

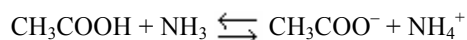
General Chemistry II Jasperse  
Acid-Base Chemistry. Extra Practice Problems

General Types/Groups of problems:

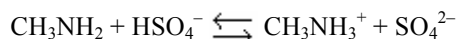
Conceptual Questions. Acids, Bases, and Conjugates, Miscellaneous	p1	$K_b$ and $pK_b$ , Base Strength, and using $K_b$ or $pK_b$ to Calculate $[OH^-]$ , pOH, pH, and/or $[H^+]$	p7-10
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**Conceptual Questions. Acids, Bases, and Conjugates, Miscellaneous**

1. In the Brønsted–Lowry definition of acids and bases, an acid \_\_\_\_\_
- is a proton donor.
  - is a proton acceptor.
  - forms stable hydrogen bonds.
  - breaks stable hydrogen bonds.
  - corrodes metals.
2. In the Brønsted–Lowry definition of acids and bases, a base \_\_\_\_\_
- is a proton donor.
  - is a proton acceptor.
  - forms stable hydrogen bonds.
  - breaks stable hydrogen bonds.
  - corrodes metals.
3. In the following reaction in aqueous solution, the acid reactant is \_\_\_\_\_ and its conjugate base product is \_\_\_\_\_.



- $CH_3COOH$ ;  $CH_3COO^-$
  - $CH_3COOH$ ;  $NH_4^+$
  - $NH_3$ ;  $CH_3COO^-$
  - $NH_3$ ;  $NH_4^+$
  - $CH_3COOH$ ;  $H_3O^+$
4. In the following reaction in aqueous solution, the acid reactant is \_\_\_\_\_, and its conjugate base product is \_\_\_\_\_.



- $CH_3NH_2$ ;  $CH_3NH_3^+$
  - $CH_3NH_2$ ;  $SO_4^{2-}$
  - $HSO_4^-$ ;  $CH_3NH_3^+$
  - $HSO_4^-$ ;  $SO_4^{2-}$
  - $HSO_4^-$ ;  $H_3O^+$
5. Which of the following is the conjugate acid of the hydrogen phosphate ion,  $HPO_4^{2-}$ ?
- $H_3PO_4$
  - $H_2PO_4^-$
  - $HPO_4^{2-}$
  - $PO_4^{3-}$
  - $H_3O^+$

6. Which one of the following is *not* a conjugate acid–base pair?

- |  |   |
|--|---|
| a. $\text{NH}_3$ and $\text{NH}_4^+$                 | d. $\text{HS}^-$ and $\text{H}_2\text{S}$ |
| b. $\text{H}_3\text{O}^+$ and $\text{OH}^-$          | e. $\text{NH}_3$ and $\text{NH}_2^-$      |
| c. $\text{H}_2\text{PO}_4^-$ and $\text{HPO}_4^{2-}$ |   |

7. Which one of the following is a conjugate acid–base pair?

- |   |   |
|---|---|
| a. $\text{NH}_3$ and $\text{NH}_4^+$        | d. $\text{H}_2\text{O}$ and $\text{O}^{2-}$ |
| b. $\text{H}_3\text{O}^+$ and $\text{OH}^-$ | e. $\text{NaF}$ and $\text{F}^-$            |
| c. $\text{NH}_2^-$ and $\text{NH}_4^+$      |   |

8. Which one of the following is a conjugate acid–base pair?

- |                                      |  |
|--------------------------------------|--|
| a. $\text{NaF}$ and $\text{F}^-$     | d. $\text{NH}_4^+$ and $\text{NH}_2^-$             |
| b. $\text{HNO}_3$ and $\text{HNO}_2$ | e. $\text{H}_2\text{O}$ and $\text{H}_2\text{O}_2$ |
| c. $\text{HI}$ and $\text{I}^-$      |  |

9. Which one of the following is *not* a conjugate acid–base pair?

- |                                      |  |
|--------------------------------------|--|
| a. $\text{NH}_3$ and $\text{NH}_2^-$ | d. $\text{H}_2\text{PO}_4^-$ and $\text{HPO}_4^{2-}$ |
| b. $\text{HNO}_3$ and $\text{HNO}_2$ | e. $\text{H}_2\text{O}$ and $\text{OH}^-$            |
| c. $\text{HI}$ and $\text{I}^-$      |  |

10. The stronger the acid, \_\_\_\_\_

- |                                     |  |
|-------------------------------------|--|
| a. the stronger its conjugate base. | d. the less concentrated the conjugate base. |
| b. the weaker its conjugate base.   | e. the more concentrated the conjugate base. |
| c. the more concentrated the acid.  |  |

11. Ammonia ( $\text{NH}_3$ ) acts as a weak base in aqueous solution. What is the acid that reacts with this base when ammonia is dissolved in water?

- none, there are no acids in pure water
- $\text{H}_2\text{O}$
- $\text{NH}_4^+$
- trick question, because no acids are present, ammonia cannot act as a base
- oxygen that always is dissolved in water

12. The base ionization constant  $K_b$  describes which of the following reactions for a weak base, B, in aqueous solution? (Note: often the base will be anionic rather than neutral, but “B” here is meant to represent anionic or neutral bases, which will gain one H and become one charge unit more positive whether starting neutral or anionic.)

- |  |   |
|--|---|
| a. $\text{B} + \text{H}^+ \rightleftharpoons \text{BH}^+$                                | d. $\text{B} + \text{OH}^- \rightleftharpoons \text{BH}^- + \text{O}^{2-}$      |
| b. $\text{B} + \text{H}_3\text{O}^+ \rightleftharpoons \text{BH}^+ + \text{H}_2\text{O}$ | e. $\text{BH}^+ + \text{OH}^- \rightleftharpoons \text{B} + \text{H}_2\text{O}$ |
| c. $\text{B} + \text{H}_2\text{O} \rightleftharpoons \text{BH}^+ + \text{OH}^-$          |   |

**Recognizing Strong versus Weak Acids; Recognizing Basic versus Nonbasic**

13. Which of the following is a **strong acid**?

- a.  $\text{HNO}_3$
- b.  $\text{H}_2\text{S}$
- c.  $\text{HNO}_2$
- d.  $\text{HCO}_3^-$
- e.  $\text{HOCl}$

14. Which one of the following is a **strong acid**?

- a. nitrous acid,  $\text{HNO}_2$
- b. sulfurous acid,  $\text{H}_2\text{SO}_3$
- c. carbonic acid,  $\text{H}_2\text{CO}_3$
- d. hydrofluoric acid,  $\text{HF}$
- e. perchloric acid,  $\text{HClO}_4$

15. Which one of the following is not a **strong acid**?

- a. nitric acid,  $\text{HNO}_3$
- b. sulfuric acid,  $\text{H}_2\text{SO}_4$
- c. carbonic acid,  $\text{H}_2\text{CO}_3$
- d. hydrochloric acid,  $\text{HCl}$
- e. perchloric acid,  $\text{HClO}_4$

16. Which of the following compounds cannot be a Brønsted–Lowry **base**?

- a.  $\text{OH}^-$
- b.  $\text{H}_2\text{O}$
- c.  $\text{NH}_3$
- d.  $\text{NH}_4^+$
- e.  $\text{SH}^-$

17. Each of the following pairs contains one strong acid and one weak acid **EXCEPT**:

- a.  $\text{H}_2\text{SO}_4$  and  $\text{H}_2\text{CO}_3$
- b.  $\text{HNO}_3$  and  $\text{HNO}_2$
- c.  $\text{HBr}$  and  $\text{H}_3\text{PO}_2$
- d.  $\text{HSO}_4^-$  and  $\text{HCN}$
- e.  $\text{HCl}$  and  $\text{H}_2\text{S}$

18. Which **one** of the following is NOT **basic**?

- a.  $\text{OH}^-$
- b.  $\text{NO}_3^-$
- c.  $\text{NH}_3$
- d.  $\text{SO}_4^{2-}$
- e.  $\text{HPO}_4^{2-}$

19. Which **one** of the following is **basic**?

- a.  $\text{Cl}^-$
- b.  $\text{NO}_3^-$
- c.  $\text{ClO}_4^-$
- d.  $\text{HSO}_4^-$
- e.  $\text{SO}_4^{2-}$

**pH Calculations; Relationships between pH and pOH**

20. If the pH of a solution increases by 2 units (e.g., from 1 to 3), then the ratio of the new to the original hydronium ion concentration is \_\_\_\_\_
- a. 2/1  
b. 100/1  
c. 1/2  
d. 1/100.  
e. 1/1, unchanged
21. When  $[H^+] = 1.0 \times 10^{-7} M$  in water at 25°C, then \_\_\_\_\_
- a. pH = 1.  
b. pH =  $10^{-7}$ .  
c.  $[OH^-] = 1.0 \times 10^{-7} M$ .  
d.  $[OH^-] = 1.0 \times 10^7 M$ .  
e.  $[OH^-] = 0 M$ .
22. When  $[H^+] = 4.0 \times 10^{-9} M$  in water at 25°C, then \_\_\_\_\_
- a. pH = 9.40.  
b. pH = 7.00.  
c. pH = -8.40.  
d. pH = 8.40.  
e. pH = -9.40
23. A solution with pH of 9.50 has a pOH of \_\_\_\_\_
- a. 9.50.  
b. 0.50.  
c. 4.50.  
d. 23.5.  
e. 19.0.
24. A solution with an  $[OH^-]$  concentration of  $1.20 \times 10^{-7} M$  has a pOH and pH of \_\_\_\_\_
- a. 6.92 and 7.08  
b. 1.00 and 13.00  
c. 5.35 and 8.75  
d. 7.08 and 6.92  
e. 5.94 and 8.06
25. A solution with a pOH of 4.3 has a  $[H^+]$  of \_\_\_\_\_
- a.  $6.8 \times 10^{-9} M$ .  
b.  $3.2 \times 10^{-4} M$ .  
c.  $4.8 \times 10^{-5} M$ .  
d.  $2.0 \times 10^{-10} M$ .  
e. 4.3 M.
26. Which statement, A–D, is not correct? If all are correct, respond E. Pure water at 25°C has \_\_\_\_\_
- a.  $K_w = 1.0 \times 10^{-14}$ .  
b. pOH = 7.  
c.  $[H_3O^+] = [OH^-]$ .  
d. pH = 7.  
e. A–D are all correct.

**K<sub>a</sub>: Sense + Calculations. Using K<sub>a</sub> or pK<sub>a</sub> to Calculate [H<sup>+</sup>] and/or pH; using pH to calculate K<sub>a</sub> or pK<sub>a</sub>**

27. Solutions of each of the hypothetical acids in the following table are prepared with an initial concentration of 0.100 M. Which of the four solutions will have the lowest pH and be most acidic?

<i>Acid</i>	<i>pK<sub>a</sub></i>
HA	4.00
HB	7.00
HC	10.00
HD	11.00

- a. HA  
b. HB  
c. HC
- d. HD  
e. All will have the same pH because the concentrations are the same.
28. What is the hydronium ion concentration of a 0.010 M solution of acetic acid? K<sub>a</sub> for acetic acid is 1.8 × 10<sup>-5</sup>
- a. 1.8 × 10<sup>-3</sup>  
b. 1.8 × 10<sup>-5</sup>  
c. 1.0 × 10<sup>-2</sup>
- d. 1.8 × 10<sup>-7</sup>  
e. 4.2 × 10<sup>-4</sup>

29. What is the pH of a 0.010 M solution of acetic acid? K<sub>a</sub> for acetic acid is 1.8 × 10<sup>-5</sup>
- a. 2.74  
b. 4.74  
c. 2.00
- d. 3.37  
e. 6.74

30. When values of K<sub>a</sub> are small (e.g., 1 × 10<sup>-5</sup>) and concentrations of weak acids [HA] are relatively large (e.g., 0.10 M), and assuming there is no other source of anion A<sup>-</sup>, the hydronium ion concentration of the solution can be calculated using which expression?
- a. [H<sup>+</sup>] = K<sub>a</sub>  
b. [H<sup>+</sup>] = K<sub>a</sub>[HA]  
c. [H<sup>+</sup>] = (K<sub>a</sub>[HA])<sup>1/2</sup>
- d. [H<sup>+</sup>] = K<sub>a</sub>K<sub>b</sub>[HA]  
e. [H<sup>+</sup>] = K<sub>a</sub>[HA]<sup>2</sup>/[A<sup>-</sup>]

31. The first disinfectant used by Joseph Lister was called carbolic acid. This substance now is known as phenol, C<sub>6</sub>H<sub>5</sub>OH (pK<sub>a</sub> = 10.0). What is the pH of a 0.10 M solution of phenol?
- a. 3.5  
b. 10.0  
c. 6.5
- d. 5.5  
e. 4.5

32. The pH of a popular soft drink is 3.4; what is its hydronium ion concentration?
- a. 5.0 × 10<sup>-4</sup> M  
b. 4.0 × 10<sup>-4</sup> M  
c. 2.5 × 10<sup>3</sup> M
- d. 1.0 × 10<sup>-7</sup> M  
e. 5.0 × 10<sup>-5</sup> M

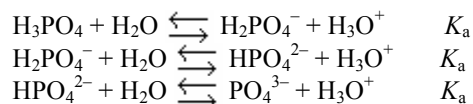
33. The concentration of acetic acid ( $pK_a = 4.75$ ) in vinegar is about  $1.0\text{ M}$ . With this information, what do you predict the pH of vinegar to be?
- 4.75
  - 2.4
  - $4.0 \times 10^{-3}$
  - 7.0
  - 5.35
34. Boric acid frequently is used as an eyewash to treat eye infections. The pH of a  $0.050\text{ M}$  solution of boric acid is 5.28. What is the value of the boric acid ionization constant,  $K_a$ ?
- $5.25 \times 10^{-6}$
  - $5.51 \times 10^{-10}$
  - $5.43 \times 10^{-8}$
  - $5.79 \times 10^{-4}$
  - $5.33 \times 10^{-12}$
35. A  $0.100\text{ M}$  solution of a monoprotic weak acid has a pH of 3.00. What is the  $pK_a$  of this acid?
- 5.00
  - 0.999
  - 3.00
  - 9.99
  - 6.00
36. The acidic ingredient in vinegar is acetic acid. The pH of vinegar is around 2.4, and the molar concentration of acetic acid in vinegar is around  $0.85\text{ M}$ . Based on this information, determine the value of the acid ionization constant,  $K_a$ , for acetic acid.
- $2.5 \times 10^{-5}$
  - $5.0 \times 10^{-5}$
  - $4.7 \times 10^{-3}$
  - $1.9 \times 10^{-5}$
  - $7.4 \times 10^{-3}$
37. Three acids found in foods are lactic acid (in milk products), oxalic acid (in rhubarb), and malic acid (in apples). The  $pK_a$  values are **LA = 3.88, OA = 1.23, and MA = 3.40**. Which list has these acids in order of decreasing acid strength?
- LA > OA > MA
  - LA > MA > OA
  - OA > MA > LA
  - OA > LA > MA
  - MA > LA > OA
38. Use the following acid ionization constants to identify the correct decreasing order of base strengths.
- |                  |                             |
|------------------|-----------------------------|
| HF               | $K_a = 7.2 \times 10^{-4}$  |
| HNO <sub>2</sub> | $K_a = 4.5 \times 10^{-4}$  |
| HCN              | $K_a = 6.2 \times 10^{-10}$ |
- $\text{CN}^- > \text{NO}_2^- > \text{F}^-$
  - $\text{NO}_2^- > \text{F}^- > \text{CN}^-$
  - $\text{F}^- > \text{CN}^- > \text{NO}_2^-$
  - $\text{F}^- > \text{NO}_2^- > \text{CN}^-$
  - $\text{NO}_2^- > \text{CN}^- > \text{F}^-$

**$K_b$  and  $pK_b$ , Base Strength, and using  $K_b$  or  $pK_b$  to Calculate  $[OH^-]$ ,  $pOH$ ,  $pH$ , and/or  $[H^+]$** 

39. A cup of coffee has a hydroxide ion concentration of  $1.0 \times 10^{-10} M$ . What is the pH of this coffee?
- $1.0 \times 10^{-4}$
  - 4
  - 10
  - 7
  - 10
40. What is the concentration of  $[OH^-]$  in a 0.20 M solution of ammonia? The  $K_b$  value for ammonia is  $1.8 \times 10^{-5}$ .
- $3.6 \times 10^{-6} M$
  - $1.8 \times 10^{-5} M$
  - 0.20 M
  - $1.9 \times 10^{-3} M$
  - $4.2 \times 10^{-4} M$
41. What is the pOH of a 0.20 M solution of ammonia? The  $K_b$  value for ammonia is  $1.8 \times 10^{-5}$ .
- 4.44
  - 4.74
  - 0.70
  - 2.72
  - 3.38
42. What is the pH of a 0.20 M solution of ammonia? The  $K_b$  value for ammonia is  $1.8 \times 10^{-5}$ .
- 9.56
  - 9.26
  - 4.74
  - 11.28
  - 2.72
43. What is the hydronium ion concentration of a 0.20 M solution of ammonia? The  $K_b$  value for ammonia is  $1.8 \times 10^{-5}$ .
- $2.8 \times 10^{-10}$
  - $5.5 \times 10^{-10}$
  - $1.8 \times 10^{-5}$
  - $5.2 \times 10^{-12}$
  - $1.9 \times 10^{-3}$
44. What is the pH of a 0.500 M solution of trimethylamine ( $pK_b = 4.13$ )?
- 2.22
  - 11.8
  - 0.00609
  - 4.42
  - 5.91

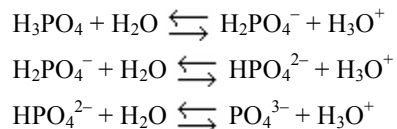
**Miscellaneous problems involving Weak Bases and perhaps their Conjugates.**

45. Phosphoric acid is a triprotic acid, ionizing in the following sequential steps:



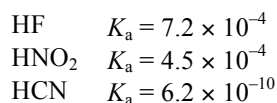
Write the  $K_b$  expression for the base, sodium phosphate ( $\text{Na}_3\text{PO}_4$ )?

46. Phosphoric acid is a triprotic acid, ionizing in the following sequential steps:



Write the  $K_b$  expression for the base, sodium dihydrogen phosphate ( $\text{NaH}_2\text{PO}_4$ )?

47. Use the following acid ionization constants to identify the correct decreasing order of base strengths.



- |   |   |
|---|---|
| a. $\text{CN}^- > \text{NO}_2^- > \text{F}^-$ | d. $\text{F}^- > \text{NO}_2^- > \text{CN}^-$ |
| b. $\text{NO}_2^- > \text{F}^- > \text{CN}^-$ | e. $\text{NO}_2^- > \text{CN}^- > \text{F}^-$ |
| c. $\text{F}^- > \text{CN}^- > \text{NO}_2^-$ |   |

48. Three acids found in foods are lactic acid (in milk products), oxalic acid (in rhubarb), and malic acid (in apples). The  $\text{p}K_a$  values are LA = 3.88, OA = 1.23, and MA = 3.40. Which list has the conjugate bases of these acids in order of decreasing strength?

- |                               |                               |
|-------------------------------|-------------------------------|
| a. lactate > oxalate > malate | d. oxalate > lactate > malate |
| b. oxalate > malate > lactate | e. malate > lactate > oxalate |
| c. lactate > malate > oxalate |                               |

49. What is the pH of a 0.20 M solution of cubaramine? The  $K_b$  value for jaspersamine is  $2.5 \times 10^{-6}$ .

50. What is the pH of a 0.10 M solution of trimethylamine ( $\text{p}K_b = 4.13$ )?





**Getting Information about an Acid or Base Based on  $K_a$  or  $pK_a$  or  $K_b$  or  $pK_b$  of the conjugate.**

56. What is the pH of a 0.20 M solution of sodium acetate? The  $K_a$  for acetic acid is  $1.8 \times 10^{-5}$ ?
57. What is the pH of a 0.40 M solution of sodium nitrite,  $\text{NaNO}_2$ ? The  $pK_a$  for nitrous acid ( $\text{HNO}_2$ ) is 3.35.
58. What is the pH of a 0.20 M solution of weak acid jaspersammonium bromide? The  $K_b$  value for jaspersamine is  $4.0 \times 10^{-5}$ .
59. What is the pH of a 0.10 M solution of weak acid trimethylammonium chloride? The  $pK_b = 4.13$  for its conjugate base triethylamine

### Recognizing Acid/Base Properties when Ionics are Dissolved in Water

60. Aqueous solutions of \_\_\_\_\_ are basic.
- |         |        |
|---------|--------|
| a. NaF  | d. NaI |
| b. NaCl | e. KI  |
| c. NaBr |        |
61. Which one of the following salts forms aqueous solutions with pH = 7?
- |                       |                                    |
|-----------------------|------------------------------------|
| a. Na <sub>2</sub> S  | d. NaNO <sub>2</sub>               |
| b. NaBr               | e. Na <sub>2</sub> CO <sub>3</sub> |
| c. NaClO <sub>2</sub> |                                    |
62. Which one of the following salts forms aqueous solutions with pH = 7?
- |                       |                                     |
|-----------------------|-------------------------------------|
| a. NaCN               | d. NaH <sub>2</sub> PO <sub>4</sub> |
| b. NH <sub>4</sub> Br | e. Na <sub>2</sub> CO <sub>3</sub>  |
| c. NaNO <sub>3</sub>  |                                     |
63. Which one of the following salts does **not** produce a **basic** solution when dissolved in water?
- |                       |                       |
|-----------------------|-----------------------|
| a. NaOCH <sub>3</sub> | d. NaNO               |
| b. NaHSO <sub>4</sub> | e. NaHCO <sub>3</sub> |
| c. NaBrO <sub>2</sub> |                       |
64. The pH of an aqueous sodium fluoride (NaF) solution is \_\_\_\_\_ because \_\_\_\_\_
- 7; sodium fluoride is a simple salt.
  - above 7; fluoride is a weak base.
  - below 7; fluoride reacts with water to make hydrofluoric acid.
  - about 7; fluoride is a weak base, but produces hydrofluoric acid, and these two neutralize one another.
  - 0; sodium fluoride is a salt not an acid or a base.
65. Which one of the following, A–D, is correct? If all are correct, respond E.
- |   |  |
|---|--|
| a. K <sub>2</sub> SO <sub>3</sub> is a stronger base than KHSO <sub>3</sub> . | d. Na <sub>2</sub> HPO <sub>4</sub> is a weaker base than NaH <sub>2</sub> PO <sub>4</sub> . |
| b. K <sub>2</sub> CO <sub>3</sub> is a weaker base than KHCO <sub>3</sub> .   | e. All of these statements are correct.  |
| c. NaHSO <sub>3</sub> is a stronger acid than NaHSO <sub>4</sub> .            |  |
66. Which of the following groups, A–D, consist of salts that all form basic solutions in water? (Ac = acetate) If none or all satisfy this criterion, respond E.
- |  |  |
|--|--|
| a. NaNO <sub>3</sub> , NH <sub>4</sub> CN, NaAc, NH <sub>4</sub> Cl                | d. NaHCO <sub>3</sub> , NaF, NH <sub>4</sub> Cl, Na <sub>2</sub> SO <sub>3</sub> |
| b. Na <sub>2</sub> CO <sub>3</sub> , KCl, NaOOCH <sub>3</sub> , NH <sub>4</sub> Cl | e. None or all of the above.   |
| c. Na <sub>2</sub> CO <sub>3</sub> , NaF, NaOOCH <sub>3</sub> , NaCN               |  |

1. A	34. B
2. B	35. A
3. A	36. D
4. D	37. C
5. <u>B</u>	38. <u>A</u>
6. B	39. B
7. A	40. D
8. C	41. D
9. B	42. D
10. B	43. D
11. B	44. <u>B</u>
12. <u>C</u>	45. $K_b = ([\text{HPO}_4^{2-}][\text{HO}^-]) / [\text{PO}_4^{3-}]$
13. A	46. $K_b = ([\text{H}_3\text{PO}_4][\text{HO}^-]) / [\text{H}_2\text{PO}_4^-]$
14. E	47. A
15. C	48. C
16. D	49. pH=10.85
17. D	50. <u>pH=11.44</u>
18. B	51. B
19. <u>E</u>	52. pH=11.45
20. D	53. D
21. C	54. C
22. D	55. <u>D</u>
23. C	56. pH = 9.02
24. A	57. pH = 8.48
25. D	58. pH = 5.15
26. <u>E</u>	59. <u>pH = 5.44</u>
27. A	60. A
28. E	61. B
29. D	62. C
30. C	63. B
31. D	64. B
32. <u>B</u>	65. A
33. B	66. C