I. Common Ion Effect  MC #1-6
   a) Definition
   b) Sample Problems #1-3: Weak electrolyte (acid) + salt
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II. Buffered Solutions MC #7-31
    a) Definition
    b) Preparation of buffers
    c) Calculations involving buffers
       i. Using ICE chart
       ii. Using Henderson-Hasselbalch equation
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III. Titrations MC #32-62
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     b) Neutralization reactions
     c) pH Calculations for Strong Acid-Strong Base Titrations
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        ii. Before the equivalence point
        iii. At the equivalence point
        iv. After the equivalence point
     d) pH Calculations for Weak Acid-Strong Base or for Strong Acid-Weak Base Titrations
        i. Before any acid or base is added
        ii. Before the equivalence point
        iii. At the equivalence point
        iv. After the equivalence point
     e) Polyprotic acids
     f) Choosing an indicator

IV. Conceptual questions 1-29
Multiple Choice questions

Common-Ion Effect

1) The pH of a solution that contains 0.818 M acetic acid ($K_a = 1.77 \times 10^{-5}$) and 0.172 M sodium acetate is __________.
   A) 4.077  B) 5.434  C) 8.571  D) 8.370  E) 9.922

2) Calculate the pH of a solution prepared by dissolving 0.37 mol of formic acid (HCO$_2$H) and 0.23 mol of sodium formate (NaCO$_2$H) in water sufficient to yield 1.00 L of solution. The $K_a$ of formic acid is $1.77 \times 10^4$.
   A) 2.1  B) 10.46  C) 3.55  D) 2.31  E) 3.95

3) Calculate the pH of a solution prepared by dissolving 0.25 mol of benzoic acid (C$_7$H$_5$O$_2$H) and 0.15 mol of sodium benzoate (NaC$_7$H$_5$O$_2$) in water sufficient to yield 1.00 L of solution. The $K_a$ of benzoic acid is $6.50 \times 10^{-5}$.
   A) 4.41  B) 2.40  C) 3.97  D) 10.08  E) 4.19

4) Calculate the pH of a solution prepared by dissolving 0.15 mol of benzoic acid (HBz) and 0.30 mol of sodium benzoate in water sufficient to yield 1.00 L of solution. The $K_a$ of benzoic acid is $6.50 \times 10^{-5}$.
   A) 2.52  B) 3.89  C) 4.49  D) 10.16  E) 4.20

5) Calculate the pH of a solution prepared by dissolving 0.750 mol of NH$_3$ and 0.250 mol of NH$_4$Cl in water sufficient to yield 1.00 L of solution. The $K_b$ of ammonia is $1.77 \times 10^{-5}$.
   A) 5.22  B) 4.27  C) 9.73  D) 8.78  E) 0.89

6) The pH of a solution prepared by dissolving 0.350 mol of solid methylamine hydrochloride (CH$_3$NH$_3$Cl) in 1.00 L of 1.10 M methylamine (CH$_3$NH$_2$) is __________. The $K_b$ for methylamine is $4.4 \times 10^{-4}$. (Assume the final volume is 1.00 L.)
   A) 1.86  B) 2.66  C) 10.15  D) 11.14  E) 10.64

Buffers

7) What does a buffer do?
   a) Keeps the pH of a solution constant
   b) Keeps the salt concentration of a solution constant
   c) Keeps the cation concentration constant
   d) Keeps the anion concentration constant

8) What substances are present in a buffer?
   a) A weak base or acid and its salt
   b) A hydrolyzing salt only
   c) A weak base or acid only
   d) A salt only

9) The addition of hydrofluoric acid and __________ to water produces a buffer solution.
   A) HCl  B) NaNO$_3$  C) NaF  D) NaCl  E) NaBr
10) Which of the following could be added to a solution of sodium acetate to prepare a buffer?

- acetic acid
- hydrochloric acid
- ammonium acetate
- sodium chloride

A) acetic acid only  D) ammonium acetate only
B) hydrochloric acid only  E) sodium chloride or ammonium acetate
C) acetic acid or hydrochloric acid

11) Which of the following could not be added to a solution of sodium acetate to prepare a buffer?

- ammonium acetate
- acetic acid
- hydrochloric acid

A) ammonium acetate  D) nitric acid
B) acetic acid  E) more than one of these answers is correct
C) hydrochloric acid

12) Which of the following could be added to a solution of potassium fluoride to prepare a buffer?

- sodium hydroxide
- potassium acetate
- ammonia
- hydrochloric acid

A) sodium hydroxide  D) sodium fluoride
B) potassium acetate  E) ammonia
C) hydrochloric acid

13) Which one of the following pairs cannot be mixed together to form a buffer solution?

- NH₃, NH₄Cl
- NaC₂H₃O₂, HCl (C₂H₃O₂⁻ = acetate)
- RbOH, HBr
- KOH, HF
- H₃PO₄, KH₂PO₄

A) NH₃, NH₄Cl  D) KOH, HF
B) NaC₂H₃O₂, HCl (C₂H₃O₂⁻ = acetate)  E) H₃PO₄, KH₂PO₄
C) RbOH, HBr

14) Which one of the following pairs cannot be mixed together to form a buffer solution?

- C₅H₅N, C₅H₅NHCl
- HC₂H₃O₂, NaOH
- KOH, HI
- NH₂CH₃, HCl
- NaClO, HNO₃

A) C₅H₅N, C₅H₅NHCl  D) NH₂CH₃, HCl
B) HC₂H₃O₂, NaOH  E) NaClO, HNO₃
C) KOH, HI

15) A solution containing which one of the following pairs of substances will be a buffer solution?

- NaI, HI
- KBr, HBr
- RbCl, HCl
- CsF, HF

A) NaI, HI  D) CsF, HF
B) KBr, HBr  E) none of the above
C) RbCl, HCl

16) Which of the following would not make a good buffer system?

- Sulfate ion and sulfuric acid
- Bicarbonate ion and carbonic acid
- Ammonia and ammonium ion
- Acetate and acetic acid

A) Sulfate ion and sulfuric acid
B) Bicarbonate ion and carbonic acid
C) Ammonia and ammonium ion
D) Acetate and acetic acid

17) Of the following solutions, which has the greatest buffering capacity?

- 0.821 M HF and 0.217 M NaF
- 0.821 M HF and 0.909 M NaF
- 0.100 M HF and 0.217 M NaF
- 0.121 M HF and 0.667 M NaF

A) 0.821 M HF and 0.217 M NaF
B) 0.821 M HF and 0.909 M NaF
C) 0.100 M HF and 0.217 M NaF
D) 0.121 M HF and 0.667 M NaF
E) They are all buffer solutions and would all have the same capacity.
18) Of the following solutions, which has the greatest buffering capacity?
   A) 0.521 M H\textsubscript{2}C\textsubscript{2}H\textsubscript{3}O\textsubscript{2} and 0.217 M NaC\textsubscript{2}H\textsubscript{3}O\textsubscript{2}
   B) 0.821 M H\textsubscript{2}C\textsubscript{2}H\textsubscript{3}O\textsubscript{2} and 0.713 M NaC\textsubscript{2}H\textsubscript{3}O\textsubscript{2}
   C) 0.365M H\textsubscript{2}C\textsubscript{2}H\textsubscript{3}O\textsubscript{2} and 0.497 M NaC\textsubscript{2}H\textsubscript{3}O\textsubscript{2}
   D) 0.121 M H\textsubscript{2}C\textsubscript{2}H\textsubscript{3}O\textsubscript{2} and 0.116 M NaC\textsubscript{2}H\textsubscript{3}O\textsubscript{2}

19) Of the following solutions, which has the greatest buffering capacity?
   A) 0.543 M NH\textsubscript{3} and 0.555 M NH\textsubscript{4}Cl
   B) 0.087 M NH\textsubscript{3} and 0.088 M NH\textsubscript{4}Cl
   C) 0.234 M NH\textsubscript{3} and 0.100 M NH\textsubscript{4}Cl
   D) 0.100 M NH\textsubscript{3} and 0.455 M NH\textsubscript{4}Cl
   E) They are all buffer solutions and would all have the same capacity.

20) The $K_a$ of acetic acid is $1.76 \times 10^{-5}$. The pH of a buffer prepared by combining 50.0 mL of 1.00 M potassium acetate and 50.0 mL of 1.00 M acetic acid is ______. 
   A) 1.705  B) 0.851  C) 3.406  D) 4.754  E) 2.383

21) The $K_b$ of ammonia is $1.77 \times 10^{-5}$. The pH of a buffer prepared by combining 50.0 mL of 1.00 M ammonia and 50.0 mL of 1.00 M ammonium nitrate is ______.
   A) 4.63  B) 9.25  C) 4.74  D) 9.37  E) 7.00

22) Which of the following reactions shows what happens when nitric acid is added to an ammonium ion-ammonia buffer?
   A) H\textsuperscript{+} + NH\textsubscript{3} $\rightarrow$ NH\textsubscript{4}^-  
   B) H + NH\textsubscript{4} $\rightarrow$ NH\textsubscript{5}  
   C) Cl + NH\textsubscript{3} $\rightarrow$ NH\textsubscript{3}Cl  
   D) Cl + NH\textsubscript{4} $\rightarrow$ N\textsubscript{2}Cl

23) Which of the following reactions shows what happens when potassium hydroxide is added to an ammonium ion-ammonia buffer?
   A) OH\textsuperscript{-} + NH\textsubscript{3} $\rightarrow$ NH\textsubscript{3}OH  
   B) OH\textsuperscript{-} + NH\textsubscript{4}\textsuperscript{+} $\rightarrow$ NH\textsubscript{3} + H\textsubscript{2}O  
   C) K\textsuperscript{+} + NH\textsubscript{3} $\rightarrow$ K\textsubscript{3}NH\textsubscript{3}  
   D) K\textsuperscript{+} + NH\textsubscript{4}\textsuperscript{+} $\rightarrow$ NH\textsubscript{4}K

24) The reaction that takes place when a strong acid is added to an acetic acid- acetate buffer (CH\textsubscript{3}COOH/ CH\textsubscript{3}COO\textsuperscript{-}) is ______.
   A) CH\textsubscript{3}COOH + H\textsuperscript{+} $\rightarrow$ CH\textsubscript{3} + CO\textsubscript{2}  
   B) CH\textsubscript{3}COOH + H\textsuperscript{+} $\rightarrow$ CH\textsubscript{3}COO\textsuperscript{-} + H\textsubscript{2}  
   C) CH\textsubscript{3}COO\textsuperscript{-} + H\textsuperscript{+} $\rightarrow$ CH\textsubscript{3}COOH  
   D) CH\textsubscript{3}COOH + H\textsuperscript{+} $\rightarrow$ CH\textsubscript{3}COO\textsuperscript{-} + H\textsubscript{2}O

25) What change will be caused by addition of a small amount of HCl to a solution containing fluoride ions and hydrogen fluoride?
   A) The concentration of hydronium ions will increase significantly.
   B) The concentration of fluoride ions will increase as will the concentration of hydronium ions.
   C) The concentration of hydrogen fluoride will decrease and the concentration of fluoride ions will increase.
   D) The concentration of fluoride ion will decrease and the concentration of hydrogen fluoride will increase.
   E) The fluoride ions will precipitate out of solution as its acid salt.
26) Consider a buffer solution containing 0.100 M fluoride ions and 0.126 M hydrogen fluoride. The pH of this solution is __________. The Ka of HF is $3.5 \times 10^{-4}$.
   A) 1.156  B) 2.256  C) 3.356  D) 8.856  E) 11.562

27) Consider a solution containing 0.100 M fluoride ions and 0.126 M hydrogen fluoride. The concentration of fluoride ions after the addition of 5.00 mL of 0.0100 M HCl to 25.0 mL of this solution is __________ M.
   A) 0.0850  B) 0.00167  C) 0.0980  D) 0.0817  E) 0.00253

28) Consider a solution containing 0.100 M fluoride ions and 0.126 M hydrogen fluoride. The concentration of hydrogen fluoride after addition of 5.00 mL of 0.0100 M HCl to 25.0 mL of this solution is __________ M.
   A) 0.107  B) 0.100  C) 0.126  D) 0.00976  E) 0.00193

29) Consider a solution containing 0.100 M fluoride ions and 0.126 M hydrogen fluoride. The pH after addition of 5.00 mL of 0.0100 M HCl to 25.0 mL of this solution is __________ M.
   A) 2.93  B) 3.13  C) 3.33  D) 4.33  E) 9.33

30) The Henderson-Hasselbalch equation is __________.
   
   A) $[\text{base}] + \log \frac{[\text{base}]}{[\text{acid}]}$  
   B) $\text{pH} = \text{pK}_a - \log \frac{[\text{base}]}{[\text{acid}]}$  
   C) $\text{pH} = \text{pK}_a + \log \frac{[\text{base}]}{[\text{acid}]}$  
   D) $\text{pH} = \text{pK}_a + \log \frac{[\text{acid}]}{[\text{base}]}$  
   E) $\text{pH} = \log \frac{[\text{acid}]}{[\text{base}]}$

31) In a solution, when the concentrations of a weak acid and its conjugate base are equal, A) the system is not at equilibrium.  
   B) the buffering capacity is significantly decreased.  
   C) the $-\log$ of the $[\text{H}^+]$ and the $-\log$ of the $K_a$ are equal.  
   D) all of the above are true.  

**Neutralization**

32) Write a complete and balanced equation for the following acid-base reaction:

$$\text{H}_2\text{SO}_4 + \text{Al(OH)}_3 \rightarrow$$

33) Write a complete balanced equation for the following acid-base reaction:

$$\text{HCl} + \text{Mg(OH)}_2 \rightarrow$$

34) Write a complete and balanced equation for the following acid-base reaction:

$$\text{H}_3\text{PO}_4 + \text{Ca(OH)}_2 \rightarrow$$

35) Write a complete and balanced equation for the following acid-base reaction:
\[ \text{HNO}_3 + \text{NH}_4\text{OH} \rightarrow \]

36) How many moles of sodium hydroxide are needed to neutralize 3.0 moles of phosphoric acid?

A) 1 mol  B) 3 mol  C) 6 mol  D) 9 mol  E) 12 mol

37) How many moles of magnesium hydroxide are needed to neutralize 2.0 moles of phosphoric acid?

A) 2 mol  B) 3 mol  C) 4 mol  D) 5 mol  E) 6 mol

**Titration**

38) What is the purpose of a titration?

A) To determine the color of the indicator  
B) To determine the concentration of acid or base  
C) To determine the concentration of acid only  
D) To determine the volume of base

39) What is the primary measurement instrument that is used when performing titrations?

A) graduate cylinder  
B) buret  
C) volumetric pipet  
D) syringe  
E) Erlenmeyer flask

40) A 25.0 mL sample of 0.723 M HClO₄ is titrated with a 0.273 M KOH solution. What is the [H⁺] (molarity) before any base is added?

A) 0.439  B) 1.00 × 10⁻⁷  C) 0.723  D) 2.81 × 10⁻¹³  E) 0.273

41) A 25.0 mL sample of 0.723 M formic acid is titrated with a 0.273 M KOH solution. The Kₐ of formic acid is 1.77 × 10⁻⁴. What is the pH of the acid before any base is added?

A) 0.14  B) 1.95  C) 3.89  D) 7.00  E) 8.19

42) A 25.0 mL sample of 0.22 M hydrazoic acid (HN₃; Kₐ = 2.6 × 10⁻⁵) is titrated with a 0.30 M KOH solution. What is the pH of the solution before any base is added?

A) 2.62  B) 5.42  C) 7.00  D) 8.97  E) 11.22

43) The pH of a solution prepared by mixing 50.0 mL of 0.125 M KOH and 50.0 mL of 0.125 M HCl is __________.

A) 6.29  B) 7.00  C) 8.11  D) 5.78  E) 0.00

44) What is the pH of a solution resulting from 65 mL of 0.15 M HClO₃ titrated with 45 mL of 0.18 M NaOH?

A) 0.65  B) 1.45  C) 1.82  D) 7.95  E) 8.21

45) A 25.0 mL sample of 0.22 M hydrazoic acid (HN₃; Kₐ = 2.6 × 10⁻⁵) is titrated with a 0.30 M KOH solution. What is the pH of the solution after 16.0 mL of base is added?

A) 2.62  B) 5.42  C) 7.00  D) 8.97  E) 11.22
46) A 25.0 mL sample of 0.800 M HClO₄ is titrated with a 0.300 M KOH solution. The H₃O⁺ concentration after the addition of 10.0 mL of KOH is __________ M.
   A) 0.486   B) 1.00 x 10⁻⁷   C) 0.723   D) 2.81 x 10⁻¹³   E) 0.273

47) A 30.0 mL sample of 0.50 M HClO₄ is titrated with a 0.25 M KOH solution. The H₃O⁺ concentration after the addition of 5.0 mL of KOH is __________ M.
   A) 0.00125   B) 0.0138   C) 0.0150   D) 0.393   E) 0.439

48) A 30.0 mL sample of 0.72 M HClO₄ is titrated with a 0.27 M KOH solution. What is the H₃O⁺ concentration after the addition of 80.0 mL of KOH?
   A) 1.00 x 10⁻⁷   B) 0.0216   C) 0.196   D) 0.27   E) 0.72

49) What volume (mL) of 0.5M HNO₃ is necessary to titrate 25 mL of 0.05M KOH solution to the endpoint?
   A) 2.5   B) 5.0   C) 10   D) 25   E) 50

50) What volume (mL) of 0.5M HNO₃ is necessary to titrate 25 mL of 0.05M Ca(OH)₂ solution to the endpoint?
   A) 2.5   B) 5.0   C) 10   D) 25   E) 50

51) How much 1.5 M NaOH is necessary to exactly neutralize 20.0 mL of 2.5 M H₃PO₄?
   A) 20   B) 33   C) 40   D) 60   E) 100

52) A 25.0 mL sample of an HCl solution is titrated with a 0.15 M NaOH solution. The equivalence point is reached with 75.0 mL of base. The concentration of HCl is __________ M.
   A) 11.7   B) 0.00214   C) 0.450   D) 0.267   E) 0.139

53) A 50.0 mL sample of an aqueous H₂SO₄ solution is titrated with a 0.100 M NaOH solution. The equivalence point is reached with 100 mL of NaOH solution. The concentration of H₂SO₄ is __________ M.
   A) 0.050   B) 0.100   C) 0.150   D) 0.200   E) 0.400

54) How many mL of 0.15 M NaOH are required to reach the equivalence point if it is titrated into a 35.0 mL sample of 0.20 M acetic acid?
   A) 8.5 x 10⁻⁴   B) 26   C) 40   D) 47   E) 58

55) A 25.0 mL sample of an acetic acid solution is titrated with a 0.18 M NaOH solution. The equivalence point is reached when 37.0 mL of the base is added. The concentration of acetic acid in the sample was __________ M.
   A) 0.119   B) 1.83 x 10⁻⁴   C) 0.266   D) 0.365   E) 0.175

56) What is the pH of the resulting solution in the previous problem? Ka acetic acid = 1.8 x 10⁻⁵
   A) 2.57   B) 5.72   C) 8.80   D) 10.65   E) 12.91

57) A 30.0 mL sample of 0.44M hydrazoic acid, (HN₃; Kₐ = 2.6 x 10⁻5) is titrated with a 0.22M KOH solution. What is the pH of the solution after 60.0 mL of base is added?
   A) 2.82   B) 4.32   C) 7.00   D) 8.87   E) 12.3

58) A 25.0 mL sample of 0.72 M HClO₄ is titrated with a 0.27 M KOH solution. The H₃O⁺ concentration after the addition of 80.0 mL of KOH is __________ M.
   A) 0.40   B) 1.00 x 10⁻⁷   C) 0.70   D) 3.00 x 10⁻¹³   E) 4.00 x 10⁻²
59) A 25.0 mL sample of 0.50 M HCl is titrated with a 0.25 M NaOH solution. The pH after the addition of 80.0 mL of NaOH is _________ M.
A) 1.146  B) 1.903  C) 2.215  D) 10.679  E) 12.854

60) A 25.0 mL sample of 0.22 M hydrazoic acid, \( \text{HN}_3 \); \( K_a = 2.6 \times 10^{-5} \) is titrated with a 0.18 M KOH solution. What is the pH of the solution after 35.0 mL of base is added?
A) 2.61  B) 6.95  C) 8.79  D) 11.62  E) 12.27

<table>
<thead>
<tr>
<th>Indicator</th>
<th>( K_a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>bromthymol blue</td>
<td>( 1 \times 10^{-7} )</td>
</tr>
<tr>
<td>indigo carmine</td>
<td>( 1 \times 10^{-12} )</td>
</tr>
<tr>
<td>m-cresol purple</td>
<td>( 1 \times 10^{-8} )</td>
</tr>
<tr>
<td>methyl orange</td>
<td>( 1 \times 10^{-4} )</td>
</tr>
</tbody>
</table>

61) Which of the indicators listed above would be appropriate for the titration of HF with NaOH?
A) bromthymol blue  B) indigo carmine  C) m-cresol purple  D) methyl orange

62) Which of the indicators listed above would be appropriate for the titration of HCl with NH\(_3\)?
A) bromthymol blue  B) indigo carmine  C) m-cresol purple  D) methyl orange

**IV Conceptual questions**

1) A certain buffer solution contains equal concentration of \( X^- \) and HX. The Ka of HX is \( 10^{-8} \). The pH of the buffer is
A) 6  B) 8  C) 11  D) 14  E) 9

2) In the titration of weak acid against strong base, at the half equivalence point,
A) pH = \( 1/2pK_a \)  B) pH = \( pK_a \)  C) pH = \( 2pK_a \)  D) neutral  E) none of the above

3) The pH indicators are
A) salts of strong acids and bases  B) salts of weak acids and weak bases  C) either weak acid or weak bases  D) either strong acids or strong bases  E) none of the above
4) The pH of a solution obtained by mixing 50 ml of 0.4 M HCl and 50 ml of 0.2M NaOH is
A) –log 2
B) –log 0.2
C) –log4
D) 1.0
E) 2.0

5) In a mixture of weak acid and its salt, the ratio of the concentration of acid to salt is increased ten fold. The pH of the solution
A) decreases by one
B) decreases by one tenth
C) increases by one
D) increases ten fold
E) decreases by 10

6) Which one of the following is true for any diprotic acid, H₂X?
A) Ka₂ > Ka₁
B) Ka₁ > Ka₂
C) Ka₂ = 1/Ka₁
D) Ka₂ = Ka₁
E) Ka₁ = 1/Ka₁

7) Which of the following statements about pH and H⁺ ion concentration is incorrect?
A) a solution of the mixture of one equivalent each of CH₃COOH and NaOH has a pH of 7
B) A cold and concentrated H₂SO₄ has lower H⁺ ion concentration than a dilute solution of H₂SO₄
C) pH of the pure neutral water is not zero
D) addition of one drop of concentrated HCl in NH₄OH solution decreases pH of the solution
E) addition of one drop of con KOH to a solution of CH₃COOH will increase the pH of the solution.

8) Which of the following has lowest pH value?
A) M HCl
B) 1M NaOH
C) 1M H₂SO₄
D) 1M C₂H₅OH
E) 1M Ca (OH)₂
9) pH of water is 7. When a substance Y is dissolved in water, the pH becomes 13.

The substance Y is a salt of
A) weak acid and weak base
B) strong acid and strong base
C) strong acid and weak base
D) weak acid and strong base
E) weak base

10) Which solutions are mixed to form a buffer solution?
A) strong acid and its salt
B) strong base and its salt
C) weak acid and its salt
D) weak acid with weak base
E) none of the above

11) The pH of an aqueous solution of CH₃COONa will be
A) 7
B) 3
C) 9
D) 14
E) 1

12) Which of the following is not a buffer?
A) H₂CO₃/HCO₃⁻
B) CH₃COOH/CH₃COONa
C) NH₄OH/NH₄Cl
D) NH₄OH/CH₃COOH
E) NH₃/NH₄Br

13) The pH of blood is maintained by a buffering system which is
A) H₂CO₃/HCO₃⁻
B) NaCl/HCl
C) NH₄OH/NH₄Cl
D) sodium citrate/citric acid
E) KCl/HCl

14) For a buffer solution with equal amounts of the salt and the acid with \( Ka = 10^{-8} \), the pH is
A) 0
B) 13
C) 6
D) 8
E) 8-log6

15) The Pka of HCN is 9.30. The pH of a solution prepared by mixing 2.5 moles of KCN and 2.5 moles of HCN in water and making up to total volume to 500 ml is
A) 9.30
B) 7.30
C) 10.30
D) 8.30
E) 4.70

16) The pH of a 0.1 M solution of the following salts increases in the order
A) NaCl < NH₄Cl < NaCN < HCl
B) HCl < NH₄Cl < NaCl < NaCN
C) NaCN < NH₄Cl < NaCl < HCl
D) HCl < NaCl < NaCN < NH₄Cl
E) NH₄Cl < NaCl < NaCN < HCl

17) which of the following solutions has a pH greater than 7.0?
A) 0.10 M KBr
B) 0.10 M NH₄Cl
C) 0.10 M HC₂H₃O₂
D) 0.01 M NaF
E) 0.01 M HI

A solution of a weak monoprotic acid is titrated with a solution of a strong base, KOH. Consider the points labeled A through E on the titration curve that results, as shown below. The questions (24-26) below are based on the graph below.
18) The point at which the moles of the added strong base are equal to the moles of the weak acid initially present
19) The point at which the pH is closest to that of the strong base being added
20) The point at which the concentrations of the weak acid and its conjugate base are approximately equal

The graph below shows the titration curve that results when 100 ml of 0.25M acetic acid is titrated with 0.10M NaOH. Answer questions 27-29 is based on the curve below.
21) Which of the following indicators is the best choice for this titration?

<table>
<thead>
<tr>
<th>Indicator</th>
<th>pH range of colors</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) methyl orange</td>
<td>3.2-4.4</td>
</tr>
<tr>
<td>B) Methyl red</td>
<td>4.8-6.0</td>
</tr>
<tr>
<td>C) Bromothymol blue</td>
<td>6.1-7.6</td>
</tr>
<tr>
<td>D) Phenolphthalein</td>
<td>8.2-10.0</td>
</tr>
<tr>
<td>E) Alizarin</td>
<td>11.2-12.4</td>
</tr>
</tbody>
</table>

22) What part of the curve corresponds to the optimum buffer action of the acetic acid /acetate ion pair?

A) point D
B) point A
C) Point E
D) all along the section BD
E) all along the section DE

23) What is the volume of the base used at the end point?
A) 14mL
B) 22mL
C) 25mL
D) 27mL
E) 40mL

24) Mixtures that would be considered buffers include which of the following?
I 0.10M HCl + 0.10M NaCl
II 0.10M HF + 0.01M NaF
III 0.01M HBr + 0.01M NaBr
A) I only
B) II only
C) III only
D) I and II
E) II and III

25) Ascorbic acid, H$_2$C$_6$H$_5$O$_6$ is a diprotic acid with K$_1$=7.9 x10$^{-5}$ and K$_2$= 1.6 x10$^{-12}$ . In a 0.005M aqueous solution of ascorbic acid, which of the following is present in lowest concentrations?
A) H$_2$O(l)
B) H$_3$O+
C) H$_2$C$_6$H$_5$O$_6$
D) HC$_6$H$_5$O$_6$\(^{-}\)
E) C$_6$H$_5$O$_6$\(^{2-}\)

The following questions 26-29 are based on the given solutions below.
A) NaCl   B) NaCN   C) NH$_4$NO$_3$   D) Ba(OH)$_2$

26) A basic solution
27) A neutral solution
28) An acidic solution
29) A strong basic solution
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
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<td>1</td>
<td>A</td>
<td>27</td>
<td>D</td>
</tr>
<tr>
<td>2</td>
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<td>28</td>
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</tr>
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<td>C</td>
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<tr>
<td>4</td>
<td>C</td>
<td>30</td>
<td>C</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>31</td>
<td>C</td>
</tr>
<tr>
<td>6</td>
<td>D</td>
<td>32</td>
<td>$3H_2SO_4 + 2Al(OH)_3 \rightarrow 2Al_2(SO_4)_3 + 6H_2O$</td>
</tr>
<tr>
<td>7</td>
<td>A</td>
<td>33</td>
<td>$2HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2H_2O$</td>
</tr>
<tr>
<td>8</td>
<td>A</td>
<td>34</td>
<td>$2H_3PO_4 + 3Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6H_2O$</td>
</tr>
<tr>
<td>9</td>
<td>C</td>
<td>35</td>
<td>$HNO_3 + NH_4OH \rightarrow NH_4NO_3 + H_2O$</td>
</tr>
<tr>
<td>10</td>
<td>C</td>
<td>36</td>
<td>D</td>
</tr>
<tr>
<td>11</td>
<td>A</td>
<td>37</td>
<td>B</td>
</tr>
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<td>12</td>
<td>C</td>
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<td>B</td>
</tr>
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</tr>
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<td>14</td>
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<td>40</td>
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</tr>
<tr>
<td>15</td>
<td>D</td>
<td>41</td>
<td>B</td>
</tr>
<tr>
<td>16</td>
<td>A</td>
<td>42</td>
<td>A</td>
</tr>
<tr>
<td>17</td>
<td>B</td>
<td>43</td>
<td>B</td>
</tr>
<tr>
<td>18</td>
<td>B</td>
<td>44</td>
<td>C</td>
</tr>
<tr>
<td>19</td>
<td>A</td>
<td>45</td>
<td>B</td>
</tr>
<tr>
<td>20</td>
<td>D</td>
<td>46</td>
<td>A</td>
</tr>
<tr>
<td>21</td>
<td>B</td>
<td>47</td>
<td>D</td>
</tr>
<tr>
<td>22</td>
<td>A</td>
<td>48</td>
<td>A</td>
</tr>
<tr>
<td>23</td>
<td>B</td>
<td>49</td>
<td>A</td>
</tr>
<tr>
<td>24</td>
<td>C</td>
<td>50</td>
<td>B</td>
</tr>
<tr>
<td>25</td>
<td>D</td>
<td>51</td>
<td>E</td>
</tr>
<tr>
<td>26</td>
<td>C</td>
<td>52</td>
<td>C</td>
</tr>
<tr>
<td>27</td>
<td>D</td>
<td>53</td>
<td>B</td>
</tr>
<tr>
<td>28</td>
<td>A</td>
<td>54</td>
<td>D</td>
</tr>
<tr>
<td>29</td>
<td>C</td>
<td>55</td>
<td>C</td>
</tr>
<tr>
<td>30</td>
<td>C</td>
<td>56</td>
<td>C</td>
</tr>
<tr>
<td>31</td>
<td>C</td>
<td>57</td>
<td>D</td>
</tr>
<tr>
<td>32</td>
<td>$3H_2SO_4 + 2Al(OH)_3 \rightarrow 2Al_2(SO_4)_3 + 6H_2O$</td>
<td>58</td>
<td>D</td>
</tr>
<tr>
<td>33</td>
<td>$2HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2H_2O$</td>
<td>59</td>
<td>E</td>
</tr>
<tr>
<td>34</td>
<td>$2H_3PO_4 + 3Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6H_2O$</td>
<td>60</td>
<td>E</td>
</tr>
<tr>
<td>35</td>
<td>$HNO_3 + NH_4OH \rightarrow NH_4NO_3 + H_2O$</td>
<td>61</td>
<td>C</td>
</tr>
<tr>
<td>36</td>
<td>D</td>
<td>62</td>
<td>D</td>
</tr>
<tr>
<td>37</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>B</td>
<td></td>
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<tr>
<td>44</td>
<td>C</td>
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<td>45</td>
<td>B</td>
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<tr>
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<td>A</td>
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</tr>
<tr>
<td>47</td>
<td>D</td>
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</tbody>
</table>
Conceptual Questions Answers:

<p>| | | | | |</p>
<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>1B</td>
<td>8C</td>
<td>15A</td>
<td>22B</td>
<td>29D</td>
</tr>
<tr>
<td>2B</td>
<td>9D</td>
<td>16B</td>
<td>23C</td>
<td></td>
</tr>
<tr>
<td>3C</td>
<td>10C</td>
<td>17D</td>
<td>24B</td>
<td></td>
</tr>
<tr>
<td>4D</td>
<td>11C</td>
<td>18C</td>
<td>25E</td>
<td></td>
</tr>
<tr>
<td>5A</td>
<td>12A</td>
<td>19E</td>
<td>26B</td>
<td></td>
</tr>
<tr>
<td>6B</td>
<td>13D</td>
<td>20B</td>
<td>27A</td>
<td></td>
</tr>
<tr>
<td>7A</td>
<td>14D</td>
<td>21D</td>
<td>28C</td>
<td></td>
</tr>
</tbody>
</table>
Write the completed balanced equation for the following reactions:

1) \( \text{H}_2\text{SO}_4 + \text{Al(OH)}_3 \rightarrow \)

2) \( \text{HCl} + \text{Mg(OH)}_2 \rightarrow \)

3) \( \text{H}_3\text{PO}_4 + \text{Ca(OH)}_2 \rightarrow \)

4) \( \text{HNO}_3 + \text{NH}_4\text{OH} \rightarrow \)

4) Calculate the concentration of hydrochloric acid if 30 ml of this acid is neutralized by 40 ml of 0.010M sodium hydroxide.

5) Calculate the concentration of sulfuric acid if 60.0 ml of this acid is neutralized by 10.0 ml of 0.010M sodium hydroxide.

6) What volume of 0.3M \( \text{H}_2\text{SO}_4 \) is required to titrate 90 ml of 0.4M \( \text{NaOH} \) to the end point?

7) How many ml of water needs to be added to make 500ml of 3M \( \text{HCl} \) from a stock solution of 250mL of the acid which is 6M ?

8) Predict the following salt solutions will be acidic, basic or neutral. Also fill in the rest of the table regarding the parent acid and base from which they were formed.

<table>
<thead>
<tr>
<th>Salt</th>
<th>Parent acid</th>
<th>Parent base</th>
<th>Type of solution (Basic or acidic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{NH}_4\text{NO}_3 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{Na}_3\text{PO}_4 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{NH}_4\text{F} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{CuI}_2 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{SrSO}_4 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{Li(CH}_3\text{COO)} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{Ba}_3(\text{PO}_4)_2 )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( \text{Ka of HF} = 3.5 \times 10^{-4}, \quad \text{Kb of NH}_3 = 1.8 \times 10^{-5} \)
Free response

1) The overall dissociation of oxalic acid, H$_2$C$_2$O$_4$, is represented below. The overall dissociation constant is also indicated.

\[
H_2C_2O_4 \leftrightarrow 2 H^+ + H_2C_2O_4^{2-} \quad K = 3.78 \times 10^{-6}
\]

(a) What volume of 0.400-molar NaOH is required to neutralize completely a 5.00 x $10^{-3}$ mole sample of pure oxalic acid?

(b) Give the equations representing the first and second dissociations of oxalic acid. Calculate the value of the first dissociation constant, $K_1$, for oxalic acid if the value of the second dissociation constant, $K_2$, is $6.40 \times 10^{-5}$.

(c) To a 0.015-molar solution of oxalic acid, a strong acid is added until the pH is 0.5. Calculate the [C$_2$O$_4^{2-}$] in the resulting solution. (Assume the change in volume is negligible.)

(d) Calculate the value of the equilibrium constant, $K_b$, for the reaction that occurs when solid Na$_2$C$_2$O$_4$ is dissolved in water.

2) A buffer solution contains 0.40 mole of formic acid, HCOOH, and 0.60 mole of sodium formate, HCOONa, in 1.00 liter of solution. The ionization constant, $K_a$, of formic acid is $1.8 \times 10^{-4}$.

(a) Calculate the pH of this solution.

(b) If 100 milliliters of this buffer solution is diluted to a volume of 1.00 liter with pure water, the pH does not change. Discuss why the pH remains constant on dilution.

(c) A 5.00 milliliter sample of 1.00 molar HCl is added to 100 milliliters of the original buffer solution. Calculate the [H$_3$O$^+$] of the resulting solution.

(d) A 800 milliliter sample of 2.00-molar formic acid is mixed with 200 milliliters of 4.80-molar NaOH. Calculate the [H$_3$O$^+$] of the resulting solution.

3) A volume of 30.0 ml of 0.10M NH$_3$ is titrated with 0.20M HCl. The value of the base dissociation constant, $K_b$ for NH$_3$ in water is $1.8 \times 10^{-5}$.

(a) Write the net ionic equation for the reaction of NH$_3$ with HCl

(b) Using the axes provided below, sketch the titration curve that results when a total of 40ml of 0.20M HCl is added drop wise to the 30ml volume of 0.10M NH$_3$
(c) From the table below, select the most appropriate indicator for the titration. Justify your answer.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>pKₐ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl red</td>
<td>5.5</td>
</tr>
<tr>
<td>Bromothymol blue</td>
<td>7.1</td>
</tr>
<tr>
<td>Phenolphalein</td>
<td>8.7</td>
</tr>
</tbody>
</table>

(d) If equal volumes of 0.10 M NH₃ and 0.10M NH₄Cl are mixed, is the resulting solution acidic, basic or neutral? Explain.

4) \[ \text{HOCl} \leftrightarrow \text{OCl}^- + \text{H}^+ \]
Hypochlorous acid, HOCl is a weak acid commonly used as a bleaching agent. The acid dissociation constant \( K_a = 3.2 \times 10^{-8} \)

a) Calculate the \([\text{H}^+]\) of a 0.14 M solution of HCl.

b) Write the correctly balanced net ionic equation for the reaction that occurs when NaOCl is dissolved in water and calculate the numerical value of the equilibrium constant for the reaction.

c) Calculate the pH of a solution made by combining 40ml of 0.14M HOCl and 10.0 ml of 0.56M NaOH

d) How many millimoles of solid NaOH must be added to 50ml of 0.20M HOCl to obtain a buffer that has a pH of 7.49? Assume that the addition of the solid NaOH results in a negligible change in volume.

e) House hold bleach is made by dissolving chlorine gas in water.
\[ \text{Cl}_2 (g) + \text{H}_2\text{O} \rightarrow \text{Cl}^- + \text{HOCl} \text{ (aq)} \]
Calculate the pH of such a solution if the concentration of HOCl in the solution is 0.065M.

5) Answer the following questions that relate to the chemistry of halogen oxoacids.
(a) Use the information in the table below to answer part (a)(i).
Acid | $K_a$ at 298 K
---|---
HOCl | $2.9 \times 10^{-8}$
HOBr | $2.4 \times 10^{-9}$

i. Which of the two acids is stronger, HOCl or HOBr? Justify your answer in terms of $K_a$.

ii. Draw a complete Lewis electron-dot diagram for the acid that you identified in part (a)(i).

iii. Hypoiodous acid has the formula HOI. Predict whether HOI is a stronger acid or a weaker acid than the acid that you identified in part (a)(i). Justify your prediction in terms of chemical bonding.

(b) Write the equation for the reaction that occurs between hypochlorous acid and water.

(c) A 1.2 $M$ NaOCl solution is prepared by dissolving solid NaOCl in distilled water at 298 K. The hydrolysis reaction $\text{OCl}^-(aq) + \text{H}_2\text{O}(l) \leftrightarrow \text{HOCl}(aq) + \text{OH}^-(aq)$ occurs.

i. Write the equilibrium-constant expression for the hydrolysis reaction that occurs between $\text{OCl}^-(aq)$ and $\text{H}_2\text{O}(l)$.

ii. Calculate the value of the equilibrium constant at 298 K for the hydrolysis reaction.

iii. Calculate the value of $[\text{OH}^-]$ in the 1.2 $M$ NaOCl solution at 298 K.

(d) A buffer solution is prepared by dissolving some solid NaOCl in a solution of HOCl at 298 K. The pH of the buffer solution is determined to be 6.48.

i. Calculate the value of $[\text{H}_3\text{O}^+]$ in the buffer solution.

ii. Indicate which of HOCl$(aq)$ or OCl$^-(aq)$ is present at the higher concentration in the buffer solution. Support your answer with a calculation.

6) A pure 14.85 g sample of the weak base ethylamine, C$_2$H$_5$NH$_2$, is dissolved in enough distilled water to make 500. mL of solution.

(a) Calculate the molar concentration of the C$_2$H$_5$NH$_2$ in the solution.

The aqueous ethylamine reacts with water according to the equation below.

$\text{C}_2\text{H}_5\text{NH}_2(aq) + \text{H}_2\text{O}(l) \leftrightarrow \text{C}_2\text{H}_5\text{NH}_3^+(aq) + \text{OH}^-(aq)$

(b) Write the equilibrium-constant expression for the reaction between C$_2$H$_5$NH$_2$ (aq) and water.

(c) Of C$_2$H$_5$NH$_2$ (aq) and C$_2$H$_5$NH$_3^+$ (aq), which is present in the solution at the higher concentration at equilibrium? Justify your answer.

(d) A different solution is made by mixing 500. mL of 0.500 $M$ C$_2$H$_5$NH$_2$ with 500. mL of 0.200 $M$ HCl. Assume that volumes are additive. The pH of the resulting solution is found to be 10.93.

i. Calculate the concentration of OH$^-(aq)$ in the solution.

ii. Write the net-ionic equation that represents the reaction that occurs when the C$_2$H$_5$NH$_2$ solution is mixed with the HCl solution.

iii. Calculate the molar concentration of the C$_2$H$_5$NH$_3^+$ (aq) that is formed in the reaction.

iv. Calculate the value of $K_b$ for C$_2$H$_5$NH$_2$. 

Lactic acid, HC₃H₅O₃, is a monoprotic acid that dissociates in aqueous solution, as represented by the equation above. Lactic acid is 1.66 percent dissociated in 0.50 M HC₃H₅O₃ (aq) at 298 K. For parts (a) through (d) below, assume the temperature remains at 298 K.

(a) Write the expression for the acid-dissociation constant, $K_a$, for lactic acid and calculate its value.

(b) Calculate the pH of 0.50 M HC₃H₅O₃.

(c) Calculate the pH of a solution formed by dissolving 0.045 mole of solid lactate, NaC₃H₅O₃, in 250 mL of 0.50 M HC₃H₅O₃. Assume that volume change is negligible.

(d) A 100mL sample of 0.10 M HCl is added to 100 mL of 0.50 M HC₃H₅O₃. Calculate the molar concentration of lactate ion, C₃H₅O₃⁻, in the resulting solution.
Answers:

1) \[3H_2SO_4 + 2 Al(OH)_3 \rightarrow Al_2(SO_4)_3 + 6H_2O\]

2) \[2HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2H_2O\]

3) \[2H_3PO_4 + 3Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6H_2O\]

4) \[HNO_3 + NH_4OH \rightarrow NH_4NO_3 + H_2O\]

5) Calculate the concentration of hydrochloric acid if 30 ml of this acid is neutralized by 40 ml of 0.010M sodium hydroxide. = 0.013M

6) Calculate the concentration of sulfuric acid if 60.0 ml of this acid is neutralized by 10.0 ml of 0.010M sodium hydroxide. = 0.00083M

7) What volume of 0.3M H_2SO_4 is required to titrate 90 ml of 0.4M NaOH? = 60 ml

8) How many ml of water needs to be added to make 500ml of 3M HCl from a stock solution, which is 6M. = 250 ml acid + 250mL water

9) Predict the following salt solutions will be acidic, basic or neutral. Also fill in the rest of the table regarding the parent acid and base from which they were formed.

<table>
<thead>
<tr>
<th>Salt</th>
<th>Parent acid</th>
<th>Parent base</th>
<th>Type of solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl</td>
<td>Hydrochloric</td>
<td>KOH</td>
<td>N</td>
</tr>
<tr>
<td>NH_4NO_3</td>
<td>Nitric</td>
<td>Ammonia</td>
<td>A</td>
</tr>
<tr>
<td>Na_3PO_4</td>
<td>phosphoric</td>
<td>NaOH</td>
<td>N</td>
</tr>
<tr>
<td>NH_4 F</td>
<td>hydrofluoric</td>
<td>ammonia</td>
<td>A (acid is stronger than base : Ka &gt; Kb)</td>
</tr>
<tr>
<td>CuI_2</td>
<td>hydroiodic</td>
<td>Cu(OH)_2</td>
<td>A</td>
</tr>
<tr>
<td>SrSO_4</td>
<td>sulfuric</td>
<td>Sr(OH)_2</td>
<td>N</td>
</tr>
<tr>
<td>Li(CH_3COO)</td>
<td>acetic</td>
<td>LiOH</td>
<td>B</td>
</tr>
<tr>
<td>Ba_3(PO_4)_2</td>
<td>phosphoric</td>
<td>Ba(OH)_2</td>
<td>N</td>
</tr>
</tbody>
</table>

Free response

1) 
   (a) \[M_1V_1 = (M_2V_2)\]
\[(0.4)(V) = (5 \times 10^{-3})2\]
\[V = 0.025 L = 25 mL\]

(b) Eq 1: \[H_2C_2O_4 \leftrightarrow H^+ + HC_2O_4^-\] \[K_1\]
Eq 2: \[HC_2O_4^- \leftrightarrow H^+ + C_2O_4^{2-}\] \[K_2\]
(c) \( pH = 0.5 \)  
\[ [H^+] = - \log 0.50 = 0.316 \text{ M} \]
\[ 3.78 \times 10^{-6} = [H^+]^2[C_2O_4^{2-}] = x(0.316)^2 = 5.6 \times 10^{-7} \text{ M} \]
\[ \frac{[H_2C_2O_4]}{(0.015-x)} \]

(d) \[ K_b = 1 \times 10^{-14} = 1.56 \times 10^{-10} \]
\[ \frac{6.4 \times 10^{-5}}{ \text{(d)} } \]

2)
(a) Use the Henderson-Hasselbalch equation:
\[ pH = pK_a + \log \frac{[A^-]}{[HA]} \]
\[ pH = -\log(1.8 \times 10^{-4}) + \log (0.6/0.4) = 3.92 \]
(b) The pH remains unchanged because the ratio of the formate and formic acid concentration stays the same.
(c) Initial concentrations
\[
\begin{align*}
1.00 \text{ M HCl} \times (5.00\text{mL}/105\text{mL}) &= 0.0476 \\
0.40 \text{ M HCOOH} \times (100\text{mL}/105\text{mL}) &= 0.38 \text{ M} \\
0.60 \text{ M HCOO}^- \times (100\text{mL}/105\text{mL}) &= 0.57 \text{ M}
\end{align*}
\]
Concentrations after \( H^+ \) reacts with \( HCOO^- \)
\[
\begin{align*}
0.38 \text{ M} + 0.05 \text{ M} &= 0.43 \text{ M HCOOH} \\
0.57 \text{ M} - 0.05 \text{ M} &= 0.52 \text{ M HCOO}^- \\
[\text{H}_2\text{O}^+] &= 1.8 \times 10^{-4} \times (0.43\text{M}/0.52\text{M}) = 1.5 \times 10^{-4} \text{ M}
\end{align*}
\]
(d) \[
\begin{align*}
0.800\text{L} \times 2.00\text{M HCOOH} &= 1.60 \text{ mol} \\
0.200\text{L} \times 4.80\text{M NaOH} &= 0.96 \text{ mol OH}^- \\
at equilibrium: (1.60 - 0.96) &= 0.64 \text{ mol HCOOH} \text{ and } 0.96 \text{ mol HCOO}^- \\
[\text{H}_2\text{O}^+] &= 1.8 \times 10^{-4} \times (0.64\text{M}/0.96\text{M}) = 1.2 \times 10^{-4} \text{ M}
\end{align*}
\]

3)
(a) \( \text{NH}_3(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq}) \)
OR
\( \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(l) \)

(b)
(c) Methyl Red would be the best choice for the indicator because the pKₐ for Methyl Red is closest to the pH at the equivalence point.

(d) The resulting solution is basic. Kₖ for NH₃ (1.8x10⁻⁵) and the Kₐ for NH₄⁺ (5.6x10⁻¹⁰) indicate that is NH₃ a stronger base than NH₄⁺.

\[
\text{OR} \\
[\text{OH}^-] = K_b = 1.8 \times 10^{-5} \text { because of equimolar and equal volume amounts of ammonia and ammonium ion, cancellation of } [\log A/B] \text { component in the buffer pH calculation. Thus } pOH \approx 5 \text { and } pH \approx 9 \text { (i.e., recognition of buffer, so that } \log(.05/.05) = 0, pOH = pK_b \approx 5, \text { pH } = 14 - pOH \approx 9) 
\]

4)

(a) \[ [H^+] = [OCl^-] = (0.14 \times 3.2 \times 10^{-8})^{1/2} = 6.7 \times 10^{-5} \text{ M} \]

(b) \[ \text{OCl}^- + H_2O \leftrightarrow \text{HOCl} + \text{OH}^- \]

\text{OR}

\[ \text{NaOCl} + H_2O \rightarrow \text{Na}^+ + \text{HOCl} + \text{OH}^- \]

\[ K_b = K_w / K_a = (1 \times 10^{-14} / 3.2 \times 10^{-8}) = 3.1 \times 10^{-7} \]

(c) \[ [\text{HOCl}] = [(0.0400) (0.14)] / 0.050 = 0.11 \text{ M} \]

\[ [\text{OH}^-] = [(0.0100) (0.56)] / 0.050 = 0.11 \text{ M} \]

Thus reaction is essentially complete and exactly equals a solution of NaOCl and [OCl⁻] = 0.11 M (or reaction is at equivalence point).

Then

\[ [\text{OH}^-] = [\text{HOCl}] \]

\[ K_b = [\text{OH}^-]^2 / [\text{HOCl}] = 3.1 \times 10^{-7} \]

\[ [\text{OH}^-] = [(0.11) (3.1 \times 10^{-7})]^{1/2} = 1.8 \times 10^{-4} \]

\[ pOH = 3.73 \]

\[ pH = 14 - 3.73 = 10.27 \]

(d) \[ pH = 7.49 \text{ therefore } [H^+] = 3.2 \times 10^{-8} \]

\[ pH = pK_a, \text{ or } [H^+] = K_a. \]

So \[ [\text{OCl}^-] / [\text{HOCl}] = 1 \], or solution must be half neutralized.

\[ \text{initial mmol HOCl} = 50.0 \times 0.20 = 10.0 \text{ mmol} \]

\[ \text{mmol NaOH required} = 10.0 / 2 = 5.0 \text{ mmol} \]

(e) From equation, 1 mol H⁺ produced for each 1 mole of HOCl produced, thus \[ [H^+] = [\text{HOCl}] = 0.065 \text{ therefore } pH = 1.19 \]

5)

(a) HOCl is the stronger acid because its Kₐ value is greater than the Kₐ value of HOBr.

(ii) \[ H : O : Cl : \]

(iii) HOI is a weaker acid than HOCl because the O—H bond in HOCl. The lower electronegativity of I compared with that of Cl results in an electron density that is higher (hence a bond that is stronger) between the H and O atoms in HOI compared with the electron density between the H and O atoms in HOCl.

\text{OR}
The conjugate base OCl\(^-\) is more stable than OI\(^-\) because Cl\(_2\), being more electronegative, is better able to accommodate the negative charge.

(b) \(\text{HOCl} + \text{H}_2\text{O} \leftrightarrow \text{OCl}^- + \text{H}_3\text{O}^+\)

OR

\(\text{HOCl} \leftrightarrow \text{OCl}^- + \text{H}^+\)

(ci) \(K_b = \frac{[\text{HOCl}][\text{OH}^-]}{[\text{OCl}^-]}\)

(ii) \(K_b = \frac{K_w}{K_a} = \frac{(1.0 \times 10^{-14})/2.9 \times 10^{-8}}{3.4 \times 10^{-7}} = 3.4 \times 10^{-7}\)

(iii) \(K = \frac{(x)(x)}{(1.2-x)} = x^2/1.2\)

\(x = [\text{OH}^-] = 6.4 \times 10^{-4} \text{ M}\)

(dii) \([\text{H}^+] = 10^{-6.48} = 3.3 \times 10^{-7} \text{ M}\)

(ii) \(K_a = \frac{[\text{H}^+][\text{OCl}^-]}{[\text{HOCl}]} = 2.9 \times 10^{-8}\)

\(\frac{[\text{OCl}^-]}{[\text{HOCl}]} = \frac{2.9 \times 10^{-8}}{3.3 \times 10^{-7}} = 0.088 \Rightarrow [\text{HOCl}] > [\text{OCl}^-]\)

(c) \(\text{C}_2\text{H}_5\text{NH}_2\) is present in the solution at the higher concentration at equilibrium. Ethylamine is a weak base, and thus it has a small \(K_b\) value. Therefore, only partial dissociation of \(\text{C}_2\text{H}_5\text{NH}_2\) occurs in water, and \([\text{C}_2\text{H}_5\text{NH}_3^+]\) is thus less than \([\text{C}_2\text{H}_5\text{NH}_2]\).

(dii) \(\text{pH} = -\log[\text{H}^+]\)

\([\text{H}^+] = 10^{-10.93} = 1.17 \times 10^{-11}\)

\([\text{OH}^-] = K_w / [\text{H}^+] = 8.5 \times 10^{-4} \text{ M}\)

OR

\(\text{pOH} = 14 - \text{pH} = 3.07\)

\([\text{OH}^-] = 10^{-3.07} = 8.5 \times 10^{-4}\)

(ii) \(\text{C}_2\text{H}_5\text{NH}_2 + \text{H}_3\text{O}^+ \leftrightarrow \text{C}_2\text{H}_5\text{NH}_3^+ + \text{H}_2\text{O}\)

(iii) moles of \(\text{C}_2\text{H}_5\text{NH}_2\) = \((0.5 \times 0.5 \text{ mol} / 1 \text{ L}) = 0.250 \text{ mol}\)

Moles of \(\text{H}_3\text{O}^+ = (0.5 \times .2 \text{ mol} / 1 \text{ L}) = 0.100 \text{ mol}\)

\[
\begin{array}{|c|c|c|}
\hline
& [\text{C}_2\text{H}_5\text{NH}_2] & [\text{H}_3\text{O}^+] & [\text{C}_2\text{H}_5\text{NH}_3^+] \\
\hline
\text{Initial} & 0.250 & 0.100 & \approx 0 \\
\text{Change} & -0.100 & -0.100 & +0.100 \\
\text{Final Value} & 0.150 & \approx 0 & 0.100 \\
\hline
\end{array}
\]

(iv) \([\text{C}_2\text{H}_5\text{NH}_2] = 0.150 \text{ M}\)

\(K_b = \frac{[\text{C}_2\text{H}_5\text{NH}_3^+][\text{OH}^-]}{[\text{C}_2\text{H}_5\text{NH}_2]} = \frac{(0.1)(8.5 \times 10^{-4})}{0.150} = 5.67 \times 10^{-4}\)

7)

a) \(K_a = [\text{H}^+][\text{C}_3\text{H}_5\text{O}_3^-] ; 0.50 \text{ m } \times 0.0166 = 0.0083 \text{ M} = x\)
\[ [\text{HC}_3\text{H}_5\text{O}_3] \]

\[
\text{HC}_3\text{H}_5\text{O}_3 \leftrightarrow \text{H}^+ + \text{C}_3\text{H}_5\text{O}_3^- \\
0.50 \quad 0 \quad 0 \\
-x \quad +x \quad +x \\
0.50 -x \quad x \quad x
\]

\[ K_a = \frac{[\text{H}^+][\text{C}_3\text{H}_5\text{O}_3^-]}{[\text{HC}_3\text{H}_5\text{O}_3]} = \frac{0.0083}{0.50 - 0.0083} = 1.4 \times 10^{-4} \\
\]

b) \[ [\text{H}^+] = 0.0083 \text{ M} ; \text{pH} = -\log(0.0083 \text{ M}) = 2.08 \]

c) 0.045 mol NaC\text{H}_3\text{H}_5\text{O}_3/ 0.250 \text{ L} = 0.18 \text{ M C}_3\text{H}_5\text{O}_3^- \\
\[ K_a = \frac{[\text{H}^+][\text{C}_3\text{H}_5\text{O}_3^-]}{[\text{HC}_3\text{H}_5\text{O}_3]} = 1.4 \times 10^{-4} = [\text{H}^+][0.18] ; [\text{H}^+] = 3.9 \times 10^{-4} ; \text{pH} = 3.41 \\
\]

\[ \frac{[\text{HC}_3\text{H}_5\text{O}_3]}{[0.50]} \]

OR

\[ \text{pH} = pK_a + \log \left( \frac{0.18}{0.50} \right) = 3.41 \]

d) 0.50 M HC\text{H}_3\text{H}_5\text{O}_3 (100mL/200mL) = 0.25 M HC\text{H}_3\text{O}_3 \\
0.10 M \text{HCl (100mL/200mL) = 0.50 M H}^+ \\
\text{HC}_3\text{H}_5\text{O}_3 \leftrightarrow \text{H}^+ + \text{C}_3\text{H}_5\text{O}_3^- \\
0.25 \quad 0.050 \quad 0 \\
-x \quad +x \quad +x \\
0.25 -x \quad 0.05 + x \quad x
\]

\[ K_a = \frac{[\text{H}^+][\text{C}_3\text{H}_5\text{O}_3^-]}{[\text{HC}_3\text{H}_5\text{O}_3]} = \frac{0.05 + x}{0.25 - x} ; \text{Assume } x << 0.050 \text{ M} \\
\]

\[ K_a = 1.4 \times 10^{-4} = \frac{0.050[x]}{0.25} ; x = 7.0 \times 10^{-4} \text{ M} = [\text{C}_3\text{H}_5\text{O}_3^-] \\
\]