Challenge Exam
Project Halo

Multiple Choice

Answer all questions. Also, provide a short justification statement for your choice. Points will be given for the correct answer and for the justification.

1 Which of the following compounds will produce a gas when HCl is added to the solid compound? HCl is a strong acid producing a yellow-green colored gas above the acid solution.

(a) $Ba(OH)_2$ (s)
(b) $CaCO_3$ (s)
(c) $CuSO_4$ (s)
(d) Na_3PO_4(s)
(e) NaCl(s)

2. When lithium metal is reacted with nitrogen gas, under proper conditions, the product is:

(a) no reaction occurs
(b) LiN
(c) Li_2N
(d) Li_3N
(e) LiN_3

3. Sodium azide is used in air bags to rapidly produce gas to inflate the bag. The products of the decomposition reaction are:

(a) Na and water.
(b) Ammonia and sodium metal.
(c) N_2 and O_2
(d) Sodium and nitrogen gas.
(e) Sodium oxide and nitrogen gas.

4. When calcium carbonate is heated it decomposes forming:
Calcium carbonate reacts with acids to produce gas

(a) Solid Ca and CO_2 gas
(b) Gaseous CaCO and CO_2 gas
(c) Solid CaO and CO_2 gas
(d) Gaseous Ca and CO_2
(e) Solid CaO and liquid CO_2

5. The most likely products for the reaction of NH_3 with oxygen are:
   Oxygen is reactive with many chemical compounds while nitrogen gas is very unreactive.

   (a) NO and water
   (b) N_2, H_2, and H_2O
   (c) N_2 and water
   (d) N_2O_5 and water
   (e) H_2 and NO

6. Which solution has the highest conductivity?

   (a) 0.5M NH_3
   (b) 0.5M NaOH
   (c) 0.5M Na_3PO_4
   (d) 0.5M HCl
   (e) 0.5M HCN

7. Which of the following is a non-electrolyte?

   (a) NaCl
   (b) CH_3COOH
   (c) NH_3
   (d) $Ba(OH)_2$
   (e) CH_3CH_2OH

8. Which of the following combinations would produce a precipitate?

   (a) Na metal and water.
   (b) 1M $AgNO_3$ solution and 1M sodium chloride.
   (c) 1M KCl and 1M $Ca(NO_3)_2$.
   (d) 0.5M $Al(CH_3COO)_3$ and 1M KNO_3.
   (e) 0.5M Hydrochloric acid and 0.5M KOH.

9. A solution of nickel nitrate and sodium hydroxide are mixed together. Which of the following statements is true?

   (a) A precipitate will not form
   (b) A precipitate of sodium nitrate will be produced.
   (c) Nickel hydroxide and sodium nitrate will precipitate.
   (d) Nickel hydroxide will precipitate.
   (e) Hydrogen gas is produced from the sodium hydroxide.

10. $Pb(NO_3)_2 + 2\ NaCl \rightarrow PbCl_2 + 2\ NaNO_3$

The correct net ionic equation for this reaction would include which of the following species?

(a) all of them
(b) Only $Pb(NO_3)_2$ and $PbCl_2$
(c) Pb^{2+}, Cl^-, and $PbCl_2$
(d) Na^+, NO_3^-, and $NaNO_3$
(e) NaCl, $Pb(NO_3)_2$, and $PbCl_2$

11. Which of the following compounds is insoluble in water?

(a) $Pb(NO_3)_2$
(b) Li_2CO_3
(c) $(NH_4)_3PO_4$
(d) $Ba(OH)_2$
(e) $BaSO_4$

12. The spectator ions in the reaction of barium nitrate with sodium sulfate are:

(a) Sodium ions and barium ions.
(b) Sodium ions and sulfate ions.
(c) Nitrate ions and sulfate ions.
(d) Sodium ions and nitrate ions.
(e) These are not ionic compounds so there are no spectator ions.

13. $H_2Te(g) + 4\ O_2F_2(g) \rightarrow TeF_6(g) + 2\ HF(g) + 4\ O_2(g)$

Which of the following is true regarding the reaction represented above?

(a) The oxidation number of O change from 2 to 0.
(b) The oxidation number of H changes.
(c) The oxidation number of F changes from +1 to -1.
(d) The oxidation number of Te changes from +6 to -2.
(e) There are no changes in oxidation states or the above answers are not correct.

14. When methane, CH_4, gas reacts with oxygen, the following changes occur

    (a) Carbon dioxide is formed and the oxidation number of oxygen remain unchanged.
    (b) Carbon dioxide and water are formed and the oxidation number of oxygen remains unchanged.
    (c) Carbon dioxide and water are formed and the oxidation number of oxygen changes from -2 to zero.
    (d) Carbon monoxide and water are formed and the oxidation number of carbon changes from -4 to +4.
    (e) Carbon dioxide and water are formed and the oxidation number of oxygen changes from zero to -2.

15. Lithium, a very reactive metal with water, is above zinc, a metal used in galvanizing, in the activity series. This means that:

    (a) Zinc will react with lithium ions to produce lithium metal.
    (b) Lithium metal will react with zinc ions to produce zinc metal.
    (c) Zinc is oxidized.
    (d) One mole of lithium reacts with one mole of zinc ions.
    (e) No reaction will take place between lithium metal and zinc ions.

16. $PbS\ (s) + 4\ H_2O_2\ (aq) \rightarrow PbSO_4\ (s) + 4\ H_2O\ (l)$
    In the reaction above, which species have a change in oxidation number?

    (a) Pb and S
    (b) Pb and O
    (c) S and O
    (d) S and H
    (e) O and H

17. $V_2O_5 + Cl_2 \rightarrow$ VOCl and O_2
    The absolute change in oxidation number of vanadium in the reaction above is:

    (a) +1
    (b) +3
    (c) -2
    (d) -3
    (e) +4

18. $HCO_3^- + H_2O \leftrightarrows H_2CO_3 + OH^-$

In the equilibrium represented above, the species that act as acids include which of the following?

I. HCO_3^-
II. H_2O
III. H_2CO_3

(a) II only
(b) III only
(c) I and II
(d) I and III
(e) II and III

19. $CHO_2^- + H_3O^+ \leftrightarrows HCHO_2 + H_2O$

The correct acid/conjugate base pair is

(a) CHO_2^-/H_2O
(b) H_3O^+/H_2O
(c) $H_3O^+/HCHO_2$
(d) $HCHO_2/H_2O$
(e) $CHO_2^-/HCHO_2$

20. The pH of a 1.0M solution of HCl is:

(a) 1.0
(b) 0.1
(c) 0.0
(d) less than zero
(e) between 0 and 1

21. The pOH of a solution containing 2.250 g of LiOH, a compound used in space craft and submarines to remove excess carbon dioxide from the atmosphere, in 250.0 mL of solution is:

(a) 0.425
(b) 13.58
(c) 0.376
(d) 13.62
(e) 0.954

22. $C_6H_5COOH\ (aq) + F^-\ (aq) \leftrightarrows HF\ (aq) + C_6H_5COO^-\ (aq)$
The equilibrium constant is less than 0.10. HF and benzoic acid are weak acids. Benzoic acid is a colorless solid with a melting point of 122^0C. Identify the species that is the strongest acid.

(a) HF
(b) C_6H_5COOH
(c) F^-
(c) $C_6H_5COO^-$
(d) H_2O

23. $H_2CO_3 + 2\ H_2O \leftrightarrows 2\ H_3O^+ + CO_3^{2-}$
Carbonic acid is a diprotic acid with $K_1 = 4.3 \times 10^{-7}$ and $K_2 = 5.6 \times 10^{-11}$. For the reaction above, what is the equilibrium constant? Carbon dioxide reacts with water to produce an acid.

(a) 4.3×10^{-7}
(b) 5.6×10^{-11}
(c) 2.4×10^{-17}
(d) 2.3×10^{-8}
(e) 1.8×10^{-4}

24. A 0.3M solution of acetic acid has a pH of 2.63. The ionization constant of this acid is

(a) 1.8×10^{-5}
(b) 7.0×10^{-4}
(c) 1.1×10^{-6}
(d) 7.8×10^{-3}
(e) 1.9×10^{-6}

25. What is the pH of a 0.05M solution of hypochlorous acid? (For HOCl, $K_a = 3.0 \times 10^{-8}$). Hypochlorous acid is colorless.

(a) 8
(b) 10
(c) Between 7 and 10
(d) Between 4 and 7
(e) 3

26. Acetic acid, CH_3COOH, has an equilibrium constant of 1.8×10^{-5}. A 0.125M acetic acid would have what percent of the acid dissociated at 25^0C?

(a) 1.0%
(b) 0.2%
(c) 1.2%
(d) 9.6%
(e) 4%

27. The concentration of hydronium ions in a 0.075 solution of acetic acid is? (For acetic acid, $K_a = 1.8 \times 10^{-5}$)

(a) 1.16×10^{-3}M
(b) 1.35×10^{-6}M
(c) 2.4×10^{-4}M
(d) 0.25M
(e) 8.5×10^{-3}M

28. How many moles of HF ($K_a = 6.8 \times 10^{-4}$) must be present in 0.500L to form a solution with a pH of 1.85?

(a) 0.147 moles
(b) 0.294 moles
(c) 0.048 moles
(d) 0.024 moles
(e) 3.41 moles

29. A particular sample of vinegar has a pH of 2.90. Assuming that acetic acid is the only acid that vinegar contains ($K_a = 1.8 \times 10^{-5}$), calculate the molar concentration of acetic acid in the sample?

(a) 0.088 M
(b) 0.126 M
(c) 1.26×10^{-3} M
(d) 0.890 M
(e) 0.014 M

30. A solution of acetic acid is 1.34% ionized. $K_a = 1.8 \times 10^{-5}$ for acetic acid. The molar concentration of the solution is:

(a) 1.0 M
(b) 0.134 M
(c) 0.0134 M
(d) 1.34×10^{-3} M
(e) lack enough information or no correct answer available.

31. Hydrofluoric acid is a weak acid, $K_a = 6.8 \times 10^{-4}$, and yet it is considered to be a very reactive compound. For example, HF dissolves glass. The major reason that it is considered highly reactive is:

    (a) It is an acid.
    (b) It forms H_3O^+.
    (c) It dissociates.
    (d) It readily forms very stable fluoride compounds.
    (e) It is a weak electrolyte.

32. The $[S^{2-}]$ in a 0.10 M solution of H_2S is: (For H_2S $K_{a1} = 9.1 \times 10^{-8}$, $K_{a2} = 1.2 \times 10^{-15}$)

    (a) 9.1×10^{-8} M
    (b) 1.2×10^{-15} M
    (c) 9.5×10^{-5} M
    (d) 3.5×10^{-7} M
    (e) 9.1×10^{-9} M

33. A 0.5M solution of a weak base B has a pH of 11.25. The K_b value for this base is

    (a) 1.2×10^{-11}
    (b) 6.3×10^{-23}
    (c) 3.6×10^{-3}
    (d) 6.3×10^{-6}
    (e) Not enough information to answer the question.

34. The acid ionization constant for benzoic acid, C_6H_5COOH, is 6.3×10^{-5}. The conjugate base of this acid has an ionization constant of

    (a) 6.3×10^{-5}
    (b) 1×10^{-14}
    (c) 1.59×10^{-10}
    (d) 6.3×10^{-19}
    (e) 6.3×10^{9}

35. Which of the following is the correct expression for the hydrolysis of sodium formate, NaCOOH? Formic acid reacts with sodium hydroxide to form sodium formate.

(a) $K = [HCOO^-]/\{[HCOOH][OH^-]\}$
(b) $K = [HCOO^-]/\{[HCOOH][H_3O^+]\}$
(c) $K = [HCOOH]/\{[HCOO^-][OH^-]\}$
(d) $K = [HCOOH][OH^-]/[HCOO^-]$
(e) $K = [HCOOH][OH^-]/\{[HCOO^-][H_2O]\}$

36. Which of the following salts, when dissolved in water to produce a 1.0 molar solution, will produce a solution with a pH greater than 7?

(a) Sodium chloride
(b) Ammonium nitrate
(c) Potassium acetate
(d) Calcium sulfate
(e) Sodium nitrate

37. Which of the following species forms an acid when added to water?

(a) NH_4NO_3
(b) NH_3
(c) KCl
(d) $NaNO_3$
(e) $Ca(CH_3COO)_2$

38. Which of the following is in correct order of increasing acidity?

(a) HClO, $HClO_4$, $HClO_2$, $HClO_3$
(b) $HClO_4$, $HClO_3$, $HClO_2$, HClO
(c) $HClO_4$, HClO, $HClO_2$, $HClO_3$
(d) HClO, $HClO_2$, $HClO_3$, $HClO_4$
(e) HCl, HClO, $HClO_2$, $HClO_4$

39. Lewis acids are sometimes used in chemical reactions to increase the speed of the reaction. Identify the Lewis acid in the following list.

(a) KNO_3
(b) $Ba(OH)_2$
(c) NH_3
(d) Cu^{2+}
(e) CO_2

40. $FeBr_3$ (s) + Br^- (aq) ⇆ $FeBr_4^-$ (aq)
For the reaction above, the Lewis acid is

(a) This reaction does not contain a Lewis acid
(b) $FeBr_3$
(c) Br^-
(d) $FeBr_4^-$
(e) Both $FeBr_3$ and $FeBr_4^-$

41. BH_3 is an electron deficient compound and thus considered to be a Lewis acid. The reaction between BH_3 and ammonia gas would produce

(a) B, H_2, and N_2.
(b) BH_3NH_3
(c) $BHNH_3$ and H_2.
(d) NH_4^+ and BH_2^-
(e) B_2H_6 and N_2H_2

Questions 42-45 refer to aqueous solutions containing equimolar ratios of the following pairs of substances.

(a) CH_3COOH and $NaCH_3COO$
(b) $HClO_4$ and NaCl
(c) KOH and HCl
(d) NH_3 and KOH
(e) CH_3NH_2 and CH_3NH_3Cl

42. The solution with the lowest pH.

43. The most nearly neutral solution.

44. A buffer with a pH > 7

45. A buffer with a pH < 7

46. A solution prepared to be initially 0.5M in CH_3COOH and 1M in CH_3COONa is:

(a) A solution with a pH less than 7 that is not a buffer solution.
(b) A buffer solution with a pH between 4 and 7.
(c) A buffer solution with a pH between 7 and 10.
(d) A solution with a pH greater than 7 that is not a buffer solution.
(e) A solution with a pH of 7.
(f)

47. One measure of the buffer capacity of an acid buffer solution is:

    (a) The ratio of acid to its conjugate base.
    (b) The value of pK_a.
    (c) Equal to its equilibrium constant.
    (d) The pH of the solution.
    (e) The ratio of pH to pK_a.

48. 1.0 L of a buffer formed by mixing 0.25 moles of ammonia solution with 0.25 moles of ammonium nitrate has a pH of (For ammonia, $K_b = 1.8 \times 10^{-5}$)

    (a) 4.24
    (b) 4.74
    (c) 5.35
    (d) 8.65
    (e) 9.26

49. How many moles of sodium cyanide must be added to 200.0 mL of a 0.100 M solution of HCN to give a solution whose pH is 9.22? Sodium cyanide, when dissolved in acid produces hydrogen cyanide. $K_a = 4.9 \times 10^{-10}$ for HCN

    (a) 0.016 moles
    (b) 0.040 moles
    (c) 0.010 moles
    (d) 0.0002 moles
    (e) None of the above

50. A student is asked to make a buffer solution with a pH between 6 and 7, using equimolar quantities of chemicals. The proper choice of compounds is:
    HF $K_a = 6.8 \times 10^{-4}$, HCN $K_a = 4.9 \times 10^{-10}$, CH_3COOH $K_a = 1.8 \times 10^{-5}$
    H_2CO_3 $K_{a1} = 4.3 \times 10^{-7}$, $K_{a2} = 5.6 \times 10^{-11}$, K_b (NH_3) $= 1.8 \times 10^{-5}$

    (a) Acetic acid and sodium acetate
    (b) HF and NaF
    (c) HCN and KCN
    (d) H_2CO_3 and $NaHCO_3$
    (e) NH_3 and NH_4Cl

Detailed Answers

1. Balance the following reactions, and indicate whether they are examples of combustion, decomposition, or combination

(a) $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$
(b) $KClO_3 \rightarrow KCl + O_2$
(c) $CH_3CH_2OH + O_2 \rightarrow CO_2 + H_2O$
(d) $P_4 + O_2 \rightarrow P_2O_5$
(e) $N_2O_5 + H_2O \rightarrow HNO_3$

2. Give an explanation and representative example for each of the following reaction types.

(a) precipitation
(b) oxidation
(c) combustion
(d) metathesis
(e) complete net ionic equation

3. Complete and balance the following chemical reactions:

(a) Lithium metal is heated in the presence of nitrogen gas.
(b) Sodium iodide solution is added to silver nitrate solution.
(c) Potassium chlorate is heated.
(d) C_2H_4 reacts with oxygen gas.
(e) Solid aluminum hydroxide is added to a solution of perchloric acid

4. Answer five of the eight options in this part. Give the formulas to show the reactants and the products for FIVE of the following chemical reactions. Each of the reactions occurs in aqueous solution unless otherwise indicated. Write the reactions as correct net ionic equations. Balance the equations.

(a) Silver nitrate reacts with calcium bromide.

(b) Solid calcium carbonate is heated to temperatures above 300^{o}C.

(c) Copper hydroxide reacts with perchloric acid.

(d) Lead nitrate reacts with potassium hydroxide.

(e) Sodium oxide is added to water.

(f) Methylamine gas is bubbled into distilled water.

(g) Copper nitrate reacts with hydrogen sulfide gas.

(h) Lithium metal is added to a 0.5 M solution of zinc nitrate.

5. Identify the precipitate (if any) that forms when the following solutions are mixed, and write a balanced net ionic equation for each reaction.

(a) $Sn(NO_3)_2$ and NaOH
(b) NaOH and K_2SO_4
(c) Na_2S and $Cu(CH_3COO)_2$

6. For the following, indicate the oxidation number of each element, which species is reduced, and which is oxidized.

(a) $Ni + Cl_2 \rightarrow NiCl_2$
(b) $3Fe(NO_3)_2 + 2Al \rightarrow 3Fe + 2Al(NO_3)_3$
(c) $Cl_2 + 2NaI \rightarrow I_2 + 2NaCl$
(d) $PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$

7. Use the following reactions to prepare an activity series for the unknown species X1, X2, and X3.

$X1(s) + X2^{+}(aq) \rightarrow X1^{+}(aq) + X2(s)$
$X1(s) + X3^{+}(aq) \rightarrow X1^{+}(aq) + X3(s)$
$X3(s) + X2^{+}(aq) \rightarrow X3^{+}(aq) + X2(s)$

(b) Which species is the most reactive in relation to the other X species?

(c) Which species most readily undergoes oxidation?

8. Acetone, CH_3COCH_3, is a nonelectrolyte; hypochlorous acid is a weak electrolyte; and ammonium chloride is a strong electrolyte. (K_a for hypochlorous acid is 3.0×10^{-8})

   (a) What are the solute species present in a solution of each of the compounds?
   (b) If 0.2 moles of each compound are dissolved in solution (compounds are not mixed together in this question), how many moles of each solute species are there in each solution? Be sure to identify the species and the amount.

9. Write balanced molecular and net ionic equations for the reactions of (assume all are aqueous solutions)

   (a) Hydrochloric acid with sodium oxide to produce water and sodium chloride.
   (b) Calcium chloride with sodium carbonate to produce calcium carbonate and sodium chloride.
   (c) Hydrobromic acid with magnesium to produce magnesium bromide and hydrogen.
   (d) Copper nitrate with sodium sulfide.

10. HCl, H_2SO_4, $HClO_4$, and HNO_3 are all examples of strong acids and are 100% ionized in water. This is known as the "leveling effect" of the solvent. Explain how you would establish the relative strengths of these acids. That is, how would you answer a question such as "which of these acids is the strongest?"

11. The acid ionization constant, K_a for propanoic acid, C_2H_5COOH, is 1.3×10^{-5}.

    (a) Calculate the hydrogen ion concentration, $[H^+]$, in a 0.35-molar solution of propanoic acid.

    (b) Calculate the percentage of propanoic acid molecules that are ionized in the solution in part (a).

    (c) What is the ratio of the concentration of propanoate ion, $C_2H_5COO^-$, to that of propanoic acid in a buffer solution with a pH of 4.90?

    (d) In a 100.0 milliliter sample of a different buffer solution, the propanoic acid concentration is 0.35-molar and the sodium propanoate concentration is 0.50-molar. To this buffer solution, solid NaOH is added. Would the pH increase or decrease?

12. The ionization constant for dimethylamine, $(CH_3)_2NH$, is 5.4×10^{-4}. Dimethyl amine is a substituted ammonia compound.

    (a) Calculate the pH and pOH of a 0.125 M solution of dimethylamine.
    (b) Write the correctly balanced net ionic equation for the reaction that occurs when $(CH_3)_2NH2NO_3$ is dissolved in water and calculate the numerical value of the equilibrium constant for the reaction.
    (c) Determine the pH of a solution made by adding 0.0250 mole of solid dimethylammonium nitrate to 250.0 mL of a 0.350 M solution of dimethylamine. Assume no volume change occurred.
    (d) Would you need to add LiOH or $HClO_4$ (state clearly which you choose) to (c) to produce a solution that has a pH of 11.00? Assume that no volume change occurred.

13. Boric acid, H_3BO_3, is a very weak acid with a $K_a = 5.8 \times 10^{-10}$. Boric acid is a colorless compound.

    (a) Calculate the pH of a 0.0010 M solution of boric acid.
    (b) What is the pH of a buffer solution produced by mixing 0.010 moles of sodium borate with 100.0 mL of 0.0150 moles of boric acid. Assume that no volume change occurred.
    (c) Would the pH increase or decrease if 20.0 ml of 0.05 M NaOH was added to the solution in part (b)? Explain your answer.
    (d) Explain whether the pH of solution (b) would increase or decrease if a small volume of 0.50 M HCl was added to the buffer solution.

14. The acid dissociation constant for benzoic acid (C_6H_5COOH) is 6.3×10^{-5}.

    (a) Calculate the equilibrium concentrations of H_3O^+, $C_6H_5COO^-$, and C_6H_5COOH in a 0.05 M solution of the acid.
    (b) Write the formula for the conjugate base of benzoic acid and determine its equilibrium constant.
    (c) What is the pH of a 1.0 M solution of benzoic acid?
    (d) What would be the percentage of ionization of benzoic acid in a solution containing 0.120 moles of sodium benzoate in 250.0 mL of 0.375 M benzoic acid. Assume that no volume change occurred.

15. The K_w value for water is dependent on temperature. At 0^0C the value is 1.2×10^{-15}. Nitrous acid $K_a = 4.5 \times 10^{-4}$.

(a) Calculate the pH and pOH of a 0.050 M solution of nitrous acid ($K_a = 4.5 \times 10^{-4}$) at 0^0C. Assume that the acid ionization constant does not change with temperature.
(b) What would the pH value be for a buffer solution made by adding 0.125 moles of calcium nitrite to 500.0 mL of a 0.500 M solution of nitrous acid? Assume no volume change occurred.
(c) Would this solution have the maximum buffer capacity possible? If not, how many moles of calcium nitrate should be added to the 500.0 mL of 0.500 M acid to produce a buffer with maximum buffer capacity?

16. Carbonic acid is a diprotic acid with $K_{a1} = 4.3 \times 10^{-7}$ and $K_{a2} = 5.6 \times 10^{-11}$.

(a) What is the ratio of HCO_3^- to H_2CO_3 in blood of pH 7.4?
(b) What is the ratio of HCO_3^- to H_2CO_3 in a patient with acidocis and a pH of 7.1?

17. The overall dissociation of carbonic acid, H_2CO_3, is represented below. The overall dissociation constant is also indicated.

$$H_2CO_3 \leftrightarrows \quad 2\ H^+ + CO_3^{2-} \quad K = 2.41 \times 10^{-17}$$

(a) Write the equation for the complete neutralization of carbonic acid using sodium hydroxide.
(b) Give the equations representing the first and second dissociations of carbonic acid. Calculate the value of the first dissociation constant, K_1, for carbonic acid if the value of the second dissociation constant, K_2, is 5.6×10^{-11}.
(c) Determine the pH and concentration of bicarbonate ion present in a 0.250 M solution of carbonic acid. What is the concentration of carbonate ion in this solution and what approximations were made in this calculation?
(d) Calculate the value of the equilibrium constant, K_b, for the reaction that occurs when solid Na_2CO_3 is dissolved in water.

18. Ascorbic acid, $H_2C_6H_6O_6$, is a diprotic acid with a K_{a1} value of 8.9×10^{-5}. The pH of a 0.125 M solution of ascorbic acid is 2.48 and the concentration of $C_6H_6O_6^{2-}$ is 1.6×10^{-12} M. Determine the value of K_{a2}.

(b) What is the pH of a 0.0010 M solution of ascorbic acid?

19. Citric acid, $H_3C_6H_5O_7$, is a triprotic acid that reacts with iron. The acid equilibrium constants are, $K_{a1} = 7.4 \times 10^{-4}$, $K_{a2} = 1.7 \times 10^{-5}$, and $K_{a3} = 4.0 \times 10^{-7}$.

    (a) Determine the equilibrium constant for the reaction

    $$H_3C_6H_5O_7 + 3\ H_2O \leftrightarrows 3\ H_3O^+ + C_6H_5O_7^{3-}$$

    (b) What is the molar concentration of each of the following species in a 0.275 M solution (assume the pH is determined by the first equilibrium).

    (i) $H_2C_6H_5O_7^-$
    (ii) $HC_6H_5O_7^{2-}$
    (iii) $C_6H_5O_7^{3-}$

20. Order the following species from the strongest acid to the weakest and support your answer with a rationale based on acid-base behavior, structure, and chemical properties.

    (a) HOF
    (b) HOCl
    (c) HOBr
    (d) HOI

21. Metal ions in solution do not exist as free ions. Rather, they are bonded to water molecules to form a hydrated ion. For example, $Fe(H_2O)_6^{3+}$. These hydrated ions act as acids according to the equilibrium:

    $$Fe(H_2O)_6^{3+} + H_2O \leftrightarrows Fe(H_2O)_5OH^+ + H_3O^+ \qquad K_a = 2 \times 10^{-3}$$

    (a) What is the pH of a 0.0125 M solution of $Fe(NO_3)_3$?

    (b) Cu^{2+} ions in water have a K_a of 1×10^{-8} and are thus less acidic than Fe^{3+} solutions. What accounts for this difference?

22. Phenol, C_6H_5OH, is a very weak acid with an acid equilibrium constant of $K_a = 1.3 \times 10^{-10}$. Determine the pH of a very dilute, 1×10^{-5} M, solution of phenol. Is the value acceptable? If not, give a possible explanation for the unreasonable pH value.

23. Determine the pH of a buffer that is 0.240 M sodium bicarbonate and 0.375 M sodium carbonate. $K_{a1} = 4.3 \times 10^{-7}$, $K_{a2} = 5.6 \times 10^{-11}$

    (b) 0.075 moles of carbonic acid is added to 1.0 L of this buffer solution. Write the reaction that occurs. Without using a calculator, indicate whether the pH of the solution increases, decreases or stays the same, Explain your answer.

24. Determine the pH of each of the following salts when added to water to produce a 0.1000 M solution: (K_a = 1.1 x 10^{-2} for HOCl, K_a = 1.7 x 10^{-1} for HIO_3, K_b = 4.4 x 10^{-4} for CH_3NH_2, K_b = 6.4 x 10^{-4} for $CH_3CH_2NH_2$)

    (a) NaCl
    (b) NaClO
    (c) CH_3NH_3Cl
    (d) KIO_3
    (e) $CH_3CH_2NH_3NO_3$

25. Explain why a solution of $HClO_4$ and $NaClO_4$ cannot act as a buffer solution while a solution of H_2CO_3 and $NaHCO_3$ can.

Free Form

1. What is the difference between the subscript 3 in HNO_3 and a coefficient 3 in front of HNO_3?

2. Pure water is a poor conductor of electricity, yet ordinary tap water is a good conductor. Account for this difference.

3. Where, in general, do the most easily oxidized metals occur in the periodic table? Where do the least easily oxidized metals occur in the periodic table?

4. The metal cadmium tends to form Cd^{2+} ions. The following observations are made: (i) When a strip of zinc metal is placed in $CdCl_2$ (aq), cadmium metal is deposited on the strip. (ii) When a strip of cadmium metal is placed in $Ni(NO_3)_2$ (aq), nickel metal is deposited.

    (a) Write net ionic equations to explain each of the observations made above.
    (b) What can you conclude about the position of cadmium in the activity series?
    (c) When calcium metal is place in $CdCl_2$(aq), cadmium metal is deposited on the strip. Is calcium above or below cadmium in the activity series?

5. How would you explain the following observations: copper metal reacts vigorously with 6 M nitric acid, yet reacts slowly with HCl.

6. A solution of **barium chloride** is a strong electrolyte and therefore conducts electricity. When a solution of $\mathbf{Ag_2SO_4}$ is added to the barium solution the conduction of electricity decreases until it no longer conducts. Explain this event.

7. An instructor handed you a bottle and indicated that the contents were one of the following: silver acetate, calcium acetate, and lead nitrate. The instructor asked you to identify the contents of the bottle. Using only solubility as a guide, indicate what chemicals you would use to test the unknown, and what the expected results would be for each of the possibilities.

8. Although nitric acid and phosphoric acid have very different properties as pure substances, their aqueous solutions possess many common properties. List some general properties of these solutions and explain their common behavior in terms of the species present.

9. Write a chemical equation that illustrates the autoionization of water.
Occasionally, chemists use solvents other than water or organic solvents. Like water, there solvents may undergo autoionization. Write chemical equations illustrating the autoionization of the following solvents:

(a) liquid ammonia
(b) liquid sulfur dioxide
(c) liquid HCN

10. Explain why the concentration of water, $[H_2O]$, is not included in the equilibrium expression.

11. Consider two solutions, acid solution **A** and solution **B.** The $[H_3O^+]$ in solution **A** is 1000 times greater than that in solution **B**. What is the difference in the pH values of the two solutions?

12. Explain why we normally ignore the $[H_3O^+]$ contributed by water to an acidic solution. Under what conditions would we need to include its contribution?

13. Explain why the percent of ionization is larger for very dilute solutions than it is for concentrated solutions.

14. Explain the acid strength trend observed for the following:

(a) $HCl > HF$ and $H_2S > H_2O$
(b) $CH_4 < NH_3 << H_2O < HF$

15. Indicate whether the pH increase, decreases, or remains the same when each of the following is added:

(a) $Ca(C_7H_5O_2)_2$ to a solution of $HC_7H_5O_2$.
(b) Pyridinium nitrate $(C_5H_5NH)(NO_3)$, to a solution of pyridine, C_5H_5N.
(c) Ammonia to a solution of hydrochloric acid.
(d) Sodium hydrogen carbonate to a solution of carbonic acid.
(e) Sodium perchlorate to a solution of sodium hydroxide.

16. How do you explain the fact that solutions of CH_3COOH are acidic while solutions of $NaCH_3COO$ are basic?

17. Give an example for each of the following and a rationale for your choice.

(a) A strong electrolyte that is not an acid or base.
(b) A Lewis acid.
(c) A weak organic acid.
(d) A buffer solution with a pH close to 7.0

18. Explain why the acid strength of oxyacids increases with increasing number of oxygen atoms.

19. Is it correct to say that all Lewis acids are Bronsted-Lowry acids? Explain

20. For the reaction $HF + NH_3 \leftrightarrows F^- + NH_4$ does the equilibrium lie predominantly to the left or to the right. Explain your answer. Base your answer on quantitative acid equilibrium expressions and not qualitative Le Chatelier arguments. K_a for HF is 6.8×10^{-4} and K_b for NH_3 is 1.8×10^{-5}.

21. HCO_3^- is amphoteric. Illustrate this fact using properly balanced equilibrium reactions.

22. When we solve equilibrium expressions for the $[H_3O^+]$ approximations are often made to reduce the complexity of the equation thus making it easier to solve. Why can we make these approximations? Would these approximations ever lead to significant errors in the answer? If so give an example of an equilibrium problem that would require use of the quadratic equation.

23. Explain why the solution resulting from a strong acid and a weak base is acidic even though all of the base and acid have reacted.

24. Benzoic acid, C_6H_5COOH, contains six hydrogen atoms, yet it is a monoprotic acid. Explain.

25. When 0.200 moles of solid sodium acetate are added to a 0.700 M solution of acetic acid the equilibrium is disturbed. Explain how the reaction shifts, that is to the right or to the left, to re-establish equilibrium. Base your answer on equilibrium expressions before and after addition.