5.11 Prove the following relation:

\[(\partial H/\partial V)_T = -V^2 (\partial p/\partial T)_V (\partial (T/V)/\partial V)_p\]

5.19 Show that, if S is regarded as a function of T and V, then

\[T \, dS = C_V \, dT + T \, (\partial p/\partial T)_V \, dV\]

5.20 Suppose that S is regarded as a function of p and T. Show that

\[T \, dS = C_p \, dT - \alpha TV \, dp\]

Hence, show that the energy transferred as heat when the pressure on an incompressible liquid or solid is increased by \(\Delta p\) is equal to \(-\alpha TV \, \Delta p\). Evaluate \(q\) when the pressure acting on 100 cm³ of mercury at 0°C is increased by 1.0 kbar. \((\alpha = 1.82 \times 10^{-4} \text{ K}^{-1})\)

5.22 Find an expression of the fugacity coefficient of a gas that obeys the equation of state

\[\frac{pV_m}{RT} = 1 + \frac{B}{V_m} + \frac{C}{V_m^2}\]

Use the resulting expression to estimate the fugacity of argon at 1.00 atm and 273 K, with the values for the constants being \(B = -21.13 \text{ cm}^3 \text{ mol}^{-1}\) and \(C = 1054 \text{ cm}^6 \text{ mol}^{-2}\).

6.16 The Clapeyron equation does not apply to second-order phase transitions, but there are two analogous equations – the *Ehrenfest equations* – which do. These are

\[\frac{dp}{dT} = \frac{\alpha_2 - \alpha_1}{\kappa_{T2} - \kappa_{T1}} \quad \frac{dp}{dT} = \frac{C_{p,m2} - C_{p,m1}}{TV(\alpha_2 - \alpha_1)}\]

where \(\alpha\) is the expansion coefficient, \(\kappa_T\) is the isothermal compressibility coefficient, and the subscripts 1 and 2 refer to two different phases. Derive these two equations. Why does the Clapeyron equation not apply to second-order phase transitions?