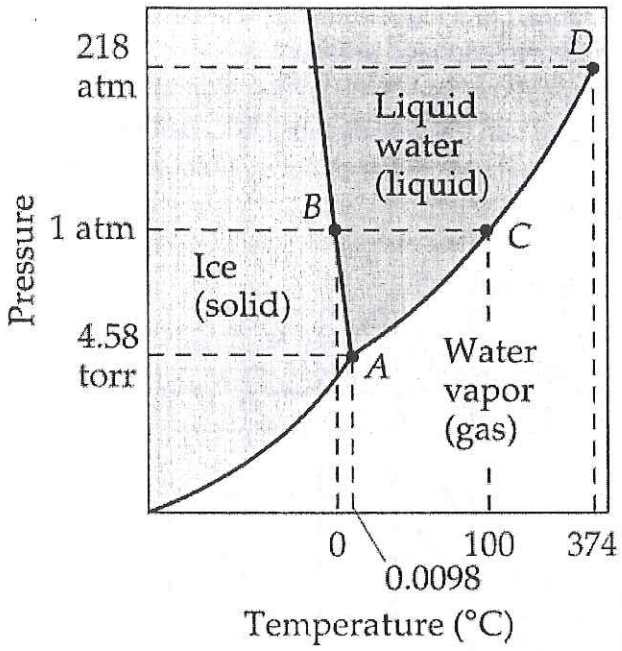
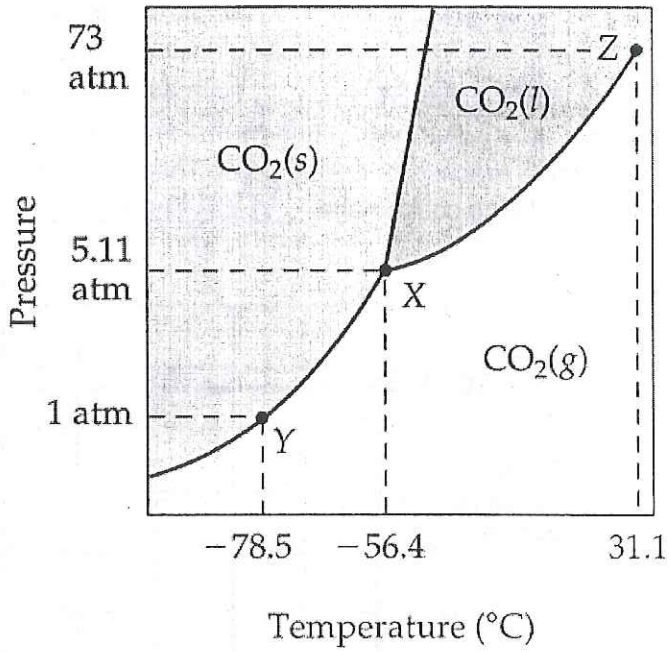
Phase Diagrams:

Comparing H_2O (left) and CO_2 (right)





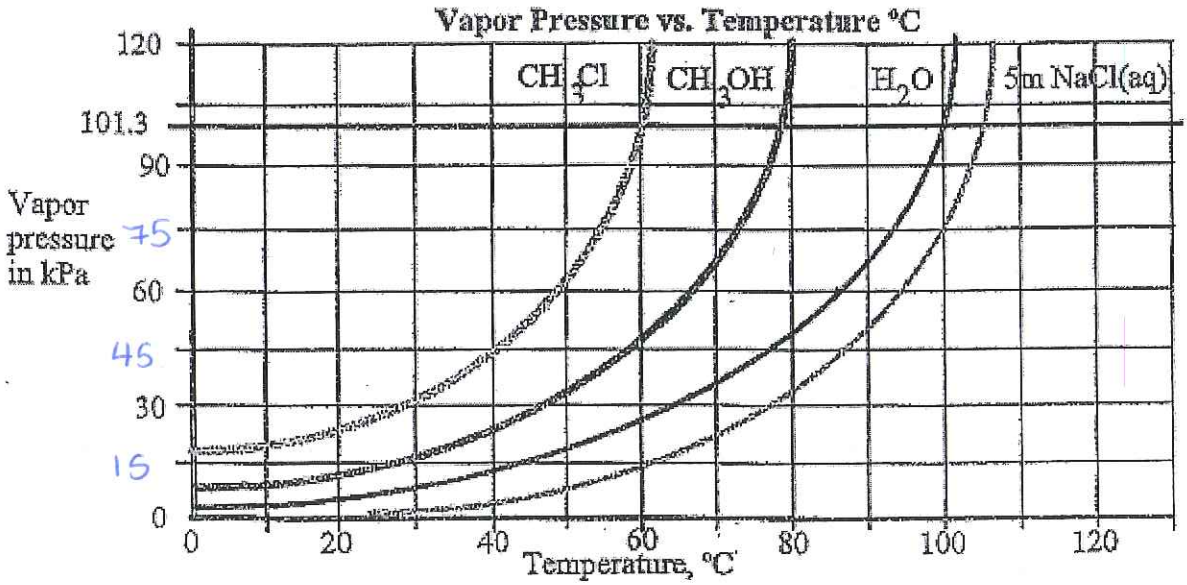
Directions: Answer the following questions regarding the two phase diagrams of H_2O and CO_2 above:

1) liquid — State of matter water at 0.8 atm and 50°C
2) s→g sublimation — Phase change for CO_2 as temperature increases from -90°C to RT at 1atm.
3) water — Which substance has the higher ΔH of vaporization?
4) l→g vaporization — Phase change for CO_2 as ΔT goes from -40°C to 100°C at 6atm.
5) solid (pos. slope) — For CO_2 which phase has the greater density, liquid or solid?
6) 0.0098°C, 4.58 torr — At what minimum temperature and pressure can H_2O exist as a liquid?
7) s→l melting — Effect of increasing pressure on the state of matter of H_2O at 1 atm and 0°C?
8) increased BP — Effect of increasing pressure on the boiling points of water and CO_2?
9) solid — What state of matter is CO_2 at 20 atm and -70°C?
10) 374°C — Temperature of the critical point of H_2O (no liquid/gas phase boundary exists)
11) CO_2 — Which of the two substances has the greater vapor pressure at 25°C?
12) increased — Pressure must be (increased/decreased) in order to liquefy water at 140°C.
13) CO_2 — Which substance is more volatile?
14) g→s deposition — Process in which CO_2 is cooled at 1atm from RT to -100°C
15) liquid (neg. slope) — For H_2O, which phase has a greater density, liquid or solid?
16) lower — Increased pressure will (lower/raise) the melting point of water.
17) hydrogen bonding — What IMFs account for water's high boiling point?
18) NO — Does CO_2 have a normal melting point? Explain in the space below.

At 1 atm, the only phase equilibrium is between solid and gas, therefore it only has a normal sublimation point.

IMFs and Changes in States of Matter

1) The normal boiling point of a liquid is the temperature at which the vapor pressure of the escaping liquid molecules is equal to (or greater than) standard atmospheric pressure of 101.3 kPa. Liquids that have stronger intermolecular attractions must be heated to a higher temperature before boiling will occur. The boiling point of a liquid is lowered when the atmospheric pressure is decreased, such as in the Rocky Mountains (high above sea level). When atmospheric pressure increases, such as in a pressure cooker, the temperature can get well above 100°C before water reaches its boiling point. Therefore, food cooks faster in a pressure cooker or covered pot because it is being cooked at a higher temperature.

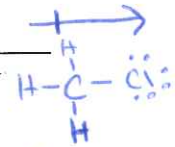


Directions: Answer the following questions using the graph above:

2) What is the boiling point of water at an external pressure of 60 kPa? 85°C

3) a. Which liquid has the strongest intermolecular forces? NaCl

b. What type of IMFs hold molecules of the substance together? ionic bonding



4) a. Which liquid has the weakest intermolecular forces? CH_3Cl

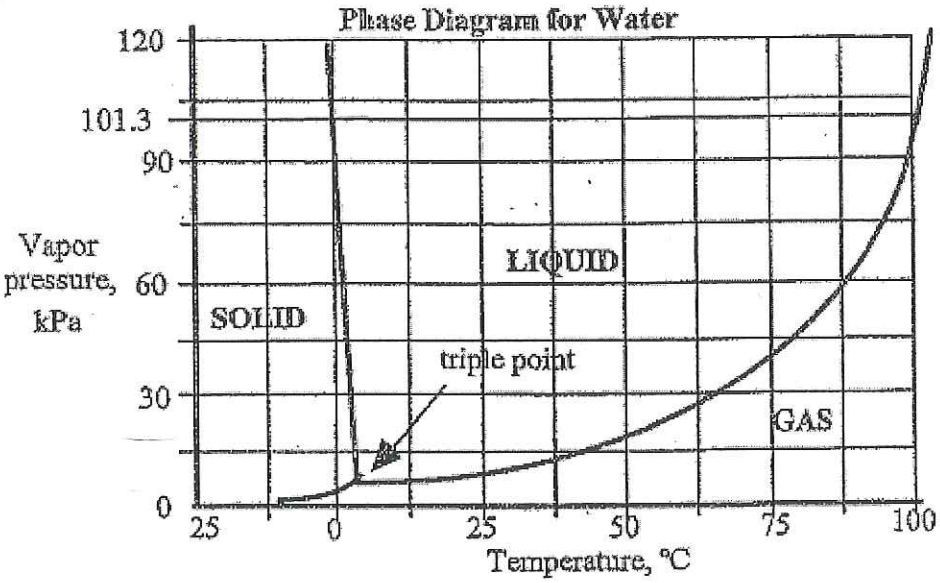
b. What type of IMFs hold molecules of this substance together? dipole - dipole forces

5) What is the vapor pressure of methanol, CH_3OH, at a temperature of 25°C? 15 kPa

6) Many chefs add salt to water when they are cooking. Beside the addition of flavor, what effect does the addition of salt, NaCl, have on the normal boiling point of water? Explain this in terms of IMFs exhibited between pure boiling water versus boiling water with salt.

Adding NaCl to H_2O will increase the normal BP of water. This is because, before the addition of NaCl, H_2O molecules can only experience hydrogen bonding. Once NaCl is added, ion-dipole forces are the predominant IMFs and, since these are stronger than H-bonds, the BP will increase. (6)

7) A phase diagram summarizes the relationships among temperature, pressure, and the physical state of a particular substance. Each line represents the conditions at which a phase change occurs. There is a point where all three states of matter are in equilibrium with each other. This is called the triple point.



Directions: Answer the following questions using the phase diagram for water shown above:

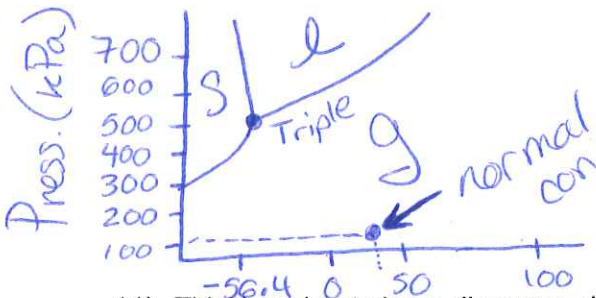
8) What happens to ice at 0°C when the blade from an Olympic ice skater increases the pressure exerted on the ice to 450 kPa?

The ice will liquify due to increased pressure at the same temp of 0°C.

9) Explain what changes occur when an ice cube at –5°C is placed in a vacuum and the atmospheric pressure is reduced to almost 0 kPa.

The ice will sublime from a solid to a gas when pressure is reduced at -5°C.

10) A particular substance has a triple point that occurs at 518 kPa and –56.4°C. Sketch a phase diagram of this substance based on this its triple point. What state of matter will this substance exist in at normal laboratory conditions (standard temperature and pressure)?



normal lab conditions = 25°C & 101.3 kPa

Under normal lab conditions the substance will be a gas.

11) Thinking about phase diagrams, describe 2 changes you would make in laboratory experimental conditions in order to liquefy any gas.

(1) Increase external pressure

(2) Decrease temperature.