

MULTIPLE CHOICE QUESTIONS

Topic: Acid-Base Definitions

1. According to the Lewis definition, a base is a(n):
- A) Proton donor.
  - B) Electron pair donor.
  - C) Hydroxide ion donor.
  - D) Hydrogen ion donor.
  - E) Electron pair acceptor.

Ans: B

Topic: Acid-Base Definitions

2. Which of the following is not both a Bronsted-Lowry acid and a Bronsted-Lowry base?
- A)  $\text{HSO}_4^-$
  - B)  $\text{H}_2\text{PO}_4^-$
  - C)  $\text{HCO}_3^-$
  - D)  $\text{OH}^-$
  - E)  $\text{SH}^-$

Ans: D

Topic: Acid-Base Definitions

3. Which of the following is not a conjugate acid - conjugate base pair (in that order)?
- A)  $\text{H}_3\text{PO}_4$ ,  $\text{H}_2\text{PO}_4^-$
  - B)  $\text{HBF}_4$ ,  $\text{BF}_4^-$
  - C)  $\text{CH}_3\text{CH}_2\text{OH}$ ,  $\text{CH}_3\text{CH}_2\text{O}^-$
  - D)  $\text{H}_3\text{O}^+$ ,  $\text{H}_2\text{O}$
  - E)  $\text{HPO}_4^-$ ,  $\text{H}_2\text{PO}_4^-$

Ans: E

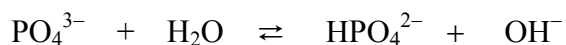
Topic: Acid-Base Definitions

4. The conjugate base of sulfuric acid is:
- A)  $\text{H}_3\text{SO}_4^+$
  - B)  $\text{SO}_3$
  - C)  $\text{HSO}_4^-$
  - D)  $\text{H}_2\text{SO}_3$
  - E)  $\text{HSO}_3^-$

Ans: C

Topic: Acid-Base Definitions

5. Consider the equilibrium



Which are the Bronsted-Lowry bases?

- A)  $\text{PO}_4^{3-}$  and  $\text{HPO}_4^{2-}$
- B)  $\text{PO}_4^{3-}$  and  $\text{OH}^-$
- C)  $\text{PO}_4^{3-}$  and  $\text{H}_2\text{O}$
- D)  $\text{H}_2\text{O}$  and  $\text{OH}^-$
- E)  $\text{H}_2\text{O}$  and  $\text{HPO}_4^{2-}$

Ans: B

Topic: Acid-Base Definitions

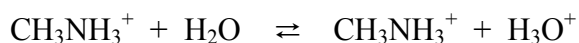
6. Which of these is not a true statement?

- A) All Lewis bases are also Bronsted-Lowry bases.
- B) All Lewis acids contain hydrogen.
- C) All Bronsted-Lowry acids contain hydrogen.
- D) All Lewis acids are electron deficient.
- E) According to the Bronsted-Lowry theory, water is both an acid and a base.

Ans: B

Topic: Acid-Base Definitions

7. For the equilibrium



the two substances which both are acids are:

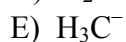
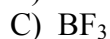
- A)  $\text{H}_2\text{O}$  and  $\text{H}_3\text{O}^+$
- B)  $\text{CH}_3\text{NH}_3^+$  and  $\text{H}_2\text{O}$
- C)  $\text{CH}_3\text{NH}_3^+$  and  $\text{CH}_3\text{NH}_2$
- D)  $\text{CH}_3\text{NH}_3^+$  and  $\text{H}_3\text{O}^+$
- E)  $\text{CH}_3\text{NH}_2$  and  $\text{H}_2\text{O}$

Ans: D

### Chapter 3

Topic: Acid-Base Definitions

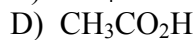
8. Which of the following is not a Lewis base?



Ans: C

Topic: Acid-Base Definitions

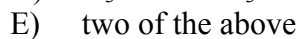
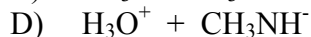
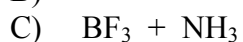
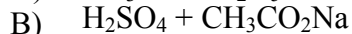
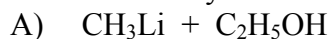
9. Which of the following is not a Bronsted-Lowry acid?



Ans: E

Topic: Acid-Base Definitions

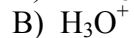
10. The reaction between which combination of substances below cannot be classified as a Bronsted-Lowry acid-base reaction?



Ans: C

Topic: Acid-Base Definitions

11. Which of these is not a Lewis acid?



Ans: E

### Chapter 3

#### Topic: Acid-Base Definitions

12. This species is a carbon-based Lewis acid:

- A)  $\text{CH}_4$
- B)  $\text{HCCl}_3$
- C)  $\text{CH}_3^+$
- D)  $\text{:CH}_3^-$
- E)  $\cdot\text{CH}_3$

Ans: C

#### Topic: Acid-Base Definitions

13. What is the conjugate base of ethanol?

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

Ans: A

#### Topic: Acid-Base Strength

14. Which of the acids below would have the strongest conjugate base?

- A)  $\text{CH}_3\text{CH}_2\text{OH}$   $\text{pK}_a = 18$
- B)  $\text{CH}_3\text{CO}_2\text{H}$   $\text{pK}_a = 4.75$
- C)  $\text{ClCH}_2\text{CO}_2\text{H}$   $\text{pK}_a = 2.81$
- D)  $\text{Cl}_2\text{CHCO}_2\text{H}$   $\text{pK}_a = 1.29$
- E)  $\text{Cl}_3\text{CCO}_2\text{H}$   $\text{pK}_a = 0.66$

Ans: A

#### Topic: Acid-Base Definitions

15. Which of the following is a Lewis acid?

- A)  $\text{H}_3\text{O}^+$
- B)  $\text{BF}_3$
- C)  $\text{NF}_3$
- D)  $\text{OH}^-$
- E)  $\text{N}\equiv\text{N}$

Ans: B

Chapter 3

Topic: Acid-Base Reactions

16. Adding sodium hydride to ethanol would produce:

- A)  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3 + \text{H}_2$                       D)  $\text{CH}_3\text{CH}_2\text{Na} + \text{NaOH}$   
B)  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3 + \text{NaOH}$                       E)  $\text{CH}_3\text{CH}_3 + \text{NaOH}$   
C)  $\text{CH}_3\text{CH}_2\text{ONa} + \text{H}_2$   
D)  $\text{CH}_3\text{CH}_2\text{Na} + \text{NaOH}$   
E)  $\text{CH}_3\text{CH}_3 + \text{NaOH}$

Ans: C

Topic: Acid-Base Reactions

17. Adding sodium amide ( $\text{NaNH}_2$ ) to 1-butyne ( $\text{CH}_3\text{CH}_2\text{C}\equiv\text{CH}$ ) would produce:

- A)  $\text{CH}_3\text{CH}_2\text{C}\equiv\text{CNa} + \text{NH}_3$   
B)  $\text{CH}_3\text{CH}_2\text{C}\equiv\text{C}-\text{C}\equiv\text{CH}_2\text{CH}_3 + \text{NaH} + \text{NH}_3$   
C)  $\text{CH}_3\text{CH}_2\text{C}\equiv\text{CNH}_2 + \text{NaH}$   
D)  $\text{NaCH}_2\text{CH}_2\text{C}\equiv\text{CH} + \text{NH}_3$   
E)  $\text{CH}_3\text{CH}(\text{Na})\text{C}\equiv\text{CH} + \text{NH}_3$

Ans: A

Topic: Acid-Base Reactions

18. Which acid-base reaction would not take place as written?

- A)  $\text{CH}_3\text{Li} + \text{CH}_3\text{CH}_2\text{OH} \longrightarrow \text{CH}_4 + \text{CH}_3\text{CH}_2\text{OLi}$   
B)  $\text{HC}\equiv\text{CH} + \text{NaOH} \longrightarrow \text{HC}\equiv\text{CNa} + \text{H}_2\text{O}$   
C)  $\text{HC}\equiv\text{CNa} + \text{H}_2\text{O} \longrightarrow \text{HC}\equiv\text{CH} + \text{NaOH}$   
D)  $\text{CH}_3\text{OH} + \text{NaH} \longrightarrow \text{CH}_3\text{ONa} + \text{H}_2$   
E)  $\text{CH}_3\text{CO}_2\text{H} + \text{CH}_3\text{ONa} \longrightarrow \text{CH}_3\text{CO}_2\text{Na} + \text{CH}_3\text{OH}$

Ans: E

Topic: Acid-Base Reactions

19. Which acid-base reaction would not take place as written?

- A)  $\text{CH}_3\text{Li} + \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2 \longrightarrow \text{CH}_4 + \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NHLi}$   
B)  $\text{CH}_3\text{C}\equiv\text{CH} + \text{NaOCH}_3 \longrightarrow \text{HC}\equiv\text{CNa} + \text{CH}_3\text{OH}$   
C)  $\text{HC}\equiv\text{CNa} + \text{H}_2\text{O} \longrightarrow \text{HC}\equiv\text{CH} + \text{NaOH}$   
D)  $\text{CH}_3\text{OH} + \text{NaNH}_2 \longrightarrow \text{CH}_3\text{ONa} + \text{NH}_3$   
E)  $\text{CH}_3\text{CO}_2\text{H} + \text{CH}_3\text{ONa} \longrightarrow \text{CH}_3\text{CO}_2\text{Na} + \text{CH}_3\text{OH}$

Ans: B

## Topic: Acid-Base Reactions

20. Which acid-base reaction would not take place as written?

- A)  $\text{CH}_3\text{Li} + \text{CH}_3\text{CH}_2\text{OH} \longrightarrow \text{CH}_4 + \text{CH}_3\text{CH}_2\text{OLi}$   
 B)  $\text{H}_2\text{C}=\text{CH}_2 + \text{NaOH} \longrightarrow \text{H}_2\text{C}=\text{CHNa} + \text{H}_2\text{O}$   
 C)  $\text{CH}_3\text{C}\equiv\text{CNa} + \text{H}_2\text{O} \longrightarrow \text{CH}_3\text{C}\equiv\text{CH} + \text{NaOH}$   
 D)  $(\text{CH}_3)_2\text{CHOH} + \text{NaH} \longrightarrow (\text{CH}_3)_2\text{CHONa} + \text{H}_2$   
 E)  $\text{CH}_3\text{CO}_2\text{H} + \text{CH}_3\text{ONa} \longrightarrow \text{CH}_3\text{CO}_2\text{Na} + \text{CH}_3\text{OH}$

Ans: B

## Topic: Acid-Base Reactions

21. The amide ion,  $\text{NH}_2^-$ , is a base which can be used only in which of the solvents shown below:

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

Ans: E

## Topic: Acid-Base Reactions

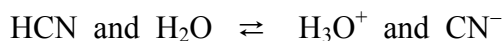
22. Acetic acid dissociates most completely in:

- A)  $\text{CCl}_4$   
 B)  $\text{Cl}_2\text{C}=\text{CCl}_2$   
 C)  $\text{H}_2\text{O}$   
 D)  $(\text{CH}_3\text{CH}_2)_2\text{O}$   
 E) the gas phase.

Ans: C

## Topic: Acid-base definitions, Acid-Base Reactions

23. Which pair of species are both bases in the following reaction?



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

Ans: A

## Topic: Acid-Base Reactions

24. What compounds are produced when sodium nitrate is added to a mixture of water and ethanol?
- A)  $\text{HNO}_3 + \text{NaOH}$
  - B)  $\text{HNO}_3 + \text{CH}_3\text{CH}_2\text{ONa}$
  - C)  $\text{NaOH} + \text{CH}_3\text{CH}_2\text{ONa}$
  - D)  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3 + \text{NaOH}$
  - E) No reaction occurs.

Ans: E

## Topic: Acid-Base Reactions

25. Which reaction of these potential acids and bases does not occur to any appreciable degree due to an unfavorable equilibrium?
- A)  $\text{NaOH (aq)} + \text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$
  - B)  $\text{CH}_3\text{CH}_2\text{ONa in ethanol} + \text{ethene}$
  - C)  $\text{CH}_3\text{Li in hexane} + \text{ethyne}$
  - D)  $\text{NaNH}_2 \text{ in liq. NH}_3 + \text{ethanol}$
  - E)  $\text{NaC}_2\text{H}_3\text{O}_2 \text{ (aq)} + \text{HI}$

Ans: B

## Topic: Acid-Base Reactions

26. Which reaction of these potential acids and bases does not occur to any appreciable degree due to an unfavorable equilibrium?
- A)  $\text{NaNH}_2 + \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
  - B)  $\text{CH}_3\text{CH}_2\text{CO}_2\text{Na} + \text{HI}$
  - C)  $\text{CH}_3\text{Li in hexane} + \text{ethyne}$
  - D)  $\text{NaH} + \text{methanol}$
  - E) Two of the above will not occur

Ans: A

## Topic: Acid-Base Reactions

27. Which reaction of these potential acids and bases does not occur to any appreciable degree due to an unfavorable equilibrium?
- A)  $\text{NaNH}_2 + \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
  - B)  $\text{CH}_3\text{CH}_2\text{CO}_2\text{H} + \text{NaCl}$
  - C)  $\text{NaHCO}_3 + \text{CH}_3\text{CH}_2\text{CO}_2\text{H}$
  - D)  $\text{NaH} + \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$
  - E) all of the above will occur due to a favorable equilibrium

Ans: E

## Topic: Acid-Base Reactions

28. Which combination of reagents is the least effective in generating sodium ethoxide,  $\text{CH}_3\text{CH}_2\text{ONa}$ ?
- A)  $\text{CH}_3\text{CH}_2\text{OH} + \text{NaH}$
  - B)  $\text{CH}_3\text{CH}_2\text{OH} + \text{NaNH}_2$
  - C)  $\text{CH}_3\text{CH}_2\text{OH} + \text{NaOH}$
  - D)  $\text{CH}_3\text{CH}_2\text{OH} + \text{CH}_3\text{Li}$
  - E)  $\text{CH}_3\text{CH}_2\text{OH} + \text{HC}\equiv\text{CNa}$
- Ans: C

## Topic: Acid-Base Reactions

29. Which combination of reagents is effective in generating sodium ethoxide,  $\text{CH}_3\text{CH}_2\text{ONa}$ ?
- A)  $\text{CH}_3\text{CH}_2\text{OH} + \text{KH}$
  - B)  $\text{CH}_3\text{CH}_2\text{OH} + \text{NaNH}_2$
  - C)  $\text{CH}_3\text{CH}_2\text{OH} + \text{Na}$
  - D) Two of the above
  - E) All of the above
- Ans: E

## Topic: Acid-Base Reactions

30. Which combination of reagents is effective in generating sodium propynide,  $\text{CH}_3\text{C}\equiv\text{CNa}$ ?
- A)  $\text{CH}_3\text{C}\equiv\text{CH} + \text{KH}$
  - B)  $\text{CH}_3\text{C}\equiv\text{CH} + (\text{CH}_3)_2\text{CHONa}$
  - C)  $\text{CH}_3\text{C}\equiv\text{CH} + \text{C}_2\text{H}_5\text{Li}$
  - D) Two of the above
  - E) All of the above
- Ans: B

## Topic: Acid-Base Reactions, base strength

31. In the reaction,  $\text{Na}^+\text{NH}_2^- + \text{CH}_3\text{OH} \longrightarrow \text{CH}_3\text{O}^-\text{Na}^+ + \text{NH}_3$ , the stronger base is:
- A)  $\text{NaNH}_2$
  - B)  $\text{CH}_3\text{OH}$
  - C)  $\text{CH}_3\text{ONa}$
  - D)  $\text{NH}_3$
  - E) This is not an acid-base reaction.
- Ans: A



Topic: Acid-Base Reactions, isotope labeling

32. Which sequence is the best one to use to prepare  $\text{CH}_3\text{C}\equiv\text{CD}$ ?

- A)  $\text{CH}_3\text{C}\equiv\text{CH} \xrightarrow{\text{NaH}} \xrightarrow{\text{D}_2\text{O}}$
- B)  $\text{CH}_3\text{C}\equiv\text{CH} \xrightarrow{\text{NaOH}} \xrightarrow{\text{D}_2\text{O}}$
- C)  $\text{CH}_3\text{C}\equiv\text{CH} \xrightarrow{\text{CH}_3\text{ONa}} \xrightarrow{\text{D}_2\text{O}}$
- D)  $\text{CH}_3\text{C}\equiv\text{CH} \xrightarrow{\text{DOH}}$
- E) None of these will be successful.

Ans: A

Topic: Acid-Base Reactions

33. Adding sodium hydride,  $\text{NaH}$ , to water produces:

- A)  $\text{H}_2$  and  $\text{NaOH}(\text{aq})$
- B)  $\text{H}(\text{aq}) + \text{Na}^+(\text{aq})$
- C)  $\text{H}_3\text{O}^+(\text{aq}) + \text{Na}^+(\text{aq})$
- D)  $\text{H}_3\text{O}^-(\text{aq}) + \text{Na}^+(\text{aq})$
- E)  $\text{Na}_2\text{O} + \text{H}_2$

Ans: A

Topic: Acid-Base Reactions

34. Adding methyllithium,  $\text{CH}_3\text{Li}$ , to ethanol produces:

- A)  $\text{CH}_3\text{CH}_2\text{Li} + \text{CH}_3\text{OH}$
- B)  $\text{CH}_3\text{CH}_2\text{OLi} + \text{CH}_4$
- C)  $\text{CH}_3\text{CH}_2\text{OCH}_3 + \text{LiH}$
- D) All of the above
- E) No reaction takes place

Ans: A

Topic: Acid-Base Reactions, isotope labeling

35. Which reaction will yield  $\text{CH}_3\text{CH}_2\text{-D}$ ?

- A)  $\text{CH}_3\text{CH}_3 + \text{D}_2\text{O}$
- B)  $\text{CH}_3\text{CH}_2\text{Li} + \text{D}_2\text{O}$
- C)  $\text{CH}_3\text{CH}_2\text{OLi} + \text{D}_2\text{O}$
- D)  $\text{CH}_3\text{CH}_2\text{OH} + \text{D}_2\text{O}$
- E) More than one of these

Ans: B

Topic: Acid-Base Reactions, isotope labeling

36. A product of the reaction,  $\text{CH}_3\text{CH}_2\text{Li} + \text{D}_2\text{O} \longrightarrow$  is
- A)  $\text{CH}_3\text{CH}_2\text{OD}$
  - B)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
  - C)  $\text{CH}_2=\text{CH}_2$
  - D)  $\text{CH}_3\text{CH}_2\text{D}$
  - E)  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$
- Ans: D

Topic: Relative acid strength

37. The compounds ethane, ethene, and ethyne exhibit this order of increasing acidity:
- A) Ethyne < ethene < ethane
  - B) Ethene < ethyne < ethane
  - C) Ethane < ethyne < ethene
  - D) Ethane < ethene < ethyne
  - E) Ethene < ethane < ethyne
- Ans: D

Topic: Relative acid/base strength

38. Which is an incorrect statement?
- A) RSH compounds are stronger acids than ROH compounds.
  - B)  $\text{PH}_3$  is a weaker base than  $\text{NH}_3$ .
  - C)  $\text{NH}_2^-$  is a stronger base than  $\text{OH}^-$ .
  - D)  $\text{OH}^-$  is a stronger base than  $\text{OR}^-$ .
  - E)  $\text{H}^-$  is a stronger base than  $\text{OR}^-$ .
- Ans: D

Topic: Relative acid/base strength

39. The correct sequence of the ions shown, in order of increasing basicity, is:
- A)  $\text{CH}_3\text{CH}_2:^- < \text{CH}_2=\text{CH}:^- < \text{HC}\equiv\text{C}:^-$
  - B)  $\text{CH}_3\text{CH}_2:^- < \text{HC}\equiv\text{C}:^- < \text{CH}_2=\text{CH}:^-$
  - C)  $\text{HC}\equiv\text{C}:^- < \text{CH}_3\text{CH}_2:^- < \text{CH}_2=\text{CH}:^-$
  - D)  $\text{CH}_2=\text{CH}:^- < \text{HC}\equiv\text{C}:^- < \text{CH}_3\text{CH}_2:^-$
  - E)  $\text{HC}\equiv\text{C}:^- < \text{CH}_2=\text{CH}:^- < \text{CH}_3\text{CH}_2:^-$
- Ans: E

Topic: Solvent effects

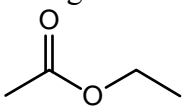
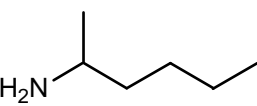
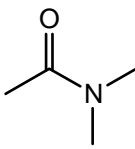
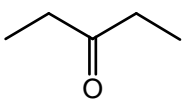
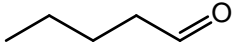
40. Which is a protic solvent?

- A)  $\text{CCl}_4$
- B)  $\text{HCCl}_3$
- C)  $\text{CH}_3\text{OH}$
- D)  $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$
- E)  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$

Ans: C

Topic: Solvent effects

41. Which might be used as protic solvent?

- A) 
- B) 
- C) 
- D) 
- E) 

Ans: B

Topic: Solvent effects

42. Which of the following classes of substances cannot be used as protic solvents?

- A) esters
- B) aldehydes
- C) ketones
- D) carboxylic acids
- E) two of the above

Ans: D

## Topic: Acid constants

43. If a 0.01 M solution of a weak acid has a pH of 4.0, the  $pK_a$  of the acid is:

- A) 10.0
- B) 8.0
- C) 6.0
- D) 4.0
- E) 2.0

Ans: C

## Topic: General

44. Which one of the following is a true statement?

- A) The stronger the acid, the larger is its  $pK_a$ .
- B) The conjugate base of a strong acid is a strong base.
- C) Acid-base reactions always favor the formation of the stronger acid and the stronger base.
- D) Strong acids can have negative  $pK_a$  values.
- E) Hydrogen need not be present in the molecular formula of a Bronsted-Lowry acid.

Ans: D

## Topic: Relative acid/base strengths

45. The basic species are arranged in decreasing order of basicity in the sequence:

- A)  $F^- > OCH_3^- > NH_2^- > CH_3CH_2^-$
- B)  $OCH_3^- > CH_3CH_2^- > NH_2^- > F^-$
- C)  $CH_3CH_2^- > NH_2^- > OCH_3^- > F^-$
- D)  $NH_2^- > CH_3CH_2^- > F^- > OCH_3^-$
- E)  $NH_2^- > OCH_3^- > CH_3CH_2^- > F^-$

Ans: C

Topic:  $pK_a$  calculations

46. A particular acid has  $K_a = 2.0 \times 10^{-5}$  (in aqueous solution). The evaluation of which of these expressions gives the value for  $pK_a$ ?

- A)  $10^{-14}/2.0 \times 10^{-5}$
- B)  $10^{-14}(2.0 \times 10^{-5})$
- C)  $5 - \log 2.0$
- D)  $-5 + \log 2.0$
- E)  $2.0 \times 10^{-5}/10^{-14}$

Ans: C

Topic: Solvent effects

47. As a consequence of the "leveling effect," the strongest acid which can exist in appreciable concentration in aqueous solution is:

A)  $\text{H}_3\text{O}^+$   
B)  $\text{H}_2\text{SO}_4$   
C)  $\text{HClO}_4$   
D)  $\text{HCl}$   
E)  $\text{HNO}_3$

Ans: A

Topic: Relative acid/base strengths

48. Based on the position of the central atom in the periodic chart, we predict that the strongest acid of the following is:

A)  $\text{H}_2\text{O}$   
B)  $\text{H}_2\text{S}$   
C)  $\text{H}_2\text{Se}$   
D)  $\text{H}_2\text{Te}$

Ans: D

Topic: Acid dissociation, thermodynamic calculations

49. An acid, HA, has the following thermodynamic values for its dissociation in water at  $27^\circ\text{C}$ :  $\Delta\text{H} = -8.0\text{ kJ mol}^{-1}$ ;  $\Delta\text{S} = -70\text{ J K}^{-1}\text{mol}^{-1}$ . The  $\Delta\text{G}$  for the process is:

A)  $+29\text{ kJ mol}^{-1}$   
B)  $+13\text{ kJ mol}^{-1}$   
C)  $-6.1\text{ kJ mol}^{-1}$   
D)  $-13\text{ kJ mol}^{-1}$   
E)  $-29\text{ kJ mol}^{-1}$

Ans: B

Topic: Relative acid/base strengths, solvent effects

50. Which of these bases is the strongest one which can be used (and retains its basic character) in aqueous solution?

A)  $\text{OCH}_3^-$   
B)  $\text{F}^-$   
C)  $\text{OH}^-$   
D)  $\text{C}_2\text{H}_3\text{O}_2^-$   
E)  $\text{HSO}_4^-$

Ans: C

Topic: Acidity constant- thermodynamic principles

51. The acidity constant,  $K_a$ , differs from the equilibrium constant,  $K_{eq}$ , for the dissociation of the same acid in water at the same temperature and concentration in what way?
- A)  $K_a$  can be determined experimentally with less accuracy than  $K_{eq}$ .
  - B) The two terms are identical numerically.
  - C)  $K_a$  is used for strong acids only;  $K_{eq}$  for weak acids.
  - D)  $K_a$  is the reciprocal of  $K_{eq}$ .
  - E)  $K_{eq} = K_a/[H_2O]$ .

Ans: E

Topic: Acids/bases-general principles

52. Which of the following is an untrue statement?
- A) The % dissociation of a weak acid increases with increasing dilution of the acid solution.
  - B) The stronger an acid, the weaker its conjugate base.
  - C) The larger the value of  $K_a$  for an acid, the smaller the value of its  $pK_a$ .
  - D) Comparison of the acidity of strong acids in solution requires the use of a solvent less basic than water.
  - E) The stronger the acid, the more positive the value of  $\Delta G^\circ$  for the dissociation.

Ans: E

Topic: Acid-base reactions

53. When proton transfer reactions reach equilibrium, there have been formed:
- A) the weaker acid and the weaker base.
  - B) the weaker acid and the stronger base.
  - C) the stronger acid and the weaker base.
  - D) the stronger acid and the stronger base.
  - E) All proton transfers go to completion; they are not equilibrium processes.

Ans: A

Topic: Relative acid-base strengths

54. For the simple hydrides,  $MH_n$ ,  $pK_a$  values decrease in the order:
- A)  $CH_4 > NH_3 > H_2O > H_2S > HBr$
  - B)  $HBr > H_2S > H_2O > NH_3 > CH_4$
  - C)  $HBr > H_2O > NH_3 > H_2S > CH_4$
  - D)  $NH_3 > H_2S > CH_4 > H_2O > HBr$
  - E)  $H_2S > H_2O > HBr > NH_3 > CH_4$

Ans: A

Topic: Relative acid-base strengths, solvent effects

55. The compound aniline,  $\text{C}_6\text{H}_5\text{NH}_2$ , has weakly basic properties in aqueous solution. In this other solvent, aniline would behave as a strong base.

- A)  $\text{CH}_3\text{OH}$
- B)  $\text{CH}_3\text{CH}_2\text{OH}$
- C)  $\text{CF}_3\text{CO}_2\text{H}$
- D) Liquid  $\text{NH}_3$
- E)  $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$

Ans: C

Topic: Relative acid-base strengths

56. Which of the following organic compounds is the strongest acid?

- A)  $\text{C}_6\text{H}_{12}$   $\text{pK}_a = 52$
- B)  $\text{CH}_3\text{CH}_3$   $\text{pK}_a = 50$
- C)  $\text{CH}_3\text{CH}_2\text{OH}$   $\text{pK}_a = 18$
- D)  $\text{CH}_3\text{CO}_2\text{H}$   $\text{pK}_a = 5$
- E)  $\text{CF}_3\text{CO}_2\text{H}$   $\text{pK}_a = 0$

Ans: E

Topic: Relative acid-base strengths

57. Which is the strongest acid?

- A)  $\text{CH}_3\text{CH}_2\text{OH}$
- B)  $\text{CH}_3\text{CO}_2\text{H}$
- C)  $\text{HC}\equiv\text{CH}$
- D)  $\text{CH}_2=\text{CH}_2$
- E)  $\text{CH}_3\text{CH}_3$

Ans: B

Topic: Relative acid-base strengths

58. Which is the strongest acid?

- A)  $\text{CH}_2\text{ClCH}_2\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$
- B)  $\text{CH}_3\text{CHBrCH}_2\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$
- C)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CBr}_2\text{CH}_2\text{CO}_2\text{H}$
- D)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHFCH}_2\text{CO}_2\text{H}$
- E)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CF}_2\text{CH}_2\text{CO}_2\text{H}$

Ans: E

Topic: Relative acid-base strengths

59. Which is the strongest acid?

- A)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHFCO}_2\text{H}$
- B)  $\text{CH}_3\text{CHBrCH}_2\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$
- C)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHClCH}_2\text{CO}_2\text{H}$
- D)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHFCH}_2\text{CO}_2\text{H}$
- E)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHICH}_2\text{CO}_2\text{H}$

Ans: A

Topic: Relative acid-base strengths

60. Which is the weakest acid?

- A)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHFCO}_2\text{H}$
- B)  $\text{CH}_3\text{CHCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
- C)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{SO}_3\text{H}$
- D)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$
- E)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$

Ans: A

Topic: Relative acid-base strengths

61. Which of the following substances has a hydrogen atom with  $\text{pK}_a \approx 25$ ?

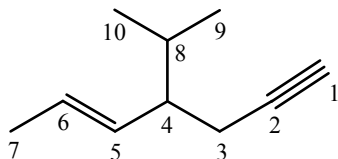
- A)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$
- B)  $\text{CH}_3\text{CHCH}_2\text{C}\equiv\text{CCH}_3$
- C)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{C}\equiv\text{CH}$
- D)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$
- E)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$

Ans: C



Topic: Relative acid-base strengths

62. Hydrogen atom(s) from which position(s) is (are) most likely to be abstracted when the following substance is treated with NaH?



- A) 1  
 B) 1, 5, 6  
 C) 1, 2  
 D) 3, 4, 7, 8, 9, 10  
 E) Hydrogens from all of the positions are equally likely to be abstracted by NaH.  
 Ans: A

Topic: Relative acid-base strengths

63. Which of the following correctly lists the compounds in order of decreasing acidity?

- A)  $\text{H}_2\text{O} > \text{HC}\equiv\text{CH} > \text{NH}_3 > \text{CH}_3\text{CH}_3$   
 B)  $\text{HC}\equiv\text{CH} > \text{H}_2\text{O} > \text{NH}_3 > \text{CH}_3\text{CH}_3$   
 C)  $\text{CH}_3\text{CH}_3 > \text{HC}\equiv\text{CH} > \text{NH}_3 > \text{H}_2\text{O}$   
 D)  $\text{CH}_3\text{CH}_3 > \text{HC}\equiv\text{CH} > \text{H}_2\text{O} > \text{NH}_3$   
 E)  $\text{H}_2\text{O} > \text{NH}_3 > \text{HC}\equiv\text{CH} > \text{CH}_3\text{CH}_3$

Ans: A

Topic: Relative acid-base strengths

64. Select the strongest base.

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

Ans: E

Topic: Relative acid-base strengths

65. A group of acids arranged in order of decreasing acidity is:



What is the arrangement of the conjugate bases of these compounds in decreasing order of basicity?

- A)  $\text{NO}_3^- > \text{CH}_3\text{COO}^- > \text{C}_6\text{H}_5\text{O}^- > \text{OH}^- > \text{HC}\equiv\text{C}^-$   
 B)  $\text{CH}_3\text{COO}^- > \text{C}_6\text{H}_5\text{O}^- > \text{NO}_3^- > \text{OH}^- > \text{HC}\equiv\text{C}^-$   
 C)  $\text{C}_6\text{H}_5\text{O}^- > \text{NO}_3^- > \text{HC}\equiv\text{C}^- > \text{OH}^- > \text{CH}_3\text{COO}^-$   
 D)  $\text{HC}\equiv\text{C}^- > \text{OH}^- > \text{C}_6\text{H}_5\text{O}^- > \text{CH}_3\text{COO}^- > \text{NO}_3^-$   
 E) No prediction of relative base strength is possible.

Ans: D

Topic: Relative acid-base strengths

66. What prediction can be made of the relative strengths of the conjugate bases of:  $\text{H}_2\text{S}$ ,  $\text{HCl}$ ,  $\text{SiH}_4$ ,  $\text{PH}_3$ ?

- A)  $\text{PH}_2^- > \text{SiH}_3^- > \text{HS}^- > \text{Cl}^-$   
 B)  $\text{SiH}_3^- > \text{PH}_2^- > \text{HS}^- > \text{Cl}^-$   
 C)  $\text{Cl}^- > \text{HS}^- > \text{PH}_2^- > \text{SiH}_3^-$   
 D)  $\text{HS}^- > \text{Cl}^- > \text{SiH}_3^- > \text{PH}_2^-$   
 E)  $\text{Cl}^- > \text{PH}_2^- > \text{SiH}_3^- > \text{HS}^-$

Ans: B

Topic: Acids/bases- general

67. Which of these species is not amphoteric?

- A)  $\text{HC}\equiv\text{C}^-$   
 B)  $\text{HS}^-$   
 C)  $\text{NH}_3$   
 D)  $\text{CH}_3^-$   
 E)  $\text{HPO}_4^-$

Ans: D

Topic: Acids/bases- general

68. Which of these phosphorus-based acids is dibasic?

- A)  $\begin{array}{c} \text{O} \\ \parallel \\ \text{HO}-\text{P}-\text{OH} \\ | \\ \text{OH} \end{array}$
- B)  $\begin{array}{c} \text{O} \\ \parallel \\ \text{HO}-\text{P}-\text{OH} \\ | \\ \text{H} \end{array}$
- C)  $\begin{array}{c} \text{O} \\ \parallel \\ \text{H}-\text{P}-\text{H} \\ | \\ \text{OH} \end{array}$
- D)  $\begin{array}{c} \text{O} \qquad \text{O} \\ \parallel \qquad \parallel \\ \text{HO}-\text{P}-\text{O}-\text{P}-\text{OH} \\ | \qquad \quad | \\ \text{OH} \qquad \quad \text{OH} \end{array}$
- E)  $\begin{array}{c} \text{O} \qquad \text{O} \\ \parallel \qquad \parallel \\ \text{HO}-\text{P}-\text{P}-\text{OH} \\ | \qquad | \\ \text{OH} \quad \text{OH} \end{array}$

Ans: B

Topic: Acids/bases- general

69. Why cannot one determine the relative acid strengths of  $\text{HClO}_4$  and  $\text{HNO}_3$  using aqueous solutions of these acids?

- A) The acids are insufficiently soluble for the measurements.
- B) A more basic solvent than  $\text{H}_2\text{O}$  must be used.
- C)  $\text{H}_2\text{O}$  is too basic a solvent for the distinction to be made.
- D) These oxidizing acids cause redox reactions to occur.
- E) Actually, the acid strengths can be determined using aqueous solutions.

Ans: C

Topic: Acids/bases- general

70. Which of these is not a diprotic acid?

- A)  $\text{H}_2\text{S}$
- B)  $\text{H}_2\text{SO}_4$
- C)  $\text{H}_2\text{O}$
- D)  $(\text{COOH})_2$
- E)  $\text{H}_2\text{PO}_4^-$

Ans: C

Topic: Acids/bases- thermodynamic principles

71. Which set contains non-equivalent members?

- A) Enthalpy and heat content
- B) Endothermic reaction and  $+\Delta H$
- C) Exothermic reaction and  $-\Delta H$
- D) Kinetic energy and energy of motion
- E) High energy and high stability

Ans: E

SHORT-ANSWER QUESTIONS:

Topic: General Reactivity

72. Addition reactions are characteristic of compounds with \_\_\_\_\_.

Ans: multiple bonds

Topic: Reaction Types

73. The four basic types of reactions are: \_\_\_\_\_.

Ans: substitution, addition, elimination, rearrangement

Topic: Reaction Mechanisms

74. The process of bond-breaking where each fragment takes away one of the electrons from the bond is called \_\_\_\_\_.

Ans: homolysis

Topic: Reaction Mechanisms

75. Heterolytic bond-breaking produces \_\_\_\_\_.

Ans: charged fragments/ions

Topic: Acids and Bases

76. According to Bronsted-Lowry theory, an acid is a substance that can \_\_\_\_\_.

Ans: donate a proton

Topic: Acids and Bases

77. According to Lewis theory, a base is a substance that can \_\_\_\_\_.

Ans: donate a lone pair of electrons

Topic: Acids and Bases

78. The molecule or ion that is formed when an acid loses its proton is called the \_\_\_\_\_.

Ans: conjugate base

Topic: Nucleophiles and Electrophiles

79. Reagents that seek to react with a proton or some other electron-deficient center are called \_\_\_\_\_.

Ans: nucleophiles

Topic: Acids and Bases

80. A substance that can donate a lone pair of electrons is a \_\_\_\_\_ according to \_\_\_\_\_ theory.

Ans: base; Lewis

Topic: Curved Arrow Notation

81. When drawing mechanisms, chemists generally use curved arrows. The curved arrow begins with \_\_\_\_\_ and points toward \_\_\_\_\_.

Ans: a lone pair or covalent bond; a site of electron deficiency

Topic: Acids and Bases

82. Why do water-insoluble carboxylic acids dissolve in aqueous sodium hydroxide?

Ans: Because they are converted to water-soluble salts.

Topic: Relative Acidity

83. Bond polarization that takes place through space and through the bonds of the molecule is called the \_\_\_\_\_.

Ans: inductive effect

Topic: Energy

84. What are the two fundamental types of energy?

Ans: potential energy and kinetic energy

Topic: Types of Solvents

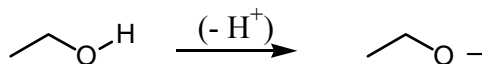
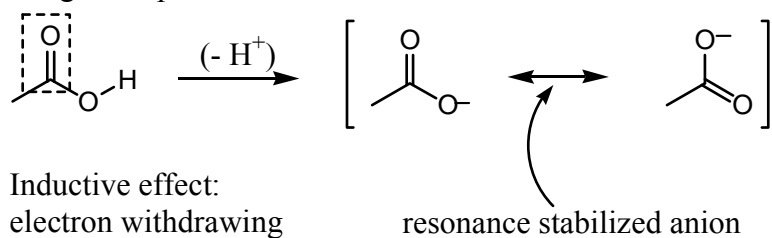
85. Define a protic solvent.

Ans: one that has a hydrogen atom attached to a strongly electronegative element such as oxygen

## Topic: Relative acid strength

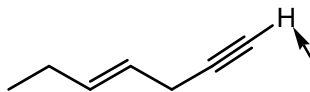
86. Briefly, but clearly, explain why the  $\text{-OH}$  hydrogen in acetic acid ( $\text{CH}_3\text{CO}_2\text{H}$ ) is more acidic than in ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ).

Ans: The greater acidity of the  $\text{-OH}$  hydrogen in acetic acid is due primarily to two factors: resonance and inductive effects. In acetic acid, the presence of the neighboring carbonyl group has an electron-withdrawing inductive effect on the  $\text{-OH}$  hydrogen, increasing its acidity relative to ethanol, in which there is no carbonyl group. Also, comparison of the respective conjugate bases shows that, unlike the ethoxide ion, the acetate ion is stabilized by resonance. This too, is reflected in the greater acid strength of the corresponding acid species.

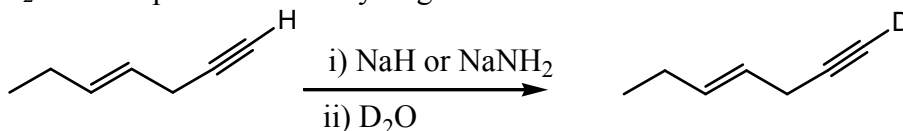


Topic: Relative acid strength, isotope labeling

87. Isotope labeling is an important tool in the study of reaction mechanisms. How will you selectively deuterate the specified hydrogen atom, indicated by an arrow, in the following compound? Use equations to clarify your answer and briefly explain your rationale.

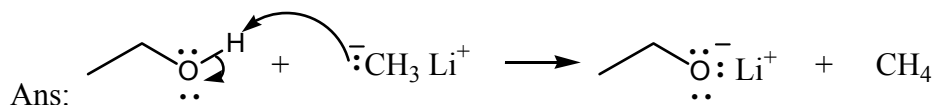


Ans: The specified hydrogen is attached to an *sp*-hybridized carbon and is thus more acidic than all the other hydrogens in the molecule. By using an appropriate strong base, such as NaH or NaNH<sub>2</sub>, the acetylenic hydrogen is selectively removed; adding D<sub>2</sub>O then replaces the lost hydrogen atom with a deuterium atom.



Topic: Acid-base reactions

88. Write an equation to show the reaction between ethanol, C<sub>2</sub>H<sub>5</sub>OH and methyllithium, CH<sub>3</sub>Li. Draw all non-bonding electrons and show electron flow with curved arrows.



Topic: Acid-base reactions, solvent selection

89. You are planning to carry out a reaction between propyne, CH<sub>3</sub>C≡CH and sodium amide, NaNH<sub>2</sub>. You also need to choose an appropriate solvent for carrying out the reaction. Would ethanol be suitable for this purpose? Explain your rationale clearly.

Ans: No, ethanol would be unsuitable for carrying out the reaction between propyne and methyllithium. The pK<sub>a</sub> of ethanol is ~16, and sodium amide is strong enough a base to readily abstract a proton from the solvent (pK<sub>a</sub> of NH<sub>3</sub> is ~38); in doing so, it becomes deactivated and is no longer available to react with propyne (pK<sub>a</sub> ~25). Typically, the selected solvent should be chemically inert toward all substances used in the reaction, so that it does not interfere with the desired reaction.

Topic: Acid-base reactions, solvent selection

90. You are planning to purify an impure sample of benzoic acid, known to be contaminated with naphthalene. Propose a strategy for purifying this sample, making use of acid-base principles, using equations to further clarify your answer.

Ans: Benzoic acid reacts with aqueous NaOH to form a water soluble salt, while naphthalene, which is not soluble in water to any appreciable extent, does not react with NaOH. So, upon shaking the impure sample with NaOH (aq), the naphthalene remains as a solid, while the benzoic acid dissolves in the aqueous medium as sodium benzoate. After filtration, HCl is added to the filtrate to regenerate benzoic acid, which precipitates as almost pure crystals. Cooling maximizes the yield of the purified product, after which pure crystals can be obtained by filtration.

Alternatively, before beginning the reaction with aqueous NaOH, the impure sample is first dissolved in diethyl ether (benzoic acid and naphthalene are both soluble in ether) and placed in a separatory funnel. After shaking thoroughly with aqueous NaOH, the aqueous layer (which now contains sodium benzoate) is collected. The rest of the procedure is as described earlier.

