ChemQuest 4

Phase Diagrams

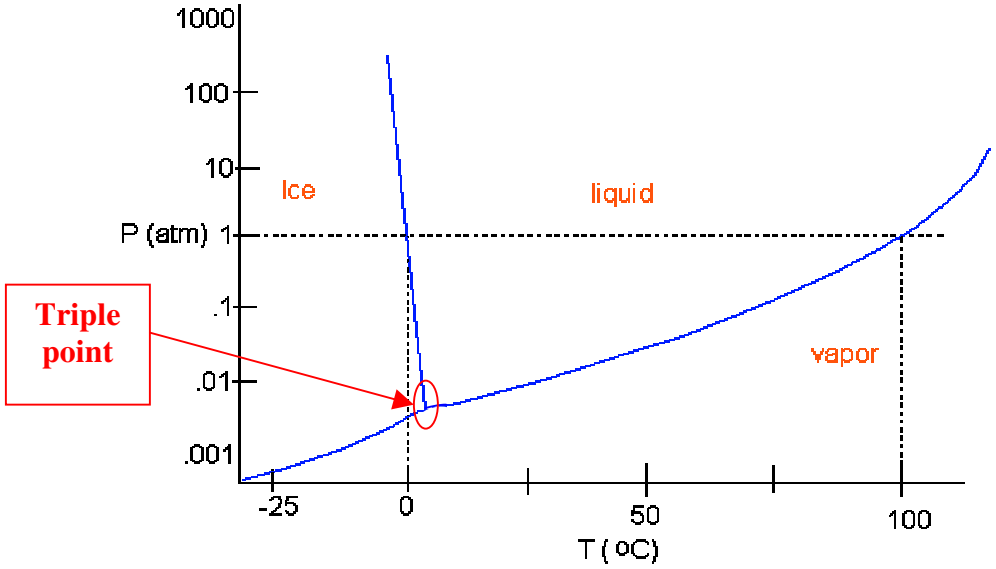
Name: _____

Date: _____

Hour: _____

Information: Phase diagrams

Figure 1: Phase diagram for water. Note that the unit for pressure on the diagram is atmospheres (atm). Another unit is the kilopascal (kPa). Standard pressure is the pressure at sea level and it is equal to 1 atm, which is equivalent to 101.325 kPa. Standard temperature is 273 Kelvin (K), which equals 0°C. The abbreviation STP is used for "standard temperature and pressure" and it denotes a temperature of 0°C and 1 atm (or 273K and 101.325 kPa).



A phase diagram is a graph that illustrates under what conditions the states of matter exist. For example, in the phase diagram of water above, it should be noted that at 1 atm (which equals 101.325 kPa) of pressure and 50 °C, H_2O exists as a liquid. The dark solid lines represent the boundaries between different states. The term "vapor" is used instead of "gas" because vapor describes a substance that is normally a liquid at STP. The line that divides the liquid area from the vapor area has a special name: the vapor pressure curve. (The vapor pressure of water at any given temperature can be found looking at the vapor pressure curve.) To the left of the line, liquid exists. To the right of the line, vapor (gaseous H_2O) exists. Right on the line, for example when the pressure is 1 atm and the temperature is 100°C, both liquid and vapor exist at the same time. When two or more things coexist at the same time it is called "equilibrium". During equilibrium, liquid changes to vapor and vapor changes to liquid all at the same time and rate.

Critical Thinking Questions

1. When a substance melts, what happens to the motion of the molecules of the substance?
The molecules begin to move faster and get farther apart.

2. What is the freezing point and boiling point of water when the pressure on the water is 1 atm? (I.e. at what temperature will the water freeze and boil when the pressure is 1 atm?)

Freezing point = 0°C; Boiling point = 100°C

3. How does lowering the pressure affect the boiling point?

The boiling point also gets lower.

4. Estimate the boiling point of water when the pressure on the water is 0.1 atm.

Approximately 73°C.

5. The triple point of a substance is the conditions under which a solid, liquid and gas all exist in equilibrium. On the phase diagram of water, label the location of the triple point.

See diagram.

6. Dry ice sublimes; that is, it changes directly from a solid to a gas. Is it ever possible for ice to sublime? If so, describe the conditions necessary for sublimation to occur.

Yes, ice will sublime at pressures below approximately 0.007 atm.

7. What is meant by the "vapor pressure" of water?

The pressure that gaseous water exerts, or, the force that water molecules exert after the molecules have evaporated.

8. From the phase diagram, estimate the vapor pressure of water at 25 °C.

Approximately 0.01 atm.

9. What is the vapor pressure of water when the temperature is 100 °C?

Approximately 1 atm.

10. When the atmospheric pressure equals 1 atm, what is the boiling point of water?

100°C

11. From your answers to questions 9 and 10, formulate a definition for boiling point in terms of atmospheric pressure and vapor pressure of the liquid.

The boiling point is the temperature at which the vapor pressure of a liquid equals the atmospheric pressure. As the atmospheric pressure decreases, so does the liquids vapor pressure and, thus, the boiling point will also decrease.

12. Is it ever possible for solid H_2O to exist at a temperature above 0 °C?

Yes, at lower pressures (pressures below 1 atm).

13. Is it ever possible for solid H_2O to exist at a temperature above 25 °C?

No, there is no solid region on the phase diagram at any temperature above roughly 5°C.

14. Describe the region where a solid-liquid equilibrium exists.

A solid liquid equilibrium exists along the line that divides the liquid region from the vapor region.

15. Why might an equilibrium situation be described as a "reversible change"?

Equilibrium describes a situation where two equal and opposite processes occur at the same rate. In this case, water evaporates and some vapor condenses, thereby "reversing" the change.