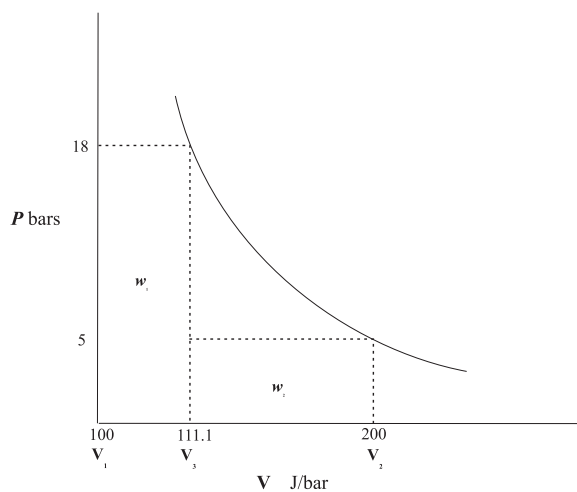


Chapter 3 Answers

1. $w = -644.5 \text{ J}$



$$P_1 V_1 = P_3 V_3$$

$$20 \cdot 100 = 18 \cdot V_3$$

$$V_3 = 111.11 \text{ J bar}^{-1}$$

$$w_1 = -18(111.11 - 100)$$

$$= -200 \text{ J}$$

$$w_2 = -5(200 - 111.11)$$

$$= -444.5 \text{ J}$$

$$w_1 + w_2 = -200 - 444.5$$

$$= -644.5 \text{ J}$$

2. $w = -1243.6 \text{ J}$

$$w = -[18(111.1 - 100) + 16(125 - 111.1) + 14(142.85 - 125) + 10(200 - 142.85)]$$

$$= -1243.6 \text{ J}$$

3.

$$\begin{aligned}
 w_{max} &= - \int_{V_1}^{V_2} P dV \\
 &= - \int_{V_1}^{V_2} (RT/V) dV \\
 &= -RT \ln(V_2/V_1) \\
 &= -8.31451 \times 298.15 \times \ln(2000/1000) \\
 &= -1718.29 \text{ J}
 \end{aligned}$$

4. +2200 J

5. The essential part of doing these work calculations is to know the gas volume as a function of pressure, that is, the equation of state (EoS) of the gas. These are sufficiently hard to use that they become a topic of study in themselves, and attention would be diverted from the simple idea of work being discussed. The *principles* of w and w_{max} are illustrated just as well with an ideal gas as with a real gas.

6.

$$\begin{aligned}
 w &= -P(V_2 - V_1) \\
 &= -1.01325(-15.867) \\
 &= 16.077 \text{ bar cm}^3 \\
 &= 1.608 \text{ J}
 \end{aligned}$$

7. By equation (3.17), $\Delta_r U^\circ = -53480 - 1.608 = -53481.6 \text{ J mol}^{-1}$. Notice how small the $P \Delta V$ term is at low pressures.

8. $\Delta_r H^\circ = -89475 \text{ J mol}^{-1}$.

9. $w_{net} = \Delta_r G^\circ = -13,903 \text{ J mol}^{-1}$ reaction (2.3).
 $w_{net} = \Delta_r G^\circ = -267,550 \text{ J mol}^{-1}$ reaction (2.5).

10. $w = -9782.6 \text{ J}$ at 1 bar, $-9912.2 \text{ J mol}^{-1}$ at 1 atm. Notice that this is considerably larger than w for reaction (2.2) (1.608 J mol^{-1}) because gases are among the products. It is still much smaller than the maximum useful work, $\Delta_r G^\circ = -267,550 \text{ J mol}^{-1}$, which is typical of chemical reactions.

11. $12.782/1500 = .00852$ days, or about 12 minutes. Unfortunately, humans cannot digest corundum.

12. $\Delta_r H^\circ = H_{water}^\circ - H_{ice}^\circ = 6008 \text{ J mol}^{-1}$.

$$\Delta_r C_P^\circ = C_{P_{water}}^\circ - C_{P_{ice}}^\circ = 76.1 - 36.5 = 39.6 \text{ J mol}^{-1} \text{ K}^{-1}.$$

$$\frac{d\Delta H}{dT} = \Delta C_P$$

$$\Delta H_{T_2} - \Delta H_{T_1} = \Delta C_P(T_2 - T_1) \quad \text{if } \Delta C_P \text{ constant.}$$

$$\begin{aligned} \Delta H_{263.15} - \Delta H_{273.15} &= 39.6(263.15 - 273.15) \\ &= -396 \text{ J mol}^{-1} \text{ K}^{-1} \end{aligned}$$

so $H_{water}^\circ - H_{ice}^\circ$ is -396 J mol^{-1} less at -10°C than at 0°C , or $6008 - 396 = 5612 \text{ J mol}^{-1}$.