Project Advance Chemistry 116 Sample Questions
on Material in *General Chemistry*, Brown, LeMay, and Bursten

Chapter 17. Additional Aspects of Aqueous Equilibria
SPRING SEMESTER 1995

1. Which of the following actions will cause the largest decrease in the degree of dissociation of acetic acid (initial concentration, 0.10 M) in an aqueous solution of volume 879 mL?

   (a) addition of 0.010 mol solid KCl
   (b) bubbling in 0.010 mol gaseous HCl (absorbed by solution)
   (c) bubbling in 0.020 mol gaseous HBr (absorbed by solution)
   (d) addition of 0.010 mol solid KI
   (e) addition of 0.010 mol solid sodium acetate

2. If the respective equilibrium concentrations of cyanide ion, [CN⁻], and hydrogen ion, [H⁺], in both HCN and KCN are (0.10 + x) M and x M, What is the equilibrium concentration of HCN?

   (a) x M

   (b) (0.10 + x) M

   (c) (0.10 - x) M

   (d) (0.10 + x)^2 M

   (e) (0.10 - x)^2 M

Substance	Concentration
[CN⁻]	(0.10 + x) M
[H⁺]	x M
[HCN]$_o$	0.10 M
[KCN]$_o$	0.10 M

3. The equation used to solve for [H⁺] (as x M) in a solution initially 0.10 M in both KF and HF is

   (a) $K_a = x^2/(0.10 + x)$ (b) $K_a = x^2/(0.10 - x)$
   (c) $K_a = x/\{(0.10 + x)(0.10 - x)\}$ (d) $K_a = x(0.10 + x)/(0.10 - x)$
   (e) $K_a = x(0.10 - x)/(0.10 + x)$

4. The pH of a buffer prepared by combining 50.0 mL of 1.00 M potassium acetate with 50.0 mL 1.00 M acetic acid is

   (a) 1.70   (b) 0.85
   (c) 3.40   (d) 4.77
   (e) 2.38

5. Determine the pH of a buffer solution prepared by dissolving 0.75 moles of NH_3 and 0.25 moles of NH_4Cl in a liter of solution. (K_b of NH_3 = 1.8 × 10⁻⁵)

   (a) 4.27   (b) 8.78
   (c) 9.73   (d) 5.22
   (e) 7.00

6. Consider a buffer solution prepared by adding 0.45 moles of potassium acetate, KOAc, to 1.00 L of 2.00 M acetic acid, HOAc. If 0.05 mol of HCl is added to this buffer solution, the pH of the solution will drop slightly. The pH does not drastically decrease because the HCl reacts with the _____ present in the buffer solution. (K_a HOAc = 1.8×10^{-5})

(a) OAc^- (b) H^+
(c) H_2O (d) HOAc
(e) H_3O^+

7. Which one of the following mixtures will be a buffer when dissolved in a liter of water?

(a) 0.2 mol of NaCl and 0.1 mol of HCl

(b) 0.1 mol of NH_3 and 0.2 mol of HCl

(c) 0.1 mol of NaOH and 0.1 mol of HCl

(d) 0.2 mol of Na_2HPO_4 and 0.1 mol of HCl

(e) 0.2 mol of H_2SO_3 and 0.1 mol of HCl.

8. Consider a buffer prepared by dissolving 0.35 mol of CH_3NH_3Cl (methylamine hydrochloride) in 1.00 L of 1.1 M CH_3NH_2 (methylamine). The K_b for methylamine is 4.4×10^{-4}. If 10 mL of 0.01 M HCl is added to this buffer solution, the pH of the solution will _____ slightly because the HCl reacts with the _____ present in the solution.

(a) increase, OH^- (b) increase, CH_3NH_2
(c) decrease, CH_3NH_2 (d) decrease, $CH_3NH_3^+$
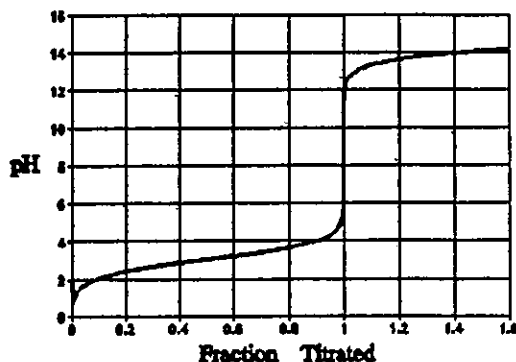(e) none of these.

9. The following plot of pH *vs.* fraction titrated corresponds to a titration curve for a

(a) strong acid titrated by a strong base.

(b) strong base titrated by a strong acid.

(c) weak acid titrated by a strong base.

(d) weak base titrated by a strong acid.

(e) weak base titrated by a weak acid.
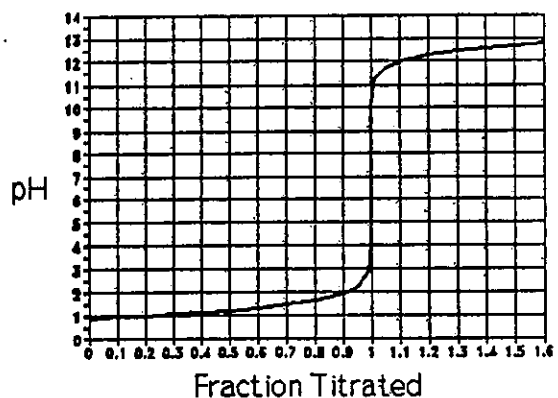
Fraction Titrated

10. The following plot of pH *vs.* fraction titrated corresponds to a titration curve for a

(a) strong acid titrated by a strong base.

(b) strong base titrated by a strong acid.

(c) weak acid titrated by a strong base.

(d) weak base titrated by a strong acid.

(e) weak base titrated by a weak acid.

11. The following plot of pH *vs.* mL of titrant corresponds to a titration curve for a

(a) strong acid titrated by a strong base.

(b) strong base titrated by a strong acid.

(c) weak acid titrated by a strong base.

(d) weak base titrated by a strong acid.

(e) weak base titrated by a weak acid.
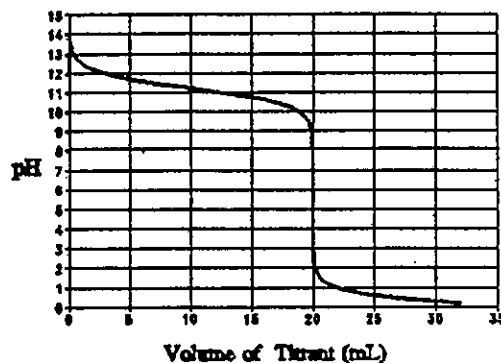
12. What is the pH of a solution prepared by mixing 45.0 mL of 0.183 M KOH with 65.0 mL of 0.145 M HCl?

(a) 1.31   (b) 2.92

(c) 0.74   (d) 1.97

(e) 7.00

13. What is the molarity of an HOAc solution if 25.5 mL of this solution requires 37.5 mL of 0.175 M NaOH to reach the equivalence point? K_a HOAc = 1.8 × 10⁻⁵.

(a) 0.119   (b) 1.83 × 10⁻⁴

(c) 0.257   (d) 0.365

(e) none of these.

14. The indicator indigo carmine can be considered to be a weak acid with the general formula HIn. Determine the ratio: $[In^-]/[HIn]$ for indigo carmine in a solution with a pH of 10.0.

(a) 10

(b) 100

(c) 0.01

(d) 1

(e) 1×10^{-10}

Indicator	K_a
methyl orange	1×10^{-4}
m-cresol purple	1×10^{-8}
indigo carmine	1×10^{-12}
bromthymol blue	1×10^{-7}

15. The solubility product expression for $La_2(CO_3)_3$ is

(a) $K_{sp} = [La^{3+}]^3[CO_3^{2-}]^2$

(b) $K_{sp} = [La^{2+}]^3[CO_3^{2-}]^2$

(c) $K_{sp} = [La^{3+}]^2[CO_3^{2-}]^3$

(d) $K_{sp} = [2La^{3+}]^2[3CO_3^{2-}]^2$

(e) $K_{sp} = [2La^{3+}][3CO_3^{2-}]^2$

16. Which of the following salts is the *least* soluble in water?

(a) $CaCO_3$

(b) PbI_2

(c) $AgBr$

(d) $Fe(OH)_2$

(e) $Co(OH)_2$

Substance	K_{sp}
$CaCO_3$	4.8×10^{-9}
PbI_2	1.1×10^{-9}
$AgBr$	5.0×10^{-13}
$Fe(OH)_2$	8.0×10^{-16}
$Co(OH)_2$	2.5×10^{-16}

17. From a consideration of the tabulated solubility products for the salts: CaF_2, $PbCrO_4$, Ag_3AsO_4, respectively, the order for the molar solubility of the salts is

(a) $CaF_2 > PbCrO_4 > Ag_3AsO_4$
(b) $PbCrO_4 > Ag_3AsO_4 > CaF_2$
(c) $CaF_2 > Ag_3AsO_4 > PbCrO_4$
(d) $PbCrO_4 > CaF_2 > Ag_3AsO_4$
(e) $Ag_3AsO_4 > PbCrO_4 > CaF_2$

Substance	K_{sp}
CaF_2	3.9×10^{-11}
$PbCrO_4$	1.8×10^{-14}
Ag_3AsO_4	1.1×10^{-20}

18. If the pH of a solution of $Ba(OH)_2$ is 10.00 at 25°C, then the barium ion concentration, $[Ba^{2+}]$, is

    (a) 1.0×10^{-4} (b) 2.0×10^{-4}
    (c) 5.0×10^{-5} (d) 1.0×10^{-10}
    (e) 5.0×10^{-11}

19. What is the pH of a solution in which the initial concentratrion of formic acid (HCOOH) is 0.010 M , and the initial concentration of sodium formate (NaCOOH) is 0.10 M? The K_a for formic acid is 1.77×10^{-4}.

    (a) 3.75   (b) 4.75

    (c) 7.00   (d) 5.75

    (e) none of these.

20. Consider the reactions:

    $$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq) \quad K_{a1} = 1.8 \times 10^7$$

    $$Ag^+(aq) + Cl^-(aq) \rightleftharpoons AgCl(s) \quad K_{a2} = 5.6 \times 10^9$$
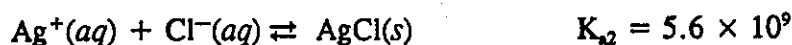
    What is the equilibrium constant for the reaction:

    $$AgCl(s) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq) + Cl^-(aq)$$

    (a) 1.0×10^{-17} (b) 3.2×10^{-3}
    (c) 1.0×10^{17} (d) 1.0×10^3
    (e) 3.1×10^{16}

21. A 25.00-mL sample of 0.147 M propionic acid, CH_3CH_2COOH, is titrated with 0.104 M KOH solution. The equivalence point is reached when 35.31 mL of KOH base has been added. What is the hydroxide ion concentration at the equivalence point? The K_a of propionic acid is 1.34×10^{-5}.

    (a) 1.5×10^{-9} (b) 6.7×10^{-6}

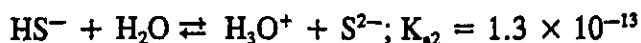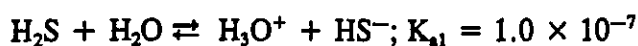   (c) 1.0×10^{-7} (d) 1.1×10^{-5}

    (e) none of these.

22. One hundred milliliters of a saturated solution of calcium sulfate contains 0.209 grams of calcium sulfate at 30°C. What is the solubility product of calcium sulfate at this temperature?

    (a) 1.0×10^{-2} to 2.0×10^{-2} (b) 3.0×10^{-3} to 3.5×10^{-3}
    (c) 1.5×10^{-1} to 2.5×10^{-1} (d) 2.0×10^{-4} to 2.5×10^{-4}
    (e) none of the above.

23. At $25°C$, the pH of a saturated solution of $Ca(OH)_2$ is 12.8. What is K_{sp} for calcium hydroxide at this temperature?

   (a) 6.3×10^{-4} (b) 1.6×10^{-5}

   (c) 7.8×10^{-6} (d) 1.6×10^{-25}

   (e) 2.3×10^{-26}

24. At $25°C$, a saturated H_2S solution is $0.10\ M$ in H_2S. An aqueous solution buffered at pH = 3.00 is saturated with H_2S at this temperature. What is the concentration of sulfide ion, S^{2-}, in this solution?

   $$H_2S + H_2O \rightleftarrows H_3O^+ + HS^-; K_{a1} = 1.0 \times 10^{-7}$$

   $$HS^- + H_2O \rightleftarrows H_3O^+ + S^{2-}; K_{a2} = 1.3 \times 10^{-13}$$

   (a) $1.3 \times 10^{-6}\ M$ (b) $1.3 \times 10^{-11}\ M$

   (c) $1.3 \times 10^{-13}\ M$ (d) $1.3 \times 10^{-15}\ M$

   (e) $1.3 \times 10^{-21}\ M$

25. At $25°C$, a solution that is $0.0010\ M$ each in Fe^{2+}, Cd^{2+}, Co^{2+}, and Mn^{2+} is saturated with H_2S at a pH of 3.00. Which metals form a sulfide precipitate at this temperature?

   (a) MnS

   (b) CdS and CoS

   (c) MnS and FeS

   (d) CdS, FeS and CoS

   (e) FeS, CdS, CoS, and MnS

Substance	K_{sp}
FeS	6.0×10^{-18}
CdS	8.0×10^{-27}
CoS	4.0×10^{-21}
MnS	2.5×10^{-10}

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1. For a solution labeled "0.10 M $H_2SO_4(aq)$,"

   (a) the pH is less than 1.0.
   (b) the pH is greater than 1.0.
   (c) the pH = 1.0.
   (d) the $[SO_4^{2-}]$ = 0.10 M.
   (e) the $[HSO_4^-]$ is greater than 0.10 M.

2. The base dissociation constant for ammonia, K_b, is 1.8×10^{-5}. The pH of a buffer prepared by combining 50.0 mL of 1.00 M ammonia and 50.0 mL 1.00 M ammonium nitrate is

   (a) 4.63
   (b) 9.26
   (c) 4.74
   (d) 9.37
   (e) 7.00

3. Calculate the pH of a buffer solution prepared by dissolving 0.37 moles of formic acid, HCO_2H, and 0.23 moles of sodium formate, $NaCO_2H$, in 1.00 L of solution. (K_a of formic acid is 1.8×10^{-4})

   (a) 2.09
   (b) 10.46
   (c) 3.54
   (d) 2.30
   (e) none of these.

4. Consider a buffer solution prepared by mixing 0.43 moles of acetic acid with 0.28 moles of sodium acetate in 1.00 liter of solution. The addition of 0.01 moles of HCl to this solution will cause the pH to _____ slightly because the HCl reacts with the _____ that is present.

   (a) increase, acetate ion
   (b) increase, sodium ion
   (c) decrease, acetate
   (d) decrease, acetic acid
   (e) none of these.

5. Lemon juice normally has a pH = 2.1. If all the acid in lemon juice is citric acid ($HCitrate \leftrightarrows H^+ + Citrate^-$, $K_a = 8.4 \times 10^{-4}$) and there are no citrate salts present, what is the citric acid concentration $[HCitrate]$? (Note: Citric acid is actually polyprotic, however, for this question assume that only the first hydrogen is important.)

   (a) $6.3 \times 10^{-5} M$
   (b) $8.4 \times 10^{-4} M$
   (c) $7.5 \times 10^{-2} M$
   (d) $1.5 \times 10^{-1} M$
   (e) 9.5 M

6. Which of the following can act as both a Bronsted acid and a Bronsted base?

   I. HCO_3^- II. $H_2PO_4^-$ III. NH_3 IV. O^{2-} V. HS^-

   (a) I and V
   (b) III and IV
   (c) I, II, and III
   (d) All of these.
   (e) None of these.

7. The amino acid glycine, $NH_2—CH_2—COOH$, can add and lose protons in aqueous solution to assume the forms:

   $NH_3^+—CH_2—COOH$ (completely protonated, a dibasic acid)
   $NH_3^+—CH_2—COO^-$ (no net charge)
   $NH_2—CH_2—COO^-$ (has no more protons that are easily donated

   which can participate in the reactions

   $NH_3^+—CH_2—COOH \leftrightarrows H^+ + NH_3^+—CH_2—COO^-$; $pK_1 = 2.35$
   $NH_3^+—CH_2—COO^- \leftrightarrows H^+ + NH_2—CH_2—COO^-$; $pK_2 = 9.78$

   What is the pH of the solution when the total numbers of positive and negative charges on the glycine molecules are equal? (This pH is called the *isoelectric point.*)

   (a) 7
   (b) $pK_1 \times pK_2$
   (c) $pK_1 + pK_2$
   (d) $2(pK_1 + pK_2)$
   (e) $\frac{1}{2}(pK_1 + pK_2)$

8. Which of the following substances, when added to a solution of nitrous acid, HNO_2, could be used to prepare a buffer solution?

   (a) HCl   (b) NaCl
   (c) HOAc   (d) KNO_2
   (e) $NaNO_3$

9. An initial pH of 13.00, an equivalence point at pH 7.0, and a relatively long, nearly vertical middle section correspond to a titration curve for a

   (a) strong acid titrated by a strong base.
   (b) strong base titrated by a strong acid.
   (c) weak acid titrated by a strong acid.
   (d) weak base titrated by a strong acid.
   (e) weak base titrated by a weak base.

10. Which one of the following indicators would be most suitable for the titration of
    0.10 M HBr(aq) with 0.10 M KOH(aq)?

    (a) bromophenol blue (pK_{In} = 3.9)
    (b) thymol blue (pK_{In} = 1.7)
    (c) methyl orange (pK_{In} = 3.4)
    (d) alizarin yellow (pK_{In} = 11.2)
    (e) bromothymol blue (pK_{In} = 7.1)

11. Estimate the pH at the equivalence point of an acetic acid solution if 25.5 mL of this
    solution required 37.5 mL of 0.175 M NaOH to reach the equivalence point?

    (a) 4
    (b) 7
    (c) 9
    (d) 12
    (e) none of these.

12. Hydrogen sulfide, H_2S, is a diprotic acid with the following acid dissociation constants:

    $$K_{a1} = 6.3 \times 10^{-8}\, M$$
    $$K_{a2} = 1.0 \times 10^{-14}\, M$$

    At 1.0 atm pressure and 25°C a solution is saturated with H_2S so that $[H_2S]$ = 0.10 M. If
    the pH = 7, what is the sulfide ion concentration, $[S^{2-}]$ in such a solution?

    (a) $6.3 \times 10^{-9}\, M$ (b) $6.3 \times 10^{-2}\, M$
    (c) $0.10\, M$ (d) 0.16×10^{7}
    (e) $6.3 \times 10^{19}\, M$

13. A 1.0 Liter saturated solution of manganese sulfide, MnS, has 10 g of MnS solid at the
    bottom of the container. The pH is changed from 6.5 to 6.0 by the addition of concentrated
    strong acid such that the volume of the solution is essentially constant ($\approx$ 1.0 L). How much
    of the solid MnS will now dissolve into the solution?

    $$K_{sp} \text{ of MnS} = 7.9 \times 10^{-13}\,;\ \text{mol. wt. MnS} = 87$$

    (a) 8.9×10^{-7} g
    (b) 1.3×10^{-3} g
    (c) 1.2×10^{-2} g
    (d) 1.0 g
    (e) 2.1 g

14. If each of the salts below has solubility of 0.0020 M, which has the largest value of K_{sp}?

   (a) CX_2
   (b) MY
   (c) A_2Z
   (d) B_2Z_3
   (e) N_3Y_2

15. The solubility of lead chloride, $PbCl_2$, is 1.6×10^{-2} M. What is the K_{sp} of $PbCl_2$?

   (a) 5.0×10^{-4}
   (b) 4.1×10^{-6}
   (c) 3.1×10^{-7}
   (d) 1.6×10^{-5}
   (e) None of these.

16. What is the molar solubility of lead sulfide, PbS?

   (a) 4.0×10^{-28}
   (b) 6.4×10^{-55}
   (c) 8.0×10^{-19}
   (d) 2.8×10^{-14}
   (e) None of these.

17. Calculate the concentration (in mole/L) of Ag^+ in a saturated solution of Ag_2CO_3 when the concentration of CO_3^{2-} ion is 0.025 M. [The K_{sp} of Ag_2CO_3 is 8.1×10^{-12}].

   (a) 1.8×10^{-5}
   (b) 1.4×10^{-6}
   (c) 2.8×10^{-6}
   (d) 3.2×10^{-10}
   (e) None of these.

18. Which one of the following compounds will *increase* in solubility if the pH of a saturated solution of the compound is lowered?

   (a) $AgCl$
   (b) AgI
   (c) $PbCl_2$
   (d) CuS
   (e) $Pb(OAc)_2$