1. What would be the pH of a solution prepared by dissolving 120.1 g of CH_3COOH and 82 g of $NaCH_3COO$ in 1 L of water? Acetic acid has a K_a of 1.8×10^{-5}.
   1. 5.05
   2. 4.78
   3. 4.12
   4. 4.44   **Correct**
Explanation:
120.1 g CH_3COOH x (1 mol / 60.05 g) = 2 mol CH_3COOH
82 g of $NaCH_3COO$ x (1 mol / 82.03 g) = 1 mol $NaCH_3COO$
For a buffer composed of a weak acid and its conjugate base,
$[H^+] = K_a(C_a/C_b) = 1.8 \times 10^{-5}(2/1) = 3.6 \times 10^{-5}$
pH = 4.44
Note, it is adequate to use the moles of HA and A^- in place of their final concentrations.

2. Which of the following pairs of solutions would **not** result in a buffer upon mixing?
   1. 100 mL of 10 mM NaOH & 80 mL of 20 mM NH_4Cl
   2. 20 mL of 0.3 M NaF & 12 mL of 0.4 M HCl
   3. 0.4 L of 10 mM $HClO_3$ & 0.5 L of 8 mM $C_6H_5NH_2$ **Correct**
   4. 2 L of 1.35 M $Ba(OH)_2$ & 3 L of 2 M CHOOH
Explanation: A buffer prepared by a neutralization reaction requires a weak acid mixed with less strong base or a weak base mixed with less strong acid. The only pair of solutions which fails to satisfy this constraint is 0.4 L of 10 mM HClO3 and 0.5 L of 8 mM $C_6H_5NH_2$.

3 Consider the following acids and their provided pK_as. Rank them in terms of increasing strength of their conjugate bases.
   CH_3COOH $pK_a = 4.75$
   $CH_3CHOHCOOH$ $pK_a = 3.85$
   $CHOOH$ $pK_a = 3.74$
   CH_3CH_2COOH $pK_a = 4.88$
   1. $CHOOH < CH_3CHOHCOOH < CH_3COOH < CH_3CH_2COOH$ **Correct**
   2. $CH_3CH_2COOH < CHOOH < CH_3CHOHCOOH < CH_3COOH$
   3. $CH_3COOH < CH_3CH_2COOH < CHOOH < CH_3CHOHCOOH$
   4. $CH_3CHOHCOOH < CH_3COOH < CH_3CH_2COOH < CHOOH$
Explanation: The strength of an acid's conjugate base is directly proportional to the pK_a of the acid.

4 Which of the following buffers could absorb the greatest amount of strong base before being exhausted?
   1. 45 mL of 2 mM N_2H_5Cl, 4 mM N_2H_4
   2. 3.2 L of 0.4 M HClO, 0.5 NaClO   **Correct**
   3. 2 L of 9 mM HF, 7 mM NaF
   4. 0.3 L of 0.4 M NH_4Cl, 0.6 M NH_3
   5. 20 mL of 5 M CHOOH, 4 M NaCHOO
Explanation: Any strong base added to a buffer will react with and be neutralized by the weak acid species that is present. The buffer with the greatest amount of weak acid is 3.2 L of 0.4 M HClO, 0.5 NaClO.

5. If one added 200 mL of 6 M HCl to 1 L of a buffer composed 4.2 M CH_3COOH and 6.6 M $NaCH_3COO$, what would be the resulting pH? The K_a of CH_3COOH is 1.8×10^{-5}.
   1. 5.3

2. 4.9
3. 5.1
4. 4.7 **Correct**

Explanation: The general reaction that takes place is $A^- + H^+ \rightleftharpoons HA$. Initial amounts of each reactant are 6.6, 1.2 and 4.2 moles respectively. After the reaction goes to completion, the equilibrium concentrations are 5.4, 0 and 5.4 respectively. There is no need to calculate the final concentrations. For a buffer composed of a weak acid and its conjugate base,

$[H^+] = K_a(C_a/C_b) = 1.8 \times 10^{-5}(5.4/5.4) = 1.8 \times 10^{-5}$

$pH = 4.7$

6. How many buffer regions and equivalence points would be visible on the titration curve of a weak tetraprotic acid?
   1. 3, 1
   2. 3, 4
   3. 1, 4
   4. 4, 1
   5. 4, 4 **Correct**

Explanation: Each ionizable proton will produce one buffer region and one equivalence point.

7. A 100 mL sample of 0.1 M H_3PO_4 is titrated with 0.2 M NaOH. What is the pH of the solution after 100 mL of NaOH has been added? Phosphoric acid has $K_{a1} = 7.5 \times 10^{-3}$, $K_{a2} = 6.2 \times 10^{-8}$ and $K_{a3} = 2.1 \times 10^{-13}$.
   1. 4.10
   2. 8.51
   3. 4.67
   4. 7.40
   5. 9.94 **Correct**

Explanation: 0.1 M H_3PO_4 x 100 mL = 0.01 moles H_3PO_4

0.2 M NaOH x 100 mL = 0.02 moles OH-

Two equivalents of OH^- have been added, and the solution will be at the second equivalence point, composed primarily of the amphoteric species HPO_4^{2-}.

$[H^+] = (K_{ax} \cdot K_{ay})^{1/2} = (6.2 \times 10^{-8} \cdot 2.1 \times 10^{-13})^{1/2} = 1.14 \times 10^{-10}$

$pH = 9.94$

8. What will be the pH at the first equivalence point of a titration of 0.2 M H_2SO_4 with 0.2 M NaOH? The K_a for HSO_4^- is 2×10^{-2}.
   1. 1.45 **Correct**
   2. 1.35
   3. 7.00
   4. not enough information

Explanation: At its first equivalence point, the predominant species of this titration will be HSO_4^-. Because the analyte and titrant are equimolar, the $[HSO_4^-]$ will be half of C_a, or 0.1 M. This is not an amphoteric solution because HSO_4^- cannot function as a base. Because the K_a of HSO_4^- is so large, a full solution is required.

R	HSO_4^-		H+	SO_4^{2-}
I	0.1		0	0
C	- x		+ x	+ x
E	0.1 - x		x	x

$K_a = 2 \times 10^{-2} = (x)(x)/(0.1 -x)$

$x^2 + 2 \times 10^{-2}x - 2 \times 10^{-3} = 0$

x = [H^+] = 0.0358
pH = 1.45

9. All of the salts below have the same **approximate** molar solubility except for one. Which is it?
  1. TlBr K_{sp} = 4.00 x 10^{-6}
  2. PbI_2 K_{sp} = 7.47 x 10^{-9}
  3. AgSCN K_{sp} = 1.16 x 10^{-12} **Correct**
  4. $CsIO_4$ K_{sp} = 5.16 x 10^{-6}
Explanation: Silver thiocyanate is a salt composed of one cation and one anion and thus its molar solubility is approximately equal to the square root of its K_{sp}. The best approximation is therefore $(10^{-12})^{1/2}$ = 10^{-6}.

10. The K_{sp} of $MgNH_4PO_4$ at 25 °C is 2.5 x 10^{-13}. What is its molar solubility at this temperature? (Hint: do the RICE diagram for this one.)
  1. 3.2 x 10^{-4}
  2. 4.0 x 10^{-5}
  3. 6.3 x 10^{-5} **Correct**
  4. 1.2 x 10^{-3}
Explanation: $MgNH_4PO_4$ will dissolve into Mg^{2+} NH_4^+ and PO_4^{3-}. Each will be produced in equal proportions and so K_{sp} = x^3 = 2.5 x 10^{-13}

11.2 What would be the molar solubility of $Sn(OH)_2$ (K_{sp} = 10^{-26}) in pH 13 NaOH solution?
  1. 1 x 10^{-24} **Correct**
  2. 4 x 10^{-24}
  3. 1 x 10^{-28}
  4. 4 x 10^{-28}
  5. not enough information
Explanation: [OH-] = 0.1 M
molar solubility = $(K_{sp}/[OH^-]^2)$ = $[10^{-26}/(10^{-1})^2]$ = 10^{-24}

12. Consider the table below. Which anion would be the best for separating Pb^{2+} from Ca^{2+}? Which would be the worst?

K_{sp} values	$C_2O_4^-$	CO_3^{2-}	SO_4^{2-}	IO_3^-
Pb^{2+}	2.74 x 10^{-11}	3.3 x 10^{-14}	1.6 x 10^{-8}	1.2 x 10^{-13}
Ca^{2+}	2.57 x 10^{-9}	8.7 x 10^{-9}	4.93 x 10^{-5}	6.44 x 10^{-7}

  1. $C_2O_4^-$ & SO_4^{2-}
  2. IO_3^- & SO_4^{2-}
  3. CO_3^{2-} & IO_3^-
  4. IO_3^- & $C_2O_4^-$ **Correct**
  5. CO_3^{2-} & $C_2O_4^-$
Explanation: The K_{sp} values for IO_3^- are farthest apart and the values for $C_2O_4^-$ are closest together.

13. A student used the equation $[H^+]$ = $(K_a \cdot C_a)^{1/2}$ to calculate $[H^+]$ and got a value of 0.4 M. The actual value was determined experimentally to be 0.35 M. Which of the following are possible explanations for this discrepancy?
    I. K_a was too small
    II. K_a was too large
    III. C_a was too small
  1. I only
  2. II only   **Correct**

3. III only
4. I & II
5. I & III
6. II & III
7. none

Explanation: If K_a had been too small, the equation $[H^+] = (K_a \cdot C_a)^{1/2}$ would result in a small number for the proton concentration. Likewise of C_a has been too small. If K_a was too large, however, our assumption that percent ionization is small is fals and we will overestimate the proton concentration - just as the student did.

14. For a solution of H_3PO_4, addition of Na_2HPO_4 will increase the concentration of which of the following species?

    I. H_3PO_4

    II. $H_2PO_4^-$

    III. PO_4^{3-}

1. I only
2. II only
3. III only
4. I & II
5. I & III
6. II & III
7. I, II and III   **Correct**

Explanation: Because all of the variously protonated species of H_3PO_4 are in equilibrium with each other, addition of any species will increase the concentration of all species.

15. Determine the pH of a 5 M solution of Na_2HPO_4. Assume H_3PO_4 has a pK_{a1} of 2.1, a pK_{a2} of 7.2 and a pK_{a3} of 12.7.

1. 9.95   **Correct**
2. 4.65
3. 7.4
4. not enough information

Explanation: $H_2PO_4^-$ is amphiprotic, and the pH is conseequnetly the average of the pK_a values according to the equation $pH = 0.5(pK_{ax} + pK_{ay})$.

16. Write a mass balance for carbon for a solution that initially contains H_2CO_3.

1. $C_{H2CO3} = [HCO_3^-] + [CO_3^{2-}]$
2. $C_{H2CO3} = [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$
3. $C_{H2CO3} = [CO_2] + [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$ **Correct**
4. $C_{H2CO3} = [CO_2] + [H_2CO_3]$

Explanation: H_2CO_3 is in equilibrium with its deprotonated species HCO_3^- and CO_3^{2-} and with its decomposition product CO_2.

17. How many equation are necessary to define a system initially composed of $MgNH_4PO_4$?

1. 9   **Correct**
2. 8
3. 7
4. 5

Explanation: Species that will have an unknown concentration are $[H^+]$, $[OH^-]$, $[PO_4^{3-}]$, $[HPO_4^{2-}]$, $[H_2PO_4^-]$, $[H_3PO_4]$, $[NH_4^+]$, $[NH_3]$ and $[Mg^{2+}]$.

18. Which of the following would be equal to K_{a1} times K_{a2} for orthocarbonic acid, H_4CO_4?

1. $[H_2CO_4^{2-}] \cdot [H^+]/[H_4CO_4]$
2. $[H_3CO_4^-] \cdot [H^+]/[H_4CO_4]$

3. $[H_2CO_4{}^{2-}]\cdot[H^+]/[H_3CO_4{}^-]$

4. $[H_2CO_4{}^{2-}]\cdot[H^+]\cdot[H_3CO_4{}^-]/[H_4CO_4]$

5. $[H_2CO_4{}^{2-}]\cdot[H^+]^2/[H_4CO_4]$ **Correct**

Explanation: $K_{a1} = [H_3CO_4{}^-]\cdot[H^+]/[H_4CO_4]$

$K_{a2} = [H_2CO_4{}^{2-}]\cdot[H^+]/[H_3CO_4{}^-]$

$K_{a1}\cdot K_{a2} = [H_2CO_4{}^{2-}]\cdot[H^+]^2/[H_4CO_4]$

19. What would be the pH of a 2×10^{-8} M solution of $Ba(OH)_2$?

   1. 7.009   **Correct**
   2. 7.019
   3. 7.013
   4. 7.004

Explanation: For a dilute strong base,

$[OH^-]^2 - C_b[OH^-] - K_w = 0$

$[OH^-] = x = (-b \pm \sqrt{(b^2 - 4ac)}) / 2a$

$pOH = 6.991$

Alternatively, one could reason that the very low concentration of $Ba(OH)_2$, 2×10^{-9} M, should result in a pH very close to, but still more than 7.

20. What would be the $[H^+]$, $[HSO_4{}^-]$ and $[SO_4{}^{2-}]$ in a 1 M solution of H_2SO_4?

   1. 1.02, 0.98, 0.02 M, respectively   **Correct**
   2. 0.00, 2.00, 1.00 M, respectively
   3. 1.14. 0.86, 0.14 M, respectively
   4. 0.14, 1.00, 0.14 M, respectively

Explanation: Because H_2SO_4 is a strong acid, the reaction $H_2SO_4 \rightarrow H^+ + HSO_4{}^-$ goes to completion. In this case, producing a $[H^+]$ of 1 M. Because $HSO_4{}^-$ is a weak acid we must solve for the proton concentration it contributes to the total.

R	$HSO_4{}^-$		H^+	$SO_4{}^{2-}$
I	1		1	0
C	- x		+ x	+ x
E	1 - x		1 + x	x

$K_a = 2 \times 10^{-2} = (1 + x)(x)/(1 - x)$

$x^2 + 1.02x - 0.02 = 0$

$x = 0.01924$

$[H^+] = 1.01924$ M

$[HSO_4{}^-] = 0.98076$

$[SO_4{}^{2-}] = 0.01924$

21. What would be the pH of a 4 mM M $Na_3C_6H_5O_7$ solution (trisodium citrate)? Citric acid has $K_{a1} = 7.1 \times 10^{-4}$, $K_{a2} = 1.7 \times 10^{-5}$ and $K_{a3} = 4.0 \times 10^{-7}$.

   1. 6.62
   2. 5.00
   3. 9.00   **Correct**
   4. 7.38
   5. 7.00

Explanation: Na^+ is a spectator, and $C_6H_5O_7{}^{3-}$ (citrate) is a weak base.

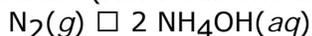40 mM = 0.004 M

$K_{b3} = K_w/K_{a3} = 10^{-14}/4.0 \times 10^{-7} = 2.5 \times 10^{-8}$
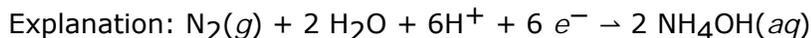
$[OH-] = (K_b \cdot C_b)^{1/2} = (2.5 \times 10^{-8} \cdot 0.004)^{1/2} = 10^{-5}$
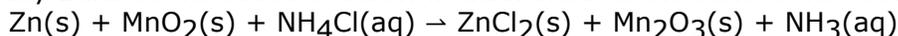
pH = 9

22. Fully balance the reaction below in acid. How many protons are needed? How many water molecules? (Hint: this one is tricky - the water molecules and protons go on the same side.)

$N_2(g) \quad 2\ NH_4OH(aq)$

   1. 3, 1
   2. 6, 2   **Correct**
   3. 2, 2
   4. 8, 2
   5. 8, 1

Explanation: $N_2(g) + 2\ H_2O + 6H^+ + 6\ e^- \rightarrow 2\ NH_4OH(aq)$

23. Fully Balance the reaction below in acid. What is the sum of the coefficients?

$Zn(s) + MnO_2(s) + NH_4Cl(aq) \rightarrow ZnCl_2(s) + Mn_2O_3(s) + NH_3(aq)$

   1. 7
   2. 12
   3. 6
   4. 10   **Correct**
   5. 9

Explanation:

$Zn(s) + 2\ MnO_2(s) + 2\ NH_4Cl(aq) \rightarrow ZnCl_2(s) + Mn_2O_3(s) + 2\ NH_3(aq) + H_2O(l)$

24. Which of the following statements is untrue concerning ranking the strength/weakness of oxidizing/reducing agents.

   1. A reactant with a high reduction potential is a good reducing reagent.   **Correct**
   2. A product with a low reduction potential is a good reducing reagent.
   3. A reactant with a low reduction potential is a poor oxidzing reagent.
   4. A product wit a high reduction potential is a poor reducing agent.

Explanation: A reactant which is easily reduced is a god oxidizing agent.

25. If the two half reactions below were used to make a battery, what species would be consumed at the anode?

$Pb^{2+}(aq) + 2\ e^- \rightarrow Pb(s) \quad E° = -0.13$

$Zn^{2+}(aq) + 2\ e^- \rightarrow Zn(s) \quad E° = -0.76$
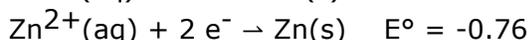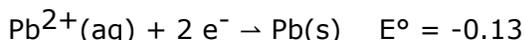
   1. Zn(s)   **Correct**
   2. $Zn^{2+}(aq)$
   3. Pb(s)
   4. $Pb^{2+}(aq)$

Explanation: A battery must have a positive standard cell potential and therefore the anodic reaction must consume Zn(s).

26. For a discharging battery, which of the following must be negative?

   I. $E°_{cell}$
   II. anode
   III. cathode

   1. I only
   2. II only   **Correct**
   3. III only
   4. I & II
   5. I & III
   6. II & III
   7. none must be negative

Explanation: By definition and by convention, in an electrolytic cell the anode is attributed a negative sign.

27. What would be the $E°_{cell}$ of an electrolytic cell made from the following two half reactions?
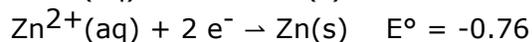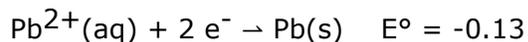
$Pb^{2+}(aq) + 2 e^- \rightarrow Pb(s)$ $E° = -0.13$
$Zn^{2+}(aq) + 2 e^- \rightarrow Zn(s)$ $E° = -0.76$
  1. -0.89
  2. 0.89
  3. 0.63   **Correct**
  4. -0.63
Explanation: $E°_{cell} = E°_{cathode} - E°_{anode} = -0.13 - ⁻0.76 = +0.63$

28. What is K for the reaction below at room temperature?
    $O_2(g) + 2H_2O(l) \rightarrow 4OH^-(aq)$ $E° = 0.40$ V

  1. 1.72×10^{-7}
  2. 5.82×10^6
  3. 8.70×10^{-28}
  4. 1.15×10^{27} **Correct**
Explanation: $K = e^{\wedge}(nFe/RT) = e^{\wedge}[4(96,485)(0.40)/(8.314)(298)] = 1.15 \times 10^{27}$

29. How many grams of solid silver (Ag) could be produce by electrolysing a solution of Ag+ for 10 hours at a current of 0.02 amperes?
  1. 0.80 g   **Correct**
  2. 2.24×10^{-5} g
  3. 1.34×10^{-3} g
  4. 0.016 g
Explanation: This is a 1 electron process.
10 hours x (3,600 s / hr) = 36,000 seconds
$n_{product} = I \cdot t/N_e \cdot F = (0.02 \cdot 36,000)/(1 \cdot 96,485) = 0.0074623$ moles Ag.
0.0074623 moles Ag x (107.8682 g/ 1 mol) = 0.80 g

30. What $[Pb^{2+}]$ and $[Sn^{2+}]$ would be present at equilibrium in in a battery built from the two half reactions below?
    $Pb^{2+} \rightarrow Pb$ $E° = -0.13$
    $Sn^{2+} \rightarrow Sn$ $E° = -0.14$
  1. 0.629 M, 1.371 M   **Correct**
  2. 1.371 M, 0.629 M
  3. 0.808 M, 1.192 M
  4. 1.192 M, 0.808 M
Explanation: $Pb^{2+} + Sn \rightarrow Pb + Sn^{2+}$ $E°_{cell} = +0.01$
$E_{cell} = E°_{cell} - (0.05916/N_e)logQ$
$0 = 0.01 - (0.05916/2)log([Sn^{2+}]/[Pb^{2+}])$
log(1+x/1-x) = 0.338
(1+x/1-x) = 2.178
1 + x = 2.178 - 2.178x
3.178x = 1.178
x = 0.371