SPONTANEITY AND ENTROPY

NAME _____ SECTION _____

1. Entropy (S) is a second driving force for chemical reactions. Define the term *entropy*. How is the sign of ΔS for a chemical reaction interpreted?

2. Predict which of the following thermodynamically favored reactions have an increase in entropy of the system.

   a. $H_2O(l) \rightarrow H_2O(g)$ @25 °C

   b. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

   c. $Ba(OH)_2 \bullet 8H_2O(s) + 2NH_4Cl(s) \rightarrow BaCl_2(aq) + 10H_2O(l) + 2NH_3(aq)$

   d. $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ or (g)

   e. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

   f. $Al(s) + \frac{3}{2}Br_2(l) \rightarrow AlBr_3(s)$

3. A table of absolute entropies (S°) for selected substances is at the end of this DCI. Identify differences between S° and $\Delta H°_f$ as thermodynamic values.

4. Write the mathematical equation that relates the standard entropy change in a chemical reaction to the absolute entropy of the reactants and products.

5. Calculate the change in entropy (ΔS°_{rxn}) for the chemical reactions in question 2.

6. The natural tendency for spontaneous chemical reactions is to increase entropy. Is the entropy an absolute predictor of spontaneity? Defend your answer.

7. Predict whether the entropy of the system increases, remains constant, or decreases when the following processes occur. Explain your reasoning.

   a. Ice melts at 0 °C.

   b. A precipitate forms in aqueous solution.

   c. A solid dissolves in water.

   d. A gas condenses to a liquid.

Thermodynamic Values (25°C)

Substance and State	ΔH^0_f $\left(\frac{kJ}{mol}\right)$	ΔG^0_f $\left(\frac{kJ}{mol}\right)$	S^0 $\left(\frac{J}{K \cdot mol}\right)$	Substance and State	ΔH^0_f $\left(\frac{kJ}{mol}\right)$	ΔG^0_f $\left(\frac{kJ}{mol}\right)$	S^0 $\left(\frac{J}{K \cdot mol}\right)$
Aluminum				**Iodine**			
$AlBr_3(g)$	−526.3	−505	184	$I_2(s)$	0	0	116.7
$Al(s)$	0	0	28.32	$I_2(g)$	62.25	19.37	260.57
				$HI(g)$	25.94	1.30	206.3
Barium							
$BaCl_2(aq)$	−872	−823	123	**Magnesium**			
$Ba(OH)_2 \cdot 8H_2O(s)$	−3342	−2793	427	$Mg(s)$	0	0	33
				$Mg^{2+}(aq)$	−492	−456	−118
Bromine				$MgO(s)$	−601	−569	26.9
$Br_2(l)$	0	0	152.231				
$BrCl(g)$	14.64	−0.96	239.99	**Oxygen**			
				$O_2(g)$	0	0	205
Carbon				$O(g)$	249	232	161
$C(s)$ (graphite)	0	0	6	$O_3(g)$	143	163	239
$C(s)$ (diamond)	2	3	2				
$CO(g)$	−110.5	−137	198	**Nitrogen**			
$CO_2(g)$	−393.5	−394	214	$N_2(g)$	0	0	192
$CH_4(g)$	−75	−51	186	$NCl_3(g)$	230	271	−137
$CH_3OH(g)$	−201	−163	240	$NF_3(g)$	−125	−83.6	−139
$CH_3OH(l)$	−239	−166	127	$NH_3(g)$	−46	−17	193
$H_2CO(g)$	−116	−110	219	$NH_3(aq)$	−80	−27	111
$HCOOH(g)$	−363	−351	249	$NH_2CONH_2(aq)$	?	?	174
$HCN(g)$	135.1	125	202	$NO(g)$	90	87	211
$C_2H_2(g)$	227	209	201	$NO_2(g)$	34	52	240
$C_2H_4(g)$	52	68	219	$N_2O(g)$	82	104	220
$CH_3CHO(g)$	−166	−129	250	$N_2O_4(g)$	10	98	304
$C_2H_5OH(l)$	−278	−175	161	$N_2O_5(g)$	⁻42	134	178
$C_2H_6(g)$	−84.7	−32.9	229.5	$N_2H_3CH_3(l)$	54	180	166
$C_3H_6(g)$	20.9	62.7	266.9	$HNO_3(aq)$	−207	−111	146
$C_3H_8(g)$	−104	−24	270	$HNO_3(l)$	−174	−81	156
				$NH_4Cl(s)$	−314	−201	95
Chlorine				$NH_4ClO_4(s)$	−295	−89	186
$Cl_2(g)$	0	0	222.957				
$Cl_2(aq)$	−23	7	121	**Silver**			
$Cl^-(aq)$	−167	−131	57	$Ag(s)$	0	0	42.6
$HCl(g)$	−92	−95	187	$Ag^+(aq)$	105.6	77.1	72.7
				$AgBr(s)$	−100.4	−96.9	107.1
Fluorine				$AgCl_3(s)$	−127.1	−109.8	96.2
$F_2(g)$	0	0	203				
$F^-(aq)$	−333	−279	−14	**Sulfur**			
$HF(g)$	−271	−273	174	S(rhombic)	0	0	31.8
				S(monocl)	0.3	0.1	32.6
Hydrogen				$SO_2(g)$	−296.8	−300.2	248.8
$H_2(g)$	0	0	131	$SO_3(g)$	−395.7	−371.1	256.3
$H(g)$	217	203	115	$H_2S(g)$	−20.17	−33.0	205.6
$H^+(aq)$	0	0	0				
$OH^-(aq)$	−230	−157	−11	**Titanium**			
$H_2O(l)$	−286	−237	70	$TiCl_4(g)$	−763	−727	355
$H_2O(g)$	−242	−229	189	$TiO_2(s)$	−945	−890	50