

is removed. The remaining gas is pure hydrogen and exerts a pressure of 0.250 atm when measured at the same values of T and V as the original mixture. What was the composition of the original mixture in mole percent?

P1.32 Suppose that you measured the product PV of 1 mol of a dilute gas and found that $PV = 27.54$ L atm at 0.00°C and 37.32 L atm at $100.^\circ\text{C}$. Assume that the ideal gas law is valid, with $T = t(^{\circ}\text{C}) + a$, and that the values of R and a are not known. Determine R and a from the measurements provided.

P1.33 Liquid N_2 has a density of 875.4 kg m^{-3} at its normal boiling point. What volume does a balloon occupy at 22.4°C and a pressure of 1.00 atm if 2.75×10^{-3} L of liquid N_2 is injected into it? Assume that there is no pressure difference between the inside and outside of the balloon.

P1.34 Calculate the volume of all gases evolved by the complete oxidation of 0.25 g of the amino acid alanine

$\text{NH}_2\text{CHCH}_3\text{COOH}$ if the products are liquid water, nitrogen gas, and carbon dioxide gas, the total pressure is 1.00 atm, and $T = 310$ K.

P1.35 As a result of photosynthesis, an acre of forest (1 acre = 4047 square meters) can take up 1000. kg of CO_2 . Assuming air is 0.0314% CO_2 by volume, what volume of air is required to provide 1000. kg of CO_2 ? Assume $T = 298$ K and $P = 1.00$ atm.

P1.36 A glass bulb of volume 0.225 L contains 1.251 g of gas at 759.0 Torr and 121.0°C . What is the molar mass of the gas?

P1.37 Use L'Hôpital's rule, $\lim_{x \rightarrow 0} [f(x)/g(x)] = \lim_{x \rightarrow 0} \left[\frac{df(x)/dx}{dg(x)/dx} \right]$ to show that the expression derived for P_f in part *b* of Example Problem 1.1 has the correct limit as $\gamma \rightarrow 0$.

CHAPTER OUTLINE

- 2.1 THE INTERNAL ENERGY AND THE FIRST LAW OF THERMODYNAMICS
- 2.2 WORK
- 2.3 HEAT
- 2.4 HEAT CAPACITY
- 2.5 STATE FUNCTIONS AND PATH FUNCTIONS
- 2.6 EQUILIBRIUM, CHANGE, AND REVERSIBILITY
- 2.7 COMPARING WORK FOR REVERSIBLE AND IRREVERSIBLE PROCESSES
- 2.8 DETERMINING ΔU AND INTRODUCING ENTHALPY, A NEW STATE FUNCTION
- 2.9 CALCULATING q , w , ΔU , AND ΔH FOR PROCESSES INVOLVING IDEAL GASES
- 2.10 THE REVERSIBLE ADIABATIC EXPANSION AND COMPRESSION OF AN IDEAL GAS

Heat, Work, Internal Energy, Enthalpy, and the First Law of Thermodynamics

In this chapter, the internal energy, U , is introduced. The first law of thermodynamics relates ΔU to the heat (q) and work (w) that flows across the boundary between the system and the surroundings. Other important concepts introduced include the heat capacity, the difference between state and path functions, and reversible versus irreversible processes. The enthalpy, H , is introduced as a form of energy that can be directly measured by the heat flow in a constant pressure process. We show how ΔU , ΔH , q , and w can be calculated for processes involving ideal gases.

2.1 THE INTERNAL ENERGY AND THE FIRST LAW OF THERMODYNAMICS

In this section, we focus on the change in energy of the system and surroundings during a thermodynamic process such as an expansion or compression of a gas. In thermodynamics, we are interested in the internal energy of the system, as opposed to the energy associated with the system relative to a particular frame of reference. For example, a spinning container of gas has a kinetic energy relative to a stationary observer. However, the internal energy of the gas is defined relative to a coordinate system fixed on the container. Viewed at a microscopic level, the internal energy can take on a number of forms such as

- the kinetic energy of the molecules;
- the potential energy of the constituents of the system; for example, a crystal consisting of polarizable molecules will experience a change in its potential energy as an electric field is applied to the system;
- the internal energy stored in the form of molecular vibrations and rotations; and
- the internal energy stored in the form of chemical bonds that can be released through a chemical reaction.