Chapter 18 Multiple Choice

1. Which of these species has the highest entropy ($S°$) at 25°C?
   A. CO(g)
   B. CH_4(g)
   C. NaCl(s)
   D. $H_2O(l)$
   E. Fe(s)

2. Arrange the following substances in the order of increasing entropy at 25°C.
   HF (g), NaF (s), SiF_4 (g), SiH_4 (g), Al (s)

   lowest → highest
   A. $SiF_4(g) < SiH_4(g) < NaF(s) < HF(g) < Al(s)$
   B. $HF(g) < Al(s) < NaF(s) < SiF_4(g) < SiH_4(g)$
   C. $Al(s) < NaF(s) < HF(g) < SiH_4(g) < SiF_4(g)$
   D. $Al(s) < HF(g) < NaF(s) < SiF_4(g) < SiH_4(g)$
   E. $NaF(s) < Al(s) < HF(g) < SiF_4(g) < SiH_4(g)$

3. Which response includes *all* the following processes that are accompanied by an *increase* in entropy?
   1. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
   2. $H_2O(l) \rightarrow H_2O(s)$
   3. $Br_2(l) \rightarrow Br_2(g)$
   4. $H_2O_2(l) \rightarrow H_2O(l) + (½)O_2(g)$
   A. 1, 2, 3, 4
   B. 1, 2
   C. 2, 3, 4
   D. 3, 4
   E. 1, 4

4. Without reference to a table, arrange these reactions according to *increasing* ΔS.
   1. $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$
   2. $C(s) + O_2(g) \rightarrow CO_2(g)$
   3. $H_2O_2(l) \rightarrow H_2O(l) + (½)O_2(g)$

   A. 1 < 3 < 2
   B. 2 < 3 < 1
   C. 2 < 1 < 3
   D. 3 < 2 < 1
   E. 3 < 1 < 2

5. Determine $\Delta S°$ for the reaction $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$.

	$S°$ (J/K·mol)
SO_3	256.2
H_2O	69.9
H_2SO_4	156.9

   A. 169.2 J/K·mol
   B. 1343.2 J/K·mol
   C. –169.2 J/K·mol
   D. –29.4 J/K·mol
   E. 29.4 J/K·mol

6. 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}).
   A. 598 J/K·mol
   B. 68.6 J/K·mol
   C. 75.2 J/K·mol
   D. 0.068 J/K·mol
   E. 89.0 J/K·mol

7. The entropy change on vaporization (ΔS_{vap}) of a compound or element is
   A. always negative.
   B. always positive.
   C. sometimes positive and sometimes negative.

8. A negative sign for ΔG indicates that, at constant T and P,
   A. the reaction is exothermic.
   B. the reaction is endothermic.
   C. the reaction is fast.
   D. the reaction is spontaneous.
   E. ΔS must be > 0.

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

	ΔG_f^o(kJ/mol)
$H_2O(l)$	–237.2
$HNO_3(l)$	–79.9
NO(g)	86.7
$NO_2(g)$	51.8

   A. 8.7 kJ/mol
   B. 192 kJ/mol
   C. –414 kJ/mol
   D. –192 kJ/mol
   E. –155 kJ/mol

10. Ozone (O_3) in the atmosphere can react with nitric oxide (NO):
    $O_3(g) + NO(g) \rightarrow NO_2(g) + O_2(g)$.

    Calculate the $\Delta G°$ for this reaction at 25°C. ($\Delta H°$ = –199 kJ/mol, $\Delta S°$ = –4.1 J/K·mol)

    A. 1020 kJ/mol
    B. -1.22×10^3 kJ/mol
    C. 2.00×10^3 kJ/mol
    D. -1.42×10^3 kJ/mol
    E. –198 kJ/mol

11. 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 $\Delta H°$ = 128.9 kJ/mol and $\Delta G°$ = 33.1 kJ/mol at 25°C, above what minimum temperature will the reaction become spontaneous under standard state conditions?

A. 0.4 K
B. 3.9 K
C. 321 K
D. 401 K
E. 525 K

12. The normal freezing point of ammonia is –78°C. Predict the signs of ΔH, ΔS, and ΔG for ammonia when it freezes at –80°C and 1 atm: $NH_3(l) \rightarrow NH_3(s)$

	ΔH	ΔS	ΔG
A.	–	–	0
B.	–	+	–
C.	+	–	+
D.	+	+	0
E.	–	–	–

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

$$H_2O_2(l) \rightarrow H_2O(l) + (1/2)O_2(g).$$

Calculate K_p for this reaction at 25°C. ($\Delta H°$ = –98.2 kJ/mol, $\Delta S°$ = 70.1 J/K·mol)

A. 1.3×10^{-21}
B. 20.9
C. 3.46×10^{17}
D. 7.5×10^{20}
E. 8.6×10^{4}

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

A. 105 kJ/mol
B. 1.07 kJ/mol
C. -233 kJ/mol
D. -105 kJ/mol
E. 233 kJ/mol

15. The equilibrium constant for the reaction

$$AgBr(s) \rightleftharpoons Ag^+(aq) + Br^-(aq)$$

is the solubility product constant, $K_{sp} = 7.7 \times 10^{-13}$ at 25°C. Calculate ΔG for the reaction when $[Ag^+] = 1.0 \times 10^{-2}$ M and $[Br^-] = 1.0 \times 10^{-3}$ M. Is the reaction spontaneous or nonspontaneous at these concentrations?

A. ΔG = 69.1 kJ/mol, nonspontaneous
B. ΔG = –69.1 kJ/mol, spontaneous
C. ΔG = 97.5 kJ/mol, spontaneous
D. ΔG = 40.6 kJ/mol, nonspontaneous
E. ΔG = –97.5 kJ/mol, nonspontaneous

16. K_w for the auto-ionization of water, $H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$, is 1.0×10^{-14}. What are the signs (+/–) of $\Delta S°$ and $\Delta H°$ for the reaction at 25°C?

A. $\Delta S°$ = (+) and $\Delta H°$ = (+)
B. $\Delta S°$ = (+) and $\Delta H°$ = (–)
C. $\Delta S°$ = (–) and $\Delta H°$ = (+)
D. $\Delta S°$ = (–) and $\Delta H°$ = (–)

17. The reaction rates of many spontaneous reactions are actually very slow. Which of these statements is the best explanation for this observation?

A. K_p for the reaction is less than one.
B. The activation energy of the reaction is large.
C. $\Delta G°$ for the reaction is positive.
D. Such reactions are endothermic.
E. The entropy change is negative.

18. *****Find the temperature at which the reaction $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ will be in equilibrium when both gases are present at partial pressures of 1.00 atm.

	ΔH_f^o(25°C)	ΔG_f^o(25°C)
$NO_2(g)$	33.85 kJ/mol	51.8 kJ/mol
$N_2O_4(g)$	9.66 kJ/mol	98.29 kJ/mol

A. 300°C
B. 28°C
C. 55°C
D. 32°C
E. 562°C

19. *****Predict the normal boiling point of triethylborane ($C_6H_{15}B$) using the following data:

	ΔH_f^o(25°C)	ΔG_f^o(25°C)
$C_6H_{15}B(l)$	–194.6 kJ/mol	9.4 kJ/mol
$C_6H_{15}B(g)$	–157.7 kJ/mol	16.1 kJ/mol

A. 92°C
B. –21°C
C. 21°C
D. 365°C
E. 256°C

20. *****A sample of solid naphthalene is introduced into an evacuated flask. Use the data below to calculate the equilibrium vapor pressure of naphthalene ($C_{10}H_8$) in the flask at 35°C.

	ΔH_f^o(25°C)	ΔG_f^o(25°C)
$C_{10}H_8(s)$	78.5 kJ/mol	201.6 kJ/mol
$C_{10}H_8(g)$	150.6 kJ/mol	224.1 kJ/mol

A. 890. mmHg
B. 0.12 mmHg
C. 696 mmHg
D. 0.086 mmHg
E. 833 mmHg

***Challenge Problems**

Answers: 1. A; 2. C; 3. D; 4. B; 5. C; 6. E; 7. B; 8. D; 9. A; 10. E; 11. D; 12. E; 13. D; 14. E; 15. D; 16. A; 17. B; 18. C; 19. A; 20. B