

Quiz V

CH 353 Sumer 2008

Vanden Bout

Name: _____ **KEY**

Carefully read all the problems. The first page has potentially useful information. The last page is for extra writing space.

$$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \quad R = 8.314 \times 10^{-2} \text{ L bar K}^{-1} \text{ mol}^{-1} \quad R = 8.206 \times 10^{-2} \text{ L atm mol}^{-1} \text{ K}^{-1}$$

$$1 \text{ atm} = 1.01325 \text{ bar} \quad T/\text{K} = T/^{\circ}\text{C} + 273.15 \quad 1 \text{ atm-L} = 101.325 \text{ J} \quad 1 \text{ bar-L} = 100 \text{ J}$$

$$g = 9.8 \text{ m s}^{-2} \quad \Pi = \rho gh$$

$$\frac{dP}{dT} = \frac{\Delta S}{\Delta V} = \frac{\Delta H}{T \Delta V} \quad \ln\left(\frac{K_2}{K_1}\right) = \frac{-\Delta_R H^{\circ}}{R} \left[\frac{1}{T_2} - \frac{1}{T_1} \right]$$

$$\Delta H = \int_{T_1}^{T_2} C_p dT \quad \Delta_R G = \Delta_R G^{\circ} + RT \ln Q \quad \Delta_R G^{\circ} = -RT \ln K$$

$$\left(\frac{\partial \mu}{\partial P}\right)_T = V_M \quad \left(\frac{\partial \mu}{\partial T}\right)_P = -S_M$$

Please sign at the bottom to certify that you have worked on your own.
I certify that I have worked the following exam without the help of others, and that the work I am turning in is my own.

Signed:

Signature

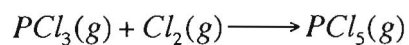
Date

1. True/False Circle either T or F for each statement (10 points each)

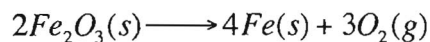
T F If $\Delta_r H^\circ > 0$ and $K > 1$, then $\Delta_r S^\circ$ is positive. $K > 1 \rightarrow \Delta_r G < 0$

T F The activity of an ideal gas is its partial pressure.

T F For the following reaction, if you add an inert gas at constant volume the equilibrium constant (K_p) will be unchanged.



T F For the following reaction $\Delta_r G^\circ > 0$ at room temperature



T F For an endothermic reaction, increasing the temperature will always increase the equilibrium constant.

2A. (25 points)

For a particular reaction you measure the equilibrium constant to be $K=2$ at 300K and $K=40$ at 400K. What are $\Delta_r H^\circ$ and $\Delta_r S^\circ$ for this reaction?

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta_r H^\circ}{R} \left[\frac{1}{T_2} - \frac{1}{T_1} \right]$$

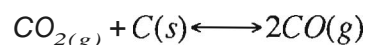
$$\ln\left(\frac{40}{2}\right) = \frac{-\Delta_r H^\circ}{8.314} \left[\frac{1}{400} - \frac{1}{300} \right]$$

$$\Delta_r H^\circ = 29,890 \text{ J mol}^{-1}$$

$$\Delta_r G^\circ = -RT \ln K = -(8.314)(300) \ln(2) = -1729 \text{ J mol}^{-1}$$

$$\Delta_r S^\circ = \frac{\Delta_r G^\circ - \Delta_r H^\circ}{-T} = \frac{-1729 - 29,890}{-298} = +106 \text{ J K}^{-1} \text{ mol}^{-1}$$

2B. For the following reaction, if $K=4$ and $P=1$ atm



What is the partial pressure of CO at equilibrium?

$$P = P_{\text{CO}} + P_{\text{CO}_2} = 1$$

$$P_{\text{CO}_2} = 1 - P_{\text{CO}}$$

$$K = \frac{P_{\text{CO}}^2}{P_{\text{CO}_2}} = \frac{P_{\text{CO}}^2}{1 - P_{\text{CO}}} = 4$$

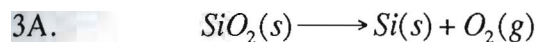
$$x^2 + 4x - 4 = 0$$

$$x = \frac{-4 \pm \sqrt{16 - (-16)}}{2} = .828 \text{ or something } < 0$$

$$x = P_{\text{CO}} = 0.828 \text{ atm}$$

What is the partial pressure of CO at equilibrium?

$$= P_{\text{CO}} + P_{\text{CO}_2} = 1$$



Given that $\Delta_r H^\circ_{\text{SiO}_2} = -910.9 \text{ kJ mol}^{-1}$ and $\Delta_r G^\circ_{\text{SiO}_2} = -856.6 \text{ kJ mol}^{-1}$, at what temperature do you think SiO_2 will decompose under a pressure of oxygen $P_{\text{O}_2} = 1 \text{ atm}$?

$$\Delta_r H^\circ = +910.9 \text{ kJ mol}^{-1}$$

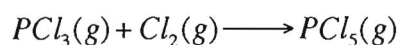
$$\Delta_r G^\circ = +856.6 \text{ kJ mol}^{-1}$$

$$\Delta_r S^\circ = \frac{\Delta_r G^\circ - \Delta_r H^\circ}{-T} = \frac{856.6 - 910.9}{-298} = +182 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$K = P_{\text{O}_2} = 1 \Rightarrow \Delta_r G^\circ = 0$$

$$T = \frac{\Delta_r H^\circ}{\Delta_r S^\circ} = \frac{910,900}{182} = 5005 \text{ K}$$

3B. For the following reaction $\Delta_r G^\circ = -37.2 \text{ kJ mol}^{-1}$ at 298K. At this particular temperature you have a mixture with 5×10^{-4} moles of Cl_2 , 9×10^{-2} moles of PCl_3 , and 2 moles of PCl_5 . The total pressure is 10^{-3} atm . Is the system at equilibrium? If not in which direction will the reaction change to get equilibrium (toward product or reactants).



$$n_{\text{Cl}_2} = 5 \cdot 10^{-4}$$

$$P_{\text{Cl}_2} = \frac{5 \cdot 10^{-4}}{2.0904} \times 10^{-3} = 2.39 \cdot 10^{-7}$$

$$n_{\text{PCl}_3} = 9 \cdot 10^{-2}$$

$$P_{\text{PCl}_3} = \frac{9 \cdot 10^{-2}}{2.0904} \cdot 10^{-3} = 4.3 \cdot 10^{-5}$$

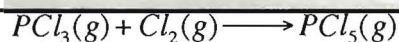
$$n_{\text{PCl}_5} = 2$$

$$n_{\text{total}} = 2.0904 \quad P_{\text{PCl}_5} = \frac{2}{2.0904} \cdot 10^{-3} = 9.57 \cdot 10^{-4}$$

$$Q = \frac{P_{\text{PCl}_5}}{P_{\text{PCl}_3} P_{\text{Cl}_2}} = \frac{9.57 \cdot 10^{-4}}{(2.39 \cdot 10^{-7})(4.3 \cdot 10^{-5})} = 9.3 \cdot 10^7$$

$$K = \exp\left[\frac{-\Delta_r G^\circ}{RT}\right] = \exp\left[\frac{37,200}{(8.314)(298)}\right] = 3.3 \cdot 10^6$$

$Q > K$
Back to react



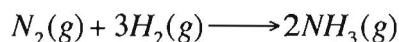
$$n = 5 \cdot 10^{-4}$$

$$P_{\text{Cl}_2} = \frac{5 \cdot 10^{-4}}{2.0904} \times 10^{-3} = 2.39 \cdot 10^{-7}$$

t

4. (50 Points)

For the following reaction



$$\Delta_r H^\circ = 2 \times \Delta_f H^\circ_{NH_3} = \boxed{-92.2 \text{ kJ mol}^{-1}}$$

Data at 298K

Substance	$\Delta_f H^\circ$ (kJ mol ⁻¹)	S° (J K ⁻¹ mol ⁻¹)	C_p (J K mol ⁻¹)
NH ₃ (g)	-46.1	192.45	35.06

You have a mixture that initially has 1 mole of nitrogen and 1 mole of hydrogen at a constant temperature of 298K and a pressure of 1 atm. As the system goes to equilibrium you measure that 28.92 kJ of heat is released from the system.

What are $\Delta_r H^\circ$, K , $\Delta_r G^\circ$, and $\Delta_r S^\circ$ for this reaction?

$$\Delta H = (\text{extent} \cdot \nu_{rxn}) \times \Delta_r H^\circ$$

$$\text{extent} = \frac{\Delta H}{\Delta_r H^\circ} = \frac{-28.92 \text{ kJ}}{-92.2 \text{ kJ mol}^{-1}} = 0.3137$$

N₂ H₂ NH₃ Total ζ

1 1 0 2

1-x 1-3x 2-2x X=0.3137

0.6863 0.0589 0.6274 1.373

P_i 0.863 0.0589 0.6274

1.373 1.373 1.373

P 0.5 0.29 0.457

$$\Delta_r G^\circ = -RT \ln K$$

$$K = \frac{(0.457)^2}{(0.5)(0.29)^3} = 5.290$$

$$\Delta_r G^\circ = -(8.314)(298)(8.574)$$

$$\Delta_r G^\circ = -21,240$$

$$\Delta_r S^\circ = \frac{\Delta_r H^\circ - \Delta_r G^\circ}{T} = \boxed{-238 \text{ J K}^{-1} \text{ mol}^{-1}}$$

mol

mol 1-x 1-3x

2-2x

X=0.3137