CHEM-2 FINAL REVIEW; SPRING 2011

1. The compound RX_3 decomposes according to the equation

$$3RX_3 \rightarrow R + R_2X_3 + 3X_2$$

In an experiment the following data were collected for the decomposition at 100°C. What is the average rate of reaction over the entire experiment?

t(s)	[RX_3](mol L–1)
0	0.85
2	0.67
6	0.41
8	0.33
12	0.20
14	0.16

A) 0.011 mol $L^{-1}s^{-1}$
B) 0.019 mol $L^{-1}s^{-1}$
C) 0.044 mol $L^{-1}s^{-1}$
D) 0.049 mol $L^{-1}s^{-1}$
E) 0.069 mol $L^{-1}s^{-1}$

2. Consider the following reaction

$$8A(g) + 5B(g) \rightarrow 8C(g) + 6D(g)$$

If [C] is increasing at the rate of 4.0 mol $L^{-1}s^{-1}$, at what rate is [B] changing?

A) –0.40 mol $L^{-1}s^{-1}$
B) –2.5 mol $L^{-1}s^{-1}$
C) –4.0 mol $L^{-1}s^{-1}$
D) –6.4 mol $L^{-1}s^{-1}$
E) none of the above, since its rate of change must be positive

3. For the reaction

$3A(g) + 2B(g) \rightarrow 2C(g) + 2D(g)$

the following data were collected at constant temperature. Determine the correct rate law for this reaction.

Trial	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial Rate (mol/(L·min))
1	0.200	0.100	6.00×10^{-2}
2	0.100	0.100	1.50×10^{-2}
3	0.200	0.200	1.20×10^{-1}
4	0.300	0.200	2.70×10^{-1}

A) Rate = $k[A][B]$
B) Rate = $k[A][B]^2$
C) Rate = $k[A]^3[B]^2$
D) Rate = $k[A]^{1.5}[B]$
E) Rate = $k[A]^2[B]$

4. For the reaction

$A(g) + 2B(g) \rightarrow 2C(g) + 2D(g)$

the following data were collected at constant temperature. Determine the correct rate law for this reaction.

Trial	Initial [A] (mol/L)	Initial [B] (mol/L)	Initial Rate (mol/(L·min))
1	0.125	0.200	7.25
2	0.375	0.200	21.75
3	0.250	0.400	14.50
4	0.375	0.400	21.75

A) Rate = $k[A]\,[B]$
B) Rate = $k[A]^2\,[B]$
C) Rate = $k[A]\,[B]^2$
D) Rate = $k[A]$
E) Rate = $k[A]^3$

5. For the reaction

$$2A + B + 2C \rightarrow D + E$$

the following initial rate data were collected at constant temperature. Determine the correct rate law for this reaction. All units are arbitrary.

Trial	[A]	[B]	[C]	Rate
1	0.225	0.150	0.350	0.0217
2	0.320	0.150	0.350	0.0439
3	0.225	0.250	0.350	0.0362
4	0.225	0.150	0.600	0.01270

A) Rate = k[A][B][C]
B) Rate = k [A]^2[B][C]
C) Rate = k [A]^2[B][C]$^{-1}$
D) Rate = k [A][B]^2[C] $^{-1}$
E) none of the above

6. The rate constant for a reaction is 4.65 L mol^{-1}s^{-1}. What is the overall order of the reaction?
A) zero
B) first
C) second
D) third
E) More information is needed to determine the overall order.

7. When the reaction A $\rightarrow$ B + C is studied, a plot of ln[A]$_t$ vs. time gives a straight line with a negative slope. What is the order of the reaction?
A) zero
B) first
C) second
D) third
E) More information is needed to determine the order.

8. When the reaction A $\rightarrow$ B + C is studied, a plot 1/[A]$_t$ vs. time gives a straight line with a positive slope. What is the order of the reaction?
A) zero
B) first
C) second
D) third
E) More information is needed to determine the order.

9. Which of the following sets of units could be appropriate for a zero-order rate constant?
   A) s^{-1}
   B) $L\ mol^{-1}\ s^{-1}$
   C) $L^2\ mol^{-2}\ s^{-1}$
   D) $L^3\ mol^{-3}\ s^{-1}$
   E) $mol\ L^{-1}\ s^{-1}$

10. A reaction has the following rate law:
    Rate = $k[A][B]^2$
    In experiment 1, the concentrations of A and B are both 0.10 mol L^{-1}; in experiment 2, the concentrations are both 0.30 mol L^{-1}. If the temperature stays constant, what is the value of the ratio, Rate(2)/Rate(1)?
   A) 3.0
   B) 6.0
   C) 9.0
   D) 18
   E) 27

11. A study of the decomposition reaction $3RS_2 \rightarrow 3R + 6S$ yields the following initial rate data

$[RS_2]$(mol L–1)	Rate (mol/(L·s))
0.150	0.0394
0.250	0.109
0.350	0.214
0.500	0.438

    What is the rate constant for the reaction?
   A) 0.0103 $L\ mol^{-1}s^{-1}$
   B) 0.263 $L\ mol^{-1}s^{-1}$
   C) 0.571 $L\ mol^{-1}s^{-1}$
   D) 1.17 $L\ mol^{-1}s^{-1}$
   E) 1.75 $L\ mol^{-1}s^{-1}$

12. A reaction is first-order with respect to the reactant R. Which of the following plots will produce a straight line?
   A) [R] vs. 1/time
   B) 1/[R] vs. time
   C) $[R]^2$ vs. time
   D) $1/[R]^2$ vs. time
   E) ln[R] vs. time

13. The reaction $X \rightarrow Y$ is first-order overall and first-order with respect to the reactant X. The result of doubling the initial concentration of X will be to
    A) shorten the half-life of the reaction.
    B) increase the rate constant of the reaction.
    C) decrease the rate constant of the reaction.
    D) shorten the time taken to reach equilibrium.
    E) double the initial rate.

14. The rate law for the reaction $3A \rightarrow 2B$ is rate = k[A] with a rate constant of 0.0447 hr^{-1}. What is the half-life of the reaction?
    A) 0.0224 hr
    B) 0.0645 hr
    C) 15.5 hr
    D) 22.4 hr
    E) 44.7 hr

15. Butadiene, C_4H_6 (used to make synthetic rubber and latex paints) reacts to C_8H_{12} with a rate law of rate = 0.014 L/(mol·s) $[C_4H_6]^2$. What will be the concentration of C_4H_6 after 3.0 hours if the initial concentration is 0.025 *M*?
    A) 0.0052 *M*
    B) 0.024 *M*
    C) 43 *M*
    D) 190 *M*
    E) 0.0000 *M*

16. In an exothermic reaction,
    A) the forward reaction is slower than the reverse reaction.
    B) the reaction rate will speed up with time.
    C) the collision energy of the reactants will be greater than that of the products.
    D) the forward reaction will have a lower activation energy than the reverse reaction.
    E) the activation energy will change as the reaction progresses.

17. An increase in temperature increases the reaction rate because
    A) a greater fraction of the collisions have the correct orientation of molecules.
    B) the activation energy of the reaction will increase.
    C) the activation energy of the reaction will decrease.
    D) temperature acts as a catalyst in chemical reactions.
    E) more collisions will have enough energy to exceed the activation energy.

18. What is the molecularity of the following elementary reaction?

$NH_2Cl(aq) + OH^-(aq) \rightarrow NHCl^-(aq) + H_2O(l)$

A) unimolecular
B) bimolecular
C) termolecular
D) tetramolecular
E) Need to know the reaction order before molecularity can be determined.

19. The gas-phase reaction $CH_3NC \rightarrow CH_3CN$ has been studied in a closed vessel, and the rate equation was found to be: Rate $= -\Delta[CH_3NC]/\Delta t = k[CH_3NC]$. Which one of the following actions is least likely to cause a change in the rate of the reaction?

A) lowering the temperature
B) adding a catalyst
C) using a larger initial amount of CH_3NC in the same vessel
D) using a bigger vessel, but the same initial amount of CH_3NC
E) continuously removing CH_3CN as it is formed

20. Consider the following mechanism for the oxidation of bromide ions by hydrogen peroxide in aqueous acid solution.

$H^+ + H_2O_2 \rightleftharpoons H_2O^+\text{–}OH$ (rapid equilibrium)
$H_2O^+\text{–}OH + Br^- \rightarrow HOBr + H_2O$ (slow)
$HOBr + H^+ + Br^- \rightarrow Br_2 + H_2O$ (fast)

What is the overall reaction equation for this process?

A) $2H_2O^+\text{–}OH + 2Br^- \rightarrow H_2O_2 + Br_2 + 2H_2O$
B) $2H^+ + 2Br^- + H_2O_2 \rightarrow Br_2 + 2H_2O$
C) $2H^+ + H_2O_2 + Br^- + HOBr \rightarrow H_2O^+\text{–}OH + Br_2 + H_2O$
D) $H_2O^+\text{–}OH + Br^- + H^+ \rightarrow Br_2 + H_2O$
E) none of the above

21. Consider the following mechanism for the oxidation of bromide ions by hydrogen peroxide in aqueous acid solution.

$H^+ + H_2O_2 \rightleftharpoons H_2O^+\text{–}OH$ (rapid equilibrium)
$H_2O^+\text{–}OH + Br^- \rightarrow HOBr + H_2O$ (slow)
$HOBr + H^+ + Br^- \rightarrow Br_2 + H_2O$ (fast)

Which of the following rate laws is consistent with the mechanism?

A) Rate $= k[H_2O_2][H^+]^2[Br^-]$
B) Rate $= k\,[H_2O^+\text{–}OH][Br^-]$
C) Rate $= k[H_2O_2][H^+][Br^-]$
D) Rate $= k[HOBr][H^+][Br^-][H_2O_2]$
E) Rate $= k[Br^-]$

22. When a catalyst is added to a reaction mixture, it
    A) increases the rate of collisions between reactant molecules.
    B) provides reactant molecules with more energy.
    C) slows down the rate of the back reaction.
    D) provides a new pathway (mechanism) for the reaction.
    E) does none of the above.

23. An equilibrium is established in which both the forward (fwd) and the reverse (rev) reactions are elementary. If the equilibrium constant $K_c = 1.6 \times 10^{-2}$ and the rate constant $k_{fwd} = 8.0 \times 10^{-7}\ s^{-1}$ what is the value of k_{rev}?
    A) $1.3 \times 10^{-8}\ s^{-1}$
    B) $7.8 \times 10^{7}\ s^{-1}$
    C) $2 \times 10^{4}\ s^{-1}$
    D) $5.0 \times 10^{-5}\ s^{-1}$
    E) none of the above

24. The two equilibrium constants for the same reaction, K_c and K_p, will always equal one another when
    A) all of the reactants and products are gases.
    B) in the reaction equation, the number of moles of gaseous products equals the number of moles of gaseous reactants.
    C) in the reaction equation, the number of moles of gaseous products is greater than the number of moles of gaseous reactants.
    D) in the reaction equation, the number of moles of gaseous products is smaller than the number of moles of gaseous reactants.
    E) in the reaction equation, the total number of moles of reactants equals that of the products.

25. The reaction quotient, Q_c, for a reaction has a value of 75 while the equilibrium constant, K_c, has a value of 195. Which of the following statements is accurate?
    A) The reaction must proceed to the left to establish equilibrium.
    B) The reaction must proceed to the right to establish equilibrium.
    C) The concentrations of the products will be much smaller than the concentrations of the reactants when the system is at equilibrium.
    D) The concentrations of the products will be about the same as the concentrations of the reactants when the system is at equilibrium.
    E) None of the above statements is accurate.

26. Write the mass-action expression, Q_c, for the following chemical reaction.

$$NO(g) + \tfrac{1}{2} Br_2(g) \rightleftharpoons NOBr(g)$$

A) $\dfrac{[NOBr]^2}{[NO]^2[Br_2]}$

B) $\dfrac{[NOBr]}{[NO]0.5[Br_2]}$

C) $\dfrac{[NO][Br_2]^{0.5}}{[NOBr]}$

D) $\dfrac{[NO]^2[Br_2]}{[NOBr]^2}$

E) $\dfrac{[NOBr]}{[NO][Br_2]^{0.5}}$

27. What is the mass-action expression, Q_c, for the following chemical reaction?

$$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4{}^{2+}(aq)$$

A) $\dfrac{[Cu(NH_3)_4{}^{2+}]}{[Cu^{2+}]\,[NH_3]}$

B) $\dfrac{[Cu(NH_3)_4{}^{2+}]}{[Cu^{2+}]\,[NH_3]^4}$

C) $\dfrac{[Cu^{2+}]\,[NH_3]}{[Cu(NH_3)_4{}^{2+}]}$

D) $\dfrac{[Cu^{2+}]\,[NH_3]^4}{[Cu(NH_3)_4{}^{2+}]}$

E) None of the above is the correct mass-action expression.

28. Consider the reactions of cadmium with the thiosulfate anion.

$$Cd^{2+}(aq) + S_2O_3{}^{2-}(aq) \rightleftharpoons Cd(S_2O_3)(aq) \qquad K_1 = 8.3 \times 10^3$$

$$Cd(S_2O_3)(aq) + S_2O_3{}^{2-}(aq) \rightleftharpoons Cd(S_2O_3)_2{}^{2-}(aq) \qquad K_2 = 2.5 \times 10^2$$

What is the value for the equilibrium constant for the following reaction?

$$Cd^{2+}(aq) + 2S_2O_3{}^{2-}(aq) \rightleftharpoons Cd(S_2O_3)_2{}^{2-}(aq)$$

A) 0.030

B) 33

C) 8.1×10^3

D) 8.6×10^3

E) 2.1×10^6

29. The equilibrium constant, K_c, for the decomposition of $COBr_2$

$$COBr_2(g) \rightleftharpoons CO(g) + Br_2(g)$$

is 0.190. What is K_c for the following reaction?

$$2CO(g) + 2Br_2(g) \rightleftharpoons 2COBr_2(g)$$

A) 0.0361
B) 2.63
C) 5.62
D) 10.5
E) 27.7

30. Consider the equilibrium reaction: $H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$
Which of the following correctly describes the relationship between K_c and K_p for the reaction?

A) $K_p = K_c$
B) $K_p = (RT)K_c$
C) $K_p = (RT)^2K_c$
D) $K_p = K_c/RT$
E) $K_p = K_c/(RT)^2$

31. Nitric oxide and bromine were allowed to react in a sealed container. When equilibrium was reached $P_{NO} = 0.526$ atm, $P_{Br_2} = 1.59$ atm, and $P_{NOBr} = 7.68$ atm. Calculate K_p for the reaction.

$$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$$

A) 7.45×10^{-3}
B) 0.109
C) 9.18
D) 91.8
E) 134

32. Compounds A, B, and C react according to the following equation.

$$3A(g) + 2B(g) \rightleftharpoons 2C(g)$$

At 100°C a mixture of these gases at equilibrium showed that [A] = 0.855 *M*, [B] = 1.23 *M*, and [C] = 1.75 *M*. What is the value of K_c for this reaction?

A) 0.309
B) 0.601
C) 1.66
D) 3.24
E) > 10

33. 10.0 mL of a 0.100 mol L^{-1} solution of a metal ion M^{2+} is mixed with 10.0 mL of a 0.100 mol l^{-1} solution of a substance L. The following equilibrium is established:

$$M^{2+}(aq) + 2L(aq) \rightleftharpoons ML_2^{2+}(aq)$$

At equilibrium the concentration of L is found to be 0.0100 mol L^{-1}. What is the equilibrium concentration of ML_2^{2+}, in mol L^{-1}?

A) 0.100 mol L^{-1}
B) 0.050 mol L^{-1}
C) 0.025 mol L^{-1}
D) 0.0200 mol L^{-1}
E) 0.0100 mol L^{-1}

34. At high temperatures, carbon reacts with O_2 to produce CO as follows:

$$C(s) + O_2(g) \rightleftharpoons 2CO(g).$$

When 0.350 mol of O_2 and excess carbon were placed in a 5.00-L container and heated, the equilibrium concentration of CO was found to be 0.060 *M*. What is the equilibrium constant, K_c, for this reaction?

A) 0.010
B) 0.072
C) 0.090
D) 0.17
E) 1.2

35. A mixture 0.500 mole of carbon monoxide and 0.400 mole of bromine was placed into a rigid 1.00-L container and the system was allowed to come to equilibrium. The equilibrium concentration of $COBr_2$ was 0.233 *M*. What is the value of K_c for this reaction?

$$CO(g) + Br_2(g) \rightleftharpoons COBr_2(g)$$

A) 5.23
B) 1.22
C) 1.165
D) 0.858
E) 0.191

36. The equilibrium constant K_c for the reaction

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$$

is 49 at 230°C. If 0.70 mol of PCl_3 is added to 0.70 mol of Cl_2 in a 1.00-L reaction vessel at 230°C, what is the concentration of PCl_3 when equilibrium has been established?

A) 0.049 *M*
B) 0.11 *M*
C) 0.30 *M*
D) 0.59 *M*
E) 0.83 *M*

37. Nitric oxide is formed in automobile exhaust when nitrogen and oxygen in air react at high temperatures.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

The equilibrium constant K_p for the reaction is 0.0025 at 2127°C. If a container is charged with 8.00 atm of nitrogen and 5.00 atm of oxygen and the mixture is allowed to reach equilibrium, what will be the equilibrium partial pressure of nitrogen?

A) 0.16 atm
B) 0.31 atm
C) 3.1 atm
D) 7.7 atm
E) 7.8 atm

38. The reaction system

$$POCl_3(g) \rightleftharpoons POCl(g) + Cl_2(g)$$

is at equilibrium. Which of the following statements describes the behavior of the system if POCl is added to the container?

A) The forward reaction will proceed to establish equilibrium.
B) The reverse reaction will proceed to establish equilibrium.
C) The partial pressures of $POCl_3$ and POCl will remain steady while the partial pressure of chlorine increases.
D) The partial pressure of chlorine remains steady while the partial pressures of $POCl_3$ and POCl increase.
E) The partial pressure of chlorine will increase while the partial pressure of POCl decreases.

39. The reaction system

$$POCl_3(g) \rightleftharpoons POCl(g) + Cl_2(g)$$

is at equilibrium. Which of the following statements describes the behavior of the system if the partial pressure of chlorine is reduced by 50%?

A) $POCl_3$ will be consumed as equilibrium is established.
B) POCl will be consumed as equilibrium is established.
C) Chlorine will be consumed as equilibrium is established.
D) The partial pressure of POCl will decrease while the partial pressure of Cl_2 increases as equilibrium is established.
E) The volume will have to decrease before equilibrium can be reestablished.

40. Magnesium hydroxide is used in several antacid formulations. When it is added to water it dissociates into magnesium and hydroxide ions.

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

The equilibrium constant at 25°C is 8.9×10^{-12}. One hundred grams of magnesium hydroxide is added to 1.00 L of water and equilibrium is established. What happens to the solution if another 10 grams of $Mg(OH)_2$ are now added to the mixture?

A) The hydroxide ion concentration will decrease.
B) The hydroxide ion concentration will increase.
C) The hydroxide ion concentration will be unchanged.
D) The solution will become supersaturated.
E) None of the above conclusions is justified without additional information.

41. Methanol can be synthesized by combining carbon monoxide and hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

A reaction vessel contains the three gases at equilibrium with a total pressure of 1.00 atm. What will happen to the partial pressure of hydrogen if enough argon is added to raise the total pressure to 1.4 atm?

A) The partial pressure of hydrogen will decrease.
B) The partial pressure of hydrogen will increase.
C) The partial pressure of hydrogen will be unchanged.
D) K_p needs to be known before a prediction can be made.
E) Both K_p and the temperature need to be known before a prediction can be made.

42. The following reaction is at equilibrium in a closed container.

$$CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4(s) + 5H_2O(g)$$

Which, if any, of the following actions will lead to an increase in the pressure of H_2O present at equilibrium?

A) increasing the volume of the container
B) decreasing the volume of the container
C) adding a catalyst
D) removing some solid $CuSO_4$
E) none of the above

43. What is the pH of a 0.20 *M* HCl solution?

A) < 0
B) 0.70
C) 1.61
D) 12.39
E) 13.30

44. What is the $[OH^-]$ for a solution at 25°C that has $[H_3O^+] = 2.35 \times 10^{-3}$ *M*?
A) 4.26×10^{-5} *M*
B) 2.35×10^{-11} *M*
C) 4.26×10^{-12} *M*
D) 2.35×10^{-17} *M*
E) none of the above

45. An aqueous solution is considered to be acidic if
A) the hydroxide ion concentration is 10^{-6} *M*.
B) the hydrogen ion concentration is 10^{-8} *M*.
C) the hydroxide and hydrogen ion concentrations are equal.
D) the hydroxide ion concentration is greater than the hydrogen ion concentration.
E) the hydroxide ion concentration is 10^{-10} *M*.

46. Butyric acid is responsible for the odor in rancid butter. A solution of 0.25 *M* butyric acid has a pH of 2.71. What is the K_a for the acid?
A) 0.36
B) 2.4×10^{-2}
C) 7.8×10^{-3}
D) 1.5×10^{-5}
E) none of the above

47. A 0.050 *M* solution of the weak acid HA has $[H_3O^+] = 3.77 \times 10^{-4}$ *M*. What is the K_a for the acid?
A) 7.5×10^{-3} *M*
B) 2.8×10^{-6} *M*
C) 7.0×10^{-7} *M*
D) 7.0×10^{-8} *M*
E) 2.6×10^{-11} *M*

48. Formic acid, which is a component of insect venom, has a $K_a = 1.8 \times 10^{-4}$. What is the $[H_3O^+]$ in a solution that is initially 0.10 *M* formic acid, HCOOH?
A) 4.2×10^{-3} *M*
B) 8.4×10^{-3} *M*
C) 1.8×10^{-4} *M*
D) 1.8×10^{-5} *M*
E) 1.8×10^{-6} *M*

49. What is the pH of a 0.0100 *M* sodium benzoate solution? K_b ($C_7H_5O_2^-$) = 1.5×10^{-10}
A) 0.38
B) 5.91
C) 8.09
D) 9.82
E) 13.62

50. A solution is prepared by adding 0.10 mol of sodium fluoride, NaF, to 1.00 L of water. Which statement about the solution is correct?
A) The solution is basic.
B) The solution is neutral.
C) The solution is acidic.
D) The concentrations of fluoride ions and sodium ions will be identical.
E) The concentration of fluoride ions will be greater than the concentration of sodium ions.

51. A solution is prepared by adding 0.10 mol of sodium sulfide, Na_2S, to 1.00 L of water. Which statement about the solution is correct?
A) The solution is basic.
B) The solution is neutral.
C) The solution is acidic.
D) The concentration of sodium ions and sulfide ions will be identical.
E) The concentration of sulfide ions will be greater than the concentration of sodium ions.

52. Ammonium chloride is used as an electrolyte in dry cells. Which of the following statements about a 0.10 *M* solution of NH_4Cl, is correct?
A) The solution is weakly basic.
B) The solution is strongly basic.
C) The solution is neutral.
D) The solution is acidic.
E) The values for K_a and K_b for the species in solution must be known before a prediction can be made.

53. Which of the following aqueous mixtures would be a buffer system?
A) HCl, NaCl
B) HNO_3, $NaNO_3$
C) H_3PO_4, $H_2PO_4^-$
D) H_2SO_4, CH_3COOH
E) NH_3, NaOH

54. Equal volumes of the following pairs of solutions are mixed. Which pair will produce a buffer solution?
A) 0.10 mol L^{-1} HCl and 0.05 mol L^{-1} NaOH
B) 0.10 mol L^{-1} HCl and 0.15 mol L^{-1} NH_3
C) 0.10 mol L^{-1} HCl and 0.05 mol L^{-1} NH_3
D) 0.10 mol L^{-1} HCl and 0.20 mol L^{-1} CH_3COOH
E) 0.10 mol L^{-1} HCl and 0.20 mol L^{-1} NaCl

55. Citric acid has an acid dissociation constant of 8.4×10^{-4}. It would be most effective for preparation of a buffer with a pH of
A) 2.
B) 3.
C) 4.
D) 5.
E) 6.

56. A phosphate buffer ($H_2PO_4^-/HPO_4^{2-}$) has a pH of 8.3. Which of the following changes will cause the pH to increase?
A) dissolving a small amount of Na_2HPO_4
B) dissolving a small amount of NaH_2PO_4
C) adding a small amount of dilute hydrochloric acid
D) adding a small amount of dilute phosphoric acid
E) making the buffer more concentrated by removing some water

57. What is the pH of a solution that consists of 0.50 *M* $H_2C_6H_6O_6$ (ascorbic acid) and 0.75 *M* $NaHC_6H_6O_6$ (sodium ascorbate)? For ascorbic acid, $K_a = 6.8 \times 10^{-5}$
A) 3.76
B) 3.99
C) 4.34
D) 4.57
E) 5.66

58. What is the pH of a buffer that consists of 0.20 *M* NaH_2PO_4 and 0.40 *M* Na_2HPO_4? For NaH_2PO_4, $K_a = 6.2 \times 10^{-8}$
A) 6.51
B) 6.91
C) 7.51
D) 7.90
E) 8.13

59. What is the $[H_3O^+]$ in a buffer that consists of 0.30 *M* HCOOH and 0.20 *M* HCOONa? For HCOOH, $K_a = 1.7 \times 10^{-4}$

A) $1.1 \times 10^{-4}\ M$
B) $2.6 \times 10^{-4}\ M$
C) $4.3 \times 10^{-4}\ M$
D) $6.7 \times 10^{-5}\ M$
E) none of the above

60. What is the $[H_3O^+]$ in a solution that consists of 1.2 *M* HClO and 2.3 *M* NaClO? $K_a = 3.5 \times 10^{-8}$

A) $7.8 \times 10^{-9}\ M$
B) $1.8 \times 10^{-8}\ M$
C) $6.7 \times 10^{-8}\ M$
D) $1.6 \times 10^{-7}\ M$
E) none of the above

61. What is the $[H_3O^+]$ in a solution that consists of 1.5 *M* NH_3 and 2.5 NH_4Cl? $K_b = 1.8 \times 10^{-5}$

A) $1.1 \times 10^{-5}\ M$
B) $3.0 \times 10^{-6}\ M$
C) $3.3 \times 10^{-9}\ M$
D) $9.3 \times 10^{-10}\ M$
E) none of the above

62. A formic acid buffer containing 0.50 *M* HCOOH and 0.50 *M* HCOONa has a pH of 3.77. What will the pH be after 0.010 mol of NaOH has been added to 100.0 mL of the buffer?

A) 3.67
B) 3.78
C) 3.81
D) 3.85
E) 3.95

63. An acetic acid buffer containing 0.50 *M* CH_3COOH and 0.50 *M* CH_3COONa has a pH of 4.74. What will the pH be after 0.0020 mol of HCl has been added to 100.0 mL of the buffer?
A) 4.77
B) 4.71
C) 4.68
D) 4.62
E) none of the above

64. A buffer is prepared by adding 1.00 L of 1.0 *M* HCl to 750 mL of 1.5 *M* NaHCOO. What is the pH of this buffer? $K_a = 1.7 \times 10^{-4}$
A) 2.87
B) 3.72
C) 3.82
D) 3.95
E) 4.66

65. If 10.0 g of NaF and 20.0 g of HF are dissolved in water to make one liter of solution, what will the pH be? For HF, $K_a = 6.8 \times 10^{-4}$.
A) 7.13
B) 2.54
C) 1.57
D) 3.17
E) 4.86

66. A change in pH will significantly affect the solubility of which, if any, of the following compounds?
A) BaF_2
B) CuCl
C) CuBr
D) AgI
E) None of the solubilities will be significantly affected.

67. The solubility of aluminum hydroxide in water _____ when dilute nitric acid is added to it.
A) increases
B) decreases
C) does not change
D) first increases, then decreases
E) first decreases, then increases

68. A saturated solution of calcium hydroxide, $Ca(OH)_2$, is in contact with excess solid $Ca(OH)_2$. Which of the following statements correctly describes what will happen when aqueous HCl (a strong acid) is added to this mixture, and system returns to equilibrium? (For $Ca(OH)_2$, $K_{sp} = 6.5 \times 10^{-6}$))
A) The solubility of $Ca(OH)_2$ will be unchanged.
B) The OH^- concentration will decrease and the Ca^{2+} concentration will increase.
C) The OH^- concentration will increase and the Ca^{2+} concentration will decrease.
D) The concentrations of both Ca^{2+} and OH^- will increase.
E) The solubility of $Ca(OH)_2$ will decrease.

69. Write the ion product expression for magnesium fluoride, MgF_2.
A) $[Mg^{2+}][F^-]$
B) $[Mg^{2+}][F^-]^2$
C) $\dfrac{[Mg^{2+}][F^-]^2}{[MgF_2(s)]}$
D) $\dfrac{1}{[Mg^{2+}][F^-]}$
E) $\dfrac{1}{[Mg^{2+}][F^-]^2}$

70. The solubility of lead(II) chloride is 0.45 g/100 mL of solution. What is the K_{sp} of $PbCl_2$?
A) 4.9×10^{-2}
B) 1.7×10^{-5}
C) 8.5×10^{-6}
D) 4.2×10^{-6}
E) $< 1.0 \times 10^{-6}$

71. The solubility of calcium chromate is 1.56×10^{-3} g/100 mL of solution. What is the K_{sp} for $CaCrO_4$?
A) 2.4×10^{-4}
B) 1.5×10^{-5}
C) 7.6×10^{-6}
D) 1.0×10^{-8}
E) $< 1.0 \times 10^{-8}$

72. The solubility of magnesium phosphate is 2.27×10^{-3} g/1.0 L of solution. What is the K_{sp} for $Mg_3(PO_4)_2$?
A) 6.5×10^{-12}
B) 6.0×10^{-14}
C) 5.2×10^{-24}
D) 4.8×10^{-26}
E) 1.0×10^{-26}

73. Calculate the solubility of barium carbonate, $BaCO_3$, in pure water. $K_{sp} = 2.0 \times 10^{-9}$
A) $1.3 \times 10^{-3}\ M$
B) $3.2 \times 10^{-5}\ M$
C) $2.2 \times 10^{-5}\ M$
D) $4.5 \times 10^{-5}\ M$
E) $4.0 \times 10^{-18}\ M$

74. Barium sulfate ($BaSO_4$) is a slightly soluble salt, with $K_{sp} = 1.1 \times 10^{-10}$. What mass of Ba^{2+} ions will be present in 1.0 L of a saturated solution of barium sulfate?
A) $< 10^{-7}$ g
B) 1.0×10^{-5} g
C) 0.0014 g
D) 0.0024 g
E) > 0.05 g

75. Calculate the solubility of lead(II) iodide, PbI_2, in 0.025 M KI. $K_{sp} = 7.9 \times 10^{-9}$
A) $4.5 \times 10^{-2}\ M$
B) $2.8 \times 10^{-2}\ M$
C) $8.9 \times 10^{-5}\ M$
D) $5.0 \times 10^{-5}\ M$
E) $1.3 \times 10^{-5}\ M$

76. A lab technician adds 0.20 mol of NaF to 1.00 L of 0.35 M cadmium nitrate, $Cd(NO_3)_2$. Which of the following statements is correct? $K_{sp} = 6.44 \times 10^{-3}$ for CdF_2.
A) Cadmium fluoride precipitates until the solution is saturated.
B) The solution is unsaturated and no precipitate forms.
C) The solubility of cadmium fluoride is increased by the presence of additional fluoride ions.
D) One must know K_{sp} for cadmium nitrate to make meaningful predictions on this system.
E) The presence of NaF will raise the solubility of $Cd(NO_3)_2$.

77. A lab technician adds 0.015 mol of KOH to 1.00 L of 0.0010 *M* $Ca(NO_3)_2$. $K_{sp} = 6.5 \times 10^{-6}$ for $Ca(OH)_2$). Which of the following statements is correct?
A) Calcium hydroxide precipitates until the solution is saturated.
B) The solution is unsaturated and no precipitate forms.
C) The concentration of calcium ions is reduced by the addition of the hydroxide ions.
D) One must know K_{sp} for calcium nitrate to make meaningful predictions on this system.
E) The presence of KOH will raise the solubility of $Ca(NO_3)_2$.

78. What is the maximum amount of sodium sulfate that can be added to 1.00 L of 0.0020 *M* $Ca(NO_3)_2$ before precipitation of calcium sulfate begins? $K_{sp} = 2.4 \times 10^{-5}$ for calcium sulfate.
A) 1.2×10^{-2} mol
B) 4.9×10^{-3} mol
C) 3.5×10^{-3} mol
D) 1.2×10^{-5} mol
E) 4.8×10^{-8} mol

79. Calculate the solubility of zinc hydroxide, $Zn(OH)_2$, in 1.00 *M* NaOH.
$K_{sp} = 3.0 \times 10^{-16}$ for $Zn(OH)_2$, $K_f = 3.0 \times 10^{15}$ for $Zn(OH)_4^{2-}$
A) 0.60 *M*
B) 0.52 *M*
C) 0.37 *M*
D) 0.32 *M*
E) 0.24 *M*

80. A solution is prepared by mixing 50.0 mL of 0.50 *M* $Cu(NO_3)_2$ with 50.0 mL of 0.50 *M* $Co(NO_3)_2$. Sodium hydroxide is added to the mixture. Which hydroxide precipitates first and what concentration of hydroxide ions present in solution will accomplish the separation?
$K_{sp} = 2.2 \times 10^{-20}$ for $Cu(OH)_2$, $K_{sp} = 1.3 \times 10^{-15}$ for $Co(OH)_2$
A) $Co(OH)_2$; $[OH^-] = 6.9 \times 10^{-6}$ *M*
B) $Co(OH)_2$; $[OH^-] = 2.6 \times 10^{-7}$ *M*
C) $Cu(OH)_2$; $[OH^-] = 1.8 \times 10^{-7}$ *M*
D) $Cu(OH)_2$; $[OH^-] = 1.1 \times 10^{-9}$ *M*
E) $Cu(OH)_2$; $[OH^-] = 1.0 \times 10^{-17}$ *M*

81. Which of the following is necessary for a process to be spontaneous?

A) $\Delta H_{sys} < 0$
B) $\Delta S_{sys} > 0$
C) $\Delta S_{surr} < 0$
D) $\Delta S_{univ} > 0$
E) $\Delta G_{sys} = 0$

82. Calculate $\Delta S°$ for the reaction

$$4Cr(s) + 3O_2(g) \rightarrow 2Cr_2O_3(s)$$

Substance:	$Cr(s)$	$O_2(g)$	$Cr_2O_3(s)$
$S°$(J/K·mol):	23.77	205.138	81.2

A) –548.1 J/K
B) –147.7 J/K
C) 147.7 J/K
D) 310.1 J/K
E) 548.1 J/K

83. Calculate $\Delta S°$ for the combustion of propane.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

Substance:	$C_3H_8(g)$	$O_2(g)$	$CO_2(g)$	$H_2O(g)$
$S°$(J/K·mol):	269.9	205.138	213.74	188.825

A) –100.9 J/K
B) –72.5 J/K
C) 72.5 J/K
D) 100.9 J/K
E) 877.5 J/K

84. Calculate $\Delta G°$ for the reaction

$$SiCl_4(g) + 2Mg(s) \rightarrow 2MgCl_2(s) + Si(s)$$

Substance:	$SiCl_4(g)$	$Mg(s)$	$MgCl_2(s)$	$Si(s)$
$\Delta G°_f$ (kJ/mol):	–616.98	0	–591.79	0

A) 566.60 kJ
B) 50.38 kJ
C) 25.19 kJ
D) –25.19 kJ
E) –566.60 kJ

85. Calculate $\Delta G°$ for the combustion of propane.

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

Substance:	$C_3H_8(g)$	$O_2(g)$	$CO_2(g)$	$H_2O(g)$
$\Delta G°_f$ (kJ/mol):	–24.5	0	–394.4	–228.6

A) –2073.1 kJ
B) –1387.3 kJ
C) –598.5 kJ
D) 598.5 kJ
E) 2073.1 kJ

86. Use the given data at 298 K to calculate $\Delta G°$ for the reaction

$2Cl_2(g) + SO_2(g) \rightarrow SOCl_2(g) + Cl_2O(g)$

Substance:	$Cl_2(g)$	$SO_2(g)$	$SOCl_2(g)$	$Cl_2O(g)$
$\Delta H°_f$ (kJ/mol):	0	–296.8	–212.5	80.3
$S°$(J/K·mol):	223.0	248.1	309.77	266.1

A) 129.3 kJ
B) 133.6 kJ
C) 196.0 kJ
D) 199.8 kJ
E) 229.6 kJ

87. Calculate the equilibrium constant at 25°C for the reaction of methane with water to form carbon dioxide and hydrogen. The data refer to 25°C.

$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$

Substance:	$CH_4(g)$	$H_2O(g)$	$CO_2(g)$	$H_2(g)$
$\Delta H°_f$ (kJ/mol):	–74.87	–241.8	–393.5	0
$\Delta G°_f$ (kJ/mol):	–50.81	–228.6	–394.4	0
$S°$(J/K·mol):	186.1	188.8	213.7	130.7

A) 8.2×10^{19}
B) 0.96
C) 0.58
D) 1.2×10^{-20}
E) 1.4×10^{-46}

88. Use the thermodynamic data at 298 K below to determine the K_{sp} for barium carbonate, $BaCO_3$ at this temperature.

Substance:	$Ba^{2+}(aq)$	$CO_3^{2-}(aq)$	$BaCO_3(s)$
$\Delta H°_f$ (kJ/mol):	–538.36	–676.26	–1219
$\Delta G°_f$ (kJ/mol):	–560.7	–528.1	–1139
$S°$(J/K·mol):	13	–53.1	112

A) 5.86
B) 6.30×10^{8}
C) 1.59×10^{-9}
D) 5.47×10^{-21}
E) 2.18×10^{-27}

89. What is the free energy change, $\Delta G°$, for the equilibrium between hydrogen iodide, hydrogen, and iodine at 453°C? $K_c = 0.020$

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

A) 6.4 kJ
B) 8.8 kJ
C) 15 kJ
D) 19 kJ
E) 24 kJ

90. Which one of the following relationships is always correct?
A) potential energy + kinetic energy = constant
B) $E = q + w$
C) $\Delta E = \Delta H - P\Delta V$
D) $H = E + PV$
E) $\Delta H = q_v$

91. Cold packs, whose temperatures are lowered when ammonium nitrate dissolves in water, are carried by athletic trainers when transporting ice is not possible. Which of the following is true of this reaction?
A) $\Delta H < 0$, process is exothermic
B) $\Delta H > 0$, process is exothermic
C) $\Delta H < 0$, process is endothermic
D) $\Delta H > 0$, process is endothermic
E) $\Delta H = 0$, since cold packs are sealed

92. Your favorite candy bar, Gummy Beakers, contains 1.2×10^6 J of energy while your favorite soft drink, Bolt, contains 6.7×10^5 J. If you eat two packs of Gummy Beakers a day and drink 3 cans of Bolt, what percent of your 2000 Calorie daily food intake is left for broccoli, beans, beef, etc.?

A) 53%
B) 47%
C) 27%
D) 11%
E) 0%

93. Calculate q when 28.6 g of water is heated from 22.0°C to 78.3°C.

A) 0.385 kJ
B) 1.61 kJ
C) 6.74 kJ
D) 9.37 kJ
E) 1.61×10^3 kJ

94. Calculate the $\Delta H°_{rxn}$ for the decomposition of calcium carbonate to calcium oxide and carbon dioxide. $\Delta H°_f$ [$CaCO_3(s)$] = –1206.9 kJ/mol; $\Delta H°_f$ [$CaO(s)$] = –635.1 kJ/mol; $\Delta H°_f$ [$CO_2(g)$] = –393.5 kJ/mol

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

A) –2235.5 kJ
B) –1448.5 kJ
C) –178.3 kJ
D) 178.3 kJ
E) 2235.5 kJ

95. Calculate the $\Delta H°_{rxn}$ for the following reaction. ($\Delta H°_f$ [$SiO_2(s)$] = –910.9 kJ/mol; $\Delta H°_f$ [$SiCl_4(g)$] = –657.0 kJ/mol; $\Delta H°_f$ [$HCl(g)$] = –92.3 kJ/mol; $\Delta H°_f$ [$H_2O\ (g)$] = –241.8 kJ/mol)

$SiO_2(s) + 4HCl(g) \rightarrow SiCl_4(g) + 2H_2O(g)$

A) –139.5 kJ
B) –137.4 kJ
C) –104.4 kJ
D) 104.4 kJ
E) 139.5 kJ

96. Calculate the $\Delta H°_{rxn}$ for the following reaction. ($\Delta H°_f$ [$AsH_3(g)$] = 66.4 kJ/mol; $\Delta H°_f$ [$H_3AsO_4(aq)$] = –904.6 kJ/mol; $\Delta H°_f$ [$H_2O(l)$] = –285.8 kJ/mol)

$$H_3AsO_4(aq) + 4H_2(g) \rightarrow AsH_3(g) + 4H_2O(l)$$

A) –1981.4 kJ
B) –685.2 kJ
C) –172.2 kJ
D) 172.2 kJ
E) 685.2 kJ

97. Use Hess's Law to calculate the enthalpy change for the reaction

$$WO_3(s) + 3H_2(g) \rightarrow W(s) + 3H_2O(g)$$

from the following data:

$$2W(s) + 3O_2(g) \rightarrow 2WO_3(s) \quad \Delta H = -1685.4 \text{ kJ}$$
$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) \quad \Delta H = -477.84 \text{ kJ}$$

A) 125.9 kJ
B) 252.9 kJ
C) 364.9 kJ
D) 1207.6 kJ
E) none of the above

98. Calculate the enthalpy change for the reaction

$$NO(g) + O(g) \rightarrow NO_2(g)$$

from the following data:

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g) \quad \Delta H = -198.9 \text{ kJ}$$
$$O_3(g) \rightarrow 1.5O_2(g) \quad \Delta H = -142.3 \text{ kJ}$$
$$O_2(g) \rightarrow 2O(g) \quad \Delta H = 495.0 \text{ kJ}$$

A) –551.6 kJ
B) –304.1 kJ
C) 190.9 kJ
D) 153.8 kJ
E) 438.4 kJ

99. Use the following data to calculate the standard heat (enthalpy) of formation, $\Delta H°_f$, of manganese(IV) oxide, MnO_2 (*s*).

$$2MnO_2(s) \rightarrow 2MnO(s) + O_2(g) \quad \Delta H = 264 \text{ kJ}$$
$$MnO_2(s) + Mn(s) \rightarrow 2MnO(s) \quad \Delta H = -240 \text{ kJ}$$

A) –504 kJ
B) –372 kJ
C) –24 kJ
D) 24 kJ
E) 504 kJ

100. Consider the reaction

$$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)$$

In this reaction, which substances are the oxidant and reductant, respectively?

A) CuO and H_2
B) H_2 and CuO
C) CuO and Cu
D) H_2O and H_2
E) none of the above

101. Which of the following statements about voltaic and electrolytic cells is correct?

A) The electrons in the external wire flow from cathode to anode in both types of cell.
B) Oxidation occurs at the cathode only in a voltaic cell.
C) The free energy change, ΔG, is negative for an electrolytic cell.
D) The cathode is labeled as positive (+) in a voltaic cell but negative (–) in an electrolytic cell.
E) Reduction occurs at the anode in an electrolytic cell.

102. Which of the following statements about voltaic and electrolytic cells is correct?

A) The anode will definitely gain weight in a voltaic cell.
B) Oxidation occurs at the cathode of both cells.
C) The free energy change, ΔG, is negative for the voltaic cell.
D) The electrons in the external wire flow from cathode to anode in an electrolytic cell.
E) None of the above statements is correct.

103. A voltaic cell is prepared using copper and silver. Its cell notation is shown below.

$$Cu(s) \mid Cu^{2+}(aq) \parallel Ag^{+}(aq) \mid Ag(s)$$

Which of the following processes occurs at the cathode?

A) $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
B) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
C) $Ag(s) \rightarrow Ag^{+}(aq) + e^-$
D) $Ag^{+}(aq) + e^- \rightarrow Ag(s)$
E) $Cu(s) + 2Ag^{+}(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$

104. A voltaic cell prepared using aluminum and nickel has the following cell notation.

$Al(s) \mid Al^{3+}(aq) \parallel Ni^{2+}(aq) \mid Ni(s)$

Which of the following represents the correctly balanced spontaneous reaction equation for the cell?

A) $Ni^{2+}(aq) + Al(s) \rightarrow Al^{3+}(aq) + Ni(s)$
B) $3Ni^{2+}(aq) + 2Al(s) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$
C) $Ni(s) + Al^{3+}(aq) \rightarrow Ni^{2+}(aq) + Al(s)$
D) $3Ni(s) + 2Al^{3+}(aq) \rightarrow 3Ni^{2+}(aq) + 2Al(s)$
E) none of the above

105. What is the $E°_{cell}$ for the cell represented by the combination of the following half-reactions?

$2Hg^{2+}(aq) + 2e^- \rightleftharpoons Hg_2^{2+}(aq) \quad E° = 0.92\ V$
$Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s) \quad E° = -0.74\ V$

A) –0.18 V
B) 0.18 V
C) 1.28 V
D) 1.66 V
E) 2.12 V

106. What is the $E°_{cell}$ for the cell represented by the combination of the following half-reactions?

$ClO_4^-(aq) + 8H^+(aq) + 8e^- \rightleftharpoons Cl^-(aq) + 4H_2O(l) \quad E° = 1.389\ V$
$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^+(aq) + H_2O(l) \quad E° = 0.991\ V$

A) –0.398 V
B) –2.380 V
C) 0.398 V
D) 2.380 V
E) none of the above

107. The voltaic cell made up of cobalt, copper, and their M^{2+} ions, has $E°_{cell} = 0.62$ V. If $E°$ of the cathode half-cell is 0.34 V, what is $E°$ of the anode half-cell?

$Cu^{2+}(aq) + Co(s) \rightarrow Cu(s) + Co^{2+}(aq)$

A) –0.28 V
B) –0.96 V
C) 0.28 V
D) 0.96 V
E) none of the above

108. Examine the following half-reactions and select the strongest oxidizing agent among the species listed.

$Cr^{2+}(aq) + 2e^- \rightleftharpoons Cr(s)$ $E° = -0.913$ V
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$ $E° = -0.447$ V
$Sr^{2+}(aq) + 2e^- \rightleftharpoons Sr(s)$ $E° = -2.89$ V
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$ $E° = -0.28$ V

A) $Cr^{2+}(aq)$
B) $Fe(s)$
C) $Fe^{2+}(aq)$
D) $Sr^{2+}(aq)$
E) $Co^{2+}(aq)$

109. Examine the following half-reactions and select the strongest reducing agent among the species listed.

$PbI_2(s) + 2e^- \rightleftharpoons Pb(s) + 2I^-(aq)$ $E° = -0.365$ V
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$ $E° = -2.868$ V
$Pt^{2+}(aq) + 2e^- \rightleftharpoons Pt(s)$ $E° = 1.18$ V
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$ $E° = 1.066$ V

A) $Pb(s)$
B) $Ca(s)$
C) $Pt(s)$
D) $Br^-(aq)$
E) $Pt^{2+}(aq)$

110. Calculate $E°_{cell}$ and indicate whether the overall reaction shown is spontaneous or nonspontaneous.

$Co^{3+}(aq) + e^- \rightleftharpoons Co^{2+}(aq)$ $E° = 1.82$ V
$MnO_4^-(aq) + 2H_2O(l) + 3e^- \rightleftharpoons MnO_2(s) + 4OH^-(aq)$ $E° = 0.59$ V

Overall reaction:

$MnO_4^-(aq) + 2H_2O(l) + 3Co^{2+}(aq) \rightarrow MnO_2(s) + 3Co^{3+}(aq) + 4OH^-(aq)$

A) $E°_{cell} = -1.23$ V, spontaneous
B) $E°_{cell} = -1.23$ V, nonspontaneous
C) $E°_{cell} = 1.23$ V, spontaneous
D) $E°_{cell} = 1.23$ V, nonspontaneous
E) $E°_{cell} = -0.05$ V, nonspontaneous

111. What is the value of the equilibrium constant for the cell reaction below at 25°C? $E°_{cell}$ = 0.30 V

$$Sn^{2+}(aq) + Fe(s) \rightleftharpoons Sn(s) + Fe^{2+}(aq)$$

A) 1.2×10^{5}
B) 1.4×10^{10}
C) 8.6×10^{-6}
D) 7.1×10^{-11}
E) 2.3×10^{23}

112. What is the value of the equilibrium constant for the cell reaction below at 25°C? $E°_{cell}$ = 0.61 V

$$2Cr(s) + 3Pb^{2+}(aq) \rightleftharpoons 3Pb(s) + 2Cr^{3+}(aq)$$

A) 4.1×10^{20}
B) 8.2×10^{30}
C) 3.3×10^{51}
D) 7.4×10^{61}
E) $> 9.9 \times 10^{99}$

113. The value of the equilibrium constant for the reaction of nickel(II) ions with cadmium metal is 1.17×10^{5}. Calculate $\Delta G°$ for the reaction at 25°C.
A) –12.6 kJ
B) –28.9 kJ
C) 12.6 kJ
D) 28.9 kJ
E) none of the above

114. A voltaic cell consists of a Ag/Ag^{+} electrode ($E°$ = 0.80 V) and a Fe^{2+}/Fe^{3+} electrode ($E°$ = 0.77 V) with the following initial molar concentrations: $[Fe^{2+}]$ = 0.30 *M*; $[Fe^{3+}]$ = 0.10 *M*; $[Ag^{+}]$ = 0.30 *M*. What is the equilibrium concentration of Fe^{3+}? (Assume the anode and cathode solutions are of equal volume, and a temperature of 25°C.)
A) 0.030 *M*
B) 0.043 *M*
C) 0.085 *M*
D) 0.11 *M*
E) 0.17 *M*

115. A current of 250. A flows for 24.0 hours at an anode where the reaction occurring is

$$Mn^{2+}(aq) + 2H_2O(l) \rightarrow MnO_2(s) + 4H^+(aq) + 2e^-$$

What mass of MnO_2 is deposited at this anode?

A) 19.5 kg
B) 12.9 kg
C) 4.87 kg
D) 2.43 kg
E) none of the above

116. Chromium metal is electroplated from acidic aqueous solutions containing the dichromate ion, $Cr_2O_7^{2-}$. What is the minimum time needed to plate out 10.0 g of chromium metal from such a solution, if the current is 50.0 A?

A) 6.2 minutes
B) 12.4 minutes
C) 18.6 minutes
D) 24.7 minute
E) 37.1 minutes

117. A solution is prepared by dissolving 32.0 g of $NiSO_4$ in water. What current would be needed to deposit all of the nickel in 5.0 hours?

A) 1.1 A
B) 2.2 A
C) 3.3 A
D) 4.4 A
E) 5.5 A

118. What mass of silver will be formed when 15.0 A are passed through molten AgCl for 25.0 minutes?

A) 0.419 g
B) 6.29 g
C) 12.6 g
D) 25.2 g
E) 33.4 g

119. A characteristic of ligands is that

A) they are Lewis acids.
B) they are Lewis bases.
C) they are ions.
D) they are electron pair acceptors.
E) they are Brønsted-Lowry acids.

120. In the formation of a transition metal complex, the central metal atom or ion acts as
A) an Arrhenius acid.
B) a Bronsted-Lowry acid.
C) a Bronsted-Lowry base.
D) a Lewis acid.
E) a Lewis base.

121. The oxidation and coordination numbers of cobalt in the compound $[Co(NH_3)_5Cl]Cl_2$ are, respectively:
A) 2 and 6.
B) 2 and 8.
C) 3 and 6.
D) 3 and 8.
E) none of the above

122. Give the systematic name for $[Cu(NH_3)_4]Cl_2$.
A) dichlorotetraamminecuprate(II)
B) tetraamminecopper(II) chloride
C) copper(II) ammonium chloride
D) tetraaminocopper(II) chloride
E) none of the above

123. The compound $K_3[Fe(CN)_6]$ is used in calico printing and wool dyeing. Give its systematic name.
A) potassium iron(III) hexacyanate
B) tripotassium iron(III) hexacyanate
C) potassium hexacyanoferrate(III)
D) potassium hexacyanideferrate
E) none of the above

124. Give the systematic name for $Cr(CO)_3(NH_3)_3$.
A) chromiumtriaminotricarbonyl
B) triamminechromium carbonate
C) triamminetricarbonylchromate(0)
D) triamminetricarbonylchromium(0)
E) none of the above

125. Give the systematic name for $[CoCl_3(H_2O)]^-$.
A) cobalt(II) chloride monohydrate
B) aquatrichlorocobalt(II)
C) aquatrichlorocobaltate(II)
D) aquatrichlorocobaltite(I)
E) none of the above

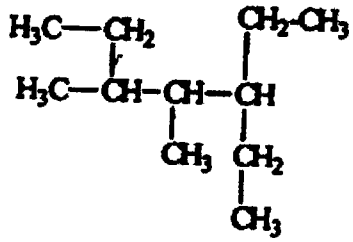
126. Which of the following ligands could participate in linkage isomerism?
A) NH_3
B) H_2O
C) NH_4^+
D) NO_2^-
E) ethylenediamine

127. Write the formula for sodium tetracyanonickelate(II).
A) $Na[Ni(CN)_4]$
B) $Na[Ni(CN)_4]_2$
C) $Na_2[Ni(CN)_4]$
D) $Na_4[Ni(CN)_4]$
E) none of the above

128. In the compound $K[Co(C_2O_4)_2(H_2O)_2]$ (where $C_2O_4^{2-}$ = oxalate) the oxidation number and coordination number of cobalt are, respectively:
A) –1 and 4.
B) –1 and 6.
C) 3 and 4.
D) 3 and 6.
E) 1 and 6.

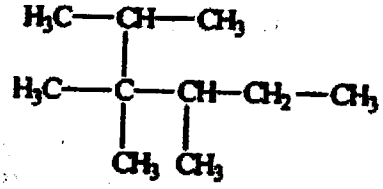
129. In the compound $[Ni(en)_2(H_2O)_2]SO_4$ (where en = ethylenediamine) the oxidation number and coordination number of nickel are, respectively:
A) 2 and 6.
B) 4 and 6.
C) 6 and 6.
D) 2 and 4.
E) 4 and 4.

130. Select the correct name for the following compound.



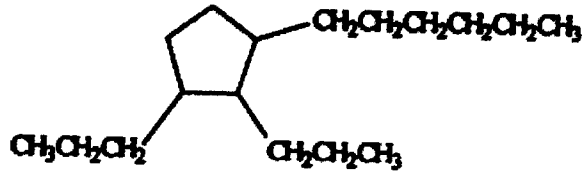
A) 1,1,3-triethyl-2-methylbutane
B) 1,1-diethyl-2,3-dimethylpentane
C) 2,4-diethyl-3-methylhexane
D) 3-ethyl-4,5-dimethylheptane
E) none of the above

131. Select the correct name for the following compound.



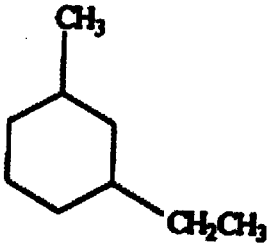
A) 2-isopropyl-2,3,4-trimethylbutane
B) 2-isopropyl-2,3-dimethylpentane
C) 2,3,3,4-tetramethylhexane
D) 1,1,2,2,3-pentamethylpentane
E) none of the above

132. Select the correct name for the following compound.



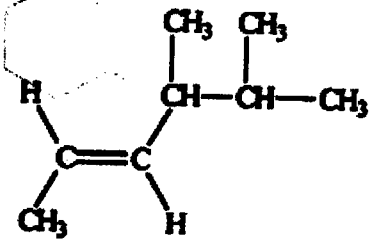
A) *ortho*-dipropylcyclopentylhexane
B) 2,3-dipropylcyclopentylhexane
C) 2-hexyl-1,5-dipropylcyclopentane
D) 1-hexyl-2,3-dipropylcyclopentane
E) 1,2-dipropyl-3-hexylcyclopentane

133. Select the correct name for the following compound.



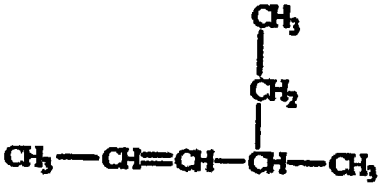
A) 1-ethyl-3-methylcyclohexane
B) 1-methyl-5-ethylcyclohexane
C) *meta*-ethylmethylcyclohexane
D) *meta*-ethylmethylbenzene
E) 3-ethyltoluene

134. Select the correct name for the following compound.



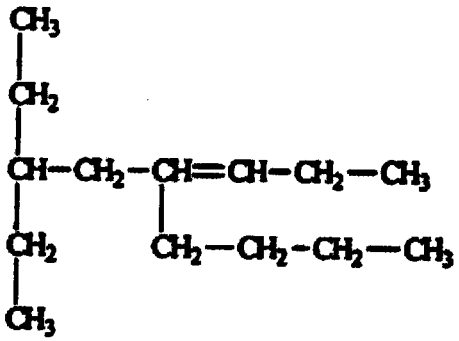
A) *cis*-2,3-dimethyl-4-hexene
B) *trans*-2,3-dimethyl-4-hexene
C) *cis*-4,5-dimethyl-2-hexene
D) *trans*-4,5-dimethyl-2-hexene
E) *trans*-4,5-dimethyl-2-heptene

135. Select the correct name for the following compound.



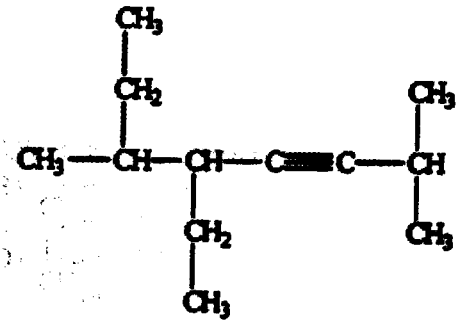
A) 2-ethyl-3-pentene
B) 4-ethyl-2-pentene
C) 3-methyl-4-hexene
D) 4-methyl-2-hexene
E) none of the above

136. Select the correct name for the following compound.



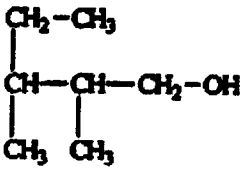
A) 1,1-diethyl-3-butyl-3-hexene
B) 5-butyl-3-ethyl-5-octene
C) 4-butyl-6-ethyl-3-octene
D) 3-ethyl-5-propyl-5-nonene
E) 4-butyl-6-ethyl-3,4-octene

137. Select the correct name for the following compound.



A) 4-ethyl-1,1,5-trimethyl-2-heptyne
B) 4,5-diethyl-1,1-dimethyl-2-heptyne
C) 5-ethyl-2,6-dimethyl-3-octene
D) 3-ethyl-3,7-dimethyl-5-octyne
E) 5-ethyl-2,6-dimethyl-3-octyne

138. Select the correct name for the following compound.



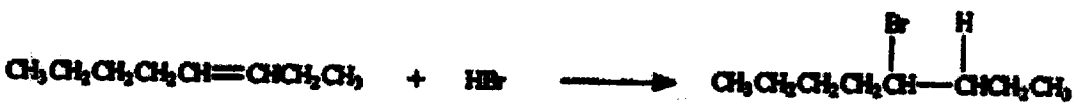
A) 3-ethyl-2,3-dimethyl-1-propanol
B) 2,3,4-trimethyl-1-butanol
C) 2,3-dimethyl-1-pentanol
D) 3,4-dimethyl-5-pentanol
E) 2,3-dimethyl-1-pentanal

139. Select the correct type for the following reaction.

$CH_3CH_2CH_2CH_2OH + HBr \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$

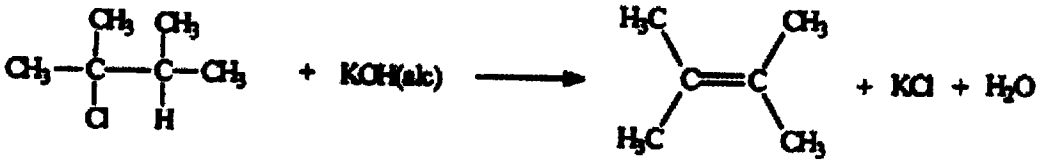
A) dehydration
B) dehydroxylation
C) addition
D) elimination
E) substitution

140. Select the correct reaction type for the following process.



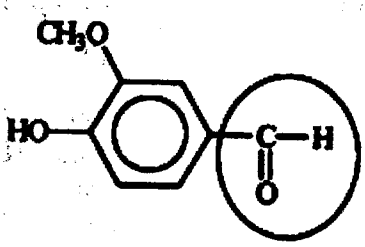
A) addition
B) elimination
C) substitution
D) oxidation
E) reduction

141. 2-chloro-2,3-dimethylbutane will react with potassium hydroxide dissolved in alcohol to produce 2,3-dimethyl-2-butene. What type of reaction is this?



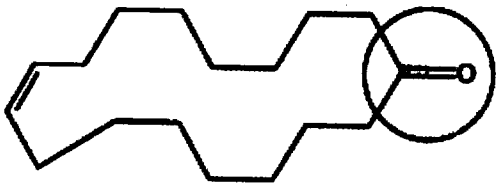
A) addition
B) elimination
C) substitution
D) oxidation
E) displacement

142. Vanillin is a flavoring agent which occurs naturally in the vanilla bean, the seed of an orchid. Identify the functional group circled.



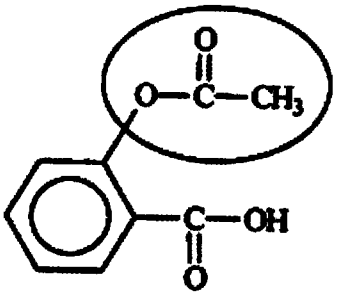
A) aldehyde
B) ketone
C) alcohol
D) carboxylic acid
E) carbonyl

143. One source of a musky odor in perfumes is civetone, a compound extracted from the scent gland of the civet cat. Identify the functional group circled.



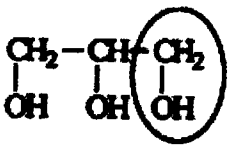
A) aldehyde
B) ketone
C) alcohol
D) carboxylic acid
E) oxide

144. Aspirin is an effective and widely used pain reliever. Identify the functional group circled.



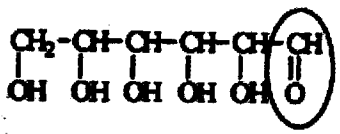
A) aldehyde
B) ketone
C) ester
D) carboxylic acid
E) carbonyl

145. Glycerin is used in cosmetics as a moisturizer. Identify the functional group circled.



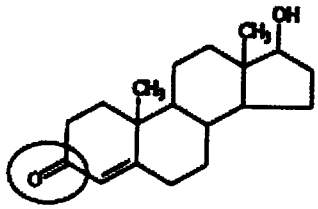
A) carboxylic acid
B) alcohol
C) ester
D) ether
E) aldehyde

146. Glucose is an important sugar in a person's metabolic cycle. Identify the functional group circled.



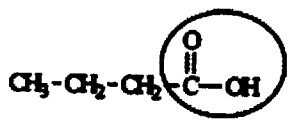
A) aldehyde
B) ketone
C) alcohol
D) ester
E) carboxylic acid

147. Testosterone is a male hormone. Identify the functional group circled.



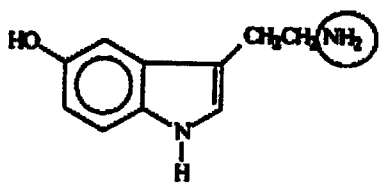
A) aldehyde
B) ketone
C) alcohol
D) ester
E) carboxyl

148. The compound shown below is responsible for the odor in rancid butter. Identify the functional group circled.



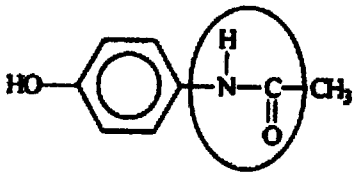
A) aldehyde
B) ketone
C) alcohol
D) carboxylic acid
E) carbonyl

149. Serotonin transmits nerve impulses through the body. Identify the functional group circled.



A) aldehyde
B) alcohol
C) amide
D) amine
E) nitride

150. Acetaminophen is a widely used and an effective pain reliever. Identify the functional group circled.



A) aldehyde
B) alcohol
C) amide
D) amine
B) carbonyl

Answer Key

1. D
2. B
3. E
4. D
5. C
6. C
7. B
8. C
9. E
10. E
11. E
12. E
13. E
14. C
15. A
16. D
17. E
18. B
19. E
20. B
21. C
22. D
23. D
24. B
25. B
26. E
27. B
28. E
29. E
30. A
31. E
32. D
33. D
34. C
35. A
36. B
37. E
38. B
39. A
40. C
41. C
42. E
43. B
44. C

45. E
46. D
47. B
48. A
49. C
50. A
51. A
52. D
53. C
54. B
55. B
56. A
57. C
58. C
59. B
60. B
61. D
62. E
63. B
64. A
65. B
66. A
67. A
68. B
69. B
70. B
71. D
72. C
73. D
74. C
75. E
76. A
77. B
78. A
79. E
80. D
81. D
82. A
83. D
84. E
85. A
86. D
87. D
88. C
89. E
90. D

91. D
92. B
93. C
94. D
95. E
96. C
97. A
98. B
99. A
100. A
101. D
102. C
103. D
104. B
105. D
106. C
107. A
108. E
109. B
110. B
111. B
112. D
113. B
114. E
115. E
116. E
117. B
118. D
119. B
120. D
121. C
122. B
123. C
124. D
125. C
126. D
127. C
128. D
129. A
130. D
131. C
132. D
133. A
134. D
135. D
136. C

137. E
138. C
139. E
140. A
141. B
142. D
143. B
144. C
145. B
146. A
147. B
148. D
149. D
150. C