CHM 152 Quiz 10b 25 Pts Spring 2013 **Name:** Key

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R = 8.314 J/(mol·K) $\Delta S° = \Sigma nS°_{(products)} - \Sigma nS°_{(reactants)}$ $\Delta S° = \Sigma nS°_{(products)} - \Sigma nS°_{(reactants)}$ $\Delta G° = \Sigma nG°_{(products)} - \Sigma nG°_{(reactants)}$

$\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT\ln Q$ $\Delta G° = -RT\ln K$

1. Calculate ΔS° at 25°C for the reduction of PbO(s), 2PbO(s) + C(s) → 2Pb(s) + CO2(g) given these absolute entropies:

	S° (J/K·mol)
PbO(s)	69.45
C(s)	5.7
Pb(s)	64.89
$CO_2(g)$	213.6

$\Delta S = \Sigma \Delta S_{prod} - \Sigma \Delta S_{react}$

342.98 − 144.6

$\Delta S = 198.38$ kJ

2. Arrange these compounds in order of increasing standard molar entropy at 25°C:
$C_3H_8(g)$, $C_2H_4(g)$, ZnS(s), and $H_2O(l)$.

ZnS(s) < $H_2O(l)$ < $C_2H_4(g)$ < $C_3H_8(g)$
Least entropy ... most entropy

3. HI has a normal boiling point of −35.4°C, and its ΔH_{vap} is 21.16 kJ/mol. Calculate the molar entropy of vaporization (ΔS_{vap}).

@ Eq. ΔG = 0
So ΔH = TΔS
$\Delta S = \frac{\Delta H}{T}$

$\Delta S = \frac{21.16 \times 10^3 \text{ J/mol}}{237 \text{ K}} = 89.3 \frac{\text{J}}{\text{mol·K}}$

4. Which one of the following reactions would you expect to have highest ΔS°?
A) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ 3 → 3
B) $C_2H_2(g) + {}^5/_2O_2(g) \rightarrow 2CO_2(g) + H_2O(g)$ 3.5 → 3
C) $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$ 4 → 4
(D) $C_2H_6(g) + {}^7/_2O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ 4.5 → 5 ⇐ mol gas

5. Calculate ΔS° at 25°C for the reduction of PbO(s), $2PbO(s) + C(s) \rightarrow 2Pb(s) + CO_2(g)$ given these absolute entropies:

	S° (J/K·mol)
PbO(s)	69.45
C(s)	5.7
Pb(s)	64.89
$CO_2(g)$	213.6

SAme as #1

6. Calculate ΔG° for the reaction $3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(l) + NO(g)$.

	$\Delta G°_f$ (kJ/mol)
$H_2O(l)$	−237.2
$HNO_3(l)$	−79.9
NO(g)	86.7
$NO_2(g)$	51.8

$\Delta G = \Sigma \Delta G_{Prod.} - \Sigma \Delta G_{React}$

−73.1 − (−81.8)

$\Delta G = 8.7$ kJ

more on back

Key

6. Sodium carbonate can be made by heating sodium bicarbonate:

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

Given that ΔH° = 128.9 kJ/mol and ΔG° = 33.1 kJ/mol at 25°C, above what minimum temperature will the reaction become spontaneous?

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

$33.1 = 128.9 - 298\Delta S$

$\Delta S = 0.322$ kJ/mol·K

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

$0 = 128.9 - T(0.322)$

T = 401 K or 128 °C

7. Hydrogen peroxide (H_2O_2) decomposes according to the equation

$$H_2O_2(l) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g).$$

Calculate K_p for this reaction at 25°C. (ΔH° = –98.2 kJ/mol, ΔS° = 70.1 J/K·mol)

$\Delta G^\circ = -98.2 - 298(0.0701)$

$\Delta G^\circ = -119$ kJ

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

$\ln K = \frac{\Delta G^\circ}{RT} = \frac{+119 \times 10^3}{8.314 \cdot 298}$

$\ln K = 48.067$ **$K = 7.5 \times 10^{20}$**

8. At 1500°C the equilibrium constant for the reaction $CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$ has the value $K_p = 1.4 \times 10^{-7}$. Calculate ΔG° for this reaction at 1500°C.

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

$\Delta G^\circ = (-8.314)(1733) \ln 1.4 \times 10^{-7} = 232632$ J

233 kJ

9. Assuming ΔS° and ΔH° do not vary with temperature, at what temperature will the reaction shown below become spontaneous?

$C(s) + H_2O(g) \rightarrow H_2(g) + CO(s)$ (ΔS° = 133.6 J/K·mol; ΔH° = 131.3 kJ/mol)

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

$0 = 131.3 - T(0.1336)$

$T = 983$ K

T > 983 K or > 710 °C

10. For the reaction $H_2O_2(g) \rightarrow H_2O(g) + \tfrac{1}{2}O_2(g)$, ΔH° = –106 kJ/mol and ΔS° = 58 J/K·mol at 25°C. Calculate ΔG° for this reaction at this temperature.

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

$= -106 - 298(0.058)$

= –123 kJ