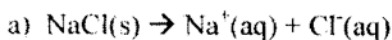


Based on your general chemistry knowledge, determine whether the chemical potential of the reactants in the following balanced equations is greater than, less than, or equal to the chemical potential of the products. You may assume each reaction is taking place under standard conditions unless otherwise indicated.

1.



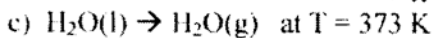
NaCl dissolves spontaneously in water

$$\mu(\text{reactants}) > \mu(\text{products})$$



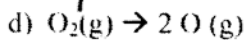
HCl is one of the "strong" acids that dissociates completely in water

$$\mu(\text{reactants}) > \mu(\text{products})$$



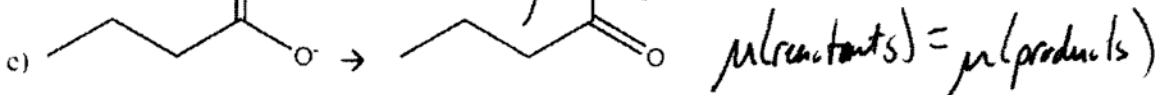
phases are in equilibrium at  $T_{\text{trans}}$  and  $P = 1 \text{ bar}$

$$\mu(\text{reactants}) = \mu(\text{products})$$



molecular  $\text{O}_2$  does not spontaneously decompose into atomic O.

$$\mu(\text{reactants}) < \mu(\text{products})$$



resonance structures

$$2. G = G(T, P, n_1, n_2)$$

$$dG = \left( \frac{\partial G}{\partial T} \right)_{P, n_1, n_2} dT + \left( \frac{\partial G}{\partial P} \right)_{T, n_1, n_2} dP + \left( \frac{\partial G}{\partial n_1} \right)_{T, P, n_2} dn_1 + \left( \frac{\partial G}{\partial n_2} \right)_{T, P, n_1} dn_2$$

$$\left( \frac{\partial G}{\partial n_i} \right)_{T, P} = \mu_i; \quad \left( \frac{\partial G}{\partial P} \right)_T = V; \quad \left( \frac{\partial G}{\partial T} \right)_P = -S$$

$$dG = -SdT + VdP + \mu_1 dn_1 + \mu_2 dn_2$$

$$3. T = 298 \text{ K}$$

50% by mass EtOH/H<sub>2</sub>O

$$\rho = 0.914 \text{ g/cm}^3$$

$$V_m(\text{H}_2\text{O}) = 17.4 \text{ cm}^3/\text{mol}$$

$$V_m(\text{EtOH}) = ?$$

Assume 100 mL soln.

$$V = n_A V_A + n_B V_B$$

$$V = n_{\text{H}_2\text{O}} V_{\text{H}_2\text{O}} + n_{\text{EtOH}} V_{\text{EtOH}}$$

$$\rho = \frac{m}{V}$$

$$m = \rho V = (0.914 \text{ g/cm}^3)(100 \text{ cm}^3)$$

$$m = 91.4 \text{ g}$$

$$50\% \text{ by mass} \Rightarrow 45.7 \text{ g H}_2\text{O} \\ 45.7 \text{ g EtOH}$$

continued:  $FW(H_2O) = 18 \text{ g/mol}$   
 $FW(ETOH) = 46 \text{ g/mol}$

$$n_{H_2O} = 2.54 \text{ mol}$$

$$n_{ETOH} = 0.993 \text{ mol}$$

$$V_{ETOH} = \frac{V - n_{H_2O} V_{H_2O}}{n_{ETOH}}$$

$$= \frac{(100 \text{ cm}^3) - (2.54 \text{ mol})(17.4 \frac{\text{cm}^3}{\text{mol}})}{0.993 \text{ mol}}$$

$$V_{ETOH} = 56.2 \text{ cm}^3/\text{mol}$$

4. maximum  $\Delta S_{mix}$   
assume ideal soln.

$$\Delta S_{mix} = -nR(x_1 \ln x_1 + x_2 \ln x_2)$$

$$x_2 = 1 - x_1$$

$$\Delta S_{mix} = -nR(x_1 \ln x_1 + (1 - x_1) \ln(1 - x_1))$$

$$\text{Optimized } \frac{d\Delta S_{mix}}{dx_1} = -nR(\ln x_1 + 1 - \ln(1 - x_1) - 1)$$

$$\frac{d\Delta S_{mix}}{dx_1} = -nR \ln\left(\frac{x_1}{1 - x_1}\right) = 0 \text{ at } x_1 = 0.5$$

So maximum entropy by mole fraction:  $x_1 = x_2 = 0.5$

completely independent of chemical identity

5.

The molar enthalpy of fusion of ice at 273.15 K and 1.0 atm is  $6010 \text{ J mol}^{-1}$ . The change in volume caused by the fusion of ice under the same conditions is  $-1.63 \text{ cm}^3 \text{ mol}^{-1}$ . You may assume that these values remain constant as a function of pressure. Estimate the melting temperature of ice at 1000 atm.

$$\frac{dP}{dT} = \frac{\Delta H_{\text{fus}}}{T_{\text{fus}} \Delta V_{\text{fus}}} ; \Delta T = \int_{P_i}^{P_f} \frac{T_{\text{fus}} \Delta V_{\text{fus}}}{\Delta H_{\text{fus}}} dP$$

$$\Delta T = T_f - T_c = \frac{T_{\text{fus}} \Delta V_{\text{fus}} \Delta P}{\Delta H_{\text{fus}}} ; T_f = \frac{T_{\text{fus}} \Delta V_{\text{fus}} \Delta P_{\text{fus}}}{\Delta H_{\text{fus}}} + T_c$$

$$\Delta T = -7.47 \text{ K}, \quad T_f(P=1000 \text{ bar}) = 266 \text{ K}$$