CH 302 Spring 2007 Practice Exam 2

1. Which of the following is **not** a strong acid?
   a. HCl
   b. H_2SO_4
   c. $HClO_4$
   d. H_2CO_3
   e. $HClO_3$

2. What is the pH of a buffer made up of 0.5 M pyridine (C_5H_5N) and 0.75 M $C_5H_5NH^+$? The pK_b of pyridine is 8.70.
   a. 8.9
   b. 6.4
   c. 5.1
   d. 7.6
   Answer: This shouldn't require any real calculation.

3. Which of the following systems produces a buffer?
   I. 0.5 M CH_3COOH and 0.5 M $NaCH_3COO$
   II. 0.5 M CH_3COOH, 1.0 M $NaCH_3COO$, and 0.25 M $Ba(OH)_2$
   III. 0.75 M CH_3COOH and 0.5 M NaOH
   IV. 1.0 M Na^+ and 1.0 M NaOH
   V. 0.5 M CH_3COOH, 1.0 M $NaCH_3COO$, and 0.5 M HCl
   a. I, II, III, IV, and IV
   b. None of them
   c. I, III, and V only
   d. I only
   e. I, II, and IV only
   f. I and II only
   Answer: Remember to neutralize.

4. Rank the following compounds in terms of increasing basicity.

Compound	pK_b
$C_6H_5NH_2$	9.38
NH_3	4.74
$HONH_2$	8.18
$(CH_3)N$	4.13
CH_3NH_2	3.30

   a. $C_6H_5NH_2 < HONH_2 < NH_3 < (CH_3)N < CH_3NH_2$
   b. $CH_3NH_2 < (CH_3)N < NH_3 < HONH_2 < C_6H_5NH_2$
   c. $C_6H_5NH_2 < HONH_2 < (CH_3)N < NH_3 < CH_3NH_2$
   d. $CH_3NH_2 < NH_3 < (CH_3)N < HONH_2 < C_6H_5NH_2$
   Answer: Remember that larger K_b => smaller pK_b

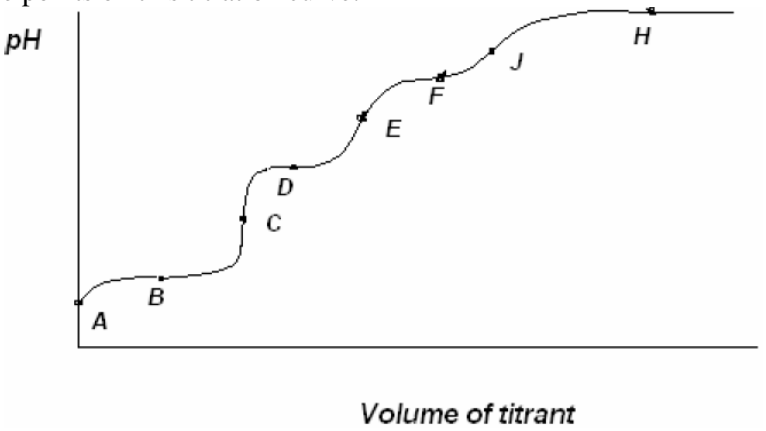
5. What is the buffer capacity of a buffer made up of 1.2 M CH_3NH_2 and 1.4 M $CH_3NH_3^+$? For CH_3NH_2, pK_b = 3.3.
   a. 1.4 M for H^+, 1.2 M for OH^-
   b. 1.2 M for H^+, 1.4 M for OH^-
   c. 0.2 M for H^+, 0.2 M for OH^-
   d. 2.6 M for H^+, 2.6 M for OH^-
   Answer: The CH_3NH_2 can react with 1.2 M of H^+; the $CH_3NH_3^+$ can react with 1.4 M OH^-.

6. 100 mL of 1.5 M HCN (pK_a = 9.40) and 75 mL of 2.5 M CN^- are mixed together, and 2 g of NaOH are added. What is the final pH?
   a. 4.60
   b. 9.13

c. 9.40
d. 9.77
e. 13.25

Answer: This shouldn't require any real calculation.

7. Identify the equivalence points on this titration curve.



a. B, D, F, and H
b. B, D, and F
c. C, E, and J
d. C and E only
e. H only

8. On the same titration curve referred to in question 7, at which points might you use the equation for an amphiprotic acid? Assume the pH does not "jump" again as more titrant is added.
a. B, D, F, and H
b. B, D, and F
c. C, E, and J
d. C and E only
e. H only

Answer: At point J, we have A^{3-}, which is not amphitprotic; it's just a weak base.

9. You start out with 1 L of 0.1 M HCl. What is the pH after you've added 3 g $Mg(OH)_2$?
a. 7
b. 0
c. 14
d. 2.54
e. 11.46

Answer: Neutralize; you end up with 0.00286 mol OH^-.
pOH = -log(0.00286) = 2.54
pH = 14-pOH = 11.46

10. You start out with 75 mL of 1.5 M HNO_3. How much NaOH must you add to reach the equivalence point?
a. 1.0 g
b. 60.0 g
c. 4.5 g
d. 3.7 g
e. 6.2 g

Answer: You have 0.1125 mol HNO_3. You need to add 0.1125 mol NaOH to reach the equivalence point.
0.1125 mol x 40 g/mol = 4.5 g

11. 100 mL 0.05 M $(CH_3)N$ ($K_b = 5.0 \times 10^{-5}$) is titrated with 3 mL 1.0 M HCl. What is the final pH?
a. 2
b. 9.52
c. 9.70

d. 9.87
e. 12

Answer: Neutralize; you have 0.002 mol $(CH_3)N$ and 0.003 mol $(CH_3)NH^+$.

$[OH^-] = K_b(C_b/C_a) = (5.0 \times 10^{-5})(0.002/0.003) = 3.33 \times 10^{-5}$ mol

$pOH = -\log[OH^-] = 4.48$ $pH = 14 - pOH = 9.52$

You should probably be able to answer this one right after the neutralization, without doing the actual pOH calculation.

12. 75 mL 0.2 M HNO_2 ($K_a = 4.5 \times 10^{-4}$) is titrated with 15 mL 1.0 M NaOH. What is the final pH?

a. 9.72
b. 5.72
c. 3.35
d. 10.23
e. 8.28

Answer: Neutralize; you have 0.015 mol NO_2^-.

$K_b = K_w/K_a = 2.22 \times 10^{-11}$

$[OH^-] = (K_bC_b)^{1/2} = ((2.22 \times 10^{-11})(0.015 \text{ mol}/0.090 \text{ L}))^{1/2}$

$= 1.92 \times 10^{-6}$ M

$pOH = 5.72$ $pH = 8.28$

13. Which of the following is the most soluble?

a. AgOH $K_{sp} = 2.0 \times 10^{-8}$ solubility ~ $(10^{-8})^{1/2} = 10^{-4}$
b. PbI_2 $K_{sp} = 8.7 \times 10^{-9}$ solubility ~ $(10^{-8})^{1/3} = 2 \times 10^{-3}$
c. Ag_3PO_4 $K_{sp} = 1.3 \times 10^{-20}$ solubility ~ $(10^{-20})^{1/4} = 10^{-5}$
d. $Ca_3(PO_4)_2$ $K_{sp} = 1.0 \times 10^{-25}$ solubility ~ $(10^{-25})^{1/5} = 10^{-5}$

14. What is the molar solubility of Fe_2S_3, given $K_{sp} = 1.4 \times 10^{-88}$?

a. 1.05×10^{-18}
b. 1.14×10^{-30}
c. 1.4×10^{-88}
d. 3.16×10^{-45}
e. 8.20×10^{-19}

Answer: $s = (K_{sp}/(2^2 3^3))^{1/(2+3)} = 1.05 \text{ X } 10^{-18}$

15. 0.05 M NaBr is added to a saturated solution of AgBr ($K_{sp} = 3.3 \times 10^{-13}$). What is the concentration of Ag^+ at equilibrium?

a. 3.3×10^{-13} M
b. 5.7×10^{-7} M
c. 6.6×10^{-12} M
d. 0.05 M

Answer: Recall that for the common ion effect, we get

$K_{sp} = x(0.05 + x) \approx 0.05x$

$x = (3.3 \times 10^{-13})/(0.05) = 6.6 \times 10^{-12}$

16. Which of these would be an appropriate C_a and K_a for a weak acid in water in order for our approximations to hold?

I. $C_a = 10^{-7}$ M, $K_a = 10^{-7}$
II. $C_a = 10^{-3}$ M, $K_a = 10^{-2}$
III. $C_a = 10^{-3}$ M, $K_a = 10^{-7}$
IV. $C_a = 10^{-3}$ M, $K_a = 10^{-12}$
V. $C_a = 10^{-1}$ M, $K_a = 10^{-9}$

a. I, II, III, IV, and V
b. None of them
c. I, III, and V only
d. II, III, IV, and V only

e. II, III, and V only
f. III and V only
g. I and IV only
Answer: Remember: $C > 10^{-4}$, $10^{-3} > K_{sp} > 10^{-10}$

17. You have HA^- at a concentration of C_{HA} in water. Which of the following statements is true for this solution?
a. $[H^+] = (K_a C_{HA})^{1/2}$ if C is large and K's are far apart
b. $[OH^-] = (K_b C_{HA})^{1/2}$ if C is large and K's are far apart
c. $[H^+] = (K_{a1}K_{a2})^{1/2}$ if the K's are far enough apart
d. $[H^+] = (K_{a1}K_{a2})^{1/2}$ if the K's are close enough together
Answer: HA^- is an amphiprotic species. The approximation for amphiprotic species is that the K values are far apart.

18. You put H_2CO_3 and $NaHCO_3$ in water. How many equations do you need to completely solve this system exactly?
a. 2
b. 4
c. 5
d. 6
e. 10
Answer: You have 6 unknowns: $[H^+]$, $[OH^-]$, $[Na^+]$, $[H_2CO_3]$, $[HCO_3^-]$, $[CO_3^{2-}]$.

19. Which of the following is a correct mass balance for the system described in problem 18?
a. $[H^+] + [Na^+] = [OH^-] + [HCO_3^-] + 2[CO_3^{2-}]$
b. $C_{H2CO3} + C_{NaHCO3} = [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$
c. $C_{H2CO3} + C_{NaHCO3} = [HCO_3^-] + 2[CO_3^{2-}]$
d. $C_{H2CO3} = [H_2CO_3]$
e. $C_{NaHCO3} = [HCO_3^-]$
Answer: All of the CO_3^{2-} in the system came from either H_2CO_3 or $NaHCO_3$, and at equilibrium it's all in the form of wither H_2CO_3, HCO_3^-, or CO_3^{2-}.

20. What is the equilibrium expression K_{a2} for H_3PO_4?
a. $K_{a2} = [H^+]^3[PO_4^{3-}]/[H_3PO_4]$
b. $K_{a2} = [H^+][H_2PO4^-]/[H_3PO_4]$
c. $K_{a2} = [H^+][HPO_4^{2-}]/[H_2PO_4^-]$
d. $K_{a2} = [H^+][PO_4^{3-}]/[HPO_4^{2-}]$
Answer: K_{a2} refers to the lost of the **second** proton.

21. What is the pH of 3.7×10^{-8} M $Sr(OH)_2$?
a. 7.47
b. 6.53
c. 6.76
d. 7.24
Answer: Remember you get 2 OH^- per $Sr(OH)_2$. Also, since C_b is small, we have to include water.
$[OH^-] = 2C_b + 10^{-7} = 1.74 \times 10^{-7}$
pOH = 6.76 pH = 7.24

22. Find the pH of 4×10^{-3} M H_2SO_4, if $K_a = 1.1 \times 10^{-2}$.
a. 2.10
b. 2.19
c. 2.40
d. 4.36
Answer: Recall that, for H_2SO_4, we have
$K_a = x(C_a + x)/(C_a - x)$
This is a quadratic equation in x. Solving using the quadratic formula yields
x = 0.00251 or -0.0175

$[H^+] = C_a + x = 0.004\ M + 0.00251\ M = 0.00651\ M$
pH = 2.19

23. What is the pH of 0.25 M $NaHCO_3$? $K_{a1} = 10^{-4}$ and $K_{a2} = 10^{-10}$.
a. 5.30
b. 2.30
c. 7.00
d. 0.602
e. 8.70
f. 11.7

Answer: Throw away the spectator and we have HCO_3^-, an amphitprotic species.
$[H^+] = (K_{a1}K_{a2})^{1/2} = (10^{-4}10^{-10})^{1/2} = 10^{-7}$
pH = 7

24. What are the proper coefficients for this reaction?

$$\_\_\_F_2(g) + \_\_\_Au(s) \rightarrow \_\_\_F^-(aq) + \_\_\_Au^{3+}(aq)$$

a. 1, 1, 2, 1
b. 3, 1, 6, 1
c. 3, 2, 6, 2
d. 1, 1, 1, 1

Answer : F_2 is reduced by one electron, but there are two of them, so 2 e^- total. Au is oxidized by 3 electrons. The lcm is 6.

25. When the equation below is properly balanced in base, how many hydroxide ions and water molecules are on each side of the equation?

$$Ag_2O_3(s) + Ti(s) \rightarrow Ag^{2+} + Ti^{3+}$$

a. 9 H_2O on the left, 18 OH^- on the right
b. 18 OH^- on the left, 9 H_2O on the right
c. 3 H_2O on the left, 6 OH^- on the right
d. 6 OH^- on the left, 3 H_2O on the right
e. 3 OH^- on the right
f. 9 OH^- on the right

Answer: The balanced equation (neglecting O) is
$3Ag_2O_3 + 2Ti \rightarrow 6Ag^{2+} + 2Ti^{3+}$
To balance in base, add twice the number of O you need as OH^-, then add half that to the other side. You need 9 O on the right, so add 8 OH^- on the right and 9 H_2O on the left.

Half-reaction	ΔE_r^0 (V)
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	-1.68
$Ti^{3+}(aq) + 3e^- \rightarrow Ti(s)$	-1.21
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+1.52

26. Refer to the table above. What is the strongest oxidizing agent in the table?
a. Al(s)
b. $Al^{3+}(aq)$
c. Ti(s)
d. $Fe^{3+}(aq)$
e. Au(s)
f. $Au^{3+}(aq)$

Answer: The species with the largest ΔE_r^0.

27. Refer to the table above. What is the strongest reducing agent in the table?
a. Al(s)
b. $Al^{3+}(aq)$

c. Ti(s)
d. $Fe^{3+}(aq)$
e. Au(s)
f. $Au^{3+}(aq)$

Answer: The species with the largest oxidation potential (the negative of the reduction potential for the other half of the reaction.)

28. For an electrolytic cell made of the following two half-reactions, which species is the anode? What is the sign of this electrode?

$$Au^{3+}(aq) + 3e^- \rightarrow Au(s) \qquad \Delta E_r^0 = +1.52\ V$$
$$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s) \qquad \Delta E_r^0 = -0.25\ V$$

a. $Au^{3+}(aq)$, positive
b. Au(s), positive
c. Au(s), negative
d. $Ni^{2+}(aq)$, positive
e. $Ni^{2+}(aq)$, negative
f. Ni(s), positive

Answer: It's electrolytic, so ΔE is negative, so Ni^{2+} is reduced and Au is oxidized. So Au is the anode. The anode is positive in an electrolytic cell.

29. Given the ΔE_r^0 values below, what type of cell is this? To which species does electrons flow?

$$Fe^{3+}(aq) + Ti(s) \rightarrow Fe^{2+}(aq) + Ti^{3+}(aq)$$

$$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq) \qquad \Delta E_r^0 = +0.77\ V$$
$$Ti^{3+}(aq) + 3e^- \rightarrow Ti(s) \qquad \Delta E_r^0 = -1.21\ V$$

a. Electrolytic; $Fe^{3+}(aq)$
b. Electrolytic; Ti(s)
c. Voltaic; $Fe^{3+}(aq)$
d. Voltaic; Ti(s)

Answer: $\Delta E = 0.77-(-1.21) = 1.98$, so it's voltaic. Fe^{3+} is reduced, so electrons flow to it.

30. Calculate E_{cell} for the oxidation-reduction reaction composed of the following half reactions.

$$NO_3^-(aq) + 2H^+(aq) + e^- \rightarrow NO_2(g) + H_2O(l) \qquad \Delta E_r^0 = +0.80$$
$$CO_2(g) + 2H^+ + 2e^- \rightarrow HCOOH(aq) \qquad \Delta E_r^0 = -0.11$$

a. -0.69
b. +0.69
c. -0.91
d. +0.91

Answer: $\Delta E = \pm (0.80-(-0.11)) = \pm 0.91$. It doesn't specify, so you should assume it's a battery, so $\Delta E = +0.91$