# Problem Set #16

CHEM101A: General College Chemistry

Donald Aingworth

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# 1 Topic H Problem 1

Classify each of the following substances as molecular, ionic, or metallic, and explain your answers. (There are no network covalent substances in this list.) Base your answers on the chemical formulas and the positions of the elements in the periodic table: you should not need to look up any additional information.

a) $Cl_2S$ b) $K_2S$ c) $H_2SO_4$ d) Fe e) He

## 1.1 Solution

a/ Cl and S are both nonmetals, so it is not metalic. Neither are natural cations, so it is not ionic. It is molecular.

b/ K is a natural cation and S is a natural anion, so it is ionic.

c/ No metals and the only natural cation is H, so it is molecular.

d/ It's a metal, so it's metallic.

e/ It's not a metal and not a cation or anion, so it must be molecular, although it si a noble gas.

# 2 Topic H Problem 2

Each of the following substances is a solid at room temperature. What would you expect to be the most important type of attractive force between individual formula units in each of these substances? Base your answers on the chemical formulas and the positions of the elements in the periodic table: you should not need to look up any additional information.

a) $CBr_4$ b) $CaBr_2$ c) Ca d) C

## 2.1 Solution

a/ Molecular bonding and London Dispersion Forces.

b/ Ionic bonding, but dipole-dipole bonds are also there.

c/ Metallic bonding.

d/ Covalent bonding.

# 3 Topic H Problem 3

For each of the following molecular substances, list all of the intermolecular forces that play a significant role in determining the physical properties of the substance. *Reminder: the three types of intermolecular forces are London dispersion forces, dipole-dipole attraction, and hydrogen bonding.*

a) $NH_3$ b) $N_2$ c) $NF_3$ d) $CH_4$ e) $CH_2O$

## 3.1 Solution

a/ LDFs and dipole-dipole (in the form of Hydrogen Bonds), so all three.

b/ LDFs.

c/ LDFs and dipole-dipole.

d/ LDFs.

e/ LDFs and dipole-dipole.

# 4 Topic H Problem 4

From each of the following pairs of compounds, select the compound that should have the higher boiling point, and explain your choice.

a) CO and BeO

b) NaF and MgO

## 4.1 Solution (a)

CO has LDFs and some dipole-dipole forces. BeO is held together by ionic bonds, so it would have stronger IMFs. For this reason, $\boxed{\text{BeO}}$ has the higher boiling point.

## 4.2 Solution (b)

Both molecules are metallic. NaF is made up of two atoms that naturally have a $\pm 1$ charge. MgO is made up of two atoms that naturally have a $\pm 2$ charge, so there would be stronger electrostatic forces between them. For this reason, $\boxed{\text{MgO}}$ would have the higher boiling point.

# 5 Topic H Problem 5

$\mathsf{HCl}$ is a strong electrolyte (as you already know!). Its melting point and boiling point are $-114°\text{C}$ and $-85°\text{C}$, respectively.

1. What state (solid/liquid/gas) is $\mathsf{HCl}$ in at room temperature?
2. A student concludes that $\mathsf{HCl}$ is an ionic compound, based on the fact that it ionizes completely in aqueous solution. Would you agree with this conclusion? If not, what sort of compound is $\mathsf{HCl}$? Be sure to discuss the melting and boiling points in your answer.

## 5.1 Solution (a)

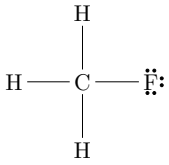
Gas.

## 5.2 Solution (b)

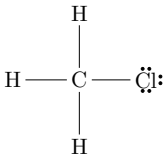
It's molecular. Hydrogen (especially $\mathsf{H}^+$ since it's just a proton) is weird. Chlorine, being a nonmetal, cannot form ionic bonds with Hydrogen, so it would have to be a molecular compound.

# 6 Topic H Problem 6

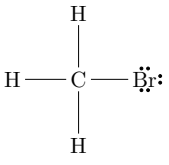
Using your knowledge of intermolecular forces, explain the trend in boiling points in the following series of compounds.



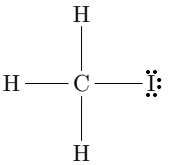
Fluoromethane
boils at $-78°C$



Chloromethane
boils at $-24°C$



Bromethane
boils at $4°C$



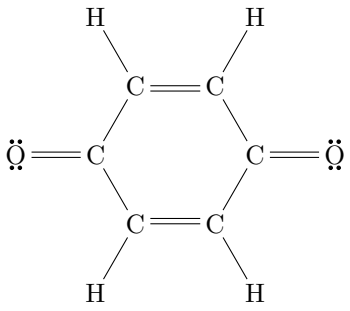
Idomethane
boils at $42°C$

## 6.1 Solution

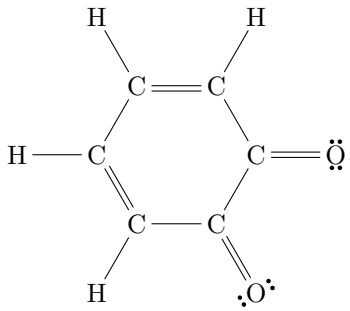
The only difference between these four is the group 7 element bonded with the Carbon, which is heavier the higher the boiling point is. Normally I would explain this with velocity from Kinetic Energy being dependent on mass, but that's not allowed here. Higher heaviness of atoms is resultant from higher amounts of protons, which leads to higher polarizability (manipulation of electron cloud shape). This in turn leads to stronger LDFs, which leads to a higher boiling point.

# 7 Topic H Problem 7

One of the compounds below boils at 70°C, while the other boils at 116°C. Which is which? Explain your reasoning.



compound 1



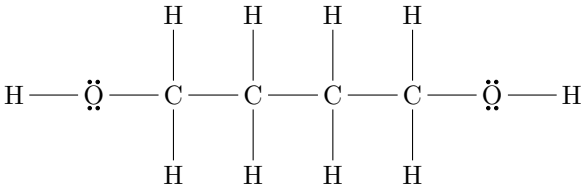
compound 2

## 7.1 Solution

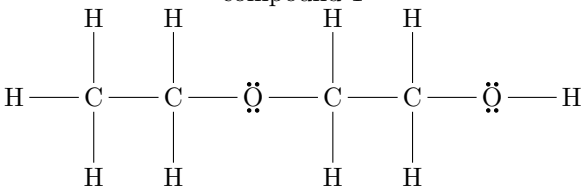
The one with the greater intermolecular forces will have the the higher boiling point. Both have the same composition and a similar structure. One has all Carbon-Oxygen combinations surrounded by Carbon-Hydrogen combinations, while the other has the Carbon-Oxygen combinations adjacent one another. The adjacency in Compound 2 leads to less symmatry in the molecule, which leads to an overall polarization of the molecule in one direction that is not canceled out. That leads to the dipole being stronger for compound 2 and as such the intermolecular forces. This leads to compount 2 having the higher boiling point. Compund 1 boils at 70°C, while compound 2 boils at 116°C.

# 8 Topic H Problem 8

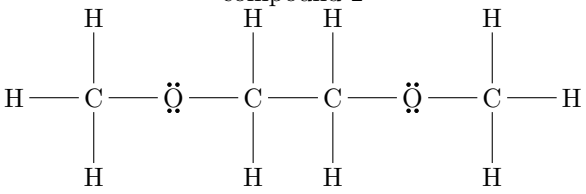
The following three compounds are isomers (they have the same chemical formula), but they have quite different boiling points: one boils at 82°C, one at 135°C, and one at 235°C. Match each substance with the correct boiling point, and explain your reasoning.



compound 1



compound 2



compound 3

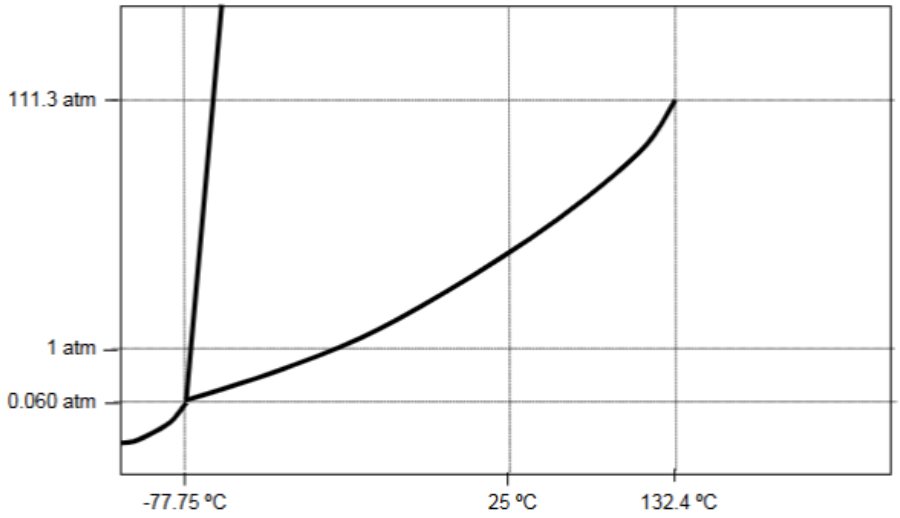
## 8.1 Solution

Compound 1 has 2 possible Hydrogen bonds. Compound 2 has 1 possible Hydrogen bonds. Compound 3 has 0 possible Hydrogen bonds. More possible Hydrogen bonds means a higher boiling point due to more intermolecular forces.

1. 82°C: Compound 3
2. 135°C: Compound 2
3. 235°C: Compound 1

# 9 Topic H Problem 9

The phase diagram for ammonia is shown below (not drawn to scale).




a) What state is ammonia in at 25°C and 1 atm?

b) What state is ammonia in at -80°C and 10 atm?

c) What are the temperature and pressure at the triple point of ammonia?

d) What are the temperature and pressure at the critical point of ammonia?

e) If you heat ammonia from $-100°C$ to 150°C at a pressure of 5 atm, what states will you observe?

f) If you heat ammonia from $-100°C$ to 150°C at a pressure of 0.01 atm, what states will you observe?

g) A container holds ammonia at $-77.70°C$ and a pressure of 0.010 atm. If the pressure is increased to 150 atm without changing the temperature, what states will you observe?

h) If you increase the temperature of ammonia from 125°C to 175°C at a pressure of 200 atm, what states will you observe?

## 9.1 Solution

a/ Gas

b/ Solid, although it would be close to liquid

c/ 0.060 atm and $-77.75°C$

d/ 111.3 atm and 132.4°C

e/ Solid, then melting to liquid, then evaporation to gas.

f/ Solid, then sublimation to gas.

g/ Gas, then condensation to liquid, then fusion to solid.

h/ Only liquid, but it would go to a point where liquid and gas are indistinguishable.

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