Chapter 16 Quiz – Thermodynamics Name: KEY

1) Which of the following processes have a $\Delta S > 0$?

A) $CH_3OH(l) \rightarrow CH_3OH(s)$ $\Delta S<0$ $l \rightarrow s$

B) $N_2(g) + 3\,H_2(g) \rightarrow 2\,NH_3(g)$ 4 mol gas → 2 mol gas $\Delta S<0$

C) $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3\,H_2(g)$ 2 mol gas → 4 mol gas $\Delta S>0$

D) $Na_2CO_3(s) + H_2O(g) + CO_2(g) \rightarrow 2\,NaHCO_3(s)$ 2 mol gas → 0 mol gas $\Delta S<0$

E) All of the above processes have a $\Delta S > 0$

F) None of the above processes have a $\Delta S > 0$

2) Which of the following processes have a $\Delta S < 0$?

A) Water freezes

B) Isopropanol condenses

C) Methanol (g, at 555 K) → methanol (g, at 400 K)

D) Carbon dioxide (g) → carbon dioxide (s)

E) All of the above processes have a $\Delta S < 0$.

F) None of the above processes have a $\Delta S < 0$

3) Predict the entropy change (ΔS increases or decreases) if:

You heat a gas from 298K to 500K I

A reaction creates fewer moles of gas product than reactant D

An old refrigerator rusts in a junk yard I

Aluminum oxidizes I

A two dimensional solid is changed to a three dimensional form D

Minerals are deposited from aqueous phase to solid phase D

4a) Consider the following reaction $4NH_3(g) + 3\,O_2(g) \rightarrow 2\,N_2(g) + 6\,H_2O(g)$
Given $\Delta H = -1267$ kJ. Determine the value of $\Delta S_{surroundings}$ at 398K. Predict whether or not this reaction will be spontaneous at this temperature. 3 S is F is

$\Delta S_{surr} = -\Delta H_{system}/T = -(-1267\text{kJ})/398\text{K} = 3180\text{J/K}$

$\Delta G = \Delta H_{syst} - T\Delta S_{syst} = -1267\text{kJ} - 398(.1788\text{kJ/K}) = -2047\text{kJ}$

SPONT.

4b) Given $\Delta S_{reaction} = 178.8$ J/K, calculate $\Delta S_{universe}$

$\Delta S_{univ} = \Delta S_{rxn} + \Delta S_{surr}$

$= 178.8\text{J/K} + 3180\text{J/K} = 3359\text{J/K}$

5) Above what temperature does the following reaction become non-spontaneous?

$2\ H_2S(g) + 3\ O_2\ (g) \rightarrow 2\ SO_2\ (g) + 2\ H_2O(g)$

$\Delta H = -1036$ kJ; $\Delta S = -153.2$ J/K 4 Sig Fig

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$\Delta G = \Delta H - T\Delta S$

$0 = -1{,}036{,}000\text{J} - T(-153.2\text{J/K})$

$T = \frac{1036000\text{J}}{153.2\text{J/K}} = 6762\text{K}$

6a) Use the following information to demonstrate the temperature dependence of ΔG in 6ii and 6iii below: $\Delta S° = -250$J/K ; $\Delta H° = -150$kJ ; T = 27°C and T= 402°C 2 Sig Figs

$\Delta S° = 250$J/K ; $\Delta H° = 150$kJ ; T = 27°C and T= 402°C

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$\Delta G = \Delta H - T\Delta S = -150{,}000\text{J} - 300\text{K}(-250\text{J/K}) = -75\text{kJ}$

$= +150{,}000\text{J} - 300\text{K}(250\text{J/K}) = +75\text{kJ}$

$= -150{,}000\text{J} - 675\text{K}(-250\text{J/K}) = +19\text{kJ}$

$= 150{,}000\text{J} - 675\text{K}(250\text{J/K}) = -19\text{kJ}$

Increasing T for $\Delta H = -$, $\Delta S = -$ ΔG goes from − to +

" T " " $= +$, " $= +$ ΔG " " + to −

6b) Given the relationship table below, use the information above to fill in the blanks:

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	ΔH	ΔS	ΔG	Low Temp	High Temp
i)	−	+	−	S	spontaneous
ii)	−	−	temp dependent	S	NS
iii)	+	+	temp dependent	NS	S
iv)	+	−	+	non-spontaneous	non-spontaneous

8) Potassium chlorate, a common oxidizing agent in explosives, fireworks, and match heads, undergoes a solid-state redox reaction when heated. In this reaction the oxidation state of Cl is higher in one of the products than in the other.

$4\ KClO3(s) \rightarrow 3\ KClO4(s) + KCl(s)$ ⇒ 5pts extra credit

+5 +7 −1

Cl oxidation	+5	+7	−1	units
S°	143	151	83	J/mol•K
$\Delta H°_f$	−398	−433	−437	kJ/mol

2 Sig Figs

3 Sig Figs

a) Calculate the Gibbs Free Energy at 25°C for this reaction.

$\Delta H = \sum n \Delta H^\circ_{prod} - \sum n \Delta H^\circ_{react}$

$= [3(-433\,kJ) + 1(-437\,kJ)] - [4(-398\,kJ)]$

$= -1736\,kJ + 1592\,kJ$

$= -144\,kJ$ (3 SIG FIG)

12 $\Delta S = \sum n \Delta S^\circ_{prod} - \sum n \Delta S^\circ_{react}$

$= [3(151\,J/K) + 1(83\,J/K)] - [4(143\,J/K)]$

$= (453\,J/K + 83\,J/K) - 572\,J/K$

$= -36\,J/K$ (2 Sig Figs)

$\Delta G = \Delta H - T\Delta S = -144000\,J - 298.15\,K(-36\,J/K)$

$= -144000\,J + 10733\,J = -144000\,J + 11000\,J$

$= -133\,kJ$

b) Tell whether the reaction is spontaneous or not and why.

$\Delta G < 0$ Spont.

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EQUATIONS TO PONDER

$\Delta H^\circ_{rxn} = \sum(n\Delta H^\circ_{prod}) - \sum(n\Delta H^\circ_{react})$

$\Delta S^\circ_{rxn} = \sum(n\Delta S^\circ_{prod}) - \sum(n\Delta S^\circ_{react})$

$\Delta G^\circ_{rxn} = \sum(n\Delta G^\circ_{prod}) - \sum(n\Delta G^\circ_{react})$

$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$

$\Delta S_{surroundings} = -\Delta H_{system} / T$

$\Delta G^\circ_{reaction} = \Delta H^\circ_{reaction} - T\Delta S^\circ_{reaction}$

$\Delta G = \Delta G^\circ + RT\ln Q$ (At equilibrium and $\Delta G = 0$, *Then* $\Delta G^\circ = -RT\ln K$)