

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,2.26m³,276K) \$\$ and \$\$

(T,Phase)_w=(276K,liquid) \$\$

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

+ 2 pts \$\$ $q_g = n_g C_P(T_{eq} - T_g)$ \$\$

+ 4 pts \$\$ $q_w = m_w \Delta H_{fus} +$

$m_w C_s(T_{eq} - T_i)$ \$\$

- 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 \$\$ $\Delta S_{sys} = \frac{m_i \Delta H_{fus}}{T_m} + m_i C_s \ln(T_{eq}/T_i) + n_g C_P \ln(T_{eq}/T_g)$ \$\$

+ 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 \$\$ $\Delta S_{sys} = \Delta S_r$ \$\$

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

- 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 ΔS_{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 $\Delta G_r^\circ = \Delta H_r^\circ - (300K)\Delta S_r^\circ$
- + 6 pts For spontaneity, $\Delta G_r = \Delta G_r^\circ + RT \ln(Q) < 0$
- + 4 pts $Q = [C]$
- 3 pts Math or unit error

QUESTION 5

5 24 pts

5.1 5.i 11 / 11

- ✓ + 11 pts Correct, $P_B = 1.31 \text{ atm}$, $P_A = 0.186 \text{ atm}$
- + 2 pts $\Delta G_r^\circ = \Delta H_r^\circ - (600K)\Delta S_r^\circ$
- + 2 pts $K = \exp(-\Delta G_r^\circ/RT)$
- + 2 pts $K = \frac{1}{P_{APB}}$
- + 2 pts $P_T = 1.5 \text{ atm} = P_A + P_B$
- 3 pts Math or unit error

5.2 5.ii 6 / 6

- ✓ + 6 pts Correct, $\Delta G_r = \Delta G_r^\circ = -7000$

$\frac{J}{\text{mol}} < 0$, so the forward rxn is spontaneous

- + 2 pts Under standard conditions, $Q = 1$
- + 2 pts $\Delta G_r = \Delta G_r^\circ + RT \ln(Q)$
- 2 pts Math or unit error

5.3 5.iii 7 / 7

- ✓ + 7 pts Correct, $\Delta G_r = 15972 \frac{J}{\text{mol}} > 0$, so the reverse rxn is spontaneous
- + 2 pts $Q = 100$
- + 2 pts $\Delta G_r = \Delta G_r^\circ + RT \ln(Q)$
- + 1 pts Correct direction based on calculation
- 2 pts Math or unit error

Chem 20B Midterm 2 Exam

Name: An Le, UID:

Problem #1

i) Monatomic ideal gas: $n = 100 \text{ mol}$, $P = 1 \text{ atm}$, $T = 20^\circ\text{C} = 293 \text{ K}$

Ice: $m = 100 \text{ g} = 0.100 \text{ kg}$, $T = 0^\circ\text{C} = 273 \text{ K}$

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

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

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

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

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

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

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

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

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

Balloon: $P = 1 \text{ atm}$,

$V = 2.27 \text{ m}^3$, $T = 276.31 \text{ K}$

Water: $T = 276.31 \text{ K}$,

phase = liquid

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

$$\Delta S_{\text{sys}} = nC_p \ln\left(\frac{T_f}{T_i}\right) + \frac{m\Delta H^\circ}{T} + mC \ln\left(\frac{T_f}{T_i}\right)$$

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

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

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

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

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

1.11.i 10 / 10

- ✓ + 10 pts Correct; $(P, V, T)_g = (1 \text{ atm}, 2.26 \text{ m}^3, 276 \text{ K})$ and $(T, \text{Phase})_w = (276 \text{ K}, \text{liquid})$
- + 2 pts $q_g = -q_w$ or $q_g + q_w = 0$
- + 2 pts $q_g = n_g C_P (T_{\text{eq}} - T_g)$
- + 4 pts $q_w = m_w \Delta H_{\text{fus}} + m_w C_s (T_{\text{eq}} - T_i)$
- 2 pts Math or unit error
- + 0 pts Incorrect

Chem 20B Midterm 2 Exam

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i) Monatomic ideal gas: $n = 100 \text{ mol}$, $P = 1 \text{ atm}$, $T = 20^\circ\text{C} = 293 \text{ K}$

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

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

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

Balloon: $P = 1 \text{ atm}$,

$V = 2.27 \text{ m}^3$, $T = 276.31 \text{ K}$

Water: $T = 276.31 \text{ K}$,

phase = liquid

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

$$\Delta S_{\text{sys}} = nC_p \ln\left(\frac{T_f}{T_i}\right) + \frac{m\Delta H^\circ}{T} + mC \ln\left(\frac{T_f}{T_i}\right)$$

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

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

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

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

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

1.2 1.ii 10 / 10

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

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

+ 4 pts $\Delta S_{\text{sys}} = \frac{m_i \Delta H_{\text{fus}}}{T_m} + m_i C_s \ln(T_{\text{eq}}/T_i) + n_g C_P \ln(T_{\text{eq}}/T_g)$

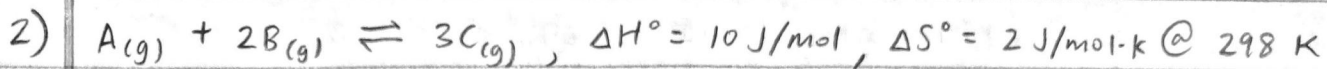
+ 2 pts $\Delta S_{\text{sur}} = 0$

- 2 pts Math or unit error

+ 0 pts Incorrect

Name: An Le, UID:

Problem #2



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

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

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

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

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

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

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

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

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

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

2.12.i 6 / 6

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

+ 2 pts $\Delta S_{\text{sys}} = \Delta S_{\text{r}^{\circ}}$

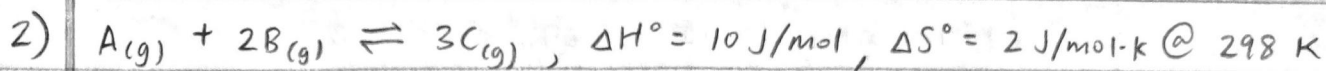
+ 2 pts $\Delta S_{\text{sur}} = \frac{-\Delta H_{\text{r}^{\circ}}}{T_{\text{sur}}}$

- 2 pts Math or unit error

+ 0 pts Incorrect

Name: An Le, UID:

Problem #2



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

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

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

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

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

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

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

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

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

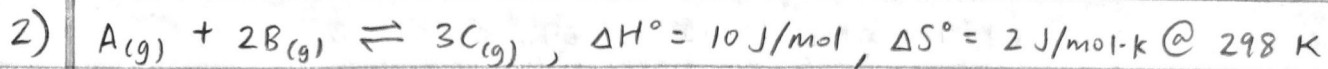
$$\Delta G = 4566 \text{ J/mol} > 0 \rightarrow \text{forward rxn NOT spontaneous}$$

2.2 2.ii 6 / 6

- ✓ + 6 pts Correct, $\Delta G_r = \Delta G_r^\circ = -586 \frac{\text{J}}{\text{mol}} < 0$, so spontaneous
- + 1 pts Under standard conditions, $Q=1$
- + 2 pts $\Delta G_r = \Delta G_r^\circ$
- + 2 pts $\Delta G_r^\circ = \Delta H_r^\circ - 298\text{K} \Delta S_r^\circ$
- 2 pts Math or unit error

Name: An Le, UID:

Problem #2



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

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

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

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

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

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

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

2.3 2.iii 8 / 8

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

+ 2 pts $Q = 8$

+ 3 pts $\Delta G_r = \Delta G_r^\circ + R(298\text{K}) \ln(Q)$ or $K = \exp(-\Delta G_r^\circ / RT)$ 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 $P_{\text{ext}} = 0$, $W = 0$ because $W = -\int P dV$

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

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

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

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

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

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

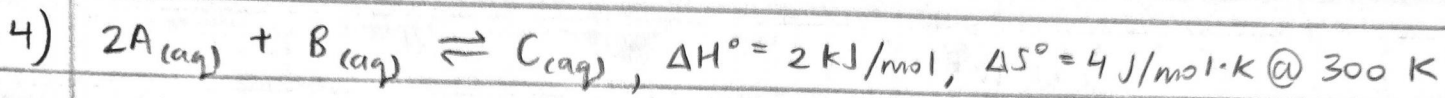
$$\Delta S_{\text{uni}} = \Delta S_{\text{sys}} + \cancel{\Delta S_{\text{surr}}} = \Delta S_{\text{sys}} > 0 \checkmark$$

33 17 / 20

- ✓ + 0 pts Correct conclusion, $\Delta S_{\text{univ}} = nR \ln(V_f/V_i) > 0$, so spontaneous
- ✓ + 2 pts $w = -P_{\text{ext}} dV = 0$, since $P_{\text{ext}} = 0$
- ✓ + 2 pts Isothermal, so $\Delta T \rightarrow \Delta U = 0$
- ✓ + 2 pts $\Delta U = q + w$, so $q = -w = 0$
- ✓ + 2 pts $\Delta S_{\text{sur}} = q/T = 0$
 - + 2 pts Use reversible, isothermal process to calculate $\Delta S_{\text{sys}} = \int dq/T$ since S is a state function (second law)
 - + 1 pts $q_{\text{rev,iso}} = -w = nRT \ln(V_f/V_i)$
- ✓ + 5 pts $\Delta S_{\text{sys}} = q/T = nR \ln(V_f/V_i)$
- ✓ + 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 $\Delta S_{\text{universe}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}}$
 - + 6 pts Concluded $\Delta S_{\text{surr}} = 0$ by other means
 - + 10 pts Arrived at correct conclusion for $\Delta S_{\text{sys}} > 0$ using $\Omega_{\text{ideal}} \propto V^N$, and $S = k_B \ln(\Omega)$
 - + 6 pts Qualitative only argument for ΔS_{sys} is positively correlated with V
 - + 0 pts No credit

Name: An Le, UID:

Problem #4



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

$$Q = \frac{[C]}{[A]^2[B]} \rightarrow [A] \text{ and } [B] \rightarrow Q = [C]$$

$$[A]^2[B] \text{ are } 1 \text{ M}$$

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

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

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

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

4 4 16 / 16

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

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

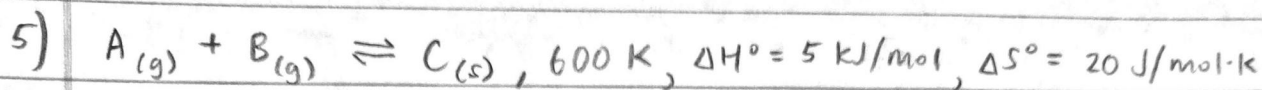
+ 6 pts For spontaneity, $\Delta G_r = \Delta G_r^o + RT \ln(Q) < 0$

+ 4 pts $Q=[C]$

- 3 pts Math or unit error

Name: An Le, UID:

Problem #5



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

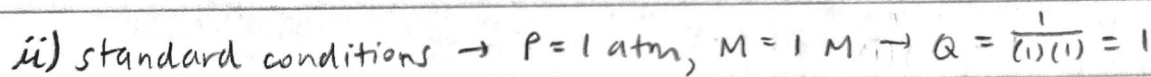
$$K = e^{-\Delta G^\circ/RT} = e^{-(-7000 \text{ J/mol})/(8.314 \text{ J/mol}\cdot\text{K})(600 \text{ K})} = 4.068$$

$$4.068 = \frac{1}{(P_A)(P_B)} \quad \left(P_{\text{final}} = 1.5 \text{ atm} = P_A + P_B \text{ @ equilibrium} \right)$$

$$\hookrightarrow P_A = 1.5 - P_B$$

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

$$1.5P_B - P_B^2 - 0.246 = 0 \rightarrow \boxed{P_B = 1.313 \text{ atm} \quad P_A = 0.187 \text{ atm}}$$



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

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

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

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

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

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

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

5.15.i 11 / 11

✓ + 11 pts Correct, $P_B=1.31\text{atm}$, $P_A=0.186\text{atm}$

+ 2 pts $\Delta G_r^\circ = \Delta H_r^\circ - (600\text{K})\Delta S_r^\circ$

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

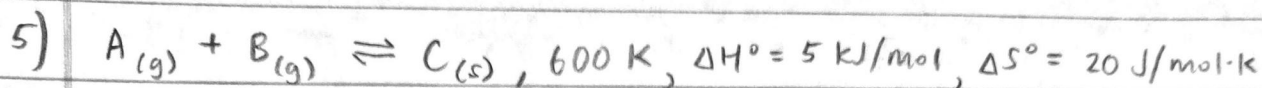
+ 2 pts $K = \frac{1}{P_{AP_B}}$

+ 2 pts $P_T = 1.5\text{atm} = P_A + P_B$

- 3 pts Math or unit error

Name: An Le, UID:

Problem #5



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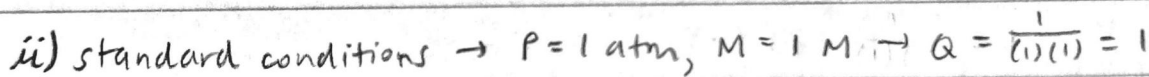
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$$\hookrightarrow P_A = 1.5 - P_B$$

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

$$1.5P_B - P_B^2 - 0.246 = 0 \rightarrow \boxed{P_B = 1.313 \text{ atm} \quad P_A = 0.187 \text{ atm}}$$



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

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

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

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

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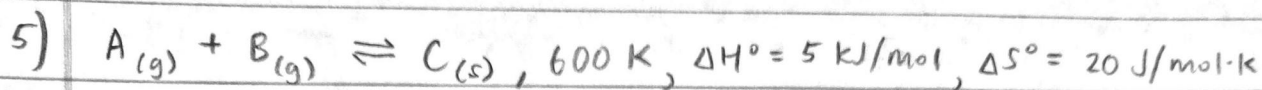
$$\Delta G = (8.314 \text{ J/mol}\cdot\text{K})(600 \text{ K}) \ln\left(\frac{100}{4.068}\right) = 15973 \text{ J/mol} > 0 \quad \checkmark$$

5.2 5.ii 6 / 6

- ✓ + 6 pts Correct, $\Delta G_r = \Delta G_r^o = -7000 \frac{\text{J}}{\text{mol}} < 0$, 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



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

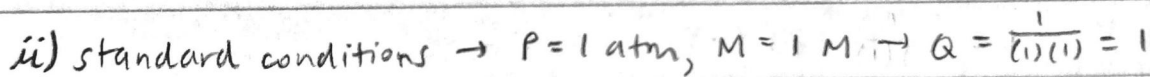
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$K = 4.068 \rightarrow Q < K$, more reactants than you should at eq.

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

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

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

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

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

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

5.3 5.iii 7 / 7

- ✓ + 7 pts Correct, $\Delta G_r = 15972 \frac{\text{J}}{\text{mol}} > 0$, so the reverse rxn is spontaneous
- + 2 pts $Q = 100$
- + 2 pts $\Delta G_r = \Delta G_r^\circ + RT \ln(Q)$
- + 1 pts Correct direction based on calculation
- 2 pts Math or unit error