**Dougherty Valley HS AP Chemistry**

**WORKSHEET #4\***

**Thermodynamics – Extra Practice Free-Energy and Spontaneity**

**Name: Date: Period: Seat #:**

Show all work. Complete the following on binder paper and BOX your final answers.

[1] Using enthalpies of formation (Appendix Four), calculate ΔH° for the following reaction at 25°C. Also calculate ΔS° for this reaction from standard entropies at 25°C. Use these values to calculate ΔG° for the reaction at this temperature.

-1453.2 KJ, -162 KJ, -1404.9 KJ

2CH3OH(*l*) + 3O2 (g) → 2CO2 (g) + 4H2O(*l*)

[2] The free energy of formation of one mole of compound refers to a particular chemical equation. For each of the following, write that equation.

[a] NaCl (s)

[b] HCN (*l*)

[c] SO2 (g)

[d] PH3 (g)

[3] Calculate the standard free energy of the following reactions at 25°C, using standard free energies of formation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| [a] CH4 (g) + 2O2 (g) → CO2 (g) + 2H2O(g) |  | $$∆H\_{f}^{°}$$ | $$∆G\_{f}^{°}$$ | $$∆S^{°}$$ |
| [b] CaCO3 (s) + 2H+ (aq) → Ca2+ (aq) + H2O(*l*) + CO2 (g) | **Ca2+** | -542.96 | -533.04 | -55.2 |

[4] On the basis of ΔG° for each of the following reactions, decided whether the reaction is spontaneous or non-spontaneous as written. Or, if you expect an equilibrium mixture with significant amounts of both reactants and products, say so.

|  |  |
| --- | --- |
| [a] SO2 + 2H2S → 3S + 2H2O | ΔG° = -91 kJ |
| [b] 2H2O2 → O2 + 2H2O | ΔG° = -211 kJ |
| [c] HCOOH → CO2 + H2 | ΔG° = 119 kJ |
| [d] I2 + Br2 → 2IBr | ΔG° = 7.5 kJ |
| [e] NH4Cl → NH3 + HCl | ΔG° = 92 kJ |

[5] Calculate ΔH° and ΔG° for the following reactions at 25°C, using thermodynamic data from your books Appendix; interpret the signs of ΔH° and ΔG°.

|  |
| --- |
| [a] Al2O3 + 2Fe → Fe2O3 + 2Al (851 kJ; 838 kJ) |
| [b] COCl2 + H2O → CO2 + 2HCl; [COCl2: $∆H\_{f}^{°}$ = -220KJ/mol and $∆G\_{f}^{°}$= -206KJ/mol] (-72 kJ; -142kJ) |

[6] Using enthalpies of formation (appendix four), calculate ΔH° for the following reactions at 25°C. Also calculate ΔS° for this reaction from standard entropies at 25 C. Use these values to calculate ΔG° for the reaction at this temperature.

4HCN + 5O2 → 2H2O + 4CO2 + 2N2

[7] The free energy of formation of one mole of compound refers to a particular chemical equation. For each of the following, write that equation.

|  |
| --- |
| [a] CaO(s) |
| [b] CH3NH2 (g) |
| [c] CS2 (*l*) |
| [d] P4O10 (s) |

[8] Calculate the standard free energy of the following reactions at 25 C, using standard free energies of formation from the appendix.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| [a] C2H4 (g) + O2 (g) → 2CO2 (g) + 2H2O (g) |  | $$∆H\_{f}^{°}$$ | $$∆G\_{f}^{°}$$ | $$∆S^{°}$$ |
| [b] Na2CO3 (s) + H+ (aq) → 2Na+ (aq)+ HCO3− (aq) | **HCO3−** | -691.11 | -587.06 | 95.0 |

[9] For each of the following reactions, state whether the reaction is spontaneous or non-spontaneous as written or is easily reversible (that is, is a mixture with significant amounts of reactants and products)

|  |  |
| --- | --- |
| [a] HCN + 2H2 → CH3NH2 | ΔG° = -92 kJ |
| [b] N2 + O2 → 2NO | ΔG° = 173 kJ |
| [c] 2NO + 3H2O → 2NH3 + $\frac{5}{2}$O2 | ΔG° = 479 kJ |
| [d] H2 + Cl2 → 2HCl | ΔG° = -191 kJ |
| [e] H2 + I2 → 2HI | ΔG° = 2.6 kJ |

[10] Calculate ΔH° and ΔG° for the following reactions at 25°C, using thermodynamic data from Appendix; interpret the signs of ΔH° and ΔG°.

|  |  |
| --- | --- |
| [a] 2PbO + N2 → 2Pb + 2NO |  |
| [b] CS2 + 2H2O → CO2 + 2H2S; | CS2: $∆H\_{f}^{°}$ = 87.9kJ and $∆G\_{f}^{°}$= 63.6kJ |

[11] Give the expression for the thermodynamic equilibrium constant for each of the following reactions:

|  |
| --- |
| [a] CO(g) + H2O(g) → CO2 (g) + H2 (g) |
| [b] Mg(OH)2 (s) → Mg2+ (aq) + 2OH− (aq) |
| [c] 2Li(s) + 2H2O(*l*) → 2Li+ (aq) + 2OH− (aq) + H2 (g) |

[12] What is the standard free energy change ΔG° at 25°C for the following reaction? Obtain necessary information from the Appendix: (-190.6kJ, 2.5E-33)

**H2(g) + Cl2(g) → 2HCl(g)**

 What is the value of the thermodynamic equilibrium constant K?

[13] Calculate the standard free energy change and the equilibrium constant Kp for the following reaction at 25°C. See appendix four for data. (-142.2kJ, 8.3E24) – From another source **CO(g) + 3H2(g) → CH4(g) + H2O(g)**

[16] Obtain the equilibrium constant Kc at 25° C from the free-energy change for the reaction:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | $$∆H\_{f}^{°}$$ | $$∆G\_{f}^{°}$$ | $$∆S^{°}$$ |
| **Mg(s) + Cu2+ → Mg2+ (aq) + Cu(s)** | **Cu2+** | 64.39 | 64.98 | -98.7 |
| (-520.99kJ, 1.88E91) | **Mg2+** | -461.96 | -456.01 | -118 |

[17] What is the standard free-energy change ΔG° at 25°C for the following reaction? Obtain necessary information from Appendix: **C(graphite) + O2(g) → CO2(g)** Calculate the value of the equilibrium constant K.

[18] Calculate the standard free energy change and the equilibrium constant Kp for the following reaction at 25°C. See appendix for data. **CO(g) + 2H2(g) → CH3OH(g)**

[19] Calculate the equilibrium constant Kc at 25 C from the free-energy change for the reaction:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | $$∆H\_{f}^{°}$$ | $$∆G\_{f}^{°}$$ | $$∆S^{°}$$ |
| **Zn(s) + Cu2+ → Zn2+ + Cu(s)** | **Cu2+** | 64.39 | 64.98 | -98.7 |
|  | **Zn2+** | -152.4 | -147.21 | -106.5 |