1. In the following reaction
   $NH_4^+(aq) + H_2O(l) \leftrightarrow NH_3(aq) + H_3O^+(aq)$
   a. NH_4^+ is an acid and NH_3 is its conjugate base.
   b. H_2O is an acid and H_3O^+ is its conjugate base.
   c. NH_4^+ is an acid and H_3O^+ is its conjugate base.
   d. H_2O is an acid and NH_4^+ is its conjugate base.
   e. NH_3 is an acid and NH_4^+ is its conjugate base.

2. Which of the following acids has the strongest conjugate base?
   a. Ascorbic acid, K_a= 8.0 x 10^{-5}
   b. Benzoic acid, K_a= 6.5 x 10^{-5}
   c. 3-chlorobenzoic acid, K_a= 1.5 x 10^{-4}
   d. 2-hydroxybenzoic acid, K_a= 1.1 x 10^{-3}
   e. Chloroacetic acid, K_a= 1.4 x 10^{-3}

3. Knowing that H_2S is a stronger acid than HCN, determine, if possible, in which direction the following equilibrium lies.
   $HCN(aq) + HS^-(aq) \leftrightarrow CN^-(aq) + H_2S(aq)$

   a. equilibrium lies to the left
   b. equilibrium lies to the right
   c. equilibrium is perfectly balanced left and right
   d. can be determined if the relative acidity of HS^- is given
   e. cannot be determined

4. What is the pH of a 0.054 M NaOH solution at 25 ºC?
   a. 1.14
   b. 1.27
   c. 8.64
   d. 12.73
   e. 13.95

5. We dilute 1.00 mL of 1.00 M HCl solution to 100.0 mL. What is $[OH^-]$ in this solution at 25 ºC?
   a. 1.00 x 10^{12} M
   b. 1 x 10^2 M
   c. 0.010 M
   d. 7.00 x 10^{-4} M
   e. 1.00 x 10^{-12} M

6. At 25 ºC, what is the pH of a 1.75 M solution of sodium cyanide NaCN? (K_b = 2.5 x 10^{-5})

   a. 11.82
   b. 10.04
   c. 3.44
   d. 2.18
   e. 0.80

7. At 25 ºC, what is the pH of a 3.25 M solution of ammonium chloride, NH_4Cl? ($K_a = 5.6 \cdot 10^{-10}$)
   a. 2.37
   b. 4.37
   c. 4.62
   d. 9.37
   e. 9.63

8. Which of the following acid-base reactions will lie predominantly toward the products? ($K_a(CH_3CO_2H) = 1.8 \cdot 10^{-5}$, $K_b(NH_3) = 1.8 \cdot 10^{-5}$)

Reaction 1: $NH_3(aq) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)$
Reaction 2: $CH_3CO_2H(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + CH_3CO_2^-(aq)$
Reaction 3: $CH_3CO_2H(aq) + NH_3(aq) \leftrightarrow NH_4^+(aq) + CH_3CO_2^-(aq)$

   a. 1 only
   b. 2 only
   c. 3 only
   d. 1 and 2 only
   e. 1 and 3 only

9. If you mix 250. mL of 0.24 M HF with 75.0 mL of 0.80 M NaOH, what is the pH of the resulting solution? For F^-, $K_b = 1.4 \times 10^{-11}$

a. 5.42
b. 5.79
c. 6.24
d. 7.53
e. 8.21

10. If you mix 125. mL of 0.50 M CH_3CO_2H with 75.0 mL of 0.83 M NaOH, what is the pH of the resulting solution? For CH_3COOH, $K_a = 1.8 \times 10^{-5}$

a. 4.88
b. 5.01
c. 7.14
d. 8.99
e. 9.76

11. If you mix equal molar quantities of NaOH and CH_3CO_2H, what are the principal species present in the resulting solution?

a. Na^+, $CH_3CO_2^-$, OH^-, and H_2O
b. Na^+, $CH_3CO_2^-$, CH_3CO_2H, OH^-, and H_2O
c. Na^+, CH_3CO_2H, OH^-, and H_2O
d. Na^+, $CH_3CO_2^-$, H_3O^+, and H_2O
e. Na^+, CH_3CO_2H, H_3O^+, and H_2O

12. The salt produced by the reaction of an equal number of moles of KOH and HNO_3 will react with water to give a solution which is

a. acidic.
b. basic.
c. neutral.
d. non-ionic.
e. impossible to determine.

13. If you mix equal molar quantities of NH_3 ($K_b = 1.8 \times 10^{-5}$) and CH_3CO_2H ($K_a = 1.8 \times 10^{-5}$), the resulting solution will be

a. acidic because K_a of NH_4^+ is greater than K_b of $CH_3CO_2^-$.
b. acidic because K_a of NH_4^+ is greater than K_a of CH_3CO_2H.
c. basic because K_b of NH_3 is greater than K_b of $CH_3CO_2^-$.
d. basic because K_a of NH_4^+ is greater than K_b of $CH_3CO_2^-$.
e. neutral because K_a of NH_4^+ equals K_b of $CH_3CO_2^-$.

14. At the neutralization point of the titration of an acid with base, what condition is met?

a. Volume of base added from buret equals volume acid in reaction flask.
b. Molarity of base from the buret equals molarity of acid in reaction flask.
c. Moles of base added from the buret equals moles of acid in the reaction flask.
d. % ionization of base added from the buret equals % ionization of the acid in flask.
e. All of the above conditions are met.

15. The solubility of $FeCO_3$ is 5.9×10^{-6} mol/L. What is K_{sp} for $FeCO_3$?

a. 5.9×10^{-6}
b. 1.2×10^{-21}
c. 3.5×10^{-11}
d. 2.8×10^{-10}
e. 1.3×10^{-14}

16. What is the concentration of CrO_4^{2-} in a saturated solution of $PbCrO_4$ if $K_{sp} = 1.8 \times 10^{-14}$?

a. 1.3×10^{-7} M
b. 7.5×10^{-6} M
c. 1.8×10^{-4} M
d. 1.3×10^{-4} M
e. 5.1×10^{-3} M

17. Which of the following has the highest molar solubility?

a. $PbCO_3$; $K_{sp} = 1.5 \times 10^{-13}$
b. PbS; $K_{sp} = 8.4 \times 10^{-28}$
c. PbI_2; $K_{sp} = 8.7 \times 10^{-9}$
d. $PbSO_4$; $K_{sp} = 1.8 \times 10^{-8}$
e. $Pb_2(PO_4)_2$; $K_{sp} = 3.0 \times 10^{-44}$

18. Calculate the equilibrium constant for the reaction:

$CdS(s) + Zn^{2+}(aq) \leftrightarrow ZnS(s) + Cd^{2+}(aq)$
CdS; $K_{sp} = 3.6 \times 10^{-29}$ ZnS; $K_{sp} = 1.1 \times 10^{-21}$

a. 3.3×10^{-8}
b. 2.7×10^{-4}
c. 4.2×10^{5}
d. 2.5×10^{49}
e. 3.1×10^{7}

19. For Ag_2SO_4, $K_{sp} = 1.7 \times 10^{-5}$. How many grams of Na_2SO_4 (MM = 142.0 g/mol) must be added to 100. mL of 0.022 M $AgNO_3$ to just initiate precipitation?

a. 5.0 g
b. 4.0 g
c. 3.0 g
d. 0.50 g
e. 0.40 g

20. For thallium bromide, TlBr, $K_{sp} = 3.4 \times 10^{-6}$. How many grams of KBr (MM = 119.0 g/mol) must be added to 100. mL of 5.5×10^{-4} M $TlNO_3$ to just initiate precipitation?

a. 0.74 g
b. 0.074 g
c. 0.065 g
d. 0.0065 g
e. 0.0033 g

21. In the following reaction

$HF(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + F^-(aq)$

a. HF is an acid and H_3O^+ is its conjugate base.
b. H_2O is an acid and H_3O^+ is its conjugate base.
c. HF is an acid and F^- is its conjugate base.
d. H_2O is an acid and H_3O^+ is its conjugate base.
e. HF is an acid and H_2O is its conjugate base.

22. What is the pH of a 4.2×10^{-4} M HBr solution at 25 ºC?

a. 2.80
b. 3.38
c. 3.80
d. 4.20
e. 4.62

23. We have a 4.63×10^{-4} M solution of HCl. What is the pH of this solution at 25 ºC?

a. 3.33
b. 4.00
c. 4.63
d. 8.37
e. 9.25

25. What is the pH of a 3.18 M CH_3COOH solution at 25 ºC? K_a = 1.8×10^{-5}?

a. 2.12
b. 2.75
c. 1.40
d. 4.24
e. 4.74

26. What is the % ionization of a 3.14 M CH_3CO_2H solution at 25 ºC? For CH_3CO_2H, K_a= 1.8×10^{-5}.

a. 0.24%
b. 0.57%
c. 1.8%
d. 3.2%
e. 7.5%

27. Which of the following acid-base reactions will lie predominantly toward the products?

Reaction 1: $HF(aq) + NH_3(aq) \leftrightarrow NH_4^+(aq) + F^-(aq)$
Reaction 2: $NH_3(aq) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)$
Reaction 3: $HF(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + F^-(aq)$

a. 1 only
b. 2 only
c. 1 and 2 only
d. 2 and 3 only
e. 1, 2, and 3

28. We add 1.00 mL of 10.0 M HNO_3 to 100. mL of 0.10 M NaHCOO. What is the pH of the resulting solution? $K_a(HCOOH) = 1.8 \times 10^{-4}$

a. 2.37
b. 3.45
c. 4.27
d. 4.35
e. 11.60

29. If you mix 100. mL of 0.11 M HCl with 50.0 mL of 0.22 M NH_3, what is the pH of the resulting solution? For NH_4^+, $K_a = 5.6 \times 10^{-10}$

a. 4.63
b. 5.19
c. 6.02
d. 8.37
e. 9.37

30. If you mix 125. mL of 0.50 M CH_3CO_2H with 75.0 mL of 0.83 M NaOH, what is the pH of the resulting solution? For CH_3COO^-, $K_b = 5.6 \times 10^{-10}$

a. 4.88
b. 5.01
c. 7.14
d. 9.12
e. 9.76

31. What effect will the addition of the reagent in each of the following have on the pH of the CH_3CO_2H solution respectively?

Flask 1: Addition of $NaCH_3CO_2$ to $CH_3CO_2H(aq)$
Flask 2: Addition of $Ca(CH_3CO_2)_2$ to $CH_3CO_2H(aq)$

a. no change, increase
b. no change, decrease
c. decrease, no change
d. decrease, decrease
e. increase, increase

32. If you add 20.0 mL of 2.30 M NH_3 to 100. mL of a 1.17 M NH_4Cl solution, what is the pH of the resulting solution? For NH_3, K_b = 1.8×10^{-5}

a. 5.15
b. 6.35
c. 7.10
d. 7.65
e. 8.85

33. We have 250. mL of a 0.56 M solution of $NaCH_3COO$. How many milliliters of a 0.50 M CH_3COOH solution should be added to make a buffer of pH = 4.40?
$K_a(CH_3COOH) = 1.8 \times 10^{-5}$

a. 200
b. 230
c. 620
d. 710
e. 750

34. Which of the following is the solubility product constant for $Mn(OH)_2$?

a. $K_{sp} = [Mn^{2+}][OH^-]^2$
b. $K_{sp} = [Mn^{2+}][2OH^-]^2$
c. $K_{sp} = [Mn^{2+}]^2[OH^-]^2$
d. $K_{sp} = [Mn^{2+}]^2[OH^-]$
e. $K_{sp} = [Mn^{2+}]^2[OH^-]^2$

35. Rank the compounds from lowest to highest molar solubility.
$FeCO_3$; $K_{sp} = 3.5 \times 10^{-11}$
$BaSO_4$; $K_{sp} = 1.1 \times 10^{-10}$
$ZnCO_3$; $K_{sp} = 1.5 \times 10^{-11}$

a. $ZnCO_3 < BaSO_4 < FeCO_3$
b. $FeCO_3 < ZnCO_3 < BaSO_4$
c. $ZnCO_3 < FeCO_3 < BaSO_4$
d. $BaSO_4 < ZnCO_3 < FeCO_3$
e. $BaSO_4 < FeCO_3 < ZnCO_3$

36. What is the concentration of SO_4^{2-} in a saturated solution of $BaSO_4$ if $K_{sp} = 1.1 \times 10^{-10}$?

a. 1.1×10^{-10} M
b. 5.5×10^{-11} M
c. 5.0×10^{-5} M
d. 1.0×10^{-5} M
e. 9.5×10^{-4} M

37. For MgF_2, $K_{sp} = 6.4 \times 10^{-9}$. If you mix 400. mL of 1×10^{-4} M $Mg(NO_3)_2$ and 500. mL of 1.00×10^{-4} M NaF, what will be observed?

a. A precipitate forms because $Q_{sp} > K_{sp}$.
b. A precipitate forms because $Q_{sp} < K_{sp}$.
c. No precipitate forms because $Q_{sp} = K_{sp}$.
d. No precipitate forms because $Q_{sp} < K_{sp}$.
e. No precipitate forms because $Q_{sp} > K_{sp}$.

38. For AgI, $K_{sp} = 8.3 \times 10^{-17}$. What is the molar solubility of AgI in a solution which is 5.1×10^{-4} M in $AgNO_3$?
a. 5.1×10^{-2} mol/L
b. 1.1×10^{-5} mol/L
c. 8.3×10^{-11} mol/L
d. 1.6×10^{-13} mol/L
e. 4.2×10^{-20} mol/L

39. Which of the following represents an increase in entropy?
a. freezing of water
b. boiling of water
c. crystallization of salt from a supersaturated solution
d. the reaction $2NO(g) \rightarrow N_2O_2(g)$
e. the reaction $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

40. If ΔH and ΔS are both negative or positive, then ΔG has a ______ sign.

a. positive
b. negative
c. variable
d. large
e. no

41. Calculate the standard entropy change for the following reaction,

$$Cu(s) + 1/2\ O_2(g) \rightarrow CuO(s)$$

given that S°[Cu(s)] = 33.15 J/K•mol, S°[O_2(g)] = 205.14 J/K•mol, and S°[CuO(s)] = 42.63 J/K•mol

a. 195.66 J/K
b. 93.09 J/K
c. -45.28 J/K
d. -93.09 J/K
e. 195.66 J/K

42. Calculate the standard entropy change for the following reaction,

$$CCl_4(l) + O_2(g) \rightarrow CO_2(g) + 2Cl_2(g)$$

given that S°[CCl_4(l)] = 216.40 J/K•mol, S°[CO_2(g)] = 213.74 J/K•mol, S°[O_2(g)] = 205.14 J/K•mol, and S°[Cl_2(g)] = 223.07 J/K•mol.

a. -25.78 J/K
b. -15.27 J/K
c. +1.93 J/K
d. 238.34 J/K
e. 317.42 J/K

43. In which of the following reactions do you expect to have the smallest entropy change?

a. $2HF(g) + Cl_2(g) \rightarrow 2HCl(g) + F_2(g)$
b. $2Fe(s) + 3/2\ O_2(g) \rightarrow Fe_2O_3(s)$
c. $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
d. $Cu(s) + 1/2\ O_2(g) \rightarrow CuO(s)$
e. $H_2(g) + I_2(g) \rightarrow 2HI(g)$

44. If ΔG is positive at all temperatures, then ΔS is ______ and ΔH is _____.

a. positive, negative
b. negative, positive
c. small, zero
d. large, zero
e. large, small

45. At what temperature would a given reaction become spontaneous if ΔH = +119 kJ and ΔS = +263 J/K?

a. 452 K
b. 2210 K
c. 382 K
d. 2.21 K
e. 363 K

46. Given the following information, calculate ΔG° for the reaction below at 25 °C:

$$SnCl_4(l) + 2H_2O(l) \rightarrow SnO_2(s) + 4HCl(g)$$

ΔH° = 133.0 kJ and ΔS° = 401.5 J/K

a. -252.6 kJ
b. -13.4 kJ
c. 13.4 kJ
d. 122.9 kJ
e. 252.6 kJ

47. For the process at 25 °C I_2(g) to I_2(s), what are the signs of ΔG, ΔH, and ΔS?

	ΔG	ΔH	ΔS
a.	+	-	-
b.	**-**	**-**	**-**
c.	-	+	+
d.	-	-	+
c.	+	+	+

48. All of the following have $\Delta G^o{}_f = O$ **EXCEPT**

a. $O_2(g)$
b. $Br_2(g)$
c. $H_2(g)$
d. Ca(s)
e. Hg(l)

49. The disorder of a system is represented by the
a. enthalpy.
b. Gibbs free energy.
c. entropy.
d. heat of vaporization.
e. equilibrium constant.

50. Calculate the standard entropy change for the following reaction,
$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
given that $S^o[CO_2(g)] = 213.74$ J/K•mol, $S^o[O_2(g)] = 205.14$ J/K•mol, $S^o[H_2O(l)] = 69.91$ J/K•mol, and $S^o[CH_4(g)] = 186.26$ J/K•mol.

a. -312.89 J/K
b. -242.98 J/K
c. -118.42 J/K
d. 23.5 J/K
e. 312.89 J/K

51. Calculate the standard molar entropy of urea ($CO(NH_2)_2(s)$ if the standard entropy change for the formation is -456.3 J/K•mol and given $S^o[C(s)] = 5.74$ J/K•mol, $S^o[O_2(g)] = 205.1$ J/K•mol, Sø$[N_2(g)] = 191.6$ J/K•mol, and $S^o[H_2(g)] = 130.7$ J/K•mol.

a. -1017.2 J/K•mol
b. +314.1 J/K•mol
c. +194.2 J/K•mol
d. +105.0 J/K•mol
e. -56.0 J/K•mol

52. For the reaction
$MgO(s) + CO_2(g) \rightarrow MgCO_3(s)$

$\Delta H^o{}_{rxn} = -178$ kJ and $\Delta S^o{}_{rxn} = -161$ J/mol•K.

Will the reaction be spontaneous at 900 ºC?

a. Yes, because ΔG will change.
b. Yes, because ΔH and ΔS are temperature independent.
c. Yes, because ΔH and ΔS are temperature dependent.
d. No, because ΔG is positive.
e. No, because ΔG is negative.

53. If a process is exothermic and not spontaneous, then what must be true?

a. ΔS>O
b. ΔH>O
c. ΔG=O
d. ΔS<O
e. ΔH=O

54. Which of the following is true about vaporization?

a. ΔS is positive and ΔH is negative.
b. ΔS, ΔH, and ΔG are all negative.
c. ΔS and ΔH are both negative.
d. ΔS and ΔH are both positive.
e. ΔS, ΔH, and ΔG are equal to zero.

55. Which of the following does not have a free energy of zero?

a. $N_2(g)$
b. $I_2(s)$
c. Fe(s)
d. Na(g)
e. He(g)

56. Ammonium nitrate spontaneously dissolves in water at room temperature and the process causes the solution to become quite cold. Which of the following is **TRUE** about the dissolution of ammonium nitrate?

a. The process is exothermic.
b. Its solubility will be greater in warmer water.
c. ΔS^o for the reaction is negative.
d. All solutions of ammonium nitrate are supersaturated.
e. All solutions of ammonium nitrate are cold.

57. The following general reaction is not spontaneous at room temperature.

$$A + B \rightarrow C + D$$

$\Delta H^o = +50.0$ kJ and $\Delta S^o = +100.$ J/K

At what temperature will the reaction become spontaneous?

a. 500 ºC
b. 0.5 K
c. 500 K
d. 250 ºC
e. Not at any temperature.