

Solutions to Even-Numbered Exercises:

- 6.2 All matter would exist only in the solid state. No matter would be present in either liquid or gaseous form.
- 6.4 The evaporation of a liquid is the transition between a partially disordered structure of molecules that are in contact to a completely disordered arrangement of molecules that are very far apart. Adding energy to the system to overcome the strong secondary attractive forces in the liquid effects this transition.
- 6.6 False. The temperature of a liquid boiling in an open beaker will remain constant until all the liquid is transformed to a gas. Consequently, the vapor pressure, which is a function of temperature, must also remain constant during the transition.
- 6.8 Because there is so much room between the molecules in a gas, the gas volume is easily reduced.

- 6.10 To melt a solid only a portion of the secondary attractive forces must be overcome; the solid simply becomes disordered. To vaporize a liquid, all secondary attractive forces must be overcome. This requires more energy than that required for melting.
- 6.12 True. Vapor bubbles appear throughout a liquid at its normal boiling point. Vapor bubbles can remain stable only when the vapor pressure is equal to atmospheric pressure.
- 6.14 1.44 kcal of heat will be released.
- 6.16 The boiling points of liquids whose molecules interact by hydrogen bonds will in general be higher than those whose molecules interact by London forces because more thermal energy (= higher temperature) is required to break the stronger hydrogen bonds.
- 6.18 Hydrogen bonds require an H covalently bonded to an O, N, or F. Answer c is the only pair where this occurs in both compounds.
- 6.20 Each of these molecules has only London Dispersion forces as intermolecular forces. Molecules with higher molecular weight have the stronger London Dispersion forces, therefore, $C_8H_{18} > C_6H_{14} > C_4H_{10} > C_3H_8$.
- 6.22 Carbon dioxide is a linear molecule. The C-O dipoles are directly opposed to each other, so the net dipole moment is zero.
- 6.24
- | | London force | Dipole–dipole | Hydrogen bond |
|---------|--------------|---------------|---------------|
| CCl_4 | Yes | No | No |
| CHF_3 | Yes | Yes | No |
| H_2O | Yes | Yes | Yes |
- 6.26 (b) has the greater heat of vaporization because it can form hydrogen bonds between molecules, whereas (a) cannot.

LIQUIDS

- 6.28 The molecules of a solid do not have sufficient kinetic energy to overcome the attractive forces holding them in fixed positions and must remain in orderly contact.
- 6.30 Yes, evaporation is the transformation of a liquid into a gas and therefore requires energy. That energy must come from the surroundings.
- 6.32 When a liquid evaporates, all attractive forces are overcome and the molecules of its vapor take up all the room of its container. The volume of the vapor is many times greater than the volume of the same mass of the liquid from which it is formed.
- 6.34 Under normal conditions of room temperature, both the liquid and gaseous forms of water and ethanol are present. Therefore, the gaseous forms of both substances at room

temperature are called vapor.

- 6.36 $a \rightarrow c \rightarrow b$ These are ordered by increasing strength of intermolecular forces, ionic > hydrogen bond > London dispersion forces.
- 6.38 Yes. In a closed container the rate of evaporation must be equal to the rate of condensation, and equilibrium will be established.
- 6.40 A dynamic equilibrium is one in which the state of the system remains constant as the result of two active opposing processes that are the reverse of each other.
- 6.42 Yes. Boiling occurs when the vapor pressure of the liquid is equal to the external or atmospheric pressure. The vapor pressure of water at 25°C is 23.8 mm. If water is contained in a closed vessel, and the gas pressure in the vessel is reduced to 23.8 mm, the water will boil at 25°C. Water boils at 94°C in mile-high Denver, Colorado, where the atmospheric pressure is much lower than at sea level.
- 6.44 Water molecules interact through both dipole–dipole forces and hydrogen bonds while hexane can interact only by London forces. The secondary attractive forces between water molecules are much stronger than those in hexane, and water will consequently have a higher surface tension.
- 6.46 A crystalline solid has a definite geometric shape, has a definite melting point, and can shatter into small pieces that resemble the original crystal.
- 6.48 $\text{H}_2\text{S} < \text{H}_2\text{O} < \text{KCl}$ These are ordered by decreasing strength of secondary forces, dipole–dipole < hydrogen bond < ionic forces.
- 6.50 $\frac{12.3}{23.6} = .52 \times 100 = 52\%$
- 6.52 Molecules that interact by London dispersion forces do not have a dipole moment, and are usually symmetric. Examples include H_2 , CCl_4 , and CH_4 .
- 6.54 Denver is at an elevation of 1 mile and, therefore, its atmospheric pressure is less than one atmosphere. This means that water will boil at a lower temperature than at sea level because the vapor pressure of H_2O will reach atmospheric pressure at a lower temperature. It will take longer for an egg to solidify at this lower temperature.
- 6.56 Rubbing alcohol is a volatile liquid. Its evaporation from an open system (skin) is rapid and requires heat. The skin provides the heat and in the process is cooled.
- 6.58 This substance undergoes sublimation at room temperature and atmospheric pressure. Therefore, its vapor is present at concentrations that can be detected by the human nose because of its distinctive odor.
- 6.60 Extrapolating the curve shows that water will boil at 93°C when you are at 8,000 feet.

- 6.62 They all form covalent crystals.
- 6.64 Although ethanol can form hydrogen bonds and hexane cannot, the molecular mass of hexane is so much greater than that of ethanol that the London forces between hexane molecules exceeds the secondary forces between the ethanol molecules.
- 6.66 (a) Boiling point, (c) vapor pressure, and (d) surface tension are each a property of liquids and depend on the type of secondary forces between molecules. (b) Melting point can also depend upon primary chemical bonds as in diamond.
- 6.68 To melt a substance, the secondary attractive forces are only loosened, so that the order is reduced, but the molecules are still largely in contact with each other, and the liquid is about as incompressible as the solid.
- 6.70 If the relative humidity is low enough, the frozen water will vaporize or sublimate.
- 6.72 An emulsion consists of colloidal size drops of one liquid dispersed in another liquid with which it is immiscible.