Problem 4-9 solution

$$dh = \Big(\frac{\partial h}{\partial P}\Big)_T dP + \Big(\frac{\partial h}{\partial T}\Big)_P dT$$

Express dT in the r.h.s. in terms of independent P,v variables: $dT = \Big(\frac{\partial T}{\partial P}\Big)_v dP + \Big(\frac{\partial T}{\partial v}\Big)_P dv$

$$\begin{aligned}\Rightarrow dh &= \Big(\frac{\partial h}{\partial P}\Big)_T dP + \Big(\frac{\partial h}{\partial T}\Big)_P \Big[\Big(\frac{\partial T}{\partial P}\Big)_v dP + \Big(\frac{\partial T}{\partial v}\Big)_P dv\Big] \\ &= \Big[\Big(\frac{\partial h}{\partial T}\Big)_P + \Big(\frac{\partial h}{\partial T}\Big)_P \Big(\frac{\partial T}{\partial P}\Big)_v\Big] dP + \Big(\frac{\partial h}{\partial T}\Big)_P \Big(\frac{\partial T}{\partial v}\Big)_P dv\end{aligned}$$

On the other hand

$$dh = \Big(\frac{\partial h}{\partial P}\Big)_v dP + \Big(\frac{\partial h}{\partial v}\Big)_P dv$$

$$\Rightarrow \begin{cases} \Big(\frac{\partial h}{\partial v}\Big)_P = \Big(\frac{\partial h}{\partial T}\Big)_P \Big(\frac{\partial T}{\partial v}\Big)_P \\ \Big(\frac{\partial h}{\partial P}\Big)_v = \Big(\frac{\partial h}{\partial T}\Big)_P \Big(\frac{\partial T}{\partial P}\Big)_v + \Big(\frac{\partial h}{\partial P}\Big)_T \end{cases}$$

Problem 4-26 solution

(a) Van der Waals equation reads

$$\Big(P + \frac{a}{v^2}\Big)(v - b) = RT$$

The specific energy of van der Waals gas is

$$u = c_v T - \frac{a}{v} + \text{const}$$

From Eq. (4.8)

$$c_v \Big(\frac{\partial T}{\partial v}\Big)_s = -\Big[\Big(\frac{\partial u}{\partial v}\Big)_T + P\Big] = -\Big[\frac{a}{v^2} + P\Big] = -\frac{RT}{v - b}$$

we get

$$\begin{aligned}\frac{c_v}{R}\frac{dT}{T} &= -\frac{dv}{v-b} \quad \Rightarrow \quad \frac{c_v}{R}\ln T = -\ln(v-b) + \text{const} \\ \Rightarrow \quad T(v-b)^{c_v/R} &= \text{const} \quad \Rightarrow \quad \Big(P + \frac{a}{v^2}\Big)(v-b)^{1+\frac{R}{c_v}} = RT(v-b)^{\frac{R}{c_v}} = \text{const} \equiv A\end{aligned}$$

(b1)

$$\begin{aligned}W &= \int_{v_i}^{v_f} dv\ P(v) = \int_{v_i}^{v_f} dv\ \Big[A(v-b)^{-1-\frac{R}{c_v}} - \frac{a}{v^2}\Big] \\ &= \frac{c_v A}{R}\Big[(v_i - b)^{-\frac{R}{c_v}} - (v_f - b)^{-\frac{R}{c_v}}\Big] + a\Big(\frac{1}{v_f} - \frac{1}{v_i}\Big)\end{aligned}$$

Since $A = RT_f(v_f - b)^{\frac{R}{c_v}} = RT_i(v_i - b)^{\frac{R}{c_v}}$

$$W = c_v(T_i - T_f) + a\Big(\frac{1}{v_f} - \frac{1}{v_i}\Big)$$

(b2)

$$u = c_v T - \frac{a}{v} + \text{const} \quad \Rightarrow \quad W = U_i - U_f = c_v(T_i - T_f) + a\left(\frac{1}{v_f} - \frac{1}{v_i}\right)$$

Problem 4-38 solution

For the Carnot refrigerator

$$C_{\text{Carnot}} = \frac{T_2}{T_2 - T_1} = 18.5$$

For the household refrigerator

$$C = 18.5 \times 0.6 = 11.1$$

Since $W = \frac{Q}{C}$ we get

$$W = \frac{3.6 \times 10^6}{11.1} = 2.7 \times 10^5 J$$

and

$$P = \frac{W}{\Delta t} = \frac{2.7 \times 10^5 J}{24 \times 60 \times 60 s} = 3.1 w$$

Cost:

$$W = 2.7 \times 10^5 J = \frac{2.7 \times 10^5}{3.6 \times 10^6} \text{ kilowatt} - \text{hours} \simeq 0.075 \text{ kilowatt} - \text{hours} \Rightarrow \text{cost} = 3 \times 0.075 = 0.225 \text{ cents}$$