5.E: The Second Law (Exercises)

Q5.1

What is the minimum amount of work needed to remove 10.0 J of energy from a freezer at -10.0 °C, depositing the energy into a room that is 22.4 °C?

Q5.2

Consider the isothermal, reversible expansion of 1.00 mol of a monatomic ideal gas (C_V = 3/2 R) from 10.0 L to 25.0 L at 298 K. Calculate q, w, ΔU, ΔH, and ΔS for the expansion.

Q5.3

Consider the isobaric, reversible expansion of 1.00 mol of a monatomic ideal gas (C_p = 5/2 R) from 10.0 L to 25.0 L at 1.00 atm. Calculate q, w, ΔU, ΔH, and ΔS for the expansion.

Q5.4

Consider the isochoric, reversible temperature increase of 1.00 mol of a monatomic ideal gas (C_V = 3/2 R) °Ccupying 25.0 L from 298 K to 345 K. Calculate q, w, ΔU, ΔH, and ΔS for this process.

Q5.5

Consider the adiabatic expansion of 1.00 mol of a monatomic ideal gas (C_V = 3/2 R) from 10.0 L at 273 K to a final volume of 45.0 L. Calculate ΔT, q, w, ΔU, ΔH, and ΔS for the expansion.

Q5.6

15.0 g of ice ($\Delta H_{fus} = 6.009\, kJ/mol$) at 0 °C sits in a room that is at 21 °C. The ice melts to form liquid at 0 °C. Calculate the entropy change for the ice, the room, and the universe. Which has the largest magnitude?

Q5.7

15.0 g of liquid water (C_p = 75.38 J mol^{-1} °C^{-1}) at 0 °C sits in a room that is at 21 °C. The liquid warms from 0 °C to 21 °C. Calculate the entropy change for the liquid, the room, and the universe. Which has the largest magnitude?

Q5.8

Calculate the entropy change for taking 12.0 g of H_2O from the solid phase (C_p = 36.9 J mol^{-1} K^{-1}) at -12.0 °C to liquid (C_p = 75.2 J mol^{-1} K^{-1}) at 13.0 °C. The enthalpy of fusion for water is $\Delta H_{fus} = 6.009\, kJ/mol$.

Q5.9

Using Table T1, calculate the standard reaction entropies (ΔS^o) for the following reactions at 298 K.

a. $CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$
b. $C_{12}H_{22}O_{11}(s) + 12O_2 \rightarrow 12CO_2(g) + 11H_2O(l)$
c. $2POCl_3(l) \rightarrow 2PCl_3(l) + O_2(g)$
d. $2KBr(s) + Cl2(g) \rightarrow 2KCl(s) + Br_2(l)$
e. $SiH_4(g) + 2Cl(g) \rightarrow SiCl_4(l) + 2H_2(g)$

Q5.10

1.00 mole of an ideal gas is taken through a cyclic process involving three steps:

I. Isothermal expansion from V_1 to V_2 at T_1
II. Isochoric heating from, T_1 to T_2 at V_2
III. Adiabatic compression from V_2 to V_1

a. Graph the process on a V-T diagram.
b. Find q, w, ΔU, and ΔS for each leg. (If you want, you can find ΔH too!)

c. Use the fact that ΔS for the entire cycle must be zero (entropy being a state function and all …), determine the relationship between V_1 and V_2 in terms of C_v, T_1 and T_2.

Q5.11

2.00 moles of a monatomic ideal gas (C_V = 3/2 R) initially exert a pressure of 1.00 atm at 300.0 K. The gas undergoes the following three steps, all of which are reversible:

I. isothermal compression to a final pressure of 2.00 atm,
II. Isobaric temperature increase to a final temperature of 400.0 K, and
III. A return to the initial state along a pathway in which

$$p = a + bT \tag{5.E.1}$$

where a and b are constants. Sketch the cycle on a pressure-temperature plot, and calculate \(\Delta U\) and \(\Delta S\) for each of the legs. Are ΔU and ΔS zero for the sum of the three legs?

Q5.12

A 10.0 g piece of iron (C = 0.443 J/g °C) initially at 97.6 °C is placed in 50.0 g of water (C = 4.184 J/g °C) initially at 22.3 °C in an insulated container. The system is then allowed to come to thermal equilibrium. Assuming no heat flow to or from the surroundings, calculate

a. the final temperature of the metal and water
b. the change in entropy for the metal
c. the change in entropy for the water
d. the change in entropy for the universe

Q5.13

Considers a crystal of $CHFClBr$ as having four energetically equivalent orientations for each molecule. What is the expected residual entropy at 0 K for 2.50 mol of the substance?

Q5.14

A sample of a certain solid is measured to have a constant pressure heat capacity of 0.436 J mol^{-1} K^{-1} at 10.0 K. Assuming the Debeye extrapolation model

$$C_p(T) = aT^3 \tag{5.E.2}$$

holds at low temperatures, calculate the molar entropy of the substance at 12.0 K.