PS 21: Problem 2.29

The Van der Waals energy equation of state is given by

$$E = \frac{3}{2}Nk_BT - N\frac{N}{V}a \tag{1}$$

The Joule coefficient is given by

$$\left(\frac{\partial T}{\partial V}\right)_E = -\frac{\left(\frac{\partial E}{\partial V}\right)_T}{\left(\frac{\partial E}{\partial T}\right)_V} \tag{2}$$

Performing the necessary derivatives indicated in (2) on (1), we have

$$\begin{aligned}\left(\frac{\partial T}{\partial V}\right)_E &= -\frac{N\frac{N}{V^2}a}{\frac{3}{2}Nk_B} \\ \boxed{\left(\frac{\partial T}{\partial V}\right)_E &= -\frac{2Na}{3k_BV^2}}\end{aligned} \tag{3}$$

The change in temperature w.r.t. volume is negative, which indicates cooling.