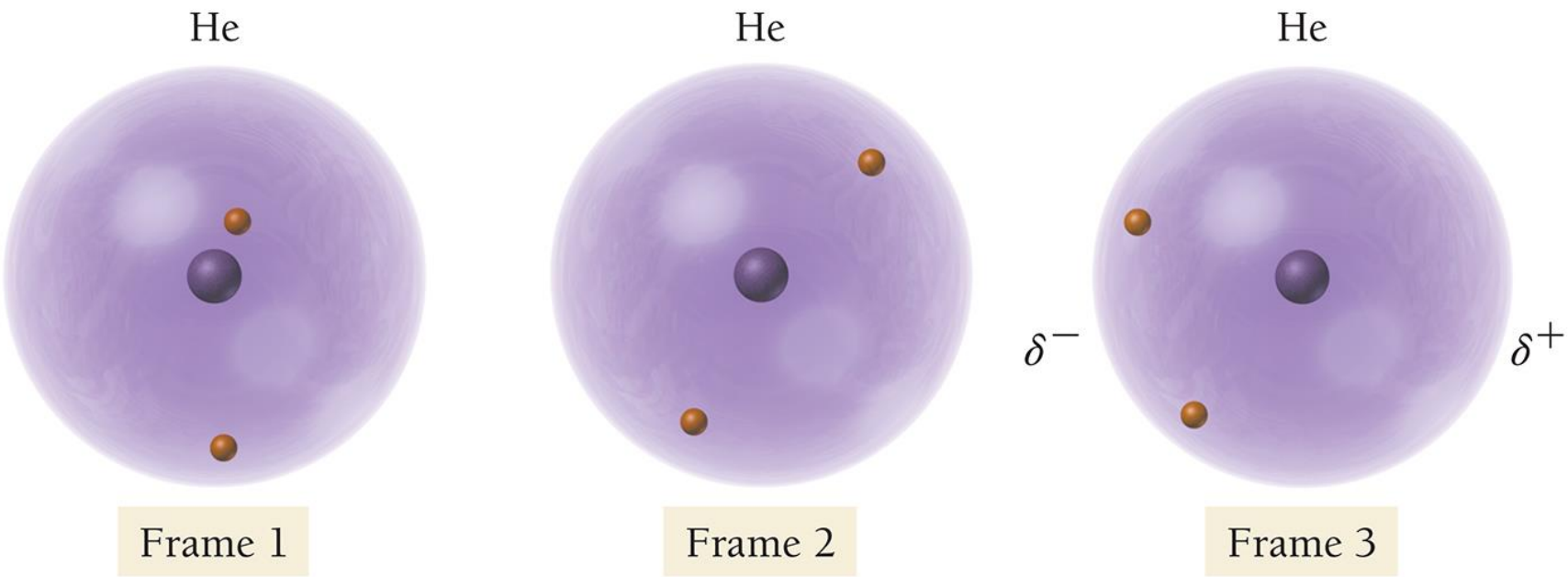
Snapshots For The Electron Density Of Helium



Snapshots For The Electron Density Of Helium

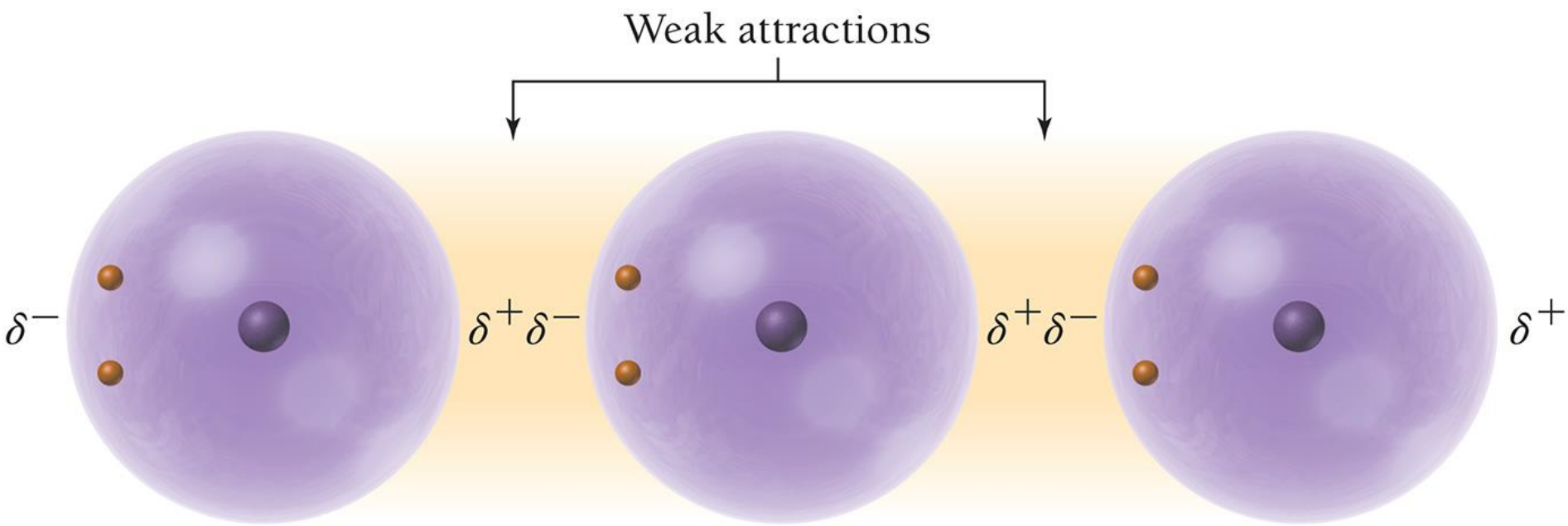


Snapshots For The Electron Density Of Helium

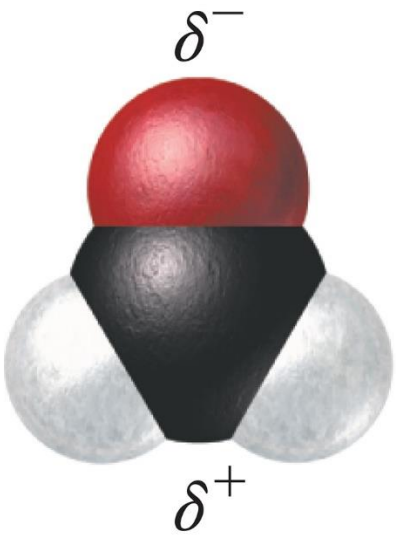


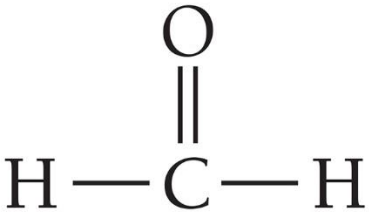
Instantaneous Dipole!!

Instantaneous Dipole-Instantaneous Dipole Interactions: Dispersion Forces

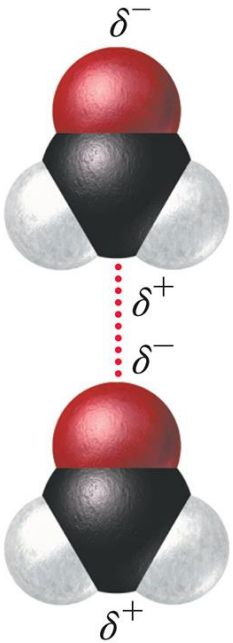


Permanent Dipole-Permanent Dipole Interactions





Formaldehyde



Problem 4

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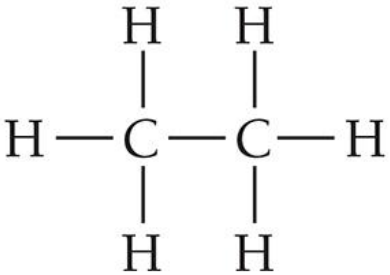
Text **MATTHEWFONTA586** to **22333** once to join

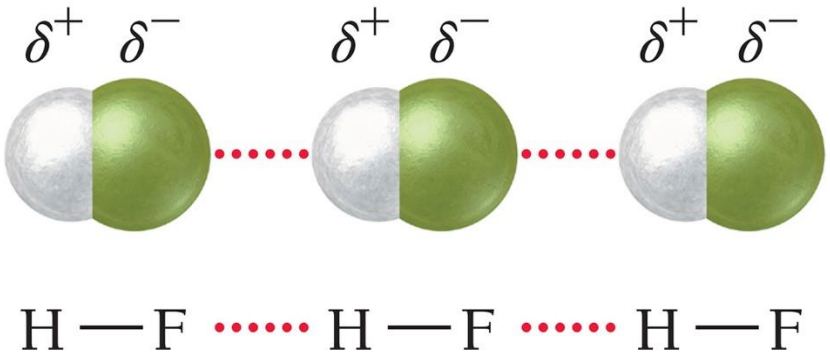
Do you expect formaldehyde or ethane to have the higher boiling point? Why?

Name	Formula	Molar mass (g/mol)	Structure
formaldehyde	CH_2O	30.0	
ethane	C_2H_6	30.1	

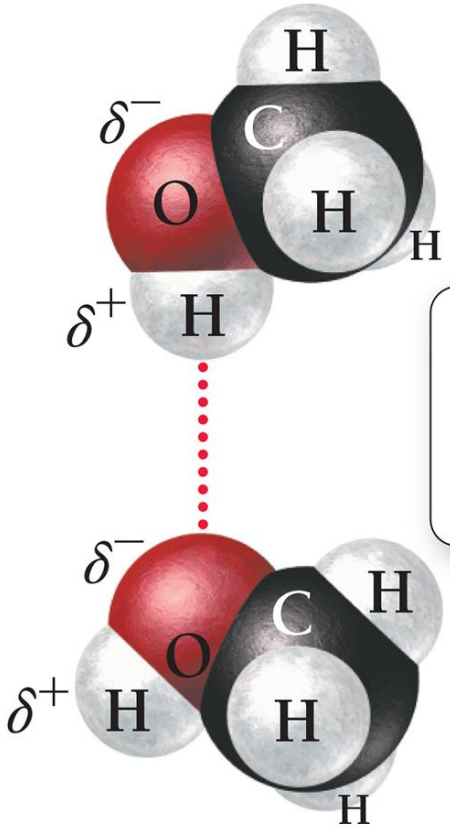
Permanent Dipole-Permanent Dipole Interactions: Hydrogen Bonding

Hydrogen bonding is a special subset of ***STRONGER*** permanent dipole-permanent dipole interactions. Hydrogen bonding occurs when a molecule has a hydrogen atom ***bonded to one*** of the following atoms: F, O, N.

Hydrogen on each molecule is strongly attracted to fluorine on its neighbor.

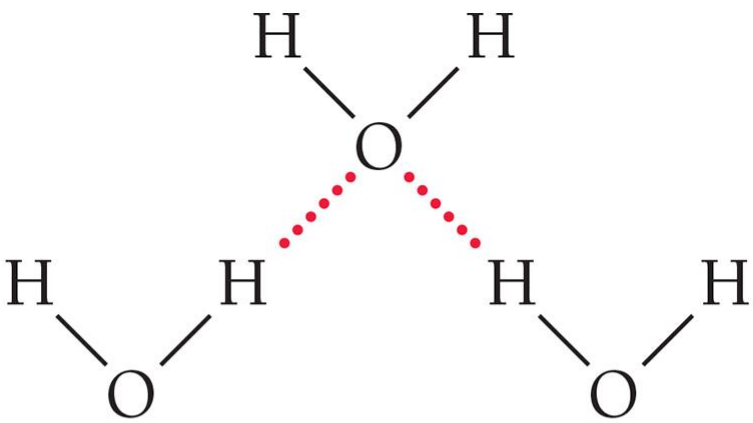


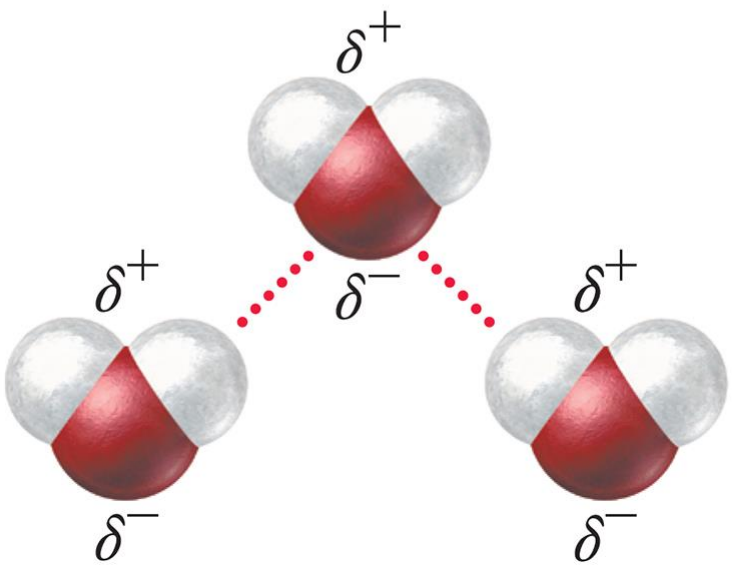
Hydrogen Bonding Examples: Methanol



The hydrogen atom on one molecule is attracted to the oxygen atom on its neighbor.

Hydrogen Bonding Examples: Water

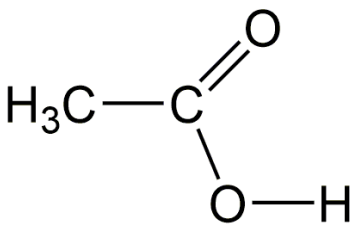




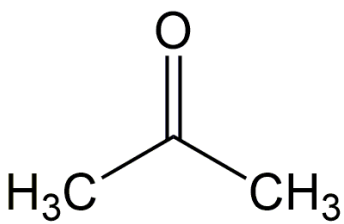
The hydrogen atoms on each water molecule are attracted to the oxygen atoms on its neighbors.

Problem 5

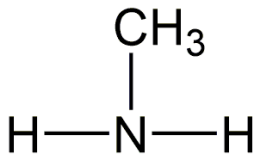
Which molecules are capable of hydrogen bonding? For those that are draw the hydrogen bonding interaction.



Acetic Acid



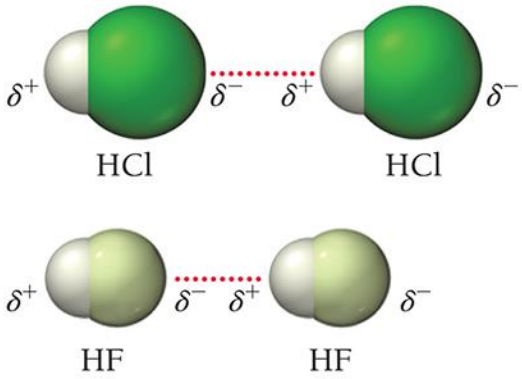
Acetone



Methyl Amine

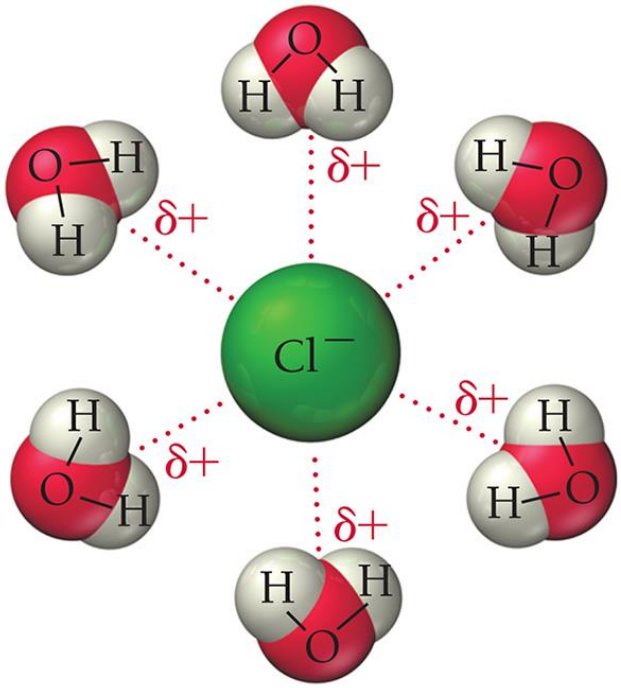
Problem 6

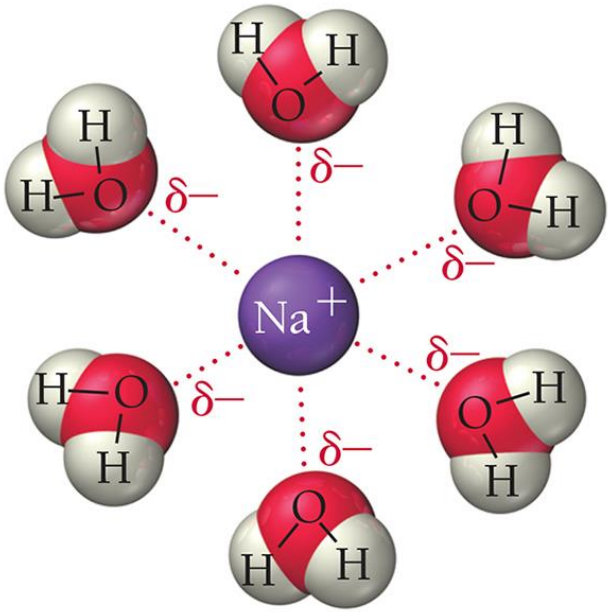
Why are permanent dipole-permanent dipole interactions stronger with H and F/O/N? Hint, why does HF have hydrogen bonding, but not HCl?



Ion-Dipole Interactions

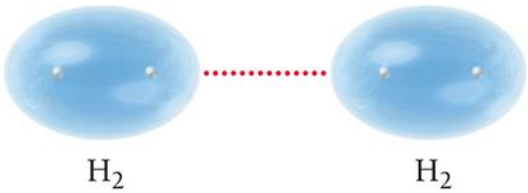
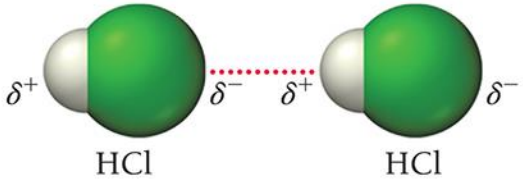
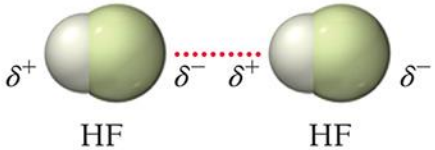
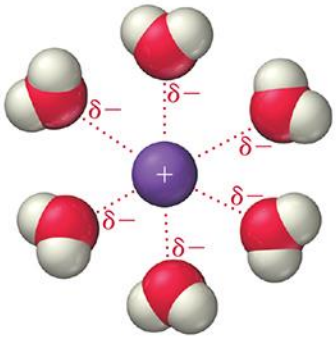
The positive sodium ions interact with the negative ends of water molecules, while the negative chloride ions interact with the positive ends of water molecules.





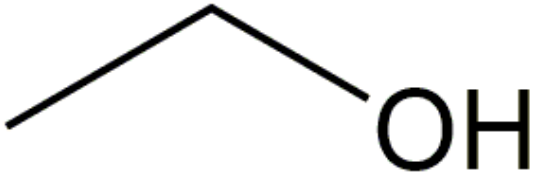
IMF Summary

TABLE 12.5 Types of Intermolecular Forces

Type of Force	Relative Strength	Present in	Example
dispersion force (or London force)	weak, but increases with increasing molar mass	all atoms and molecules	
dipole–dipole force	moderate	only polar molecules	
hydrogen bond	strong	molecules containing H bonded directly to F, O, or N	
ion–dipole force	very strong	mixtures of ionic compounds and polar compounds	

Problem 7

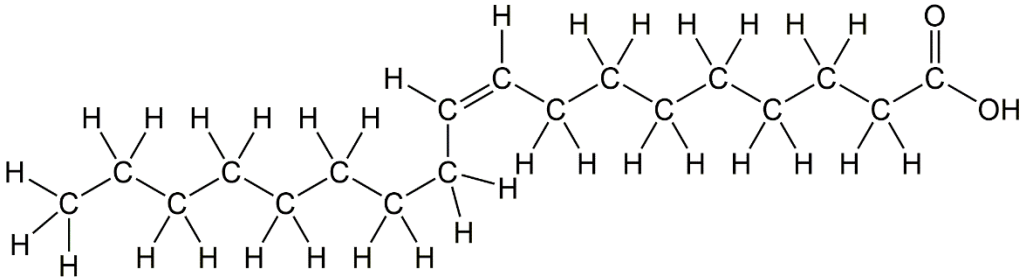
What kinds of intermolecular forces are present for ethanol?



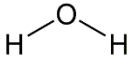
Ethanol

Problem 8

Explain why olive oil (mostly oleic acid) and water do not mix.



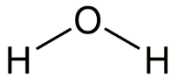
Oleic Acid



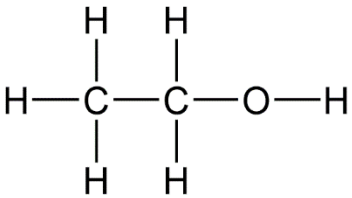
Water

Problem 9

Do water and ethanol mix? Explain why.



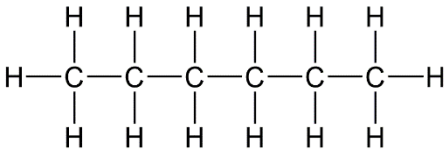
Water



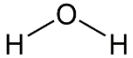
Ethanol

Problem 10

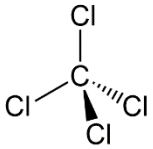
Explain the following laboratory observation.



Hexane



Water



Carbon Tetrachloride

Compound	Density (g/mL)
Hexane	0.66
Water	1.00
Carbon Tetrachloride	1.59