**Dougherty Valley HS AP Chemistry**

**WORKSHEET #5**

**Thermodynamics – Practice ΔH°, ΔG°, ΔS°**

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

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

[1] Consider the decomposition of H2O2 (hydrogen peroxide) at 298 K and 1 atm pressure according to:

**2 H2O2(liq) → 2 H2O(liq) + O2(gas)**

|  |  |  |  |
| --- | --- | --- | --- |
| Substance | $$∆G\_{f}^{°} \left(\frac{kJ}{mol}\right)$$ | $$∆H\_{f}^{°} \left(\frac{kJ}{mol}\right)$$ | $$S^{°}(J/mol^{-1}K^{-1})$$ |
| H2O2 (*l*) | -120.2 | -187.6 | 109.5 |
| H2O (*l*) | -237.0 | -285.8 | 69.4 |
| O2 (g) | ---- | ---- | 205 |

Please find the

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| a) standard enthalpy of reaction |
| b) standard entropy of reaction. |

[2] For the reaction in the previous question, please find the

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| a) standard (Gibbs) free energy of reaction |
| b) the value of the (thermodynamic) equilibrium constant at 298 K, 1 atm |

[3] From the indicated standard enthalpies of formation given in kJ/mol, please calculate the standard enthalpy of reaction for:

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| **NH4Cl(s) → NH3 (g) + HCl(g)** |
| -314.4 | -46.0 | -92.5 |
|  |

[4] Carbon monoxide in the atmosphere slowly converts to carbon dioxide at normal atmospheric temperatures according to:

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| **CO(g) + ½ O2 (g) ⇔ CO2 (g)** |
| The standard enthalpy of reaction is -284 kJ and the standard entropy of reaction is -87 J/K. Estimate the temperature at which the equilibrium begins to favor the decomposition of CO2. Assume that the enthalpy and the entropy of reaction are not affected by temperature |
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[5] From the indicated standard entropies given in J/K, please calculate the standard entropy of reaction for:

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| **2 NH3 (g) → N2H4 (liq) + H2 (g)** |
| 192.5 | 121.2 | 130.6 |
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[6] Please calculate the standard (Gibbs) free energy of reaction for:

**2 NO(g) + O2(g) ⇔ 2 NO2(g)**

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| --- | --- | --- | --- |
| Substance | $$∆G\_{f}^{°} \left(\frac{kJ}{mol}\right)$$ | $$∆H\_{f}^{°} \left(\frac{kJ}{mol}\right)$$ | $$S^{°}(J/mol^{-1}K^{-1})$$ |
| NO (g) | 86.69 | 90.4 | 210.6 |
| NO2 (g) | 51.84 | 34.0 | 240.5 |
| O2 (g) | ---- | ---- | 205.0 |

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[7] Calculate the entropy of vaporization of propane given that its enthalpy of vaporization is 16.9 kJ/mol at its normal boiling point of -42.1°C.

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[8] Obtain the numerical value of the equilibrium constant (at 298K) for the following reaction:

CO2(g) + H2O(liq) ⇔ H2CO3(aq)

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| --- | --- | --- | --- |
| Substance | $$∆G\_{f}^{°} \left(\frac{kJ}{mol}\right)$$ | $$∆H\_{f}^{°} \left(\frac{kJ}{mol}\right)$$ | $$S^{°}(J/mol^{-1}K^{-1})$$ |
| H2CO3(*aq*) | -623 | -700 | 187 |
| H2O(*liq*) | -237 | -286 | 70 |
| CO2(*gas*) | -394 | -394 | 213 |

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[9] Please indicate if TRUE or FALSE (Explain why as well):

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| --- | --- |
|  | The entropy of a gas increases with increasing temperature |
|  | The energy of a perfect crystal is zero at 0 K. |
|  | Spontaneous processes always increase the entropy of the reacting system |
|  | All spontaneous processes release heat to the surroundings |
|  | An endothermic reaction is more likely to be spontaneous at high temperatures than at low temperatures |
|  | The entropy of sugar decreases as it precipitates from an aqueous solution |

[10] Ammonia gas a standard (Gibbs) free energy of formation equal to -16.367 kJ/mol

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| a) Find ΔG° for the reaction: **N2 (g) + 3 H2 (g) ⇔ 2 NH3 (g)** |
| b) In which direction will this reaction proceed if a mixture of gases is made with:$P\_{NH\_{3}}$= 1.00 atm $P\_{H\_{2}}$= 0.50 atm $P\_{N\_{2}}$= 0.50 atm |
| c) What pressure of hydrogen gas should be added to a mixture already containing 0.20 atm NH3 and 0.50 atm N2 if one does not want the amounts of NH3 and N2 to change? |

ANSWERS:

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| 1. -196.4 kJ; 125 J/K | 2. -233.6 kJ; 8.85 x 1040 |
| 3. 175.9 kJ | 4. 3260 K or 3300K |
| 5. -133.2 J/K | 6. -69.7 kJ |
| 7. 73.1 J/K | 8. 4.0 x 10-2 (using $∆G\_{f}^{°} $data); 3.1 x 10-2 (using $∆H\_{f}^{°} $and S° data) |
| 9. T F F F T T | 10. -32.734 kJ; proceed to the right; 5.3x10-3 atm |