You are allowed 2 consecutive hours (no cutting classes) for this test. You may use your calculator but NO extra "scratch paper". Use the back of pages if necessary.

LECTURE: Multiple Choice -- (36 pts) 3 points each.
Choose the BEST answer and write the letter in the left margin next to the question.

1. We have used the term counter ion. Which of the following is true for a counter ion?
   a) It is a base
   b) It is the "leftover" part of a weak acid
   c) It is the "leftover" part of a strong acid or a strong base
   d) It is negatively charged
   e) It can neither compete for nor lose a proton
   f) none of the above
   g) two of the above

2. Suppose you were to add solid NaCl and solid (NH₄)₂SO₄ to water in a beaker. After the salts dissolve completely, you boil the water to evaporate all of the water. What would be left in the beaker?
   a) nothing — everything would evaporate
   b) NaCl and (NH₄)₂SO₄
   c) NH₄Cl and Na₂SO₄
   d) NaCl, (NH₄)₂SO₄, NH₄Cl, Na₂SO₄, and Na(NH₄)SO₄
   e) Na⁺, NH₄⁺, Cl⁻, and SO₄²⁻ ions

3. Which of the following values is inconsistent with the other values?
   a) pH = -0.54
   b) [H₃O⁺] = 3.5 M
   c) pOH = 14.46
   d) [OH⁻] = 2.9x10⁻¹⁵ M
   e) All the values are consistent with each other

4. Which of the following would not ever appear on the pH line?
   b) A polyprotic strong acid such as H₂SO₄ with a concentration expressed in Normality. Solutions expressed in normalities cannot be made to fit on a pH line.
   c) The equivalence point if a strong base is titrated with a strong acid
   d) The equivalence point if a weak base is titrated with a strong acid
   e) All the above systems can be made to fit on a pH line.

5. In the complex ion Cu(NH₃)₄²⁺ the ligand is:
   a) Cu
   b) Cu²⁺
   c) N
   d) NH₃
   e) (NH₃)₄²⁺
6. In the titration of a weak acid HA with NaOH solution, what reaction sets the pH at the equivalence point?
   a) HA + H₂O ⇄ A⁻ + H₃O⁺
   b) A⁻ + H₂O ⇄ HA + OH⁻
   c) HA + OH⁻ ⇄ H₂O + A⁻
   d) H₂O + H₂O ⇄ H₃O⁺ + OH⁻

7. For which of the following cases must the indicated glassware be both clean AND dry to avoid introducing error into the analysis?
   a) the beakers in which you obtain your vinegar samples from the Kindly Old Professor
   b) the titration flask to which you add your unknown KHP sample
   c) the volumetric flask into which you transfer 25.00 mL of your original vinegar sample
   d) the pipet you use to transfer the original vinegar sample to the volumetric flask. A wet pipet will dilute the original vinegar sample.
   e) All of the above
   f) Two of the above

8. Many local anesthetics are weak bases. Which of the following is the weakest base?
   a) phenol, Kᵦ = 1.0x10⁻²
   b) benzocaine, pKᵦ = 5.50
   c) cocaine, pKᵦ = 5.39
   d) lidocaine, Kᵦ = 6.3x10⁻⁷

9. Which of the following can be characterized as the “parent” of a polyprotic acid family?
   a) HOAc
   b) H₂CO₃
   c) NH₃
   d) H₃PO₄
   e) The “zwitterionic” form of EDTA
   f) Three of the above
   g) Two of the above
   h) Four of the above

10. In the process of diluting 25.00 mL of your original vinegar sample to 250.00 mL in a volumetric flask, you accidentally add water so that the meniscus is above the mark on the flask. If you continue with the determination, which of the following is true?
    a) you have not changed the number of mmoles of HOAc in the volumetric flask, so you have not introduced any error
    b) the resulting %HOAc will be erroneously low
    c) the resulting %HOAc will be erroneously high
    d) you no longer know the concentration of the HOAc to high quality in the volumetric flask, but that will be OK because ultimately you’ll only need to report two digits of information as your final %HOAc
11. Which of the following is true of the titration of a strong acid with a strong base AND the titration of a weak acid with a strong base?
   a) pH at the equivalence point is calculated using a $K_a$ value
   b) pH of the solution increases as the titration proceeds
   c) pH at 100.1% titration is determined using a “direct” calculation
   d) major amounts of both the acid and the conjugate base are present at 50% titration
   e) three of the above
   f) two of the above

12. Which of the following could be used to express the concentration of species X in a solution, whether for calculation purposes or not?
   a) mmoles X/ mL of solution
   b) grams X/ liter of solution
   c) ppm X
   d) Normality of X
   e) Grams X / grams of solution
   f) All of the above
   g) 3 of the above

DEFINE OR EXPLAIN (39 pts):
1. (12 pts) List 4 of the 6 requirements which must be met for a titration to be successful

2. (17 pts) A critical stage in any titration occurs at the equivalence point. In that sense the following 4 terms are very important. Define each of these terms, showing how they interrelate to each other.
   a) equivalence point
   b) end point
   c) region of 0.1% accuracy
   d) indicator window
e) If you were to go and carry out a titration of a strong acid, such as HCl, with a standardized NaOH titrant, you would undoubtedly be told in the recipe to add phenolphthalein as your indicator. It is known that phenolphthalein has an indicator window of 8-10. Using the concepts and terms introduced above (parts a) thru d) of this question), what is the apparent difficulty in using phenolphthalein as the choice of indicator? How do you explain that this indicator is almost universally used in this kind of titration, given this possible difficulty?

2. (10 pts) In talking about complex ions, we have introduced the terms monodentate and polydentate ligands
   a) define each of these terms

   b) explain clearly why monodentate ligands are NOT suitable for use in a titration.
The following table contains information which may be needed in the set of problems below:

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<th>Name</th>
<th>Formula</th>
<th>MW</th>
<th>Other</th>
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<td>HOAc</td>
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<td>pK_a = 4.74</td>
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<td>pK_b = 4.75</td>
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<td>CH_3NH_2</td>
<td>33.00</td>
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<td>Methyl ammonium benzoate</td>
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<tr>
<td>Hydrochloric Acid</td>
<td>HCl</td>
<td>36.50</td>
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1. (42 pts) For the following Acid/Base systems described below, determine the pH in each case:
   a) 50.00 mL of 0.15 M Benzoic Acid to which is added 75.00 mL of 0.10 M Sodium Benzoate

   b) 50.00 mL of 0.15 M Benzoic Acid to which is added 75.00 mL of 0.10 M Sodium Hydroxide

   c) 70.00 mL of 0.20 M Sodium Hydroxide to which is added 100.0 mL of 0.12 M Hydrochloric Acid

   d) 70.00 mL of 0.20 N Sulfuric Acid which is diluted to a final volume of 100.00 mL with a 0.10 M solution of Potassium Chloride
f) 25.00 mL of 0.25 M Methyl ammonium benzoate diluted to a final volume of 250.00 mL in a volumetric flask

g) 10.00 mL of Concentrated HCl diluted to 2000 mL. (NOTE: Concentrated HCl has an assay value of 37.3% (w/w) and a specific gravity of 1.19)

2. (8 pts) In performing your vinegar determination in the laboratory, you or your partner inadvertently take a 500.00 mL volumetric flask out of the cabinet instead of the 250.00 mL volumetric flask called for in the recipe. Thus, when you dilute the 25.00 mL sample of original vinegar solution given to you by the Kindly Old Professor (it’s actually HIS fault you’ve got the wrong flask; if he had labeled things better, you’d not be in this mess) you are diluting the original 25.00 mL of vinegar sample up to 500.00 mL instead of the called-for 250.00 mL. You take 50.00 mL of this diluted solution and titrate it with your NaOH solution. It takes 19.11 mL of standardized 0.1023 M NaOH to reach a satisfactory end point.

a) Is the determination of the %HOAc ruined by the use of the wrong flask? Explain your reasoning clearly, pointing out the effect on your results of having used the wrong volumetric flask.

b) Calculate the %HOAc (w/v) in the sample

c) BONUS -- 3 pts -- What, if anything, could you have done prior to actually titrating the diluted sample (starting over is NOT an option) to undo the misstep incurred with the use of the wrong volumetric flask, so that your titration data would have turned the same as if you HAD used the proper (250.00 mL) volumetric flask?

Please write and sign the pledge: