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

General Types/Groups of problems:

| Conceptual Questions. Acids, Bases, and Conjugates, Miscellaneous | p1 | Kₐ and pKₐ, Base Strength, and using Kₐ or pKₐ to Calculate [OH⁻], pOH, pH, and/or [H⁺] | p7-10 |
| Recognizing Strong versus Weak Acids; Recognizing Basic versus Nonbasic | p3 | Recognizing Acid/Base Properties when Ionics are Dissolved in Water | p11 |
| pH Calculations; Relationships between pH and pOH | p4 | Answers | p12 |
| Kₐ: Sense + Calculations. Using Kₐ or pKₐ to Calculate [H⁺] and/or pH; using pH to calculate Kₐ or pKₐ | p5 |

Conceptual Questions. Acids, Bases, and Conjugates, Miscellaneous

1. In the Brønsted–Lowry definition of acids and bases, an acid __________
   a. is a proton donor.  
   b. is a proton acceptor.  
   c. forms stable hydrogen bonds.  
   d. breaks stable hydrogen bonds.  
   e. corrodes metals.

2. In the Brønsted–Lowry definition of acids and bases, a base __________
   a. is a proton donor.  
   b. is a proton acceptor.  
   c. forms stable hydrogen bonds.  
   d. breaks stable hydrogen bonds.  
   e. corrodes metals.

3. In the following reaction in aqueous solution, the acid reactant is __________ and its conjugate base product is __________.
   \[
   \text{CH}_3\text{COOH} + \text{NH}_3 \rightleftharpoons \text{CH}_3\text{COO}^- + \text{NH}_4^+ 
   \]
   a. CH₃COOH; CH₃COO⁻  
   b. CH₃COOH; NH₄⁺  
   c. NH₃; CH₃COO⁻  
   d. NH₃; NH₄⁺  
   e. CH₃COOH; H₂O⁺

4. In the following reaction in aqueous solution, the acid reactant is __________, and its conjugate base product is __________.
   \[
   \text{CH}_3\text{NH}_2 + \text{HSO}_4^- \rightleftharpoons \text{CH}_3\text{NH}_3^+ + \text{SO}_4^{2-}
   \]
   a. CH₃NH₂⁺; CH₃NH₃⁺  
   b. CH₃NH₂⁺; SO₄²⁻  
   c. HSO₄⁻; CH₃NH₃⁺  
   d. HSO₄⁻; SO₄²⁻  
   e. HSO₄⁻; H₂O⁺

5. Which of the following is the conjugate acid of the hydrogen phosphate ion, HPO₄²⁻?
   a. H₃PO₄  
   b. H₃PO₄⁻  
   c. HPO₄²⁻  
   d. PO₄³⁻  
   e. H₃O⁺
6. Which one of the following is not a conjugate acid–base pair?
   a. NH₃ and NH₄⁺  
   b. H₂O⁺ and OH⁻  
   c. H₃PO₄⁻ and HPO₄²⁻  
   d. HS⁻ and H₂S  
   e. NH₃ and NH₂⁻

7. Which one of the following is a conjugate acid–base pair?
   a. NH₃ and NH₄⁺  
   b. H₂O⁺ and OH⁻  
   c. NH₂⁻ and NH₄⁺  
   d. H₂O and O²⁻  
   e. NaF and F⁻

8. Which one of the following is a conjugate acid–base pair?
   a. NaF and F⁻  
   b. HNO₃ and HNO₂  
   c. HI and I⁻  
   d. NH₄⁺ and NH₂⁻  
   e. H₂O and H₂O₂

9. Which one of the following is not a conjugate acid–base pair?
   a. NH₃ and NH₂⁻  
   b. HNO₃ and HNO₂  
   c. HI and I⁻  
   d. H₃PO₄⁻ and HPO₄²⁻  
   e. H₂O and OH⁻

10. The stronger the acid, __________
    a. the stronger its conjugate base.  
    b. the weaker its conjugate base.  
    c. the more concentrated the acid.  
    d. the less concentrated the conjugate base.  
    e. the more concentrated the conjugate base.

11. Ammonia (NH₃) acts as a weak base in aqueous solution. What is the acid that reacts with this base when ammonia is dissolved in water?
    a. none, there are no acids in pure water  
    b. H₂O  
    c. NH₄⁺  
    d. trick question, because no acids are present, ammonia cannot act as a base  
    e. 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. $B + H^+ \leftrightarrow BH^+$  
    b. $B + H_2O \leftrightarrow BH^+ + H_2O$  
    c. $B + H_2O \leftrightarrow BH^+ + OH^-$  
    d. $B + OH^- \leftrightarrow BH^- + O^2-$  
    e. $BH^+ + OH^- \leftrightarrow B + H_2O$
Recognizing Strong versus Weak Acids; Recognizing Basic versus Nonbasic

13. Which of the following is a strong acid?
   a. HNO$_3$
   b. H$_2$S
   c. HNO$_2$
   d. HCO$_3^-$
   e. HOC$_2$H

14. Which one of the following is a strong acid?
   a. nitrous acid, HNO$_2$
   b. sulfurous acid, H$_2$SO$_3$
   c. carbonic acid, H$_2$CO$_3$
   d. hydrofluoric acid, HF
   e. perchloric acid, HClO$_4$

15. Which one of the following is not a strong acid?
   a. nitric acid, HNO$_3$
   b. sulfuric acid, H$_2$SO$_4$
   c. carbonic acid, H$_2$CO$_3$
   d. hydrochloric acid, HCl
   e. perchloric acid, HClO$_4$

16. Which of the following compounds cannot be a Brønsted–Lowry base?
   a. OH$^-$
   b. H$_2$O
   c. NH$_3$
   d. NH$_4^+$
   e. SH$^-$

17. Each of the following pairs contains one strong acid and one weak acid except:
   a. H$_2$SO$_4$ and H$_2$CO$_3$
   b. HNO$_3$ and HNO$_2$
   c. HBr and H$_3$PO$_2$
   d. HSO$_4^-$ and HCN
   e. HCl and H$_2$S

18. Which one of the following is NOT basic?
   a. OH$^-$
   b. NO$_3^-$
   c. NH$_3$
   d. SO$_4^{2-}$
   e. HPO$_4^{2-}$

19. Which one of the following is basic?
   a. Cl$^-$
   b. NO$_3^-$
   c. ClO$_4^-$
   d. HSO$_4^-$
   e. 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    d. 1/100.
   b. 100/1   e. 1/1, unchanged
   c. 1/2

21. When [H\(^+\)] = 1.0 \times 10^{-7} M in water at 25°C, then __________
   a. pH = 1.    d. [OH\(^-\)] = 1.0 \times 10^7 M.
   b. pH = 10^{-7}. e. [OH\(^-\)] = 0 M.
   c. [OH\(^-\)] = 1.0 \times 10^{-7} M.

22. When [H\(^+\)] = 4.0 \times 10^{-9} M in water at 25°C, then __________
   b. pH = 7.00. e. pH = -9.40
   c. pH = -8.40.

23. A solution with pH of 9.50 has a pOH of __________
   a. 9.50.    d. 23.5.
   b. 0.50.    e. 19.0.
   c. 4.50.

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 d. 7.08 and 6.92
   b. 1.00 and 13.00 e. 5.94 and 8.06
   c. 5.35 and 8.75

25. A solution with a pOH of 4.3 has a [H\(^+\)] of __________
   a. 6.8 \times 10^{-9} M. d. 2.0 \times 10^{-10} M.
   b. 3.2 \times 10^{-4} M. e. 4.3 M.
   c. 4.8 \times 10^{-5} M.

26. Which statement, A–D, is not correct? If all are correct, respond E. Pure water at 25°C has __________
   a. \(K_w = 1.0 \times 10^{-14}\). d. pH = 7.
   b. pOH = 7. e. A–D are all correct.
   c. [H\(_2\)O\(^+\)] = [OH\(^-\)].
K₂: Sense + Calculations. Using $K_a$ or $pK_a$ to Calculate $[H^+]$ and/or pH; using pH to calculate $K_a$ or $pK_a$

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?

<table>
<thead>
<tr>
<th>Acid</th>
<th>$pK_a$</th>
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</thead>
<tbody>
<tr>
<td>HA</td>
<td>4.00</td>
</tr>
<tr>
<td>HB</td>
<td>7.00</td>
</tr>
<tr>
<td>HC</td>
<td>10.00</td>
</tr>
<tr>
<td>HD</td>
<td>11.00</td>
</tr>
</tbody>
</table>

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? $K_a$ for acetic acid is $1.8 \times 10^{-5}$

a. $1.8 \times 10^{-3}$ 

b. $1.8 \times 10^{-5}$ 

c. $1.0 \times 10^{-2}$ 

d. $1.8 \times 10^{-7}$ 

e. $4.2 \times 10^{-4}$

29. What is the pH of a 0.010 $M$ solution of acetic acid? $K_a$ for acetic acid is $1.8 \times 10^{-5}$

a. 2.74 

b. 4.74 

c. 2.00 

d. 3.37 

e. 6.74

30. When values of $K_a$ are small (e.g., $1 \times 10^{-5}$) and concentrations of weak acids [HA] are relatively large (e.g., 0.10 $M$), and assuming there is no other source of anion $A^-$, the hydronium ion concentration of the solution can be calculated using which expression?

a. $[H^+] = K_a$  

b. $[H^+] = K_a[HA]$  

c. $[H^+] = (K_a[HA])^{1/2}$  

d. $[H^+] = K_a[HA]$  

e. $[H^+] = K_a[HA]^{2/3}[A^-]$  

31. The first disinfectant used by Joseph Lister was called carbolic acid. This substance now is known as phenol, C₆H₅OH ($pK_a = 10.0$). 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. $5.0 \times 10^{-4} M$ 

b. $4.0 \times 10^{-4} M$ 

c. $2.5 \times 10^{-3} M$ 

d. $1.0 \times 10^{-7} M$ 

e. $5.0 \times 10^{-5} M$
33. The concentration of acetic acid \( (pK_a = 4.75) \) in vinegar is about 1.0 \( M \). With this information, what do you predict the pH of vinegar to be?

a. 4.75  
   b. 2.4  
   c. \( 4.0 \times 10^{-3} \)  
   d. 7.0  
   e. 5.35

34. Boric acid frequently is used as an eyewash to treat eye infections. The pH of a 0.050 \( M \) solution of boric acid is 5.28. What is the value of the boric acid ionization constant, \( K_a \)?

a. \( 5.25 \times 10^{-6} \)  
   b. \( 5.51 \times 10^{-10} \)  
   c. \( 5.43 \times 10^{-8} \)  
   d. \( 5.79 \times 10^{-4} \)  
   e. \( 5.33 \times 10^{-12} \)

35. A 0.100 \( M \) solution of a monoprotic weak acid has a pH of 3.00. What is the \( pK_a \) of this acid?

a. 5.00  
   b. 0.999  
   c. 3.00  
   d. 9.99  
   e. 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 \( M \). Based on this information, determine the value of the acid ionization constant, \( K_a \), for acetic acid.

a. \( 2.5 \times 10^{-5} \)  
   b. \( 5.0 \times 10^{-5} \)  
   c. \( 4.7 \times 10^{-3} \)  
   d. \( 1.9 \times 10^{-5} \)  
   e. \( 7.4 \times 10^{-3} \)

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 \( \text{LA} = 3.88, \text{OA} = 1.23, \text{and MA} = 3.40 \). Which list has these acids in order of decreasing acid strength?

a. \( \text{LA} > \text{OA} > \text{MA} \)  
   b. \( \text{LA} > \text{MA} > \text{OA} \)  
   c. \( \text{OA} > \text{MA} > \text{LA} \)  
   d. \( \text{OA} > \text{LA} > \text{MA} \)  
   e. \( \text{MA} > \text{LA} > \text{OA} \)

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

\[ \begin{align*}
\text{HF} & \quad K_a = 7.2 \times 10^{-4} \\
\text{HNO}_2 & \quad K_a = 4.5 \times 10^{-4} \\
\text{HCN} & \quad K_a = 6.2 \times 10^{-10}
\end{align*} \]

a. \( \text{CN}^- > \text{NO}_2^- > \text{F}^- \)  
   b. \( \text{NO}_2^- > \text{F}^- > \text{CN}^- \)  
   c. \( \text{F}^- > \text{CN}^- > \text{NO}_2^- \)  
   d. \( \text{F}^- > \text{NO}_2^- > \text{CN}^- \)  
   e. \( \text{NO}_2^- > \text{CN}^- > \text{F}^- \)
**Kₐ and pKₐ, Base Strength, and using Kₐ or pKₐ to Calculate [OH⁻], pOH, pH, and/or [H⁺]**

39. A cup of coffee has a hydroxide ion concentration of $1.0 \times 10^{-10} \text{M}$. What is the pH of this coffee?
   
a. $1.0 \times 10^{-4}$  
b. 4  
c. 10  
d. 7  
e. $-10$

40. What is the concentration of [OH⁻] in a 0.20 M solution of ammonia? The $K_b$ value for ammonia is $1.8 \times 10^{-5}$.
   
a. $3.6 \times 10^{-6} \text{M}$  
b. $1.8 \times 10^{-5} \text{M}$  
c. $0.20 \text{M}$  
d. $1.9 \times 10^{-3} \text{M}$  
e. $4.2 \times 10^{-4} \text{M}$

41. What is the pOH of a 0.20 M solution of ammonia? The $K_b$ value for ammonia is $1.8 \times 10^{-5}$
   
a. 4.44  
b. 4.74  
c. 0.70  
d. 2.72  
e. 3.38

42. What is the pH of a 0.20 M solution of ammonia? The $K_b$ value for ammonia is $1.8 \times 10^{-5}$
   
a. 9.56  
b. 9.26  
c. 4.74  
d. 11.28  
e. 2.72

43. What is the hydronium ion concentration of a 0.20 M solution of ammonia? The $K_b$ value for ammonia is $1.8 \times 10^{-5}$
   
a. $2.8 \times 10^{-10}$  
b. $5.5 \times 10^{-10}$  
c. $1.8 \times 10^{-5}$  
d. $5.2 \times 10^{-12}$  
e. $1.9 \times 10^{-3}$

44. What is the pH of a 0.500 M solution of trimethylamine ($pK_b = 4.13$)?
   
a. 2.22  
b. 11.8  
c. 0.00609  
d. 4.42  
e. 5.91
Miscellaneous problems involving Weak Bases and perhaps their Conjugates.

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

\[
\begin{align*}
\text{H}_3\text{PO}_4 + \text{H}_2\text{O} & \rightleftharpoons \text{H}_2\text{PO}_4^- + \text{H}_3\text{O}^+ & K_a \\
\text{H}_2\text{PO}_4^- + \text{H}_2\text{O} & \rightleftharpoons \text{HPO}_4^{2-} + \text{H}_3\text{O}^+ & K_a \\
\text{HPO}_4^{2-} + \text{H}_2\text{O} & \rightleftharpoons \text{PO}_4^{3-} + \text{H}_3\text{O}^+ & K_a
\end{align*}
\]

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:

\[
\begin{align*}
\text{H}_3\text{PO}_4 + \text{H}_2\text{O} & \rightleftharpoons \text{H}_2\text{PO}_4^- + \text{H}_3\text{O}^+ \\
\text{H}_2\text{PO}_4^- + \text{H}_2\text{O} & \rightleftharpoons \text{HPO}_4^{2-} + \text{H}_3\text{O}^+ \\
\text{HPO}_4^{2-} + \text{H}_2\text{O} & \rightleftharpoons \text{PO}_4^{3-} + \text{H}_3\text{O}^+
\end{align*}
\]

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.

\[
\begin{align*}
\text{HF} & \quad K_a = 7.2 \times 10^{-4} \\
\text{HNO}_2 & \quad K_a = 4.5 \times 10^{-4} \\
\text{HCN} & \quad K_a = 6.2 \times 10^{-10}
\end{align*}
\]

a. $\text{CN}^- > \text{NO}_2^- > \text{F}^-$

b. $\text{NO}_2^- > \text{F}^- > \text{CN}^-$

c. $\text{F}^- > \text{CN}^- > \text{NO}_2^-$

d. $\text{F}^- > \text{NO}_2^- > \text{CN}^-$

e. $\text{NO}_2^- > \text{CN}^- > \text{F}^-$

48. 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 $\text{LA} = 3.88$, $\text{OA} = 1.23$, and $\text{MA} = 3.40$. 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

d. oxalate $>$ lactate $>$ malate

e. malate $>$ lactate $>$ 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 ($pK_b = 4.13$)?
51. How would you calculate $K_b$ for the formate ion, given that the $K_a$ for formic acid is $1.8 \times 10^{-4}$? ($K_w=1.0 \times 10^{-14}$)
   a. $K_b = K_a \times K_w$
   b. $K_b = K_w/K_a$
   c. $K_b = K_a/K_w$
   d. $K_b = K_w + K_a$
   e. $K_b = K_w - K_a$

52. What is the pH of a 0.20 $M$ solution of jaspersamine? The $pK_b$ value for jaspersamine 4.40.

53. What is the pH of a 0.15 $M$ solution of weak acid ammonium bromide? The $K_b$ value for ammonia is $1.8 \times 10^{-5}$.
   a. 11.22
   b. 7.00
   c. 2.78
   d. 5.04
   e. 10.08

54. Phosphoric acid is a triprotic acid, ionizing in the following sequential steps:
   \[ \text{H}_3\text{PO}_4 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{PO}_4^- + \text{H}_3\text{O}^+ \]
   \[ \text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{HPO}_4^{2-} + \text{H}_3\text{O}^+ \]
   \[ \text{HPO}_4^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{PO}_4^{3-} + \text{H}_3\text{O}^+ \]
Which equilibrium is most important in determining the pH of a solution of sodium phosphate?
   a. $\text{HPO}_4^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{PO}_4^{3-} + \text{H}_3\text{O}^+$
   b. $\text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{PO}_4^- + \text{H}_3\text{O}^+$
   c. $\text{PO}_4^{3-} + \text{H}_2\text{O} \rightleftharpoons \text{HPO}_4^{2-} + \text{OH}^-$
   d. $\text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{PO}_4 + \text{OH}^-$
   e. $2\text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{O}^+ + \text{OH}^-$

55. Solutions of sodium salts of the acids in the following table are prepared with an initial concentration of 0.500 $M$. Which solution will have the highest pH and be the most basic?

<table>
<thead>
<tr>
<th>Acid</th>
<th>$pK_a$</th>
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<tbody>
<tr>
<td>HA</td>
<td>4.00</td>
</tr>
<tr>
<td>HB</td>
<td>7.00</td>
</tr>
<tr>
<td>HC</td>
<td>10.00</td>
</tr>
<tr>
<td>HD</td>
<td>11.00</td>
</tr>
</tbody>
</table>

   a. NaA
   b. NaB
   c. NaC
   d. NaD
   e. All will have the same pH because the concentrations are the same.
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, NaNO$_2$? The $pK_a$ for nitrous acid (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 it’s conjugate base triethylamine
Recognizing Acid/Base Properties when Ionics are Dissolved in Water

60. Aqueous solutions of _________ are basic.
   a. NaF
   b. NaCl
   c. NaBr
   d. NaI
   e. KI

61. Which one of the following salts forms aqueous solutions with pH = 7?
   a. Na₂S
   b. NaBr
   c. NaClO₂
   d. NaNO₂
   e. Na₂CO₃

62. Which one of the following salts forms aqueous solutions with pH = 7?
   a. NaCN
   b. NH₄Br
   c. NaNO₃
   d. NaH₂PO₄
   e. Na₂CO₃

63. Which one of the following salts does not produce a basic solution when dissolved in water?
   a. NaOCH₃
   b. NaHSO₄
   c. NaBrO₂
   d. NaNO
   e. NaHCO₃

64. The pH of an aqueous sodium fluoride (NaF) solution is _________ because _________
   a. 7; sodium fluoride is a simple salt.
   b. above 7; fluoride is a weak base.
   c. below 7; fluoride reacts with water to make hydrofluoric acid.
   d. about 7; fluoride is a weak base, but produces hydrofluoric acid, and these two neutralize one another.
   e. 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. K₂SO₃ is a stronger base than KHSO₃
   b. K₂CO₃ is a weaker base than KHCO₃
   c. NaHSO₃ is a stronger acid than NaHSO₄
   d. Na₂HPO₄ is a weaker base than NaH₂PO₄
   e. All of these statements are correct.

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. NaNO₃, NH₄CN, NaAc, NH₄Cl
   b. Na₂CO₃, KCl, NaOCH₃, NH₄Cl
   c. Na₂CO₃, NaF, NaOCH₃, NaCN
   d. NaHCO₃, NaF, NH₄Cl, Na₂SO₃
   e. None or all of the above.
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