1 Morning class week 5 day 4: phase diagrams

1. **Phase diagrams**, like the one below left, tell the reader the physical form a pure substance adopts at equilibrium and at a specified temperature and pressure. Phase diagrams illustrate:

   (a) The region where the pure substance is a gas,

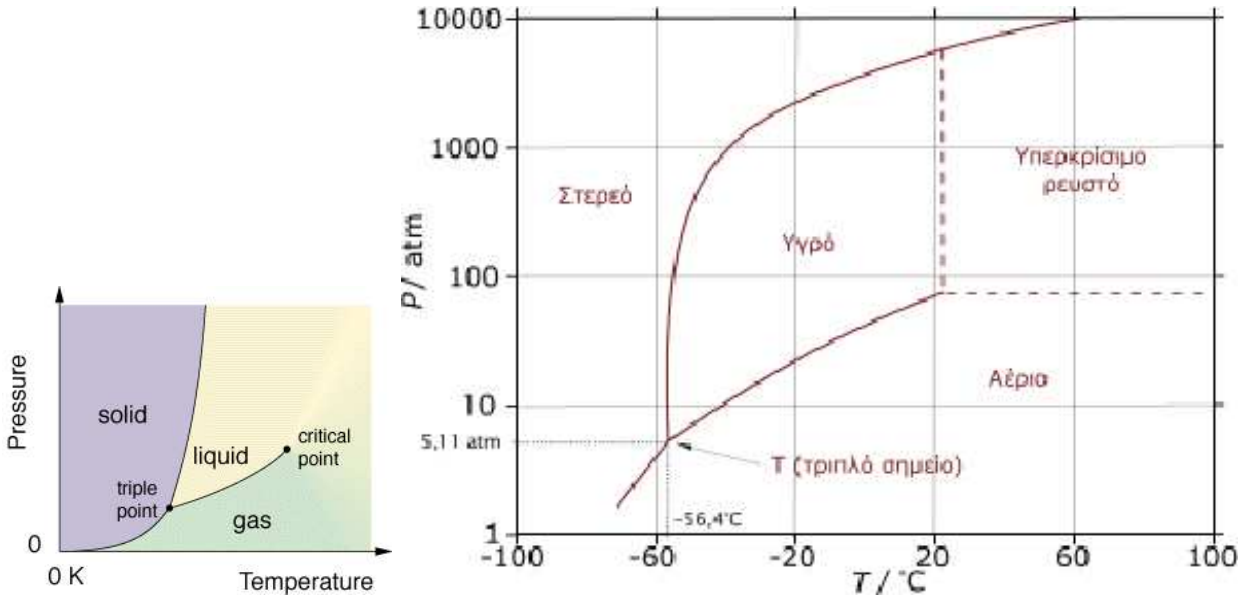
   (b) The region where the pure substance is a liquid, and

   (c) The region where the pure substance is a solid.

   (d) Lines indicate where solid/gas, solid/liquid or gas/liquid mixtures (at equilibrium) can co-exist.

   (e) The triple point specifies the only temperature and pressure where solid, liquid, and gas can all co-exist. It is the United Nations of Phases.

   (f) Beyond a *critical point* we can no longer see a difference between liquids and gases. Beyond this critical point, the compound is a *supercritical fluid*. Miscellaneous information: The theory of the critical point came originally from both the chemistry and physics department at Cornell. A Nobel prize in physics was awarded to Kenneth Wilson for this achievement.



2. The phase diagram, above right, was taken from the Greek Wikipedia site. Without consulting a greek-english dictionary, please translate each of the greek words in the diagram.

   (a) What is the temperature and pressure of the critical point?

   (b) At room temperature and pressure is the substance a gas, solid, or liquid?

   (c) Assume you have a sample of this compound at room temperature and pressure. (Room temperature is 25 ^{o}C. Would you have to increase temperature or pressure to turn this substance into a supercritical fluid?

   (d) At 10 atm pressure, for what temperature can the substance be a mixture of solid and liquid? of liquid and gas?

   (e) If you heat a solid sample of this compound at 1 atm pressure, does the substance turn directly from a solid to a liquid? (You will have to extrapolate the data in this curve to find the answer to your question.

(f) Is the substance whose phase diagram is reported in this phase diagram: H_2O, octane (one of the main molecules in gasoline), CO_2, or ethyl alcohol?

(g) Try your hand at reading greek. The word steric refers to solid bulk in chemistry. What greek word does steric appear to come from? What english word does the greek word gas appear to be related to? Remember Σ, ρ, and τ are the greek letters S, r, and t.

3. The phase diagram below is that of H_2O. Pressure is given in a log scale. Units are Pa, or Pascals eg., MPa are MegaPascals. Temperature is in Kelvin. Ice has a number of different crystal structures, each is labelled in this diagram.

(a) Use your knowledge of the ordinary boiling point of water to find the conversion factor between atmospheres and Pascals.

(b) Is the critical point for H_2O above or below 1 atmospheres?

(c) Ice has a number of different crystal structures. What is the name of the solid ice which we have in our fridges?

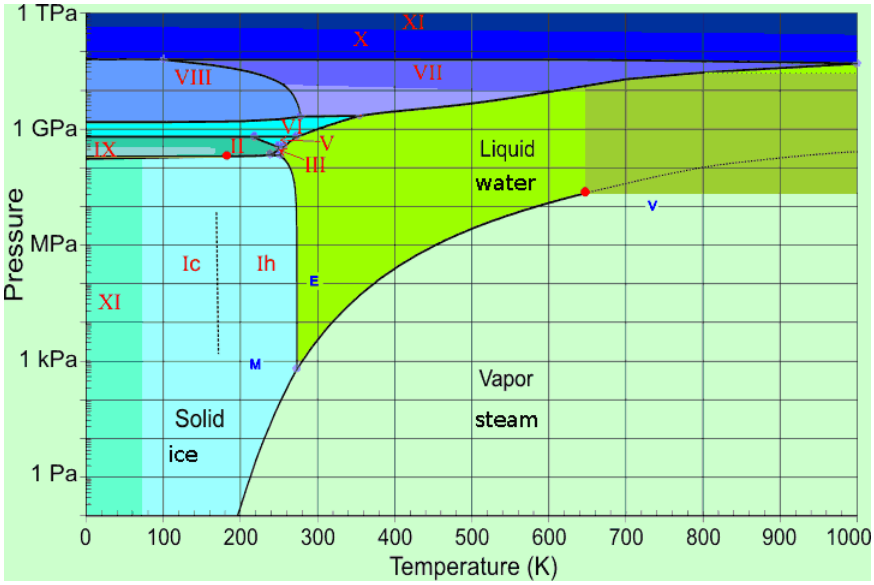
(d) When one increases the temperature, one increases the energy. This energy is used to break apart the intermolecular interactions. Are there more hydrogen bonds in water or ice?

(e) Are there more hydrogen bonds in steam or water?

(f) Assuming pressure is constant, is there a pressure where increasing temperature results in a sample turning from a liquid into solid? Please explain your answer.

(g) Is there a constant temperature where increasing pressure results in a solid turning into a liquid and then at even higher pressure back into a solid? Please explain your answer.

(h) Increasing the pressure increases the density. Which ice is denser: XI, Ic, or Ih?



4. On a hot humid day on the beach, there is both water liquid and water vapor. How is this possible?

5. Draw pictures of ice, water, and steam. In order to make drawing easier, assume that all the molecules are in the same 2-D plane. Include at least six molecules in each of your drawings. Your drawings should indicate where the atoms in the different H_2O molecules are located. Lone pairs should be indicated. Covalent bonds should be represented as solid lines and hydrogen bonds as dotted lines.