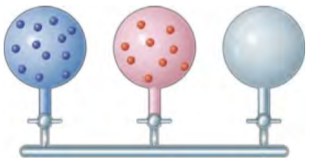
Gases
Problem Set

10.1 Mars has an average atmospheric pressure of 0.007 atm. Would it be easier or harder to drink from a straw on Mars than on Earth? Explain. [Section 10.2]

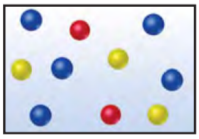
10.4 Imagine that the reaction $2\,CO(g) + O_2(g) \longrightarrow 2\,CO_2(g)$ occurs in a container that has a piston that moves to maintain a constant pressure when the reaction occurs at constant temperature. **(a)** What happens to the volume of the container as a result of the reaction? Explain. **(b)** If the piston is not allowed to move, what happens to the pressure as a result of the reaction? [Sections 10.3 and 10.5]

10.5 Suppose you have a fixed amount of an ideal gas at a constant volume. If the pressure of the gas is doubled while the volume is held constant, what happens to its temperature? [Section

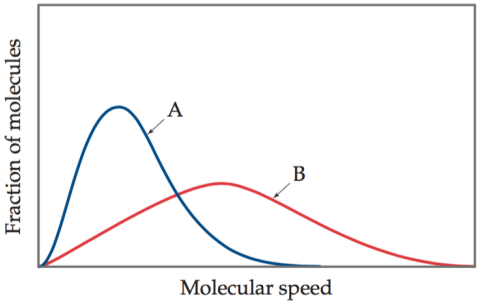
10.6 The apparatus shown here has two gas-filled containers and one empty container, all attached to a hollow horizontal tube. When the valves are opened and the gases are allowed to mix at constant temperature, what is the distribution of atoms in each container? Assume that the containers are of equal volume and ignore the volume of the connecting tube. Which gas has the greater partial pressure after the valves are opened? [Section 10.6]



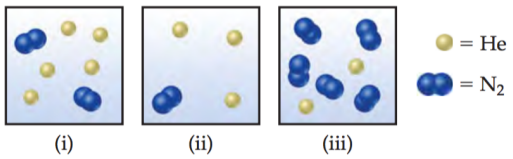
10.7 The accompanying drawing represents a mixture of three different gases. **(a)** Rank the three components in order of increasing partial pressure. **(b)** If the total pressure of the mixture is 1.40 atm, calculate the partial pressure of each gas. [Section 10.6]



10.9 Consider the following graph. **(a)** If curves A and B refer to two different gases, He and O_2, at the same temperature, which is which? Explain. **(b)** If A and B refer to the same gas at two different temperatures, which represents the higher temperature? **(c)** Redraw the graph and put in vertical lines that indicate the approximate positions of the most probable speeds and root-mean-square speeds for each curve. [Section 10.7]

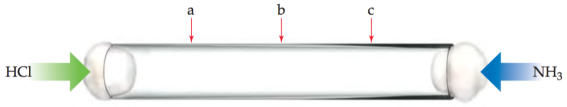


10.10 Consider the following samples of gases:



If the three samples are all at the same temperature, rank them with respect to **(a)** total pressure, **(b)** partial pressure of helium, **(c)** density, **(d)** average kinetic energy of particles.

10.11 A thin glass tube 1 m long is filled with Ar gas at 1 atm, and the ends are stoppered with cotton plugs:



HCl gas is introduced at one end of the tube, and simultaneously NH_3 gas is introduced at the other end. When the two gases diffuse through the cotton plugs down the tube and meet, a white ring appears due to the formation of $NH_4Cl(s)$. At which location—a, b, or c—do you expect the ring to form? Explain your choice. [Section 10.8]

10.13 How does a gas compare with a liquid for each of the following properties: **(a)** density, **(b)** compressibility, **(c)** ability to mix with other substances of the same phase to form homogeneous mixtures, **(d)** ability to conform to the shape of its container?

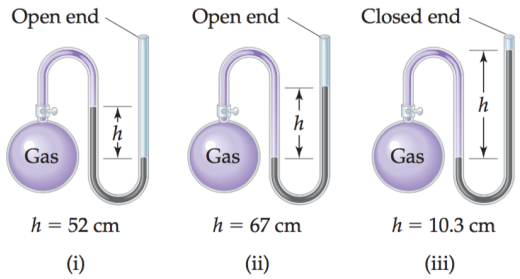
10.14 **(a)** A liquid and a gas are moved to larger containers. How does their behavior differ once they are in the larger containers? Explain the difference in molecular terms. **(b)** Although liquid water and carbon tetrachloride, $CCl_4(l)$, do not mix, their vapors form a homogeneous mixture. Explain. **(c)** Gas densities are generally reported in grams per liter, whereas liquid densities are reported in grams per milliliter. Explain the molecular basis for this difference.

10.15 Suppose that a woman weighing 130 lb and wearing high-heeled shoes momentarily places all her weight on the heel of one foot. If the area of the heel is 0.50 $in.^2$, calculate the pressure exerted on the underlying surface in **(a)** kilopascals, **(b)** atmospheres, and **(c)** pounds per square inch.

10.17 **(a)** How high in meters must a column of water be to exert a pressure equal to that of a 760-mm column of mercury? The density of water is 1.0 g/mL, whereas that of mercury is 13.6 g/mL. **(b)** What is the pressure, in atmospheres, on the body of a diver if he is 39 ft below the surface of the water when atmospheric pressure at the surface is 0.97 atm?

10.21 The typical atmospheric pressure on top of Mt. Everest (29,028 ft) is about 265 torr. Convert this pressure to **(a)** atm, **(b)** mm Hg, **(c)** pascals, **(d)** bars, **(e)** psi.

10.25 If the atmospheric pressure is 0.995 atm, what is the pressure of the enclosed gas in each of the three cases depicted in the drawing? Assume that the gray liquid is mercury.



10.27 You have a gas confined to a cylinder with a movable piston. What would happen to the gas pressure inside the cylinder if you do the following? **(a)** Decrease the volume to one-fourth the original volume while holding the temperature constant. **(b)** Reduce the temperature (in kelvins) to half its original value while holding the volume constant. **(c)** Reduce the amount of gas to one-fourth while keeping the volume and temperature constant.

10.28 A fixed quantity of gas at 21 °C exhibits a pressure of 752 torr and occupies a volume of 5.12 L. **(a)** Calculate the volume the gas will occupy if the pressure is increased to 1.88 atm while the temperature is held constant. **(b)** Calculate the volume the gas will occupy if the temperature is increased to 175 °C while the pressure is held constant.

10.30 Nitrogen and hydrogen gases react to form ammonia gas as follows:

$$N_2(g) + 3\,H_2(g) \longrightarrow 2\,NH_3(g)$$

At a certain temperature and pressure, 1.2 L of N_2 reacts with 3.6 L of H_2. If all the N_2 and H_2 are consumed, what volume of NH_3, at the same temperature and pressure, will be produced?

10.32 **(a)** What conditions are represented by the abbreviation STP? **(b)** What is the molar volume of an ideal gas at STP? **(c)** Room temperature is often assumed to be 25 °C. Calculate the molar volume of an ideal gas at 25 °C and 1 atm pressure.

10.33 Suppose you are given two 1-L flasks and told that one contains a gas of molar mass 30, the other a gas of molar mass 60, both at the same temperature. The pressure in flask A is X atm, and the mass of gas in the flask is 1.2 g. The pressure in flask B is 0.5X atm, and the mass of gas in that flask is 1.2 g. Which flask contains the gas of molar mass 30, and which contains the gas of molar mass 60?

10.35 Complete the following table for an ideal gas:

P	*V*	*n*	*T*
2.00 atm	1.00 L	0.500 mol	? K
0.300 atm	0.250 L	? mol	27 °C
650 torr	? L	0.333 mol	350 K
? atm	585 mL	0.250 mol	295 K

10.38 A neon sign is made of glass tubing whose inside diameter is 2.5 cm and whose length is 5.5 m. If the sign contains neon at a pressure of 1.78 torr at 35 °C, how many grams of neon are in the sign? (The volume of a cylinder is $\pi r^2 h$.)

10.39 **(a)** Calculate the number of molecules in a deep breath of air whose volume is 2.25 L at body temperature, 37 °C, and a pressure of 735 torr. **(b)** The adult blue whale has a lung capacity of 5.0×10^3 L. Calculate the mass of air (assume an average molar mass 28.98 g/mol) contained in an adult blue whale's lungs at 0.0 °C and 1.00 atm, assuming the air behaves ideally.

10.40 **(a)** If the pressure exerted by ozone, O_3, in the stratosphere is 3.0×10^{-3} atm and the temperature is 250 K, how many ozone molecules are in a liter? **(b)** Carbon dioxide makes up approximately 0.04% of Earth's atmosphere. If you collect a 2.0-L sample from the atmosphere at sea level (1.00 atm) on a warm day (27 °C), how many CO_2 molecules are in your sample?

10.42 An aerosol spray can with a volume of 250 mL contains 2.30 g of propane gas (C_3H_8) as a propellant. **(a)** If the can is at 23 °C, what is the pressure in the can? **(b)** What volume would the propane occupy at STP? **(c)** The can's label says that exposure to temperatures above 130 °F may cause the can to burst. What is the pressure in the can at this temperature?

10.50 Rank the following gases from least dense to most dense at 1.00 atm and 298 K: SO_2, HBr, CO_2. Explain.

10.53 **(a)** Calculate the density of NO_2 gas at 0.970 atm and 35 °C. **(b)** Calculate the molar mass of a gas if 2.50 g occupies 0.875 L at 685 torr and 35 °C.

10.59 The metabolic oxidation of glucose, $C_6H_{12}O_6$, in our bodies produces CO_2, which is expelled from our lungs as a gas:

$$C_6H_{12}O_6(aq) + 6\,O_2(g) \longrightarrow 6\,CO_2(g) + 6\,H_2O(l)$$

(a) Calculate the volume of dry CO_2 produced at body temperature (37 °C) and 0.970 atm when 24.5 g of glucose is consumed in this reaction. **(b)** Calculate the volume of oxygen you would need, at 1.00 atm and 298 K, to completely oxidize 50.0 g of glucose.

10.61 Hydrogen gas is produced when zinc reacts with sulfuric acid:

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

If 159 mL of wet H_2 is collected over water at 24 °C and a barometric pressure of 738 torr, how many grams of Zn have been consumed? (The vapor pressure of water is tabulated in Appendix B.)

10.64 Consider a mixture of two gases, A and B, confined in a closed vessel. A quantity of a third gas, C, is added to the same vessel at the same temperature. How does the addition of gas C affect the following: **(a)** the partial pressure of gas A, **(b)** the total pressure in the vessel, **(c)** the mole fraction of gas B?

10.66 A deep-sea diver uses a gas cylinder with a volume of 10.0 L and a content of 51.2 g of O_2 and 32.6 g of He. Calculate the partial pressure of each gas and the total pressure if the temperature of the gas is 19 °C.

10.67 The atmospheric concentration of CO_2 gas is presently 390 ppm (parts per million, by volume; that is, 390 L of every 10^6 L of the atmosphere are CO_2). What is the mole fraction of CO_2 in the atmosphere?

10.69 A piece of dry ice (solid carbon dioxide) with a mass of 5.50 g is placed in a 10.0-L vessel that already contains air at 705 torr and 24 °C. After the carbon dioxide has totally vaporized, what is the partial pressure of carbon dioxide and the total pressure in the container at 24 °C?

10.71 A mixture of gases contains 0.75 mol N_2, 0.30 mol O_2, and 0.15 mol CO_2. If the total pressure of the mixture is 2.15 atm, what is the partial pressure of each component?

10.73 At an underwater depth of 250 ft, the pressure is 8.38 atm. What should the mole percent of oxygen be in the diving gas for the partial pressure of oxygen in the mixture to be 0.21 atm, the same as in air at 1 atm?

10.77 What change or changes in the state of a gas bring about each of the following effects? **(a)** The number of impacts per unit time on a given container wall increases. **(b)** The average energy of impact of molecules with the wall of the container decreases. **(c)** The average distance between gas molecules increases. **(d)** The average speed of molecules in the gas mixture is increased.

10.78 Indicate which of the following statements regarding the kinetic-molecular theory of gases are correct. For those that are false, formulate a correct version of the statement. **(a)** The average kinetic energy of a collection of gas molecules at a given temperature is proportional to $m^{1/2}$. **(b)** The gas molecules are assumed to exert no forces on each other. **(c)** All the molecules of a gas at a given temperature have the same kinetic energy. **(d)** The volume of the gas molecules is negligible in comparison to the total volume in which the gas is contained. **(e)** All gas molecules move with the same speed if they are at the same temperature.

[10.82] You have an evacuated container of fixed volume and known mass and introduce a known mass of a gas sample. Measuring the pressure at constant temperature over time, you are surprised to see it slowly dropping. You measure the mass of the gas-filled container and find that the mass is what it should be—gas plus container—and the mass does not change over time, so you do not have a leak. Suggest an explanation for your observations.

10.84 Suppose you have two 1-L flasks, one containing N_2 at STP, the other containing CH_4 at STP. How do these systems compare with respect to **(a)** number of molecules, **(b)** density, **(c)** average kinetic energy of the molecules, **(d)** rate of effusion through a pinhole leak?

10.86 **(a)** Place the following gases in order of increasing average molecular speed at 300 K: CO, SF_6, H_2S, Cl_2, HBr. **(b)** Calculate and compare the rms speeds of CO and Cl_2 molecules at 300 K. **(c)** Calculate and compare the most probable speeds of CO and Cl_2 molecules at 300 K.

10.93 **(a)** List two experimental conditions under which gases deviate from ideal behavior. **(b)** List two reasons why the gases deviate from ideal behavior. **(c)** Explain how the function PV/RT can be used to show how gases behave nonideally.

10.96 Briefly explain the significance of the constants a and b in the van der Waals equation.

10.98 Calculate the pressure that CCl_4 will exert at 40 °C if 1.00 mol occupies 33.3 L, assuming that **(a)** CCl_4 obeys the ideal-gas equation; **(b)** CCl_4 obeys the van der Waals equation. (Values for the van der Waals constants are given in Table 10.3.) **(c)** Which would you expect to deviate more from ideal behavior under these conditions, Cl_2 or CCl_4? Explain.