Chapter 13 Answers

1. (a) $a = 3655953.2$
   $b = 42.82691$

   (b) Van der Waals:

P bars	V cm^3 mol^{-1}
10	2370.347
20	1126.166
30	707.283
40	493.408
50	359.429
60	260.594

2. Redlich-Kwong:

P bars	V cm^3 mol^{-1}
10	2353.671
20	1109.279
30	690.214
40	475.953
50	341.285
60	240.522

3. (a) The cylinder pressure is $2200/14.504 = 151.682$ bars.
   The cylinder volume is $(11/2)^2 \times \pi \times 155 = 14730.14\,\mathrm{cm}^3$, or $1473.01\,\mathrm{J\,bar}^{-1}$.
   The moles of argon assuming ideal gas is
   $151.682 \times 1473.01/(8.31451 \times 298.15) = 90.13$ moles.
   The ideal gas mass is then $90.13 \times 39.948/1000 = 3.601$ kg.

   (b) Solving the vdW equation iteratively, the vdW molar volume is $149.2\,\mathrm{cm}^3\,\mathrm{mol}^{-1}$.
   The number of moles is $14730.13/149.2 = 98.728$ moles.
   The mass is then $98.728 \times 39.948/1000 = 3.944$ kg.

   (c) The ideal gas molar volume is $14730.14/90.13 = 163.432\,\mathrm{cm}^3\,\mathrm{mol}^{-1}$

   (d) Note that $V_2/V_1 = P_1/P_2$ for ideal gas, and work done is negative.

$$\begin{aligned} \boldsymbol{w} &= -nRT\ \ln\left(P_1/P_2\right) \\ &= -90.13 \cdot 8.31451 \cdot 298.15 \cdot \ln\frac{2200}{1000} \\ &= -176165\,\mathrm{J} \end{aligned}$$

   This is the reversible work, the maximum possible.

   (e) For vdW gas, $a = 1340000\,\mathrm{cm}^6\,\mathrm{bar\,mol}^{-2}$; $b = 32.2\,\mathrm{cm}^3\,\mathrm{mol}^{-1}$
   $V_1 = 149.2\,\mathrm{cm}^3\,\mathrm{mol}^{-1}$. For V_2, solve vdW equation using
   $P = 1000/14.504 = 68.946$ bars.

Find $V_2 = 340.001\,\text{cm}^3\,\text{mol}^{-1}$. Then

$$\begin{aligned} w &= -\int_{V_1}^{V_2} \left[\frac{RT}{V-b} - \frac{a}{V^2} \right] dV \\ &= -18938.6\,\text{cm}^3\,\text{bar}\,\text{mol}^{-1} \\ \boldsymbol{w} &= w \cdot 98.728/10 \\ &= -186976\,\text{J} \end{aligned}$$

(f) The minimum work available is zero, which would be the case on expanding the argon into a vacuum.

(g) Note: $\text{m} \cdot \text{kg} \cdot \text{m/s}^2 = \text{J}$ (see Appendix A).
The work required to lift a 100 kg weight a distance h is $100gh$, where g is $9.80\,\text{m}\,\text{s}^{-2}$ and h is in meters. So

$$\begin{aligned} h &= -\boldsymbol{w}/(100 \cdot g) \\ &= 176165/(100 \cdot 9.80) \\ &= 179.76\,\text{meters} \end{aligned}$$

(h) Using Matlab with calculated values of P at intervals of $1\,\text{cm}^3\,\text{mol}^{-1}$, the area under the curve using the trapezoidal rule (function trapz) is $18969\,\text{cm}^3\,\text{bar}\,\text{mol}^{-1}$, or 187276 J.

4. See spreadsheet EoS.xls