20S-CHEM20B-1 Exam 2

AN LE

TOTAL POINTS

97 / 100

QUESTION 1

1 20 pts

1.1 1.i 10 / 10

✓ **+ 10 pts Correct; $$ (P,V,T)_g=(1atm,2.26m^3,276K) $$ and $$ (T,Phase)_w=(276K,liquid)$$**

+ 2 pts $$ q_g=-q_w$$ or $$ q_g + q_w=0$$

+ 2 pts $$ q_g = n_gC_P(T_{eq}-T_g)$$

+ 4 pts $$q_w= m_w \Delta H_{fus}^o + m_wC_s(T_{eq}-T_i)$$

- 2 pts Math or unit error

+ 0 pts Incorrect

1.2 1.ii 10 / 10

✓ **+ 10 pts Correct, $$ \Delta S_{univ} = 2.33 \frac {J}{K}>0$$, so spontaneous**

+ 2 pts $$ \Delta S_{sys}= \Delta S_1+\Delta S_2+\Delta S_3$$

+ 4 pts $$ \Delta S_{sys}= \frac {m_i\Delta H_{fus}^o}{T_m}+m_iC_s*ln(T_{eq}/T_i)+n_gC_P*ln(T_{eq}/T_g)$$

+ 2 pts $$\Delta S_{sur}=0$$

- 2 pts Math or unit error

+ 0 pts Incorrect

QUESTION 2

2 20 pts

2.1 2.i 6 / 6

✓ **+ 6 pts Correct, $$ \Delta S_{univ}=1.97 \frac {J}{molK}>0$$, so spontaneous**

+ 2 pts $$\Delta S_{sys}=\Delta S_r^o$$

+ 2 pts $$\Delta S_{sur}=\frac {-\Delta H_r^o}{T_{sur}}$$

- 2 pts Math or unit error

+ 0 pts Incorrect

2.2 2.ii 6 / 6

✓ **+ 6 pts Correct, $$ \Delta G_r = \Delta G_r^o = -586 \frac {J}{mol}<0$$, so spontaneous**

+ 1 pts Under standard conditions, $$Q=1$$

+ 2 pts $$ \Delta G_r = \Delta G_r^o$$

+ 2 pts $$ \Delta G_r^o=\Delta H_r^o-298K\Delta S_r^o$$

- 2 pts Math or unit error

2.3 2.iii 8 / 8

✓ **+ 8 pts Correct, $$ \Delta G_r=4566 \frac {J}{mol}>0$$, so the forward reaction is not spontaneous; or $$Q>K$$, so the forward reaction is not spontaneous**

+ 2 pts $$ Q = 8 $$

+ 3 pts $$ \Delta G_r=\Delta G_r^o + R(298K)*ln(Q)$$ or $$K=exp(-\Delta G_r^o/RT)$$ and $$ \Delta G_r=RT*ln(Q/K)$$

- 2 pts Math or unit error

+ 0 pts Incorrect

QUESTION 3

3 3 17 / 20

✓ **+ 0 pts Correct conclusion, $$ \Delta S_{univ}=nR*ln(V_f/V_i)>0$$, so spontaneous**

✓ **+ 2 pts $$w=-P_{ext}dV=0$$, since $$P_{ext}=0$$**

✓ **+ 2 pts Isothermal, so $$\Delta T \propto \Delta U=0$$**

✓ **+ 2 pts $$ \Delta U = q+w$$, so $$q=-w=0$$**

✓ **+ 2 pts $$\Delta S_{sur}=q/T=0$$**

+ 2 pts Use reversible, isothermal process to calculate $$ \Delta S_{sys}=\int dq/T $$ since S is a state function (second law)

+ **1 pts** $$q_{rev,iso}=-w=nRT*ln(V_f/V_i)$$

✓ **+ 5 pts** **$$\Delta S_{sys}=q/T=nR*ln(V_f/V_i)$$**

✓ **+ 3 pts** **However, systems state has changed since $$ V_f>V_i$$, $$ln(V_f/V_i) >0$$ (or $$ ln(\Omega_f/\Omega_i) > 0$$ if relevant)**

✓ **+ 1 pts** **$$\Delta S_{universe} = \Delta S_{sys} + \Delta S_{surr} $$**

+ **6 pts** Concluded $$\Delta S_{surr} = 0 $$ by other means

+ **10 pts** Arrived at correct conclusion for $$\Delta S_{sys} > 0$$ using $$ \Omega_{ideal} \propto V^N $$, and $$ S = k_b ln(\Omega) $$

+ **6 pts** Qualitative only argument for $$ \Delta S_{sys} $$ is positively correlated with $$V$$

+ **0 pts** No credit

QUESTION 4

4 4 16 / 16

✓ **+ 16 pts** **Correct, $$[C]=0.726M$$ or $$[C]<0.726M$$ for spontaneity**

+ **3 pts** $$ \Delta G_r^o=\Delta H_r^o -(300K)\Delta S_r^o$$

+ **6 pts** For spontaneity, $$ \Delta G_r = \Delta G_r^o+RT*ln(Q)<0 $$

+ **4 pts** $$Q=[C]$$

- **3 pts** Math or unit error

QUESTION 5

5 24 pts

5.1 5.i 11 / 11

✓ **+ 11 pts** **Correct, $$P_B=1.31atm$$, $$P_A=0.186atm$$**

+ **2 pts** $$ \Delta G_r^o=\Delta H_r^o -(600K)\Delta S_r^o$$

+ **2 pts** $$ K=exp(-\Delta G_r^o/RT)$$

+ **2 pts** $$K=\frac {1}{P_AP_B}$$

+ **2 pts** $$ P_T=1.5atm=P_A+P_B$$

- **3 pts** Math or unit error

5.2 5.ii 6 / 6

✓ **+ 6 pts** **Correct, $$\Delta G_r=\Delta G_r^o = -7000 \frac {J}{mol}<0$$, so the forward rxn is spontaneous**

+ **2 pts** Under standard conditions, $$ Q=1$$

+ **2 pts** $$ \Delta G_r = \Delta G_r^o+RT*ln(Q)$$

- **2 pts** Math or unit error

5.3 5.iii 7 / 7

✓ **+ 7 pts** **Correct, $$ \Delta G_r=15972 \frac {J}{mol}>0$$, so the reverse rxn is spontaneous**

+ **2 pts** $$ Q=100$$

+ **2 pts** $$ \Delta G_r = \Delta G_r^o+RT*ln(Q)$$

+ **1 pts** Correct direction based on calculation

- **2 pts** Math or unit error

Chem 20B Midterm 2 Exam

Name: An Le, UID:

Problem #1

1) Monatomic ideal gas: $n = 100\ mol$, $P = 1\ atm$, $T = 20°C = 293\ K$

Ice: $m = 100\ g = 0.100\ kg$, $T = 0°C = 273\ K$

i) $q_{balloon} = -q_{ice}$ (isobaric, $\Delta P = 0$)

$$q_{balloon} = nC_p\Delta T = (100\ mol)\left(\frac{5}{2}\right)\left(8.314\ \frac{J}{mol\cdot K}\right)(T_{eq} - 293\ K) = (2078.5\ J/K)(T_{eq} - 293\ K)$$

$$q_{ice} = m_{ice}\Delta H_{fus} + m_{ice}C_w\Delta T_w$$

$$= (100\ g)\left[(333\ J/g) + (4.2\ J/g\cdot K)(T_{eq} - 273\ K)\right]$$

$$= 33300\ J + (420\ J/K)(T_{eq} - 273\ K)$$

$$(2078.5\ J/K)(T_{eq} - 293\ K) = -\left[33300\ J + (420\ J/K)(T_{eq} - 273\ K)\right]$$

$$2078.5\,T_{eq} - 609001\ J = -33300\ J - 420\,T_{eq} + 114660\ J$$

$$2498.5\,T_{eq} = 690361\ J \rightarrow T_{eq} = 276.31\ K$$

$$PV = nRT \rightarrow (1\ atm)(V) = (100\ mol)\left(8.314\ \frac{J}{mol\cdot K}\right)(276.31\ K) \rightarrow V = 2.27\ m^3$$

Balloon: $P = 1\ atm$,	Water: $T = 276.31\ K$,
$V = 2.27\ m^3$, $T = 276.31\ K$	phase = liquid

ii) $\Delta S_{uni} = \Delta S_{sys} + \Delta S_{surr}$

$$\Delta S_{sys} = nC_p Ln\left(\frac{T_f}{T_i}\right) + \frac{m\Delta H°}{T} + mC\,Ln\left(\frac{T_f}{T_i}\right)$$

$$= (100\ mol)\left(\frac{5}{2}\right)\left(8.314\ \frac{J}{mol\cdot K}\right)Ln\left(\frac{276.31\ K}{293\ K}\right) + \frac{(100\ g)(333\ J/g)}{(273\ K)} + (100\ g)\left(4.2\ \frac{J}{g\cdot K}\right)Ln\left(\frac{276.31\ K}{273\ K}\right)$$

$$= -121.902 + 121.978 + 5.06168 = 5.14\ J/K$$

$$\Delta S_{surr} = \frac{-q_{sys}}{T_{surr}} = \frac{-(-34690.2\ J + 33300\ J + 1390.2\ J)}{(276.31\ K)} = 0 \quad \text{(isolated system)}$$

$$\Delta S_{uni} = \Delta S_{sys} + \Delta S_{surr} = 5.14\ J/K + 0 = 5.14\ J/K$$

$\Delta S_{uni} = 5.14\ J/K > 0 \rightarrow$ Thus, the process is spontaneous.

1.1 1.i **10 / 10**

✓ **+ 10 pts** **Correct; $$ (P,V,T)_g=(1atm,2.26m^3,276K) $$ and $$ (T,Phase)_w=(276K,liquid)$$**

+ 2 pts $$ q_g=-q_w$$ or $$ q_g + q_w=0$$

+ 2 pts $$ q_g = n_gC_P(T_{eq}-T_g)$$

+ 4 pts $$q_w= m_w \Delta H_{fus}^o + m_wC_s(T_{eq}-T_i)$$

- 2 pts Math or unit error

+ 0 pts Incorrect

Chem 20B Midterm 2 Exam

Name: An Le, UID:

Problem #1

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Ice: $m = 100\ g = 0.100\ kg$, $T = 0°C = 273\ K$

i) $q_{balloon} = -q_{ice}$ (isobaric, $\Delta P = 0$)

$$q_{balloon} = nC_p\Delta T = (100\ mol)\left(\frac{5}{2}\right)\left(8.314\ \frac{J}{mol\cdot K}\right)(T_{eq} - 293\ K) = (2078.5\ J/K)(T_{eq} - 293\ K)$$

$$q_{ice} = m_{ice}\Delta H_{fus} + m_{ice}C_w\Delta T_w$$

$$= (100\ g)\left[(333\ J/g) + (4.2\ J/g\cdot K)(T_{eq} - 273\ K)\right]$$

$$= 33300\ J + (420\ J/K)(T_{eq} - 273\ K)$$

$$(2078.5\ J/K)(T_{eq} - 293\ K) = -\left[33300\ J + (420\ J/K)(T_{eq} - 273\ K)\right]$$

$$2078.5\,T_{eq} - 609001\ J = -33300\ J - 420\,T_{eq} + 114660\ J$$

$$2498.5\,T_{eq} = 690361\ J \rightarrow T_{eq} = 276.31\ K$$

$$PV = nRT \rightarrow (1\ atm)(V) = (100\ mol)\left(8.314\ \frac{J}{mol\cdot K}\right)(276.31\ K) \rightarrow V = 2.27\ m^3$$

Balloon: $P = 1\ atm$,	Water: $T = 276.31\ K$,
$V = 2.27\ m^3$, $T = 276.31\ K$	phase = liquid

ii) $\Delta S_{uni} = \Delta S_{sys} + \Delta S_{surr}$

$$\Delta S_{sys} = nC_p Ln\left(\frac{T_f}{T_i}\right) + \frac{m\Delta H°}{T} + mC\,Ln\left(\frac{T_f}{T_i}\right)$$

$$= (100\ mol)\left(\frac{5}{2}\right)\left(8.314\ \frac{J}{mol\cdot K}\right)Ln\left(\frac{276.31\ K}{293\ K}\right) + \frac{(100\ g)(333\ J/g)}{(273\ K)} + (100\ g)\left(4.2\ \frac{J}{g\cdot K}\right)Ln\left(\frac{276.31\ K}{273\ K}\right)$$

$$= -121.902 + 121.978 + 5.06168 = 5.14\ J/K$$

$$\Delta S_{surr} = \frac{-q_{sys}}{T_{surr}} = \frac{-(-34690.2\ J + 33300\ J + 1390.2\ J)}{(276.31\ K)} = 0 \quad \text{(isolated system)}$$

$$\Delta S_{uni} = \Delta S_{sys} + \Delta S_{surr} = 5.14\ J/K + 0 = 5.14\ J/K$$

$\Delta S_{uni} = 5.14\ J/K > 0 \rightarrow$ Thus, the process is spontaneous.

1.2 1.ii 10 / 10

✓ **+ 10 pts** **Correct, $$ \Delta S_{univ} = 2.33 \frac {J}{K}>0$$, so spontaneous**

+ 2 pts $$ \Delta S_{sys}= \Delta S_1+\Delta S_2+\Delta S_3$$

+ 4 pts $$ \Delta S_{sys}= \frac {m_i\Delta H_{fus}^o}{T_m}+m_iC_s*ln(T_{eq}/T_i)+n_gC_P*ln(T_{eq}/T_g)$$

+ 2 pts $$\Delta S_{sur}=0$$

- 2 pts Math or unit error

+ 0 pts Incorrect

Name: An Le, UID:

Problem #2

2) $A_{(g)} + 2B_{(g)} \rightleftharpoons 3C_{(g)}$, $\Delta H^\circ = 10\ J/mol$, $\Delta S^\circ = 2\ J/mol\cdot K$ @ 298 K

i) $\Delta S_{uni} = \Delta S_{sys} + \Delta S_{surr}$

$\Delta S_{sys} = \Delta S^\circ = 2\ J/mol\cdot K$

$\Delta S_{surr} = \frac{-q_{sys}}{T} = \frac{-\Delta H^\circ}{T} = \frac{-(10\ J/mol)}{(298\ K)} = -0.034\ J/mol\cdot K$

$\Delta S_{uni} = 2\ J/mol\cdot K - 0.034\ J/mol\cdot K =$ **$1.966\ J/mol\cdot K > 0$, spontaneous**

ii) $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \rightarrow \Delta G = (10\ J/mol) - (298\ K)(2\ J/mol\cdot K)$

$\Delta G^\circ = -586\ J/mol < 0$, spontaneous

iii) $Q = \frac{(P_C)^3}{(P_A)^1(P_B)^2} = \frac{(0.5\ atm)^3}{(0.25\ atm)(0.25\ atm)^2} = 8$

$K = e^{-(-586\ J/mol)/(8.314\ J/mol\cdot K)(298\ K)} = 1.267$

$\Delta G = RT\ln\left(\frac{Q}{K}\right) = \left(8.314\ \frac{J}{mol\cdot K}\right)(298\ K)\ln\left(\frac{8}{1.267}\right)$

$\Delta G = 4566\ J/mol > 0 \rightarrow$ **forward rxn NOT spontaneous**

2.1 2.i 6 / 6

✓ **+ 6 pts Correct, $$ \Delta S_{univ}=1.97 \frac {J}{molK}>0$$, so spontaneous**

+ 2 pts $$\Delta S_{sys}=\Delta S_r^o$$

+ 2 pts $$\Delta S_{sur}=\frac {-\Delta H_r^o}{T_{sur}}$$

- 2 pts Math or unit error

+ 0 pts Incorrect

Name: An Le, UID:

Problem #2

2) $A_{(g)} + 2B_{(g)} \rightleftharpoons 3C_{(g)}$, $\Delta H^\circ = 10\ J/mol$, $\Delta S^\circ = 2\ J/mol\cdot K$ @ 298 K

i) $\Delta S_{uni} = \Delta S_{sys} + \Delta S_{surr}$

$\Delta S_{sys} = \Delta S^\circ = 2\ J/mol\cdot K$

$\Delta S_{surr} = \frac{-q_{sys}}{T} = \frac{-\Delta H^\circ}{T} = \frac{-(10\ J/mol)}{(298\ K)} = -0.034\ J/mol\cdot K$

$\Delta S_{uni} = 2\ J/mol\cdot K - 0.034\ J/mol\cdot K =$ **$1.966\ J/mol\cdot K > 0$, spontaneous**

ii) $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \rightarrow \Delta G = (10\ J/mol) - (298\ K)(2\ J/mol\cdot K)$

$\Delta G^\circ = -586\ J/mol < 0$, spontaneous

iii) $Q = \frac{(P_C)^3}{(P_A)^1(P_B)^2} = \frac{(0.5\ atm)^3}{(0.25\ atm)(0.25\ atm)^2} = 8$

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$\Delta G = RT\ln\left(\frac{Q}{K}\right) = \left(8.314\ \frac{J}{mol\cdot K}\right)(298\ K)\ln\left(\frac{8}{1.267}\right)$

$\Delta G = 4566\ J/mol > 0 \rightarrow$ **forward rxn NOT spontaneous**

2.2 2.ii 6 / 6

✓ **+ 6 pts Correct, $$ \Delta G_r = \Delta G_r^o = -586 \frac {J}{mol}<0$$, so spontaneous**

+ 1 pts Under standard conditions, $$Q=1$$

+ 2 pts $$ \Delta G_r = \Delta G_r^o$$

+ 2 pts $$ \Delta G_r^o=\Delta H_r^o-298K\Delta S_r^o$$

- 2 pts Math or unit error

Name: An Le, UID:

Problem #2

2) $A_{(g)} + 2B_{(g)} \rightleftharpoons 3C_{(g)}$, $\Delta H^\circ = 10\ J/mol$, $\Delta S^\circ = 2\ J/mol\cdot k$ @ 298 K

i) $\Delta S_{uni} = \Delta S_{sys} + \Delta S_{surr}$

$\Delta S_{sys} = \Delta S^\circ = 2\ J/mol\cdot k$

$\Delta S_{surr} = \frac{-q_{sys}}{T} = \frac{-\Delta H^\circ}{T} = \frac{-(10\ J/mol)}{(298\ K)} = -0.034\ J/mol\cdot k$

$\Delta S_{uni} = 2\ J/mol\cdot k - 0.034\ J/mol\cdot K =$ **$1.966\ J/mol\cdot K > 0$, spontaneous**

ii) $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \rightarrow \Delta G = (10\ J/mol) - (298\ K)(2\ J/mol\cdot K)$

$\Delta G^\circ = -586\ J/mol < 0$, spontaneous

iii) $Q = \frac{(P_C)^3}{(P_A)^1(P_B)^2} = \frac{(0.5\ atm)^3}{(0.25\ atm)(0.25\ atm)^2} = 8$

$K = e^{-(-586\ J/mol)/(8.314\ J/mol\cdot K)(298\ K)} = 1.267$

$\Delta G = RT\ln\left(\frac{Q}{K}\right) = \left(8.314\ \frac{J}{mol\cdot k}\right)(298\ K)\ln\left(\frac{8}{1.267}\right)$

$\Delta G = 4566\ J/mol > 0 \rightarrow$ **forward rxn NOT spontaneous**

2.3 2.iii 8 / 8

✓ **+ 8 pts Correct, $$ \Delta G_r=4566 \frac {J}{mol}>0$$, so the forward reaction is not spontaneous; or $$Q>K$$, so the forward reaction is not spontaneous**

+ 2 pts $$ Q = 8 $$

+ 3 pts $$ \Delta G_r=\Delta G_r^o + R(298K)*ln(Q)$$ or $$K=exp(-\Delta G_r^o/RT)$$ and $$ \Delta G_r=RT*ln(Q/K)$$

- 2 pts Math or unit error

+ 0 pts Incorrect

Name: An Le, UID:

Problem #3

3) Since $P_{ext} = 0$, $W = 0$ because $W = -\int P dV$

For an isothermal process, $\Delta T = 0$

$\Delta U = \frac{3}{2} nR\Delta T = \frac{3}{2} nR(0) = 0 \rightarrow \Delta U = 0 = q + w \rightarrow q = -w$

$\Delta S = \Delta S_{sys} + \Delta S_{surr}$

$\Delta S_{surr} = \frac{-q}{T} = \frac{-(-w)}{T} = \frac{0}{T} \rightarrow \Delta S_{surr} = 0$

$\Delta S_{sys} = nR\,Ln\left(\frac{V_f}{V_i}\right)$

Expansion so we can assume $V_f > V_i$

If $V_f > V_i$, $Ln\left(\frac{V_f}{V_i}\right)$ will be a positive number $\rightarrow Ln\left(\frac{V_f}{V_i}\right) > 0$

Thus, $\Delta S_{sys} = nR\,Ln\left(\frac{V_f}{V_i}\right) > 0 \rightarrow$ spontaneous

$\Delta S_{uni} = \Delta S_{sys} + \Delta S_{surr} = \Delta S_{sys} > 0$ ✓

3 3 **17 / 20**

✓ **+ 0 pts** **Correct conclusion, $$ \Delta S_{univ}=nR*ln(V_f/V_i)>0$$, so spontaneous**

✓ **+ 2 pts** **$$w=-P_{ext}dV=0$$, since $$P_{ext}=0$$**

✓ **+ 2 pts** **Isothermal, so $$\Delta T \propto \Delta U=0$$**

✓ **+ 2 pts** **$$ \Delta U = q+w$$, so $$q=-w=0$$**

✓ **+ 2 pts** **$$\Delta S_{sur}=q/T=0$$**

+ 2 pts Use reversible, isothermal process to calculate $$ \Delta S_{sys}=\int dq/T $$ since S is a state function (second law)

+ 1 pts $$q_{rev,iso}=-w=nRT*ln(V_f/V_i)$$

✓ **+ 5 pts** **$$\Delta S_{sys}=q/T=nR*ln(V_f/V_i)$$**

✓ **+ 3 pts** **However, systems state has changed since $$ V_f>V_i$$, $$ln(V_f/V_i) >0$$ (or $$ ln(\Omega_f/\Omega_i) > 0$$ if relevant)**

✓ **+ 1 pts** **$$\Delta S_{universe} = \Delta S_{sys} + \Delta S_{surr} $$**

+ 6 pts Concluded $$\Delta S_{surr} = 0 $$ by other means

+ 10 pts Arrived at correct conclusion for $$\Delta S_{sys} > 0$$ using $$ \Omega_{ideal} \propto V^N $$, and $$ S = k_b ln(\Omega) $$

+ 6 pts Qualitative only argument for $$ \Delta S_{sys} $$ is positively correlated with $$V$$

+ 0 pts No credit

Name: An Le, UID:

Problem #4

4) $2A_{(aq)} + B_{(aq)} \rightleftharpoons C_{(aq)}$, $\Delta H^\circ = 2\ kJ/mol$, $\Delta S^\circ = 4\ J/mol\cdot K$ @ 300 K

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = (2000\ J/mol) - (300\ K)(4\ J/mol\cdot K) = 800\ J/mol$

$Q = \dfrac{[C]}{[A]^2[B]}$ → [A] and [B] → $Q = [C]$ are 1 M

To be spontaneous, $\Delta G < 0$ (forward rxn)

$\Delta G = \Delta G^\circ + RT\ln Q < 0 \rightarrow -RT\ln Q < -\Delta G^\circ$

$\ln Q < \dfrac{-\Delta G^\circ}{RT} \rightarrow \ln[C] < \dfrac{-\Delta G^\circ}{RT} \rightarrow [C] < e^{-\Delta G^\circ/RT}$

$[C] < e^{-(800\ J/mol)/(8.314\ J/mol\cdot K)(300\ K)} \rightarrow \boxed{[C]_{max} = 0.726\ M}$

4 4 **16 / 16**

✓ **+ 16 pts Correct, $$[C]=0.726M$$ or $$[C]<0.726M$$ for spontaneity**

+ 3 pts $$ \Delta G_r^o=\Delta H_r^o -(300K)\Delta S_r^o$$

+ 6 pts For spontaneity, $$ \Delta G_r = \Delta G_r^o+RT*ln(Q)<0 $$

+ 4 pts $$Q=[C]$$

- 3 pts Math or unit error

Name: An Le, UID:

Problem #5

5) $A_{(g)} + B_{(g)} \rightleftharpoons C_{(s)}$, 600 K, $\Delta H° = 5$ kJ/mol, $\Delta S° = 20$ J/mol·K

i) $\Delta G° = \Delta H° - T\Delta S° = (5000\ J/mol) - (600\ K)(20\ J/mol\text{-}K) = -7000\ J/mol$

$K = e^{-\Delta G°/RT} = e^{-(-7000\ J/mol)/(8.314\ J/mol\text{-}K)(600\ K)} = 4.068$

$4.068 = \dfrac{1}{(P_A)(P_B)}$ — $P_{final} = 1.5\ atm = P_A + P_B$ @ equilibrium

↳ $P_A = 1.5 - P_B$

$(P_A)(P_B) = \frac{1}{4.068} = 0.246 \rightarrow (1.5 - P_B)(P_B) = 0.246$

$1.5P_B - P_B^2 - 0.246 = 0 \rightarrow$ **$P_B = 1.313$ atm** | **$P_A = 0.187$ atm**

ii) standard conditions → P = 1 atm, M = 1 M → $Q = \frac{1}{(1)(1)} = 1$

$K = 4.068 \rightarrow Q < K$, more reactants than you should at eq.

$Ln\left(\frac{Q}{K}\right) < 0 \rightarrow \Delta G < 0$ | **forward rxn is spontaneous**

$\Delta G = (8.314\ J/mol\text{-}K)(600\ K)\,Ln\left(\frac{1}{4.068}\right) = -6999.48\ J/mol < 0$ ✓

iii) $Q = \dfrac{1}{(P_A)(P_B)} = \dfrac{1}{(1\ atm)(0.01\ atm)} = 100$

$K = 4.068 \rightarrow Q > K$, more products than you should at eq.

$Ln\left(\frac{Q}{K}\right) > 0 \rightarrow \Delta G > 0$ | **reverse rxn is spontaneous**

$\Delta G = (8.314\ J/mol\text{-}K)(600\ K)\,Ln\left(\frac{100}{4.068}\right) = 15973\ J/mol > 0$ ✓

5.1 5.i **11 / 11**

✓ **+ 11 pts** **Correct, $$P_B=1.31atm$$, $$P_A=0.186atm$$**

+ 2 pts $$ \Delta G_r^o=\Delta H_r^o -(600K)\Delta S_r^o$$

+ 2 pts $$ K=exp(-\Delta G_r^o/RT)$$

+ 2 pts $$K=\frac {1}{P_AP_B}$$

+ 2 pts $$ P_T=1.5atm=P_A+P_B$$

- 3 pts Math or unit error

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5) $A_{(g)} + B_{(g)} \rightleftharpoons C_{(s)}$, 600 K, $\Delta H° = 5$ kJ/mol, $\Delta S° = 20$ J/mol·K

i) $\Delta G° = \Delta H° - T\Delta S° = (5000\ J/mol) - (600\ K)(20\ J/mol\text{-}K) = -7000\ J/mol$

$K = e^{-\Delta G°/RT} = e^{-(-7000\ J/mol)/(8.314\ J/mol\text{-}K)(600\ K)} = 4.068$

$4.068 = \frac{1}{(P_A)(P_B)}$ — $P_{final} = 1.5\ atm = P_A + P_B$ @ equilibrium

↳ $P_A = 1.5 - P_B$

$(P_A)(P_B) = \frac{1}{4.068} = 0.246 \rightarrow (1.5 - P_B)(P_B) = 0.246$

$1.5P_B - P_B^2 - 0.246 = 0 \rightarrow$ **$P_B = 1.313\ atm$** | **$P_A = 0.187\ atm$**

ii) standard conditions → P = 1 atm, M = 1 M → $Q = \frac{1}{(1)(1)} = 1$

$K = 4.068 \rightarrow Q < K$, more reactants than you should at eq.

$Ln\left(\frac{Q}{K}\right) < 0 \rightarrow \Delta G < 0$ | **forward rxn is spontaneous**

$\Delta G = (8.314\ J/mol\text{-}K)(600\ K)\,Ln\left(\frac{1}{4.068}\right) = -6999.48\ J/mol < 0$ ✓

iii) $Q = \frac{1}{(P_A)(P_B)} = \frac{1}{(1\ atm)(0.01\ atm)} = 100$

$K = 4.068 \rightarrow Q > K$, more products than you should at eq.

$Ln\left(\frac{Q}{K}\right) > 0 \rightarrow \Delta G > 0$ | **reverse rxn is spontaneous**

$\Delta G = (8.314\ J/mol\text{-}K)(600\ K)\,Ln\left(\frac{100}{4.068}\right) = 15973\ J/mol > 0$ ✓

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✓ **+ 6 pts** **Correct, $$\Delta G_r=\Delta G_r^o = -7000 \frac {J}{mol}<0$$, so the forward rxn is spontaneous**

+ 2 pts Under standard conditions, $$ Q=1$$

+ 2 pts $$ \Delta G_r = \Delta G_r^o+RT*ln(Q)$$

- 2 pts Math or unit error

Name: An Le, UID:

Problem #5

5) $A_{(g)} + B_{(g)} \rightleftharpoons C_{(s)}$, 600 K, $\Delta H° = 5$ kJ/mol, $\Delta S° = 20$ J/mol·K

i) $\Delta G° = \Delta H° - T\Delta S° = (5000 \text{ J/mol}) - (600 \text{ K})(20 \text{ J/mol-K}) = -7000 \text{ J/mol}$

$K = e^{-\Delta G°/RT} = e^{-(-7000 \text{ J/mol})/(8.314 \text{ J/mol-K})(600 \text{ K})} = 4.068$

$4.068 = \dfrac{1}{(P_A)(P_B)}$ — $P_{final} = 1.5 \text{ atm} = P_A + P_B$ @ equilibrium

↳ $P_A = 1.5 - P_B$

$(P_A)(P_B) = \frac{1}{4.068} = 0.246 \rightarrow (1.5 - P_B)(P_B) = 0.246$

$1.5P_B - P_B^2 - 0.246 = 0 \rightarrow$ | $P_B = 1.313$ atm | $P_A = 0.187$ atm |

ii) standard conditions → P = 1 atm, M = 1 M → $Q = \frac{1}{(1)(1)} = 1$

$K = 4.068 \rightarrow Q < K$, more reactants than you should at eq.

$\ln\left(\frac{Q}{K}\right) < 0 \rightarrow \Delta G < 0$ | forward rxn is spontaneous |

$\Delta G = (8.314 \text{ J/mol-K})(600 \text{ K}) \ln\left(\frac{1}{4.068}\right) = -6999.48 \text{ J/mol} < 0$ ✓

iii) $Q = \dfrac{1}{(P_A)(P_B)} = \dfrac{1}{(1 \text{ atm})(0.01 \text{ atm})} = 100$

$K = 4.068 \rightarrow Q > K$, more products than you should at eq.

$\ln\left(\frac{Q}{K}\right) > 0 \rightarrow \Delta G > 0$ | reverse rxn is spontaneous |

$\Delta G = (8.314 \text{ J/mol-K})(600 \text{ K}) \ln\left(\frac{100}{4.068}\right) = 15973 \text{ J/mol} > 0$ ✓

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✓ **+ 7 pts Correct, $$ \Delta G_r=15972 \frac {J}{mol}>0$$, so the reverse rxn is spontaneous**

+ 2 pts $$ Q=100$$

+ 2 pts $$ \Delta G_r = \Delta G_r^o+RT*ln(Q)$$

+ 1 pts Correct direction based on calculation

- 2 pts Math or unit error