

PROBLEM SET No. 6: ACID-BASE EQUILIBRIA

(All questions are no calculator friendly.)

- 1) Give the formula of the conjugate base:
 - a) HPO_4^{-2}
 - b) NH_4^+
 - c) HS^{-1}
- 2) Give the formula of the conjugate acid:
 - a) O^{-2}
 - b) SO_4^{-2}
 - c) H_2O
- 3) Which are Lewis acids and which are Lewis bases?
 - a) Na^+
 - b) NH_3
 - c) CN^{-1}
 - d) 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 are 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 H_2A , $K_{a1} = 1 \times 10^{-4}$ 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 H_2A .
- 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 4×10^{-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 acetic 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
 - NH_4I
 - KCN
- 12) Explain with equations and calculations, when necessary, whether an aqueous solution of each of these salts is acidic, basic, or neutral:
- 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 2×10^{-5}).
- 14) Calculate the pH of a solution that consists of 0.50 M NH_3 and 0.50 M NH_4Cl . 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 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 BH^+ (the salt of the weak base) has a $\text{pH} = 10.30$. What is the 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 pH of the solution at the start of the titration.
 - Calculate the pH of the solution when 10.0 mL of the acid solution have been added.
 - Calculate the pH at the equivalence point of this titration.
 - Calculate the 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 = 2.0×10^{-4} .
- Calculate the 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 pH when a total of 30.00 mL of NaOH solution have been added.
 - Calculate the 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) PO_4^{-3} (b) NH_3 (c) S^{-2}
2. (a) OH^{-1} (b) HSO_4^{-1} (c) H_3O^+
3. Lewis acids: Na^+ , BF_3 Lewis Bases: NH_3 , CN^{-1}
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. $[\text{H}^+] = [\text{HA}^{-1}] = 0.01 \text{ M}$; $[\text{H}_2\text{A}] = 0.99 \text{ M}$; $\text{pH} = 2.0$ 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. $[\text{HA}/\text{A}^{-1}] = 2$
16. $\text{pH} = 3.00$
17. $\text{pH} = 10.00$
18. 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 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