Chapter 7

States of Matter and Changes in State

1. A weather report indicates a barometric pressure of 29.2 in. What is this pressure expressed in torr?

$29.2 \text{ in} \times \frac{25.4 \text{ mm}}{1 \text{ in}} = 742 \text{ mm Hg} = 742 \text{ torr}$

3. If the gas in Exercise 2 is heated to 35 ^{o}C, what would be the separation between the two mercury levels?

Write the gas law for the two experiments: $P_1V = nRT_1$ & $P_2V = nRT_2$

V,n, and R are not subscripted because they are unchanged.

Dividing the two equations eliminates V, n, and R to yield $\frac{P_1}{P_2} = \frac{T_1}{T_2}$, so $P_2 = P_1 \times \frac{T_2}{T_1}$

$T_2 = 273 + 35 = 308$, $T_1 = 273 + 20 = 293$, and $P_1 = 758 + 423 = 1181$ mm from Exercise 2, so

$P_2 = 1183 \text{ mm} \times \frac{308}{293} = 1241$ mm, and the height of the column = 1241 - 758 = 483 mm

5. Convert the following temperatures to the Celsius scale: Use K = °C + 273.15

a) 4 K = -269°C **b) 350 K** = 77°C **c) 186.4 K** = -86.8°C **d) 657 K** = 384°C

7. What is the pressure inside a 7.20-L container filled with 0.254 moles of CO_2 at 35 ^{o}C?

$$P = \frac{nRT}{V} = \frac{(0.254)(0.0821)(308)}{7.20} = 0.892 \text{ atm}$$

9. The pressure of air in a tire at 10 ^{o}C is 22 psi. After several miles of driving at high speed, the pressure is 28 psi. Assume the volume of the tire is unchanged and calculate the temperature of the air in the tire.

The number of moles of gas, its volume and the ideal gas law constant are all unchanged so we can write

$\frac{nR}{V} = \frac{P_1}{T_1} = \frac{P_2}{T_2}$ or $T_2 = T_1 \times \frac{P_2}{P_1}$, $T_1 = 10 + 273 = 283$ K, $P_1 = 22$ psi, and $P_2 = 28$ psi. Note we can use any units for the two pressures as long as they are the same because the ratio of pressures is unitless.

$T_2 = 283 \times \frac{28}{22} = 360$ K which is 360 - 273 = 87 ^{o}C

11. Determine the concentrations of the following gases in moles/L:

a) 3.0 moles of gas at 900 K and 2.6 atm

First, determine the volume: $V = \frac{nRT}{P} = \frac{(3.0 \text{ mol})(0.0821 \text{ L} \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1})(900 \text{ K})}{2.6 \text{ atm}} = 85 \text{ L}$

Then determine the concentration: $[\text{gas}] = \frac{n}{V} = \frac{3.0 \text{ mol}}{85 \text{ L}} = 0.035 \text{ mol/L} = 0.035 \text{ M}$

b) 6.2 L of a gas at 250 °C and 800 torr

First, determine the number of moles: $n = \frac{PV}{RT} = \frac{(\frac{800}{760} \text{ atm})(6.2 \text{ L})}{(0.0821 \text{ L} \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1})(523 \text{ K})} = 0.15 \text{ mol}$

Then determine the concentration: $[\text{gas}] = \frac{n}{V} = \frac{0.15 \text{ mol}}{6.2 \text{ L}} = 0.025 \text{ mol/L} = 0.025 \text{ M}$

c) 4.0 g of Ne in a 0.56 L container at 200 °C.

First determine the number of moles: $4.0 \text{ g Ne} \times \frac{1 \text{ mole}}{20.18 \text{ g}} = 0.20 \text{ mol Ne}$

Then determine the concentration: $[\text{Ne}] = \frac{n}{V} = \frac{0.20 \text{ mol}}{0.56 \text{ L}} = 0.35 \text{ mol/L} = 0.35 \text{ M}$

13. What are the partial pressures of O_2 and N_2 and the total pressure in a 3.5-L flask at 77 °C that contains 4.0 g O_2 and 7.0 g N_2? Express your answer in torr.

Convert the masses into moles, then use the ideal gas law to determine the partial pressures of the gases.

$$n_{O_2} = 4.0 \text{ g } O_2 \times \frac{1 \text{ mol } O_2}{32 \text{ g } O_2} = 0.125 \text{ mol } O_2$$

$$P_{O_2} = \frac{n_{O_2} RT}{V} = \frac{(0.125 \text{ mol})(0.0821 \text{ L}\cdot\text{atm}\cdot\text{K}^{-1}\cdot\text{mol}^{-1})(350 \text{ K})}{3.5 \text{ L}} = 1.03 \text{ atm} \times \frac{760 \text{ torr}}{1 \text{ atm}} = 780 \text{ torr}$$

$$n_{N_2} = 7.0 \text{ g } N_2 \times \frac{1 \text{ mol } N_2}{28 \text{ g } N_2} = 0.25 \text{ mol } N_2$$

$$P_{N_2} = \frac{n_{N_2} RT}{V} = \frac{(0.25 \text{ mol})(0.0821 \text{ L}\cdot\text{atm}\cdot\text{K}^{-1}\cdot\text{mol}^{-1})(350 \text{ K})}{3.5 \text{ L}} = 2.1 \text{ atm} \times \frac{760 \text{ torr}}{1 \text{ atm}} = 1560 \text{ torr}$$

The total pressure equals the sum of the partial pressures: $P_{tot} = P_{O2} + P_{N2} = 780 + 1560 = 2340$ torr

15. What is the approximate thermal energy in kJ/mol of molecules at each of the following temperatures?

	a. -200 °C	**b. 300 °C**	**c. 75 °C**
T =	-200 + 273 = 73 K	200 + 273 = 573 K	75 + 273 = 348
RT =	8.3 J/K·mol^{-1} × 73 K	8.3 J/K·mol^{-1} × 573 K	8.3 J/K·mol^{-1} × 348 K
E ~	0.60 kJ/mol	4.8 kJ/moll	2.9 kJ/mol

17. How does the thermal energy compare to the energy of attraction between molecules in a solid and in a gas?

Solid: Energy of attraction > Thermal energy Gas: Thermal energy > Energy of attraction

19. Explain why the boiling point of a substance increases as the pressure increases.

The boiling point is the temperature at which the vapor pressure equals the external pressure. If the external pressure is increased, then the temperature must increase to produce the greater vapor pressure.

21. Explain why bubbles form when a liquid boils.

Bubbles are cause by the molecules in the liquid that have sufficient kinetic energy to escape the liquid but are not at the surface. At the boiling point, the pressure in these bubbles is equal to the external pressure, so they do not collapse.

23. Which has a greater potential energy at 270 K, ice or water vapor? Explain.

The potential energy of the vapor is greater than that of the solid at any temperature.

25. Why are ionic substances solids under normal conditions?

To melt ionic substances, ionic bonds must be broken. Ionic bonds are strong interactions and require a great deal of energy to break. Thus, ionic substances are solids at normal conditions.

27. Explain why many gases are liquefied by increasing the pressure.

Increasing the external pressure increases the boiling point. Thus, if the pressure of the gas is increased to the point that the boiling point drops below the external pressure, the gas liquefies.

29. Explain how snow can disappear without melting.

A solid can be converted directly to the gas in a process called sublimation. If the temperature remains below the melting point, the solid does not melt. However, it will slowly sublime.

31. Explain why the temperature of a solid $\rightleftharpoons$ liquid mixture does not change when it is heated.

Any additional heat that is added is used to melt the solid (increase the potential energy) not to increase the temperature (increase the kinetic energy).

33. What is a dynamic equilibrium? Give two examples dynamic equilibria.

A dynamic equilibrium occurs when the rates of two opposing processes are equal. The result is that there is no net change although both processes continue.

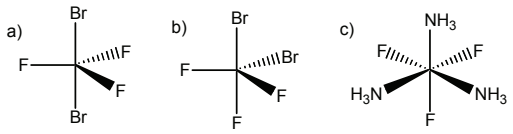
35. Define the term "heat of fusion". The heat of fusion of water at 0 °C is 6.0 kJ/mol. Write the chemical equation for the process to which this number applies.

The *heat of fusion* is the heat required to melt some amount, usually a mole or a gram, of substance. The "heat of fusion of water" applies to the following process $H_2O(s) \rightarrow H_2O(l)$, *i.e.*, to the melting of one mole of water at its melting point.

37. Refer to Figure 7.15 to determine whether H_2O is a liquid or a gas under the following conditions of temperature and pressure.

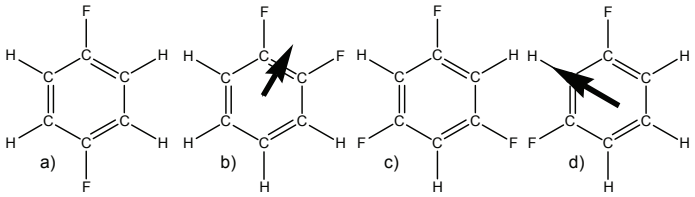
a) 50 °C and 500 torr (liquid) **b) 77 °C; 500 torr** (liquid) **c) 100 °C; 800 torr** (liquid)

39. Indicate which of the following molecules is polar:



Compound a is not polar because the centers of the fluorine atoms and the centers of the bromine atoms both coincide with the phosphorus atom. Compound b is polar with the dipole pointing from the center of bromine atoms to the center of the fluorine atoms. Compound c is polar with the dipole pointing from the center of the fluorine atoms to the center of the ammonia molecules.

41. Indicate whether or not each of the following compounds is (are) polar?



Compounds a and c are not polar because the centers of the hydrogen atoms, the fluorine atoms and the carbon atoms all coincide. Compounds b and d are polar with dipoles pointing from the center of the hydrogen atoms toward the center of the two fluorine atoms.

43. In which of the following molecules is hydrogen bonding between like molecules important?

Hydrogen bonding is important only in compounds with H-O, H-N or H-F bonds. Consequently, only ethanol molecules can hydrogen bond to one another.

45. Indicate which of the following substances has the higher boiling point and the type of force that is most responsible for the difference:

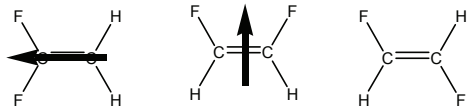
a) **CCl_4 or CF_4** CCl_4 – dispersion

b) **CH_3-CH_3 or CH_3-NH_2** CH_3NH_2 – hydrogen bonding

c) **H_2Se or Kr** H_2Se – dipole-dipole

d) **KF or HF** KF – ionic bonds

47. Draw the Lewis structures of the three isomers of $C_2H_2F_2$ and indicate whether each is polar.



The dipole points from the center of H atoms to the center of F atoms. There is no dipole if the centers are the same.

49. Indicate all of the forces that exist between molecules in the condensed states of the following:

a) **CCl_4** dispersion

b) **CH_2O** dispersion, dipole-dipole

c) **CO_2** dispersion

d) **HF** dispersion, dipole-dipole, hydrogen bonding

e) **H_3C-OH** dispersion, dipole-dipole, hydrogen bonding

51. Consider the phase diagram in the text.

a. What are the normal boiling and melting points of the substance?
Boiling point: liquid/vapor line crosses 1 atm at ~500 ^{O}C
Melting point: solid/liquid line crosses 1 atm at ~200 ^{O}C

b. In what state of matter does the substance exist under room conditions?
At room conditions, 25^{O}C and 1 atm, the substance is a solid.

c. What is the vapor pressure of the substance at 300 ^{o}C?
The pressure at which the liquid/vapor line crosses 300 ^{o}C is ~0.7 atm

d. What phase transition occurs when the pressure at point 'A' is increased?
An increase in pressure at constant temperature at point A takes the material into the liquid phase; it melts.

e. Is the solid or liquid phase more dense?
An increase in pressure at the melting point causes the substance to melt, the liquid phase is more dense.

f. At what temperature and pressure is the triple point of the substance?
The solid, liquid, and vapor coexist at 250 ^{O}C and 0.65 atm