ACTIVITY/WORKSHOP on THERMODYNAMICS & ELECTROCHEMISTRY

1. Consider the reaction listed below along with the accompanying thermodynamic data, carried out at 25 °C and 1 atm: $2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$

Substance	**$\Delta H_f°$ (kJ/mol)**	**S° (J/K • mol)**
$SO_2(g)$	-297	248
$O_2(g)$	0	205
$SO_3(g)$	-396	257

A. Calculate ΔH°.
B. Calculate ΔS°.
C. Calculate ΔG°. Is this reaction spontaneous? Briefly explain.
D. At what temperature will this reaction first become spontaneous?
E. Calculate the equilibrium constant for this reaction.

2. One method for synthesizing methanol (CH_3OH) involves reacting carbon monoxide and hydrogen gases: $CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$

Calculate ΔG at 25 °C for this reaction where carbon monoxide gas at 5.0 atm and hydrogen gas at 3.0 atm are converted to liquid methanol.

Substance	**$\Delta G_f°$ (kJ/mol)**
CO(g)	-137
$H_2(g)$	0
CH_3OH	-166

3. The equilibrium constant for $PCl_5(g) \leftrightarrow PCl_3(g) + Cl_2(g)$ is 78.3 at 523 K. Predict its value at 800 K.

Compound	**$\Delta H_f°$ (kJ/mol)**
$PCl_5(g)$	-402
$PCl_3(g)$	-287
$Cl_2(g)$	0

4. (4 pts.) When most biological enzymes are heated, they lose their catalytic activity. The change that occurs on heating is endothermic and spontaneous. Is the structure of the original enzyme or its new form more ordered? Explain.

Original enzyme → new form

5. Predict the signs of ΔSº for each of the following changes and briefly explain your identifications:

A. $Fe_2O_3(s) + 3H_2(g) \rightarrow 2Fe(s) + 3H_2O(g)$

B. $2H_2S(g) + SO_2(g) \rightarrow 3S_{rhombic}(s) + 2H_2O(g)$

6. Use the standard heats of reaction given below to determine $\Delta H°$ for the following reaction (in kcal): $3V_2O_3(s) \rightarrow V_2O_5(s) + 4VO(s)$.

$4VO(s) + O_2(g) \rightarrow 2V_2O_3(s)$	$\Delta H° = -180$ kcal
$2V_2O_3(s) + O_2(g) \rightarrow 4VO_2(s)$	$\Delta H° = -108$ kcal
$4VO_2(s) + O_2(g) \rightarrow 2V_2O_5(s)$	$\Delta H° = -58$ kcal

7. A galvanic cell consists of a nickel electrode immersed in a $NiSO_4$ solution and an aluminum electrode immersed in an $Al_2(SO_4)_3$ solution under standard conditions. A salt bridge comprised of KNO_3 connects the two half-cells.

A. Diagram this voltaic cell, indicating the direction of flow of electrons in the external circuit and the motion of the ions in the salt bridge. Make sure to identify which metal is the anode and which metal is the cathode.

B. Write balanced chemical equations for the half-reactions at the anode and the cathode as well as for the overall cell reaction.

C. Calculate the standard cell potential for this galvanic cell.

D. Write the abbreviated notation to describe this cell.

E. Calculate the standard free-energy change, $\Delta G°$, for the balanced reaction.

F. Determine the value of the equilibrium constant, K_c, for the Rx at 25 °C.

G. Determine the cell potential for this galvanic cell when $[Al^{+3}] = 2.0 \times 10^{-3}$ M and $[Ni^{+2}] = 6.0 \times 10^{-2}$ M.

8. Balance the following reaction under *basic* conditions, and label both the oxidizing/reducing agents: $IO_6^{-5}(aq) + Cr(s) \rightarrow IO_3^-(aq) + Cr^{+3}(aq)$

9. Determine the unknown concentration of the ion in each of the following concentration cells where $\Delta \mathcal{E} = 0.050$ V: $Pb \mid Pb^{+2}\ (?) \parallel Pb^{+2}\ (0.10\ M) \mid Pb$

10. PUTTING IT ALL TOGETHER! Consider the following *balanced* reaction at 25 °C:

$$O_2(g) + 4H^+(aq) + 4Br^-(aq) \rightarrow 2H_2O(l) + 2Br_2(l)$$

If $[H^+]$ is adjusted by adding a buffer that is 750 mL of 0.150 M $NaC_2H_3O_2$ and 350 mL of 0.250 M $HC_2H_3O_2$ ($K_a = 1.8 \times 10^{-5}$), the pressure of oxygen gas is 720 mm Hg, and the bromide concentration is 0.100 M, what is the calculated cell voltage?