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 =8.314J K^{-1} mol"   R = 8.314x1O-^{2} L bar K^{-1} mol'   R =8.206x1O-^{2} L atm rnol' K^{-1}

1 atm = 1.01325 bar   T/K = T/°C + 273.15   1 atrn-L =101.325 J   1 bar-L =100 J

g = 9.8 m s·2   n = pgh

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

$$\Delta H = \int_{T_1}^{T_2} C_P dT \qquad \Delta_R G = \Delta_R G^o + RT\ln Q \qquad \Delta_R G^o = -RT\ln K$$

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

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 $\Delta_R H° > 0$ and $K > 1$, then $\Delta_R S°$ 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.

$$PCl_3(g) + Cl_2(g) \longrightarrow PCl_5(g)$$

T F   For the following reaction $\Delta_R G° > 0$ at room temperature

$$2Fe_2O_3(s) \longrightarrow 4Fe(s) + 3O_2(g)$$

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 $\Delta_R H°$ and $\Delta_R S°$ for this reaction?

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

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

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

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

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

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

$CO_{2(g)} + C(s) \longleftrightarrow 2CO(g)$

What is the partial pressure of CO at equilibrium?

$$P = P_{CO} + P_{CO_2} = 1$$

$$P_{CO_2} = 1 - P_{CO}$$

$$K = \frac{P_{CO}^2}{P_{CO_2}} = \frac{P_{CO}^2}{1 - P_{CO}} = \frac{x^2}{1-x} = 4$$

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

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

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

What is the partial pressure of CO at equilibrium?

$$= P_{CO} + P_{CO_2} = 1$$

3A. $SiO_2(s) \longrightarrow Si(s) + O_2(g)$

Given that $\Delta_f H°_{SiO2}$ = -910.9 kJ mol" and $\Delta_f G°_{SiO2}$ = -856.6 kJ mol', at what temperature do you think SrO, will decompose under a pressure of oxygen *Paz* = latm?

$\Delta_R H^0 = +910.9 \text{ kJ mol}^{-1}$

$\Delta_R G^0 = +856.6 \text{ kJ mol}^{-1}$

$\Delta_R S^0 = \frac{\Delta_R G^0 - \Delta_R H^0}{-T} = \frac{856.6 - 910.9}{-298} = +182 \text{ J K}^{-1} \text{ mol}^{-1}$

$K = P_{O_2} = 1 \Rightarrow \Delta_R G^0 = 0$

$T = \frac{\Delta_R H^0}{\Delta_R S^0} \quad \frac{910{,}900}{182} = 5005 \text{ K}$

3B. For the following reaction $\Delta_R G°$ = -37.2 kJ mol' at 298K. At this particular temperature you have a mixture with 5xlO-4 moles of Cl, , 9xlO-^{Z} moles of PCl_3, and 2 moles of PCl_S. 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).

$PCl_3(g) + Cl_2(g) \longrightarrow PCl_5(g)$

$n_{Cl_2} = 5 \cdot 10^{-4}$ $\quad P_{Cl_2} = \frac{5 \cdot 10^{-4}}{2.0904} \times 10^{-3} = 2.39 \cdot 10^{-7}$

$n_{Cl_3} = 9 \cdot 10^{-2}$ $\quad P_{PCl_3} = \frac{9 \cdot 10^{-2}}{2.0904} \cdot 10^{-3} = \cancel{3.40}\ 4.3 \cdot 10^{-5}$

$n_{PCl_5} = 2$

$n_{TOTAL} = 2.0904$ $\quad P_{PCl_5} = \frac{2}{2.0904} \cdot 10^{-3} = \cancel{6.9}\ 9.57 \cdot 10^{-4}$

$Q = \frac{P_{PCl_5}}{P_{PCl_3} P_{Cl_2}} = \frac{9.57 \cdot 10^{-4}}{(2.39 \cdot 10^{-7})(\cancel{3.40}\ 4.3 \cdot 10^{-5})} = \cancel{1.3 \cdot 10^{8}}\ 9.3 \cdot 10^{7}$

$K = \exp\left[\frac{-\Delta_R G^0}{RT}\right] = \exp\left[\frac{37{,}200}{(8.314)(298)}\right] = 3.3 \cdot 10^{6}$

$Q > K$

Back to react

$PCl_3(g) + Cl_2(g) \longrightarrow PCl_5(g)$

$n = 5 \cdot 10^{-4}$ $\quad P_{Cl_2} = \frac{5 \cdot 10^{-4}}{2.0904} \times 10^{-3} = 2.39 \cdot 10^{-7}$

t

4. (50 Points)

For the following reaction

$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

$\Delta_R H^o = 2 \times \Delta_f H^o_{NH_3} = \boxed{-92.2\ kJ\ mol^{-1}}$

Data at 298K

Substance	$\Delta_f H°$ (kJ rnol')	S0 (J K^{-1} mol')	C_p (J K rnol')
$NH_3(g)$	-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 $\Delta_R H°$, K, $\Delta_R G°$, and $\Delta_R S°$ for this reaction?

$\Delta H = (\text{extent of rxn}) \times \Delta_R H^o$

$\text{extent} = \dfrac{\Delta H}{\Delta_R H^o} = \dfrac{-28.92\ kJ}{-92.2\ kJ\ mol^{-1}} = 0.3137$

N_2	H_2	NH_3	total G
1	1	0	2
1-x	1 3x		2-2x
0.6863	.0588	.6274	1.373

X=0.3137

P_i: $\dfrac{0.863}{1.373}$ $\dfrac{.0589}{1.373}$ $\dfrac{6274}{1.373}$

P: .05 .0 29 ~~.0Y~~ .457

$\Delta_R G^o = -RT \ln K$

$K = \dfrac{(.4\ 7)^2}{(.5)(.0\ 29)^3} = \boxed{5290}$

$\Delta_R G^o = -(8.314)(298)(8.574)$

$\boxed{\Delta_R G^o = -21,240\ J}$

$\Delta_R S^o = \dfrac{\Delta_R H^o - \Delta_R G^o}{T} = \boxed{-238\ JK^{-1}\ mol^{-1}}$

init 1

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