PHYS 351 #4

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1 Q1

Recall that the van der Waals equation of state is $(P+\frac{a}{v^2})(v-b)=RT$, where v is the molar volume and a and b depend only on the type of gas.

1.1 a

The coefficient of thermal expansion is defined as follows:

$$\beta \equiv \frac{1}{V}(\frac{\partial V}{\partial T})\Big|_P$$

Find β for a van der Waals gas. Show that this reduces to the ideal gas result, $\beta_{ideal}=\frac{1}{T}$, when a = 0 and b = 0.

Lets start by taking a $\frac{\partial}{\partial T}$ holding P as a constant. Noting that $v=V/n$ we begin taking a implicit derivative on boath sides.

$$\frac{\partial}{\partial T}(P+\frac{an^2}{V^2})(V/n-b)=\frac{\partial}{\partial T}RT$$

$$(\frac{-2an^2}{V^3}\frac{\partial V}{\partial T}\Big|_P)(V/n-b)+(P+\frac{an^2}{V^2})(1/n\frac{\partial V}{\partial T}\Big|_P)=R$$

$$\frac{\partial V}{\partial T}\Big|_P=\frac{R}{(\frac{-2an^2}{V^3})(V/n-b)+(P+\frac{an^2}{V^2})(1/n)}$$

$$\frac{\partial V}{\partial T}\Big|_P=\frac{Rv^2V}{(-2a)(v-b)+(P+a)(v)}=\frac{Rv^2V}{2ab+(P-a)v}$$

$$\beta=\frac{Rv^2}{2ab+(P-a)v}$$

(Cool β is size independent, not dependent on V)