

1. (3 points) Use the acid-base chart to decide on the relative strengths of the following acids:

- (a) acetic acid, $\text{CH}_3\text{CO}_2\text{H}$ (b) HCl (c) boric acid (d) ammonium ion

_____ *weakest*

_____ *strongest*

2. (12 points) *Conjugate acids and bases.*

- a) What is the formula for the conjugate acid of pyridine, $\text{C}_5\text{H}_5\text{N}$?

- b) What is the formula for the *conjugate base* of the dihydrogen phosphate ion, H_2PO_4^- ? _____

- c) Consider the reaction of hydrazine with the hydrogen sulfate ion.



What are the two bases in this reaction? _____

Given that K_a for $\text{N}_2\text{H}_5^+ = 1.2 \times 10^{-8}$, which is the stronger *acid* in the reaction of N_2H_4 and HSO_4^- ? _____

- d) Complete and balance the following acid-base reaction:



Does the equilibrium in this reaction lie to the *right* or to the *left*? _____

3. (6 points) Predict the relative pH for each of the following salts. That is, state whether each solution has a pH greater than 7 (>7); less than 7 (<7); or equal to 7 (=7).

(a) NaH_2PO_4 _____

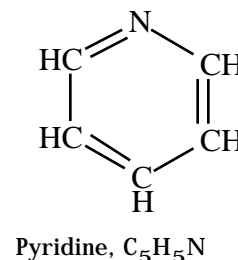
(b) KBr _____

(c) FeCl_3 _____

(d) NH_4Br _____

(e) NaCN _____

(f) Na_3PO_4 _____



4. (8 points) *Solution pH*

- a) A solution has a pH of 10.5 at 25 °C. Is it acidic, neutral, or basic? _____
- b) A solution has $[\text{H}_3\text{O}^+] = 1.0 \times 10^{-8}$. The pH = _____
- c) A solution has pH = 4.5. The $[\text{H}_3\text{O}^+] =$ _____
- d) A solution has $[\text{H}_3\text{O}^+] = 2.6 \times 10^{-4}$ M. What is $[\text{OH}^-]$? _____

5. (3 points) Consider a 4.8×10^{-3} M solution of KOH. What are $[\text{H}_3\text{O}^+]$, $[\text{OH}^-]$, and the pH of this solution?

- (a) $[\text{H}_3\text{O}^+] = 4.8 \times 10^{-3}$ M; $[\text{OH}^-] = 2.1 \times 10^{-12}$ M; pH = 2.32
- (b) $[\text{H}_3\text{O}^+] = 2.1 \times 10^{-12}$ M; $[\text{OH}^-] = 4.8 \times 10^{-3}$ M; pH = 11.68
- (c) $[\text{H}_3\text{O}^+] = 4.8 \times 10^{-3}$ M; $[\text{OH}^-] = 2.1 \times 10^{-12}$ M; pH = 11.68
- (d) $[\text{H}_3\text{O}^+] = 1.0 \times 10^{-10}$ M; $[\text{OH}^-] = 1.0 \times 10^{-2}$ M; pH = 11.68
- (e) $[\text{H}_3\text{O}^+] = 2.1 \times 10^{-12}$ M; $[\text{OH}^-] = 4.8 \times 10^{-3}$ M; pH = 4.80

6. (3 points) What is the pH of a 0.10 M solution of formic acid?

- (a) 1.80
- (b) 2.37
- (c) 3.74
- (d) 4.24
- (e) 11.63

7. (3 points) A 0.20 M solution of an unknown acid, HA, has a pH of 2.67. What is the ionization constant, K_a , for this weak acid?

- (a) $K_a = 2.1 \times 10^{-3}$
- (b) $K_a = 2.3 \times 10^{-5}$
- (c) $K_a = 4.6 \times 10^{-6}$
- (d) $K_a = 1.0 \times 10^{-7}$

8. (2 points) Novocaine is the conjugate acid of a weak base. K_a for novocaine is 1.4×10^{-9} . The value of pK_a for this acid is _____

9. (3 points) You have 0.10 M solutions of the bases listed below. Place the solutions in order of *increasing pH*.

- (a) sulfide ion, S^{2-} (c) bicarbonate ion, HCO_3^-
 (b) ammonia, NH_3 (d) borate ion, $B(OH)_4^-$

_____ *lowest pH*

_____ *highest pH*

10. (4 points) Place the following acids in order of (a) increasing strength and (b) increasing pH. Assume you have a 0.10 M solution of each acid.

- (a) 4-chlorobenzoic acid, $ClC_6H_4CO_2H$ $pK_a = 4.0$
 (b) Bromoacetic acid, $BrCH_2CO_2H$ $pK_a = 2.9$
 (c) Trimethylammonium ion, $(CH_3)_3NH^+$ $pK_a = 9.8$

Order of increasing acid strength: _____

Order of increasing pH: _____

11. (8 points) Acid-Base Reactions

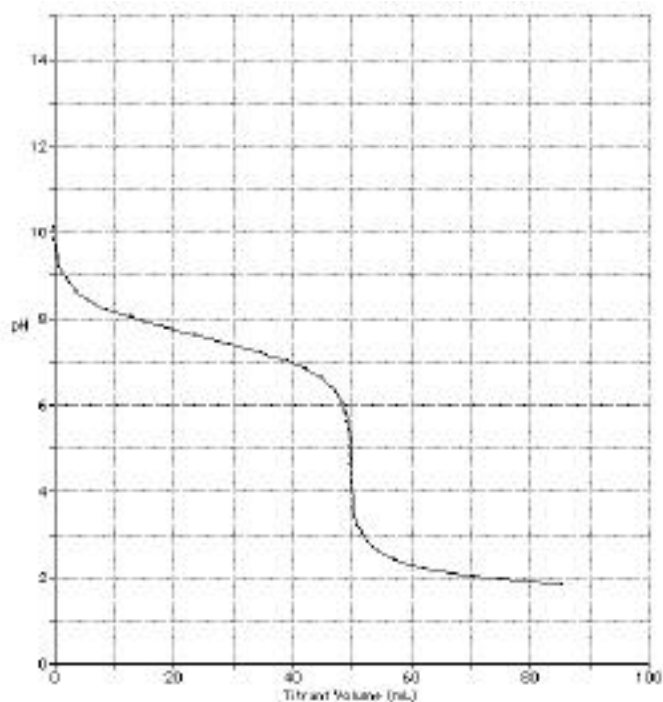
- a) After you mix 25 mL of 0.10 M CH_3CO_2H with 25 mL of 0.10 M NaOH, does the resulting solution have a $pH = 7$, $pH < 7$, or $pH > 7$? _____
- b) Does the pH increase, decrease, or stay the same when you add some solid NH_4Cl to a 0.10 M solution of NH_3 ? _____
- c) Does the pH increase, decrease, or stay the same when you add 10.0 mL of 0.10 M HCl to 25.0 mL of 0.10 M NH_3 ? _____
- d) Does the pH increase, decrease, or stay the same when you add water to a solution of 0.1 M NH_3 and 0.1 M NH_4Cl ? _____

12. (3 points) What is the pH of a buffer solution made by adding 12.0 g of NaH_2PO_4 (molar mass = 120 g/mol) and 7.1 g of Na_2HPO_4 (molar mass = 142 g/mol) to 500 mL of water?

- (a) 4.1
 (b) 6.9
 (c) 7.2
 (d) 7.5

13. (6 points) *Titration curves.* Consider the titration curve at the right. Is this curve appropriate for

- the titration of a strong acid with a strong base?
- the titration of a weak acid with a strong base?
- the titration of a strong base with a weak acid?
- the titration of a weak base with a strong acid?



What is the equivalence point for this titration?

_____. Explain why this value is (acidic), (basic), (neutral).

14. (6 points) The plot on the next page shows the result of titrating exactly 100 mL of a 0.050 M solution of the weak acid $C_3H_6O_2$ with 0.050 M NaOH.

- What is the pH before the titration begins? _____
- What is the pK_a of the acid? _____ What is its K_a value? _____

15. (5 points) Arrange the following solutions in order of increasing pH. (All solutes are 0.1 M.)

- | | |
|----------------------------|-------------------|
| (a) NaCl | (d) HCl |
| (b) NH_3 | (e) NH_3/NH_4Cl |
| (c) $CH_3CO_2H/NaCH_3CO_2$ | (f) CH_3CO_2H |

_____ lowest pH

_____ Place the appropriate letter on a blank line

_____ highest pH

16. (6 points) Buffers. What mass of ammonium chloride, NH_4Cl (molar mass = 53.5 g/mol), would have to be added to exactly 5.00×10^2 mL of 0.10 M NH_3 solution to give a buffer solution with a pH of 9.0?

17. (3 points) Copper(II) ion in water is surrounded by water molecules as

illustrated in the figure. Is the Cu^{2+} ion a Lewis acid, Lewis base,

Brønsted acid, or Brønsted base? _____

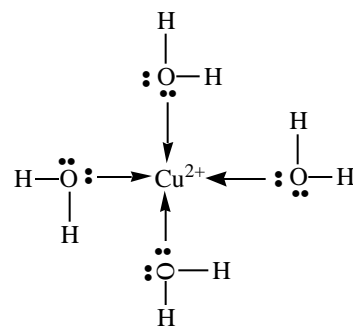
Is the water molecule a Lewis acid or Lewis base?

The water molecules on the Cu^{2+} ion can be replaced by NH_3 molecules.



Is ammonia a Lewis acid, Lewis base, Brønsted acid, or Brønsted base

in this reaction? _____



SOLUBILITY

1. (2 points) Barium phosphate, $\text{Ba}_3(\text{PO}_4)_2$, is considered very poorly soluble in water. Its solubility can be estimated using its K_{sp} value. The calculation assumes that the ions produced, Ba^{2+} and PO_4^{3-} do not react further in solution. What would happen to the solubility of $\text{Ba}_3(\text{PO}_4)_2$ if some of the phosphate ion reacted with water? Would the solubility increase, decrease, or stay the same?



2. (2 points) Name or give correct formulas for two insoluble salts of the sulfate ion, SO_4^{2-} .
- a) _____
- b) _____
3. (3 points) In each case below, decide if a precipitate will form when mixing the indicated reagents (answer *yes or no*):
- _____ $\text{NaBr}(\text{aq}) + \text{AgNO}_3(\text{aq})$
- _____ $\text{KCl}(\text{aq}) + \text{Pb}(\text{NO}_3)_2(\text{aq})$
- _____ $\text{Na}_2\text{SO}_4(\text{aq}) + \text{Mg}(\text{NO}_3)_2(\text{aq})$
4. (3 points) Which salt is the most soluble: Ag_2CO_3 , BaCO_3 , or SrCO_3 ? _____
5. (3 points) What is the solubility of AgBr (molar mass = 187.8 g/mol) in 1.0 L of water at 25 °C?
- (a) 0.108 milligrams
- (b) 1.88 milligrams
- (c) 6.20 grams
- (d) 10.8 grams
6. (3 points) A metal hydroxide with the formula $\text{M}(\text{OH})_2$ is very poorly soluble in water. If a saturated solution has a pH of 9.46, what is the K_{sp} for the metal hydroxide?
- (a) 8.3×10^{-10}
- (b) 1.2×10^{-14}
- (c) 1.2×10^{-19}
- (d) 1.7×10^{-28}
- (e) none of the above