

## ACID-BASE EQUILIBRIA (no calculator)

(All questions may be done without a calculator. Answers given were generated without the use of a calculator.)

- 1) Give the formula of the conjugate base:
  - a)  $\text{HPO}_4^{-2}$
  - b)  $\text{NH}_4^+$
  - c)  $\text{HS}^{-1}$
- 2) Give the formula of the conjugate acid:
  - a)  $\text{O}^{-2}$
  - b)  $\text{SO}_4^{-2}$
  - c)  $\text{H}_2\text{O}$
- 3) Which are Lewis acids and which are Lewis bases?
  - a)  $\text{Na}^+$
  - b)  $\text{NH}_3$
  - c)  $\text{CN}^{-1}$
  - d)  $\text{BF}_3$
- 4) Classify the following as Arrhenius, Bronsted-Lowry, or Lewis acid-base reactions. A reaction may fit all, two, one, or none of the categories:
  - a)  $\text{Ag}^+ + 2\text{NH}_3 \rightleftharpoons \text{Ag}(\text{NH}_3)_2^+$
  - b)  $\text{H}_2\text{SO}_4 + \text{NH}_3 \rightleftharpoons \text{HSO}_4^{-1} + \text{NH}_4^+$
  - c)  $2\text{HCl} \rightleftharpoons \text{H}_2 + \text{Cl}_2$
  - d)  $\text{AlCl}_3 + \text{Cl}^{-1} \rightleftharpoons \text{AlCl}_4^{-1}$
- 5) A 0.040 M solution of a weak acid (HA) has a pH of 4.70. What re the  $K_a$  and  $\text{p}K_a$ ?
- 6) A 0.25 mol sample of a weak acid HA is dissolved in water to make 500 mL of the solution. The pH of the solution is measured to be 3.30, what is the  $K_a$  of the weak acid?
- 7) For a diprotic weak acid  $\text{H}_2\text{A}$ ,  $K_{a1} = 1 \times 10^{-4}$  and  $K_{a2} = 1 \times 10^{-8}$ . Calculate  $[\text{H}_2\text{A}]$ ,  $[\text{HA}^{-1}]$ ,  $[\text{A}^{-2}]$ ,  $[\text{H}^+]$ , pH and pOH in a 1.00 M solution of  $\text{H}_2\text{A}$ .
- 8) Phenol ( $\text{C}_6\text{H}_5\text{OH}$ ) is a weak acid with a  $K_a = 1.0 \times 10^{-10}$ . What is the pH of 0.100 M sodium phenolate ( $\text{C}_6\text{H}_5\text{ONa}$ ), the sodium salt of phenol?
- 9) What is the pH of a 0.40 M anilinium chloride ( $\text{C}_6\text{H}_5\text{NH}_3\text{Cl}$ ) solution?  $K_b$  of aniline ( $\text{C}_6\text{H}_5\text{NH}_2$ ) is  $4 \times 10^{-10}$ .
- 10) Calculate the pH of a 6.0% (mass/volume) acetic acid (molar mass = 60.0 g/mol) solution in water if the  $\text{p}K_a$  of aceic acid is 4.74.

- 11) Explain with equations and calculations, when necessary, whether an aqueous solution of each of these salts is acidic, basic, or neutral:
- KBr
  - $\text{NH}_4\text{I}$
  - KCN
- 12) Explain with equations and calculations, when necessary, whether an aqueous solution of each of these salts is acidic, basic, or neutral:
- $\text{SrBr}_2$
  - $\text{Ba}(\text{CH}_3\text{COO})_2$
  - $(\text{CH}_3)_2\text{NH}_2\text{Br}$
- 13) Calculate the pH of a buffer solution that has 0.50 M HA and 1.0 M KA. ( $K_a$  of HA is  $2 \times 10^{-5}$ ).
- 14) Calculate the pH of a solution that consists of 0.50 M  $\text{NH}_3$  and 0.50 M  $\text{NH}_4\text{Cl}$ . The  $\text{p}K_b$  of ammonia is 4.74.
- 15) What is the ratio of  $[\text{HA}/\text{A}^{-1}]$  of a buffer solution that has a  $\text{pH} = 2.70$  if the  $\text{p}K_a$  of HA is 3.00?
- 16) A solution containing 0.10 M HA (a weak acid) and 0.20 M NaA (the salt of the weak acid) has a  $\text{pH} = 3.30$ . What is the  $\text{pH}$  after 25 mmol of HCl is added to 500 mL of this solution?
- 17) A solution containing 0.40 M B (a weak base) and 0.20 M  $\text{BH}^+$  (the salt of the weak base) has a  $\text{pH} = 10.30$ . What is the  $\text{pH}$  after 25 mmol of HCl is added to 250 mL of this solution?
- 18) The indicator cresol red has  $K_a = 5.0 \times 10^{-9}$ . Over what approximate pH range does it change colour?
- 19) A 25.0 mL sample of a weak base B is titrated with 50.0 mL of 0.20 M HCl. The  $\text{p}K_b$  of the weak base B is 3.60.
- Calculate the  $\text{pH}$  of the solution at the start of the titration.
  - Calculate the  $\text{pH}$  of the solution when 10.0 mL of the acid solution have been added.
  - Calculate the  $\text{pH}$  at the equivalence point of this titration.
  - Calculate the  $\text{pH}$  when 25.0 mL beyond the equivalence point have been added.
  - If you were to select an indicator for the above titration, approximately what should be its  $\text{p}K_a$ ? EXPLAIN YOUR ANSWER.
- 20) A 10.0 mL sample of 0.300 M weak acid (HA) is titrated with 0.100 M NaOH solution. The  $K_a$  for HA =  $2.0 \times 10^{-4}$ .
- Calculate the  $\text{pH}$  of the solution when no base has been added.
  - Calculate how many mL of NaOH solution have been added when the  $\text{pH} = 3.00$ .
  - Calculate the  $\text{pH}$  when a total of 30.00 mL of NaOH solution have been added.
  - Calculate the  $\text{pH}$  when a total of 40.00 mL of NaOH solution have been added.
  - The indicators bromcresol green and thymol blue go through a colour change from yellow to blue, however their  $\text{p}K_a$ 's are different:  $\text{p}K_a(\text{bromcresol green}) = 4.5$  and  $\text{p}K_a(\text{thymol blue}) = 8.5$
  - Which indicator should be used in the above titration so that the end point corresponds with the equivalence point? SHOW YOUR WORK TO SUPPORT YOUR CHOICE.

## ANSWERS

1. (a)  $\text{PO}_4^{3-}$  (b)  $\text{NH}_3$  (c)  $\text{S}^{2-}$
2. (a)  $\text{OH}^-$  (b)  $\text{HSO}_4^-$  (c)  $\text{H}_3\text{O}^+$
3. Lewis acids:  $\text{Na}^+$ ,  $\text{BF}_3$  Lewis Bases:  $\text{NH}_3$ ,  $\text{CN}^-$
4. (a) Lewis (b) Bronsted-Lowry and Lewis (c) None (d) Lewis
5.  $K_a = 1.0 \times 10^{-8}$  and  $\text{p}K_a = 8.00$
6.  $K_a = 5 \times 10^{-7}$
7.  $[\text{H}^+] = [\text{HA}^-] = 0.01 \text{ M}$ ;  $[\text{H}_2\text{A}] = 0.99 \text{ M}$ ;  $\text{pH} = 2.0$  and  $\text{pOH} = 12.0$ ;  $[\text{A}^{2-}] = K_{a2} = 1 \times 10^{-8} \text{ M}$
8.  $\text{pH} = 11.50$
9.  $\text{pH} = 2.50$
10.  $\text{pH} = 2.37$
11. (a) neutral (b) acidic (c) basic
12. (a) neutral (b) basic (c) acidic
13.  $\text{pH} = 5.00$
14.  $\text{pH} = 9.26$
15.  $[\text{HA}/\text{A}^-] = 2$
16.  $\text{pH} = 3.00$
17.  $\text{pH} = 10.00$
18.  $\text{pH}$  range for this indicator is about 7.3 to 9.3.
19. (a)  $\text{pH} = 12.00$  (b)  $\text{pH} = 11.00$  (c)  $\text{pH} = 5.64$  (d)  $\text{pH} = 1.30$   
(e)  $\text{p}K_a$  of the indicator should be around 5.5 because that is the  $\text{pH}$  at the equivalence point.
20. (a)  $\text{pH} = 2.11$  (b) 5.00 mL (c)  $\text{pH} = 9.41$  (d)  $\text{pH} = 12.30$  (e) Thymol blue