

**Organic Chemistry, 7e (Bruice)**

**Chapter 2 Acids and Bases: Central to Understanding Organic Chemistry**

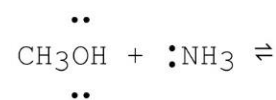
1) Which of the following is not a conjugate acid-base pair?

- A)  $\text{H}_2\text{O}$ ,  $\text{HO}^-$
- B)  $\text{H}_2\text{O}$ ,  $\text{H}_3\text{O}^+$
- C)  $\text{HSO}_4^-$ ,  $\text{H}_2\text{SO}_4$
- D)  $-\text{OH}$ ,  $\text{O}^{2-}$
- E)  $\text{NO}_3^-$ ,  $\text{NO}_2^-$

Answer: E

Section: 2-1

2) What is the product formed from the following acid-base reaction when ammonia functions as a base? The equilibrium lies far to the reactants.



- A)  $\text{CH}_3\text{O}^- + ^+\text{NH}_4$
- B)  $\text{CH}_2\text{OH} + ^+\text{NH}_3$
- C)  $\text{CH}_3\text{OH}_2^+ + ^-\text{NH}_2$
- D)  $\text{CH}_3\text{NH}_2 + \text{H}_2\text{O}$
- E)  $\text{CH}_4 + \text{NH}_2\text{OH}$

Answer: A

Section: 2-1

3) The conjugate acid of  $\text{H}_2\text{O}$  is \_\_\_\_\_.

- A)  $\text{H}_3\text{O}^-$
- B)  $\text{H}_3\text{O}$
- C)  $\text{H}_3\text{O}^+$
- D)  $\text{HO}^-$
- E)  $\text{H}_2\text{O}^+$

Answer: C

Section: 2-1

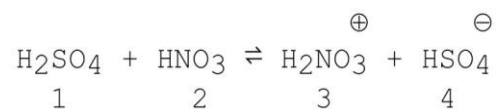
4) Which of the following ions is the strongest acid?

- A)  $\text{H}^-$
- B)  $\text{HO}^-$
- C)  $\text{HSO}_4^-$
- D)  $\text{H}_2\text{O}$
- E)  $\text{H}_3\text{O}^+$

Answer: E

Section: 2-1

5) Which species act as bases in the following reaction?



A) 1 and 2

B) 3 and 4

C) 2 and 4

D) 1 and 3

E) 2 and 3

Answer: C

Section: 2-1

6) What is the conjugate acid of  $\text{NH}_3$ ?

A)  $+\text{NH}_3$

B)  $-\text{NH}$

C)  $+\text{NH}_4$

D)  $-\text{NH}_2$

E)  $+\text{NH}_2$

Answer: C

Section: 2-1

7) What is the conjugate acid of  $\text{CH}_3\text{NH}_2$ ?

A)  $\text{CH}_3\text{NH}_3^+$

B)  $\text{CH}_3\text{NH}^-$

C)  $\text{NH}_4^+$

D)  $\text{NH}_2^-$

Answer: A

Section: 2-1

8) What is the conjugate base of  $\text{CH}_3\text{NH}_2$ ?

A)  $\text{CH}_3\text{NH}_3^+$

B)  $\text{CH}_3\text{NH}^-$

C)  $\text{NH}_4^+$

D)  $\text{NH}_2^-$

Answer: B

Section: 2-1

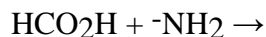
9) Give the conjugate acid and the conjugate base for  $\text{HSO}_4^-$ .

Answer: conjugate acid:  $\text{H}_2\text{SO}_4$

conjugate base:  $\text{SO}_4^{2-}$

Section: 2-1

10) Write a completed equation for the acid-base pair shown below.



Answer:  $\text{HCO}_2\text{H} + ^-\text{NH}_2 \rightarrow \text{HCO}_2^- + \text{NH}_3$

Section: 2-1

11) What is the pH of a 0.1 M solution of HCl? (Note:  $\text{pK}_a$  for HCl is -6.)

A) 6

B) -6

C) 1

D) -8

E) -1

Answer: C

Section: 2-2

12) If  $\text{H}_2\text{O}$  has a  $\text{pK}_a$  value of 15.7 and HF has a  $\text{pK}_a$  value of 3.2, which is a stronger base,  $\text{HO}^-$  or  $\text{F}^-$ ? Explain.

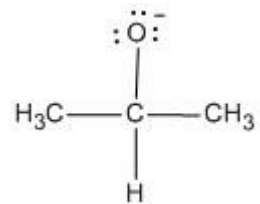
Answer:  $\text{HO}^-$  is a stronger base than  $\text{F}^-$  because HF is a stronger acid than  $\text{H}_2\text{O}$ , and the stronger the acid the weaker its conjugate base.

Section: 2-2

13) 2-Propanol is shown below. Draw the structure of its conjugate base.



Answer:



Section: 2-3

14) Which of the following is the strongest acid?

- A)  $\text{CH}_3\text{OH}$
- B)  $\text{CH}_3\text{OH}_2^+$
- C)  $\text{H}_2\text{N}^-$
- D)  $\text{CH}_3\text{NH}_2$
- E)  $\text{CH}_3\text{NH}_3^+$

Answer: B

Section: 2-6

15) The  $\text{pK}_a$  of  $\text{CH}_3\text{COOH}$  is 4.8 and the  $\text{pK}_a$  of  $\text{HCOOH}$  is 3.8. Given this information, one knows that \_\_\_\_\_.

- A)  $\text{CH}_3\text{COOH}$  completely ionizes in water
- B)  $\text{HCOOH}$  is a weaker acid than  $\text{CH}_3\text{COOH}$
- C)  $\text{HCOO}^-$  is a weaker base than  $\text{CH}_3\text{COO}^-$
- D)  $\text{CH}_3\text{COOH}$  reacts with  $\text{HO}^-$  while  $\text{HCOOH}$  does not
- E)  $\text{HCOOH}$  reacts with  $\text{HO}^-$  while  $\text{CH}_3\text{COOH}$  does not

Answer: C

Section: 2-6

16) Which of the following is the strongest acid?

- A)  $\text{HF}$
- B)  $\text{H}_2\text{O}$
- C)  $:\text{NH}_3$
- D)  $\text{CH}_4$
- E)  $\text{CH}_3\text{OH}$

Answer: A

Section: 2-6

17) Which of the following is the strongest acid?

- A)  $\text{CH}_3\text{CH}_2\text{OH}$
- B)  $\text{CH}_3\text{OCH}_3$
- C)  $\text{CH}_3\text{—NH—CH}_3$
- D)  $\text{CH}_3\text{—C}\equiv\text{CH}$
- E)  $\text{CH}_3\text{—CH=CH}_2$

Answer: A

Section: 2-6

18) Consider the set of compounds,  $\text{NH}_3$ ,  $\text{HF}$ , and  $\text{H}_2\text{O}$ . Rank these compounds in order of increasing acidity and discuss your rationale.

Answer:  $\text{NH}_3 < \text{H}_2\text{O} < \text{HF}$

When determining relative acidity, it is often useful to look at the relative basicity of the conjugate bases. The stronger the acid, the weaker (more stable, less reactive) the conjugate base. In this case, one would look at the relative basicity of  $\text{F}^-$ ,  $\text{OH}^-$ , and  $\text{NH}_2^-$ . The relative strengths of these species can be gauged based on the electronegativity of the charged atom in each base. Since fluorine is the most electronegative,  $\text{F}^-$  is the most stable, least reactive base in the group. This means that its conjugate acid,  $\text{HF}$ , is the strongest.

Section: 2-6

19) Identify the compound with the highest  $\text{pK}_a$ .

- A)  $\text{CH}_3\text{NH}_2$
- B)  $\text{CH}_3\text{OH}$
- C)  $\text{CH}_3\text{COOH}$
- D)  $\text{H}_2\text{O}$
- E)  $\text{CH}_3\text{NH}_3^+$

Answer: A

Section: 2-6

20) Identify the compound with the highest  $\text{pK}_a$ .

- A)  $\text{CH}_3\text{CH}_3$
- B)  $\text{HCCH}$
- C)  $\text{CH}_2\text{CH}_2$
- D)  $\text{CH}_3\text{OH}$
- E)  $\text{CH}_3\text{NH}_2$

Answer: A

Section: 2-6

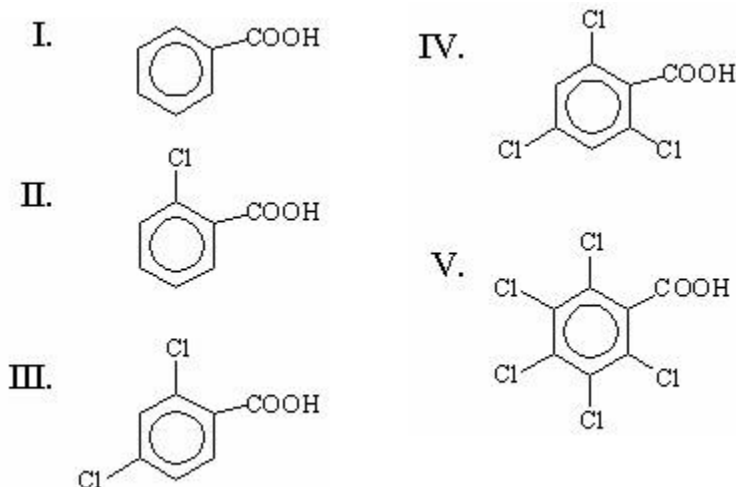
21) Identify the most acidic carboxylic acid.

- A)  $\text{ICH}_2\text{COOH}$
- B)  $\text{BrCH}_2\text{COOH}$
- C)  $\text{CH}_3\text{COOH}$
- D)  $\text{FCH}_2\text{COOH}$
- E)  $\text{ClCH}_2\text{COOH}$

Answer: D

Section: 2-7

22) Which of the following is the strongest acid?



- A) I  
B) II  
C) III  
D) IV  
E) V

Answer: E

Section: 2-7

23) Explain why :NF<sub>3</sub> is a weaker base than :NH<sub>3</sub>.

Answer: Fluorine has an electron withdrawing effect that reduces the availability of the pair of electrons on nitrogen. Thus the basicity of :NF<sub>3</sub> is less than that of :NH<sub>3</sub>.

Section: 2-7

24) Would you predict trifluoromethanesulfonic acid, CF<sub>3</sub>SO<sub>3</sub>H, to be a stronger or weaker acid than methanesulfonic acid, CH<sub>3</sub>SO<sub>3</sub>H? Explain your reasoning.

Answer: Trifluoromethanesulfonic acid is a stronger acid. Compare the strengths of the conjugate bases and remember that the weaker the base, the stronger the conjugate acid. In the case of the trifluoro derivative, the presence of the highly electronegative fluorine atoms serves to delocalize the negative charge to a greater extent. This additional delocalization makes trifluoromethanesulfonate a weaker base.

Section: 2-7

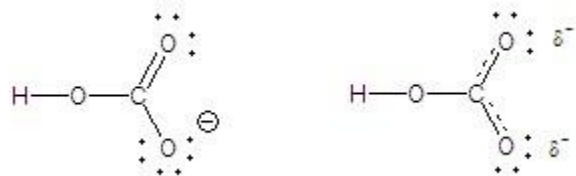
25) Which of the following anions, CH<sub>3</sub>CHBrCO<sub>2</sub><sup>-</sup> or CH<sub>3</sub>CHFCO<sub>2</sub><sup>-</sup> is the stronger base? Explain your choice.

Answer: CH<sub>3</sub>CHBrCO<sub>2</sub><sup>-</sup> is the stronger base. The more electronegative F atom can more effectively delocalize the negative charge via induction. This greater delocalization stabilizes CH<sub>3</sub>CHFCO<sub>2</sub><sup>-</sup> relative to CH<sub>3</sub>CHBrCO<sub>2</sub><sup>-</sup> and makes it a weaker base.

Section: 2-7

26) Draw a resonance contributor and the resonance hybrid for  $\text{HOCO}_2^-$ .

Answer: resonance contributor:      resonance hybrid:



Section: 2-8

27) The  $\text{pK}_a$  of  $\text{CH}_3\text{COOH}$  is 4.8. If the pH of an aqueous solution of  $\text{CH}_3\text{COOH}$  and  $\text{CH}_3\text{COO}^-$  is 4.8, then one knows \_\_\_\_\_.

- A)  $\text{CH}_3\text{COOH}$  is completely ionized
- B)  $[\text{CH}_3\text{COOH}] > [\text{CH}_3\text{COO}^-]$
- C)  $[\text{CH}_3\text{COOH}] = [\text{CH}_3\text{COO}^-]$
- D)  $[\text{CH}_3\text{COOH}] < [\text{CH}_3\text{COO}^-]$
- E)  $\text{CH}_3\text{COOH}$  is completely unionized

Answer: C

Section: 2-10

28) When a small amount of hexanoic acid [ $\text{CH}_3(\text{CH}_2)_4\text{CO}_2\text{H}$ ,  $\text{pK}_a \sim 4.8$ ], is added to a separatory funnel which contains the organic solvent diethyl ether and water with a pH of 2.0, it is found mainly in the \_\_\_\_\_ phase as \_\_\_\_\_.

- A) ether;  $\text{CH}_3(\text{CH}_2)_4\text{CO}_2^-$
- B) water;  $\text{CH}_3(\text{CH}_2)_4\text{CO}_2^-$
- C) ether;  $\text{CH}_3(\text{CH}_2)_4\text{CO}_2\text{H}$
- D) water;  $\text{CH}_3(\text{CH}_2)_4\text{CO}_2\text{H}$
- E) none of the above

Answer: C

Section: 2-10

29) When a small amount of hexanoic acid [ $\text{CH}_3(\text{CH}_2)_4\text{CO}_2\text{H}$ ,  $\text{pK}_a \sim 4.8$ ], is added to a separatory funnel which contains the organic solvent diethyl ether and water with a pH of 12.0, it is found mainly in the \_\_\_\_\_ phase as \_\_\_\_\_.

- A) ether;  $\text{CH}_3(\text{CH}_2)_4\text{CO}_2^-$
- B) water;  $\text{CH}_3(\text{CH}_2)_4\text{CO}_2^-$
- C) ether;  $\text{CH}_3(\text{CH}_2)_4\text{CO}_2\text{H}$
- D) water;  $\text{CH}_3(\text{CH}_2)_4\text{CO}_2\text{H}$
- E) none of the above

Answer: B

Section: 2-10

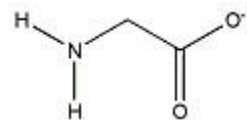
30) At what pH will 25% of a compound with a pK<sub>a</sub> of 5.3 be in its basic form?

Answer: 4.8

Section: 2-10

31) The amino acid glycine ( $\text{H}_3\text{N}^+\text{CH}_2\text{CO}_2\text{H}$ ) has two acidic Hs, one with pK<sub>a</sub> = 2.34 and the other with pK<sub>a</sub>=9.60. Draw the structure of the form of glycine that predominates at a pH of 12.

Answer:



Section: 2-10

32) H-A is an acid with a pK<sub>a</sub> of 4.5. Which of the following statements about an aqueous solution of H-A is true?

A) At pH = 4.5, the solution contains much more H-A than A<sup>-</sup>

B) At pH = 4.5, the solution contains much more A<sup>-</sup> than H-A

C) At pH = 3.5, the solution contains about 90% A<sup>-</sup> and 10% H-A

D) At pH = 6.5, the solution contains about 80% A<sup>-</sup> and 20% H-A

E) At pH = 5.5, the solution contains about 90% A<sup>-</sup> and 10% H-A

Answer: E

Section: 2-10

33) At what pH will the concentration of a compound with a pK<sub>a</sub> of 5.7 be 100 times greater in its acidic form than in its basic form?

Answer: 3.7

Section: 2-10

34) HCN has a pK<sub>a</sub> = 9.1. What form of the compound, HCN or CN<sup>-</sup>, will predominate in a solution of pH = 7.0

Answer: HCN

Section: 2-10

35) Propanoic acid,  $\text{CH}_3\text{CH}_2\text{COOH}$ , has a pK<sub>a</sub> = 4.9. Draw the structure of the conjugate base of propanoic acid and give the pH above which 90% of the compound will be in this conjugate base form.

Answer:  $\text{CH}_3\text{CH}_2\text{COO}^-$ ; 5.9

Section: 2-10



36) Buffering is used to maintain the pH of human blood in the relatively narrow 7.3 - 7.4 range. What acid/base pair serves to buffer the blood?

- A)  $\text{H}_2\text{O}$  /  $\text{HO}^-$
- B)  $\text{H}_3\text{O}^+$  /  $\text{H}_2\text{O}$
- C)  $\text{H}_2\text{CO}_3$  /  $\text{HCO}_3^-$
- D)  $\text{NH}_4^+$  /  $\text{NH}_3$
- E)  $\text{HCl}$  /  $\text{Cl}^-$

Answer: C

Section: 2-11

37) Explain why  $\text{AlCl}_3$  is a Lewis acid.

Answer: A Lewis acid is an electron pair acceptor. Aluminum in  $\text{AlCl}_3$  has an empty p orbital that can accommodate the pair of electrons provided by a Lewis base.

Section: 2-12