Big Idea 2: Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.

Enduring Understanding

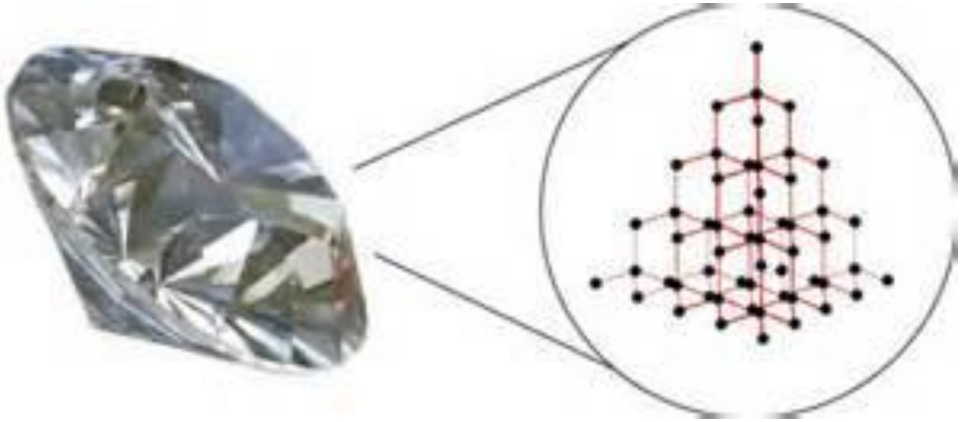
- 2.A: Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.
- 2.B: Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.
- 2.C: The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds.
- 2.D: The type of bonding in the solid state can be deduced from the properties of the solid state.

Types of bonds = Characteristics

- Types of solids:
  - Network covalent: Very strong web Attractions (carbon family, SiO_2)
  - Ionic: Very strong web of attractions
  - Molecular solid (covalent)
    - Strong Intramolecular bonds (covalent)
    - Relatively weak Intermolecular bonds.
      - Still must be present in a quantity sufficient to make a solid

Network Covalent- Always solid

- Highest melting point:
- Hardest substances
- Web of covalent bonds
- Examples
  - Diamond
  - Silicon Carbide
  - Silicon Oxide



Ionic compound:

- What holds together an ionic bond?
- Electrostatic attraction of a cation to an anion.
- Important: When you melt an ionic bond you break an ionic bond!

$$F = k\frac{q_1 \times q_2}{d^2}$$

- Factors affecting melting points of ionic compounds
  - Charge of Cation and anion
    - Melting point: $NaCl < AlCl_3$
  - Radius: Larger radius would reduce columbic attraction.
    - Melting point: $NaCl > NaI$

Rank the following substances solid in order of increasing Melting point.

- NaCl
- Al_2O_3
- $MgCl_2$
- C (diamond)
- MgI_2

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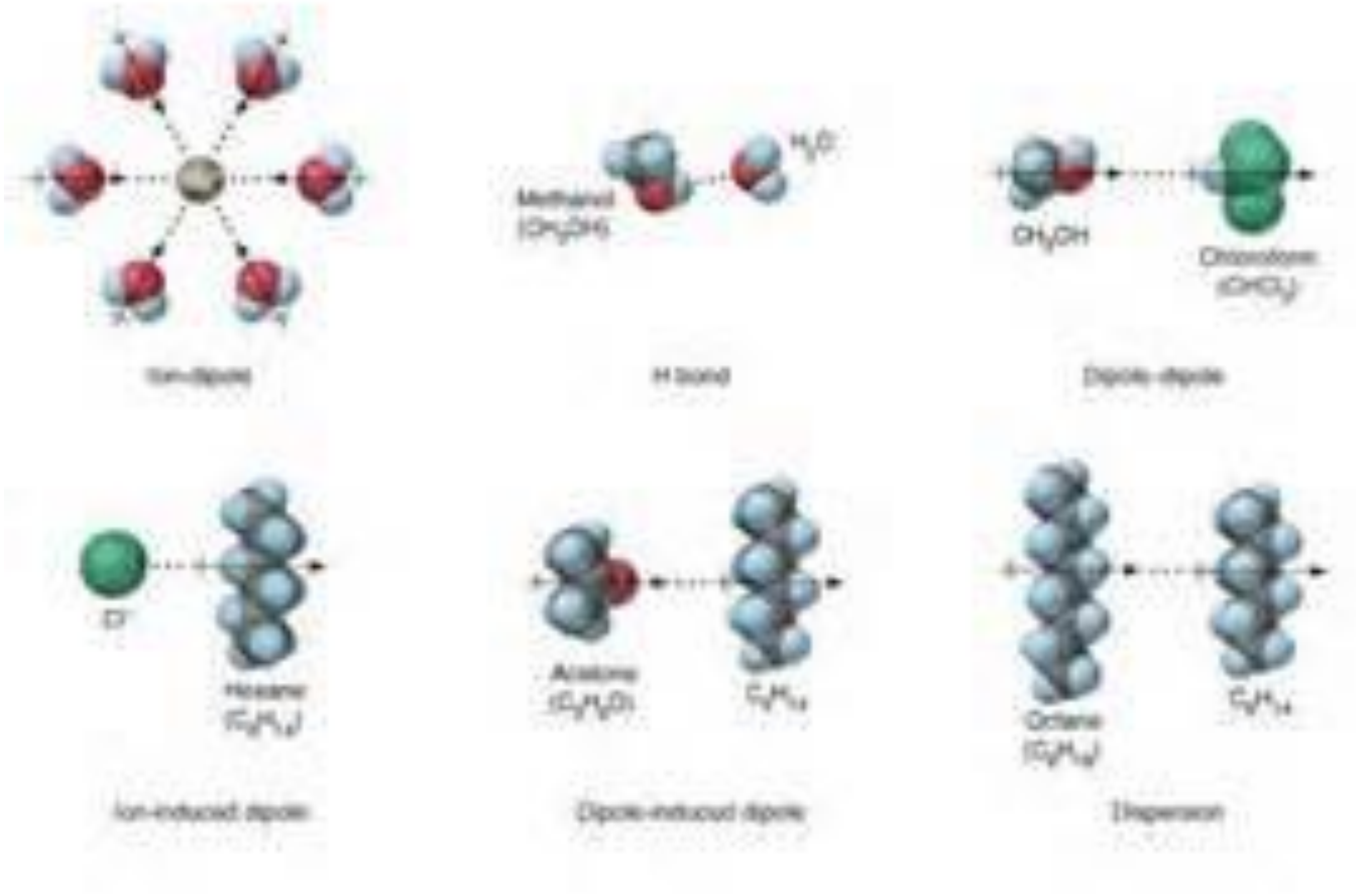
- $MgCl_2$
- MgI_2
- NaCl

Molecular solids: Covalent molecules with IMF

- Intermolecular Forcers
- Intramolecular Forces
- Note: When you melt a covalent substance you break an intermolecular bond (IMF)



General affects of IMF

CREATES A DIPOLE THAT ATTRACTS TO ANTHER DIPOLE

- Melting points

↑ IMF causes greater attraction

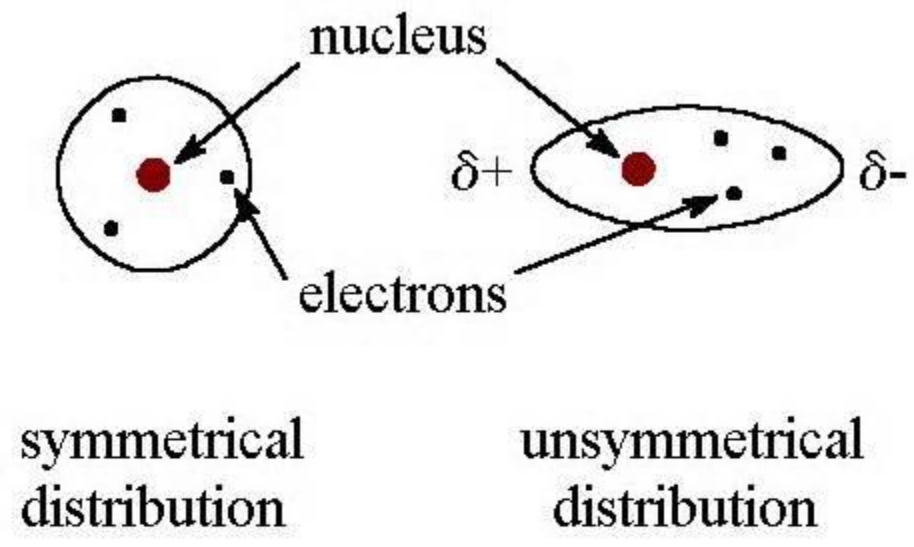
This will cause an ↑ MP.

- Vapor Pressure

↑ In IMF will cause greater attraction which will cause a ↓ in vapor pressure

Types of Intermolecular forces: London Forces
-Dipole creation

- Unequal distribution of electrons causes temporary dipole.
- Why? Electrons are moving



- Factors:
  - Quantity of electrons (not mass)
  - Long chains

Types of Intermolecular forces: Hydrogen bonding
-DIPOLE CREATION!

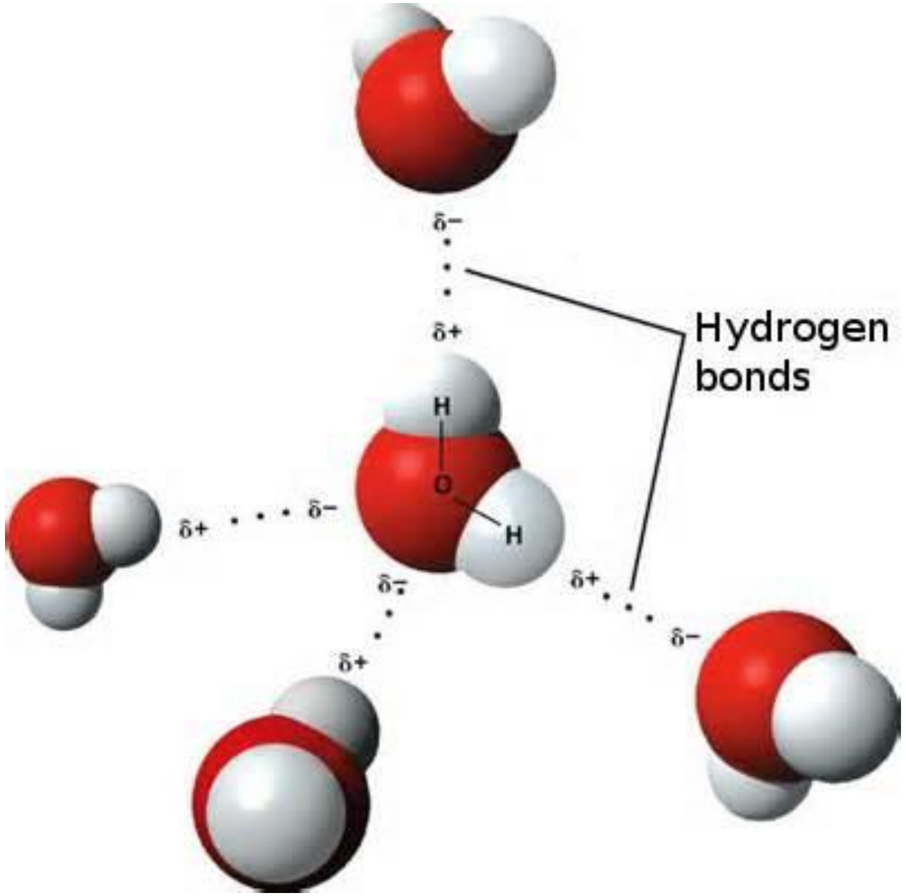
- Un-equal sharing of electrons due to unequal electronegativity

- Highly electronegative atoms

N --- H

O --- H

F --- H



Types of Intermolecular forces: Generic Dipole Dipole

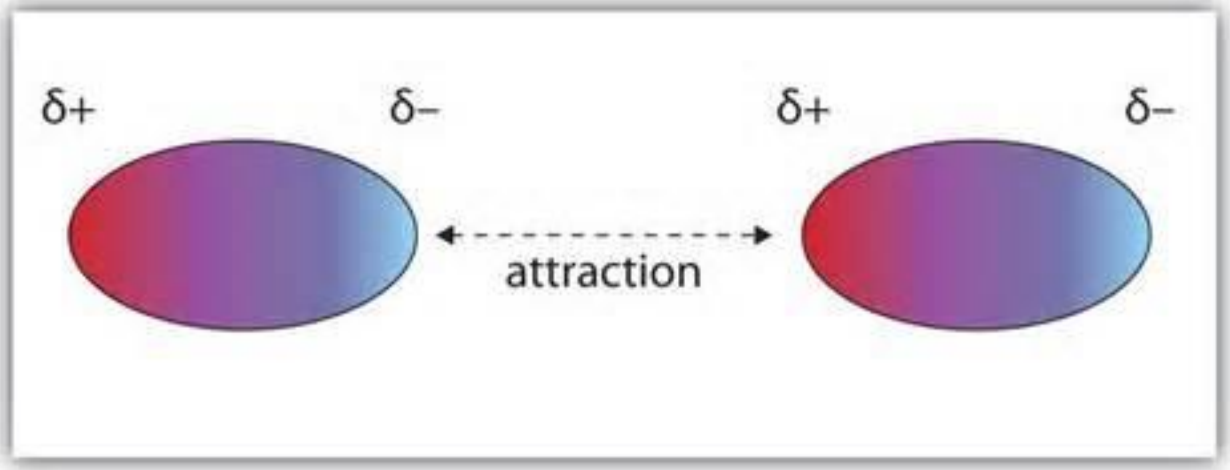
- This is the same as Hydrogen bonding just does not contain H.

- Highly electronegative atom

N -- ?

O -- ?

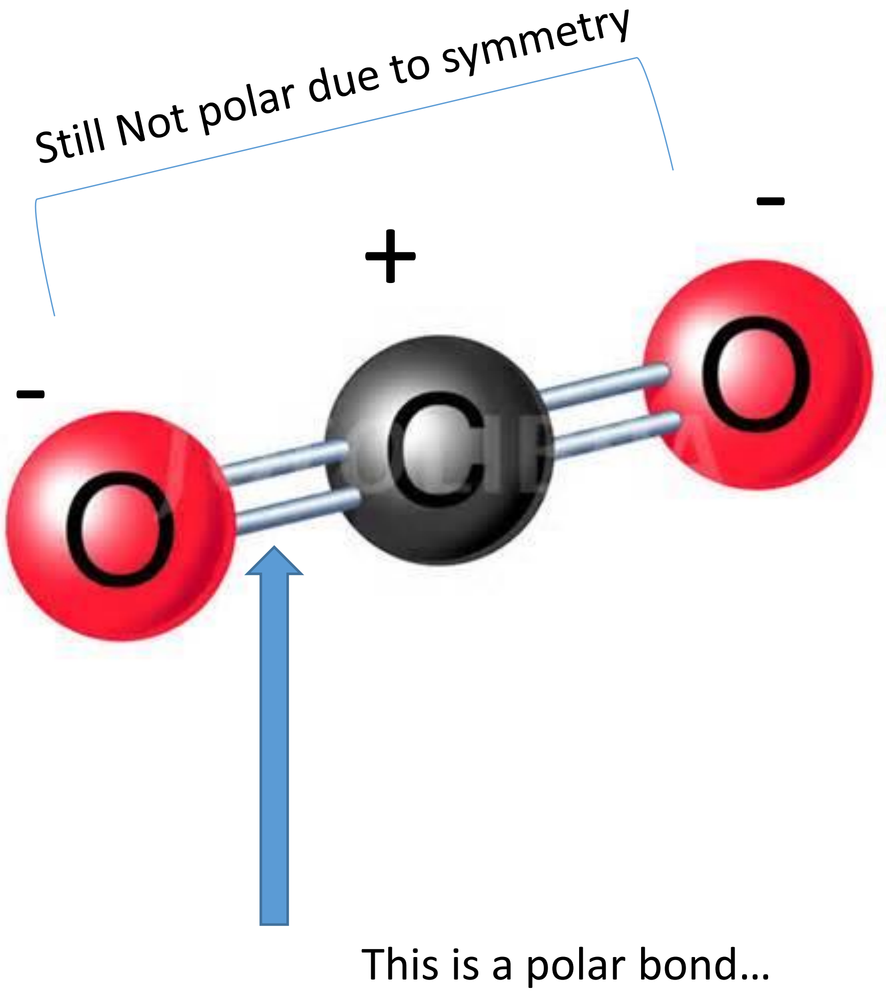
F -- ?



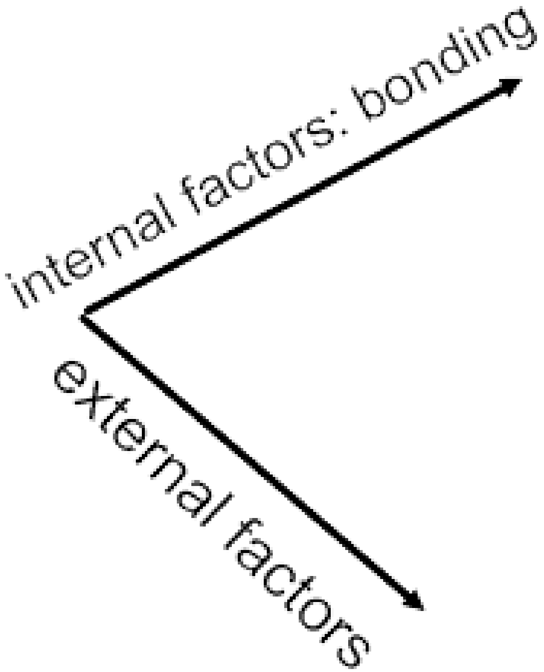
Types of Intermolecular forces: Dipole-Dipole

- Factors affecting Dipole - dipole
  - Electronegativity difference:
  - Symmetry:

CO_2 -- Carbon dioxide see right



States of matter: Solids
Q: Why is a solid a solid?

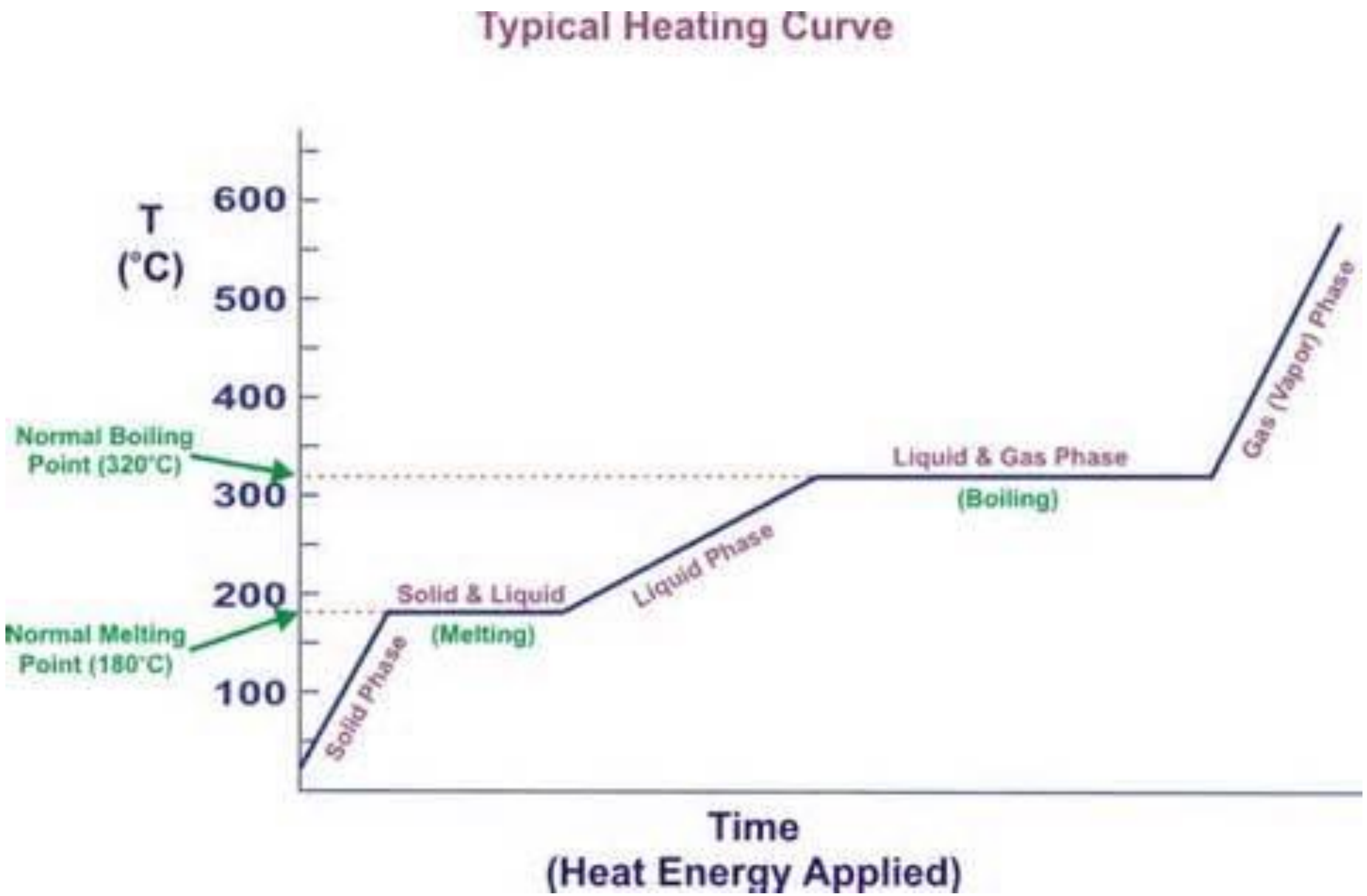


- Bond type:
  - Network covalent: Always strong
  - Ionic: Always solid strong interaction
  - Molecular solid: dependent on IMFs

- External Factors (things you can control)
  - Temperature: Average Kinetic energy
    - Increases motion of particles eventually breaking localized attractions

  - Pressure: Increasing pressure can squeeze into a tighter solid???

Heating curve

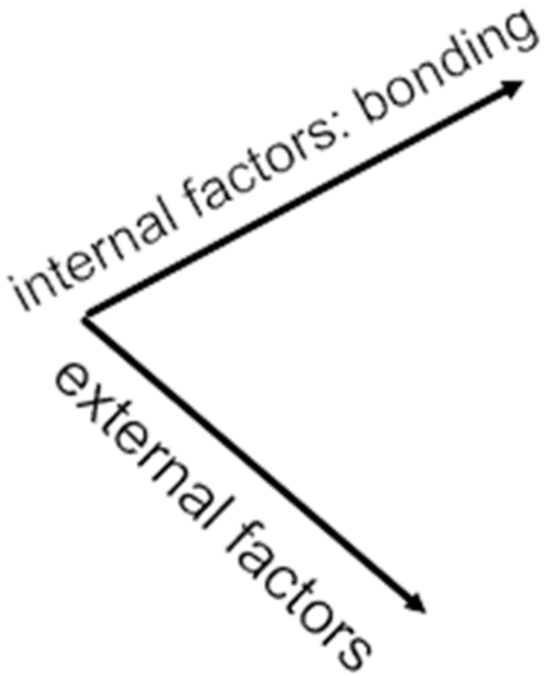


Solid $\Rightarrow$ liquid

- Motion of a particle
  - Rotational : Solids can rotate in a single location
  - Translational: Liquids can move across the medium

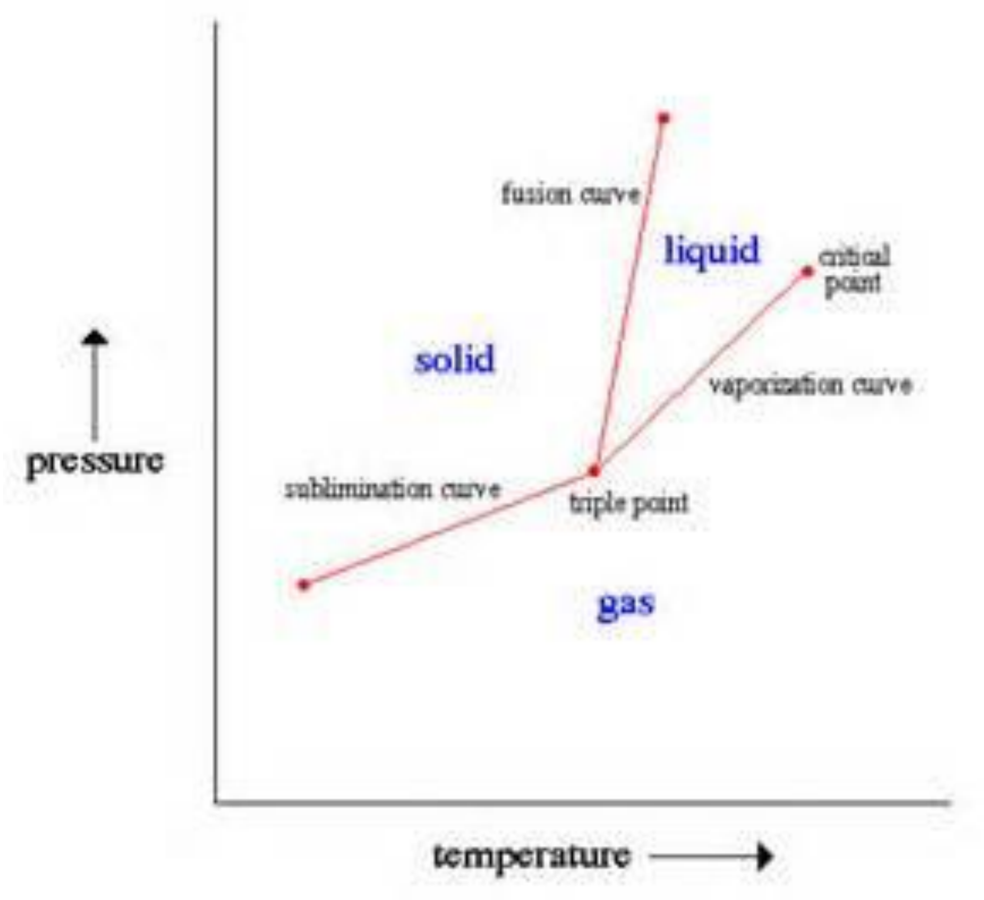
  - The movement of the particles has sufficient energy to break local interactions allowing it to move translationally.
  - These interactions could be
    - Ionic
    - Network covalent
    - IMF

Liquids: Why is a liquid a liquid?



- Bonding
  - Must be a molecular substance with a moderate amount of IMF….
- External factors
  - Temperature
  - pressure

Factors affecting liquids: Triple phase diagram

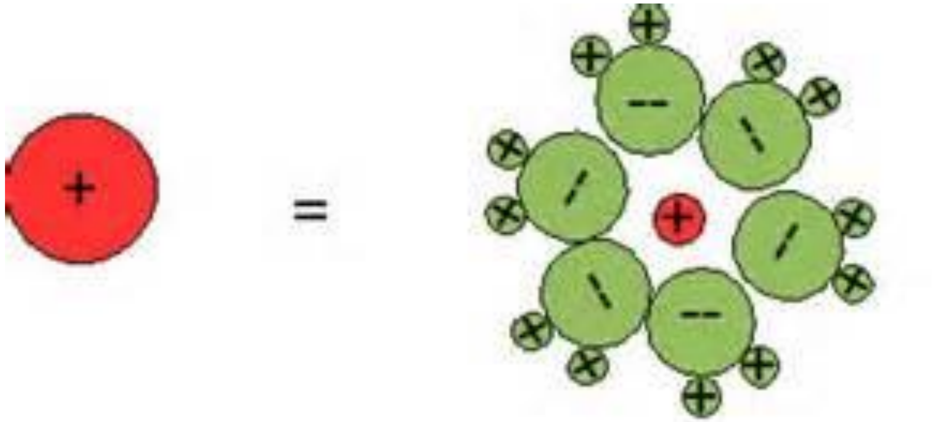


- This diagram is not going to be on the exam… it is to easy…
- Notice: increase in pressure has little affect on the melting point but dramatically affects the Boiling point.

Liquids dissolve: Why

- Why do substances dissolve?
  - How do you explain this???
  - Important: You must use coulombs law to describe the attraction between solute and solvent?

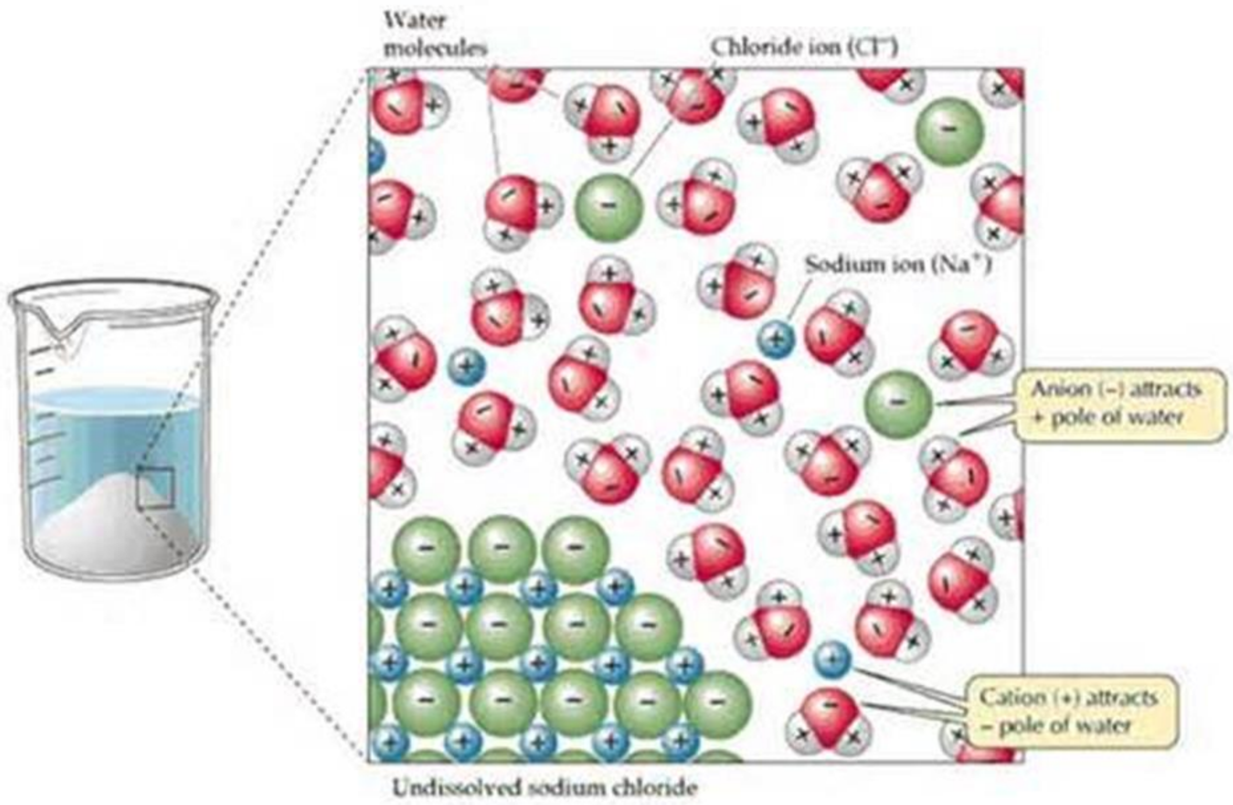
- Must draw like this!



Ionic compounds dissociate in the dissolving process!!!!

$Al(OH)_3 \leftrightarrow 3OH^- + Al^{+3}$

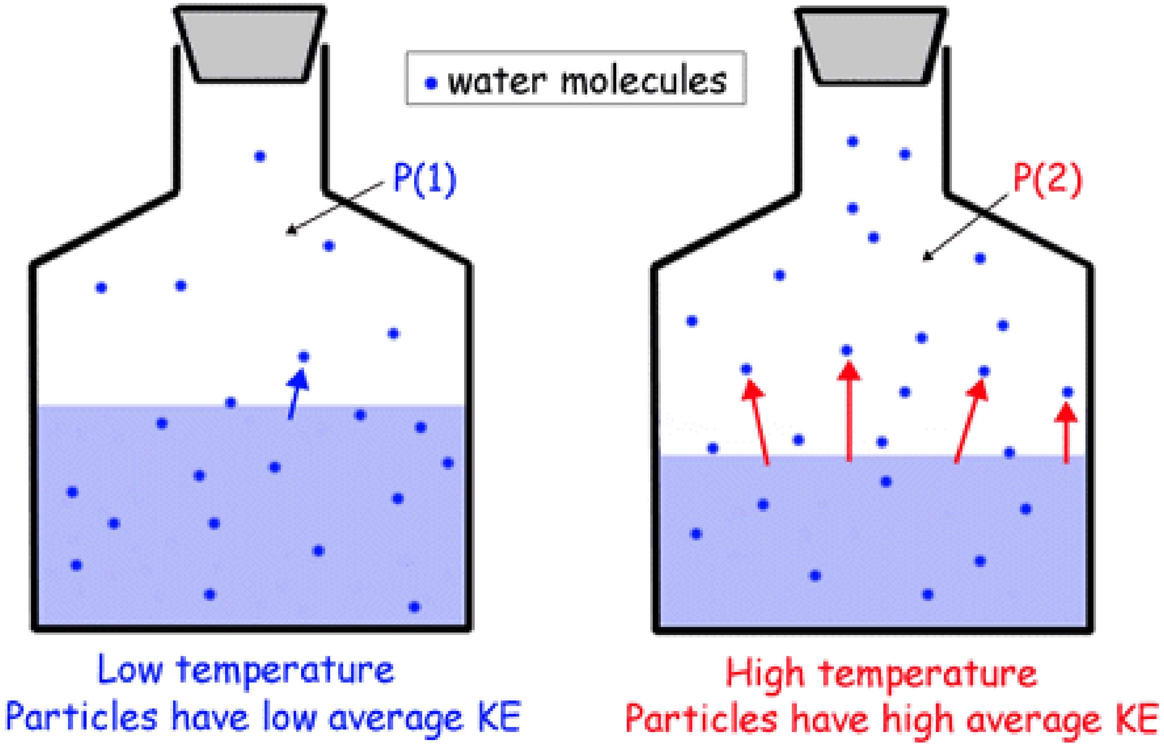
Note: $[OH^{-1}]$ would triple



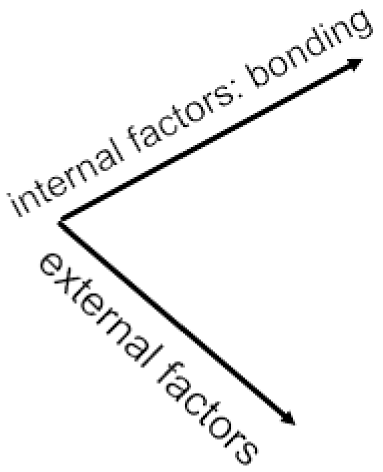
Liquid ⇒ Gas

Boiling occurs when

Vapor pressure > atmospheric pressure



States of matter: Gases
Why is a gas a gas?



- Internal factors:
  - Molecular with nearly no IMF attractions

(ideal gas)

External factors (PV=nRT)

P = pressure

V = volume

n = moles

T = temperature

Properties of gases relative to their containers

Balloon

P = constant

↑T = ↑V

Ridged container

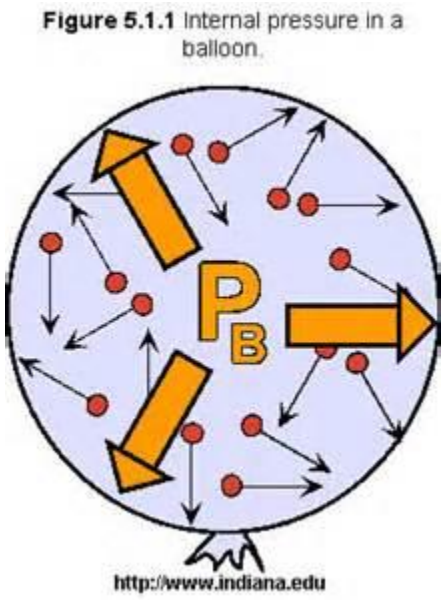
v = constant

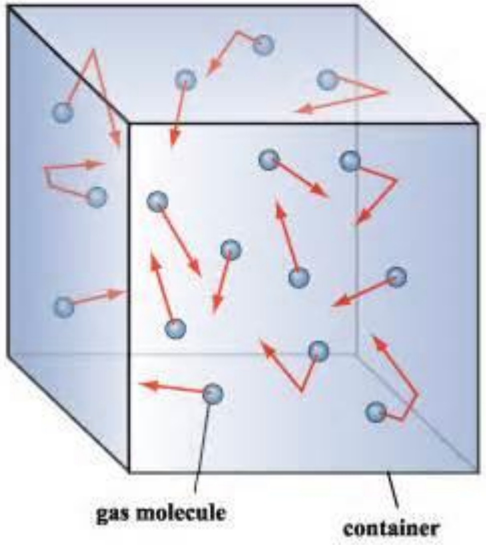
↑T = ↑P

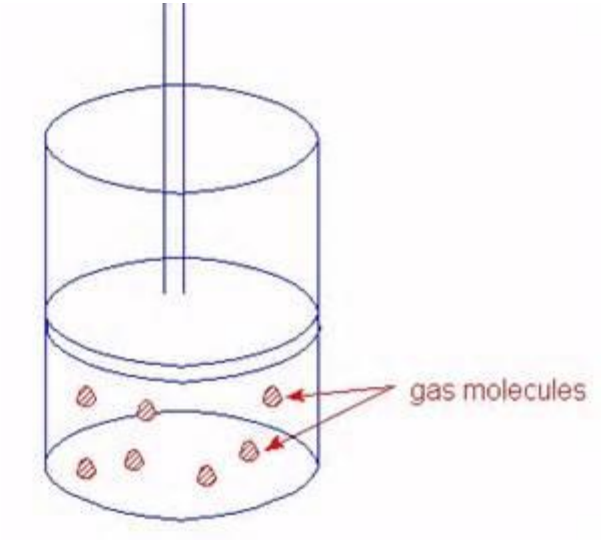
Piston

T=constant (for this example)

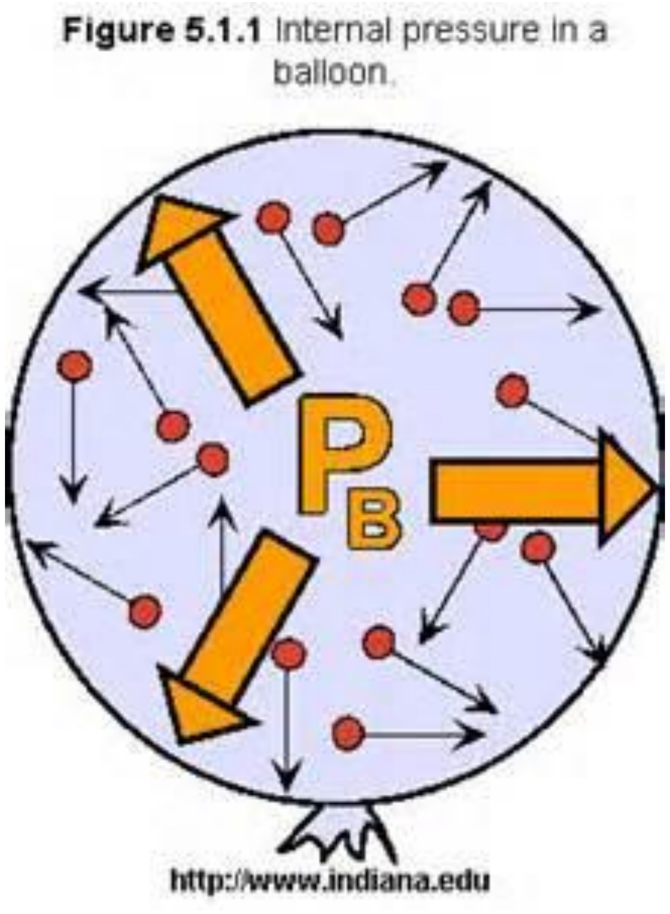
↓V = ↑P





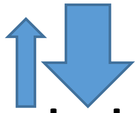


Average Kinetic energy vs. Molecular speed



- Average Kinetic energy = temperature
- Molecular velocity = speed of actual item

Given Temperature = KE = $1/2MV^2$



More massive particle will travel slower then less massive particles at a given temperature.

Calculating actual speed in meters per second

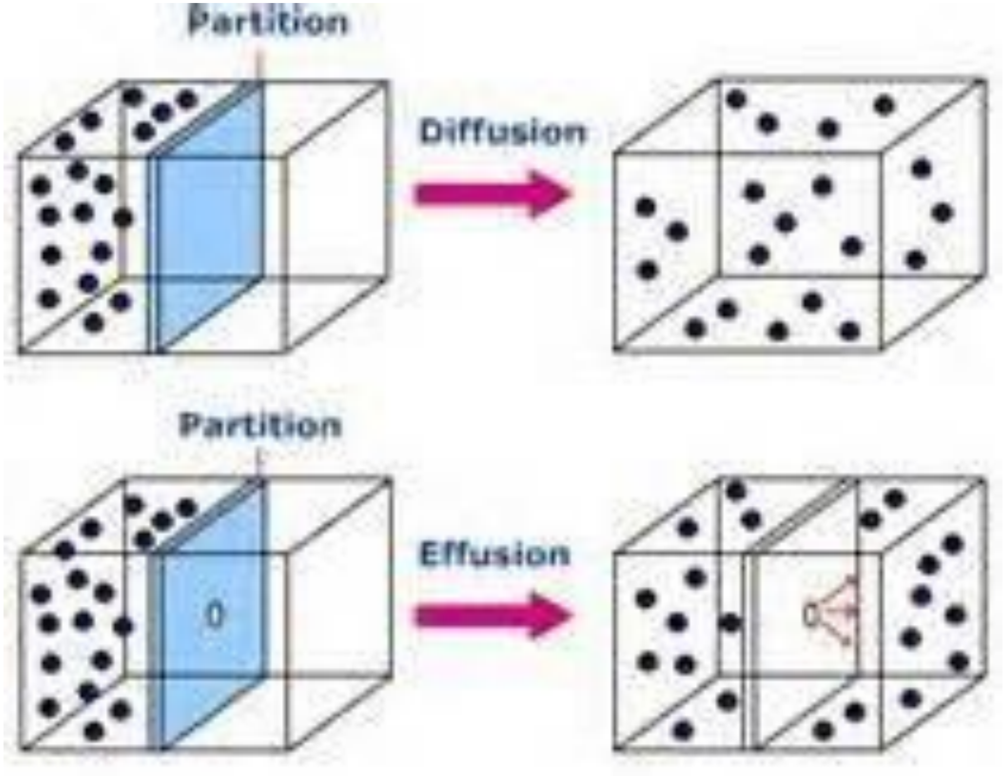
$$RMS = \sqrt{\frac{3RT}{M}}$$

$$u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\left(8.314\ \frac{1\cancel{Kg}.m^2}{s^2.\cancel{mol}.\cancel{K}}\right)(300\ \cancel{K})}{0.03995\ \frac{\cancel{Kg}}{\cancel{mol}}}}$$

$$= 433\ m/s$$

This is for a Argon particle!
40 grams/mol = .04kg/mol

Diffusion and effusion

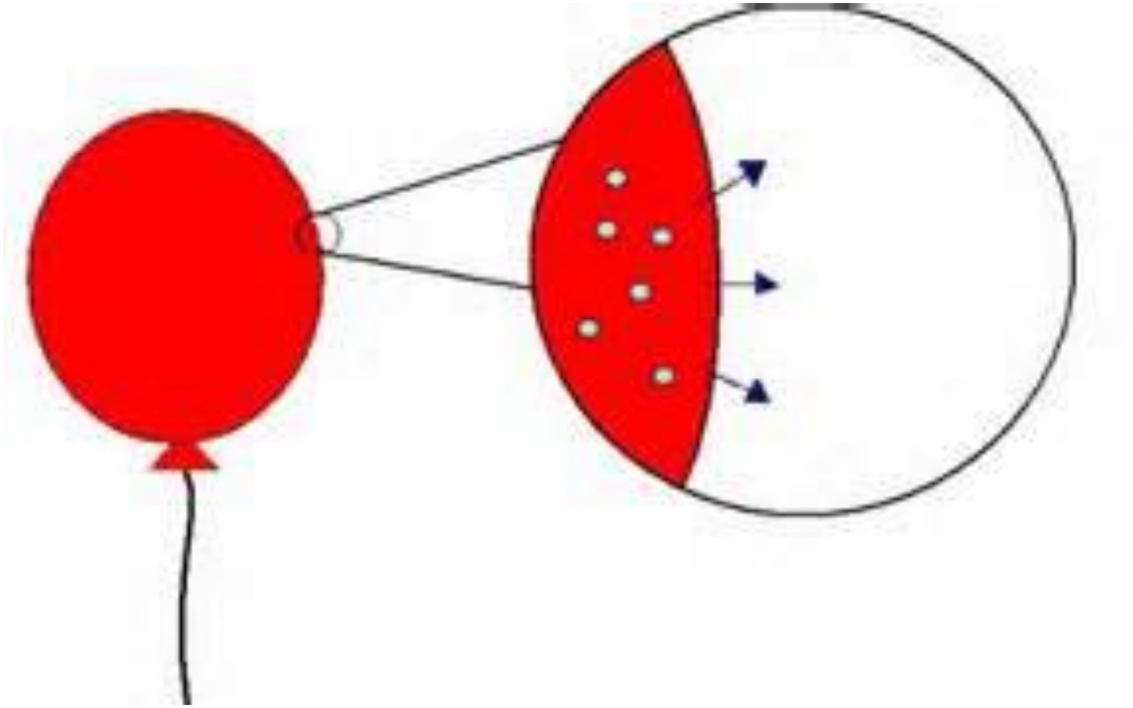


$$\frac{Rate_A}{Rate_B} = \sqrt{\frac{Molar\ Mass_B}{Molar\ Mass_A}}$$

Effusion & Diffusion

- Faster particles will effuse faster!
- For a given Temperature less massive particles move faster!

- Helium (4g/mol) effuse faster then Nitrogen (28g/mol) for a given temperature due to higher molecular velocities!



$$\frac{Rate_A}{Rate_B} = \sqrt{\frac{Molar\ Mass_B}{Molar\ Mass_A}}$$

Ideal gas vs. non- ideal gas

- Gas properties
  - Traveling very fast
  - Large distance between particles
  - Elastic Collisons
  - Straight line paths

Result: no interactions between particles

ALL PARTICLES ACT THE SAME

IDENTITY OF PARTICLE DOES NOT MATTER!

- Can I convert an ideal gas to a non-ideal?
- Yes:
  - Slow them down (cool them)
  - Get them closer together so they can interact (compress them)

Combined Gas law

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Must be in Kelvin

$PV = nRT$

- P = pressure (atm)
- V = volume (L)
- n = moles
- R = .0821
- T = temperature (kelvin)

Partial pressure: Individual pressure of a gas amongst other gases…

- Ptotal = $P_1 + P_2 + P$….

Proportional to total particles

- $n_{total} = n_1 + n_2 + n$…..

Applications:

- 10 percent of the particles in a balloon are O_2 therefore 10% of the pressure is the partial pressure of the O_2
- PV = nRT: if you put in just the moles of O_2 you would get just the partial pressure of the O_2.
- We track partial pressures in equilibrium systems!

Substance	Equilibrium Vapor Pressure at 20°C (torr)
$C_6H_6(l)$	75
$C_2H_5OH(l)$	44
$CH_3OH(l)$	92
$C_2H_6O_2(l)$	0.06

2. Based on the data in the table above, which of the following liquid substances has the weakest intermolecular forces?

(A) $C_6H_6(l)$
(B) $C_2H_5OH(l)$
(C) $CH_3OH(l)$
(D) $C_2H_6O_2(l)$

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(C) $CH_3OH(l)$ ←
(D) $C_2H_6O_2(l)$

General Idea:

↑ Intermolecular forces

↕

↓ Vapor Pressure

Lowest VP = Greatest IMF = C

More attraction between particles yields less particles escaping off the surface (vapor pressure)

Ion	Ionic Radius (pm)
Zn^{2+}	74
Ca^{2+}	100
Ba^{2+}	135

3. Based on the data in the table above, which of the following correctly predicts the relative strength of the attraction of Zn^{2+}, Ca^{2+}, and Ba^{2+} ions to water molecules in a solution, from strongest to weakest, and provides the correct reason?

(A) $Zn^{2+} > Ca^{2+} > Ba^{2+}$ because the smaller ions have a stronger coulombic attraction to water

(B) $Zn^{2+} > Ca^{2+} > Ba^{2+}$ because the smaller ions are more electronegative

(C) $Ba^{2+} > Ca^{2+} > Zn^{2+}$ because the larger ions are more polarizable

(D) $Ba^{2+} > Ca^{2+} > Zn^{2+}$ because the larger ions are less electronegative

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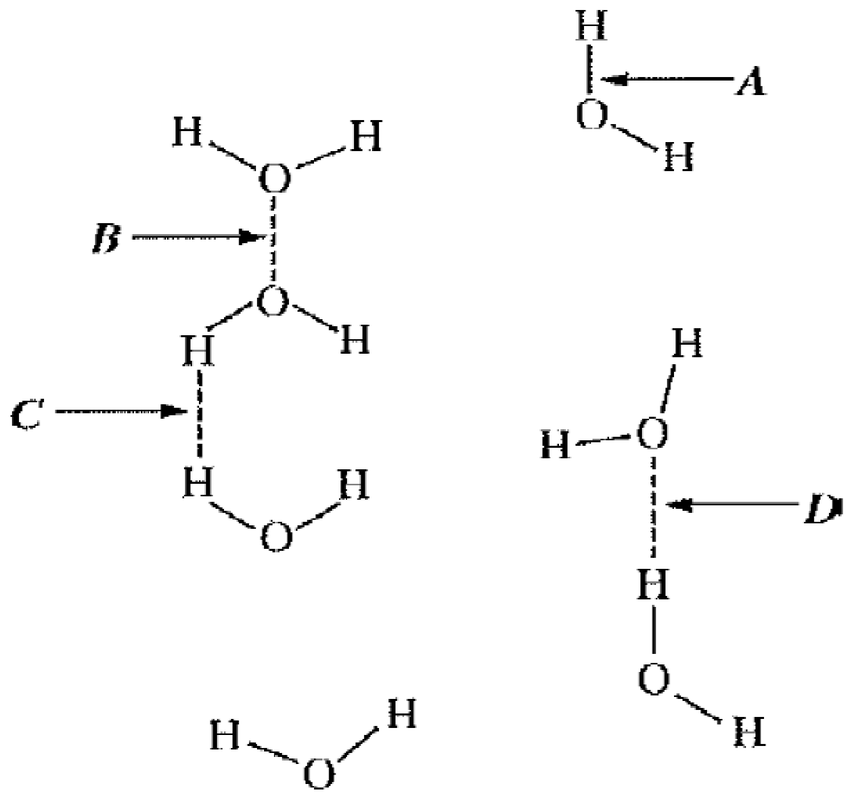
(D) $Ba^{2+} > Ca^{2+} > Zn^{2+}$ because the larger ions are less electronegative

- This is a Coulombs law question. The force is inversely proportional to the square or gets a lot smaller as the distance gets bigger!

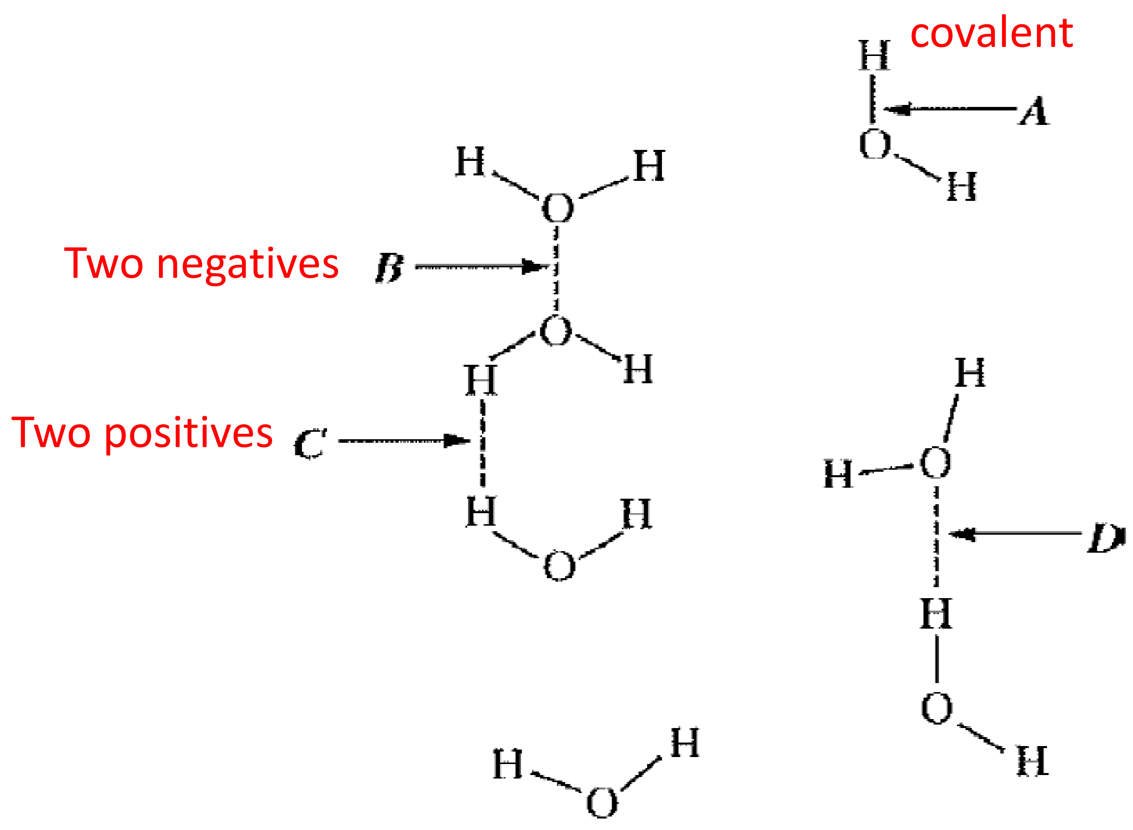
$Zn^{2+} > Ca^{2+} > Ba^{2+}$

$$F = k\frac{q_1 \times q_2}{d^2}$$



5. In the diagram above, which of the labeled arrows identifies hydrogen bonding in water?

(A) *A*
(B) *B*
(C) *C*
(D) *D*



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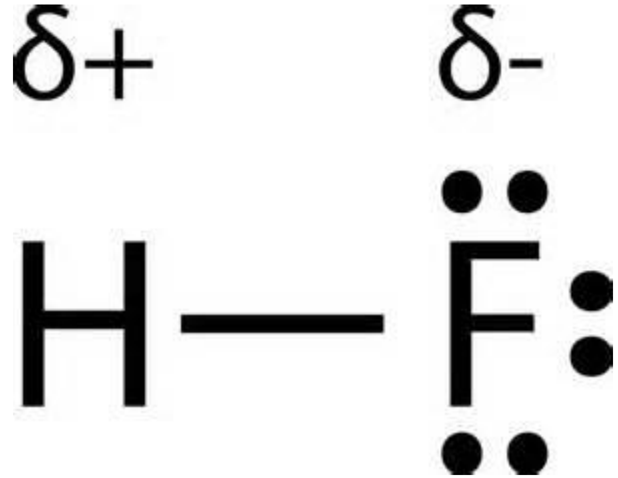
(A) *A*
(B) *B*
(C) *C*
(D) *D*

- Note that the highly electronegative atom (N,O, F) will always be negative.
- Example



- D is correct answer

Questions 18-20 refer to three gases in identical rigid containers under the conditions given in the table below.

Container	A	B	C
Gas	Methane	Ethane	Butane
Formula	CH_4	C_2H_6	C_4H_{10}
Molar mass (g/mol)	16	30.	58
Temperature (°C)	27	27	27
Pressure (atm)	2.0	4.0	2.0

18. The average kinetic energy of the gas molecules is

(A) greatest in container A
(B) greatest in container B
(C) greatest in container C
(D) the same in all three containers

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Average Kinetic energy = Temperature

They are all equal!

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19. The density of the gas, in g/L, is

(A) greatest in container A
(B) greatest in container B
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19. The density of the gas, in g/L, is

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(D) the same in all three containers

- This is a very common problem – simply a proportional problem
- D = m/v : PV = nRT and they all have the same v and T.
- B has twice the pressure = twice the particles
- C is not quite twice as heavy
- B is therefore more dense.

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Alternate method

- Alternate method:
- D = M/V $\Rightarrow$ V = M/D
- PV = nRT Sub in for volume
- PM/D = nRT = D = P M/nRT
- Density is directly proportional to P* Molar mass

30 * 4 > 2 * 58

I would not do this problem like this..

Just saying

Questions 18-20 refer to three gases in identical rigid containers under the conditions given in the table below.

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20. If the pressure of each gas is increased at constant temperature until condensation occurs, which gas will condense at the lowest pressure?

(A) Methane
(B) Ethane
(C) Butane
(D) All the gases will condense at the same pressure.

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(A) Methane
(B) Ethane
(C) Butane ←
(D) All the gases will condense at the same pressure.

- This is an IMF question

↑IMF = likeliness to condense to liquid

Note: Hydrogen bonding is out. We are only concerned about London Forces.

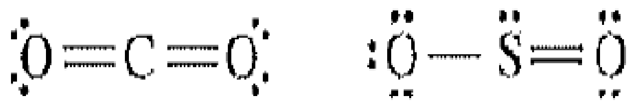
Note: Lowest pressure, does not matter that B starts at a higher pressure.

CH_4: Smallest chain

C_2H_6:

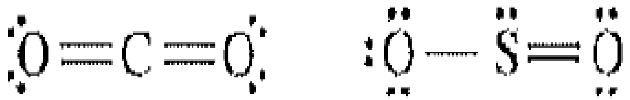
C_4H_{10}: Longest chain = most IMF

C = answer



23. Lewis electron-dot diagrams for CO_2 and SO_2 are given above. The molecular geometry and polarity of the two substances are

(A) the same because the molecular formulas are similar
(B) the same because C and S have similar electronegativity values
(C) different because the lone pair of electrons on the S atom make it the negative end of a dipole
(D) different because S has a greater number of electron domains (regions of electron density) surrounding it than C has



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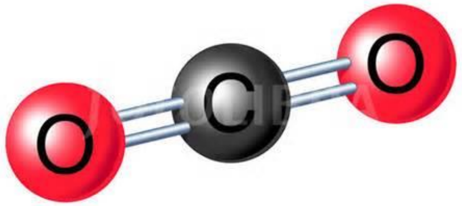
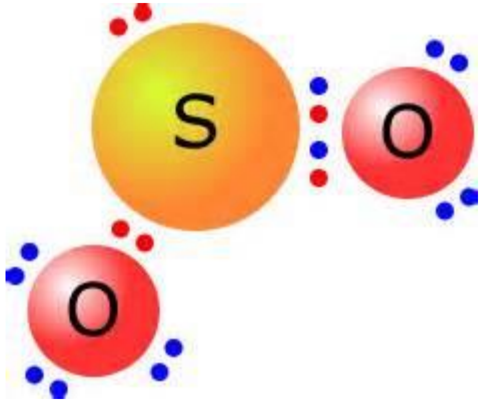
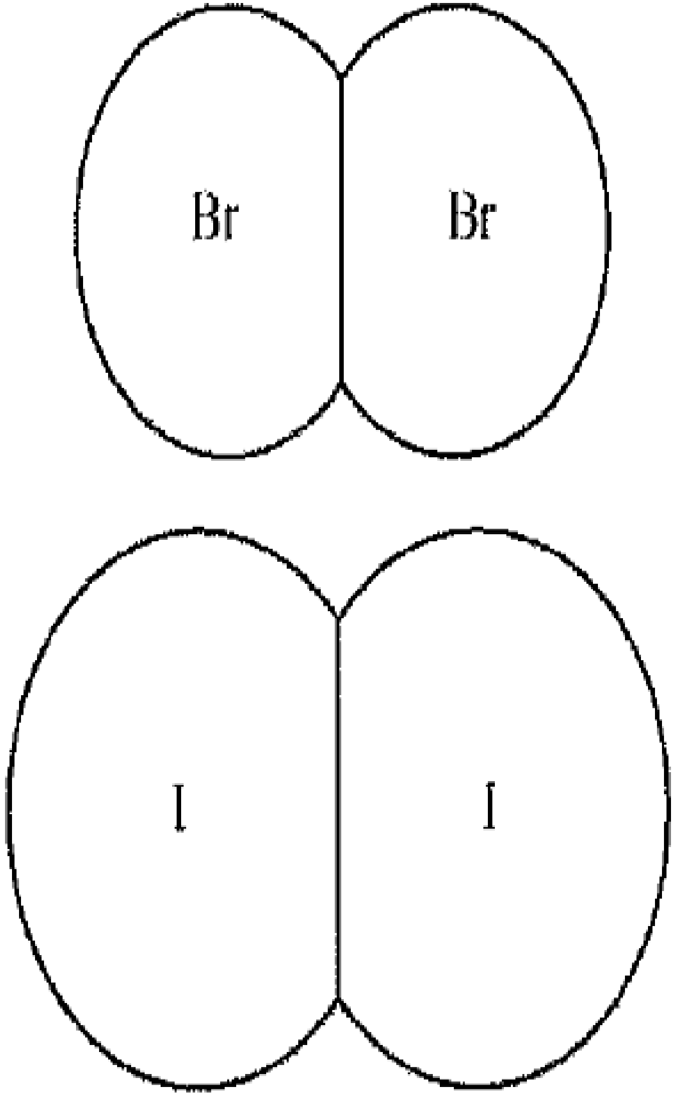




- Electron Domains: These are either bonded or non-bonded.
- CO_2 = 2 both bonded
- SO_2 = 3 two bonded 1 non- bonded



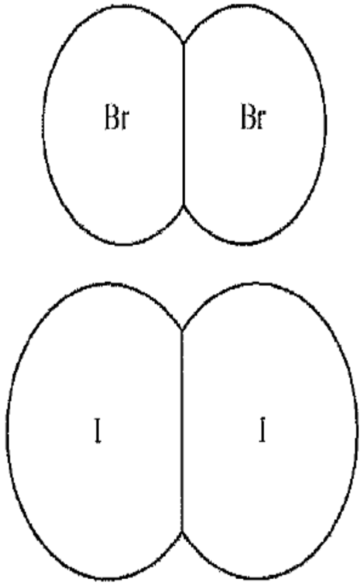
25. The diagram above shows molecules of Br_2 and I_2 drawn to the same scale. Which of the following is the best explanation for the difference in the boiling points of liquid Br_2 and I_2, which are 59°C and 184°C, respectively?

(A) Solid iodine is a network covalent solid, whereas solid bromine is a molecular solid.

(B) The covalent bonds in I_2 molecules are weaker than those in Br_2 molecules.

(C) I_2 molecules have electron clouds that are more polarizable than those of Br_2 molecules, thus London dispersion forces are stronger in liquid I_2.

(D) Bromine has a greater electronegativity than iodine, thus there are stronger dipole-dipole forces in liquid bromine than in liquid iodine.



25. The diagram above shows molecules of Br_2 and I_2 drawn to the same scale. Which of the following is the best explanation for the difference in the boiling points of liquid Br_2 and I_2, which are 59°C and 184°C, respectively?

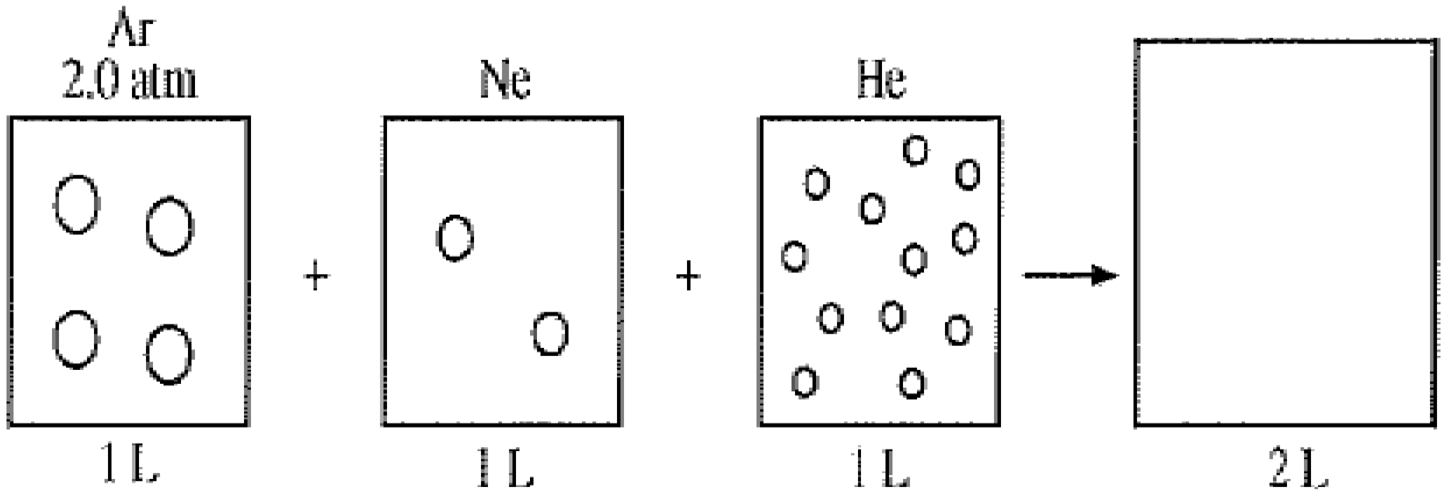
(A) Solid iodine is a network covalent solid, whereas solid bromine is a molecular solid.

(B) The covalent bonds in I_2 molecules are weaker than those in Br_2 molecules.

(C) I_2 molecules have electron clouds that are more polarizable than those of Br_2 molecules, thus London dispersion forces are stronger in liquid I_2.

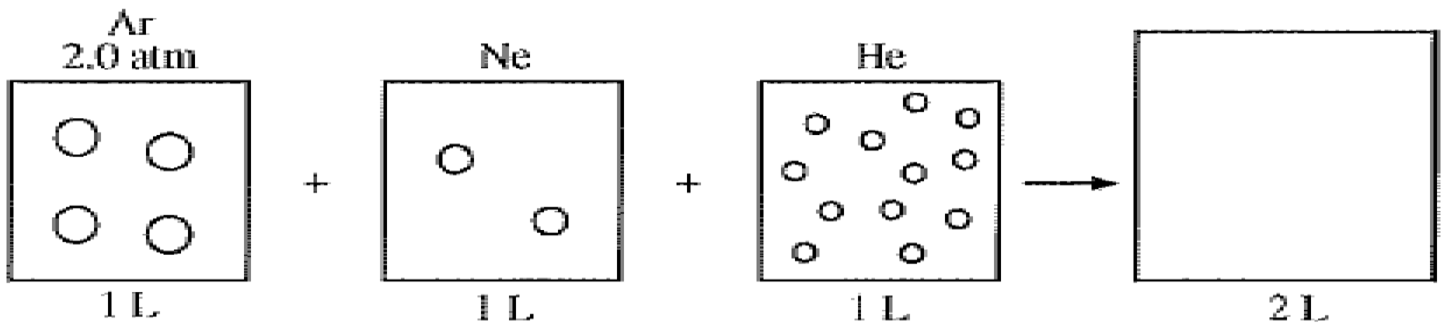
(D) Bromine has a greater electronegativity than iodine, thus there are stronger dipole-dipole forces in liquid bromine than in liquid iodine.

- This is a London Forces question. Fundamental to how London forces form.
- More e- makes the atom more polarizable or increases chances more electrons will be on one side vs. the other creating small temporary dipoles.



26. The figure above represents three sealed 1.0 L vessels, each containing a different inert gas at 298 K. The pressure of Ar in the first vessel is 2.0 atm. The ratio of the numbers of Ar, Ne, and He atoms in the vessels is 2:1:6, respectively. After all the gases are combined in a previously evacuated 2.0 L vessel, what is the total pressure of the gases at 298 K?

(A) 3.0 atm
(B) 4.5 atm
(C) 9.0 atm
(D) 18 atm



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(B) 4.5 atm ⟵
(C) 9.0 atm
(D) 18 atm

- This is proportionality issue. Find all the pressures in each container
- Ar = 2 Atm Ne = 1 atm He= 6 atm total pressure if in a 1 L container?
- 2 + 1 + 6 = 9 atm but since we doubled the container size the pressure is 4.5.

Note use of Daltons law of partial pressure. $P_{total} = P_1 + P_2 + p_2$

Answer = B

$$PCl_5(g) \rightleftarrows PCl_3(g) + Cl_2(g)$$

$PCl_5(g)$ decomposes into $PCl_3(g)$ and $Cl_2(g)$ according to the equation above. A pure sample of $PCl_5(g)$ is placed in a rigid, evacuated 1.00 L container. The initial pressure of the $PCl_5(g)$ is 1.00 atm. The temperature is held constant until the $PCl_5(g)$ reaches equilibrium with its decomposition products. The figures below show the initial and equilibrium conditions of the system.

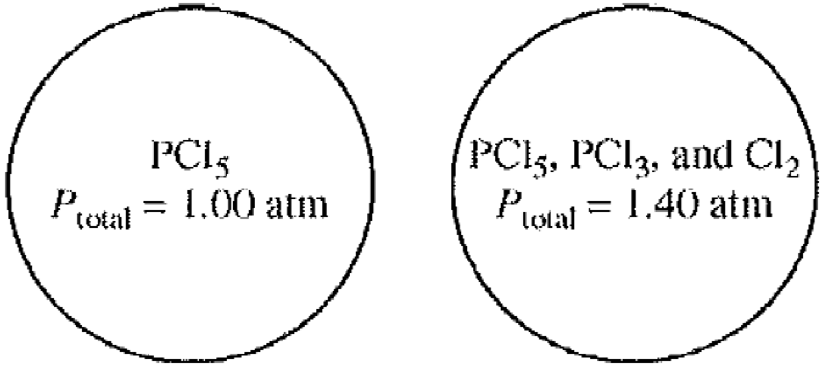

Figure 1: Initial   Figure 2: Equilibrium

29. Which of the following is the most likely cause for the increase in pressure observed in the container as the reaction reaches equilibrium?

(A) A decrease in the strength of intermolecular attractions among molecules in the flask
(B) An increase in the strength of intermolecular attractions among molecules in the flask
(C) An increase in the number of molecules, which increases the frequency of collisions with the walls of the container
(D) An increase in the speed of the molecules that then collide with the walls of the container with greater force

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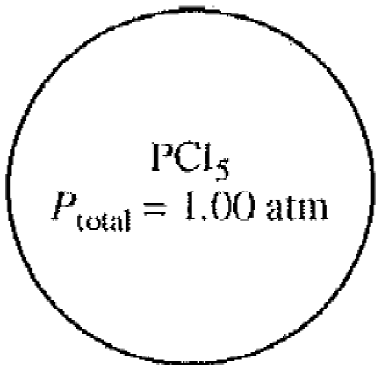
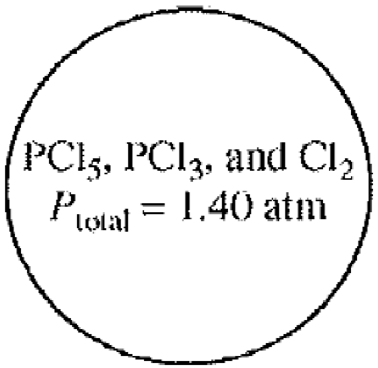


Figure 1: Initial



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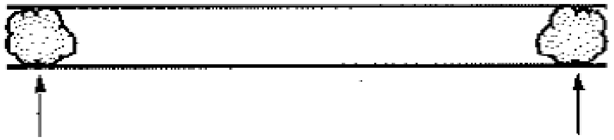
- This reaction is proceeding to the products $\Rightarrow$ as it approaches equilibrium. So the pressure increases due to more gas particles.
- C is correct



39. The experimental apparatus represented above is used to demonstrate the rates at which gases diffuse. When the cotton balls are placed in the ends of a tube at the same time, the gases diffuse from each end and meet somewhere in between, where they react to form a white solid. Which of the following combinations will produce a solid closest to the center of the tube?

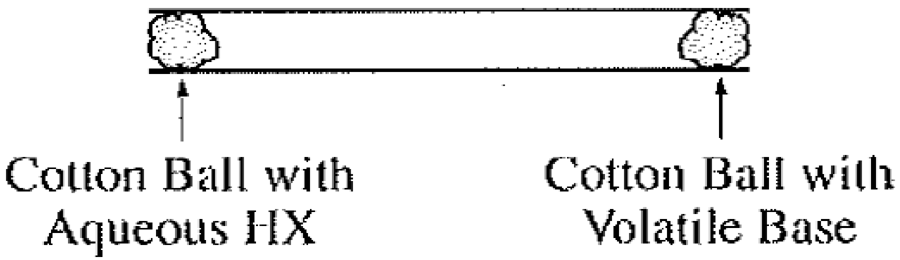
(A) HCl and CH_3NH_2

(B) HCl and NH_3

(C) HBr and CH_3NH_2

(D) HBr and NH_3

Diffusion



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(B) HCl and NH_3

(C) HBr and CH_3NH_2

(D) HBr and NH_3

- This problem is a diffusion problem. At a given temperature the rate of diffusion is controlled by molar mass. Which two substances have similar molar masses?
- A is correct answer

Element	Metallic Radius (pm)	Melting Point (°C)	Common Oxidation State
Au	144	1064	1+, 3+
Cu	128	1085	1+, 2+
Ag	144	961	1+

42. To make Au stronger and harder, it is often alloyed with other metals, such as Cu and Ag. Consider two alloys, one of Au and Cu and one of Au and Ag, each with the same mole fraction of Au. If the Au/Cu alloy is harder than the Au/Ag alloy, then which of the following is the best explanation based on the information in the table above?

(A) Cu has two common oxidation states, but Ag has only one.

(B) Cu has a higher melting point than Au has, but Ag has a lower melting point than Au has.

(C) Cu atoms are smaller than Ag atoms, thus they interfere more with the displacement of atoms in the alloy.

(D) Cu atoms are less polarizable than are Au or Ag atoms, thus Cu has weaker interparticle forces.

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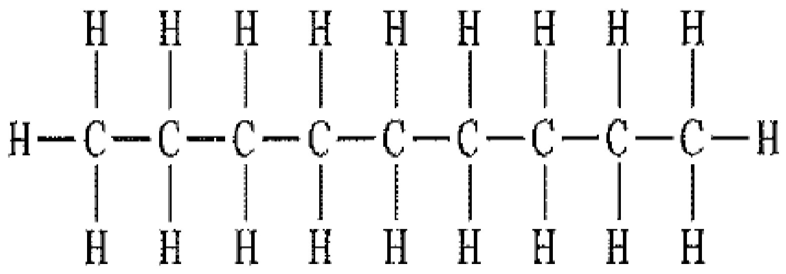
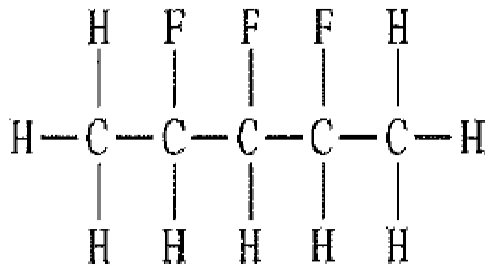
- **It reflects the data provided that the radii of Cu atoms is smaller than Ag atoms, which would prevent movement of Ag atoms in the alloy by creating points where Ag atoms could not slip past other atoms, making the overall alloy less deformable (i.e., less malleable).**



Nonane



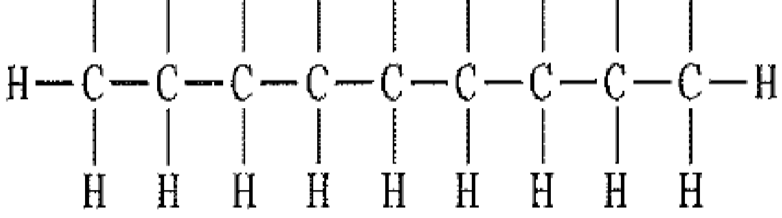
2,3,4-trifluoropentane

44. Consider the molecules represented above and the data in the table below.

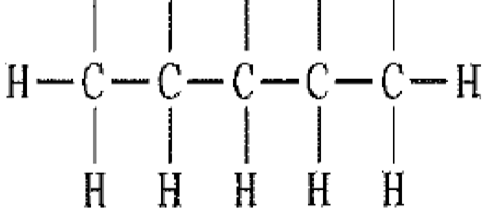
Compound	Molecular Formula	Molar Mass (g/mol)	Boiling Point (°C)
Nonane	C_9H_{20}	128	151
2,3,4-trifluoropentane	$C_5H_9F_3$	126	89

Nonane and 2,3,4-trifluoropentane have almost identical molar masses, but nonane has a significantly higher boiling point. Which of the following statements best helps explain this observation?

(A) The C–F bond is easier to break than the C–H bond.
(B) The C–F bond is more polar than the C–H bond.
(C) The carbon chains are longer in nonane than they are in 2,3,4-trifluoropentane.
(D) The carbon chains are farther apart in a sample of nonane than they are in 2,3,4-trifluoropentane.



Nonane



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(C) The carbon chains are longer in nonane than they are in 2,3,4-trifluoropentane.
(D) The carbon chains are farther apart in a sample of nonane than they are in 2,3,4-trifluoropentane.

- London Forces question. Nonane has a longer chain therefore it has more IMF and therefore an higher melting point.
- C = correct answer

	NaF	MgO
Boiling Point (°C)	1695	3600

	Na^+	Mg^{2+}	F^-	Cl^-	O^{2-}
Ionic Radius (pm)	76	72	133	181	140

54. Based on the data in the tables above, which of the following statements provides the best prediction for the boiling point of NaCl ?

(A) NaCl will have a lower boiling point than NaF because the coulombic attractions are weaker in NaCl than in NaF.

(B) NaCl will have a boiling point between that of NaF and MgO because the covalent character of the bonds in NaCl is intermediate between that of MgO and NaF.

(C) NaCl will have a higher boiling point than MgO because the ions are spaced farther apart in NaCl.

(D) NaCl will have a higher boiling point than MgO because the energy required to transfer electrons from the anion to the cation is larger in NaCl than in MgO.

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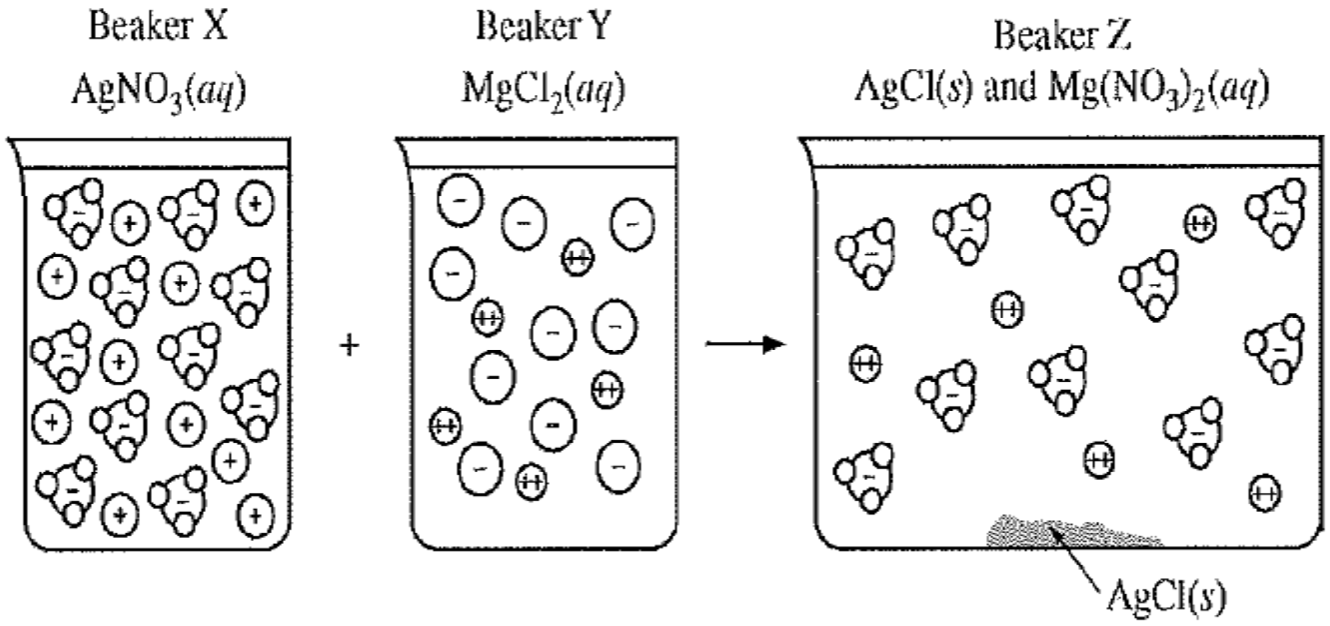
(C) NaCl will have a higher boiling point than MgO because the ions are spaced farther apart in NaCl.

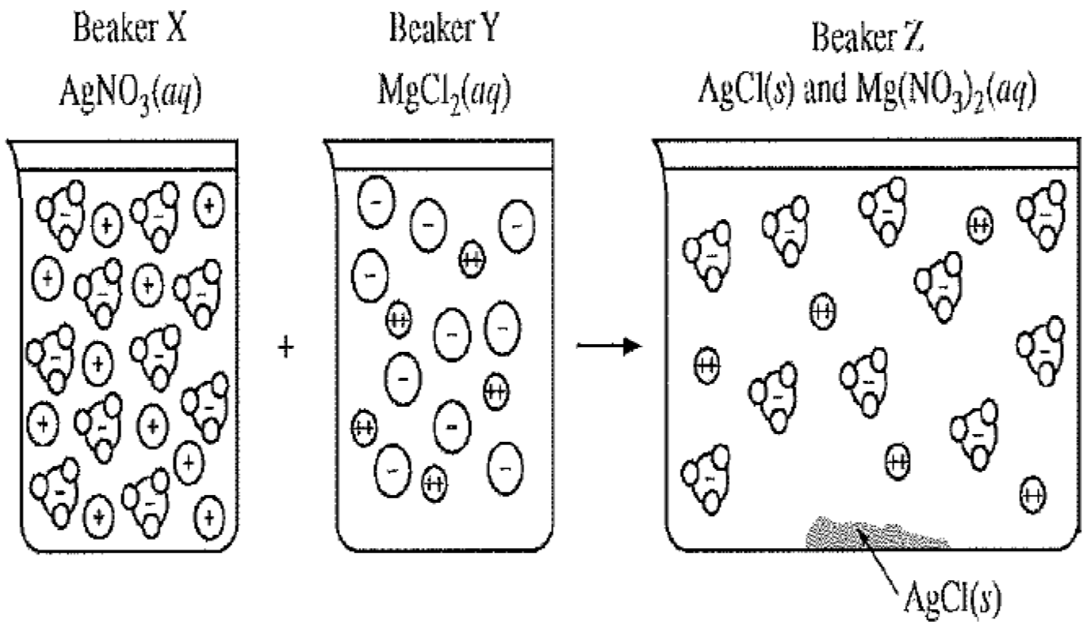
(D) NaCl will have a higher boiling point than MgO because the energy required to transfer electrons from the anion to the cation is larger in NaCl than in MgO.

- This is a coulombs law question. The larger radius of Cl makes the columbic attraction drop.
- A = correct answer



56. Beaker X and beaker Y each contain 1.0 L of solution, as shown above. A student combines the solutions by pouring them into a larger, previously empty beaker Z and observes the formation of a white precipitate. Assuming that volumes are additive, which of the following sets of solutions could be represented by the diagram above?

	Beaker X	Beaker Y	Beaker Z
(A)	2.0 M $AgNO_3$	2.0 M $MgCl_2$	4.0 M $Mg(NO_3)_2$ and $AgCl(s)$
(B)	2.0 M $AgNO_3$	2.0 M $MgCl_2$	2.0 M $Mg(NO_3)_2$ and $AgCl(s)$
(C)	2.0 M $AgNO_3$	1.0 M $MgCl_2$	1.0 M $Mg(NO_3)_2$ and $AgCl(s)$
(D)	2.0 M $AgNO_3$	1.0 M $MgCl_2$	0.50 M $Mg(NO_3)_2$ and $AgCl(s)$



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(B)	2.0 *M* $AgNO_3$	2.0 *M* $MgCl_2$	2.0 *M* $Mg(NO_3)_2$ and $AgCl(s)$
(C)	2.0 *M* $AgNO_3$	1.0 *M* $MgCl_2$	1.0 *M* $Mg(NO_3)_2$ and $AgCl(s)$
(D)	2.0 *M* $AgNO_3$	1.0 *M* $MgCl_2$	0.50 *M* $Mg(NO_3)_2$ and $AgCl(s)$

- Proportions will answer this question:
- $2AgNO_3 + MgCl_2 \Rightarrow Mg(NO_3)_2 + 2AgCl_{(s)}$
- For there to be no excess the $AgNO_3$ will need to be twice as concentrated.
  - Eliminate A and B
- The magnesium does not precipitate and since the volume doubles its concentration will get halved. Eliminate C
- D is correct answer

Element	Atomic Radius	First Ionization Energy
Calcium	194 pm	590 kJ/mol
Potassium	—	—

58. Based on periodic trends and the data in the table above, which of the following are the most probable values of the atomic radius and the first ionization energy for potassium, respectively?

(A) 242 pm, 633 kJ/mol
(B) 242 pm, 419 kJ/mol
(C) 120 pm, 633 kJ/mol
(D) 120 pm, 419 kJ/mol

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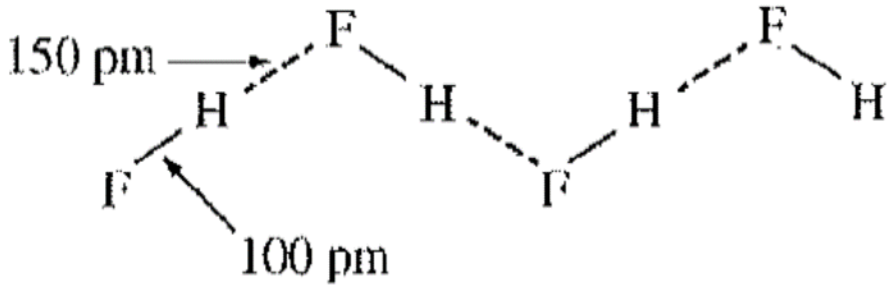
(B) 242 pm, 419 kJ/mol
(C) 120 pm, 633 kJ/mol
(D) 120 pm, 419 kJ/mol

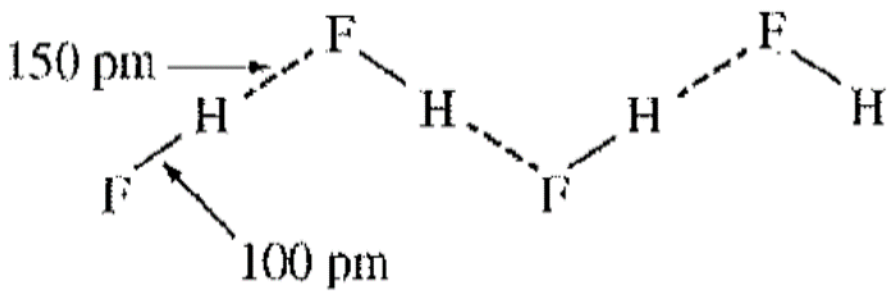
- First, Find potassium on the periodic table. Base on its location K should be slightly bigger. (less protons)
  - Eliminate C and D
- Due to coulombs law an electron that is farther away is easier to remove.
- B is correct.



59. The figure above shows that in solid hydrogen fluoride there are two different distances between H atoms and F atoms. Which of the following best accounts for the two different distances?

(A) Accommodation of the necessary bond angles in the formation of the solid
(B) Difference in strength between covalent bonds and intermolecular attractions
(C) Different isotopes of fluorine present in the samples
(D) Uneven repulsions among nonbonding electron pairs

- This problem is asking to see if you recognize the presence of a Hydrogen Bond….
- The large dashes are covalent
- The --- are weaker hydrogen bonds.



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