IPFs

Inter Particle Forces

What makes particles sticky to each other?

often less correctly called IMFs
(InterMolecular forces)

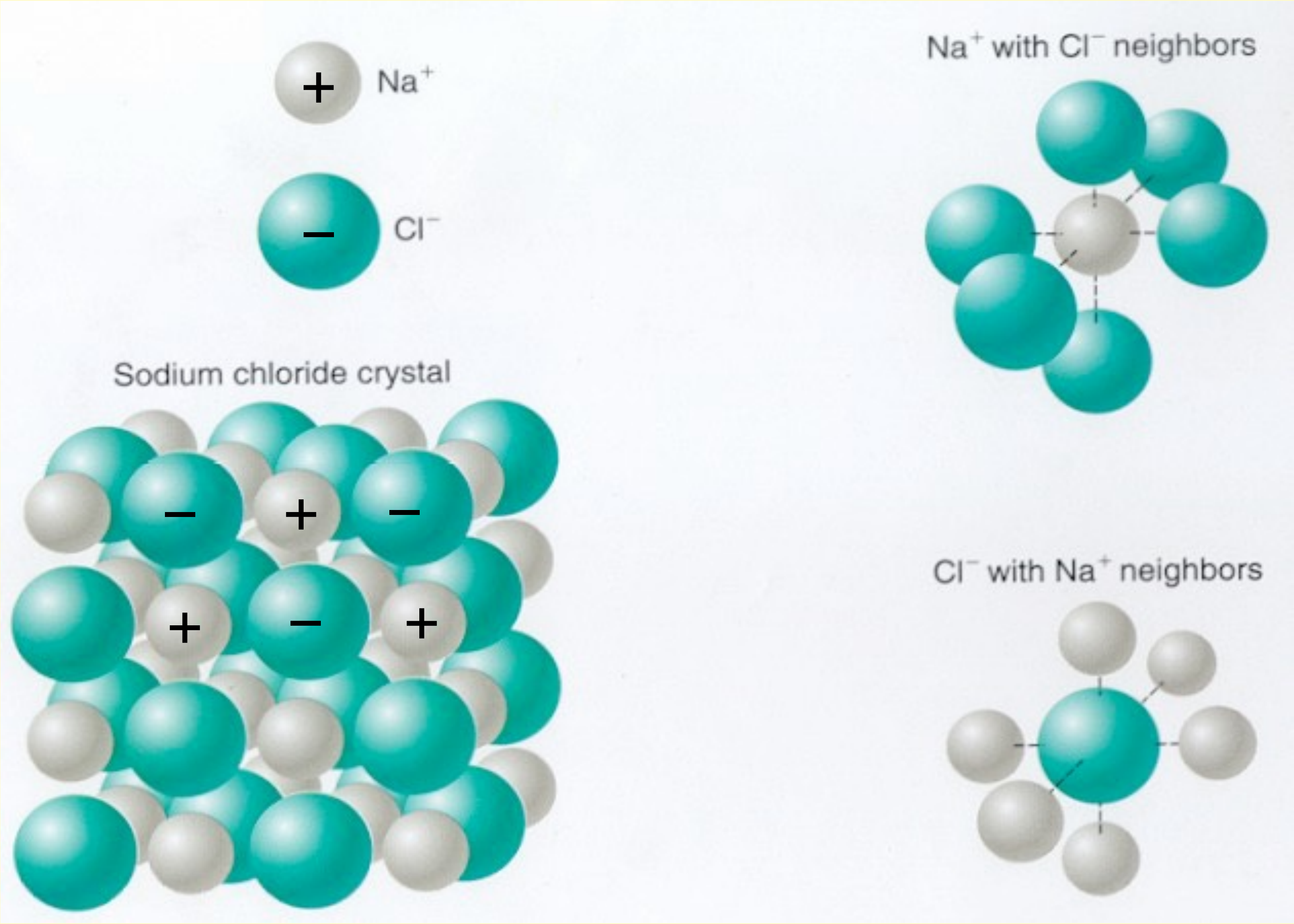
Ionic Solids

Metals + Nonmetals

Factors that affect the +/- force holding **ionic compounds** together.

Ionic Solids

- Ions pack together to maximize their (+ / −) attractions and minimize their (− / − and + / +) repulsions



Lattice Energy

$$\downarrow\uparrow F_{Lattice} = k\frac{Q^{+}_{cation}\uparrow Q^{-}_{anion}}{d^{2}\uparrow}$$

- Lattice energy is enthalpy change (always positive) that accompanies the separation of a solid ionic compound into separate gaseous ions.

✓ Lattice energy gives us insight about the strength of ionic forces.

- Factors that affect lattice energy
  - ✓ The *magnitude of the ionic charge* *(directly proportional)*
    - ◉ 3+ / 3− stronger than 1+/1−, thus 3+/3− has higher lattice energy
  - ✓ The *ionic radius*, *(inversely proportional)*
    - ◉ Smaller ions get closer to each other and the +/− pull experienced is stronger thus higher lattice energy

Lattice Energy

$$\downarrow F_{Lattice} = k\frac{Q^{+}_{cation}Q^{-}_{anion}}{d^2 \uparrow}$$

$$\uparrow F_{Lattice} = k\frac{Q^{+}_{cation}\uparrow Q^{-}_{anion}\uparrow}{d^2}$$

Compound	Lattice Energy (kJ/mol)	Compound	Lattice Energy (kJ/mol)
LiF	1030	$MgCl_2$	2326
LiCl	834	$SrCl_2$	2127
LiI	730		
NaF	910	MgO	3795
NaCl	788	CaO	3414
NaBr	732	SrO	3217
NaI	682		
KF	808	ScN	7547
KCl	701	ScF_3	5096
KBr	671		
CsCl	657		
CsI	600		

all +1 / −1 (LiF, LiCl, LiI)

similar sized ions (NaF ↔ MgO)

Network Covalent Solids

Molecular solids with unusually high metling points because the solid is a large web of strong covalent bonds.

Network Covalent Solids

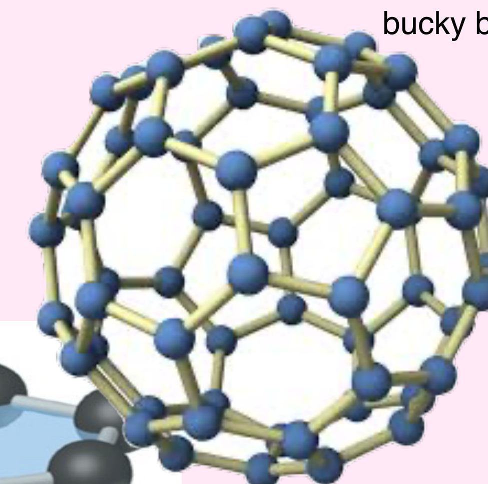
- Carbon, C
  - » Diamonds
  - » Graphite
- Silicon dioxide, SiO_2
  - » Quartz
  - » Glass
- Silicon Carbide
  - » SiC
- Silicon
  - » Si

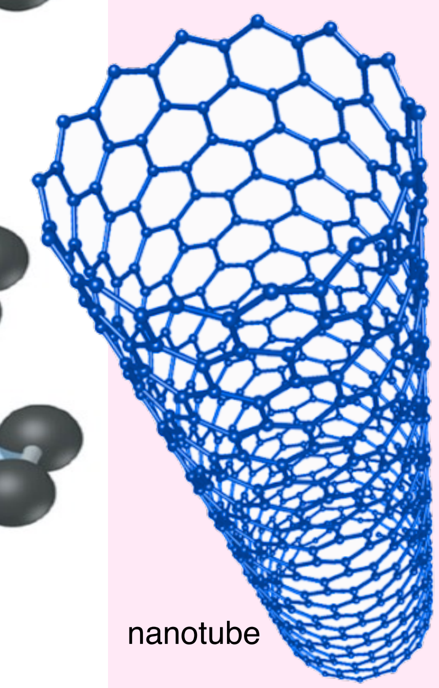
MEMORIZE this LIST
NO Excuses

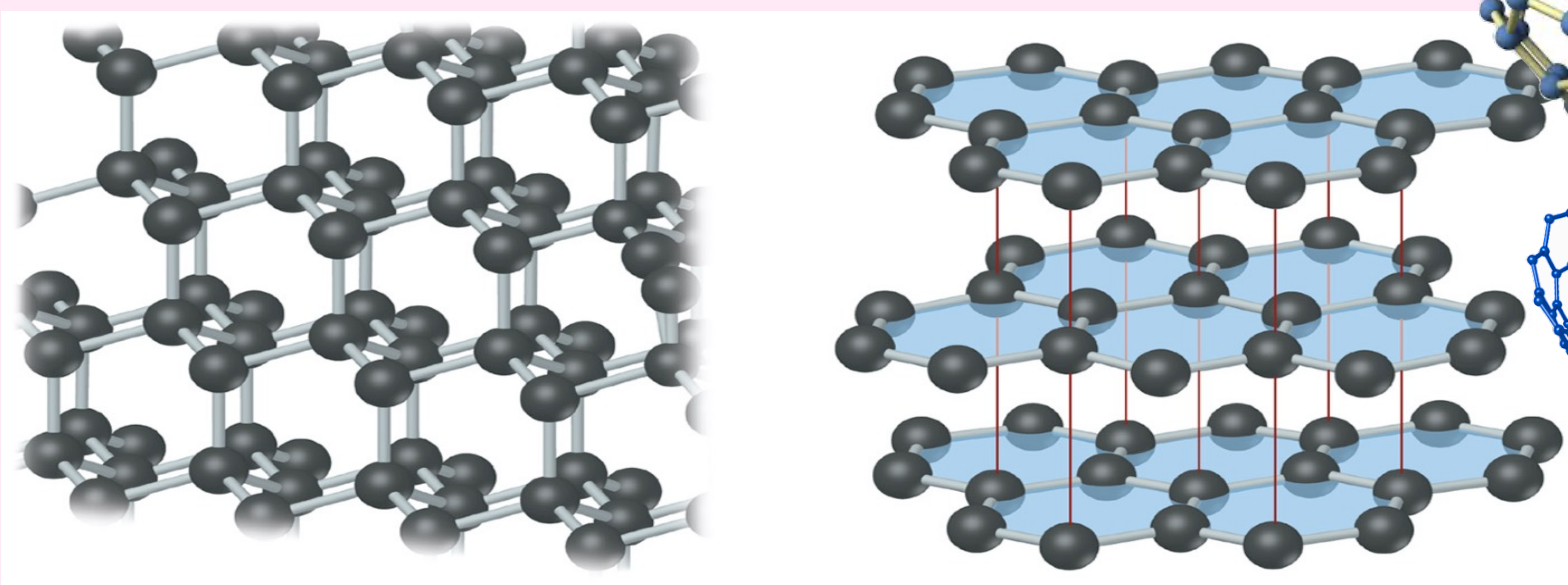
Network Covalent Solids

- Diamonds
  » Atoms are covalently bonded 4 times.
  » Very strong and hard.
  » High MP = 4400ºC

- Graphite
  » Atoms are covalently bonded 3 times within the layer.
  » Layers are loosely bonded by overlapping, unhybridized p orbitals.
  » Slides off easily for pencils & lubricant.
  » Delocalized electrons
  » Conducts electricity
  » High MP = 4492C

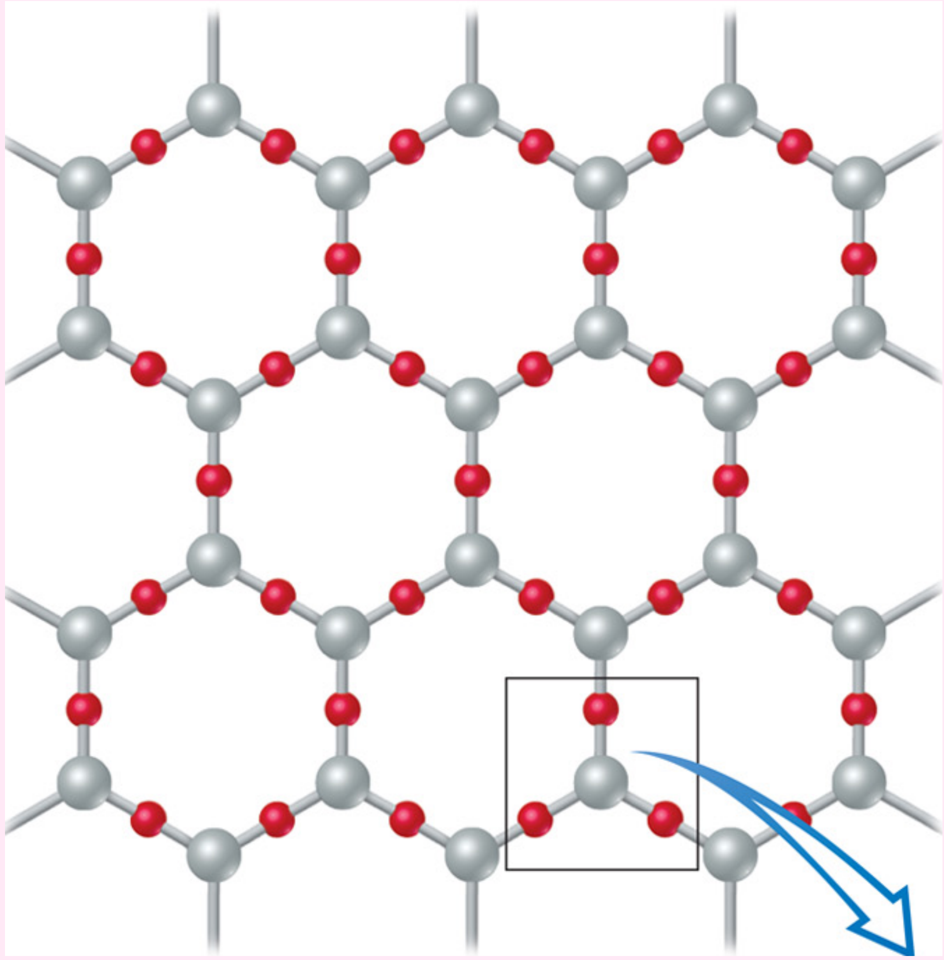




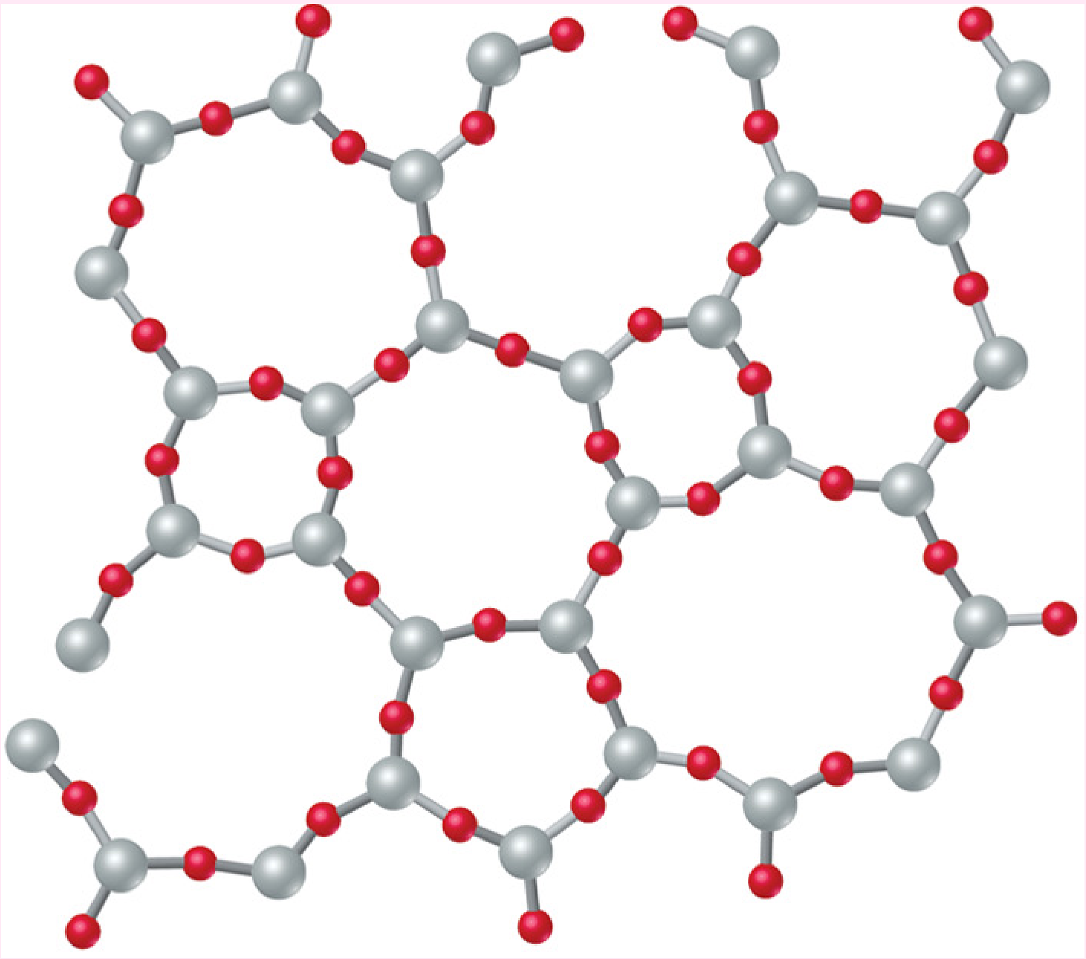

(a) Diamond (b) Graphite

SiO_2 Network Covalent Solid

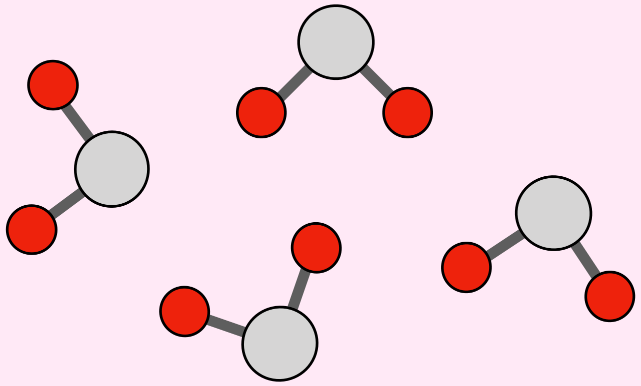
Network Solid
quartz



Amorphous Solid
glass



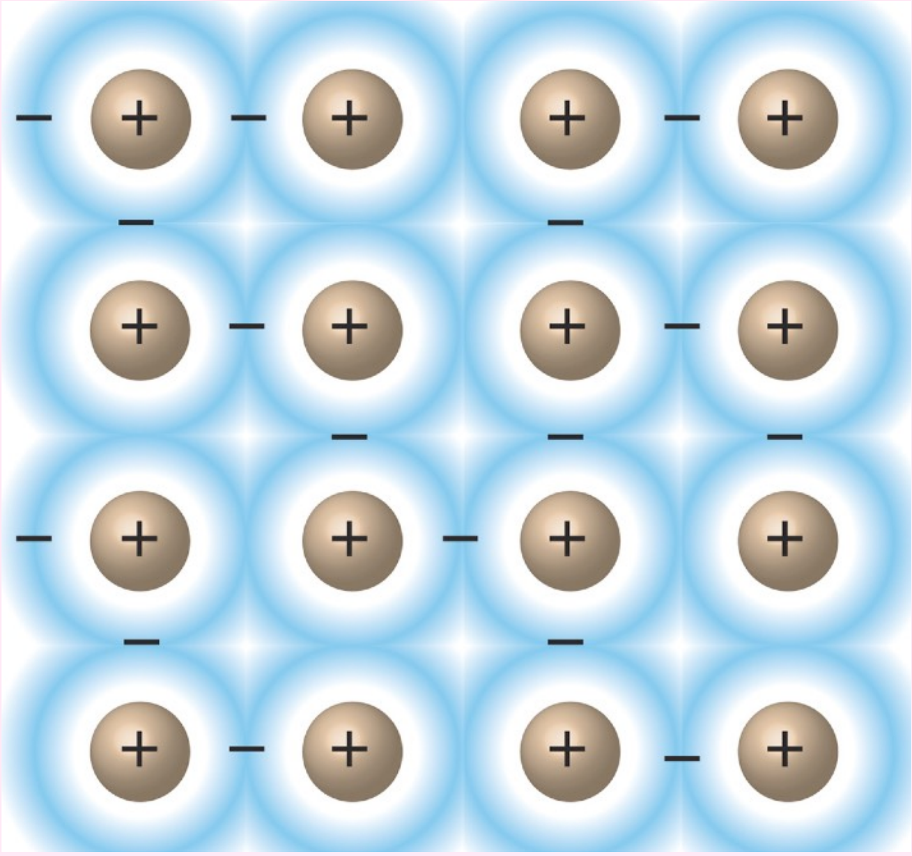
Not just a collection of SiO_2 molecules experiencing IPFs, but actual covalent bonds holding the entire network together



Metals and Alloys

Metallic Solids – A model to explain metallic properties

- Metal atoms are aligned in a regular and repeating pattern.
- Outermost electrons can wander freely throughout - essentially “delocalized”



- Electrons move easily in response to electrical field making metals good conductors of electricity.
- Free electrons can transmit kinetic energy easily making metals good conductors of heat.
- low ionization energies
- easily oxidized
- malleable and ductile
- shiny luster

Alloys

Mixtures of Metals

Alloy

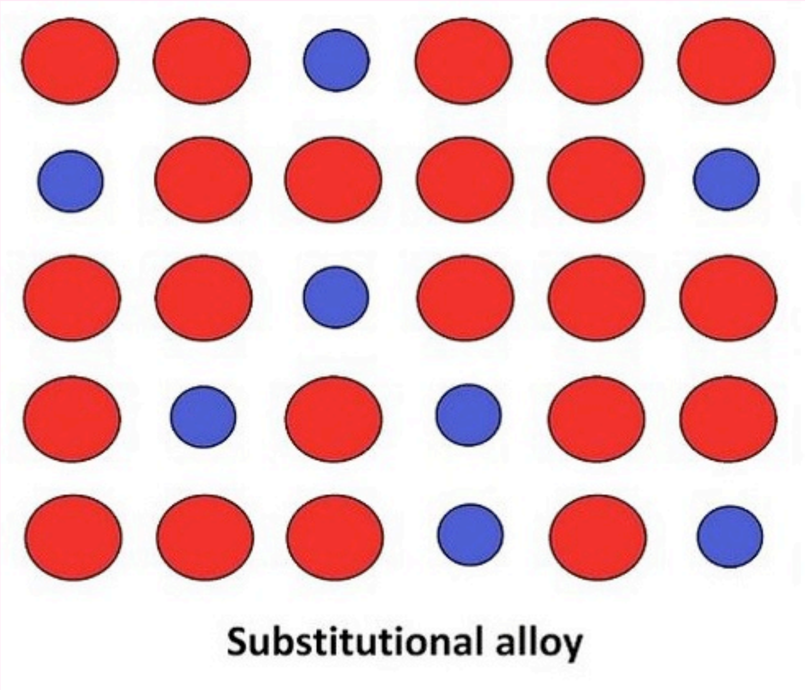
- A blend of elements
  (at least one metal)

- to improve desired properties.
  - ✓ harder, nicer color, different melting temp,
  - ✓ Prepared by melting, mixing the constituents, and then cooling the mixture. (Mixture, not compound)

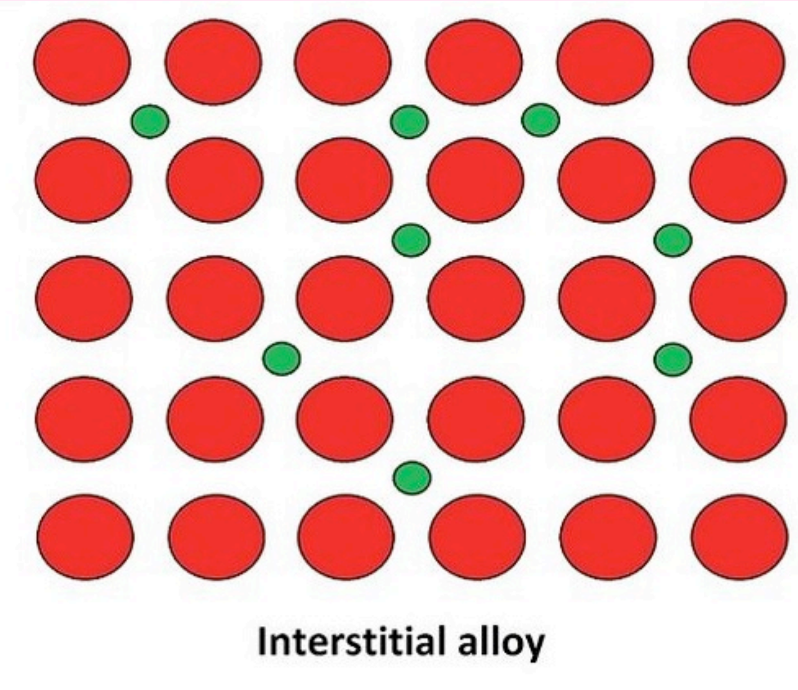
- Two types
  - ✓ Substitutional
  - ✓ Interstitial

Two Alloy Types

- Substitutional
  - ✓ constituents have similar atomic radii allowing one element to substitute into the lattice of another element.
  - ✓ Often changes color, conductivity,



- Interstitial
  - ✓ constituents have different atomic radii allowing the smaller element to fit into the spaces of the lattice of the other element.
  - ✓ Generally make alloys harder



InterParticle Forces
IPFs

often less correctly called IMFs
(InterMolecular Forces)

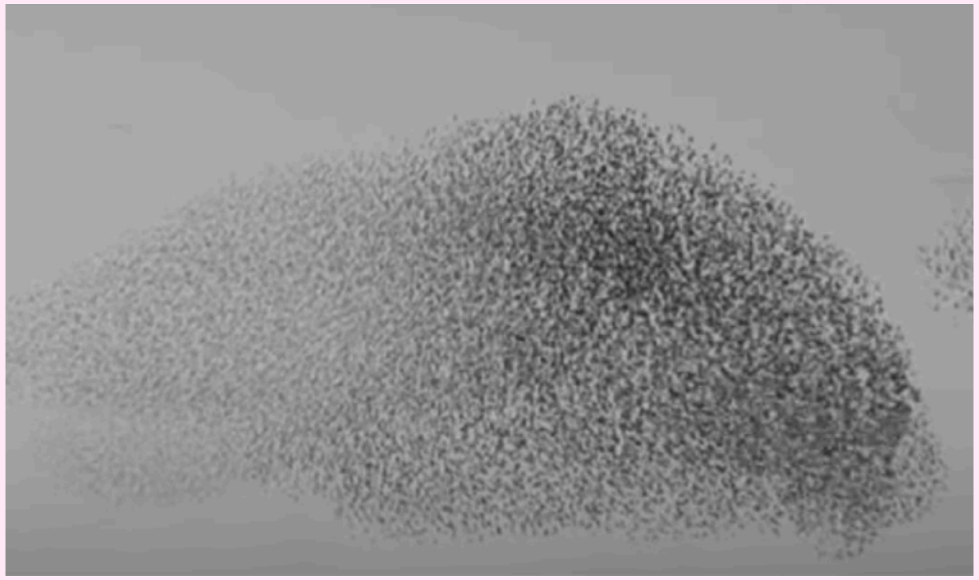
Interparticle Forces (IPFs)

Forces that exist *between* molecules.

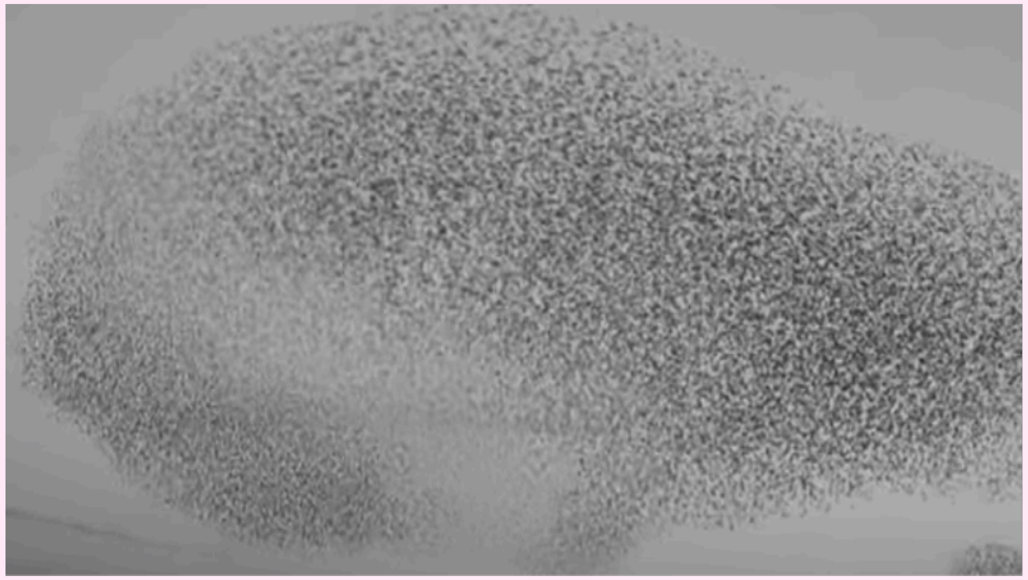
1. **London Dispersion Forces (aka LDFs)**
   ✓Between all molecules
   (but this is the ***only*** force between nonpolar molecules.)
2. **Dipole-dipole forces**
   ✓Between all polar molecules
3. **Hydrogen "bonding"**
   ✓Between "special" polar molecules
4. **Ion-dipole forces**
   ✓Between ions and polar molecules
   ✓Particularly between ions and water in a solution

Polarizability of Electron Clouds

- While we think of atoms as hard (they are) and the outer edge of atoms is defined by the electron cloud, the reality is that the electron cloud can be quite “floppy.”

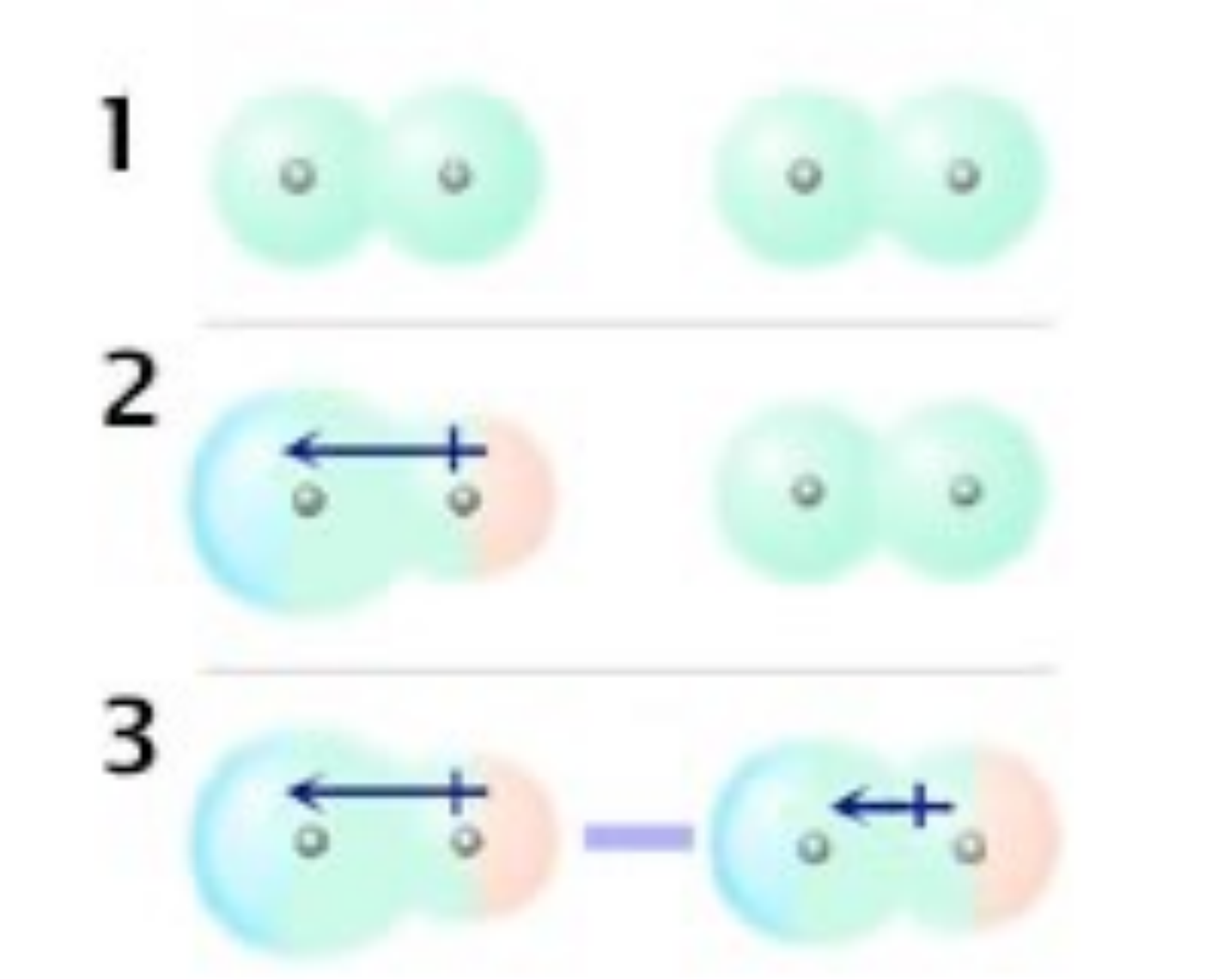


Starling Murmurations



London Dispersion Forces

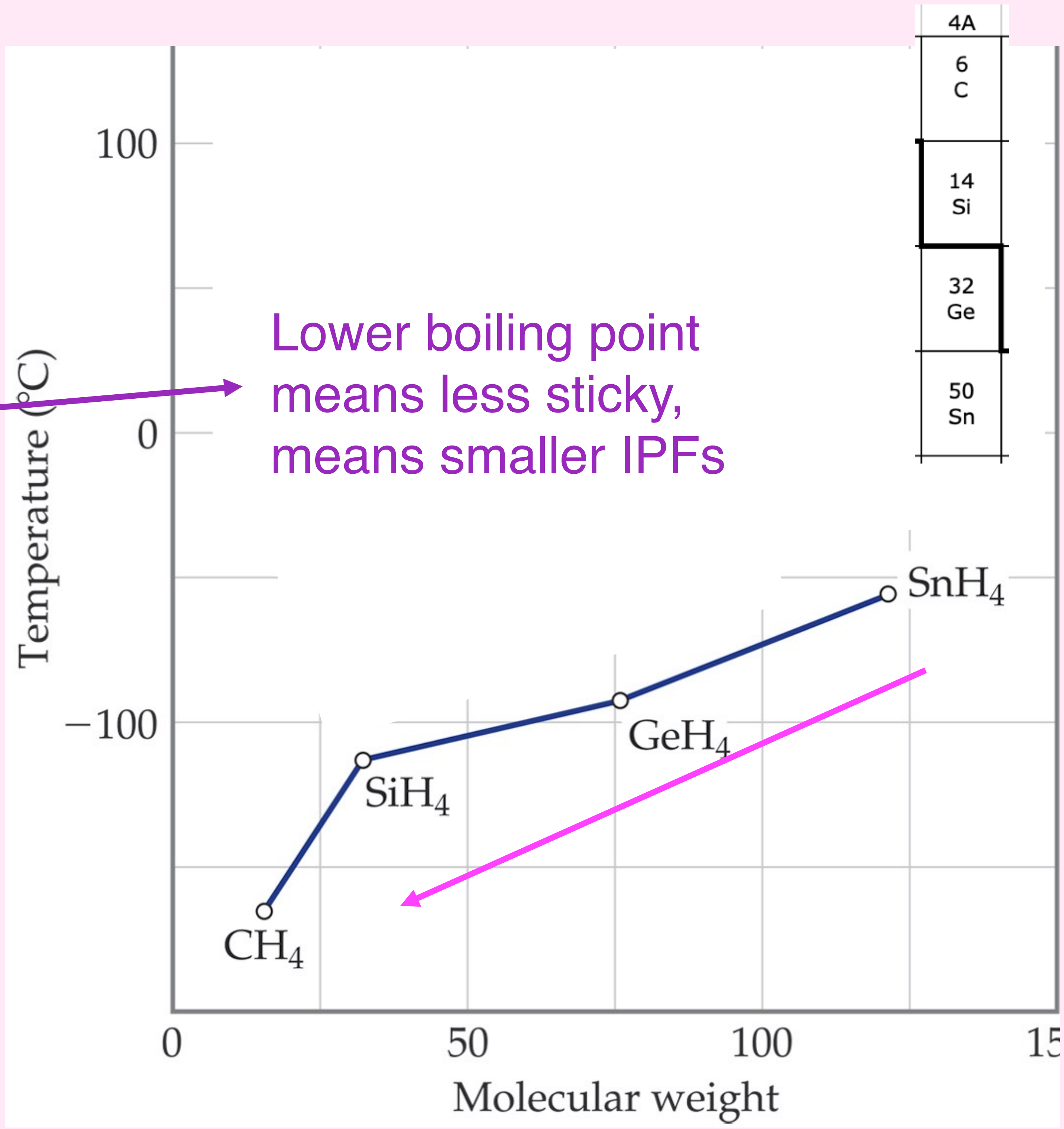
- When the electron cloud "swishes" to one side by chance, a temporary dipole occurs that can *induce* temporary dipoles in nearby molecules.
- ALL molecules exhibit dispersion forces.
  - » But, these are the ONLY forces that occur among nonpolar molecules
- The ease with which an electron cloud can be distorted by another molecule is called its *polarizability*. (aka "swishability", "floppiness")



- Factors that affect LDFs
  - » Larger size, larger electron cloud is more polarizable
  - » Longer straighter chain, more surface area for LDFS to attract

Boiling Point Trend Group IV Hydrides

- What does this graph tell us about the BP of these similar nonpolar molecules?
- What does a BP tell us about the stickiness of a molecule to itself?
- To what should we attribute this trend in BP?
  - » BP decreases as size of molecule decreases.
  - » The electron cloud of a smaller molecule is less polarizable and thus exhibits smaller LDFs and therefore a lower BP.



Periodic Trend of the Noble gas Boiling Points?

Which molecule would you suspect has a
a higher boiling temperature?

1. Ne

2. Kr

What information can we deduce from comparing Boiling Points?

Which molecule would you suspect has a a higher boiling temperature?

1. Ne

2. Kr

- Kr has a larger more polarizable electron cloud, thus has stronger LDF’s and therefore a higher BP

He	−269ºC
Ne	−246ºC
Ar	−185ºC
Kr	−153ºC
Xe	-108ºC

Look at the physical state of the halogens?

- Solid, liquid, gas?
- Turn to your mate and explain why.
- Which halogen has the highest boiling temp?

1. F_2
2. Cl_2
3. Br_2
4. I_2

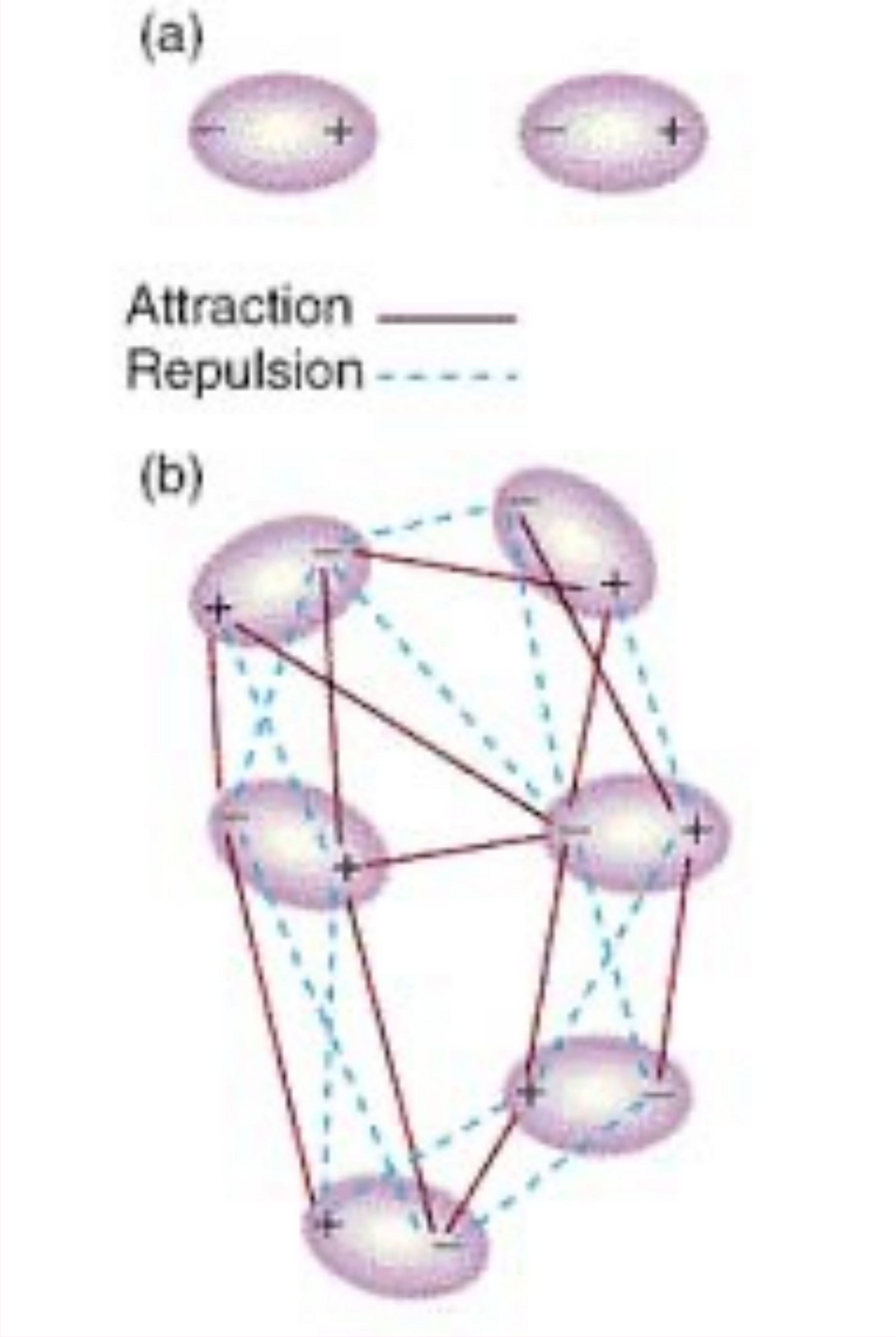
What makes I_2 a solid at room temperature, yet Cl_2 a gas?

- Boiling temperatures to give us insight to strength of IMF's
- BP increases as the size of the molecule increases.
- The larger electron cloud of I_2 is more polarizable ("squishable or floppier") leading to stronger LDFs and thus a higher BP.

F_2	-187.9ºC
Cl_2	-34.4ºC
Br_2	59ºC
I_2	184.6ºC

Dipole-Dipole Forces

- Positive and negative attractive (and repulsive) forces that occur between **polar** molecules.
- Polar molecules exhibit coulombic "sticky" forces for one another.



Dipole-Dipole Forces

- Which boils at a lower temperature, and why?

1. SO_2
2. CO_2

Dipole-Dipole Forces

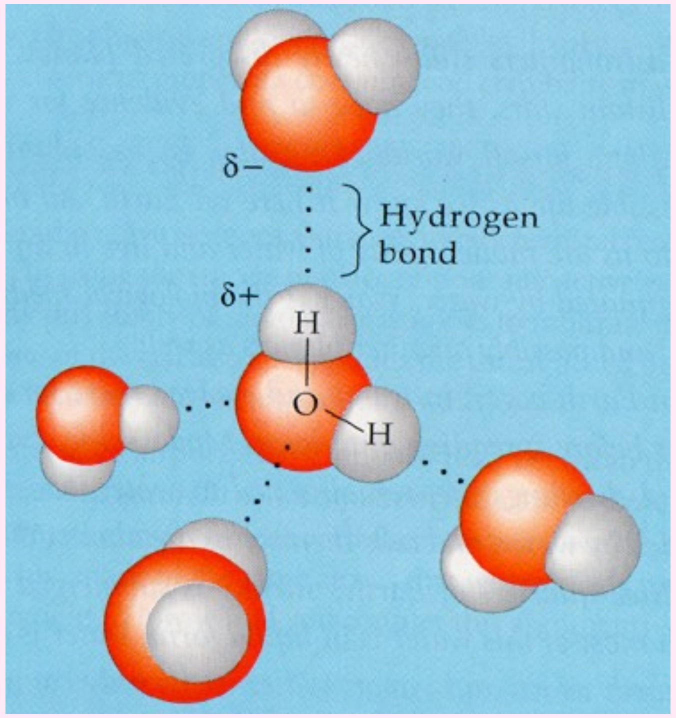
- Which boils at a lower temperature?

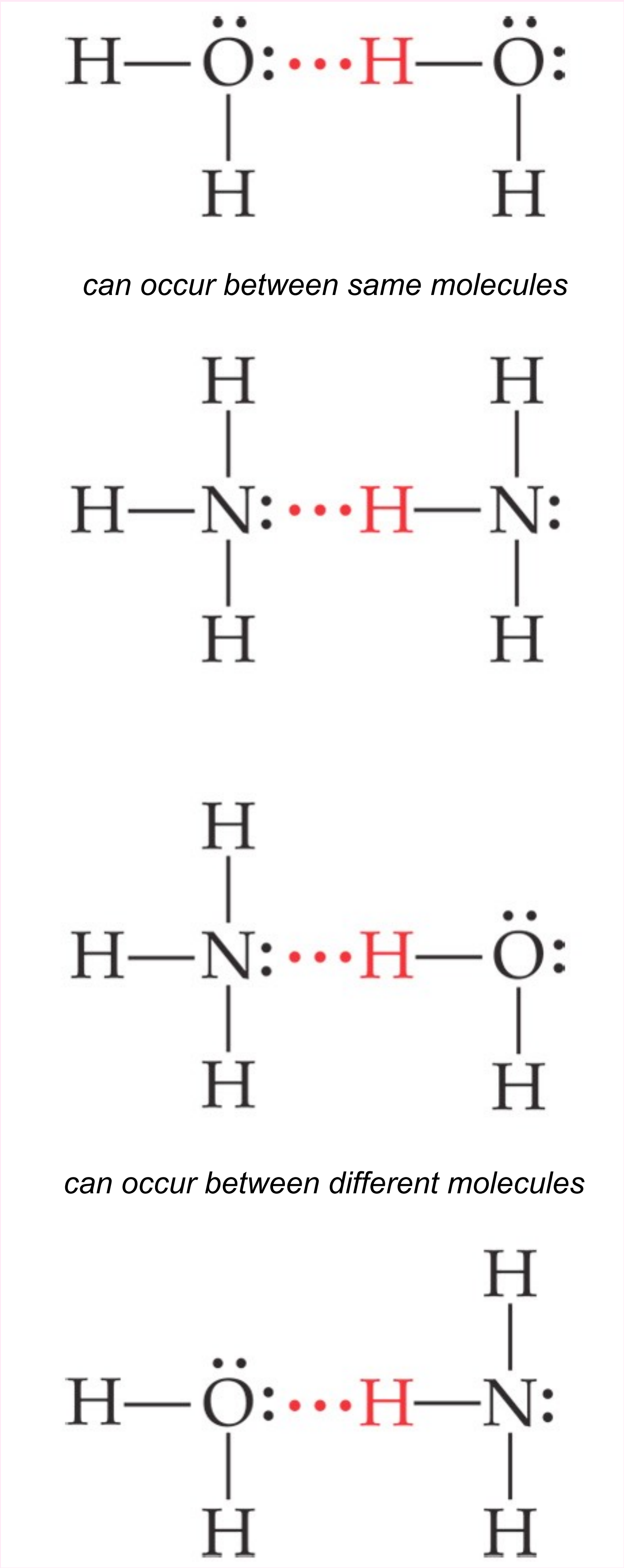
1. SO_2
2. CO_2 nonpolar
   - CO_2 is nonpolar and does not exhibit dipole-dipole interactions
   - CO_2 is a smaller molecule that is less polarizable and thus has lower LDFs

Hydrogen “bonding”
turbo dipole-dipole forces

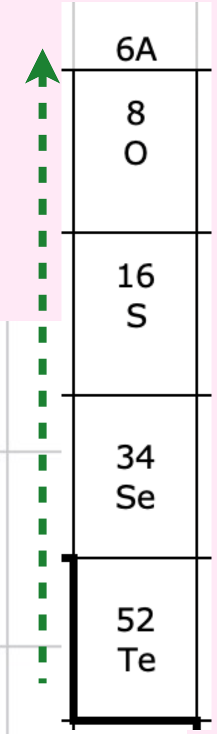
- Interactions between a hydrogen (**attached to O, N, F**) on one molecule and the electronegative atom (O, N or F) on another molecule.

- “A hydrogen bond is something that a molecule does, not something that a molecule has.”
  ✓Fred Vital

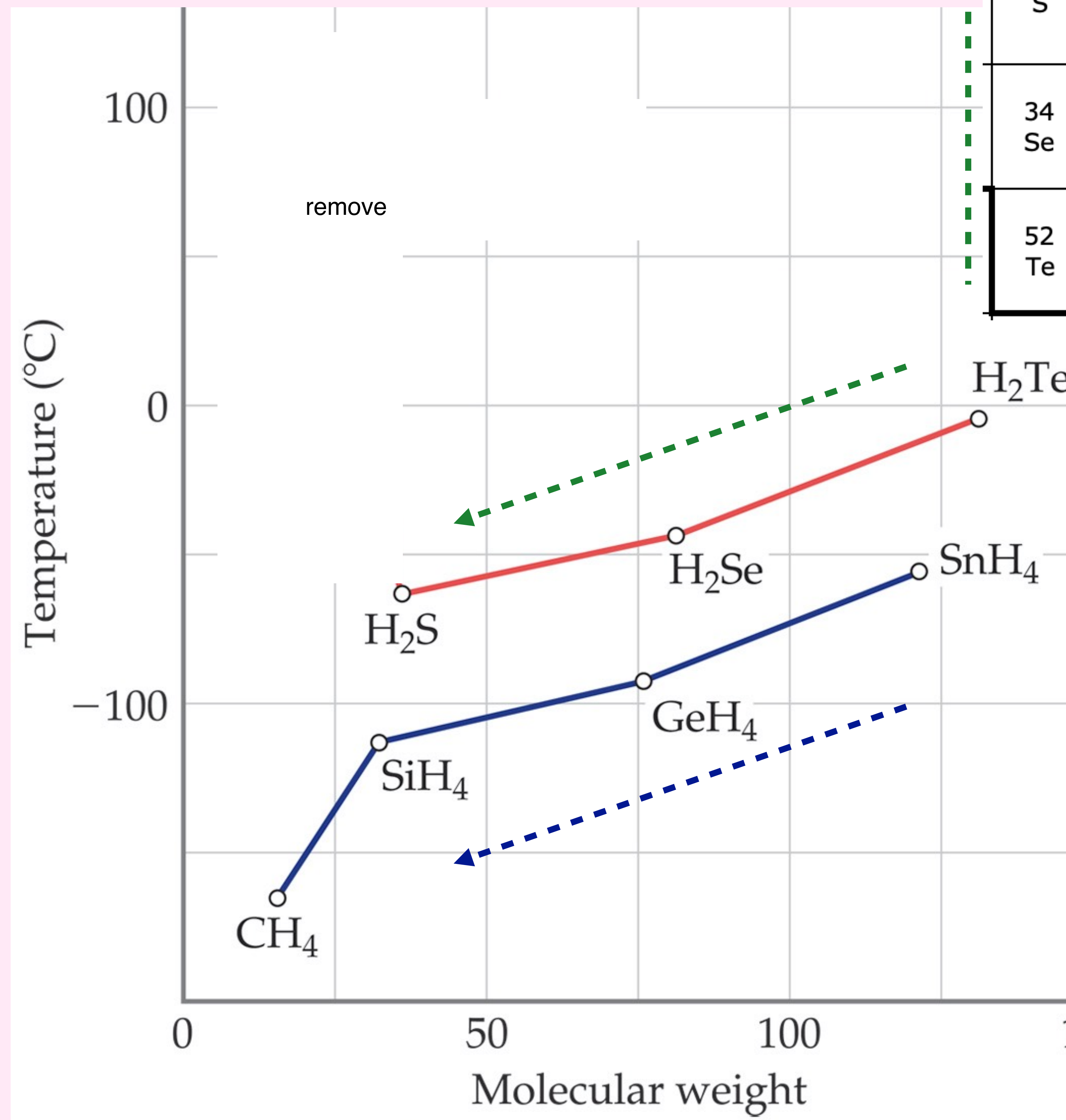




Hydrogen “Bonding” breaks the trend

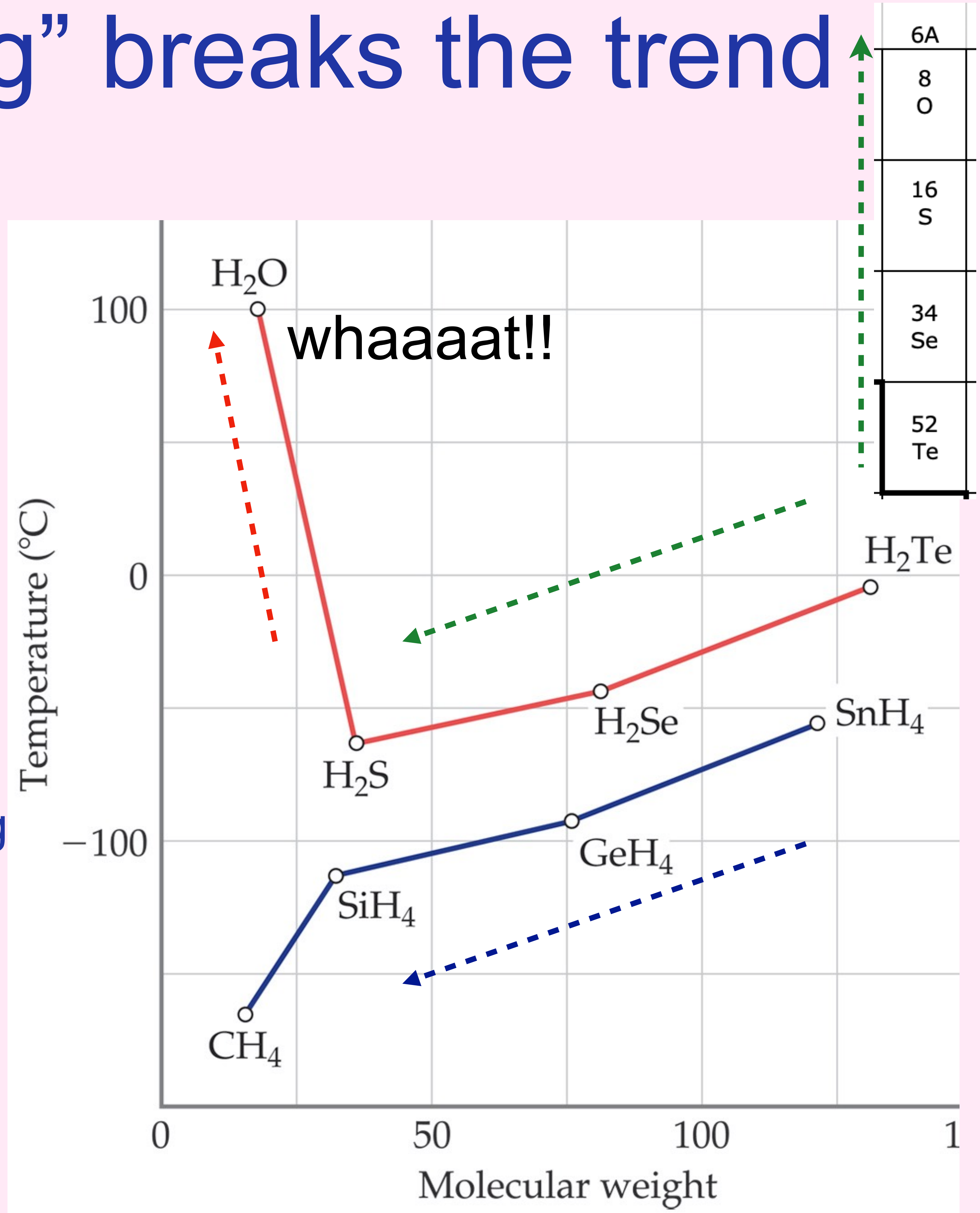


- Similar to the Group IV hydrides, decreasing molecular size, results in decreasing BP due to smaller LDFs
- Group VI hydrides
  - » Polarity increases up the column which should increase the IPFs and raise the BP,
  - » but the size of the molecule decreases up the column which must be playing a bigger role causing weaker IPFs and lowering the BP
  - » But wait….check out water!



Hydrogen "Bonding" breaks the trend

- Similar to the Group IV hydrides, decreasing molecular size, results in decreasing BP due to smaller LDFs
- Group VI hydrides
  - » Polarity increases up the column which should increase the IPFs and raise the BP,
  - » but the size of the molecule decreases up the column which must be playing a bigger role causing weaker IPFs and lowering the BP
  - » But the BP of H_2O BP is much higher due to the very strong IPFs called hydrogen "bonding"



Justifying IPF Strengths

- First and foremost listen to the question, then justify with….
- Is the substance ionic?
  - » Invoke ONLY Coulombs Law.
- Is the substance network covalent?
  - » Invoke only covalent bonding
- Is the substance molecular?
  - » Molecule size, size of electron cloud? *(Do NOT reference molar mass)*
  - » Polar or nonpolar?
  - » Hydrogen bonding?

Clicker Question Practice

https://forms.gle/LUjB9tmcpQ56PL7A8

Google Forms

What type of intermolecular forces exist in dimethyl ether, CH_3OCH_3

Chose all that apply. (or H_3COCH_3)

Draw a Lewis Structure to help.

Q# 1

1. dipole-dipole forces
2. hydrogen bonding
3. London dispersion forces

Take note: the expanded formula above is to help you draw the correct structure.

The above structure is different compared to ethanol, C_2H_5OH

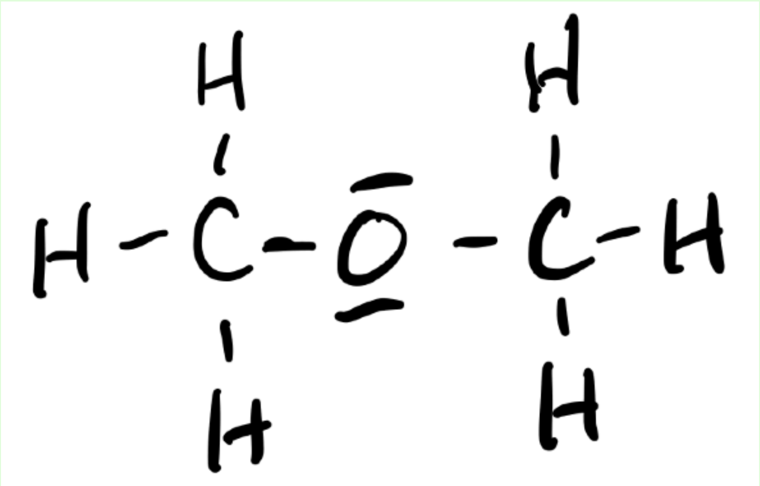
What type of intermolecular forces exist in dimethyl ether, CH_3OCH_3

Chose all that apply.

1. dipole-dipole forces
2. hydrogen bonding

- None of the hydrogens are attached to oxygen, so there cannot be hydrogen bonding.

3. London dispersion forces



What type of intermolecular forces exist in ethanol, C_2H_5OH

Chose all that apply.

Draw a Lewis Structure to help.

Q# 2

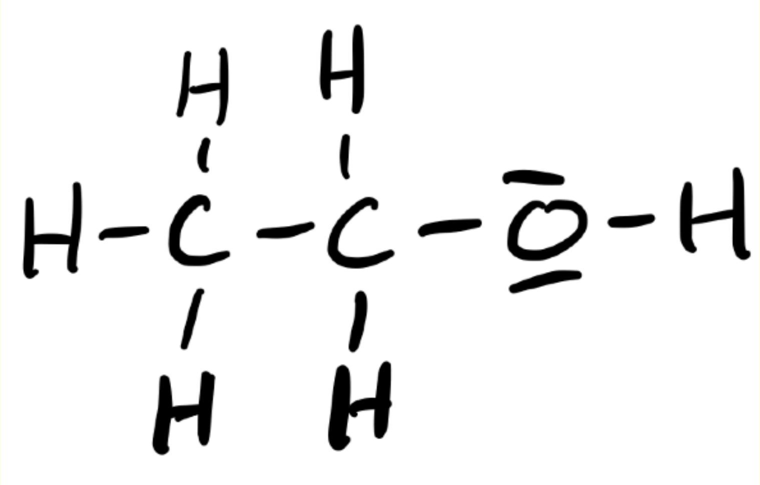
1. dipole-dipole forces
2. hydrogen bonding
3. London dispersion forces

What type of intermolecular forces exist in ethanol, C_2H_5OH

Chose all that apply.

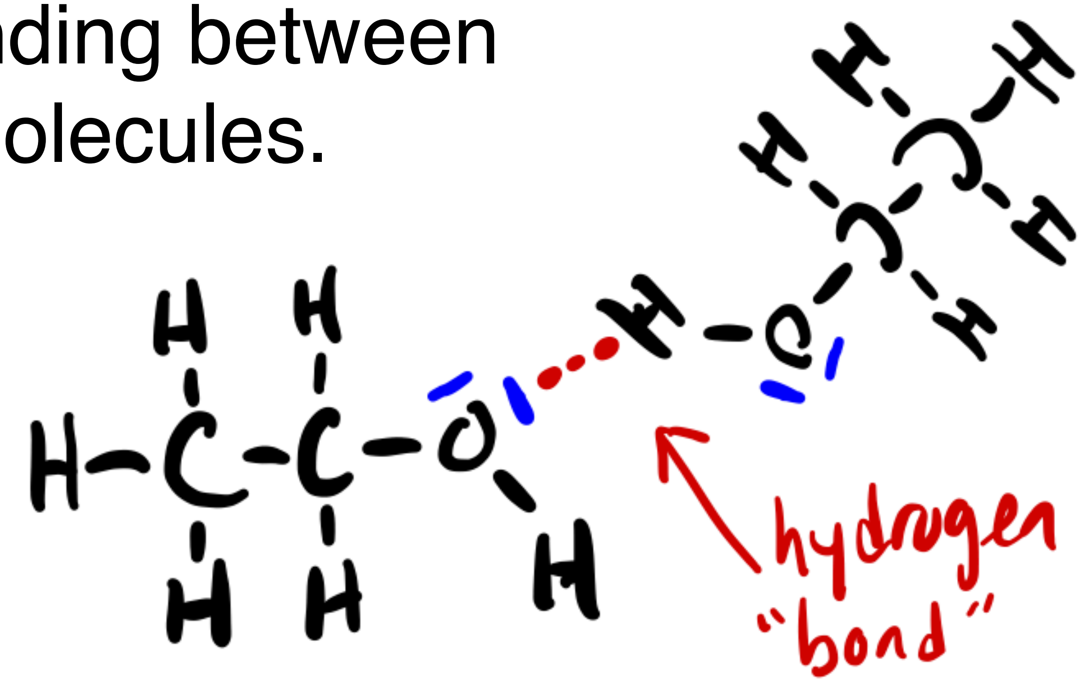
Draw a Lewis Structure to help.

1. dipole-dipole forces
2. hydrogen bonding
3. London dispersion forces



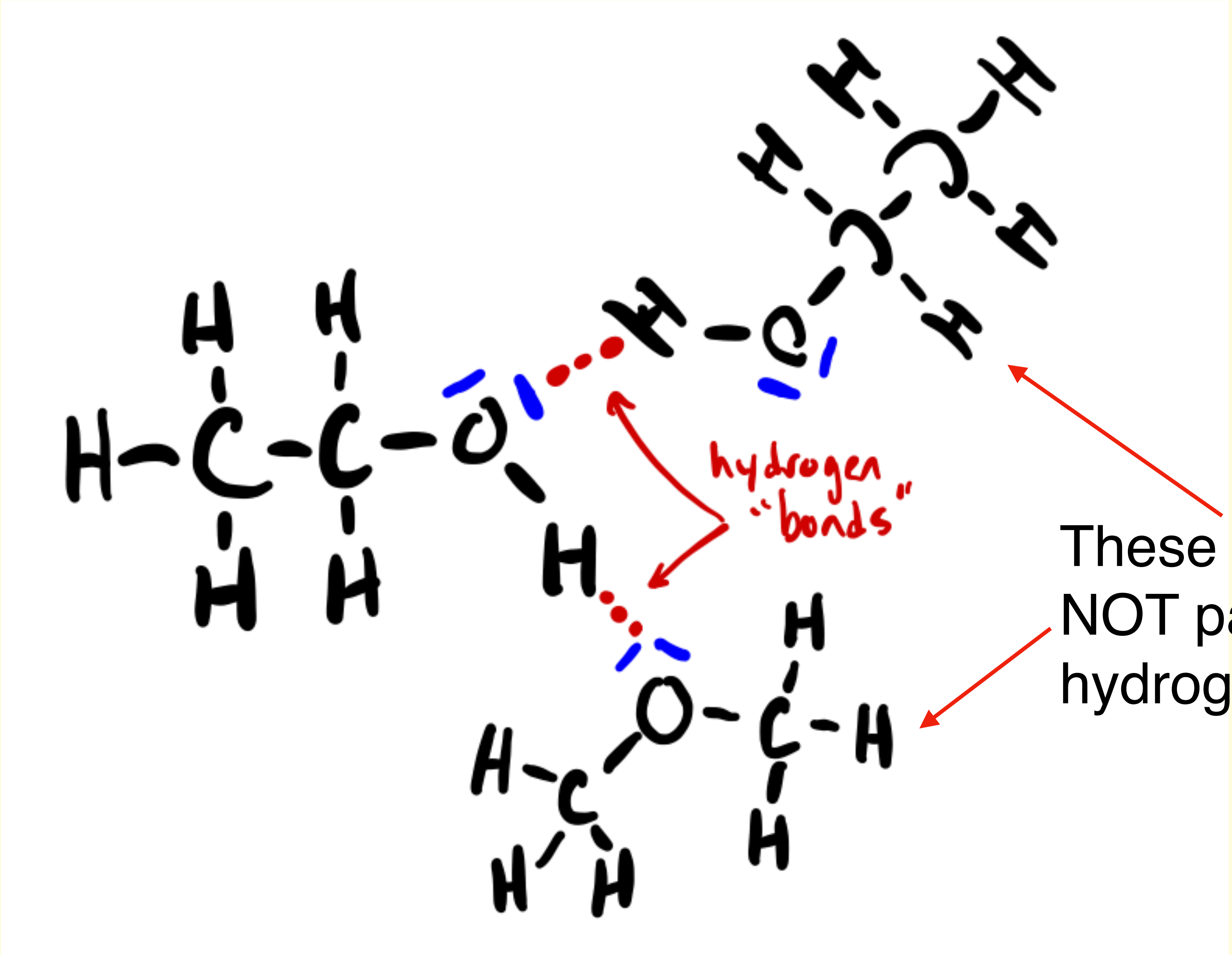
Arrange two sketched ethanol molecules while using a dashed line to demonstrate hydrogen "bonding" between the two molecules.

Hydrogen bonding between two ethanol molecules.



Now add one dimethyl ether, CH_3OCH_3 into your sketch of the two ethanol molecules, C_2H_5OH. Again, use dashed lines to demonstrate hydrogen “bonding.” Involve all three molcules.

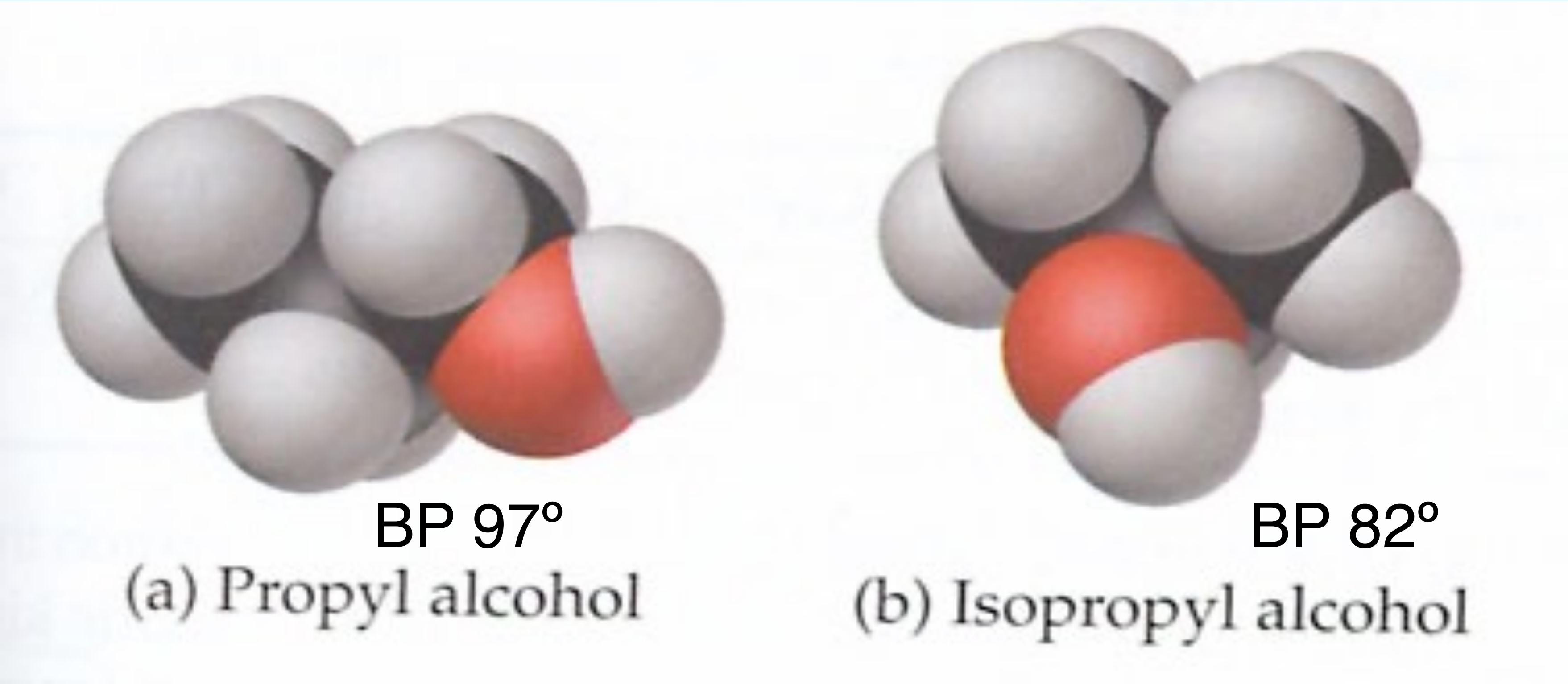
Hydrogen "bonding" between different molecules

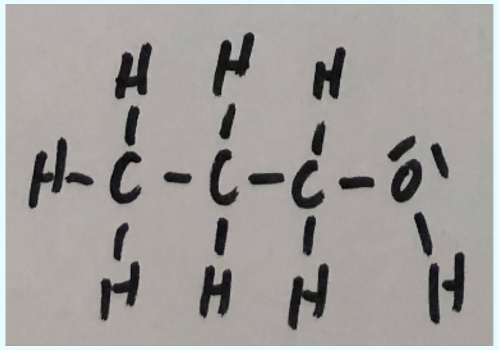


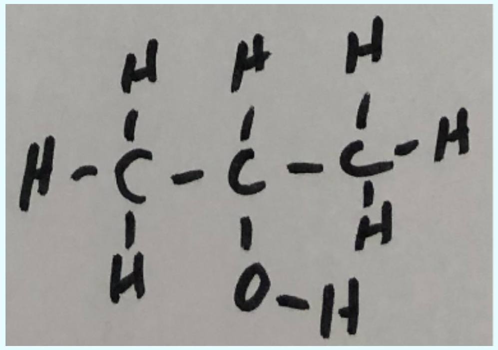
These H's can NOT participate in hydrogen bonding

C_3H_7OH

Which has stronger IPFs?





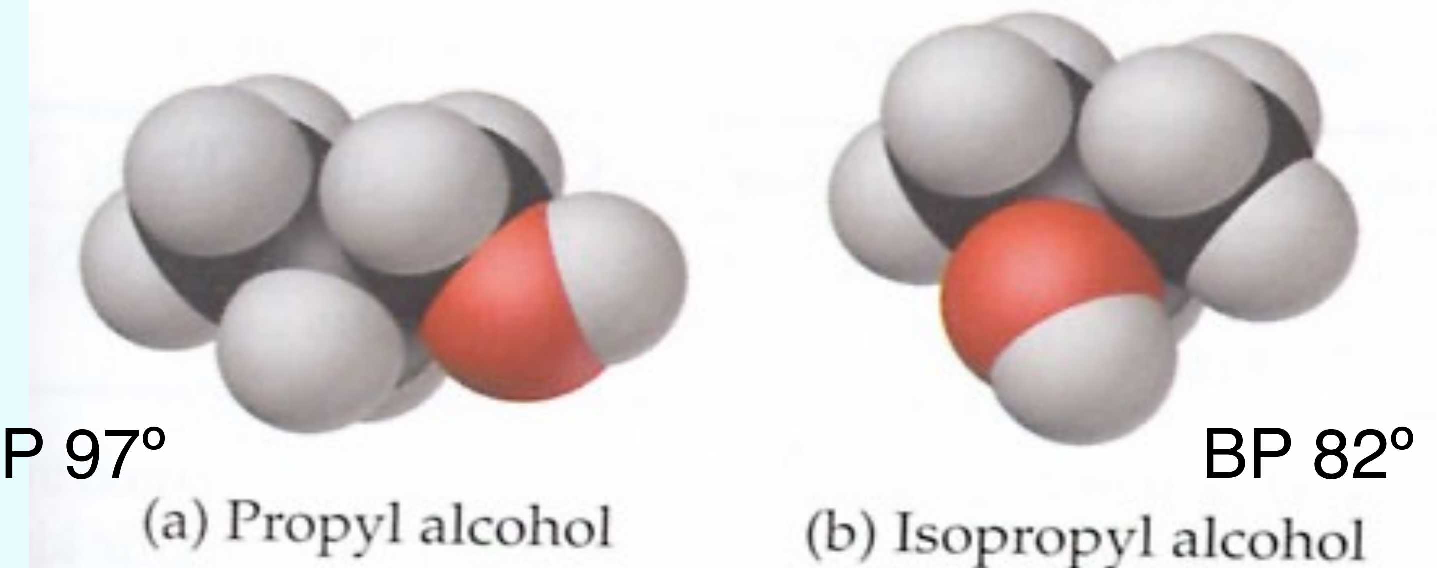


1. Propyl alcohol
2. Isopropyl alcohol

- Justify

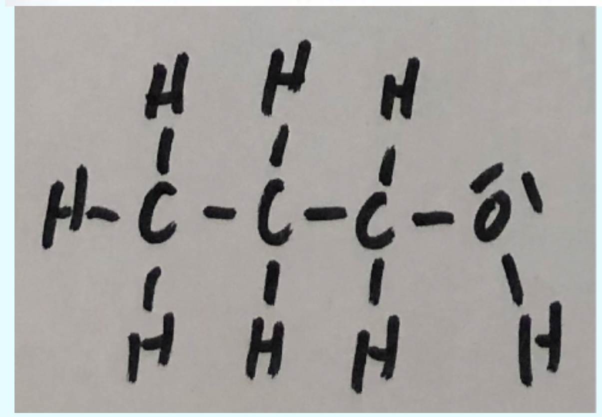
Q# 3

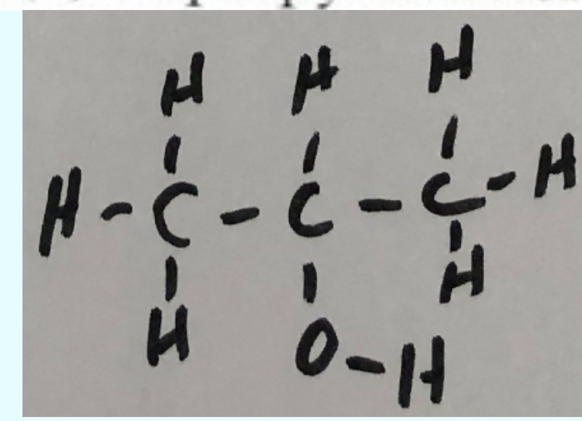
Same chemical formula and size just different shapes.



BP 97º

BP 82º





1. Propyl alcohol
2. Isopropyl alcohol

- **Propyl alcohol has stronger IPF’s**
- Both exhibit hydrogen “bonding” and dispersion forces, so why are their BP’s different? Two Reasons.
  1. The straight chain of propyl alcohol allows for **greater surface area** contact which makes the molecule have more effective dispersion forces than isopropyl alcohol.
  2. The central position of the -OH in isopropyl alcohol is somewhat blocked and is prevented from hydrogen bonding as effectively as in propyl alcohol.

Just how strong?

- Intermolecular forces are much weaker than ionic or covalent bonds. Yet strong enough to have an impact on the physical properties of substances

	per mole of substance
Dipole-dipole	5 - 20 kJ
London Dispersion forces	2 - 100 kJ whoa! what a range
Hydrogen “bonding”	4 - 60 kJ
Covalent (H−O) bond	430 kJ

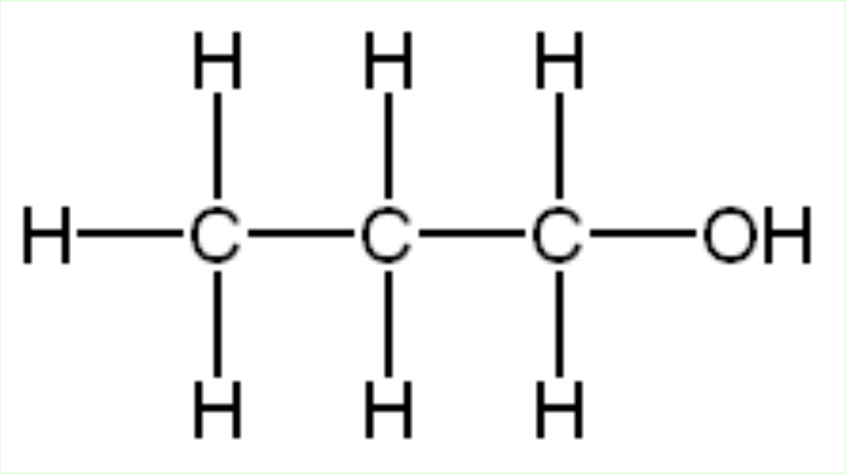
What type of intermolecular forces does propanol experience?

1. dipole-dipole forces
2. hydrogen bonding
3. London dispersion forces

Q# 4

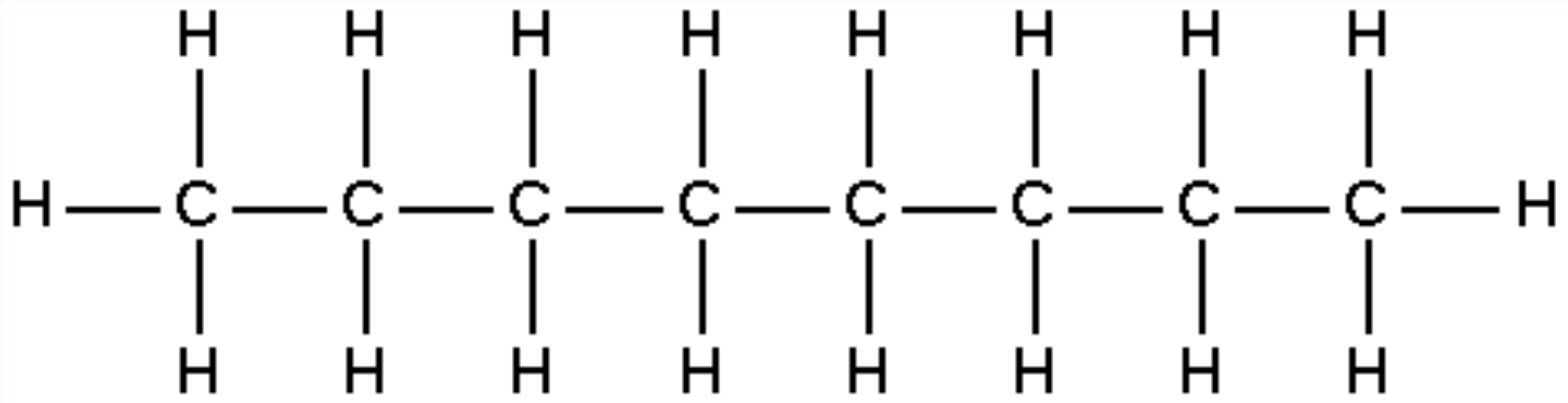
propanol

BP 97ºC



octane

BP 125ºC

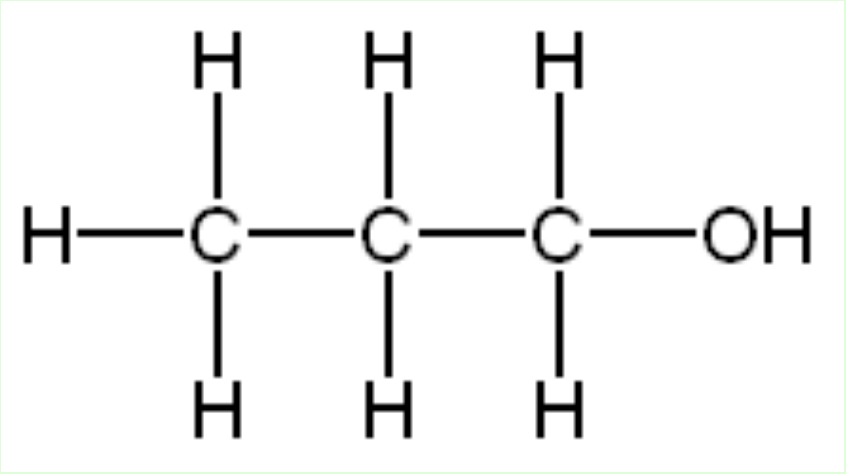


What type of intermolecular forces does propanol experience?

1. dipole-dipole forces
2. hydrogen bonding
3. London dispersion forces

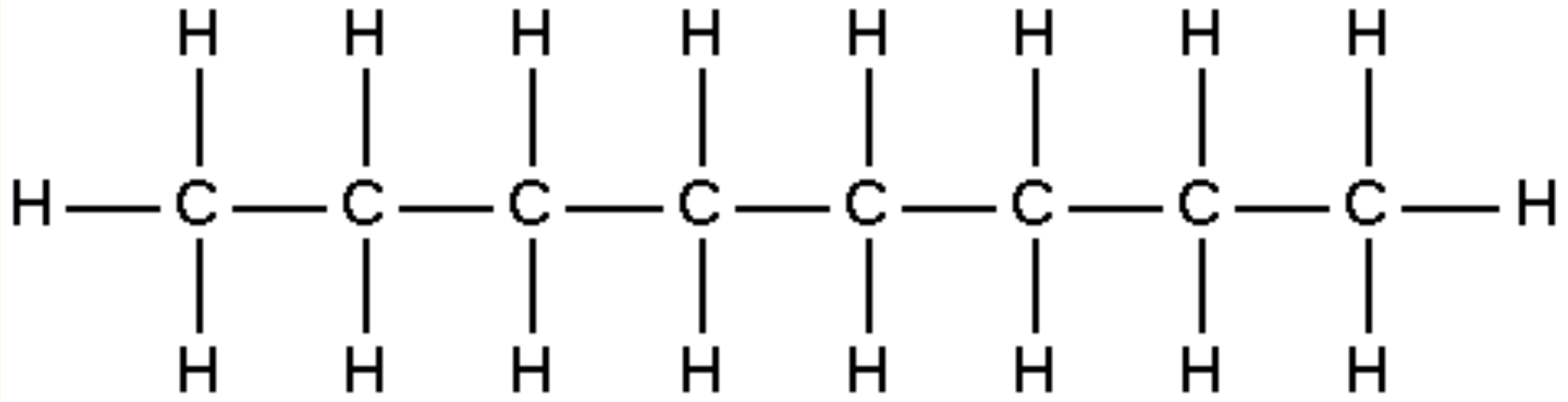
propanol

BP 97ºC



octane

BP 125ºC



What type of intermolecular forces does octane experience?

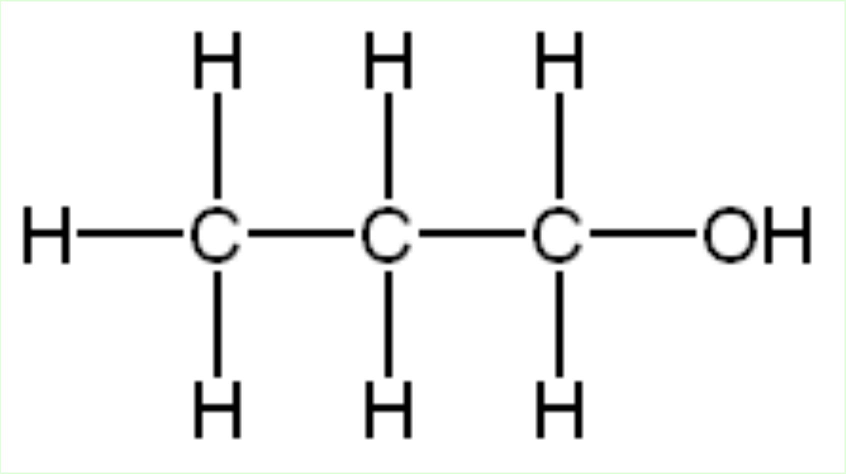
1. dipole-dipole forces
2. hydrogen bonding
3. London dispersion forces

Q# 5

Justify the difference in the boiling temperatures of these two substances.

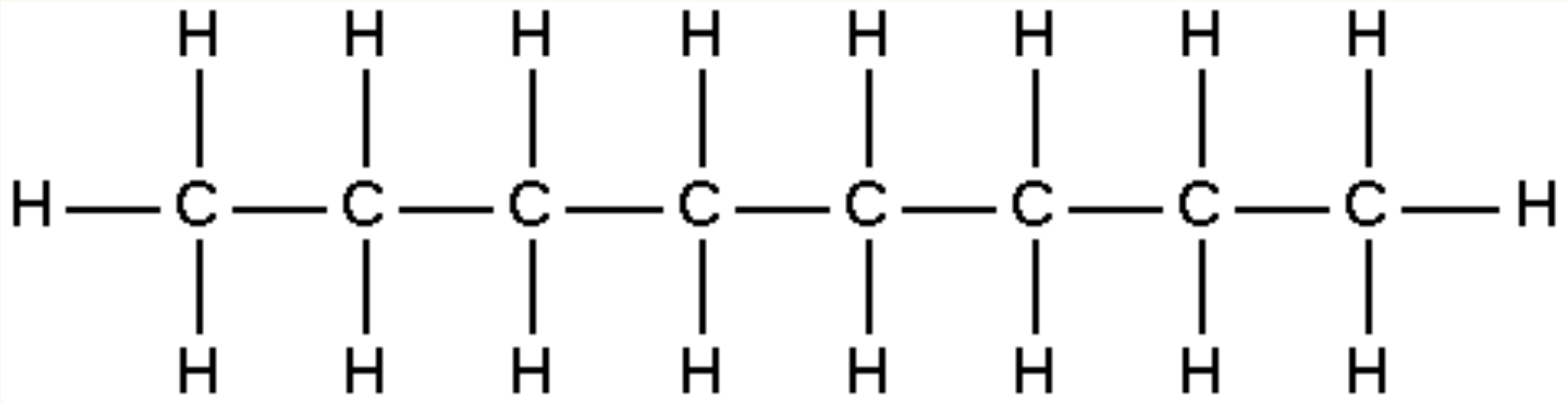
propanol

BP 97ºC



octane

BP 125ºC



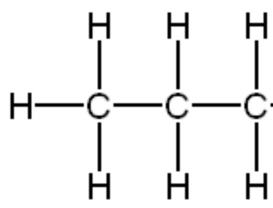
propanol boils at 97ºC, and octane boils at 125ºC.

What type of intermolecular forces occur for each substance?

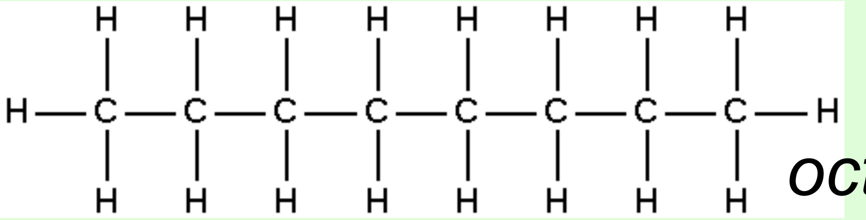
Justify the difference in the substances boiling temperatures.

	propanol	octane
polar?	yes	no
LDFs	yes	yes
dipole-dipole forces	yes	no
Hydrogen "bonding"	yes	no

FYI...LDF means London Dispersion Forces



propanol



octane

- In spite of the fact that H-bonding is quite strong, the **higher boiling temperature** of octane must be a result of **very high LDFs** which are caused by the fact that the octane molecule is so much **larger** (thus more **polarizable** and **particularly long** (thus **more surface area** over which the LDFs can attract).
- Do NOT ever talk about IMFs as BONDs, unless you are specifically referring to hydrogen "bonding." IPFs are NOT BONDs.

What properties are affected by intermolecular forces?

1. Boiling point
2. Vapor pressure
3. Solubility in water
4. Melting point
5. Viscosity – Corn syrup viscosity at various temps demo
6. Surface tension – We looked at the lizard video
7. Energy required to make phase changes: $\Delta H_{vaporization}$ and ΔH_{fusion}
8. Energy require to make temperature changes: Specific heat capacity
9. The density of ice

Q# 6

What properties are affected by intermolecular forces?

1. Boiling point
2. Vapor pressure
3. Solubility in water
4. Melting point
5. Viscosity – Corn syrup viscosity at various temps demo
6. Surface tension – We looked at the lizard video
7. Energy required to make phase changes: $\Delta H_{vaporization}$ and ΔH_{fusion}
8. Energy require to make temperature changes: Specific heat capacity
9. The density of ice

High values for the property is a function of high or low IPFs?

1. High Boiling point = high or low IPFs?
2. High Vapor pressure = high or low IPFs?
3. High Solubility in water? = what type of IPFs?
4. High Melting point = high or low IPFs?
5. High Viscosity = high or low IPFs?
6. High Surface tension = high or low IPFs?
7. High $\Delta H_{vaporization}$ and ΔH_{fusion} = high or low IPFs?
8. High Specific heat capacity? = high or low IPFs?

What properties are affected by intermolecular forces?

1. High Boiling point = high IPFs
2. High Vapor pressure = low IPFs
3. High Solubility in water? = H-bonding or ion-dipole
4. High Melting point = high IPFs
5. High Viscosity = high IPFs
6. High Surface tension = high IPFs
7. High $\Delta H_{vaporization}$ and ΔH_{fusion} = high IPFs
8. High Specific heat capacity? = high IPFs

Which suubstance is likely to be most soluble in water.

Justify your answer.

Q# 7

	substance	structure
1	1-octanol	H H H H H H H H H C C C C C C C C O H H H H H H H H H
2	1-butanol	H H H H H C C C C O H H H H H
3	1-propanol	H H H H C C C O H H H H

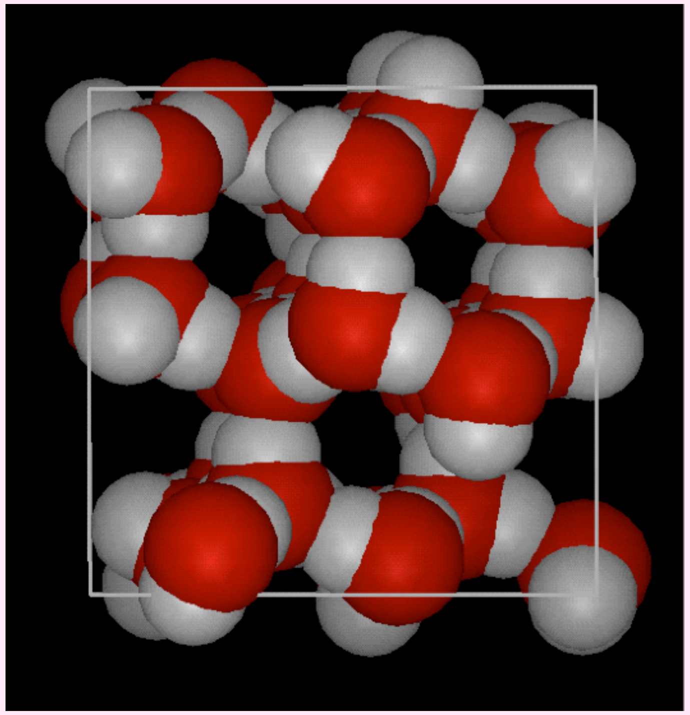
Consider the following solubility data, and explain in terms of molecular structure and intermolecular forces.

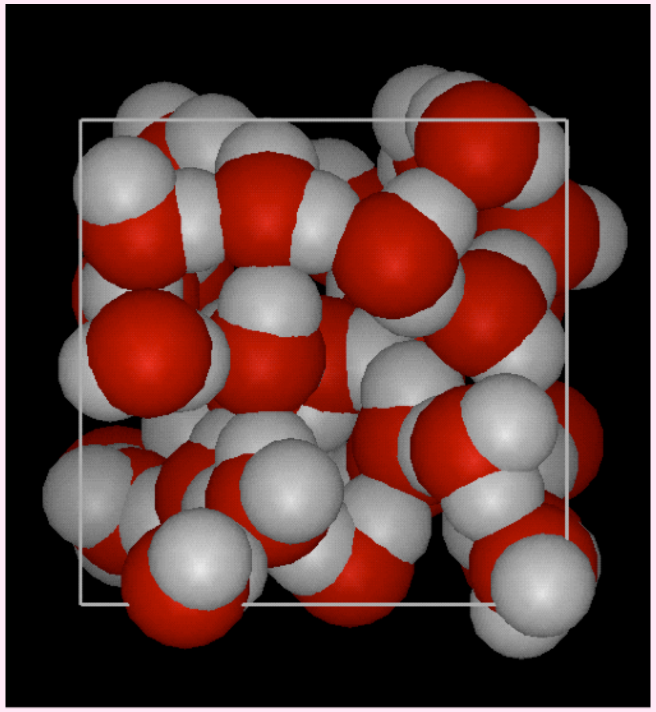
substance	structure	solubility (g/L)
1-octanol	H H H H H H H H H C C C C C C C C O H H H H H H H H H	0.46
1-butanol	H H H H H C C C C O H H H H H	73
1-propanol	H H H H C C C O H H H H	miscible (dissolves in any proportions)

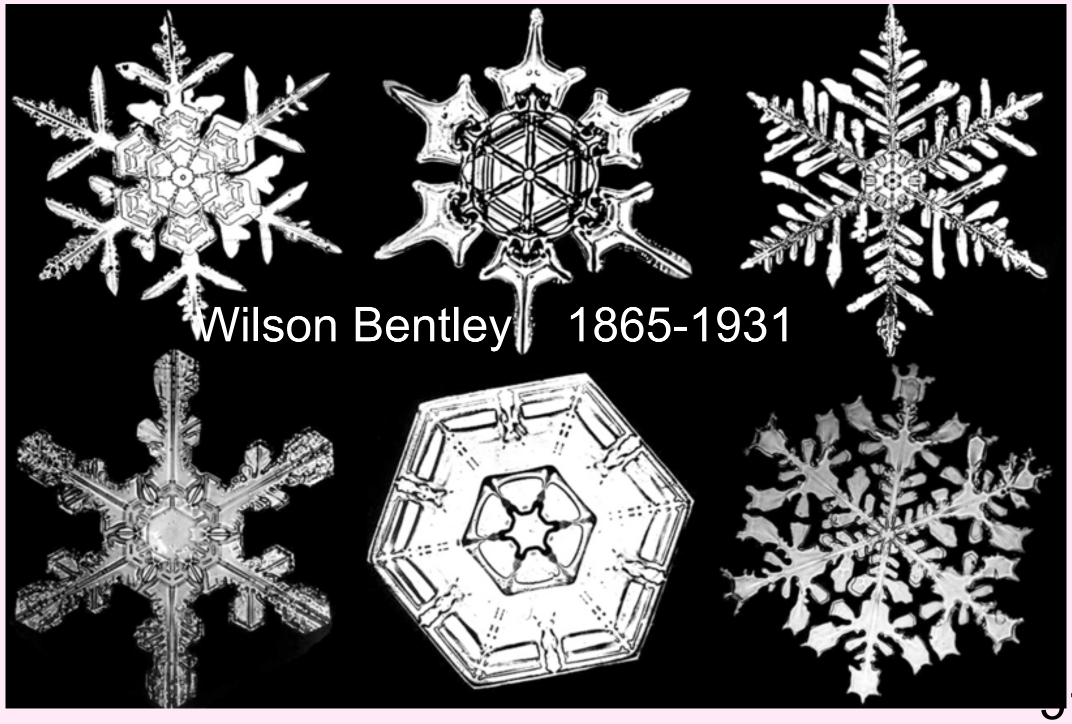
- For a substance to dissolve in water, the substance must be able to engage in **IPFs similar** to those that water is engaging in.
- Thus molecules that can H-“bond” can mix well in water.
- If the nonpolar part of the molecule overshadows the polar/H-“bonding” part, the molecule will be less soluble

Density of Ice

- Break out the water molecule kits to understand the low density of ice
  - »observe the hexagonal crystals below left
  - »observe the six-sided snow flakes below right
- Observe the ethanol in contact with the water. What to you notice?
- Mix in the NaCl crystals. What evidence indicates which ion is blue, which is green. Two reasons.







Under the same conditions of pressure, sulfur dioxide liquefies at a much higher temperature than carbon dioxide. Which of the following would be important points to make to explain this phenomenon. *Select all that apply. (Sketch both Lewis Structures.)*

1. Each sulfur dioxide molecule has a greater molecular size than a carbon dioxide molecule
2. Sulfur dioxide molecules are heavier than carbon dioxide molecules.
3. S-O bonds illustrate resonance; C-O bonds do not.
4. Sulfur dioxide molecules are bent and carbon dioxide molecules are linear.
5. An S-O bond is more polar than a C-O bond.
6. At the same conditions of temperature and pressure, a sulfur dioxide molecule has greater density than a carbon dioxide molecule.
7. SO_2 is polar, CO_2 is not.

Q# 8

Under the same conditions of pressure, sulfur dioxide liquefies at a much higher temperature than carbon dioxide. Which of the following would be important points to make to explain this phenomenon. *Select all that apply. (Sketch both Lewis Structures.)*

1. Each sulfur dioxide molecule has a greater molecular size than a carbon dioxide molecule
2. Sulfur dioxide molecules are heavier than carbon dioxide molecules. ...don't you dare say this! it's the larger electron cloud that matters.
3. S-O bonds illustrate resonance; C-O bonds do not.
4. Sulfur dioxide molecules are bent and carbon dioxide molecules are linear.
5. An S-O bond is more polar than a C-O bond.
6. At the same conditions of temperature and pressure, a sulfur dioxide molecule has greater density than a carbon dioxide molecule.
7. SO_2 is polar CO_2 is not

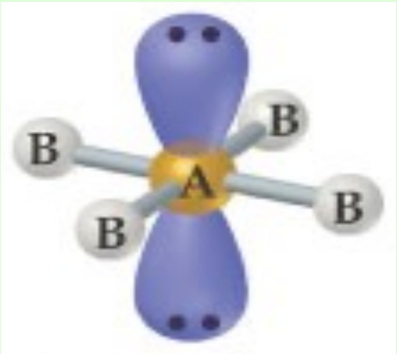
Which one(s) of the following exhibits dipole-dipole as well as London dispersion forces between molecules? *Select all that apply.*

If you haven't already, draw a Lewis Structure for each and consider the polarity of the bonds as well as the molecular geometry.

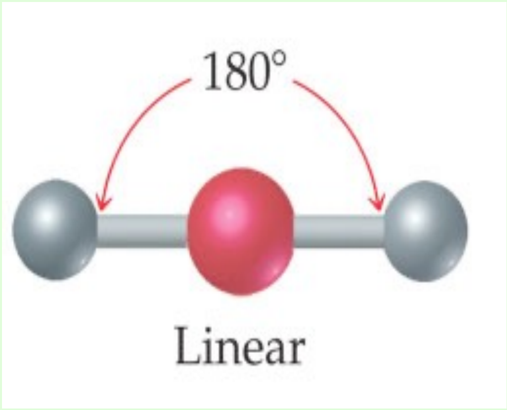
1. XeF_4
2. H_2S
3. CO_2
4. BrF_3
5. PCl_5

Q# 9

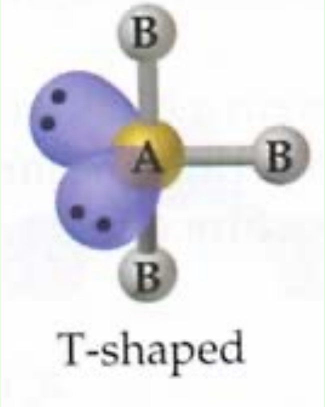
Which of the following exhibit(s) dipole-dipole as well as dispersion forces between molecules?



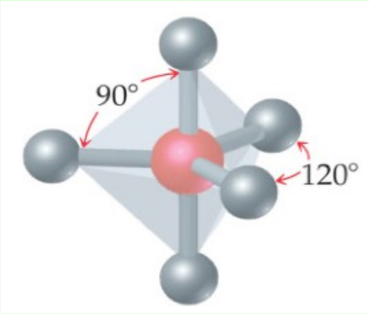
1. XeF_4
   - Square planar, nonpolar, polar bonds are symmetrically opposed



2. CO_2
   - Linear, nonpolar, polar bonds are symmetrically opposed



3. BrF_3
4. PCl_5
   - Trigonal bipyramid, nonpolar, polar bonds are symmetrically opposed



Of the following pure substances, which has the highest melting point?

Q# 10

1. CO_2
2. I_2
3. C_6H_6
4. H_2O
5. $C_{(graphite)}$

Of the following pure substances, which has the highest melting point?

1. CO_2
2. I_2
3. C_6H_6
4. H_2O
5. $C_{(graphite)}$
   Network Covalent Compound
   all true bonds, no IPFs

In which of the following molecules can hydrogen "bonding" occur within a pure sample?

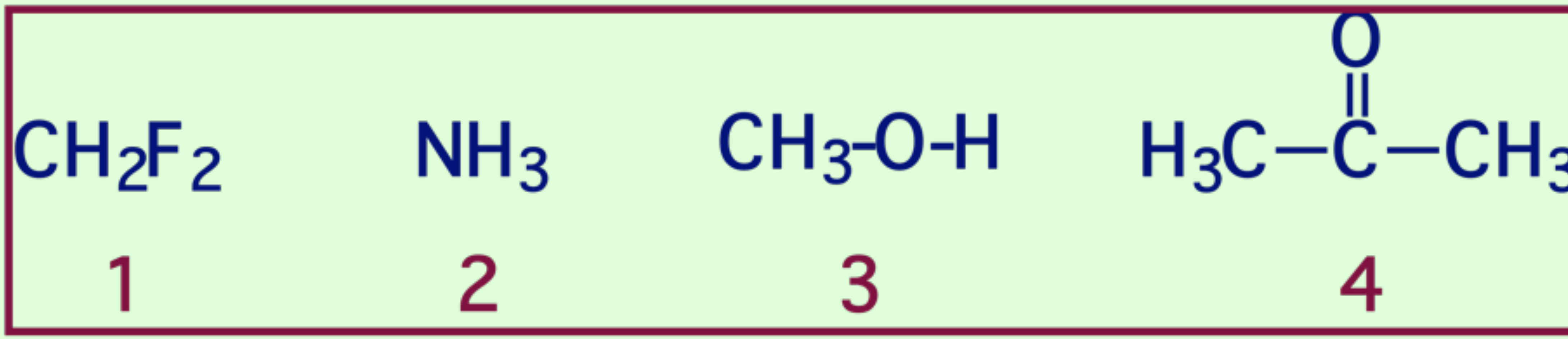
(Choose all that apply.)

Q# 11

CH_2F_2	NH_3	CH_3-O-H	$H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$
1	2	3	4

In which of the following molecules can hydrogen “bonding” occur within a pure sample?

(Choose all that apply.)



2 and 3 only

1 & 4 are both polar but can not participate in hydrogen bonding.

Arrange the following substances in order of increasing melting point.

1. MgO
2. CO_2
3. SiO_2
4. O_2
5. H_2O
6. NaCl

It is best to identify what you have; ionic, molecular, network covalent?

Q# 12

Arrange the following substances in order of increasing melting point.

1. MgO
2. CO_2
3. SiO_2
4. O_2
5. H_2O
6. NaCl

O_2 < CO_2 < H_2O < NaCl < SiO_2 < MgO

4 < 2 < 5 < 6 < 3 < 1

-183º -78º 0º 801º ~1700º 2852º

Ionic and network covalent are a close call. AP will give you the info if they ask you to discuss these.

So you would be expected to know

4 < 2 < 5 < 6 < 1 (and where the 3 falls in relation to the ionic, well…. I think they would help you with MP.

Arrange the following substances in order of increasing vapor pressure at a particular temp.

Q# 13

1. NH_3
2. I_2
3. Br_2
4. CH_4

Arrange the following substances in order of increasing vapor pressure.

1. NH_3
2. I_2
3. Br_2
4. CH_4

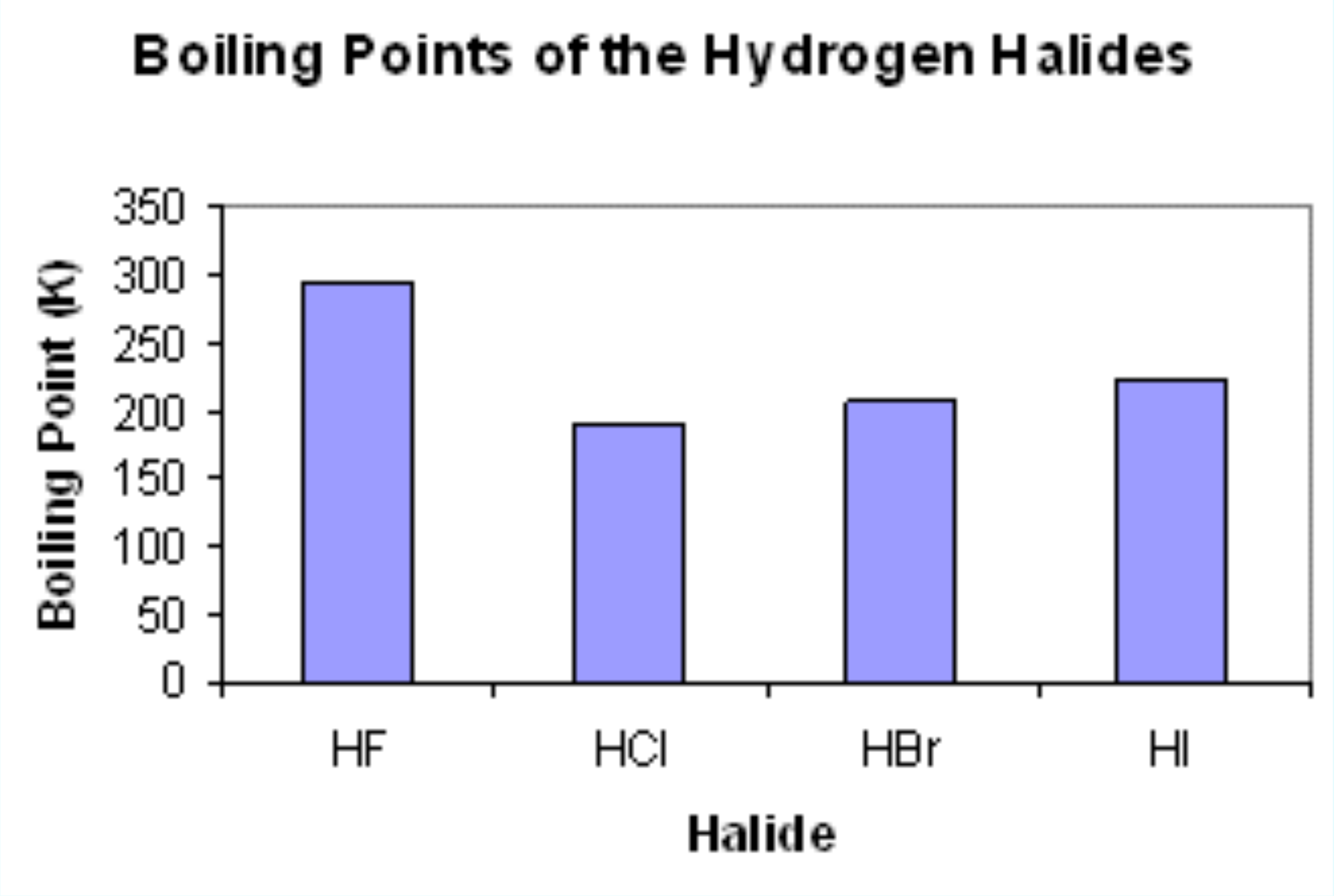
$I_2 < Br_2 < NH_3 < CH_4$

2 < 3 < 1 < 4

Which molecule has the strongest IPFs?

Q# 14

1. HF
2. HCl
3. HBr
4. HI

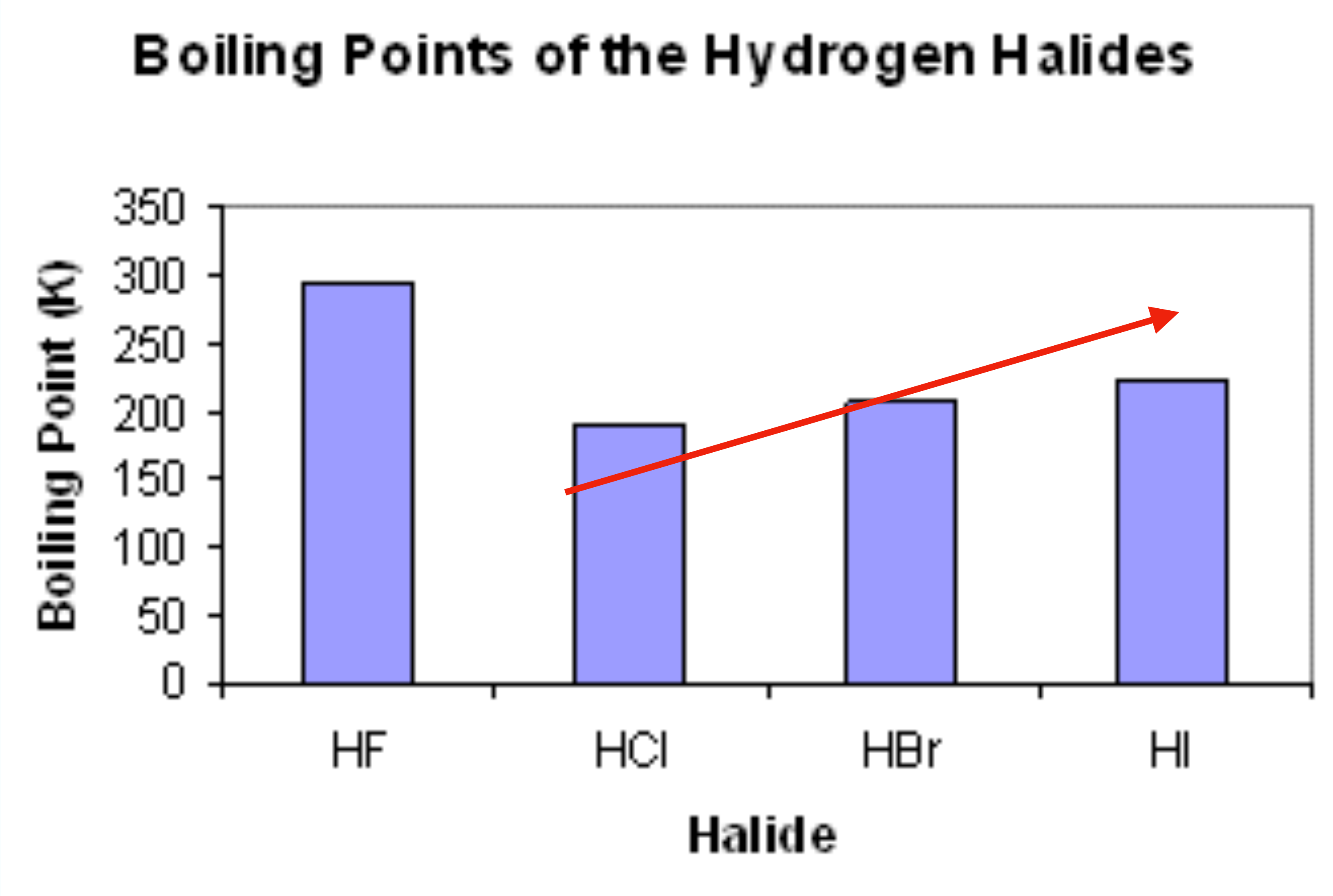


What causes the trend shown by the red arrow, and why does HF not follow this trend?

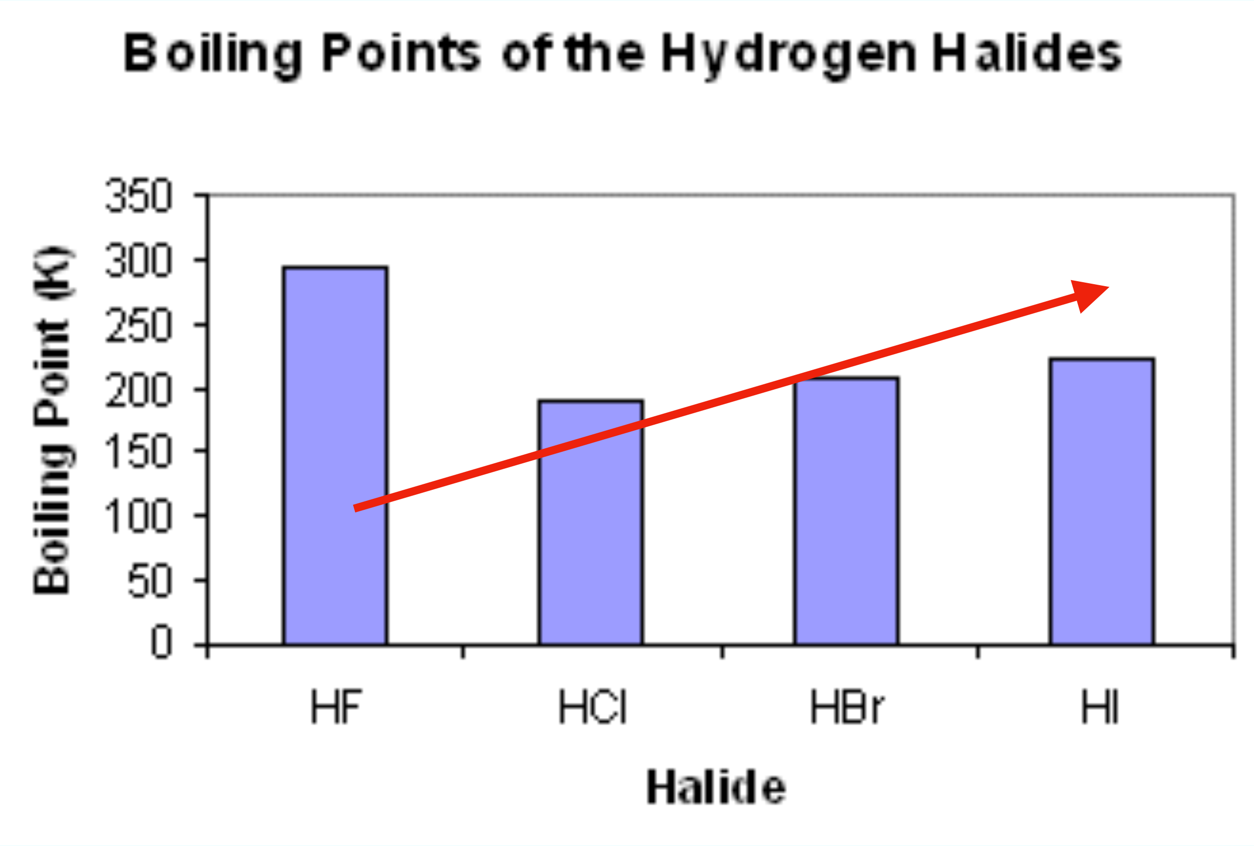
Q# 14

Highest BP?

1. HF
2. HCl
3. HBr
4. HI



What causes the trend shown by the red arrow, and why does HF not follow this trend?



1. HF has the highest BP

- To some degree they all engage in dipole-dipole forces (decreasing HF > HI)
- All four molecules engage in LDF's which increase as molecule size increases, because of the polarizability of the larger electron cloud. (increasing HF < HI)
- HF engages in H-"bonding" making its IPF's quite strong, causing the large BP

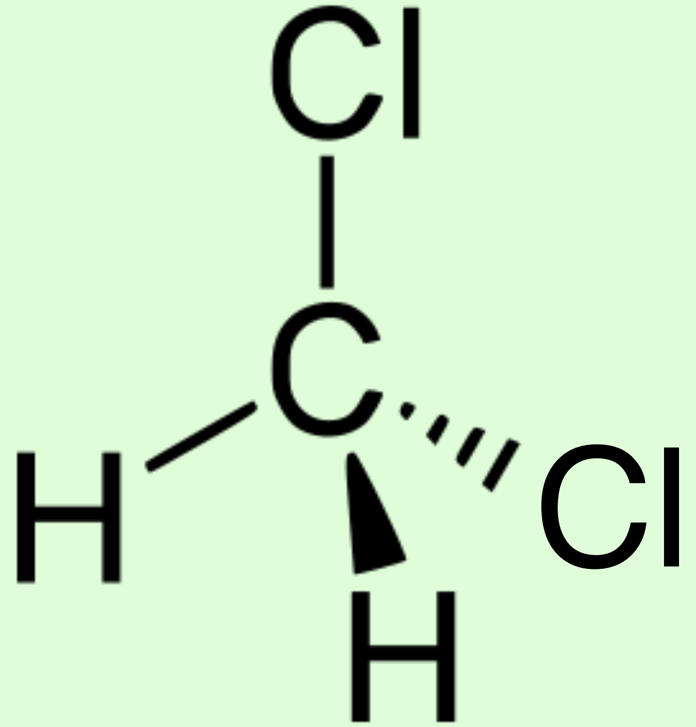
What type of intermolecular forces exist in methyl chloride? CH_2Cl_2

1. dipole-dipole forces
2. hydrogen bonding
3. London Dispersion forces

Q# 14

What type of intermolecular forces exist in methyl chloride? CH_2Cl_2

1. dipole-dipole forces
2. hydrogen bonding
3. London Dispersion forces



Which molecule exibits greater IPFs?

Justify with a discussion of the IPFs that each molecule exhibits.

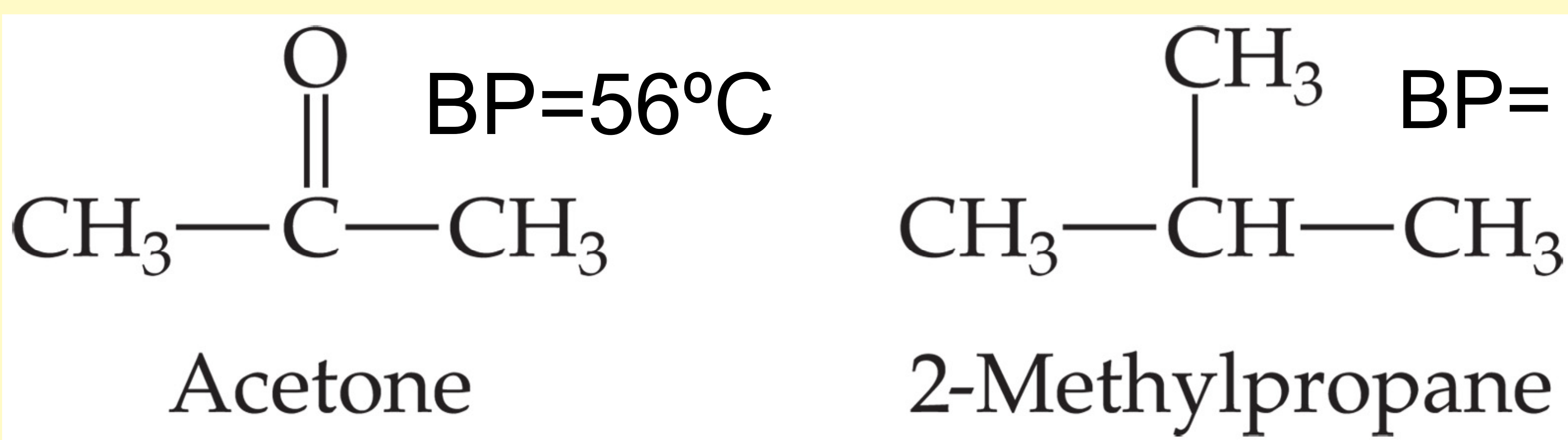
Q# 15

BP=56ºC

BP= -12ºC

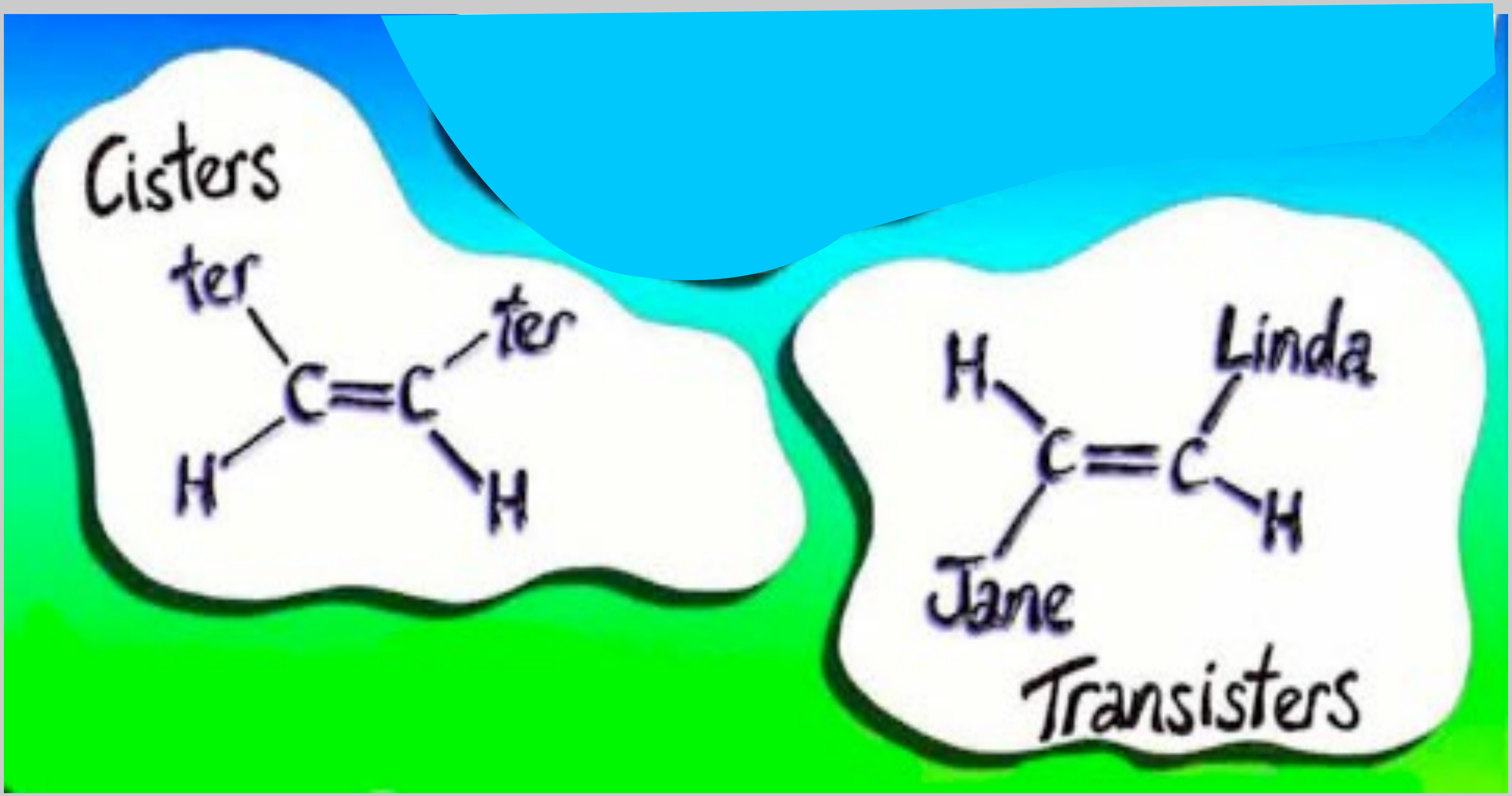
Which molecule exibits greater IPFs, and justify with a discussion of the IPFs that each molecule exhibits

- The higher BP tells us the acetone has stronger IPFs *(state the obvious)*
- The molecules appear to be similar size, which would cause similar LDFs
- Thus the dipole-dipole forces in the acetone must be contributing to the stronger total IPFs



BP= -12ºC

Chemistry Humor



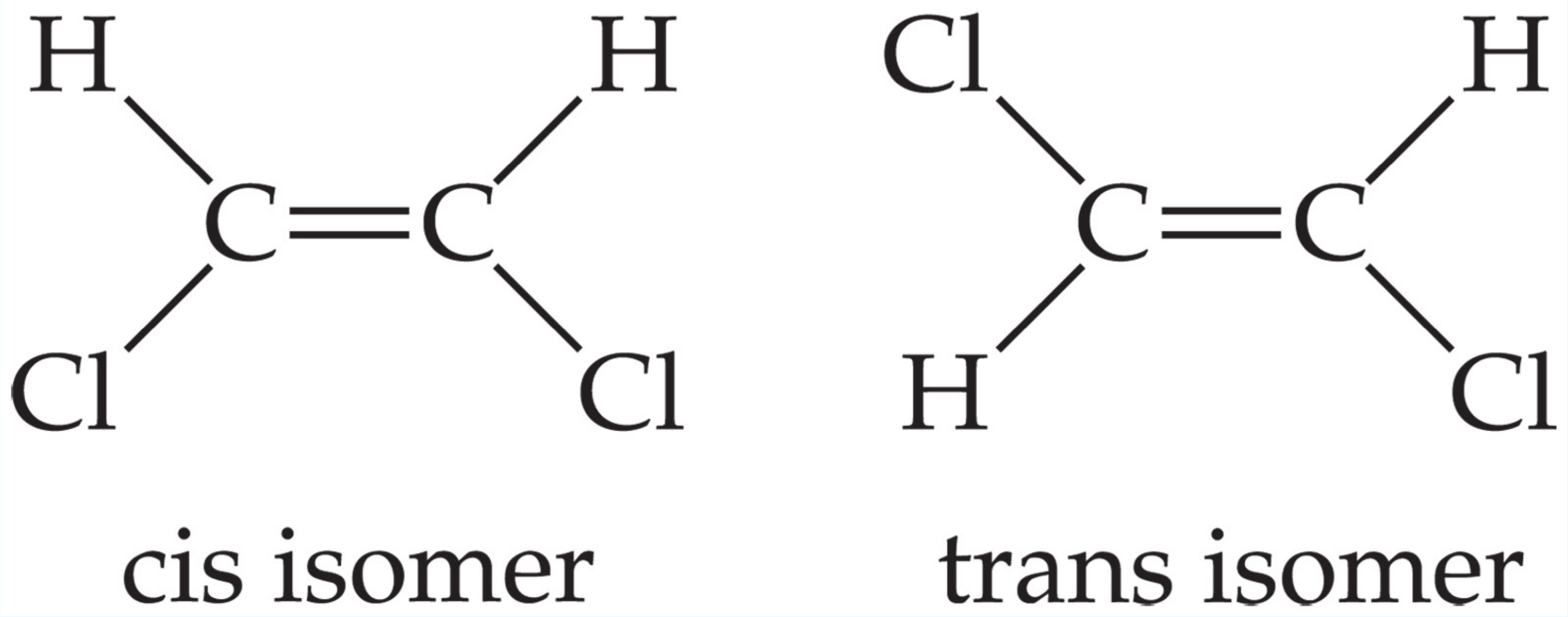
Draw the structures for the two isomers named below. *Just a little taste of IUPAC naming.*

Just to be clear AP will never expect you to draw these structures from their names.

- 1,2-cis dichloroethene, $C_2H_2Cl_2$
- 1,2-trans dichloroethene, $C_2H_2Cl_2$
- (1,1- dichloroethene, $C_2H_2Cl_2$)

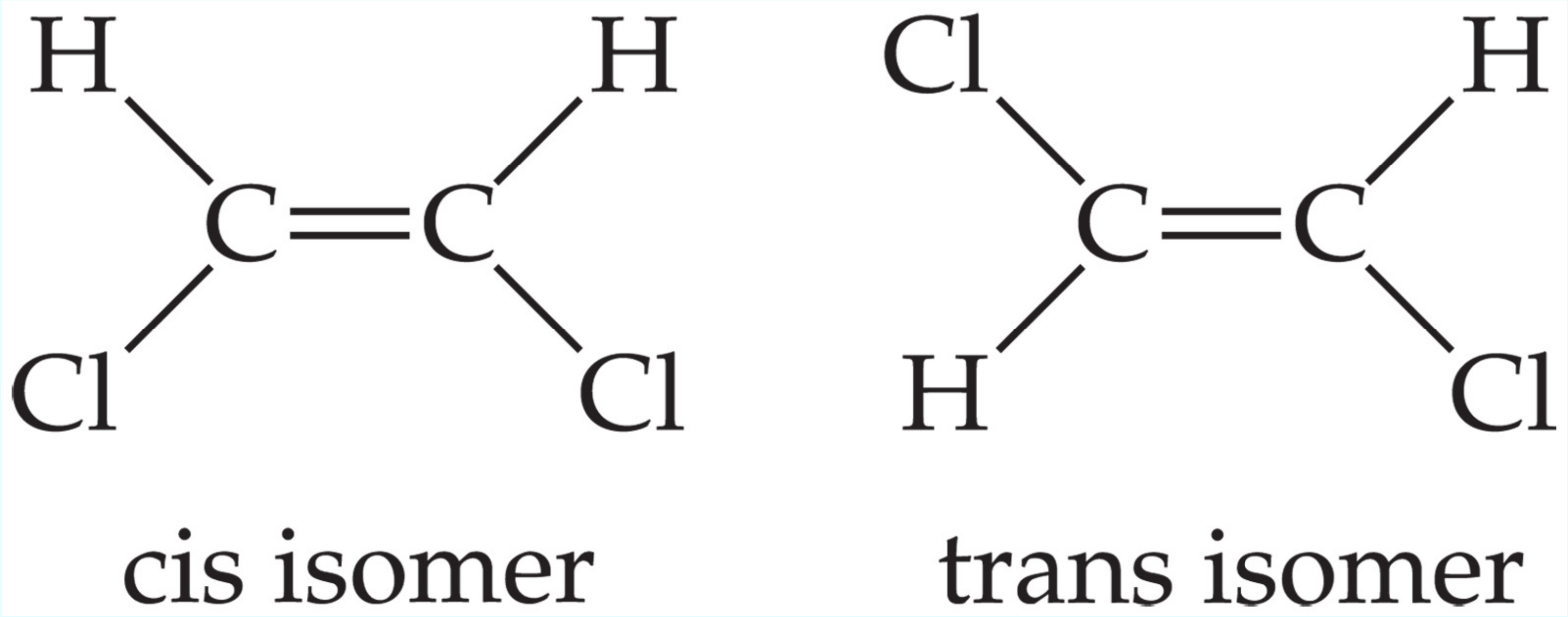
Which boils at the lower temperature?

1. 1,2-cis dichloroethene, $C_2H_2Cl_2$
2. 1,2-trans dichloroethene, $C_2H_2Cl_2$
3. They boil at the same temperature since they have the same chemical formula, $C_2H_2Cl_2$



Which boils at the lower temperature?

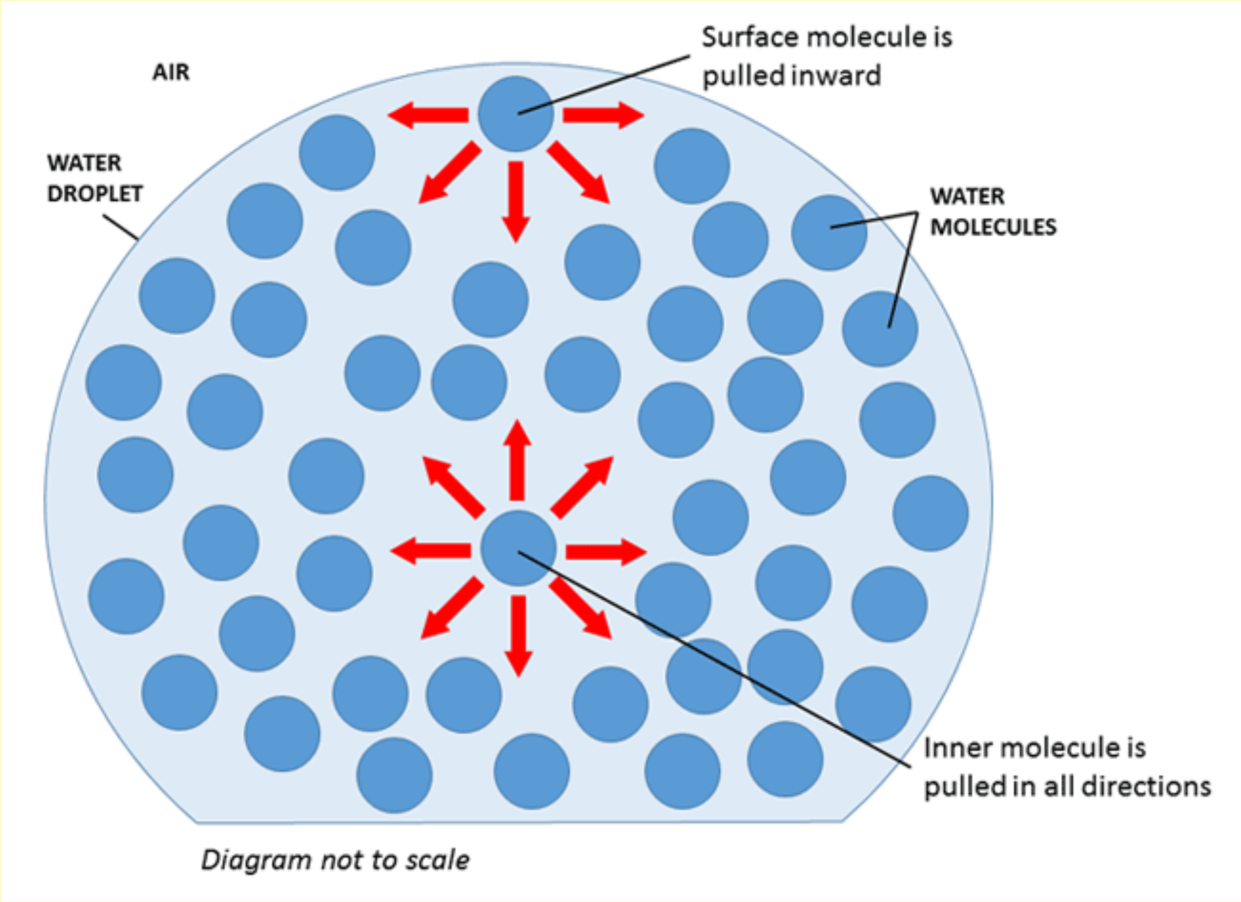
1. 1,2-cis dichloroethene, $C_2H_2Cl_2$
2. 1,2-trans dichloroethene, $C_2H_2Cl_2$
   - The trans isomer is nonpolar, thus lower IMFs
3. They boil at the same temperature since they have the same chemical formula, $C_2H_2Cl_2$

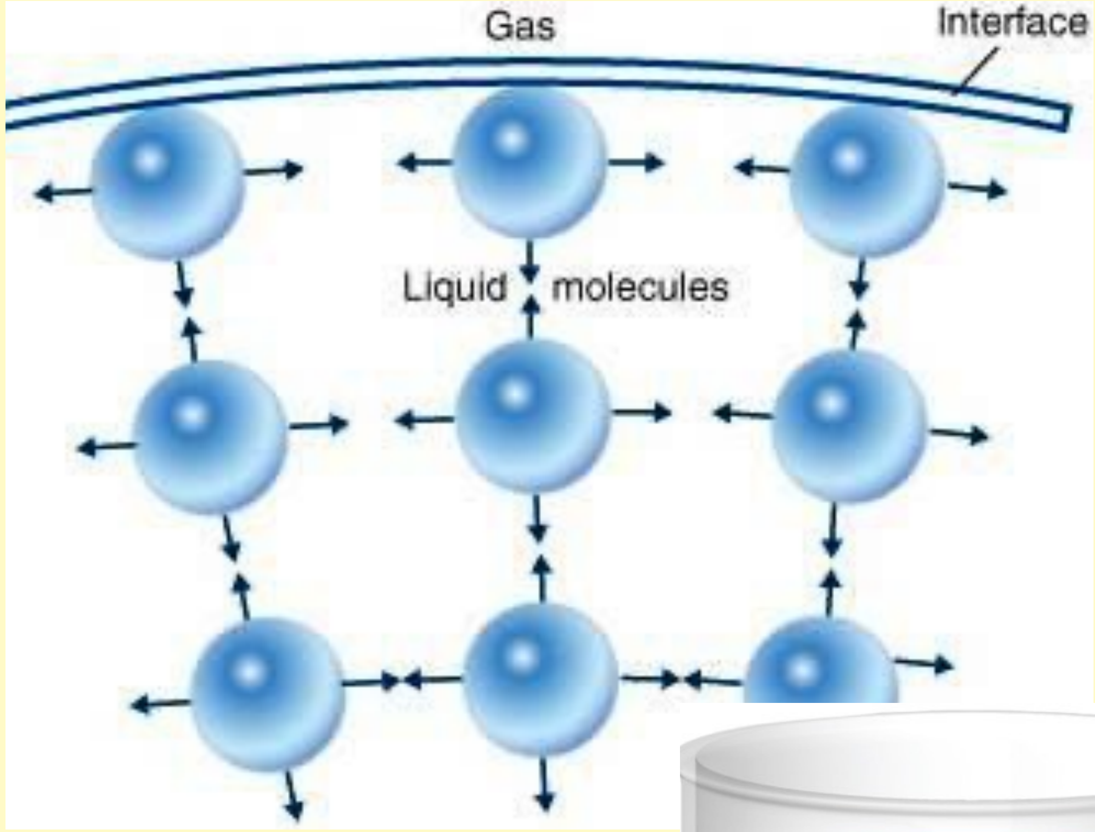


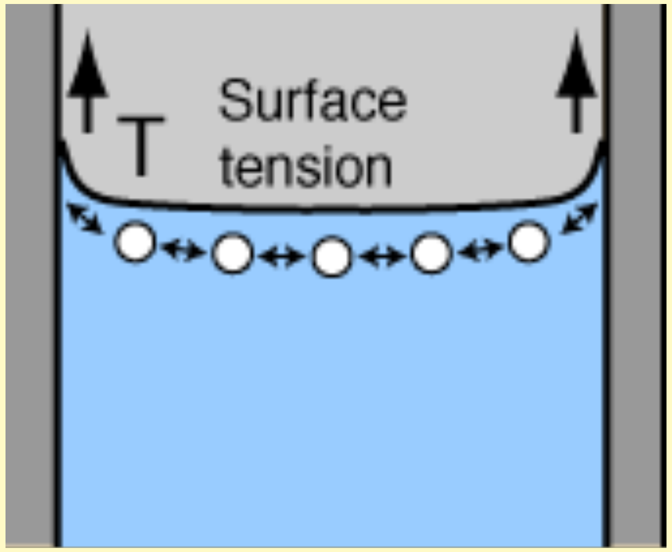
Surface tension in water is a phenomenon that causes droplets of water to form, a glass of water to be filled beyond the brim, and a meniscus to form in the graduated cylinder. Sketch and describe the forces or lack of forces that cause surface tension.

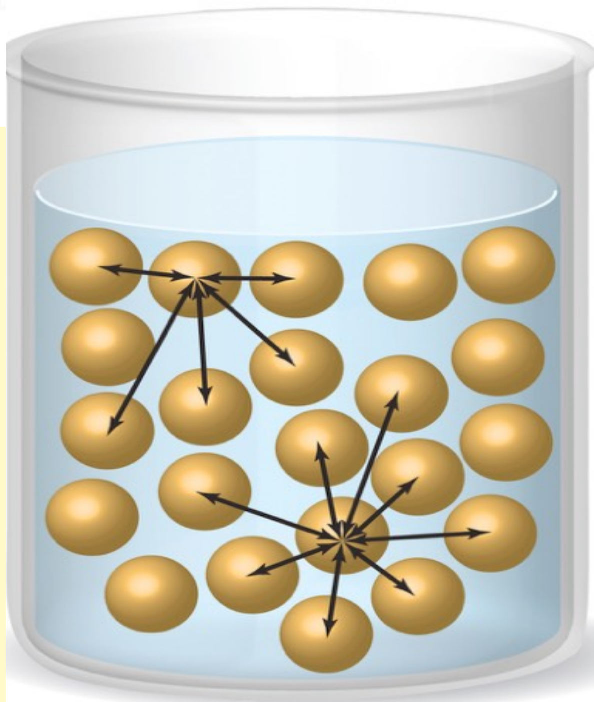
We'll discuss the inverted meniscus in mercury after answering the question.

The water molecules on the surface do not have any IPFs with the air, only with the water beside and inward, thus the H-bonding (most importantly) and dipole-dipole, and LDF forces tend to pull the water molecules inward.





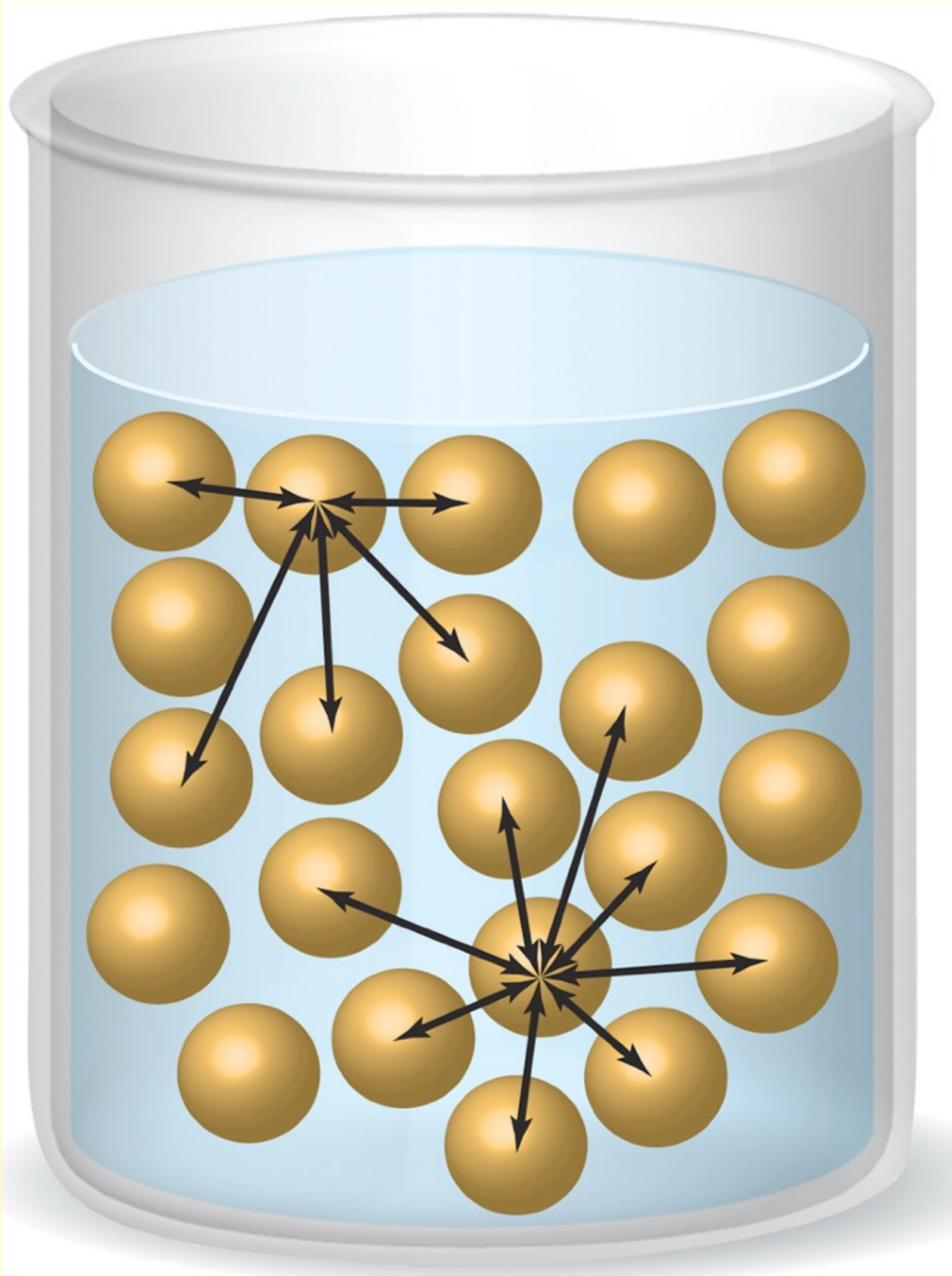


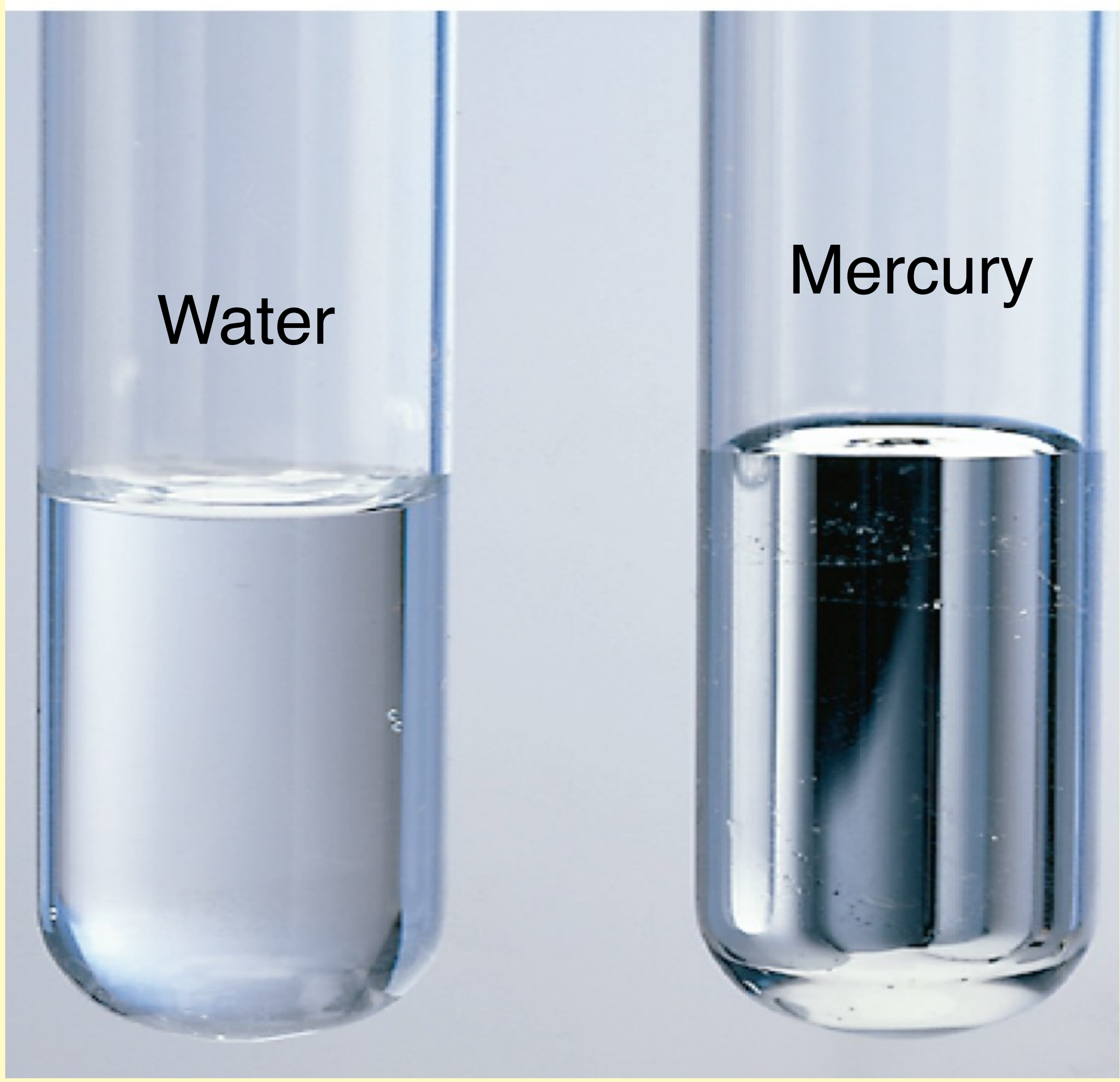


Clearly mercury is very attracted to itself, but considering the two very different menisci for water compared to mercury, what might you suggest about the strength IPFs of Hg for glass compared to the strength IPFs of water to glass. Glass is SiO_2.

Surface Tension

caused by IPFs





- Adhesion
- Cohesion
- creates a meniscus

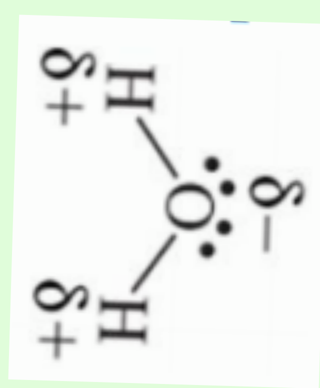
- only cohesion
- no adhesion
- reverse meniscus

Acetone $(CH_3)_2CO$, nail polish remover, can H-“bond” with water.

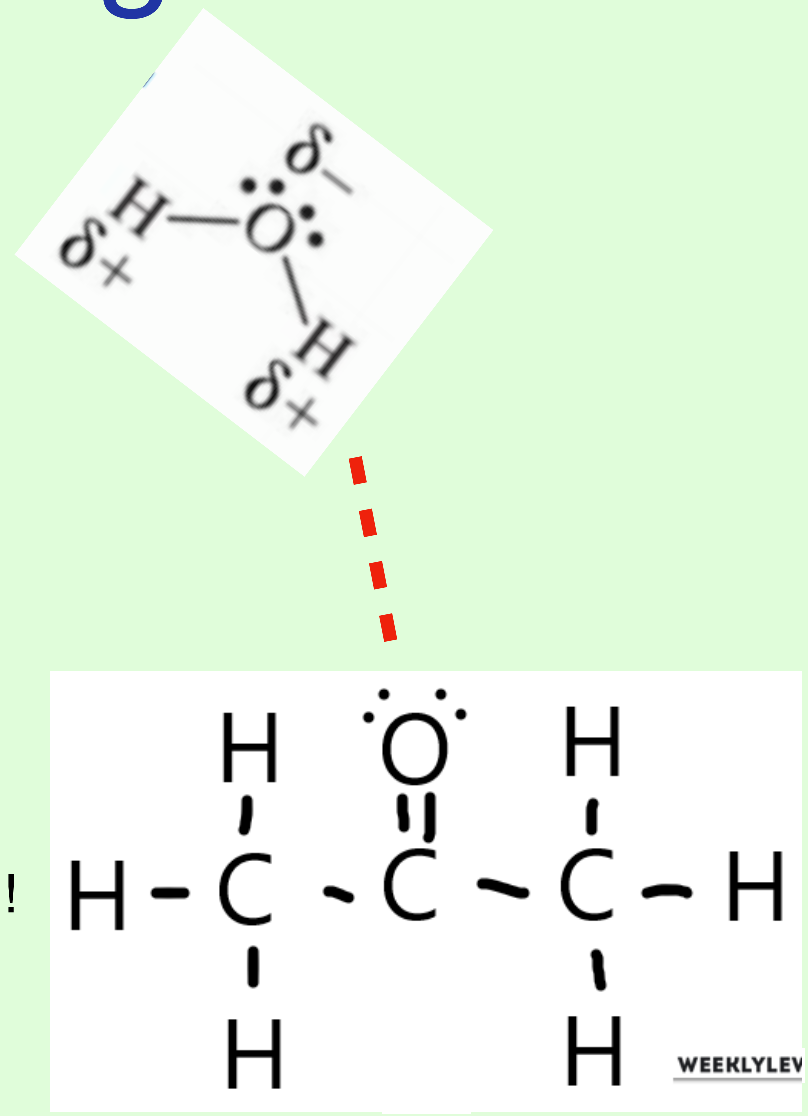
Sketch a Lewis structure of both water and acetone *(No formal charges on acetone, follow* $\overset{\textit{HONC}}{\textit{1 2 3 4}}$ *)*.

Indicate the hydrogen “bonding” between the two molecules with a dashed line.

Acetone $(CH_3)_2CO$, nail polish remover, can H-“bond” with water.
Sketch a Lewis structure of both molecules (NO formal charges) and indicate the H-“bonding”



NOT!!



When CO_2 sublimes *(solid directly to gas)* which of the following forces must be overcome?

1. Covalent bonds must be broken.
2. Hydrogen bonding
3. Dipole- dipole interactions
4. London dispersion forces
5. Lattice interactions
6. Both London dispersion AND dipole-dipole interactions must be overcome
7. No forces need to be overcome since sublimation occurs so easily at room pressure

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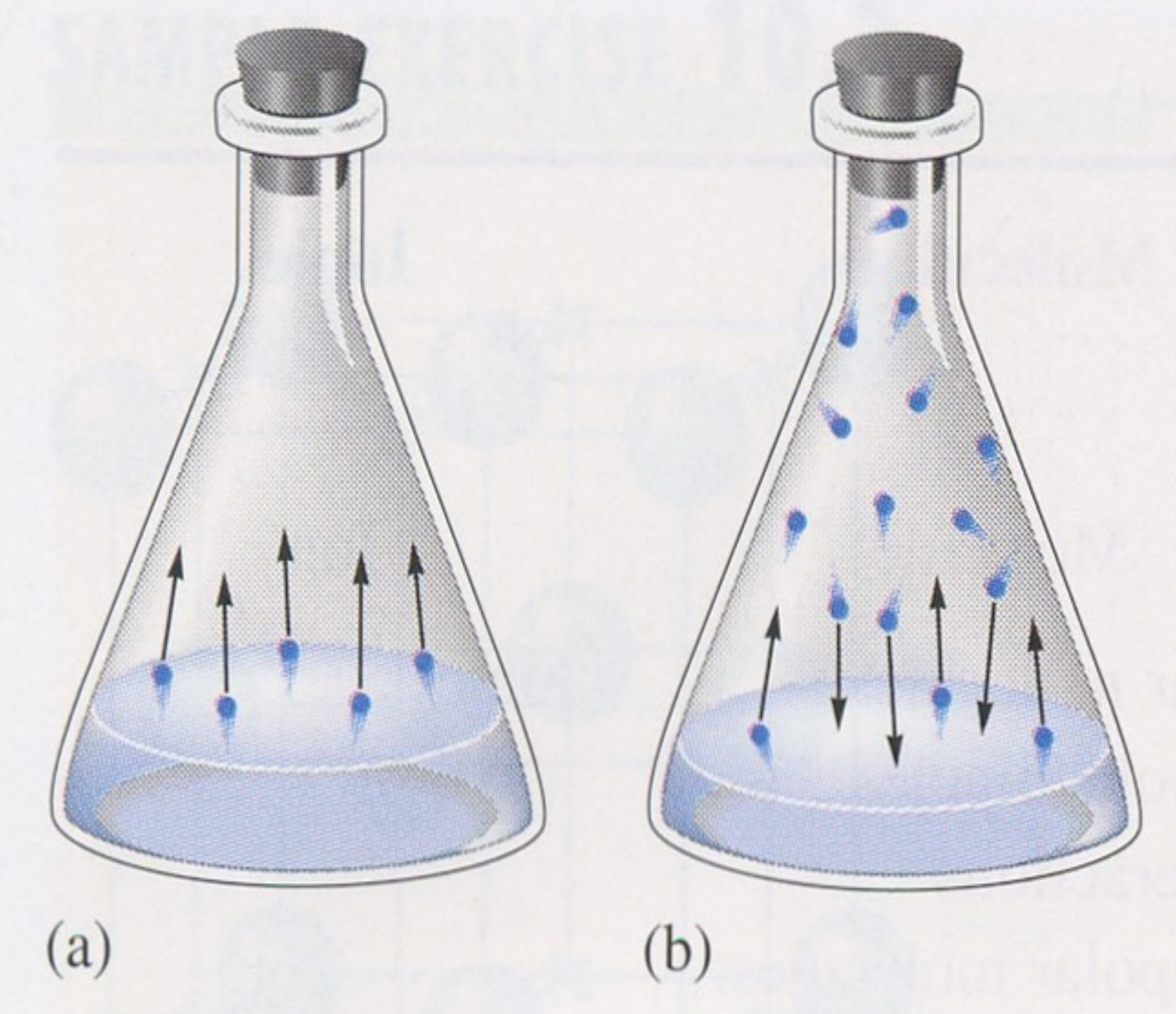
Vapor Pressure

Liquid evaporating
in a sealed container

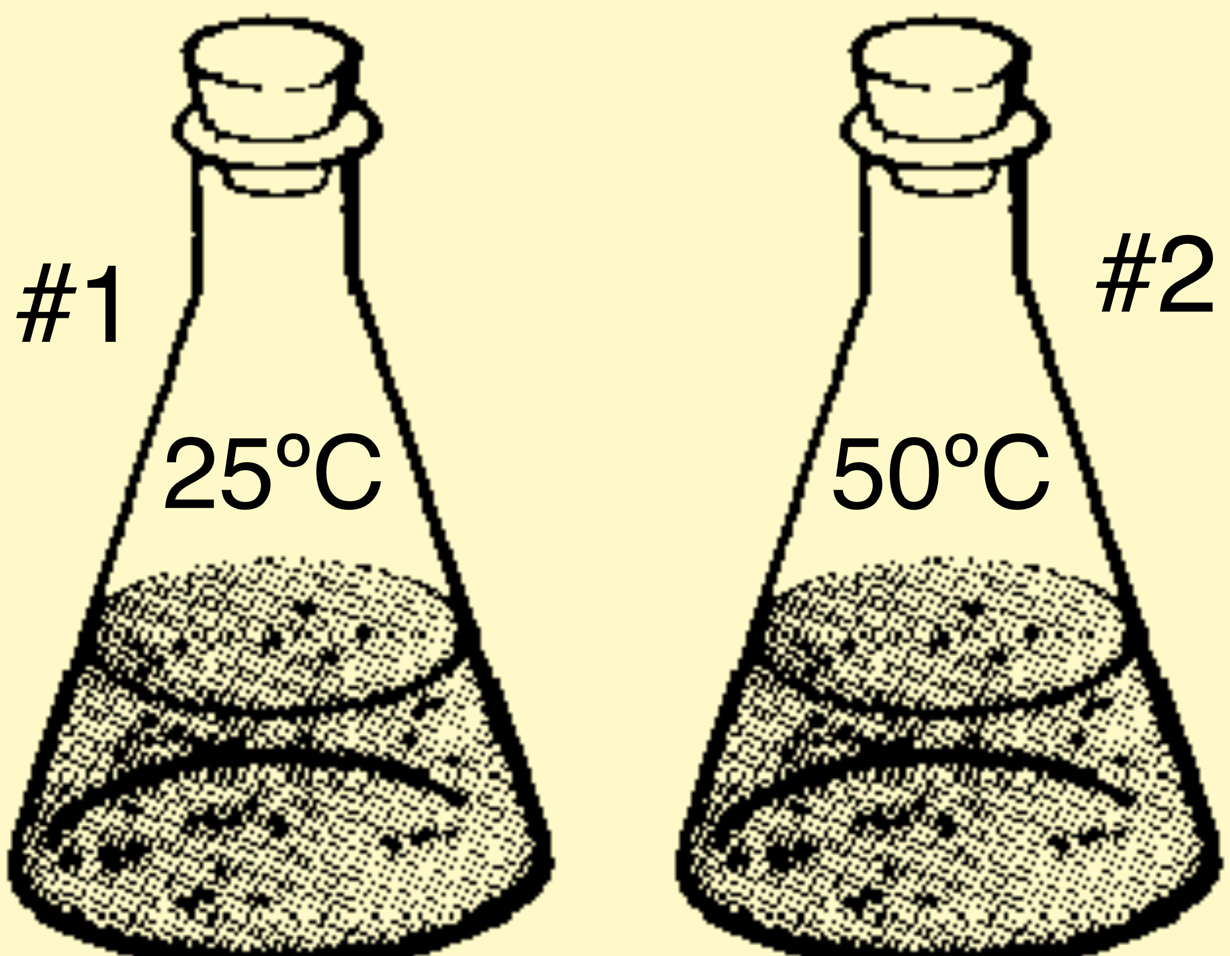
Vapor (Dynamic) Equilibrium

- When first put into an enclosed space, molecules will vaporize.
- Vapor Equilibrium
  - » Eventually the amount vaporizing will equal the amount condensing.
  - » This causes a particular vapor pressure based completely on the temperature in the flask.
  - » The size of the container or the presence of other gases play no role.
  - » This is a *dynamic* equilibrium.



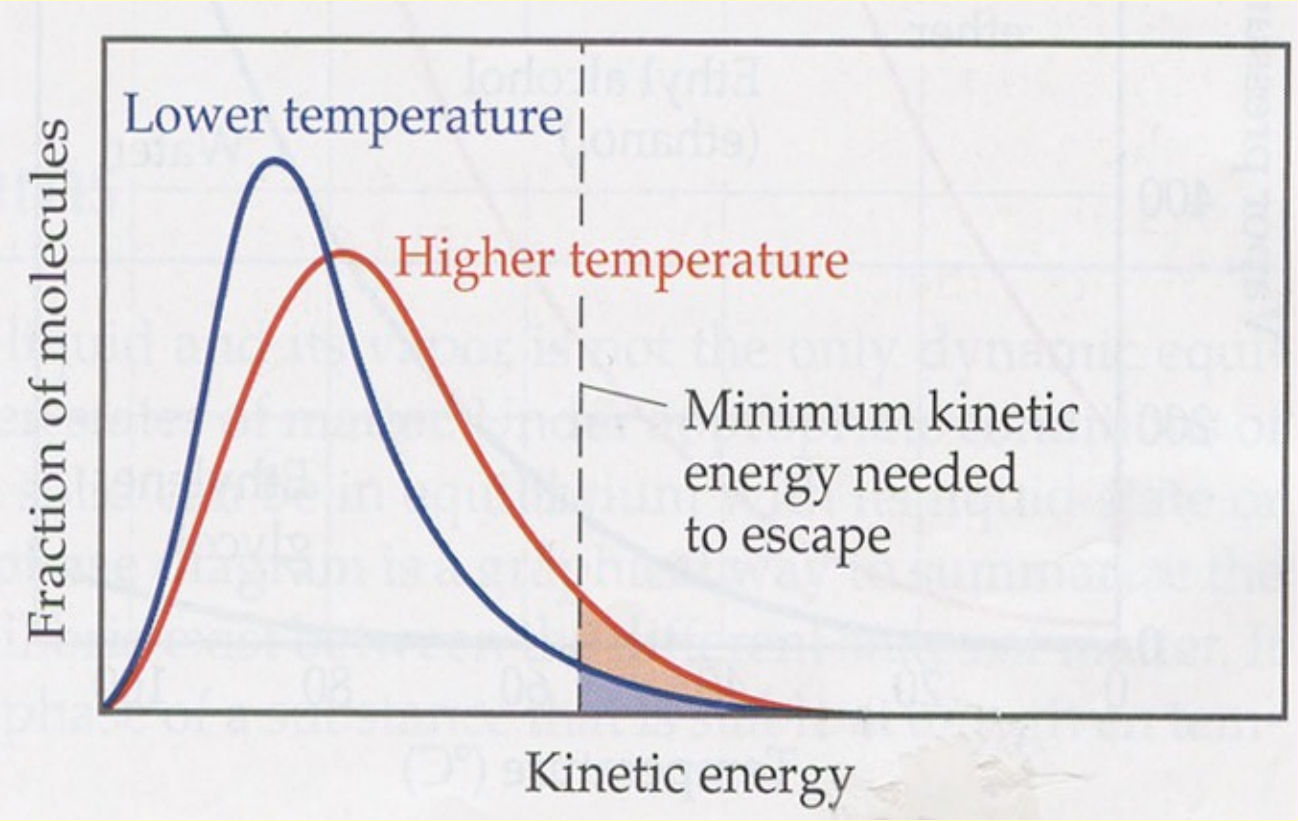
Effect of Temp on Equilibrium Vapor Pressure

- Which situation will have a higher vapor pressure?
- Send in your answer, then write an explanation on your white board
- Hint: Maybe a Boltzmann distribution curve that would represent the molecules in the liquid could assist in your explanation.



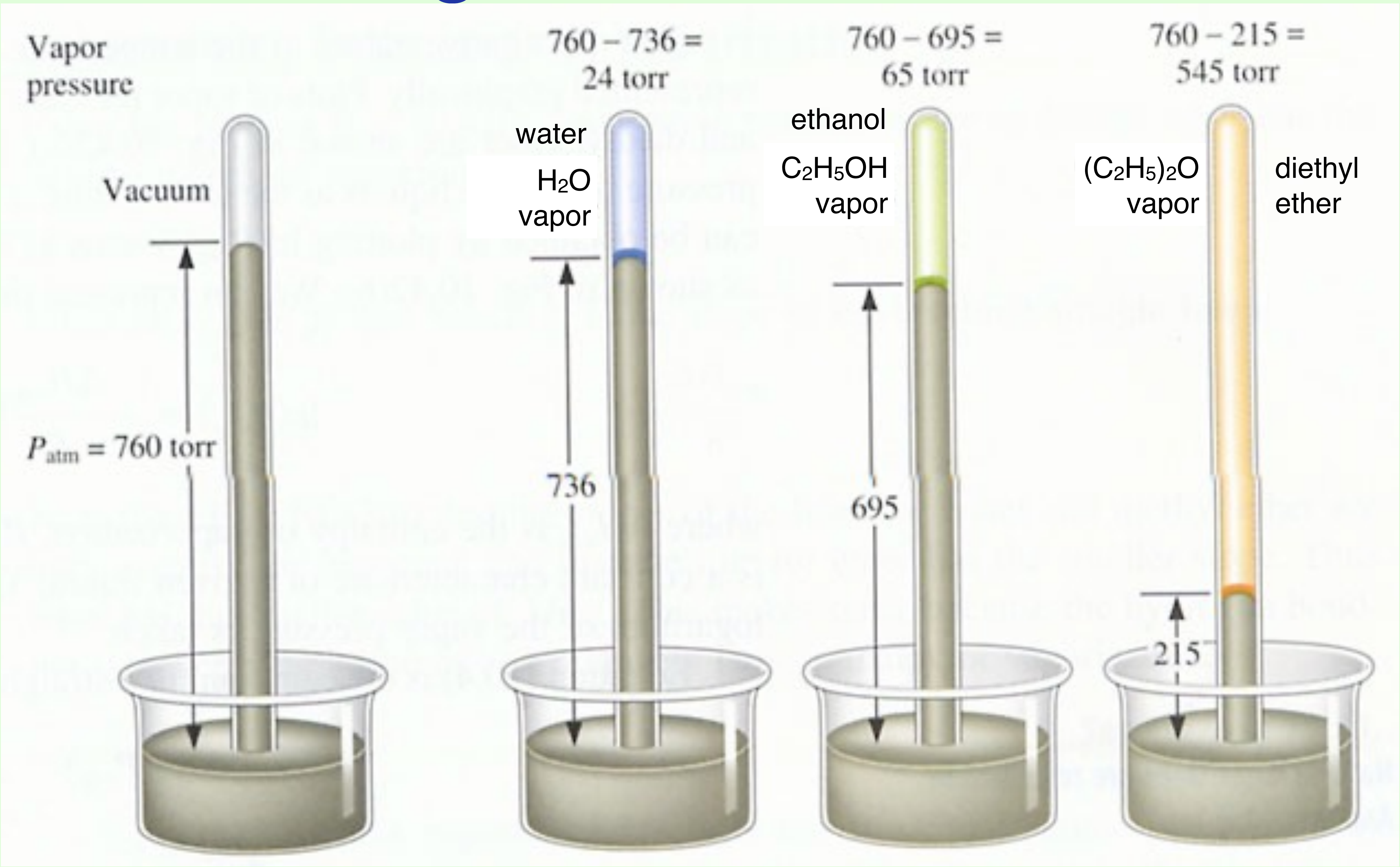
Vaporization or Evaporation

- Remember that temperature is an <u>average</u>.
- At a particular temp some molecules go fast some go slow.
- A certain amount of molecules will have enough energy to sever all attractions to the liquid and fly into the air.
- Remember that the shape of the curve changes as temperature increases



- Thus at a higher temperature, a larger number of molecules, meet the energy requirement to fly off as a gas.

Measuring VP with a Barometer



Pick two of the three substances (A, B or C) and justify the difference in vapor pressure using molecular structure and IPFs

Measuring VP with a Barometer

water

- H-“bonding”
- dipole-dipole forces
- LDFs

ethanol

- H-“bonding”
- (not as strong as water’s)
- dipole-dipole forces
- LDFs

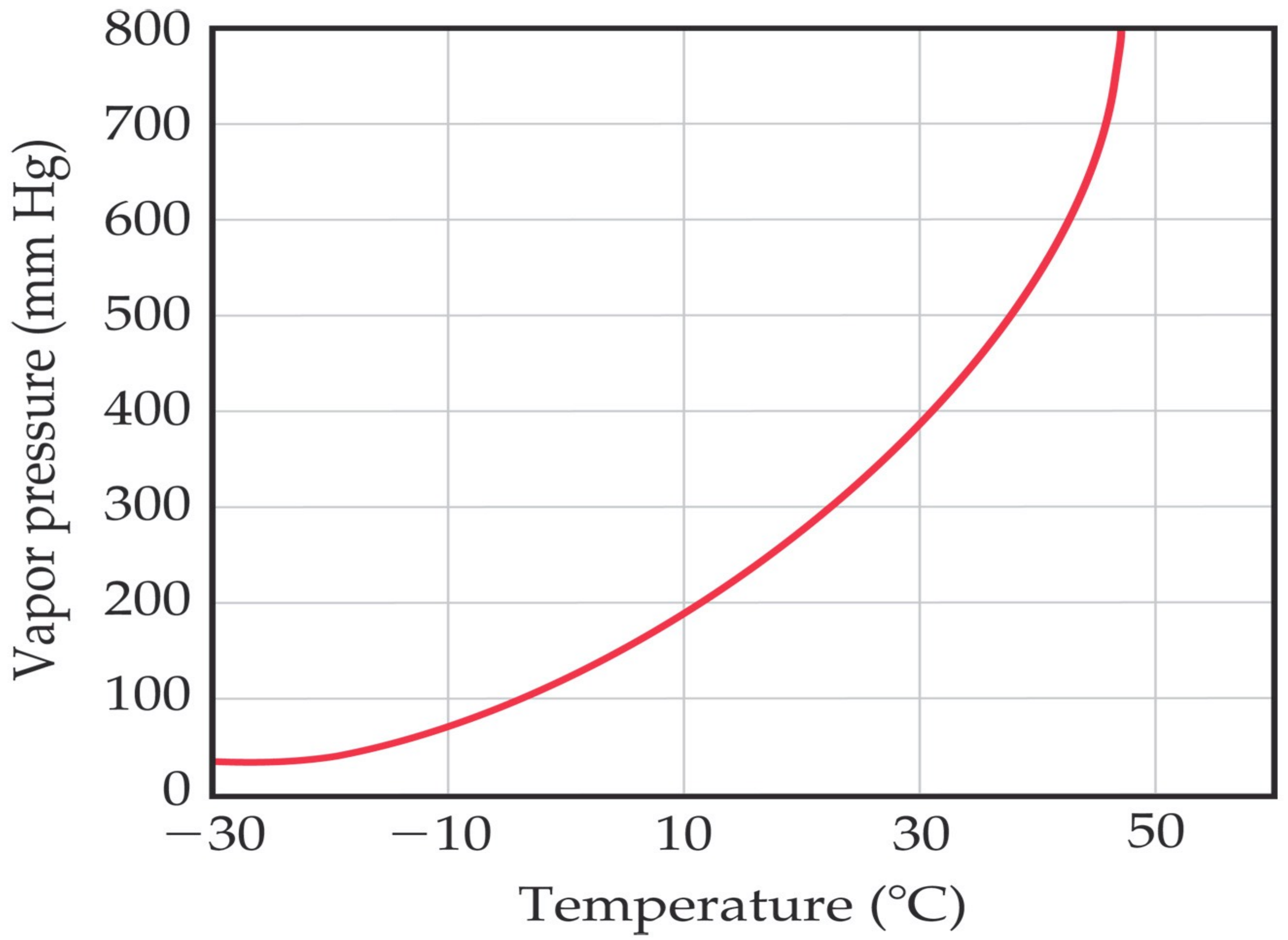
diethyl ether

- NO H-“bonding”
- dipole-dipole forces
- LDFs

Pick two of the three liquids and justify the difference in vapor pressure using molecular structure and IPFs

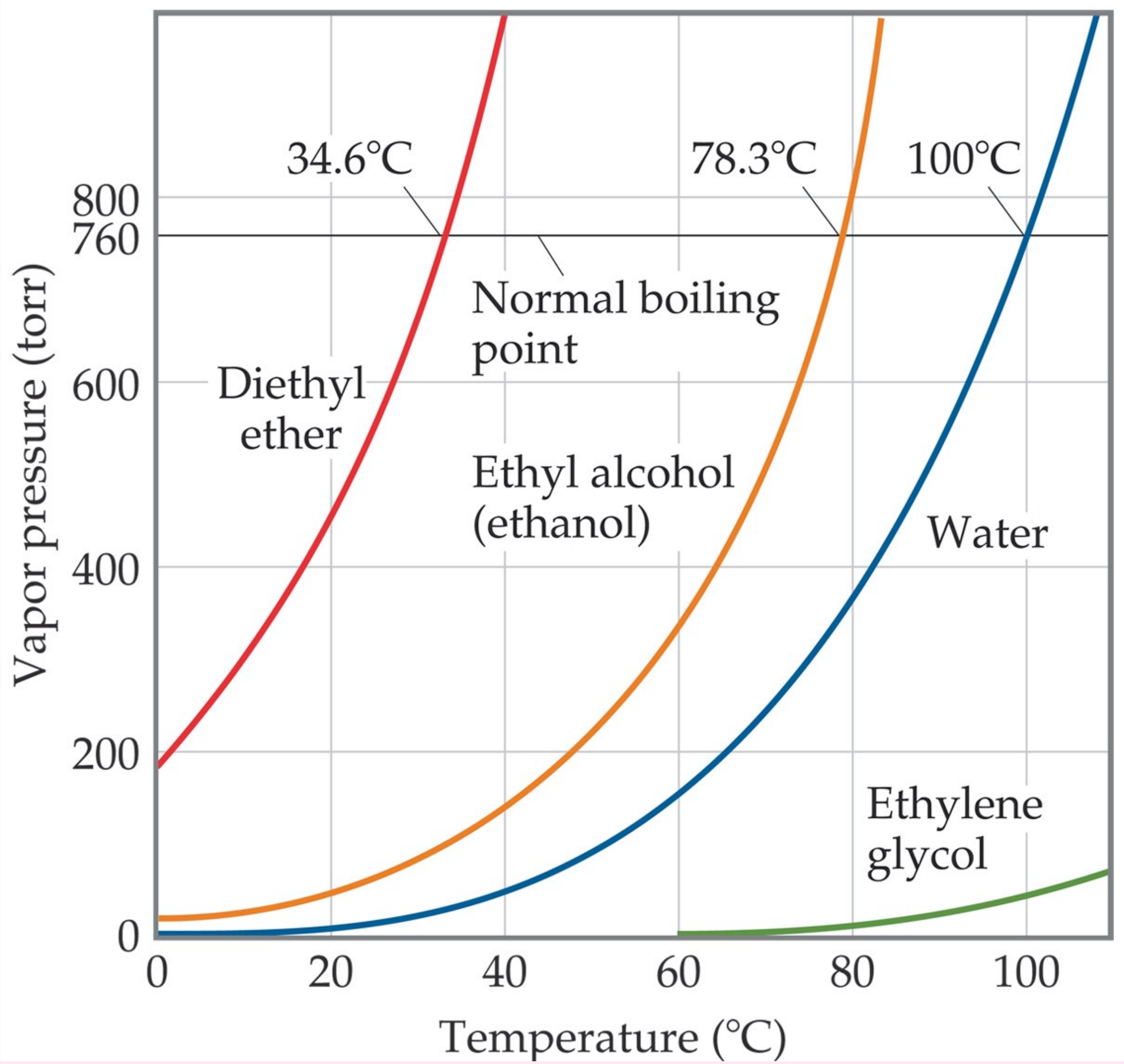
Vapor Pressure Problems

Turn to your mate and tell them something you notice about the graph.



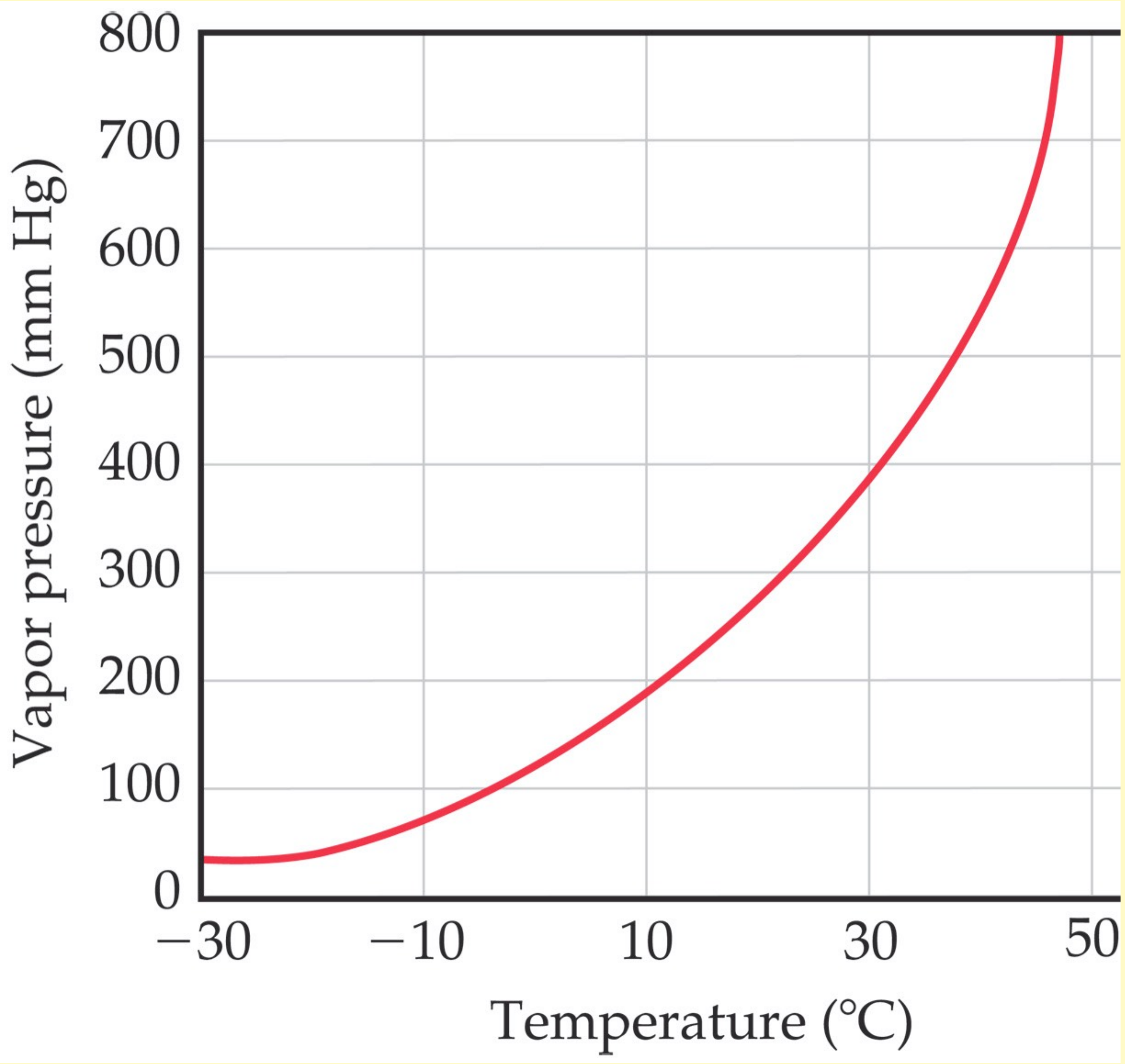
Vapor Pressure Curves

- IPF's will effect the shape and location of the vapor pressure curve.
- Lower IPF liquids evaporate more easily.
- A liquid is said to be *boiling* when its vapor pressure reaches atmospheric pressure.



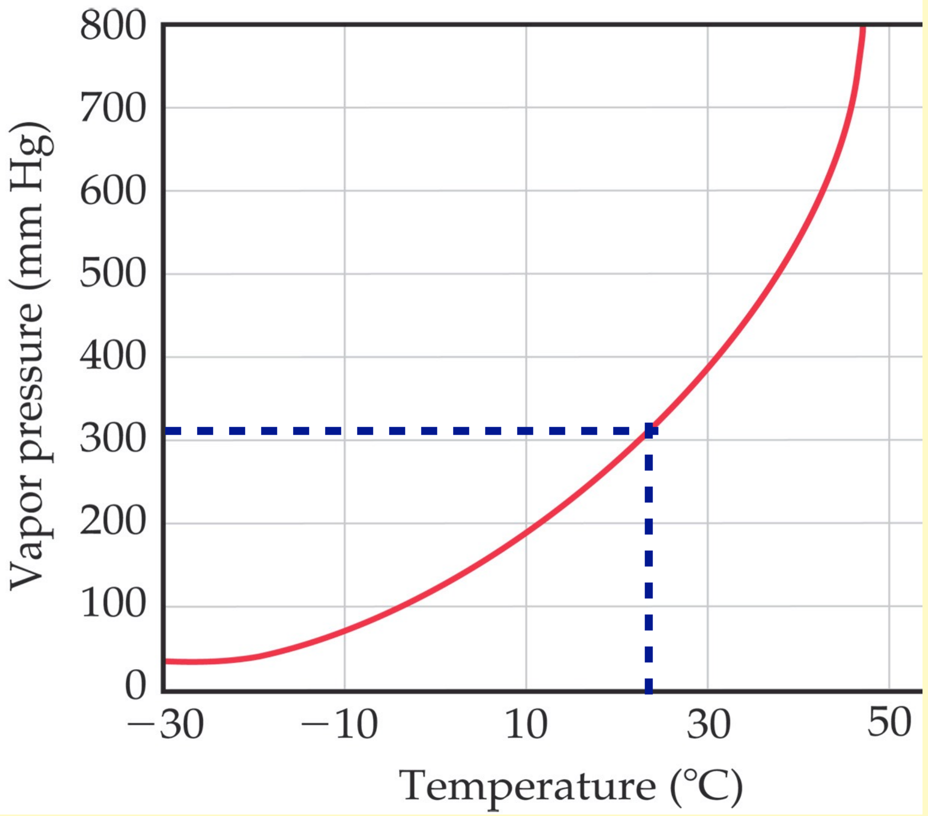
Vapor Pressure Problems

1. This particular volatile liquid has a molar mass of 78 g/mole.
2. At 25ºC if you sealed 0.5 g of this liquid into a 650 ml flask, will equilibrium vapor pressure be reached?
3. If yes, how much liquid is left on the bottom?
4. If no, what is the pressure?
5. If no, what is the vapor pressure?
6. If no, what mass more should be added to reach equilibrium vapor pressure?



Assume the volume of the liquid is negligible compared to the 650 ml of flask

Vapor Pressure



- Let's assume ~300 mm at 25°
- This particular volatile liquid has a molar mass of 78 g/mole.
- At 25ºC if you sealed 0.5 g of this liquid into a 650 ml flask, will equilibrium vapor pressure be reached?
- If yes, how much liquid is left on the bottom?
- If no, what is the vapor pressure?
- If no, what mass more should be added to reach equilibrium vapor pressure?

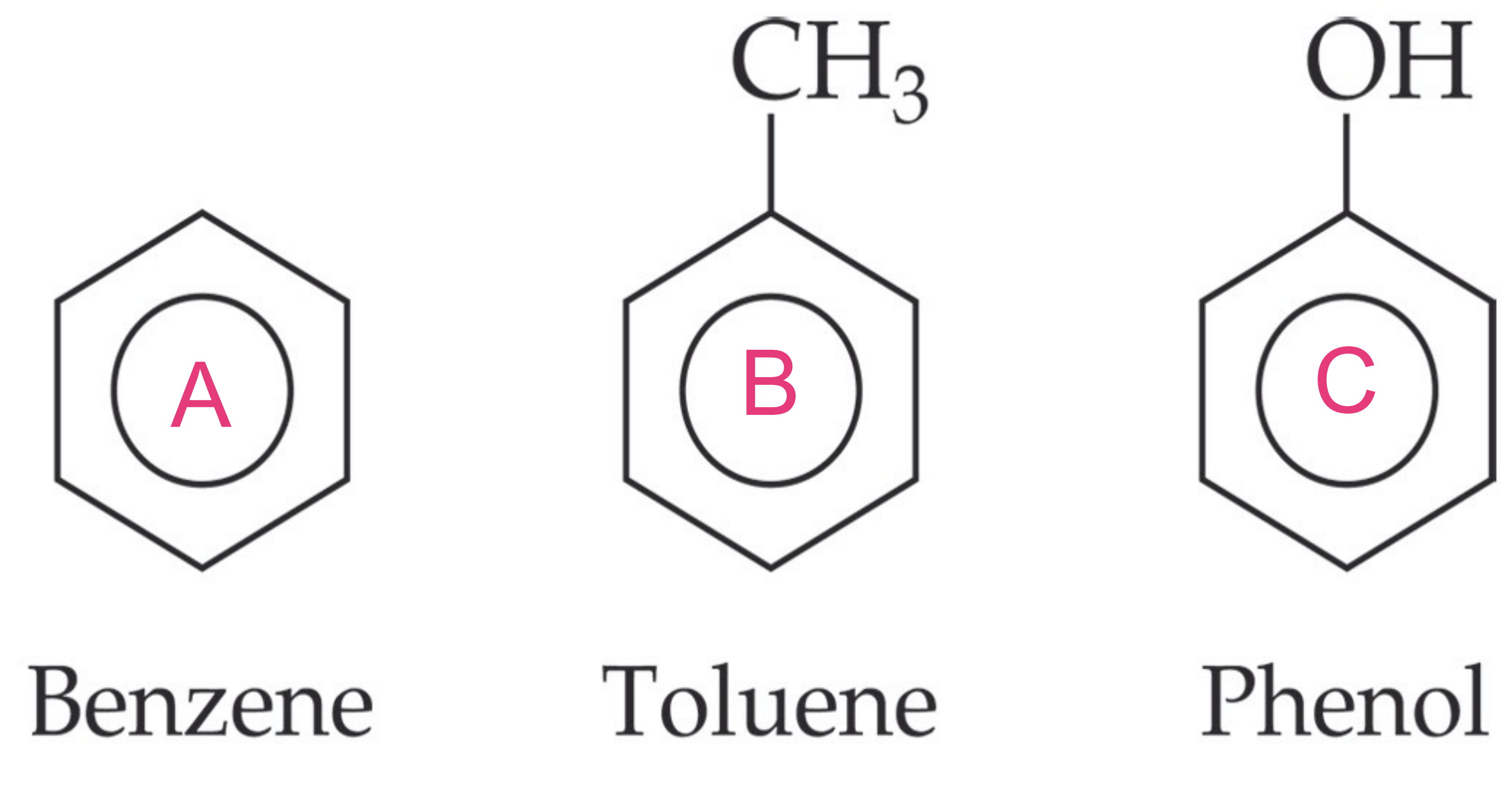
$$P=\frac{nRT}{V} \quad \frac{(0.5/78)(62.36)(298)}{0.65}=183mm$$

$$n=\frac{PV}{RT} \quad \frac{(325)(0.65)}{(62.36)(298)}=0.0105mol\times 78g/mol=0.88g$$

Shape Can Affect Melting Points

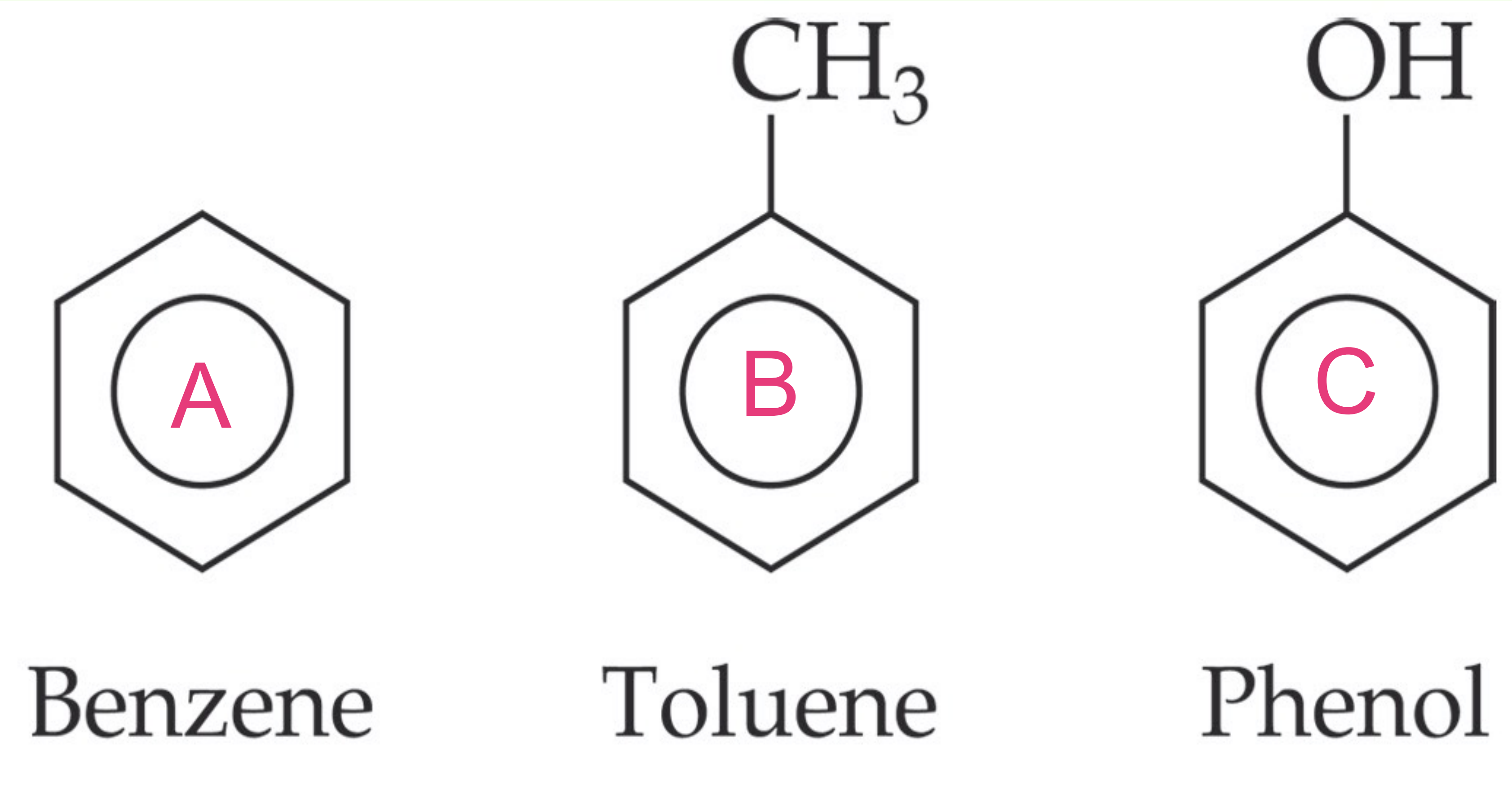
List the molecules in order of lowest to highest boiling temp?

1. A < B < C
2. C < B < A
3. B < C < A
4. A < C < B
5. B < A < C
6. C < A < B



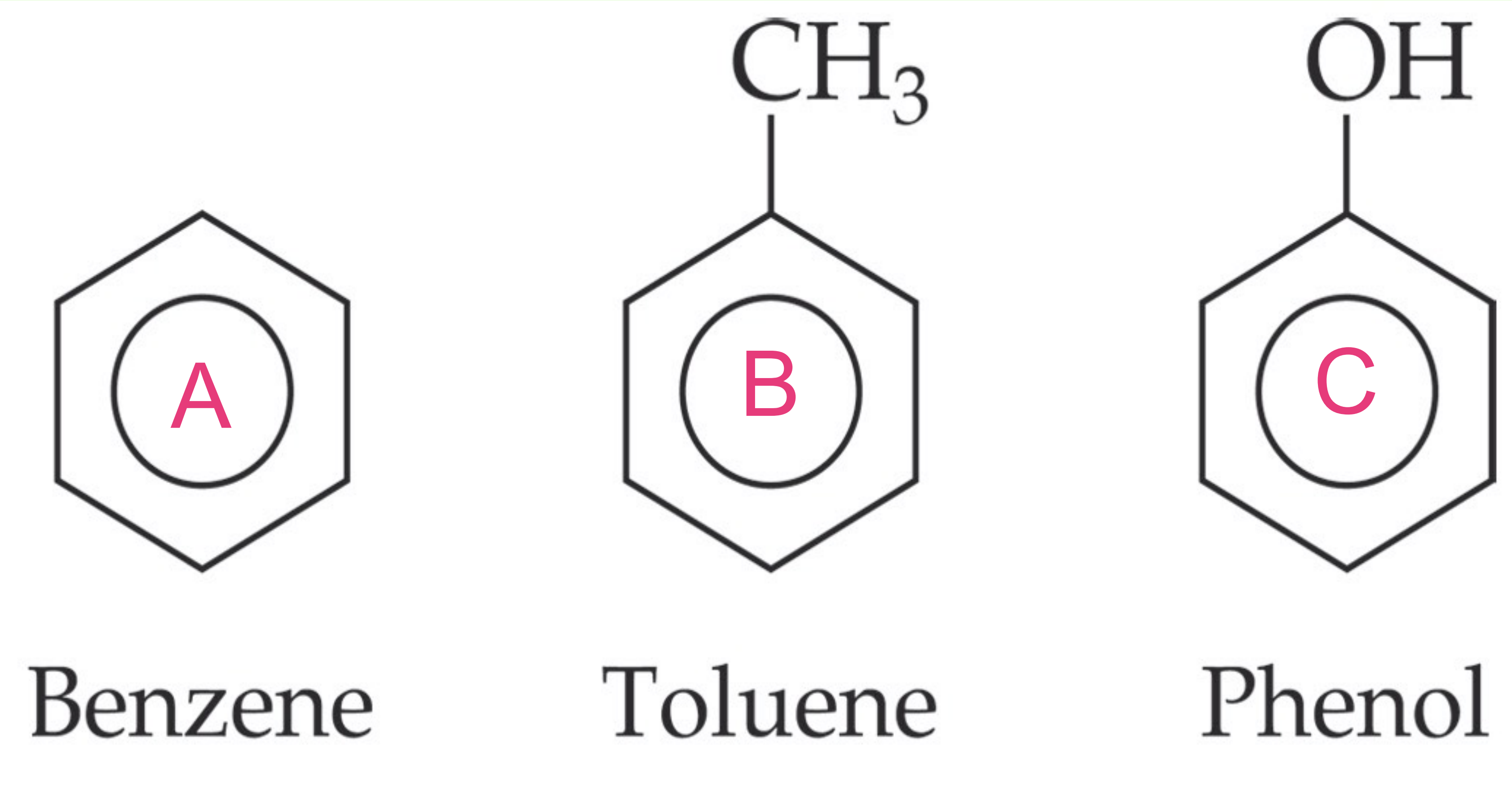
List the molecules in order of lowest to highest boiling temp?

1. A < B < C
2. C < B < A
3. B < C < A
4. A < C < B
5. B < A < C
6. C < A < B



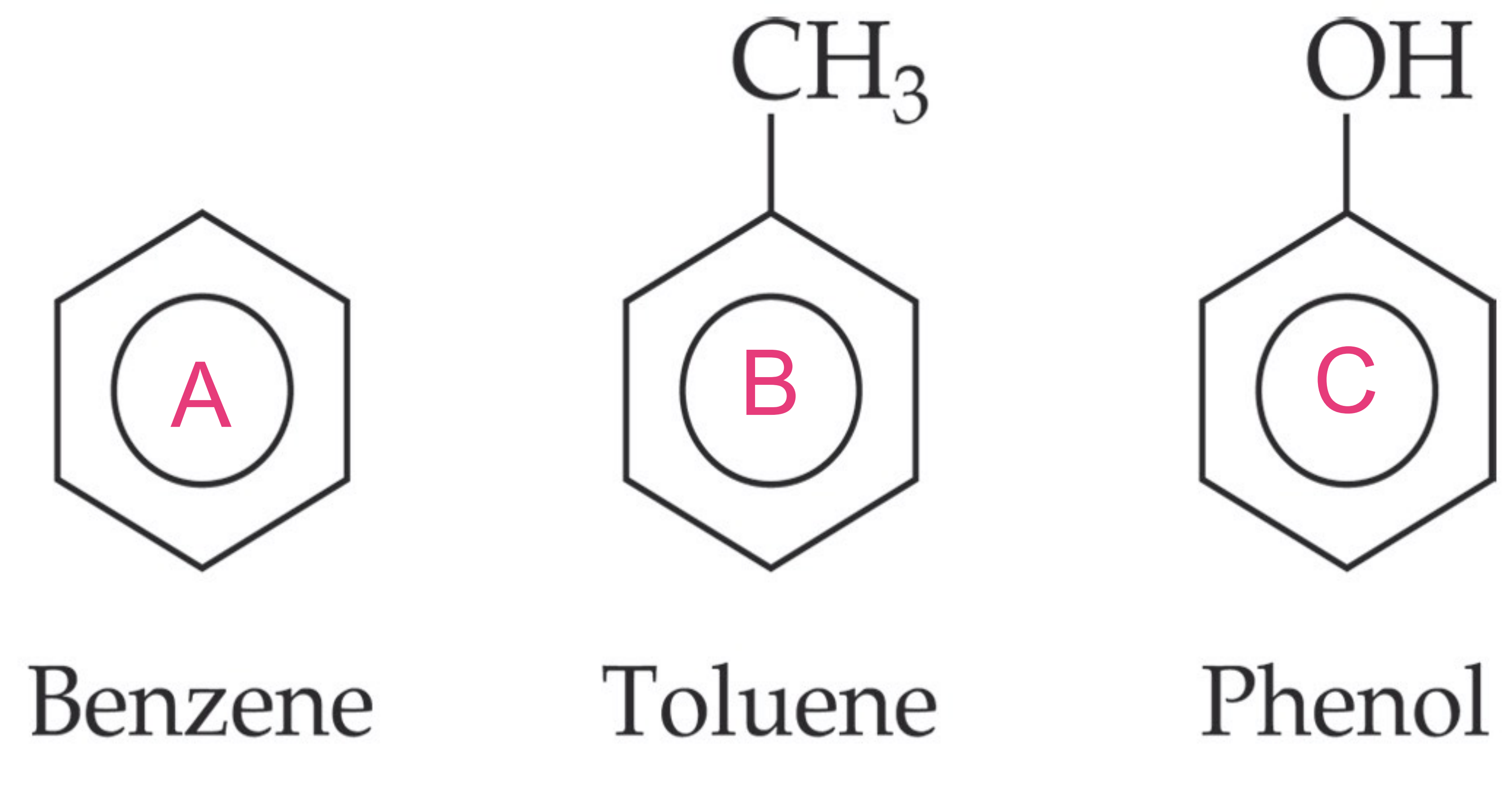
List the molecules in order of lowest to highest *melting* temp?

1. A < B < C
2. C < B < A
3. B < C < A
4. A < C < B
5. B < A < C
6. C < A < B



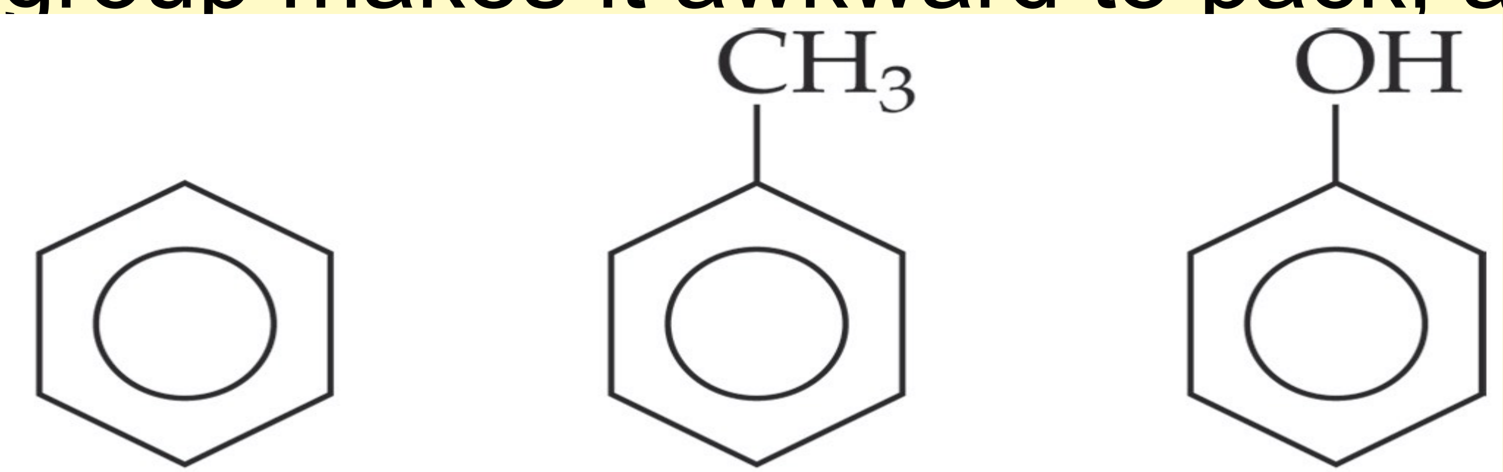
List the molecules in order of lowest to highest *melting* temp?

1. A < B < C
2. C < B < A
3. B < C < A
4. A < C < B
5. B < A < C
6. C < A < B



Molecular Solid Examples

- BP is affected by the IMF’s between molecules in the liquid phase.
- MP is affected by the IMF’s AND the efficiency of the packing ability.
- The H bonding in phenol beats all and makes it hard to boil and hard to melt.
- Toluene’s dispersion forces are greater than benzene making it’s boiling point higher, but it’s “dangling” methyl group makes it awkward to pack, and thus easier to melt.



	Benzene		Toluene		Phenol
	5	MP ºC	−95	MP ºC	43
	80	BP ºC	111	BP ºC	182

- Benzene’s dispersion forces are weakest making it have the lowest boiling point, but its very efficient packing makes it have a higher melting point than toluene.

What's so Ideal about the Ideal Gas Law?

$$PV = nRT$$

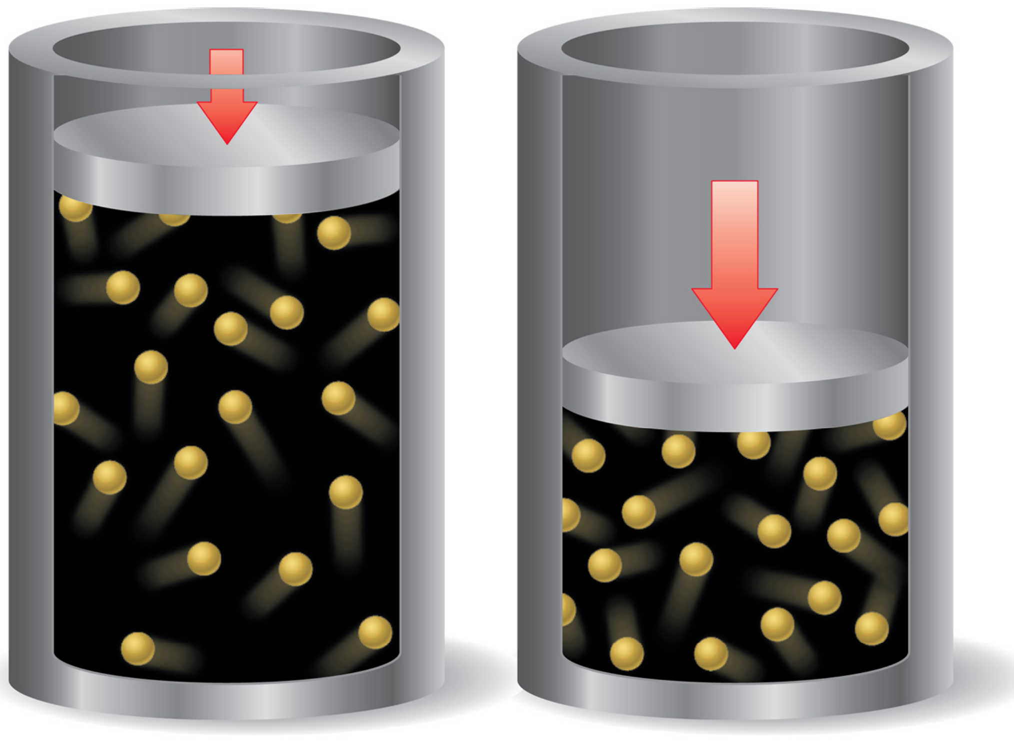
What's so ideal about The "Ideal" Gas Law?

- Kinetic Molecular Theory is dependent upon a gas behaving as if the gas particles have NO IMFs.
- KMT also considers gases to be "point masses," meaning the size of each atom is insignificant.
- When the two statements above are true, the gases behave "ideally."
- However, we know these two statements aren't always perfectly true.

Pressure can make Volume larger than predicted by the Ideal Gas Law??

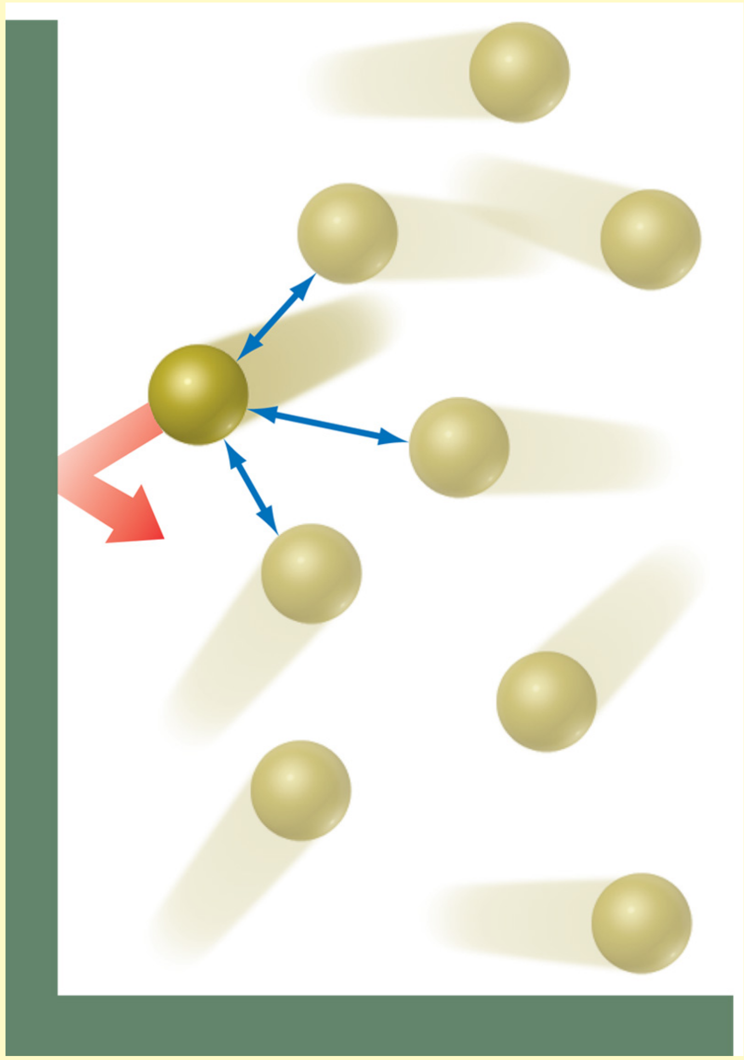
- Usually gas particles are far apart and their personal molecule size is irrelevant, however…
- when pressure is great enough and particles are "cramped" together, the actual size of the particle begins to matter.

- The volume of each individual particle can actually take up some space making the measured lab volume larger than the volume predicted by the ideal gas law.



IPFs can make Volume smaller than predicted by the Ideal Gas Law??

- At low enough temps
  or high enough pressures…
- The volume might measure smaller in the lab than predicted by the ideal gas law because the IMFs are playing a role.
- The molecules may begin top experience attraction and not push as hard as they “ideally should” causing less volume if in a flexible container. (or less pressure if in a rigid container)



Some gases do exhibit IMFs

- Order the IMFs from weakest to strongest for:
  - » N_2, CH_4, CO_2, H_2
  - » All of these gases are nonpolar, thus which would have the weakest to strongest dispersion forces?

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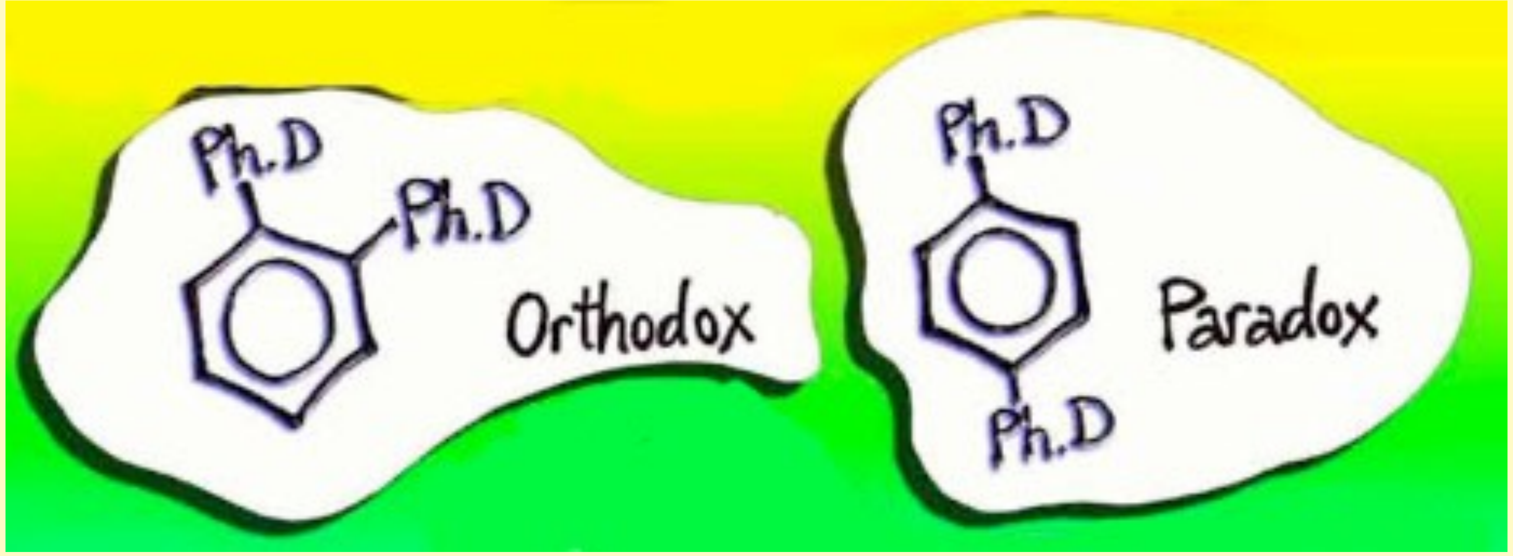
  - » $H_2 < N_2 < CH_4 < CO_2$

Do you remember these terms?

Ortho, Meta, Para



The End

Born Haber Diagrams

Determining Lattice Energy by Calculation, since LE is difficult to measure experimentally

Each of the processes below are measurable and represent some process. Identify all of the ΔH's below.

- $Na_{(s)} + \frac{1}{2}Cl_{2(g)} \rightarrow NaCl_{(s)}$ $\Delta H\_ = -411$ kJ
- $Na_{(g)} \rightarrow Na^{+}_{(g)} + 1e^{-}$ $\Delta H\_ = 496$ kJ
- $Cl_{2(g)} \rightarrow 2Cl_{(g)}$ $\Delta H\_ = 243$ kJ
- $Cl_{(g)} + 1e^{-} \rightarrow Cl^{-}_{(g)}$ $\Delta H\_ = -349$ kJ
- $Na_{(s)} \rightarrow Na_{(g)}$ $\Delta H\_ = 109$ kJ

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- $Na_{(g)} \rightarrow Na^+_{(g)} + 1e^-$ $\Delta H_{IE} = 496$ kJ
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- $Cl_{(g)} + 1e^- \rightarrow Cl^-_{(g)}$ $\Delta H_{EA} = -349$ kJ
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Lattice energy can not be measured directly, it must be calculated. Calculate the lattice energy for $NaCl_{(s)}$ using Hess' Law and the following information.

$NaCl_{(s)} \rightarrow Na^+_{(g)} + Cl^-_{(g)}$

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- $\frac{1}{2}Cl_{2(g)} \rightarrow Cl_{(g)}$ $\Delta H_{\frac{1}{2}BDE} = 121.5$ kJ
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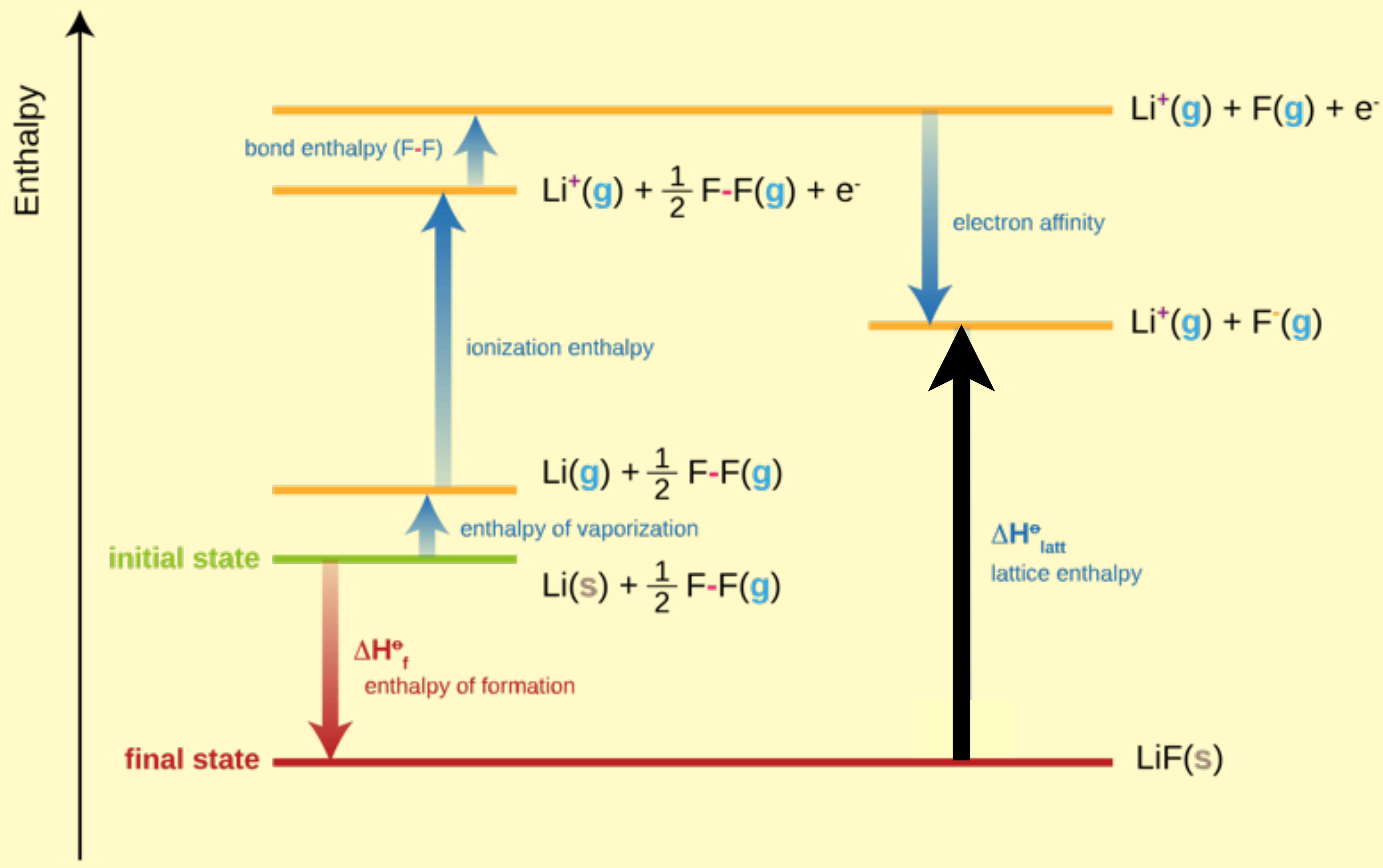
- +788.5 kJ (788 or 789)

Born Haber Diagram

- Using measurable processes to calculate a process that is not so easy to measure.



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