(1) From Maxwell's relations we know $C_p - C_v = \frac{TV\beta^2}{K}$

$V = 7.06 \text{ cm}^3/\text{mol} = 7.06 \times 10^{-6} \text{ m}^3/\text{mol}$

$$\therefore C_p - C_v = \frac{300 \times 7.06\times10^{-6} \times (50.4\times10^{-6})^2}{7.78\times10^{-12}} = 0.6915 \text{ J/mol-K}$$

$$\therefore C_v = C_p - 0.6915 = 24.5 - 0.6915 = 23.8085 \text{ J/mol-K}$$

(2) $\alpha_s = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_S$, $\alpha_p = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$ so $\frac{\alpha_s}{\alpha_p} = \frac{\left(\frac{\partial V}{\partial T}\right)_S}{\left(\frac{\partial V}{\partial T}\right)_P} = \frac{1}{\left(\frac{\partial T}{\partial V}\right)_S\left(\frac{\partial V}{\partial T}\right)_P}$

Using Maxwell's relation $\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$

$$\therefore \frac{\alpha_s}{\alpha_p} = -\frac{1}{\left(\frac{\partial P}{\partial S}\right)_V\left(\frac{\partial V}{\partial T}\right)_P} = -\frac{1}{\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial T}{\partial S}\right)_V\left(\frac{\partial V}{\partial T}\right)_P} = -\frac{\left(\frac{\partial S}{\partial T}\right)_V}{\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial V}{\partial T}\right)_P}$$

$$= -\frac{T\left(\frac{\partial S}{\partial T}\right)_V}{T\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial V}{\partial T}\right)_P}$$

But $C_p - C_v = T\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial V}{\partial T}\right)_P$ & $C_v = T\left(\frac{\partial S}{\partial T}\right)_V = \left(\frac{\partial Q}{\partial T}\right)_V$

$$\therefore \frac{\alpha_s}{\alpha_p} = -\frac{C_v}{C_p - C_v} = \frac{1}{1 - C_p/C_v} = \frac{1}{1-\gamma}$$ (Proved)

Again $E_T = -V\left(\frac{\partial P}{\partial V}\right)_T$, $E_S = -V\left(\frac{\partial P}{\partial V}\right)_S$ $\therefore \frac{E_S}{E_T} = \frac{\left(\frac{\partial P}{\partial V}\right)_S}{\left(\frac{\partial P}{\partial V}\right)_T}$

$$= \frac{\left(\frac{\partial P}{\partial T}\right)_S\left(\frac{\partial T}{\partial V}\right)_S}{\left(\frac{\partial P}{\partial S}\right)_T\left(\frac{\partial S}{\partial V}\right)_T} = \frac{\left(\frac{\partial S}{\partial P}\right)_T\left(\frac{\partial T}{\partial V}\right)_S}{\left(\frac{\partial T}{\partial P}\right)_S\left(\frac{\partial S}{\partial V}\right)_T}$$

Using Maxwell's relations, $\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$, $\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$

$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$, $\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$ we get

$$\frac{E_S}{E_T} = \frac{\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial P}{\partial S}\right)_V}{\left(\frac{\partial V}{\partial S}\right)_P\left(\frac{\partial P}{\partial T}\right)_V} = \frac{\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial S}{\partial V}\right)_P}{\left(\frac{\partial S}{\partial P}\right)_V\left(\frac{\partial P}{\partial T}\right)_V} = \frac{\left(\frac{\partial S}{\partial T}\right)_P}{\left(\frac{\partial S}{\partial T}\right)_V} = \frac{\left(\frac{\partial Q}{\partial T}\right)_P}{\left(\frac{\partial Q}{\partial T}\right)_V} = \frac{C_p}{C_v}$$

$$= \gamma$$

(3) $\beta_S = \frac{1}{P}\left(\frac{\partial P}{\partial T}\right)_S$, $\beta_V = \frac{1}{P}\left(\frac{\partial P}{\partial T}\right)_V$ $\therefore$ $\frac{\beta_S}{\beta_V} = \frac{\left(\frac{\partial P}{\partial T}\right)_S}{\left(\frac{\partial P}{\partial T}\right)_V}$

$$= \frac{1}{\left(\frac{\partial T}{\partial P}\right)_S\left(\frac{\partial P}{\partial T}\right)_V} = \frac{1}{\left(\frac{\partial V}{\partial S}\right)_P\left(\frac{\partial P}{\partial T}\right)_V} \qquad \left[\text{as } \left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P\right]$$

$$= \frac{1}{\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial T}{\partial S}\right)_P\left(\frac{\partial P}{\partial T}\right)_V} = \frac{\left(\frac{\partial S}{\partial T}\right)_P}{\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial P}{\partial T}\right)_V} = \frac{T\left(\frac{\partial S}{\partial T}\right)_P}{T\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial P}{\partial T}\right)_V}$$

$$\frac{\beta_S}{\beta_V} = \frac{C_P}{C_P - C_V} = \frac{C_P/C_V}{C_P/C_V - 1} = \frac{\gamma}{\gamma - 1}. \qquad \left[\text{as } C_P - C_V = T\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial P}{\partial T}\right)_V\right]$$