2 a. $dA = -SdT - PdV$

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

$S_m = \frac{S}{n}$

$$\left(\frac{\partial^2 A}{\partial V \partial T}\right) = \left(\frac{-\partial S}{\partial V}\right)_T \qquad \left(\frac{\partial^2 A}{\partial T \partial V}\right)_V = \left(\frac{-\partial P}{\partial T}\right)$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \frac{B}{K} \qquad \left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)$$

$$\frac{1}{n}\left(\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{B}{K}\right)\right)$$

$$\left(\frac{\partial S_m}{\partial V}\right)_T = \left(\frac{B}{nK}\right)$$

b. as $V\uparrow$ then $S_m\uparrow$

as volume increases then molar entropy increases.

c. $dG = -SdT + VdP + \mu_i dn_i$

$$\left(\frac{\partial G}{\partial P}\right)_{T,n_i} = V \qquad \left(\frac{\partial G}{\partial T}\right)_{P,n_i} = -S \qquad \left(\frac{\partial G}{\partial n_i}\right)_{T,P,n_i \neq n_j} = \mu_i$$

$$\left(\frac{\partial}{\partial n_i}\left(\frac{\partial G}{\partial P}\right)_{T,n_i}\right) = V \qquad \frac{\partial}{\partial P}\left(\frac{\partial G}{\partial n_i}\right)_{T,P,n_i \neq n_j} = \mu_i$$

$$\frac{\partial^2 G}{\partial n_i \partial P} = \left(\frac{\partial V}{\partial n_i}\right)_{T,P} \qquad \frac{\partial^2 G}{\partial P \partial n_i} = \left(\frac{\partial \mu_i}{\partial P}\right)_{T,n_i \neq n_j}$$

$$\left(\frac{\partial V}{\partial n_i}\right)_{T,P,n_{j\neq i}} = \left(\frac{\partial \mu_i}{\partial P}\right)_{T,P,n_{j\neq i}}$$

d. $dG = -SdT + VdP + \mu_{H_2}\,dn_{H_2} + \mu_{CO}\,dn_{CO} + \mu_{COH_2}\,dn_{COH_2}$

$$\frac{\partial}{\partial n_{COH_2}}\left(\frac{\partial G}{\partial P}\right)_{T,n_{CO},n_{H_2}} = V \qquad \frac{\partial}{\partial P}\left(\frac{\partial G}{\partial n_{COH_2}}\right)_{T,P,n_{H_2},n_{CO}} = \mu_{COH_2}$$

$$\left(\frac{\partial^2 G}{\partial n_{COH_2} \partial P}\right) = \left(\frac{\partial V}{\partial n_{COH_2}}\right) \left(\frac{\partial^2 G}{\partial P\, \partial n_{COH_2}}\right) = \left(\frac{\partial \mu_{COH_2}}{\partial P}\right) \quad \mu\uparrow \text{ as } P\uparrow$$

$$\left(\frac{\partial V}{\partial n_{COH_2}}\right)_{T,P,n_{H_2},n_{CO}} = \left(\frac{\partial \mu_{COH_2}}{\partial P}\right)_{T,n_{CO},n_{H_2}}$$

e. $$\left(\frac{\partial V}{\partial n_{COH_2}}\right)_{T,P,n_{H_2},n_{CO}} = \left(\frac{\partial \mu_{COH_2}}{2}\right)_{T,n_{H_2},n_{CO},n_{COH_2}}$$

$$\int_{P^\circ}^{P} \partial \mu_{COH_2} = \int_{P^\circ}^{P} \left(\frac{\partial V}{\partial n_{COH_2}}\right) \partial P$$

$$\mu_{COH_2}(P) = RT \int_{P^\circ}^{P} \frac{1}{P}\, \partial P = RT \ln \frac{P}{P^\circ}$$

For an ideal gas:

$V = \frac{nRT}{P}$ V is function of P, n, T

$\left(\frac{\partial V}{\partial n_{COH_2}}\right)_{P,T,n_{CO},n_{H_2}} = \frac{RT}{P}$

$$V = \frac{nRT}{P}$$

$$\partial V = \frac{\partial n R \partial T}{\partial P}$$