PHASE CHANGES

1. What is a phase? Phase change? Name all the possible changes that can occur among the gas, liquid, and solid phases of a substance.

2. What is equilibrium vapor pressure of a liquid? How is it measured and how does it change with temperature?

3. Use any one of the phase changes to explain what is meant by dynamic equilibrium.

4. Define the following terms and identify their units:
   a. Molar heat of vaporization
   b. Molar heat of fusion
   c. Molar heat of sublimation

5. How is the molar heat of sublimation related to the molar heats of vaporization and fusion? On what law are these relationships based?

6. What can we learn about the intermolecular forces in a liquid from the molar heat of vaporization?

7. Define boiling point. How does the boiling point of a liquid depend on external pressure?

8. Calculate the amount of heat (in kJ) required to convert 74.6 g of water to steam at 100°C.

9. How much heat (in kJ) is needed to convert 866 g of ice at −10°C to steam at 126°C? (The specific heats of ice and steam are 2.03 J/g°C and 1.99 J/g°C, respectively.)

10. Calculate the heat released when 68.0 g of steam at 124°C is converted to water at 45°C.

11. How is the rate of evaporation of a liquid affected by (a) temperature, (b) the surface area of a liquid exposed to air, (c) intermolecular forces?

12. The molar heats of fusion and sublimation of molecular iodine are 15.27 kJ/mol and 62.30 kJ/mol, respectively. Estimate the molar heat of vaporization of liquid iodine.

13. The following compounds, listed with their boiling points, are liquid at −10°C: butane, −0.5°C; ethanol, 78.3°C; toluene, 110.6°C. At −10°C, which of these liquids would you expect to have the highest vapor pressure? Which the lowest? Explain.

14. A phase diagram of water is shown to the right.
   a. Label the regions
   b. Explain how water phase diagram differs from those of most substances. What property of water causes the difference?
   c. Predict what would happen as a result of the following changes
      i. Starting at A, we raise the temperature at constant pressure
      ii. Starting at C, we lower the temperature at constant pressure
      iii. Starting at B, we lower the pressure at constant temperature
15. The phase diagram of sulfur is shown to the right.
   a. How many triple points are there?
   b. Monoclinic and rhombic are two allotropes of sulfur. Which is more stable under atmospheric conditions?
   c. Describe what happens when sulfur at 1 atm is heated from 80°C to 200°C.

16. Which phase diagram corresponds to a substance that will sublime rather than melt as it is heated at 1 atm?

17. Referring to figure 11.41 (page 506) determine the stable phase of CO2 at
   a. 4 atm and −60°C
   b. 0.5 atm and −20°C

18. The vapor pressure of a liquid in a closed container depends on which of the following?
   a. The volume above the liquid
   b. The amount of liquid present
   c. Temperature
   d. Intermolecular forces between the molecules in the liquid

19. A beaker of water is placed in a closed container. Predict the effect on the vapor pressure of the water when (a) its temperature is lowered (b) the volume of the container is doubled (c) more water is added to the beaker.

20. A sample of limestone (CaCO3) is heated in a closed vessel until it is partially decomposed. Write an equation for the reaction and state how many phases are present.

21. Given the phase diagram of carbon shown, answer the following questions:
   a. How many triple points are there and what are the phases that can coexist at each triple point?
   b. Which has a higher density, graphite or diamond
   c. Synthetic diamond can be made from graphite. Using the phase diagram, how would you go about making diamond?

22. Why do citrus growers spray their trees with water to protect them from freezing?

23. The compound dichlorodifluoromethane (CCl2F2) has a normal boiling point of −30°C, a critical temperature of 112°C, and a corresponding critical pressure of 40 atm. If the gas is compressed to 18 atm and 20°C, will the gas condense? Your answer should be based on a graphical interpretation.