Chapter 3

Acids and Bases

Revision Paper

SECTION 1: INTRODUCTION TO ACIDS AND BASES
SECTION 2: STRENGTHS OF ACIDS AND BASES
SECTION 3: HYDROGEN IONS AND PH
SECTION 4: NEUTRALIZATION

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Introduction to Acids and Bases

Chapter 3

Lesson 1 – Revision Paper

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Section Summary

- The concentrations of hydrogen ions and hydroxide ions determine whether an aqueous solution is acidic, basic, or neutral.

- An Arrhenius acid must contain an ionizable hydrogen atom. An Arrhenius base must contain an ionizable hydroxide group.

- A Brønsted-Lowry acid is a hydrogen ion donor. A Brønsted-Lowry base is a hydrogen ion acceptor.

- A Lewis acid accepts an electron pair. A Lewis base donates an electron pair.

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Applications 1

Write balanced equations for the reactions between the following.

a) aluminum and sulfuric acid

b) calcium carbonate and hydrobromic acid

Applications 1

Write balanced equations for the reactions between the following.

a) aluminum and sulfuric acid

$$2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$$

b) calcium carbonate and hydrobromic acid

$$CaCO_3(s) + 2HBr(aq) \rightarrow CaBr_2(aq) + H_2O(l) + CO_2(g)$$

Applications 2

CHALLENGE Write the net ionic equation for this reaction.

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$$CaCO3(s) + 2HBr(aq) \longrightarrow CaBr2(aq) + H2O(l) + CO2(g)$$

$$Ca^{2+}(aq) + CO_3{}^{2-}(aq) + 2H^+(aq) + 2Br^-(aq) \longrightarrow$$
$$Ca^{2+}(aq) + 2Br^-(aq) + H_2O(l) + CO_2(g)$$

$$CO_3{}^{2-}(aq) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$$

Applications 3

Identify the conjugate acid-base pairs in each reaction.

a. $NH_4^+(aq) + OH^-(aq) \rightleftharpoons NH_3(aq) + H_2O(l)$

b. $HBr(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Br^-(aq)$

c. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$

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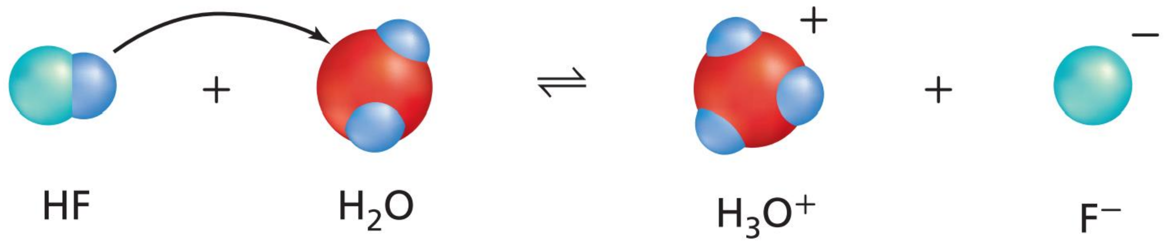
c. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$

Acid	Conjugate base	Base	Conjugate acid
a. NH_4^+	NH_3	OH^-	H_2O
b. HBr	Br^-	H_2O	H_3O^+
c. H_2O	OH^-	CO_3^{2-}	HCO_3^-

Figure 7

Which species is the conjugate base of hydrogen fluoride.



a) HF

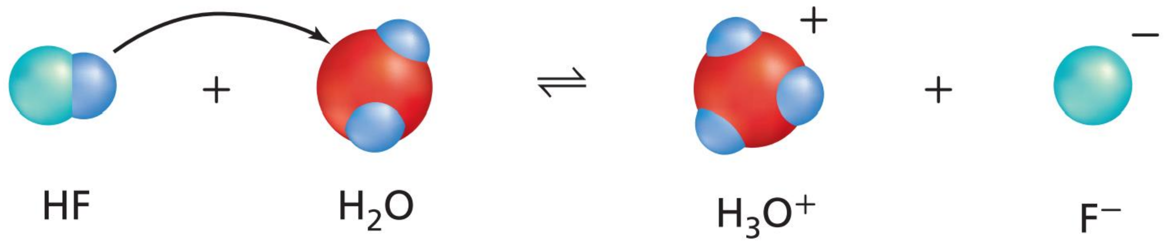
b) H2O

c) H_3O^+

d) F^-

Figure 7

Which species is the conjugate base of hydrogen fluoride.



a) HF

b) H2O

c) H_3O^+

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Applications 4

CHALLENGE The products of an acid-base reaction are **H_3O^+** and **SO_4^{2-}**. Write a balanced equation for the reaction and identify the conjugate acid-base pairs.

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CHALLENGE The products of an acid-base reaction are **H_3O^+** and **SO_4^{2-}**. Write a balanced equation for the reaction and identify the conjugate acid-base pairs.

$HSO_4^-(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + SO_4^{2-}(aq)$.

Reactant base: H_2O; conjugate acid: H_3O^+

Reactant acid: HSO_4^-; conjugate base: SO_4^{2-}

Review 5

Many Lewis acids and bases are not classified as Arrhenius or Brønsted-Lowry acids and bases because Lewis acids are electron pair ________ and Lewis bases are ________.

a) donors – electron pair acceptors

b) acceptors – electron pair receivers

c) acceptors – electron pair donors

d) acceptors – proton pair acceptors

Review 5

Many Lewis acids and bases are not classified as Arrhenius or Brønsted-Lowry acids and bases because Lewis acids are electron pair ________ and Lewis bases are ________.

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Review 6

Which is not a property of acids?

a) taste sour

b) turn litmus paper blue

c) react with some metals to produce hydrogen gas

d) react with carbonates to produce carbon dioxide

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Review 6

Which is not a property of bases?

a) taste bitter

b) conduct electricity

c) feel slippery

d) react with some metals to produce hydrogen gas

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Review 6

Which is not a property of bases?

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Review 7

Which is true about an acidic solution?

a) $[H^+] > [OH^-]$

b) $[H^+] = [OH^-]$

c) $[H^+] < [OH^-]$

d) feel slippery

Review 7

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Review 8

EXPLAIN why many compounds that contain one or more hydrogen atoms are not classified as Arrhenius acids.

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EXPLAIN why many compounds that contain one or more hydrogen atoms are not classified as Arrhenius acids.

Only compounds that have one or more <u>ionizable</u> hydrogen atom are Arrhenius acids. An ionizable hydrogen atom is an atom that is bonded to an electronegative element such as oxygen.

If the electronegativity difference between the hydrogen atom and the other element in the compound is low, then the compound is nonpolar and its not an acid.

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Review 9

Identify the conjugate acid-base pairs in the following equation.

$$HNO_2 + H_2O \rightleftharpoons NO_2^{-} + H_3O^{+}$$

Page 97

Review 9

Identify the conjugate acid-base pairs in the following equation.

$$HNO_2 + H_2O \rightleftharpoons NO_2^- + H_3O^+$$

HNO_2 (acid) and NO_2^- (conjugate base); H_2O (base) and H_3O^+ (conjugate acid)

Review 10

Write the Lewis structure for **phosphorus trichloride (PCl_3)**. Is **PCl_3** a Lewis acid, a Lewis base, or neither?

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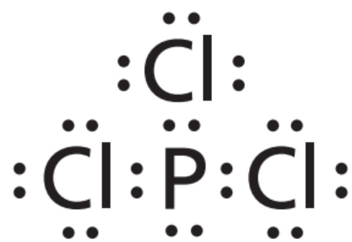
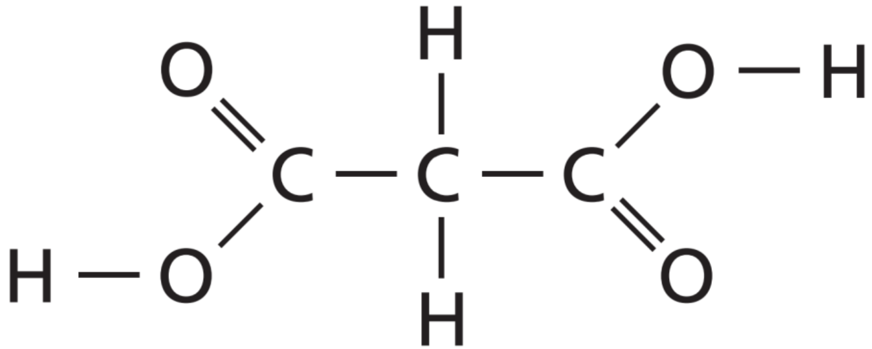


Phosphorus in PCl_3 has three electrons, which it shares with three chlorine atoms, and an unshared pair of electrons. The unshared pair can act as Lewis base

Review 11

In the accompanying structural formula, identify any hydrogen atoms that are likely to be ionizable.



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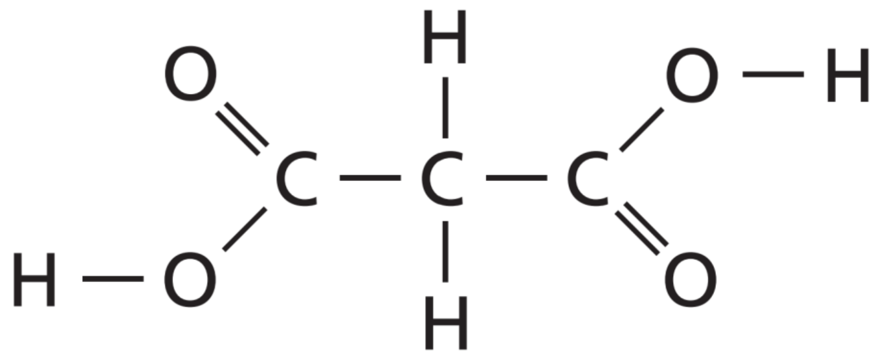

The two hydrogen atoms attached to oxygen atoms are ionizable.

Mastering Concepts 55

Which is true about a basic solution?

a) $[H^+] > [OH^-]$

b) $[H^+] = [OH^-]$

c) $[H^+] < [OH^-]$

d) Taste sour

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3.1 Introduction to Acids and Bases

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Mastering Concepts 55

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a) $[H^+] > [OH^-]$

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d) Taste sour

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Mastering Concepts 56

Write a balanced chemical equation that represents the self-ionization of water.

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Write a balanced chemical equation that represents the self-ionization of water.

$$H_2O(l) + H_2O(l) \leftrightarrow H_3O^+(aq) + OH^-(aq)$$

Mastering Concepts 57

Classify each compounds as an Arrhenius acid or an Arrhenius base.

a) H_2S __________

b) RbOH __________

c) $Mg(OH)_2$ __________

d) H_3PO_4 __________

Mastering Concepts 57

Classify each compounds as an Arrhenius acid or an Arrhenius base.

a) H_2S **Acid**

b) RbOH **Base**

c) $Mg(OH)_2$ **Base**

d) H_3PO_4 **Acid**

Mastering Concepts 58

GEOLOGY When a geologist adds a few drops of **HCl** to a rock, gas bubbles form. What might the geologist conclude about the nature of the gas and the rock?

a) The gas is carbon dioxide, CO_2; the rock is limestone.

b) The gas is hydrogen, H_2; the rock is limestone.

c) The gas is water vapor, H_2O; the rock is limestone.

d) Not enough information.

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Mastering Concepts 58

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b) The gas is hydrogen, H_2; the rock is limestone.

c) The gas is water vapor, H_2O; the rock is limestone.

d) Not enough information.

The gas is carbon dioxide, CO_2 ; the rock is limestone, or calcium carbonate, $CaCO_3$.

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Mastering Concepts 60

Which is true of the following?

a) A monoprotic acid can donate two H^+ ion, (HCl).

b) A diprotic acid can donate two H^+ ions, (H_3CO_4).

c) A triprotic acid can donate three H^+ ions, (H_2CO_3).

d) A monoprotic acid can donate one H^+ ion, (CH_3COOH).

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Mastering Concepts 61

Why can $\mathbf{H^+}$ and $\mathbf{H_3O^+}$ be used interchangeably in chemical equations?

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3.1 Introduction to Acids and Bases

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Mastering Concepts 61

Why can $\mathbf{H^+}$ and $\mathbf{H_3O^+}$ be used interchangeably in chemical equations?

H_3O^+ is a hydrated hydrogen ion. The hydronium ion is a hydrogen ion that has a water molecule attached to it by a covalent bond.

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Mastering Concepts 62

Use the symbols **<**, **>** and **=** to express the relationship between the concentrations of **H^+** ions and **OH^-** ions in acidic, neutral, and basic solutions.

Mastering Concepts 62

Use the symbols **<**, **>** and **=** to express the relationship between the concentrations of **H^+** ions and **OH^-** ions in acidic, neutral, and basic solutions.

acidic: $[H^+] > [OH^-]$; neutral: $[H^+] = [OH^-]$; basic: $[H^+] < [OH^-]$

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Mastering Concepts 63

Choose the best answer that completes the table.

Model	Acid Definition	Base Definition
b.	H^+ producer	OH^- producer
c.	H^+ donor	H^+ acceptor
a.	electron-pair acceptor	electron-pair donor

a) (a) Arrhenius – (b) Lewis – (c) Brønsted-Lowry

b) (a) Brønsted-Lowry – (b) Lewis – (c) Arrhenius

c) (a) Brønsted-Lowry – (b) Arrhenius – (c) Lewis

d) (a) Lewis – (b) Arrhenius – (c) Brønsted-Lowry

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Mastering Concepts 63

Choose the best answer that completes the table.

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a) (a) Arrhenius – (b) Lewis – (c) Brønsted-Lowry

b) (a) Brønsted-Lowry – (b) Lewis – (c) Arrhenius

c) (a) Brønsted-Lowry – (b) Arrhenius – (c) Lewis

d) (a) Lewis – (b) Arrhenius – (c) Brønsted-Lowry

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Mastering Problems 64

Write a balanced chemical equation for each of the following.

a) the dissociation of solid magnesium hydroxide in water

b) the reaction of magnesium metal and hydrobromic acid

Mastering Problems 64

Write a balanced chemical equation for each of the following.

a) the dissociation of solid magnesium hydroxide in water

$$Mg(OH)_2(s) \longrightarrow Mg^{2+}(aq) + 2OH^-(aq)$$

b) the reaction of magnesium metal and hydrobromic acid

$$Mg(s) + 2HBr(aq) \longrightarrow H_2(g) + MgBr_2(aq)$$

Mastering Problems 64

Write a balanced chemical equation for each of the following.

c) the ionization of propanoic acid (CH_3CH_2COOH) in water

d) the second ionization of sulfuric acid in water

Mastering Problems 64

Write a balanced chemical equation for each of the following.

c) the ionization of propanoic acid (CH3CH2COOH) in water

$$CH_3CH_2COOH(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + CH_3CH_2COO^-(aq)$$

d) the second ionization of sulfuric acid in water

$$HSO_4^-(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + SO_4^{2-}(aq)$$

Mixed Review 97

Which of the following are polyprotic acids? Write successive ionization equations for the polyprotic acids in water.

a. H_3BO_3 b. CH_3COOH c. HNO_3 d. H_2SeO_3

Mixed Review 97

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a. H_3BO_3 b. CH_3COOH c. HNO_3 **d. H_2SeO_3**

$$H_3BO_3(aq) \leftrightarrow H^+(aq) + H_2BO_3^-(aq)$$

$$H_2BO_3^-(aq) \leftrightarrow H^+(aq) + HBO_3^{2-}(aq)$$

$$HBO_3^{2-}(aq) \leftrightarrow H^+(aq) + BO_3^{3-}(aq)$$

$$H_2SeO_3(aq) \leftrightarrow H^+(aq) + HSeO_3^-(aq)$$

$$HSeO_3^-(aq) \leftrightarrow H^+(aq) + SeO_3^{2-}(aq)$$

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Mixed Review 98

Write balanced chemical equations for the two successive ionizations of **carbonic acid** in water. Identify the conjugate-base pair in each of the equations.

Mixed Review 98

Write balanced chemical equations for the two successive ionizations of **carbonic acid** in water. Identify the conjugate-base pair in each of the equations.

$H_2CO_3(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + HCO_3^-(aq)$
acid (H_2CO_3)/conjugate base (HCO_3^-); base (H_2O)/ conjugate acid H_3O^+

$HCO_3^-(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + CO3_3^{2-}(aq$
acid (HCO_3^-)/conjugate base (CO_3^{2-}); base (H_2O)/ conjugate acid (H_3O^+)

Think Critically 104

Which is not a counterexample for the following statement: “A substance whose chemical formula contains a hydroxyl group must be considered to be a base.”?

a) CH_3CH_2COOH

b) $NaOH$

c) NH_3

d) CH_3COOH

Think Critically 104

Which is not a counterexample for the following statement: “A substance whose chemical formula contains a hydroxyl group must be considered to be a base.”?

a) CH_3CH_2COOH

b) $NaOH$

c) NH_3

d) CH_3COOH

Think Critically 107

Identify the Lewis acids and bases in the following reactions.

a. $H^+ + OH^- \leftrightarrow H_2O$

b. $Cl^- + BCl_3 \leftrightarrow BCl_4^-$

c. $SO_3 + H_2O \leftrightarrow H_2SO_4$

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Think Critically 107

Identify the Lewis acids and bases in the following reactions.

a. $H^+ + OH^- \leftrightarrow H_2O$

a. Lewis acids: H^+ and H_2O; Lewis base: OH^-

b. $Cl^- + BCl_3 \leftrightarrow BCl_4^-$

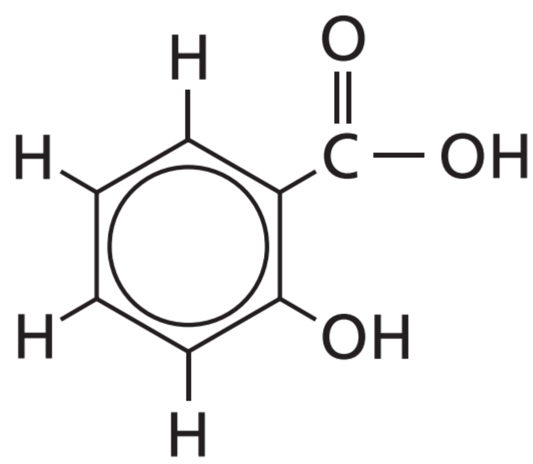
b. Lewis acid: BCl_3; Lewis bases: Cl^-, BCl_4^-

c. $SO_3 + H_2O \leftrightarrow H_2SO_4$

c. :Lewis acid: SO_3; Lewis base: H_2O

Think Critically 110

Salicylic acid, shown in the figure, is used to manufacture acetylsalicylic acid, commonly known as aspirin. Evaluate the hydrogen atoms in the salicylic acid molecule based on your knowledge about the ionizable hydrogen in the acetic acid molecule, CH_3COOH. Predict which of salicylic acid's hydrogen atoms is likely to be ionizable.



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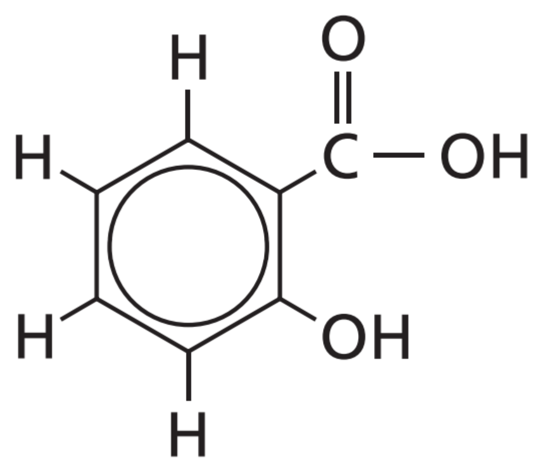
Think Critically 110

Salicylic acid, shown in the figure, is used to manufacture acetylsalicylic acid, commonly known as aspirin. Evaluate the hydrogen atoms in the salicylic acid molecule based on your knowledge about the ionizable hydrogen in the acetic acid molecule, CH_3COOH. Predict which of salicylic acid's hydrogen atoms is likely to be ionizable.

Only the hydrogen atom in the COOH group is likely to be ionizable.



Strengths of Acids and Bases

Chapter 3
Lesson 2 – Revision Paper

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Section Summary

- In solution, strong acids and bases ionize completely, but weak acids and bases ionize only partially.

- For weak acids and weak bases, the value of the acid or base ionization constant is a measure of the strength of the acid or base.

- Strong acids and strong bases are completely ionized in a dilute aqueous solution. Weak acids and weak bases are partially ionized in a dilute aqueous solution.

Figure 12

Explain the difference in the brightness of the bulbs in terms of the concentration of ions in solution.

a) It is brighter when the solution contains less ions.

b) It is brighter when the solution contains positive ions.

c) It is brighter when the solution contains more ions.

d) It is brighter when the solution contains negative ions.

Figure 12

Explain the difference in the brightness of the bulbs in terms of the concentration of ions in solution.

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Reading Check

Which of the following is true?

a) The conjugate base of a strong acid is very strong.

b) The conjugate acid of a strong base is very strong.

c) The conjugate base of a strong acid is very weak.

d) The conjugate acid of a strong base is very strong.

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Reading Check

Which of the following is true?

a) The conjugate base of a strong acid is very strong.

b) The conjugate acid of a strong base is very strong.

c) The conjugate base of a strong acid is very weak.

d) The conjugate acid of a strong base is very strong.

القاعدة المرافقة للحمض القوي تكون ضعيفة جـدا، ولذلـك قدرتها على جذب أيـون هيدروجين تكون ضعيفـة أيضا. في حـين تكـون القاعدة المرافقـة للحمض الضعيـف أقوى، وتنافـس بنجاح في سـبيل الحصول على الهيدروجين.

Applications 12

Write ionization equations and acid ionization constant expressions for,

a. $HClO_2$

b. HNO_2

c. HIO

Applications 12

Write ionization equations and acid ionization constant expressions for,

a. $HClO_2$

$$HClO_2(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + ClO_2^-(aq)$$

$$K_a = \frac{[H_3O+][ClO_2]}{[HClO_2]}$$

b. HNO_2

$$HNO_2(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + NO_2^-(aq)$$

$$K_a = \frac{[H_3O^+]\,[NO_2^-]}{[HNO_2]}$$

c. HIO

$$HIO(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + IO^-(aq)$$

$$K_a = \frac{[H_3O^+][IO^-]}{[HIO]}$$

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Applications 13

Write the first and second ionization equations for **H_2SeO_3**.

Applications 13

Write the first and second ionization equations for **H2SeO3**.

$$H_2SeO_3(aq) + H_2O(l) \leftrightarrow HSeO_3^{-}(aq) + H_3O^{+}(aq)$$

$$HSeO_3^{-}(aq) + H_2O(l) \leftrightarrow SeO_3^{2-}(aq) + H_3O^{+}(aq)$$

Applications 14

CHALLENGE Given the expression below, write the balanced equation for the corresponding reaction.

$$K_a = \frac{[ASO_4^{3-}]\,[H_3O^+]}{[HAsO_4^{2-}]}$$

Applications 14

CHALLENGE Given the expression below, write the balanced equation for the corresponding reaction.

$$K_a = \frac{[ASO_4^{3-}]\,[H_3O^+]}{[HAsO_4^{2-}]}$$

$$HAsO_4^{2-}(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + AsO_4^{3-}$$

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Applications 15

Write ionization equations and base ionization constant expressions for the following bases.

a. hexylamine ($C_6H_{13}NH_2$)

b. propylamine ($C_3H_7NH_2$)

Applications 15

Write ionization equations and base ionization constant expressions for the following bases.

a. hexylamine ($C_6H_{13}NH_2$)

$C_6H_{13}NH_2(aq) + H_2O(l) \leftrightarrow C_6H_{13}NH_3^+(aq) + OH^-(aq)$

$$K_b = \frac{[C_6H_{13}NH_3^+]\,[OH^-]}{[C_6H_{13}NH_2]}$$

b. propylamine ($C_3H_7NH_2$)

$C_3H_7NH_2(aq) + H_2O(l) \leftrightarrow C_3H_7NH_3^+(aq) + OH^-(aq)$

$$K_b = \frac{[C_3H_7NH_3^+]\,[OH^-]}{[C_3H_7NH_2]}$$

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Applications 15

Write ionization equations and base ionization constant expressions for the following bases.

c. carbonate ion (CO_3^{2-})

d. hydrogen sulfite ion (HSO_3^{-})

Applications 15

Write ionization equations and base ionization constant expressions for the following bases.

c. carbonate ion (CO_3^{2-})

$$CO_3^{2-}(aq) + H_2O(l) \leftrightarrow HCO^{3-}(aq) + OH^-(aq)$$

$$K_b = \frac{[HCO_3^-]\,[OH^-]}{[CO_3^{2-}]}$$

d. hydrogen sulfite ion (HSO_3^-)

$$HSO_3^-\,(aq) + H_2O(l) \leftrightarrow H_2SO_3(aq) + OH^-\,(aq)$$

$$K_b = \frac{[H_2SO_3]\,[OH^-]}{[HSO_3^-]}$$

Applications 16

CHALLENGE Write an equation for a base equilibrium in which the base in the forward reaction is **PO_4^{3-}** and the base in the reverse reaction is **OH^-**.

Applications 16

CHALLENGE Write an equation for a base equilibrium in which the base in the forward reaction is **PO_4^{3-}** and the base in the reverse reaction is **OH^-**.

$$PO_4^{3-}(aq) + H_2O(l) \leftrightarrow HPO_4^{2-}(aq) + OH^-(aq)$$

Review 17

Which is true about the contents of dilute aqueous solutions of the strong acid **HI** and the weak acid **HCOOH**?

I. The solution of ***HI*** *contains only* H_3O^+ *and* I^- *ions and water molecules.*

II. The solution of ***HCOOH*** *contains* H_3O^+ *and* $HCOO^-$ *ions, and* ***HCOOH*** *and* H_2O *molecules.*

III. The solution of ***HI*** *contains* H_3O^+, I^- *ions and* ***HI*** *and water molecules.*

IV. The solution of ***HCOOH*** *contains only* H_3O^+ *and* $HCOO^-$ *ions, and* H_2O *molecules.*

a) I and II b) III and IV c) II and III d) I and IV

Review 17

Which is true about the contents of dilute aqueous solutions of the strong acid **HI** and the weak acid **HCOOH**?

I. *The solution of **HI** contains only **H_3O^+** and **I^-** ions and water molecules.*

II. *The solution of **HCOOH** contains **H_3O^+** and **$HCOO^-$** ions, and **HCOOH** and **H_2O** molecules.*

III. *The solution of **HI** contains **H_3O^+**, **I^-** ions and **HI** and water molecules.*

IV. *The solution of **HCOOH** contains only **H_3O^+** and **$HCOO^-$** ions, and **H_2O** molecules.*

a) I and II b) III and IV c) II and III d) I and IV

Review 18

Which of the following is true?

a) The weaker the acid is, the weaker its conjugate base.

b) The weaker the base is, the weaker its conjugate acid.

c) The stronger the acid is, the stronger its conjugate base.

d) The weaker the acid is, the stronger its conjugate base.

Review 18

Which of the following is true?

a) The weaker the acid is, the weaker its conjugate base.

b) The weaker the base is, the weaker its conjugate acid.

c) The stronger the acid is, the stronger its conjugate base.

d) The weaker the acid is, the stronger its conjugate base.

The stronger the acid is, the weaker its conjugate base. The weaker the acid is, the stronger its conjugate base.

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مكتبة الفكر

Review 19

Identify the conjugate acid-base pairs in each equation.

a. $HCOOH(aq) + H_2O(l) \leftrightarrow HCOO^-(aq) + H_3O^+(aq)$

b. $NH_3(aq) + H_2O(l) \leftrightarrow NH_4{}^+(aq) + OH^-(aq)$

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Review 19

Identify the conjugate acid-base pairs in each equation.

a. $HCOOH(aq) + H_2O(l) \leftrightarrow HCOO^-(aq) + H_3O^+(aq)$

acid: $HCOOH$; conjugate base: $HCOO^-$; base: H_2O; conjugate acid: H_3O^+;

b. $NH_3(aq) + H_2O(l) \leftrightarrow NH_4{}^+(aq) + OH^-(aq)$

acid: H_2O; conjugate base: OH^-; base: NH_3; conjugate acid: $NH_4{}^+$

Review 20

Explain what the $\boldsymbol{K_b}$ for aniline tells you. ($\boldsymbol{K_b = 4.3 \times 10^{-10}}$).

a) The size of aniline's K_b indicates that aniline is a strong base.

b) The size of aniline's K_b indicates that aniline is a weak acid.

c) The size of aniline's K_b indicates that aniline is a strong acid.

d) The size of aniline's K_b indicates that aniline is a weak base.

مكتبة الفكر

Review 20

Explain what the $\boldsymbol{K_b}$ for aniline tells you. ($\boldsymbol{K_b = 4.3 \times 10^{-10}}$).

a) The size of aniline's K_b indicates that aniline is a strong base.

b) The size of aniline's K_b indicates that aniline is a weak acid.

c) The size of aniline's K_b indicates that aniline is a strong acid.

d) The size of aniline's K_b indicates that aniline is a weak base.

The size of aniline's K_b indicates that aniline is a weak base.

مكتبة الفكر

Review 21

Use the data in the table to put the seven acids in order according to increasing electrical conductivity.

Ionization Equation	K_a (298 K)
$H_2S \rightleftharpoons H^+ + HS^-$	8.9×10^{-8}
$HS^- \rightleftharpoons H^+ + S^{2-}$	1×10^{-19}
$HF \rightleftharpoons H^+ + F^-$	6.3×10^{-4}
$HCN \rightleftharpoons H^+ + CN^-$	6.2×10^{-10}
$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$	1.8×10^{-5}
$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$	4.5×10^{-7}
$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$	4.7×10^{-11}

Review 21

Use the data in the table to put the seven acids in order according to increasing electrical conductivity.

HS^-, HCO_3^-, H_2S, H_2CO_3, CH_3COOH, $HCOOH$, HF

Ionization Equation	K_a (298 K)
$H_2S \rightleftharpoons H^+ + HS^-$	8.9×10^{-8}
$HS^- \rightleftharpoons H^+ + S^{2-}$	1×10^{-19}
$HF \rightleftharpoons H^+ + F^-$	6.3×10^{-4}
$HCN \rightleftharpoons H^+ + CN^-$	6.2×10^{-10}
$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$	1.8×10^{-5}
$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$	4.5×10^{-7}
$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$	4.7×10^{-11}

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مكتبة الفكر

Mastering Concepts 65

Explain the difference between a strong acid and a weak acid in dilute aqueous solution.

Mastering Concepts 65

Explain the difference between a strong acid and a weak acid in dilute aqueous solution.

In dilute aqueous solution,

- **a strong acid ionizes completely;**
- **a weak acid ionizes slightly.**

Mastering Concepts 66

________ are used for weak acids, which are partially ionized in water and create equilibria. ________ are used for strong acids, which may be considered to be 100% ionized in dilute aqueous solutions.

a) Reaction arrows – Equilibrium arrows

b) Straight arrows – Equilibrium arrows

c) Equilibrium arrows – Reaction arrows

d) Reaction arrows – Straight arrows

Mastering Concepts 66

_________ are used for weak acids, which are partially ionized in water and create equilibria. _________ are used for strong acids, which may be considered to be 100% ionized in dilute aqueous solutions.

a) Reaction arrows – Equilibrium arrows

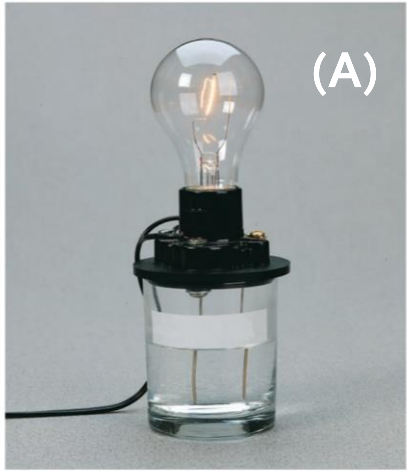
b) Straight arrows – Equilibrium arrows

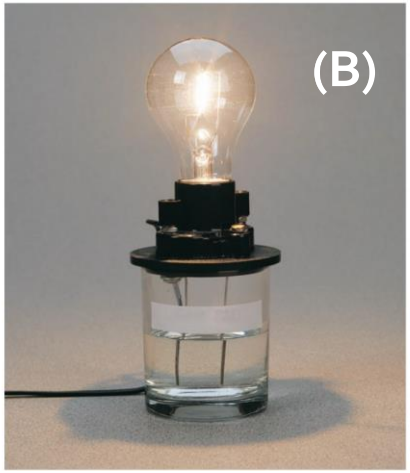
c) Equilibrium arrows – Reaction arrows

d) Reaction arrows – Straight arrows

Mastering Concepts 67

Which of the following can be true about the solutions inside the beakers?





a) (A) HCl – (B) HF

b) (A) H_2SO_4 – (B) $HClO_4$

c) (A) $NaOH$ – (B) NH_3

d) (A) NH_3 – (B) HNO_3

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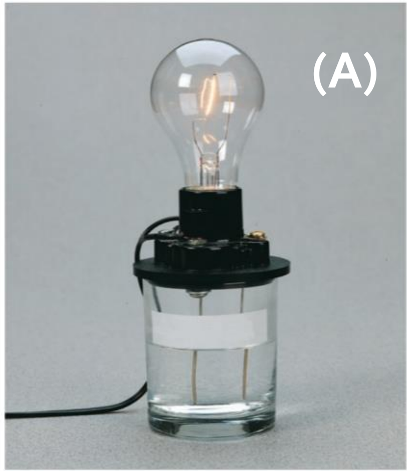
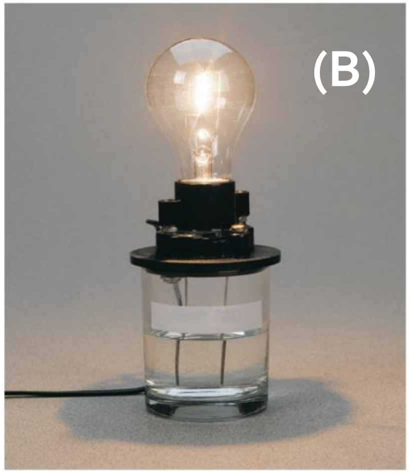
مكتبة الفكر

Mastering Concepts 67

Which of the following can be true about the solutions inside the beakers?





a) (A) HCl – (B) HF

b) (A) H_2SO_4 – (B) $HClO_4$

c) (A) $NaOH$ – (B) NH_3

d) (A) NH_3 – (B) HNO_3

Beaker (A) has a weak acid/base.
Beaker (B) has a strong acid/base.

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مكتبة الفكر

Mastering Concepts 68

How would you compare the strengths of two weak acids experimentally?

Mastering Concepts 68

How would you compare the strengths of two weak acids experimentally?

1. **Compare the conductivities of equimolar solutions of the acids.**
2. **Compare acid ionization constants of the two acids.**

Mastering Concepts 69

Identify the conjugate acid-base pairs in the reaction of $\mathbf{H_3PO_4}$ with water.

Mastering Concepts 69

Identify the conjugate acid-base pairs in the reaction of **H_3PO_4** with water.

$$H_3PO_4(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + H_2PO_4^-(aq)$$

acid (H_3PO_4)/conjugate base ($H_2PO_4^-$); base (H_2O)/ conjugate acid (H_3O^+)

Mastering Problems 70

Write the chemical equation and K_b expression for the ionization of **ammonia** in water. How is it safe for a window washer to use a solution of ammonia, which is basic?

Mastering Problems 70

Write the chemical equation and K_b expression for the ionization of **ammonia** in water. How is it safe for a window washer to use a solution of ammonia, which is basic?

$$NH_3(aq) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)$$

$K_b = \dfrac{[NH_4^+][OH^-]}{[NH_3]}$; **Ammonia is a weak base, therefore, its aqueous solution is not highly basic.**

Mastering Problems 71

Hypochlorous acid is an industrial disinfectant. Write the chemical equation and the K_a expression for the ionization of hypochlorous acid in water.

Mastering Problems 71

Hypochlorous acid is an industrial disinfectant. Write the chemical equation and the K_a a expression for the ionization of hypochlorous acid in water.

$$HClO \leftrightarrow H^{+} + ClO^{-};$$

$$K_a = \frac{[H^{+}][ClO^{-}]}{[HClO]}$$

Mastering Problems 72

Write the chemical equation and the K_b expression for the ionization of **aniline** in water. Aniline is a weak base with the formula **$C_2H_5NH_2$**.

Mastering Problems 72

Write the chemical equation and the K_b expression for the ionization of **aniline** in water. Aniline is a weak base with the formula **C2H5NH2**.

$$C_2H_5NH_2(aq) + H_2O(l) \longrightarrow C_2H_5NH_3^+(aq) + OH^-(aq)$$

$$K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]}$$

Mastering Problems 73

A fictional weak base, **ZaH_2**, reacts with water to yield a solution with a **OH^-** ion concentration of **2.68×10^{-4} mol/L**. The chemical equation for the reaction is **ZaH_2 (aq) + H_2O (l) $\rightleftharpoons$ ZaH_3^+ (aq) + OH^- (aq).** If **[ZaH_2]** at equilibrium is **0.0997 mol/L**, what is the value of K_b for ZaH_2?

Mastering Problems 73

A fictional weak base, **ZaH2**, reacts with water to yield a solution with a **OH^-** ion concentration of **2.68×10^{-4} mol/L**. The chemical equation for the reaction is **ZaH_2 (aq) + H_2O (l) ⇌ ZaH_3^+ (aq) + OH^- (aq).** If **[ZaH_2]** at equilibrium is **0.0997 mol/L**, what is the value of K_b for ZaH_2?

$$K_b = \frac{[ZaH_3^{+}][OH^{-}]}{[ZaH_2]} = \frac{(2.68 \times 10^{-4})(2.68 \times 10^{-4})}{0.0997 - 2.68 \times 10^{-4}}$$

$$= 7.22 \times 10^{-7}$$

Mastering Problems 74

Select a strong acid, and explain how you would prepare a dilute solution of the acid. Select a weak acid, and explain how you would prepare a concentrated solution of the acid.

Mastering Problems 74

Select a strong acid, and explain how you would prepare a dilute solution of the acid. Select a weak acid, and explain how you would prepare a concentrated solution of the acid.

The dilute solution of a strong acid is prepared by dissolving a small quantity of the strong acid in a large quantity of water.

The concentrated solution of a weak acid is prepared by dissolving a large quantity of the weak acid in a small quantity of water.

Mixed Review 99

Strontium hydroxide is used in the refining of beet sugar. Only **4.1 g** of strontium hydroxide can be dissolved in **1 L** of water at 273 K. Given that its solubility is so low, explain how is it possible that strontium hydroxide is considered to be a strong base.

Mixed Review 99

Strontium hydroxide is used in the refining of beet sugar. Only **4.1 g** of strontium hydroxide can be dissolved in **1 L** of water at 273 K. Given that its solubility is so low, explain how is it possible that strontium hydroxide is considered to be a strong base.

All of the $Sr(OH)_2$ that dissolves dissociates to form Sr^{2+} and OH^- ions.

Hydrogen Ions and pH

Chapter 3
Lesson 3 – Revision Paper

InLibrary

مكتبة الفكر

مكتبة الفكر

Section Summary

- pH and pOH are logarithmic scales that express the concentrations of hydrogen ions and hydroxide ions in aqueous solutions.

- The ion product constant for water, K_w, equals the product of the H^+ ion concentration and the OH^- ion concentration.

- The pH of a solution is the negative log of the hydrogen ion concentration. The pOH is the negative log of the hydroxide ion concentration. pH plus pOH equals 14.

- A neutral solution has a pH of 7.0 and a pOH of 7.0 because the concentrations of hydrogen ions and hydroxide ions are equal.

مكتبة الفكر

Reading Check

Why K_w does not change when the concentration of hydrogen ions increases?

Reading Check

Why K_w does not change when the concentration of hydrogen ions increases?

The added H^+ ions react with OH^- ions to form more water molecules. Thus, the concentration of OH^- ions decreases such that the product of the two concentrations of ions always be constant.

عندما يزداد تركيـز أيونات الهيدروجين ينقص تركيز أيونات الهيدروكسيد، بحيث يكون حاصل ضرب تركيز الأيونين ثابتا دائما.

Example 1

At **298 K**, the **H^+** ion concentration in a cup of coffee is **1.0×10^{-5} M**. What is the **OH^-** ion concentration in the coffee? Is the coffee acidic, basic, or neutral?

Example 1

At **298 K**, the **H^+** ion concentration in a cup of coffee is **1.0×10^{-5} M**. What is the **OH^-** ion concentration in the coffee? Is the coffee acidic, basic, or neutral?

$K_w = [H^+][\mathbf{OH^-}]$ — **State the ion product expression.**

$[\mathbf{OH^-}] = \dfrac{K_w}{[H^+]}$ — **Solve for $[OH^-]$.**

$[\mathbf{OH^-}] = \dfrac{1.0 \times 10^{-14}}{1.0 \times 10^{-5}} = \mathbf{1.0 \times 10^{-9}\ mol/L}$ — **Substitute $K_w = 1.0 \times 10^{-14}$. Substitute $[H^+] = 1.0 \times 10^{-5} M$ and solve.**

Because $[H^+] > [OH^-]$, **the coffee is acidic.**

Applications 22

For each solution, calculate **$[H^+]$** or **$[OH^-]$**. State whether the solution is acidic, basic, or neutral.

a. $[H^+] = 1.0 \times 10^{-13} M$

b. $[OH^-] = 1.0 \times 10^{-7} M$

مكتبة الفكر

Applications 22

For each solution, calculate **[H⁺]** or **[OH⁻]**. State whether the solution is acidic, basic, or neutral.

a. $[H^+] = 1.0 \times 10^{-13} M$

$K_w = [H^+][OH^-]$

$1.0 \times 10^{-14} = (1.0 \times 10^{-13})[OH^-]$

$$\frac{1.0 \times 10^{-14}}{1.0 \times 10^{-13}} = \frac{(1.0 \times 10^{-13})[OH^-]}{1.0 \times 10^{-13}}$$

$[OH^-] = 1.0 \times 10^{-1} M$

$[OH^-] > [H^+]$, the solution is basic.

b. $[OH^-] = 1.0 \times 10^{-7} M$

$K_w = [H^+][OH^-]$

$$\frac{1.0 \times 10^{-14}}{1.0 \times 10^{-7}} = \frac{[H^+](1.0 \times 10^{-7})}{1.0 \times 10^{-7}}$$

$[H^+] = 1.0 \times 10^{-7} M$

$[OH^-] = [H^+]$, the solution is neutral.

Applications 22

For each solution, calculate **[H⁺]** or **[OH⁻]**. State whether the solution is acidic, basic, or neutral.

c. $[OH^-] = 1.0 \times 10^{-3} M$

d. $[H^+] = 4.0 \times 10^{-5} M$

Applications 22

For each solution, calculate **[H⁺]** or **[OH⁻]**. State whether the solution is acidic, basic, or neutral.

c. $[OH^-] = 1.0 \times 10^{-3} M$

$K_w = [H^+][OH^-]$

$1.0 \times 10^{-14} = [H^+](1.0 \times 10^{-3})$

$$\frac{1.0 \times 10^{-14}}{1.0 \times 10^{-3}} = \frac{[H^+](1.0 \times 10^{-3})}{1.0 \times 10^{-3}}$$

$[H^+] = 1.0 \times 10^{-11} M$

$[OH^-] > [H^+]$, the solution is basic.

d. $[H^+] = 4.0 \times 10^{-5} M$

$K_w = [H^+][OH^-]$

$1.0 \times 10^{-14} = (4.0 \times 10^{-5})[OH^-]$

$$= \frac{1.0 \times 10^{-14}}{4.0 \times 10^{-5}} = \frac{(4.0 \times 10^{-5})[OH^-]}{(4.0 \times 10^{-5})}$$

$[OH^-] = 2.5 \times 10^{-10} M$

$[H^+] > [OH^-]$, the solution is acidic

Applications 23

CHALLENGE Calculate the number of $\mathbf{H^+}$ ions and the number of $\mathbf{OH^-}$ ions in **300 mL** of pure water at 298 K.

Applications 23

CHALLENGE Calculate the number of **H^+** ions and the number of **OH^-** ions in **300 mL** of pure water at 298 K.

At 298 K, $[H^+] = [OH^-] = 1.0 \times 10^{-7} M$

$$\text{Mol } H^+ = \frac{1.0 \times 10^{-7}\ \text{mol}}{1\text{L}} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times$$

$$300\ \text{mL} = 3.0 \times 10^{-8}\ \text{mol}$$

$$3.0 \times 10^{-8}\ \text{mol } H^+ \text{ ions} \times \frac{6.02 \times 10^{23}\ H^+ \text{ ions}}{1\ \text{mol}} =$$

$$1.8 \times 10^{16}\ H^+ \text{ ions}$$

$$\text{Number of } H^+ = \text{number of } OH^- =$$

$$1.8 \times 10^{16} \text{ ions}$$

Figure 14

Determine whether seawater or detergent has a higher concentration of H^+ ions. How many times higher?

a) Water; 10 times.

b) Water; 2 times.

c) Detergent; 2 times.

d) Water; 100 times.

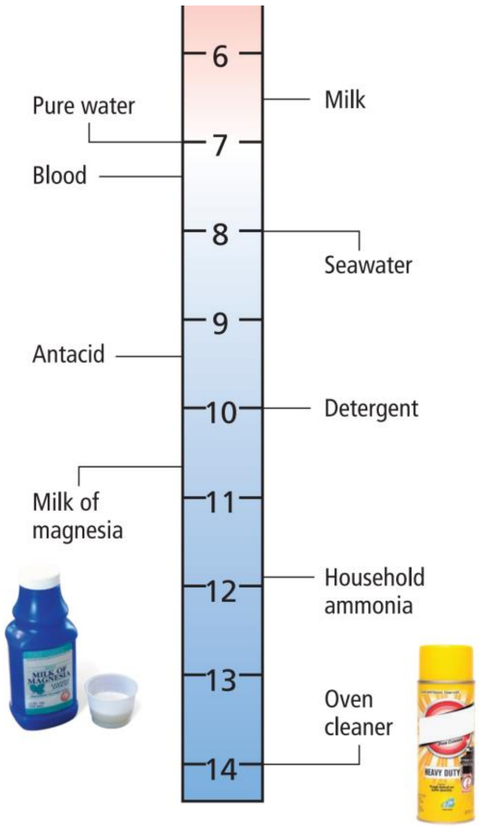


Figure 14

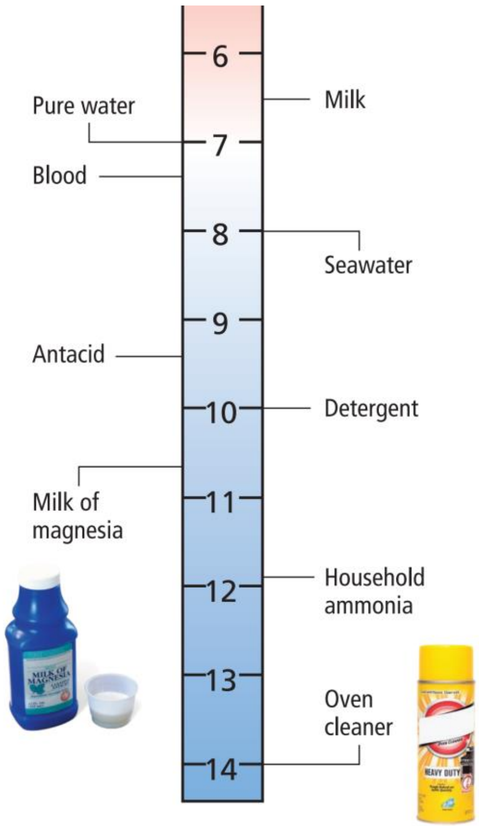
Determine whether seawater or detergent has a higher concentration of H^+ ions. How many times higher?

a) Water; 10 times.

b) Water; 2 times.

c) Detergent; 2 times.

d) Water; 100 times.



يحتوي ماء البحر على التركيز الأعلى من أيونات الهيدروجين؛ بأكثر من مئة مرة.

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Example 2

What is the pH of a neutral solution at **298 K**?

Example 2

What is the pH of a neutral solution at **298 K**?

$$\mathbf{pH} = -\log\,[H^+]$$

State the equation for pH.

$$\mathbf{pH} = -\log\,(1.0 \times 10^{-7})$$

Substitute $[H^+] = 1.0 \times 10^{-7} M$.

The pH of the neutral solution at 298 K is **7.00.**

Applications 24

Calculate the pH of solutions having the following ion concentrations at **298 K**.

a. $[H^+] \times 1.0 \times 10^{-2} M$

b. $[H^+] = 3.0 \times 10^{-6} M$

Applications 24

Calculate the pH of solutions having the following ion concentrations at **298 K**.

a. $[H^+] \times 1.0 \times 10^{-2} M$

$$pH = -\log [H^+]$$

$$pH = -\log(1.0 \times 10^{-2})$$

$$pH = 2.00$$

b. $[H^+] = 3.0 \times 10^{-6} M$

$$pH = -\log [H^+]$$

$$pH = -\log(3.0 \times 10^{-6})$$

$$pH = 5.52$$

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Applications 25

Calculate the **pH** of aqueous solutions with the following $[H^+]$ at 298 K.

a. $[H^+] = 0.0055 M$

b. $[H^+] = 0.000084 M$

Applications 25

Calculate the **pH** of aqueous solutions with the following $[H^+]$ at 298 K.

a. $[H^+] = 0.0055M$

$$pH = -\log [H^+]$$

$$pH = -\log 0.0055$$

$$pH = 2.26$$

b. $[H^+] = 0.000084M$

$$pH = -\log [H^+]$$

$$pH = -\log 0.000084$$

$$pH = 4.08$$

Applications 26

CHALLENGE Calculate the pH of a solution having **$[OH^-]$** = **8.2×10^{-6} M**.

Applications 26

CHALLENGE Calculate the pH of a solution having **$[OH^-]$** = **8.2×10^{-6} M**.

$$[OH^-] = 8.2 \times 10^{-6} M$$

$$K_w = [H^+][OH^-] \times [H^+](8.2 \times 10^{-6})$$

$$[H^+] = \frac{1.0 \times 10^{-14}}{8.2 \times 10^{-6}} = 1.2 \times 10^{-9}$$

$$pH = -\log [H^+]$$

$$pH = -\log(1.2 \times 10^{-9})$$

$$pH = 8.92$$

Example 3

A typical cleaner has a hydroxide-ion concentration of **4.0×10^{-3} M**. Calculate the **pOH** and **pH** of a cleaner at 298 K.

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3.3 Hydrogen Ions and pH

مكتبة الفكر

Example 3

A typical cleaner has a hydroxide-ion concentration of $\mathbf{4.0 \times 10^{-3}}$ **M**. Calculate the **pOH** and **pH** of a cleaner at 298 K.

$\mathbf{pOH} = -\log [OH^-]$	**State the equation for pOH.**
$\mathbf{pOH} = -\log (4.0 \times 10^{-3})$	**Substitute $[OH^-] = 4.0 \times 10^{-3} M$.**

The **pOH** of the solution is **2.40.**

Use the relationship between pH and pOH to find the pH.

$\mathbf{pH} + pOH = 14.00$	**State the equation that relates pH and pOH.**
$\mathbf{pH} = 14.00 - pOH$	**Solve for pH.**
$\mathbf{pH} = 14.00 - 2.40 = \mathbf{11.60}$	**Substitute pOH = 2.40.**

The **pH** of the solution is **11.60.**

Applications 27

Calculate the **pH** and **pOH** of aqueous solutions with the following concentrations at 298 K.

a. $[OH^-] = 1.0 \times 10^{-6} M$

b. $[OH^-] = 6.5 \times 10^{-4} M$

Applications 27

Calculate the **pH** and **pOH** of aqueous solutions with the following concentrations at 298 K.

a. $[OH^-] = 1.0 \times 10^{-6} M$

$pOH = -\log [OH^-]$

$pOH = -\log(1.0 \times 10^{-6})$

$pOH = 6.00$

$pH = 14.00 - pOH = 14.00 - 6.00 = 8.00$

b. $[OH^-] = 6.5 \times 10^{-4} M$

$pOH = -\log [OH^-]$

$pOH = -\log(6.5 \times 10^{-4})$

$pOH = 3.19$

$pH = 14.00 - pOH = 14.00 - 3.19 = 10.81$

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Applications 27

Calculate the **pH** and **pOH** of aqueous solutions with the following concentrations at 298 K.

c. $[H^+] = 3.6 \times 10^{-9} M$

d. $[H^+] = 2.5 \times 10^{-2} M$

مكتبة الفكر

Applications 27

Calculate the **pH** and **pOH** of aqueous solutions with the following concentrations at 298 K.

c. $[H^+] = 3.6 \times 10^{-9} M$

$pH = -\log [H^+]$

$pH = -\log(3.6 \times 10^{-9})$

$pH = 8.44$

$pOH = 14.00 - pH = 14.00 - 8.44 = 5.56$

d. $[H^+] = 2.5 \times 10^{-2} M$

$pH = -\log(-2.5 \times 10^{-2})$

$pH = 1.60$

$pOH = 14.00 - pH = 14.00 - 1.60 = 12.40$

Applications 28

Calculate the **pH** and **pOH** of aqueous solutions with the following concentration at 298 K.

a. $[OH^-] = 0.000033M$

b. $[H^+] = 0.0095M$

Applications 28

Calculate the **pH** and **pOH** of aqueous solutions with the following concentration at 298 K.

a. $[OH^-] = 0.000033M$

$$pOH = -\log [OH^-]$$

$$pOH = -\log (0.000033)$$

$$pOH = 4.48$$

$$pH = 14.00 - 4.48 = 9.52$$

b. $[H^+] = 0.0095M$

$$pH = -\log [H^+]$$

$$pH = -\log (0.0095)$$

$$pH = 2.02$$

$$pOH = 14.00 - 2.02 = 11.98$$

مكتبة الفكر

Applications 29

CHALLENGE Calculate **pH** and **pOH** for an aqueous solution containing **1.0×10^{-3} mol** of **HCl** dissolved in **5.0 L** of solution.

Applications 29

CHALLENGE Calculate **pH** and **pOH** for an aqueous solution containing **1.0×10^{-3} mol** of **HCl** dissolved in **5.0 L** of solution.

$$[\mathrm{HCl}] = [\mathrm{H^+}] = \frac{1.0 \times 10^{-3}\ \mathrm{mol}}{5.0\ \mathrm{L}} = 0.00020M = 2.0 \times 10^{-4}M$$

$$\mathrm{pH} = -\log(2.0 \times 10^{-4}) = -(-3.70) = 3.70$$

$$\mathrm{pOH} = 14.00 - 3.70 = 10.30$$

Example 4

What are $[H^+]$ and $[OH^-]$ in a healthy person's blood that has a pH of **7.40**? Assume that the temperature of the blood is 298 K.

Example 4

What are $[H^+]$ and $[OH^-]$ in a healthy person's blood that has a pH of **7.40**? Assume that the temperature of the blood is 298 K.

Determine $[H^+]$.

$pH = -\log [H^+]$	**State the equation for pH.**
$-pH = \log [H^+]$	**Multiply both sides of the equation by −1.**
$[H^+] = \text{antilog}(-pH)$	**Take the antilog of each side to solve for $[H^+]$.**
$[H^+] = \text{antilog}(-7.40)$	**Substitute pH = 7.40.**
$[H^+] = 4.0 \times 10^{-8} M$	**A calculator shows that the antilog of −7.40 is 4.0×10^{-8}.**

The concentration of H^+ ions in the blood is $4.0 \times 10^{-8} M$.

Determine $[OH^-]$.

$pH + pOH = 14.00$	**State the equation that relates pH and pOH.**
$pOH = 14.00 - pH$	**Solve for pOH.**
$pOH = 14.00 - 7.40 = 6.60$	**Substitute pH = 7.40.**
$pOH = -\log [OH^-]$	**State the equation for pOH.**
$-pOH = \log [OH^-]$	**Multiply both sides of the equation by −1.**
$[OH^-] = \text{antilog}(-6.60)$	**Take the antilog of each side and substitute pOH = 6.60.**
$[OH^-] = 2.5 \times 10^{-7} M.$	**A calculator shows that the antilog of −6.60 is 2.5×10^{-7}.**

The concentration of OH^- ions in the blood is $2.5 \times 10^{-7} M$.

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Applications 30

Calculate $[H^+]$ and $[OH^-]$ in each of the following solutions.

a. Milk, pH = 6.50

b. Lemon juice, pH = 2.37

Applications 30

Calculate $[H^+]$ and $[OH^-]$ in each of the following solutions.

a. Milk, pH = 6.50

$[H^+] = \text{antilog}\ (-pH)$

$[H^+] = \text{antilog}\ (-6.50) = 3.2 \times 10^{-7} M$

$pOH = 14.00 - pH = 14.00 - 6.50 = 7.50$

$[OH^-] = \text{antilog}\ (-pOH)$

$[OH^-] = (-7.50) = 3.2 \times 10^{-8} M$

b. Lemon juice, pH = 2.37

$[H^+] = \text{antilog}\ (-pH)$

$[H^+] = \text{antilog}\ (-2.37) = 4.3 \times 10^{-3} M$

$pOH = 14.00 - pH = 14.00 - 2.37 = 11.63$

$[OH^-] = \text{antilog}\ (-\ pOH)$

$[OH^-] = \text{antilog}\ (-11.63) = 2.3 \times 10^{-12} M$

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3.3 Hydrogen Ions and pH

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Applications 30

Calculate $[H^+]$ and $[OH^-]$ in each of the following solutions.

c. Milk of magnesia, pH = 10.50

d. Household ammonia, pH 11.90

Applications 30

Calculate [H^+] and [OH^-] in each of the following solutions.

c. Milk of magnesia, pH = 10.50

$[H^+]$ = antilog (−pH)

$[H^+]$ = antilog (−10.50) = 3.2×10^{-11}M

pOH = 14.00 − pH = 14.00 − 10.50 = 3.50

$[OH^-]$ = antilog (−3.50) = 3.2×10^{-4}*M*

d. Household ammonia, pH 11.90

$[H^+]$ = antilog (−pH)

$[H^+]$ = antilog (−11.90) = 1.3×10^{-12}*M*

pOH = 14.00 − pH = 14.00 −11.90 = 2.10

$[OH^-]$ = antilog (−2.10) = $7.9 \times 10–^{3}$*M*

Applications 31

CHALLENGE Calculate the $[H^+]$ and $[OH^-]$ in a sample of seawater with a **pOH = 5.60**.

Applications 31

CHALLENGE Calculate the $[H^+]$ and $[OH^-]$ in a sample of seawater with a **pOH = 5.60**.

$$[OH^-] = \text{antilog}\ (-pOH)$$

$$[OH^-] = \text{antilog}\ (-5.60) = 2.5 \times 10^{-6} M$$

$$pH = 14.00 - 5.60 = 8.40$$

$$[H^+] = \text{antilog}\ (-8.40) = 4.0 \times 10^{-9} M$$

Reading Check

Explain why you cannot obtain the [H^+] directly from the molarity of a weak acid solution.

Reading Check

Explain why you cannot obtain the $[H^+]$ directly from the molarity of a weak acid solution.

Weak acids only ionizes partially; therefore, the concentration of the weak acid in a solution is not equal to $[H^+]$

لا يتأين الحمض الضعيف كليّاً؛ لذا لا يساوي عدد مولات الحمض المذابة في لتر من المحلول تركيز أيونات الهيدروجين.

Figure 17

State the $[H^+]$ in the HCl flask and the $[OH^-]$ in the NaOH flask.

a) $[H^+] = 0.1$ M || $[OH^-] = 0.1$ M

b) $[H^+] = 0.5$ M || $[OH^-] = 0.5$ M

c) $[H^+] = 0.1$ M || $[OH^-] = 0.5$ M

d) $[H^+] = 0.5$ M || $[OH^-] = 0.1$ M

e) $[H^+] = 0.2$ M || $[OH^-] = 0.2$ M

f) Not enough information

مكتبة الفكر

Figure 17

State the $[H^+]$ in the HCl flask and the $[OH^-]$ in the NaOH flask.

a) $[H^+] = 0.1$ M || $[OH^-] = 0.1$ M

b) $[H^+] = 0.5$ M || $[OH^-] = 0.5$ M

c) $[H^+] = 0.1$ M || $[OH^-] = 0.5$ M

d) $[H^+] = 0.5$ M || $[OH^-] = 0.1$ M

e) $[H^+] = 0.2$ M || $[OH^-] = 0.2$ M

f) Not enough information

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3.3 Hydrogen Ions and pH

مكتبة الفكر

Example 5

Formic acid is used to process latex tapped from rubber trees into natural rubber. The **pH** of a **0.100*M*** solution of formic acid (**HCOOH**) is **2.38**. What is K_a for HCOOH?

Example 5

Formic acid is used to process latex tapped from rubber trees into natural rubber. The **pH** of a **0.100*M*** solution of formic acid (**HCOOH**) is **2.38**. What is K_a for HCOOH?

Use the pH to calculate $[H^+]$.

$pH = -\log [H^+]$	**Write the equation for pH.**
$[H^+] = \text{antilog}(-pH)$	**Multiply both sides by −1 and take the antilog of each side.**
$[H^+] = \text{antilog}(-2.38)$	**Substitute pH = 2.38.**
$[H^+] = 4.2 \times 10^{-3}M$	**A calculator shows that the antilog of −2.38 is 4.2×10^{-3}.**
$[HCOO^-] = [H^+] = 4.2 \times 10^{-3}M$	
[HCOOH] equals the initial concentration minus $[H^+]$.	
$[HCOOH] = 0.100M - 4.2 \times 10^{-3}M = 0.096M$	**Subtract $[H^+]$ from the initial [HCOOH].**
$K_a = \dfrac{[H^+][HCOO^-]}{[HCOOH]}$	**State the acid ionization constant expression.**
$K_a = \dfrac{(4.2 \times 10^{-3})(4.2 \times 10^{-3})}{(0.096)} = \mathbf{1.8 \times 10^{-4}}$	**Substitute $[H^+] = 4.2 \times 10^{-3}M$, $[HCOO^-] = 4.2 \times 10^{-3}M$, and $[HCOOH] = 0.096M$.**

The acid ionization constant for HCOOH is 1.8×10^{-4}.

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Applications 32

Calculate the K_a for the following acids using the given information.

a. $0.220M$ solution of H_3AsO_4, pH = 1.50 **b.** $0.0400M$ solution of $HClO_2$, pH = 1.80

Applications 32

Calculate the K_a for the following acids using the given information.

a. $0.220M$ solution of H_3AsO_4, pH $= 1.50$

$$K_a = \frac{[H+][H_2AsO_4^-]}{[H_3AsO_4]}$$

$[H^+] = \text{antilog}(-pH)$

$[H^+] = \text{antilog}(-1.50) = 3.2 \times 10^{-2}M$

$[H_2AsO_4^-] = [H^+] = 3.2 \times 10^{-2}M$

$[H_3AsO_4] = 0.220M - 3.2 \times 10^{-2}M = 0.188M$

$$K_a = \frac{(3.2 \times 10^{-2})(3.2 \times 10^{-2})}{0.188} = 5.4 \times 10^{-3}$$

b. $0.0400M$ solution of $HClO_2$, pH $= 1.80$

$$K_a = \frac{[H^+][ClO_2^-]}{[HClO_2]}$$

$[H^+] = \text{antilog}(-pH)$

$[H^+] = \text{antilog}(-1.80) = 1.6 \times 10^{-2}M$

$[ClO_2^-] = [H^+] = 1.6 \times 10^{-2}M$

$[HClO_2] = 0.0400M - 1.6 = 10^{-2}M = 0.024M$

$$K_a = \frac{(1.6 \times 10^{-2})(1.6 \times 10^{-2})}{0.024} = 1.1 \times 10^{-2}$$

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3.3 Hydrogen Ions and pH

مكتبة الفكر

Applications 33

Calculate the K_a of the following acids using the given information.

a. 0.00330*M* solution of benzoic acid (C_6H_5COOH), pOH = 10.70

مكتبة الفكر

Applications 33

Calculate the K_a of the following acids using the given information.

a. $0.00330M$ solution of benzoic acid (C_6H_5COOH), $pOH = 10.70$

$pH = 14.00 - pOH$

$pH = 14.00 - 10.70 = 3.30$

$[H^+] = \text{antilog}\,(-pH)$

$[H^+] = \text{antilog}\,(-3.30) = 5.0 \times 10^{-4}M$

$[C_6H_5COO^-] = [H^+] = 5.0 \times 10^{-4}M$

$[C_6H_5COOH] = 0.00330M - 5.0 \times 10^{-4}M = 0.0028M$

$$K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]} = \frac{(5.0 \times 10^{-4})(5.0 \times 10^{-4})}{(3.5 \times 10^{-3})}$$

$K_a = 8.9 \times 10^{-5}$

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Applications 33

Calculate the K_a of the following acids using the given information.

b. 0.100*M* solution of cyanic acid (HCNO), pOH = 11.00

Applications 33

Calculate the K_a of the following acids using the given information.

b. $0.100M$ solution of cyanic acid (HCNO), pOH $= 11.00$

$$pH = 14.00 - pOH$$

$$pH = 14.00 - 11.00 = 3.00$$

$$[H^+] = \text{antilog}\,(-pH)$$

$$[H^+] = \text{antilog}(-3.00) = 1.0 \times 10^{-3} M$$

$$[CNO^-] = [H^+] = 1.0 \times 10^{-3} M$$

$$[HCNO] = 0.100 - 1.0 \times 10^{-3} M = 0.099 M$$

$$K_a = \frac{[H^+][CNO^-]}{[HCNO]} = \frac{(1.0 \times 10^{-3})(1.0 \times 10^{-3})}{(0.099)}$$

$$K_a = 1.0 \times 10^{-5}$$

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Applications 33

Calculate the K_a of the following acids using the given information.

c. $0.150M$ solution of butanoic acid (C_3H_7COOH), pOH = 11.18

Applications 33

Calculate the K_a of the following acids using the given information.

c. $0.150M$ solution of butanoic acid (C_3H_7COOH), pOH = 11.18

$$pH = 14.00 - pOH$$

$$pH = 14.00 - 11.18 = 2.82$$

$$[H^+] = \text{antilog}\,(-pH)$$

$$[H^+] = \text{antilog}(-2.82) = 1.5 \times 10^{-3}M$$

$$[C_3H_7COO^-] = [H^+] = 1.5 \times 10^{-3}M$$

$$[C_3H_7COOH] = 0.150M - 1.5 \times 10^{-3}M = 0.149M$$

$$K_a = \frac{[H^+]\,[C_3H_7COO^-]}{[C_3H_7COOH]} = \frac{(1.5 \times 10^{-3})(1.5 \times 10^{-3})}{(0.149)}$$

$$K_a = 1.5 \times 10^{-5}$$

مكتبة الفكر

Applications 34

CHALLENGE Calculate the K_a of a **0.0091*M*** solution of an unknown acid (HX) having a **pOH** of **11.32**. Use Table 4 to identify the acid.

Applications 34

CHALLENGE Calculate the K_a of a **0.0091*M*** solution of an unknown acid (HX) having a **pOH** of **11.32**. Use Table 4 to identify the acid.

$$pH = 14.00 - pH$$

$$pH = 14.00 - 11.32 = 2.68$$

$$[H^+] = \text{antilog}\ (-pH)$$

$$[H^+] = \text{antilog}\ (-2.8) = 2.1 \times 10^{-3} M$$

$$[X^-] = [H^+] = 2.1 \times 10^{-3} M$$

$$[HX] = 0.0091 - 0.0021 = 0.0070 M$$

$$K_a = \frac{(0.0021)(0.0021)}{(0.0070)} = 6.3 \times 10^{-4}$$

The acid could be hydrofluoric acid (HF).

Review 35

Why is the pH of an acidic solution always a smaller number than the pOH of the same solution?

Review 35

Why is the pH of an acidic solution always a smaller number than the pOH of the same solution?

The sum of pH and pOH is 14.00. If a solution is acidic, its pH is less than 7.00. Therefore, pOH must be greater than 7.00.

Review 36

How can you determine the pH of a solution if you know its pOH?

a) Subtract the pOH from 14.00.

b) Subtract the pOH from 7.00.

c) Add the pOH to 14.00.

d) Add the pOH from 7.00.

Review 36

How can you determine the pH of a solution if you know its pOH?

a) Subtract the pOH from 14.00.

b) Subtract the pOH from 7.00.

c) Add the pOH to 14.00.

d) Add the pOH from 7.00.

Review 37

Which of the following is true about K_w in aqueous solutions?

a) Can be used to find H^+ or OH^- ions concentrations.

b) Its value at 273 K is 1.00×10^{-14}.

c) Its value at 298 K is 1.00×10^{-7}.

d) It can be applied to other solutions than water.

Review 37

Which of the following is true about K_w in aqueous solutions?

a) Can be used to find H^+ or OH^- ions concentrations.

b) Its value at 273 K is 1.00×10^{-14}.

c) Its value at 298 K is 1.00×10^{-7}.

d) It can be applied to other solutions than water.

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Review 38

What happens to the $[H^+]$ of a **0.10*M*** solution of acetic acid when a drop of NaOH solution is added?

a) The equilibrium shifts to the right

b) $[H^+]$ increases.

c) $[OH^-]$ decreases.

d) Water molecules increases.

Review 38

What happens to the $[H^+]$ of a **0.10*M*** solution of acetic acid when a drop of NaOH solution is added?

a) The equilibrium shifts to the right

b) $[H^+]$ increases.

c) $[OH^-]$ decreases.

d) Water molecules increases.

الزيـادة في أيونـات OH^- مـن قطـرة واحـدة مـن NaOH تدفع التأيُّن الذاتي للماء نحو اليسار، وتزيد كميّة جزيئات الماء غير المفكّكة. فيزداد $[OH^-]$، أمّا $[H^+]$ فينقص.

Review 39

List the information needed to calculate the K_a of a weak acid.

Review 39

List the information needed to calculate the K_a of a weak acid.

- **pH, pOH, or [H^+]**
- **the initial concentration of the acid**
- **Kb can also be used.**

Review 40

The pH of a tomato is approximately **4.50**. What are $[H^+]$ and $[OH^-]$ in a tomato?

Review 40

The pH of a tomato is approximately **4.50**. What are $[H^+]$ and $[OH^-]$ in a tomato?

$$[H^+] = \text{antilog}\ (-4.50) = 3.2 \times 10^{-5} M$$

$$pOH = 14.00 - 4.50 = 9.50$$

$$[OH^-] = \text{antilog}\ (-9.50) = 3.2 \times 10^{-10} M$$

Review 41

Determine the pH of a solution that contains **1.0×10^{-9} mol** of OH^- ions per liter.

Review 41

Determine the pH of a solution that contains **1.0×10^{-9} mol** of OH^- ions per liter.

$$[OH^-] = \frac{1.0 \times 10^{-9}\ \text{mol}}{1\ \text{L}} = 1.0 \times 10^{-9} M$$

$$pOH = -\log 1.0 \times 10^{-9} = 9.00$$

$$pH = 14.00 - pOH$$

$$pH = 14.00 - 9.00 = 5.00$$

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Review 42

Calculate the pH of the following solutions.

a. $1.0M$ HI

c. $1.0M$ KOH

b. $0.050M$ HNO_3

d. $2.4 \times 10^{-5}M$ $Mg(OH)_2$

Review 42

Calculate the pH of the following solutions.

a. $1.0M$ HI

$[H^+] = 1.0M$

$pH = -\log[H^+] = -\log 1.0$

$pH = 0.00$

b. $0.050M$ HNO_3

$[H^+] = 0.050M$

$pH = -\log[H^+] = -\log 0.050$

$pH = 1.30$

c. $1.0M$ KOH

$[OH^-] = 1.0M$

$pOH = -\log[OH^-] = -\log 1.0$

$pOH = 0.00$

$pH = 14.00 - 0.00 = 14.00$

d. $2.4 \times 10^{-5}M$ $Mg(OH)_2$

$[OH^-] = 2 \times [Mg(OH)_2] = (2)(2.4 \times 10^{-5}M) = 4.8 \times 10^{-5}M$

$pOH = -\log 4.8 \times 10^{-5} = 4.32$

$pH = 14.00 - 4.32 = 9.68$

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3.3 Hydrogen Ions and pH

مكتبة الفكر

Review 43

What happens to the $[H^+]$, $[OH^-]$, pH, and pOH as a neutral solution becomes more acidic? As a neutral solution become more basic?

Review 43

What happens to the $[H^+]$, $[OH^-]$, pH, and pOH as a neutral solution becomes more acidic? As a neutral solution become more basic?

As the solution becomes more acidic, $[H^+]$ increases from 10^{-7} to 1, $[OH^-]$ decreases from 10^{-7} to 10^{-14}, pH changes from 7 to 0 and pOH changes from 7 to 14. As a neutral solution becomes more basic, $[H^+]$ decreases from 10^{-7} to 10^{-14}, $[OH^-]$ increases from 10^{-7} to 1, pH changes from 7 to 14 and pOH changes from 7 to 0.

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3.3 Hydrogen Ions and pH

مكتبة الفكر

Mastering Concepts 75

What is the relationship between the pOH and the OH^- ion concentration of a solution?

a) $[OH^-] = -\log(pOH)$

b) $pOH = \log[OH^-]$

c) $[OH^-] = 10^{pOH}$

d) $pOH = -\log[OH^-]$

Mastering Concepts 75

What is the relationship between the pOH and the OH^- ion concentration of a solution?

a) $[OH^-] = -\log(pOH)$

b) $pOH = \log[OH^-]$

c) $[OH^-] = 10^{pOH}$

d) $pOH = -\log[OH^-]$

$$pOH = -\log[OH^-]$$

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Mastering Concepts 76

Solution (A) has a pH of **2.0**. Solution (B) has a pH of **5.0**. Which solution is more acidic? Based on the H^+ ion concentrations in the two solutions, how many times more acidic?

a) (A) is more acidic; 100 times.

b) (B) is more acidic; 100 times.

c) (A) is more acidic; 300 times.

d) (B) is more acidic; 300 times.

e) (A) is more acidic; 1000 times.

f) (B) is more acidic; 1000 times.

مكتبة الفكر

Mastering Concepts 76

Solution (A) has a pH of **2.0**. Solution (B) has a pH of **5.0**. Which solution is more acidic? Based on the H^+ ion concentrations in the two solutions, how many times more acidic?

a) (A) is more acidic; 100 times.

b) (B) is more acidic; 100 times.

c) (A) is more acidic; 300 times.

d) (B) is more acidic; 300 times.

e) (A) is more acidic; 1000 times.

f) (B) is more acidic; 1000 times.

Solution A is more acidic than solution B. It is 10^3, or 1000 times more acidic.

Mastering Concepts 77

If the concentration of H^+ ions in an aqueous solution decreases, what must happen to the concentration of OH^- ions? Why?

Mastering Concepts 77

If the concentration of H^+ ions in an aqueous solution decreases, what must happen to the concentration of OH^- ions? Why?

$[OH^-]$ increases. $[H^+][OH^-] = K_w$

Mastering Concepts 78

Use Le Châtelier's principle to explain what happens to the equilibrium H_2O (l) $\rightleftharpoons$ H^+ (aq) + OH^- (aq) when a few drops of HCl are added to pure water.

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Mastering Concepts 78

Use Le Châtelier's principle to explain what happens to the equilibrium H_2O (l) ⇌ H^+ (aq) + OH^- (aq) when a few drops of HCl are added to pure water.

The HCl adds H^+ ions to the water, which causes the equilibrium to shift the left.

Mastering Concepts 79

Use the data in table to answer the following questions.

a) Which substance is the most basic?
b) Which substance is closest to neutral?
c) Which has a concentration of $H^+ = 4.0 \times 10^{-10}$ M?
d) Which has a pOH of 11.0?
e) How many times more basic is antacid than blood?

pH values

Substance	pH
Household ammonia	11.3
Lemon juice	2.3
Antacid	9.4
Blood	7.4
Soft drinks	3.0

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مكتبة الفكر

Mastering Concepts 79

Use the data in table to answer the following questions.

a) Which substance is the most basic?
b) Which substance is closest to neutral?
c) Which has a concentration of $H^+ = 4.0 \times 10^{-10}$ M?
d) Which has a pOH of 11.0?
e) How many times more basic is antacid than blood?

a) household ammonia
b) blood
c) antacid
d) soft drinks
e) 100 times

pH values	
Substance	**pH**
Household ammonia	11.3
Lemon juice	2.3
Antacid	9.4
Blood	7.4
Soft drinks	3.0

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Mastering Problems 80

What is **$[OH^-]$** in an aqueous solution at **298 K** in which **$[H^+]$ = 5.40×10^{-3} M**?

Mastering Problems 80

What is **[OH⁻]** in an aqueous solution at **298 K** in which **[H⁺] = 5.40 × 10⁻³ M**?

$$K_w = [H^+][OH^-]$$

$$1.00 \times 10^{-14} = (5.40 \times 10^{-3})[OH^-]$$

$$[OH^-] = 1.85 \times 10^{-12} M$$

Mastering Problems 82

If 5.00 mL of 6.00M HCl is added to 95.00 mL of pure water, the final volume of the solution is 100.00 mL. What is the pH of the solution?

Mastering Problems 82

If 5.00 mL of 6.00M HCl is added to 95.00 mL of pure water, the final volume of the solution is 100.00 mL. What is the pH of the solution?

$$\text{mol HCl} = \text{mol H}^+ = 0.00500 \text{ L} \times 6.00 \text{ mol/L}$$
$$= 0.0300 \text{ mol}$$

$$[\text{H}^+] = \frac{0.0300 \text{ Mol H}^+}{0.100 \text{ L}} = 0.300M$$

$$\text{pH} = -\log [\text{H}^+] = -\log (0.300) = 0.523$$

$$\mathbf{M_1V_1 = M_2V_2}$$
$$\mathbf{(6)(0.005) = M_2(0.1)}$$
$$\mathbf{M_2 = 0.3\ \mathit{M}}$$

Mastering Problems 83

Given two solutions, 0.10M HCl and 0.10M HF, which solution has the greater concentration of H^+ ions? Calculate pH values for the two solutions, given that $[H^+] = 7.9 \times 10^{-3}$M in the 0.10M HF.

Mastering Problems 83

Given two solutions, 0.10M HCl and 0.10M HF, which solution has the greater concentration of H^+ ions? Calculate pH values for the two solutions, given that $[H^+] = 7.9 \times 10^{-3}M$ in the 0.10M HF.

For 0.10*M* HCl, a strong acid, $[H^+] = 0.10M$

$pH = -\log [H^+] = -\log 0.10 = 1.00$

For 0.10*M* HF, $[H^+] = 7.9 \times 10^{-3}M$

$pH = -\log [H^+] = -\log 7.9 \times 10^{-3} = 2.10.$

HCl has the greater concentration of hydrogen ions because it has the greater pH.

Mastering Problems 84

Chromic acid is used as an industrial cleaner for metals. What is K_a for the second ionization of chromic acid (H_2CrO_4) if a 0.040M solution of sodium hydrogen chromate has a pH of 3.946?

Mastering Problems 84

Chromic acid is used as an industrial cleaner for metals. What is K_a for the second ionization of chromic acid (H_2CrO_4) if a 0.040M solution of sodium hydrogen chromate has a pH of 3.946?

$$HCrO_4^-(aq) + H_2O(l) \rightarrow H^+(aq) + CrO_4^{2-}(aq)$$

$$[H^+] = \text{antilog}(-pH)$$

$$[H^+] = \text{antilog}(-3.946) = 1.13 \times 10^{-4} M$$

$$[H^+] = [CrO_4^{2-}] = 1.13 \times 10^{-4} M$$

$$K_a = \frac{[H^+][CrO_4^{2-}]}{[HCrO_4^-]} = \frac{(1.13 \times 10^{-4})^2}{(0.040 - 1.13 \times 10^{-4})}$$

$$= 3.2 \times 10^{-7}$$

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3.3 Hydrogen Ions and pH

مكتبة الفكر

Mixed Review 96

What is the pH of a 0.200M solution of hypobromous acid ($HBrO$)?
$K_a = 2.8 \times 10^{-9}$

Mixed Review 96

What is the pH of a 0.200M solution of hypobromous acid (HBrO)?
$K_a = 2.8 \times 10^{-9}$

$$K_a = \frac{[H^+][BrO^-]}{[HBrO]}$$

$$\frac{[H^+]^2}{0.200} = 2.8 \times 10^{-9}$$

$$[H^+]^2 = 2.8 \times 10^{-9} \times 0.200$$

$$[H^+] = 2.4 \times 10^{-5} M$$

$$pH = -\log(2.43\ 10^{-5}) = 4.63$$

Mixed Review 101

The pH probe shown is immersed in a 0.200M solution of a monoprotic acid, HA, at 303 K. What is the value of Ka for the acid at 303 K?

Mixed Review 101

The pH probe shown is immersed in a 0.200M solution of a monoprotic acid, HA, at 303 K. What is the value of Ka for the acid at 303 K?

$[H^+] = \text{antilog}\ (-pH) = \text{antilog}\ (-3.10)$
$= 7.9 \times 10^{-4} M$

$$K_a = \frac{(7.9 \times 10^{-4})(7.9 \times 10^{-4})}{(0.200 - 7.9 \times 10^{-4})} = 3.1 \times 10^{-6}$$

Challenge Problem 112

You have 20.0 mL of a solution of a weak acid, HX, whose K_a equals 2.14 × 10^{-6}. The pH of the solution is found to be 3.800. How much distilled water would you have to add to the solution to increase the pH to 4.000?

Challenge Problem 112

You have 20.0 mL of a solution of a weak acid, HX, whose K_a equals 2.14 × 10^{-6}. The pH of the solution is found to be 3.800. How much distilled water would you have to add to the solution to increase the pH to 4.000?

$[H^+]$ = antilog(−pH) = antilog (−3.800) = 1.58×10^{-4}

$$\frac{[H^+][X^-]}{[HX]} = \frac{(1.58 \times 10^{-4})^2}{M_{initial}} = 2.14 \times 10^{-6}$$

$$M_{initial} = \frac{(1.58 \times 10^{-4})^2}{(2.14 \times 10^{-6})} = 0.0117M$$

Diluted solution:

$[H^+]$ = antilog(−pH) = antilog (−4.000) = 1.00×10^{-4}

$$2.14 \times 10^{-6} \cong \frac{(1.00 \times 10^{-4})^2}{M_{final}}$$

$$M_{final} = \frac{(1.00 \times 10^{-4})^2}{2.14 \times 10^{-6}} = 0.00467M$$

Moles of HX in the initial and final solutions are equal.

$$(M_{initial})(V_{initial}) = (M_{finall})(V_{final})$$

$$(0.0117M \times 20.00\text{ mL}) = (0.00467M \times V_{final})$$

$$V_{final} = \frac{(0.0117\text{ mol/L})\,(20.00\text{ mL})}{0.00467\text{ mol/L}}$$

Add 30.1 mL of distilled water to the original 20.0 mL.

Multiple Choice 3

Hydrogen bromide (HBr) is a strong, highly corrosive acid. What is the pOH of a 0.0375M HBr solution?

a) 12.574

b) 12.270

c) 1.733

d) 1.433

Multiple Choice 3

Hydrogen bromide (HBr) is a strong, highly corrosive acid. What is the pOH of a 0.0375M HBr solution?

a) 12.574

b) 12.270

c) 1.733

d) 1.433

$$pH = -\log(0.0375) = 1.430$$

$$pOH = 14 - 1.43 = 12.574$$

مكتبة الفكر

Multiple Choice 4

Use the table below to answer question, which acid is the strongest?

a) formic acid

b) lutidinic acid

c) cyanoacetic acid

d) barbituric acid

Ionization Constants and pH Data for Several Weak Organic Acids

Acid	pH of 1.000 *M* Solution	K_a
Formic	1.87	1.78×10^{-4}
Cyanoacetic	?	3.55×10^{-3}
Propanoic	2.43	?
Lutidinic	1.09	7.08×10^{-3}
Barbituric	2.01	9.77×10^{-5}

Page 130

3.3 Hydrogen Ions and pH

مكتبة الفكر

Multiple Choice 4

Use the table below to answer question, which acid is the strongest?

a) formic acid

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c) cyanoacetic acid

d) barbituric acid

Ionization Constants and pH Data for Several Weak Organic Acids		
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Barbituric	2.01	9.77×10^{-5}

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3.3 Hydrogen Ions and pH

مكتبة الفكر

Multiple Choice 5

What is the hydronium ion concentration of the propanoic acid?

a) 1.4×10^{-5}

b) 3.72×10^{-3}

c) 2.43×10^{0}

d) 7.3×10^{4}

Ionization Constants and pH Data for Several Weak Organic Acids

Acid	pH of 1.000 *M* Solution	K_a
Formic	1.87	1.78×10^{-4}
Cyanoacetic	?	3.55×10^{-3}
Propanoic	2.43	?
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3.3 Hydrogen Ions and pH

مكتبة الفكر

Multiple Choice 5

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b) 3.72×10^{-3}

c) 2.43×10^{0}

d) 7.3×10^{4}

Ionization Constants and pH Data for Several Weak Organic Acids

Acid	pH of 1.000 *M* Solution	K_a
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Propanoic	2.43	?
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Barbituric	2.01	9.77×10^{-5}

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3.3 Hydrogen Ions and pH

مكتبة الفكر

Multiple Choice 6

What is the pH of a 0.40M solution of cyanoacetic acid?

a) 2.06

b) 1.22

c) 2.45

d) 1.42

Ionization Constants and pH Data for Several Weak Organic Acids

Acid	pH of 1.000 *M* Solution	K_a
Formic	1.87	1.78×10^{-4}
Cyanoacetic	?	3.55×10^{-3}
Propanoic	2.43	?
Lutidinic	1.09	7.08×10^{-3}
Barbituric	2.01	9.77×10^{-5}

Multiple Choice 6

What is the pH of a 0.40M solution of cyanoacetic acid?

a) 2.06

b) 1.22

c) 2.45

d) 1.42

$$3.55 \times 10^{-3} \times 0.40\ M = [H^+]^2$$

$$[H^+] = 0.038M$$

$$pH = -\log(0.038) = 1.42$$

Ionization Constants and pH Data for Several Weak Organic Acids

Acid	pH of 1.000 *M* Solution	K_a
Formic	1.87	1.78×10^{-4}
Cyanoacetic	?	3.55×10^{-3}
Propanoic	2.43	?
Lutidinic	1.09	7.08×10^{-3}
Barbituric	2.01	9.77×10^{-5}

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3.3 Hydrogen Ions and pH

مكتبة الفكر

Neutralization

Chapter 3
Lesson 4 – Revision Paper

InLibrary

مكتبة الفكر

مكتبة الفكر

Section Summary

- In a neutralization reaction, an acid reacts with a base to produce a salt and water.

- The net ionic equation for the neutralization of a strong acid by a strong base is $H^+ (aq) + OH^- (aq) \rightarrow H_2O (l)$.

- Titration is the process in which an acid-base neutralization reaction is used to determine the concentration of a solution.

Reading Check

01

Write the complete ionic equation and the net ionic equation for the neutralization of HNO_3 by KOH.

Page 114

3.4 Neutralization

مكتبة الفكر

Reading Check

Write the complete ionic equation and the net ionic equation for the neutralization of HNO3 by KOH.

$$HNO_{3(aq)} + KOH_{(aq)} \rightarrow KNO_{3(aq)} + H_2O_{(l)};$$

$$H^+{}_{(aq)} + NO_3^-{}_{(aq)} + K^+{}_{(aq)} + OH^-{}_{(aq)} \rightarrow$$

$$K^+{}_{(aq)} + NO_3^-{}_{(aq)} + H_2O_{(l)}$$

احذف الأيونات المشتركة

$$H^+{}_{(aq)} + OH^-{}_{(aq)} \rightarrow H_2O_{(l)}$$

مكتبة الفكر

Figure 22

Identify two ways in which the graphs are different.

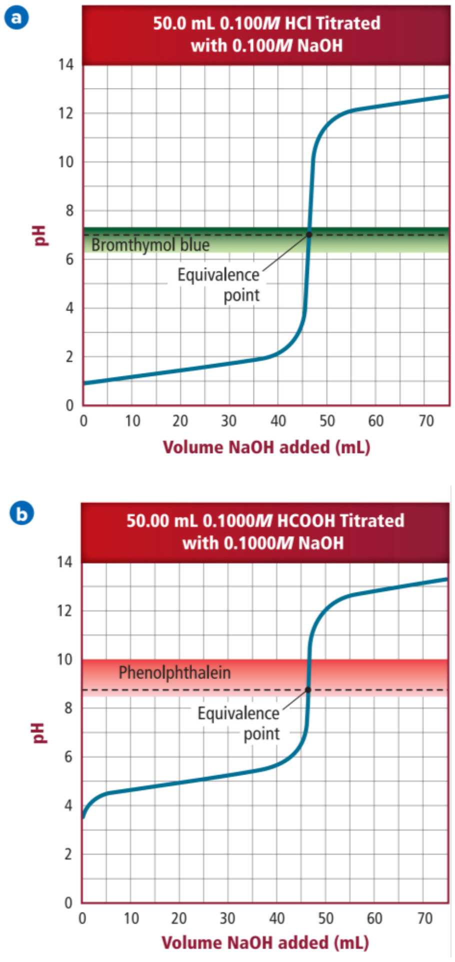
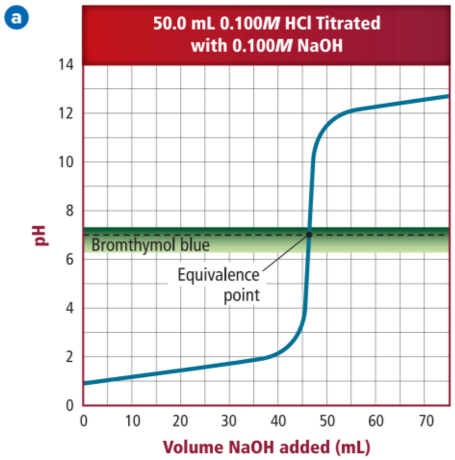


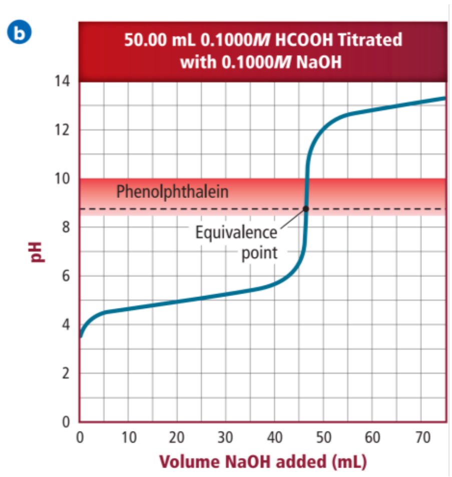
Figure 22

Identify two ways in which the graphs are different.

- **The equivalence point is different.**
- **The difference in pH levels is bigger in the strong acid titration.**

- نقطتا التكافؤ مختلفتان.
- الجزء العمودي لمنحنى الحمض القوي مع القاعدة القوية أطول من الجزء العمودي لمعايرة الحمض الضعيف.





Example 6

A volume of **18.28 mL** of a standard solution of **0.1000M NaOH** was required to neutralize **25.00 mL** of a solution of **methanoic acid** (HCOOH). What is the molarity of the methanoic acid solution?

Example 6

A volume of **18.28 mL** of a standard solution of **0.1000M NaOH** was required to neutralize **25.00 mL** of a solution of **methanoic acid** (HCOOH). What is the molarity of the methanoic acid solution?

$$HCOOH(aq) + NaOH(aq) \longrightarrow HCOONa(aq) + H_2O(l)$$

$$\frac{M_1V_1}{n_1} = \frac{M_2V_2}{n_2} \rightarrow \frac{(0.1)(18.28 \times 10^{-3})}{1} = \frac{(M_2)(25 \times 10^{-3})}{1}$$

$$M_2 = \frac{(0.1)(18.28 \times 10^{-3})}{(25 \times 10^{-3})} = \mathbf{7.312 \times 10^{-2}\ mol/L}$$

Applications 44

What is the molarity of a nitric acid solution if **43.33 mL** of **0.1000M KOH** solution is needed to neutralize **20.00 mL** of the acid solution?

Applications 44

What is the molarity of a nitric acid solution if **43.33 mL** of **0.1000M KOH** solution is needed to neutralize **20.00 mL** of the acid solution?

$$HNO_3 + KOH \longrightarrow KNO_3 + H_2O$$

$$\frac{M_{\mathrm{KOH}} V_{\mathrm{KOH}}}{n_{\mathrm{KOH}}} = \frac{M_{\mathrm{HNO_3}} V_{\mathrm{HNO_3}}}{n_{\mathrm{HNO_3}}} \rightarrow \frac{(0.1)(43.33 \times 10^{-3})}{1} = \frac{\left(M_{\mathrm{HNO_3}}\right)(20 \times 10^{-3})}{1}$$

$$M_{\mathrm{HNO_3}} = \frac{(0.1)(43.33 \times 10^{-3})}{(20 \times 10^{-3})} = \mathbf{0.2167\ mol/L}$$

Applications 45

What is the concentration of a household ammonia cleaning solution if **49.90 mL** of **0.5900M** HCl is required to neutralize **25.00 mL** of the solution?

Applications 45

What is the concentration of a household ammonia cleaning solution if **49.90 mL** of **0.5900M** HCl is required to neutralize **25.00 mL** of the solution?

$$HCl + NH_3 \longrightarrow NH_4^{+} + Cl^{-}$$

$$\frac{M_{HCl}V_{HCl}}{n_{HCl}} = \frac{M_{NH_3}V_{NH_3}}{n_{NH_3}} \rightarrow \frac{(0.59)(49.9\times10^{-3})}{1} = \frac{\left(M_{NH_3}\right)(25\times10^{-3})}{1}$$

$$M_{NH_3} = \frac{(0.59)(49.9\times10^{-3})}{(25\times10^{-3})} = \mathbf{1.178\ mol/L}$$

Applications 46

CHALLENGE How many milliliters of **0.500M** NaOH would neutralize **25.00 mL** of **0.100M** H_3PO_4?

Applications 46

CHALLENGE How many milliliters of **0.500M** NaOH would neutralize **25.00 mL** of **0.100M** H_3PO_4?

$$3NaOH + H_3PO_4 \rightarrow Na_3PO_4 + 3H_2O$$

$$\frac{M_{H_3PO_4} V_{H_3PO_4}}{n_{H_3PO_4}} = \frac{M_{NaOH} V_{NaOH}}{n_{NaOH}} \rightarrow \frac{(0.1)(25)}{1} = \frac{(0.5)(V_{NaOH})}{3}$$

$$V_{NaOH} = \frac{(0.1)(25)(3)}{(0.5)} = \mathbf{15\ mL}$$

Applications 47

Write equations for the salt hydrolysis reactions occurring when the following salts dissolve in water. Classify each as acidic, basic, or neutral.

a. ammonium nitrate

b. potassium sulfate

Applications 47

Write equations for the salt hydrolysis reactions occurring when the following salts dissolve in water. Classify each as acidic, basic, or neutral.

a. ammonium nitrate **NH_4NO_3**

$$NH_4^+(aq) + H_2O(l) \leftrightarrow NH_3(aq) + H_3O^+(aq)$$

The solution is acidic.

b. potassium sulfate **K_2SO_4**

$$SO_4^{2-}(aq) + H_2O(l) \leftrightarrow HSO_4^-(aq) + OH^-(aq)$$

The solution is neutral.

Applications 47

Write equations for the salt hydrolysis reactions occurring when the following salts dissolve in water. Classify each as acidic, basic, or neutral.

c. rubidium acetate

d. calcium carbonate

Applications 47

Write equations for the salt hydrolysis reactions occurring when the following salts dissolve in water. Classify each as acidic, basic, or neutral.

c. rubidium acetate **$C_2H_3O_2Rb$**

$CH_3COO^-(aq) + H_2O(l) \leftrightarrow CH_3COOH(aq) + OH^-(aq)$

The solution is basic.

d. calcium carbonate **$CaCO_3$**

$CO_3^{2-}(aq) + H_2O(l) \leftrightarrow HCO_3^-(aq) + OH^-(aq)$

The solution is basic.

Applications 48

CHALLENGE Write the equation for the reaction that occurs in a titration of **ammonium hydroxide** (NH_4OH) with **hydrogen bromide** (HBr). Will the pH at the equivalence point be greater or less than 7?

Applications 48

CHALLENGE Write the equation for the reaction that occurs in a titration of **ammonium hydroxide** (NH_4OH) with **hydrogen bromide** (HBr). Will the pH at the equivalence point be greater or less than 7?

$$NH_4OH(aq) + HBr(aq) \longrightarrow NH_4Br(aq) + H_2O(l)$$

$$NH_4^+(aq) + H_2O(aq) \leftrightarrow H_3O^+(aq) + NH_3$$

Hydronium ions are formed so the pH will be less than 7.

Review 49

Explain why the net ionic equation for the neutralization reaction of any strong acid with any strong base is always the same.

Review 49

Explain why the net ionic equation for the neutralization reaction of any strong acid with any strong base is always the same.

After the elimination of spectator ions from the neutralization equation, each neutralization reaction is the reaction of one mole of hydrogen ion with one mole of hydroxide to form one mole of water.

كل تفاعـل تعادل هو تفاعل 1 mol من أيون الهيدروجين مع mol1من الهيدروكسيد؛ لتكوين 1 molمن الماء.

Review 50

Which of the following is true?

a) The equivalence point is where the pH equals 7.

b) The end point is the point at which the solution have equal moles of H^+ and OH^- ions

c) The equivalence point is the point at which the indicator used in a titration changes color.

d) The end point is the point at which the indicator used in a titration changes color.

Review 50

Which of the following is true?

a) The equivalence point is where the pH equals 7.

b) The end point is the point at which the solution have equal moles of H^+ and OH^- ions

c) The equivalence point is the point at which the indicator used in a titration changes color.

d) The end point is the point at which the indicator used in a titration changes color.

Review 50

What is the difference between the equivalence point and the end point of a titration?

Review 50

What is the difference between the equivalence point and the end point of a titration?

- **Equivalence point is the pH at which the moles of H+ ions from the acid equal the moles of OH- ions from the base.**
- **The end point is the point at which the indicator used in a titration changes color.**

- **نقطة التكافؤ هي pH التي تتساوى عندها مولات أيونات H+ من الحمض، مع مولات أيونات OH- من القاعدة.**
- **نقطة النهاية هي النقطة التى يتغيّر عندها لون الكاشف المستعمل في المعايرة.**

Review 52

Calculate the molarity of a solution of **hydrobromic acid** (HBr) if **30.35 mL** of **0.1000M NaOH** is required to titrate **25.00 mL** of the acid to the equivalence point.

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3.4 Neutralization

Review 52

Calculate the molarity of a solution of **hydrobromic acid** (HBr) if **30.35 mL** of **0.1000M NaOH** is required to titrate **25.00 mL** of the acid to the equivalence point.

$$HBr(aq) + NaOH(aq) \longrightarrow NaBr(aq) + H_2O(l)$$

$$\frac{M_{\mathrm{NaOH}} V_{\mathrm{NaOH}}}{n_{\mathrm{NaOH}}} = \frac{M_{\mathrm{HBr}} V_{\mathrm{HBr}}}{n_{\mathrm{HBr}}} \rightarrow \frac{(0.1)(30.35)}{1} = \frac{(M_{\mathrm{HBr}})(25)}{1}$$

$$M_{\mathrm{HBr}} = \frac{(0.1)(30.35)}{(25)} = \mathbf{0.1214\ mol/L}$$

Mastering Concepts 85

What acid and base must react to produce an aqueous sodium iodide solution?

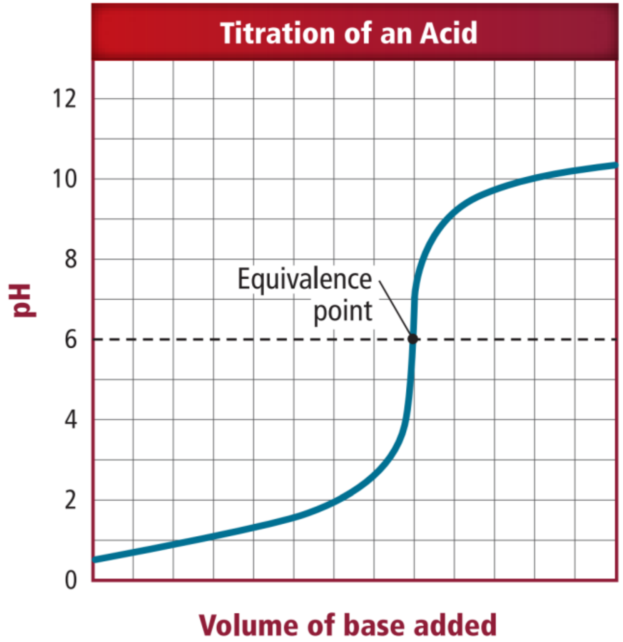
Mastering Concepts 85

What acid and base must react to produce an aqueous sodium iodide solution?

Hydroiodic acid (HI) and sodium hydroxide (NaOH) must react.

Mastering Concepts 86

What acid-base indicators would be suitable for the neutralization reaction whose titration curve is shown in the figure?



a) Bromphenol (3-5)

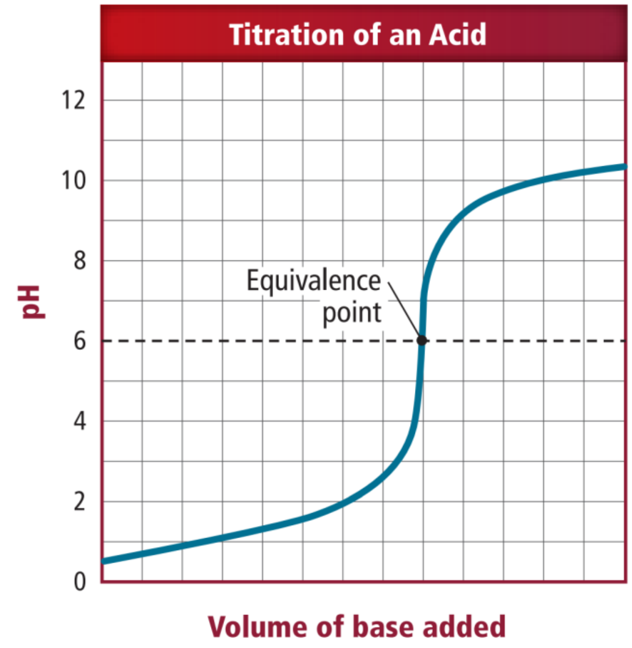
b) Methyl red (4-6)

c) Bromcresol purple (5-6.5)

d) Bromthymol blue (6-7.5)

Mastering Concepts 86

What acid-base indicators would be suitable for the neutralization reaction whose titration curve is shown in the figure?



a) Bromphenol (3-5)

b) Methyl red (4-6)

c) Bromcresol purple (5-6.5)

d) Bromthymol blue (6-7.5)

Bromcresol purple or alizarin would be suitable because they would change color near a pH 6.0 equivalence point.

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Mastering Concepts 87

When might a pH meter be better than an indicator to determine the end point of an acid-base titration?

Mastering Concepts 87

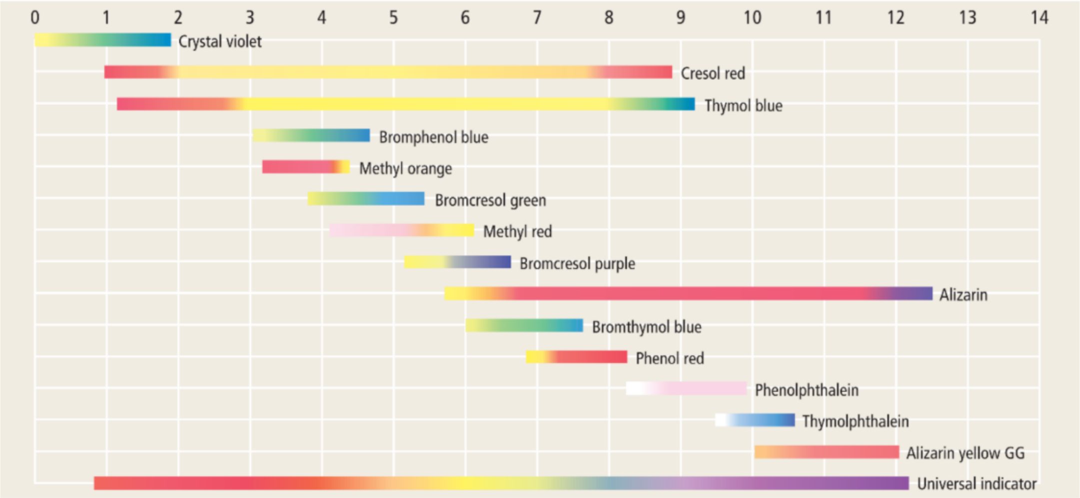
When might a pH meter be better than an indicator to determine the end point of an acid-base titration?

A pH meter could be used when there is no acid-base indicator that changes color at or near the equivalence point, or when such an indicator is not available

Mastering Concepts 89

When methyl red is added to an aqueous solution, a pink color results. When methyl orange is added to the same solution, a yellow color is produced. What is the approximate pH range of the solution?

Use the figure below

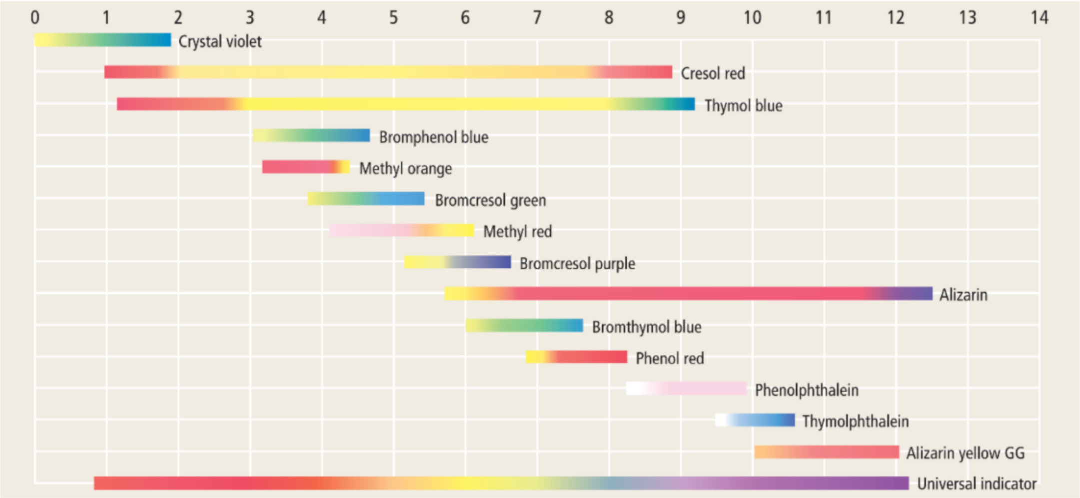


Mastering Concepts 89

When methyl red is added to an aqueous solution, a pink color results. When methyl orange is added to the same solution, a yellow color is produced. What is the approximate pH range of the solution?

Use the figure below

The pH is between approximately 4.2 and 5.6.



Mastering Concepts 90

Give the name and formula of the acid and the base from which each salt was formed.

a. NaCl

b. $KHCO_3$

Mastering Concepts 90

Give the name and formula of the acid and the base from which each salt was formed.

a. NaCl

base: sodium hydroxide (NaOH); acid: hydrochloric acid (HCl)

b. $KHCO_3$

base: potassium hydroxide (KOH); acid: carbonic acid (H_2CO_3)

Mastering Concepts 90

Give the name and formula of the acid and the base from which each salt was formed.

c. NH_4NO_2

d. CaS

Mastering Concepts 90

Give the name and formula of the acid and the base from which each salt was formed.

c. NH_4NO_2

base: ammonia (NH_3); acid nitrous acid (HNO_2)

d. CaS

base: calcium hydroxide ($Ca(OH)_2$); acid hydrosulfuric acid (H_2S)

Mastering Problems 91

Write formula equations and net ionic equations for the hydrolysis of each salt in water.

a. sodium carbonate

b. ammonium bromide

Mastering Problems 91

Write formula equations and net ionic equations for the hydrolysis of each salt in water.

a. sodium carbonate

$Na_2CO_3(s) + H_2O(l) \longrightarrow NaHCO_3(aq) +$
$NaOH(aq);$

$CO_3^{-2}(aq) + H_2O(l) \longrightarrow HCO_3^{-}(aq) + OH^{-}(aq)$

b. ammonium bromide

$NH_4Br(s) + H_2O(l) \longrightarrow HBr(aq) + NH_3(aq);$

$NH_4^{+}(aq) + H_2O(l) \longrightarrow NH_3(aq) + H_3O^{+}(aq)$

Mastering Problems 92

Lithium hydroxide is used to purify air by removing carbon dioxide. A **25.00-mL** sample of lithium hydroxide solution is titrated to an end point by **15.22 mL** of **0.3340M** hydrochloric acid solution. What is the molarity of the **LiOH** solution?

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3.4 Neutralization

Mastering Problems 92

Lithium hydroxide is used to purify air by removing carbon dioxide. A **25.00-mL** sample of lithium hydroxide solution is titrated to an end point by **15.22 mL** of **0.3340M** hydrochloric acid solution. What is the molarity of the **LiOH** solution?

$$HCl + LiOH \longrightarrow LiCl + H_2O$$

$$\frac{M_{\mathrm{HCl}}V_{\mathrm{HCl}}}{n_{\mathrm{HCl}}} = \frac{M_{\mathrm{LiOH}}V_{\mathrm{LiOH}}}{n_{\mathrm{LiOH}}} \rightarrow \frac{(0.334)(15.22)}{1} = \frac{(M_{\mathrm{LiOH}})(25)}{1}$$

$$M_{\mathrm{LiOH}} = \frac{(0.334)(15.22)}{(25)} = \mathbf{0.2033\ mol/L}$$

Mastering Problems 93

In an acid-base titration, **45.78 mL** of a sulfuric acid solution is titrated to the end point by **74.30 mL** of **0.4388M** sodium hydroxide solution. What is the molarity of the **H_2SO_4** solution?

Mastering Problems 93

In an acid-base titration, **45.78 mL** of a sulfuric acid solution is titrated to the end point by **74.30 mL** of **0.4388M** sodium hydroxide solution. What is the molarity of the **H_2SO_4** solution?

$$H_2SO_4 + NaOH \longrightarrow Na_2SO_4 + H_2O$$

$$\frac{M_{\mathrm{NaOH}}V_{\mathrm{NaOH}}}{n_{\mathrm{NaOH}}} = \frac{M_{\mathrm{H_2SO_4}}V_{\mathrm{H_2SO_4}}}{n_{\mathrm{H_2SO_4}}} \rightarrow \frac{(0.4388)(74.3)}{2} = \frac{\left(M_{\mathrm{H_2SO_4}}\right)(45.78)}{1}$$

$$M_{\mathrm{H_2SO_4}} = \frac{(0.4388)(74.3)}{(2)(45.78)} = \mathbf{0.3561\ mol/L}$$

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3.4 Neutralization

Mixed Review 95

How many milliliters of **0.225M HCl** would be required to titrate **6.00 g** of KOH? *(KOH molar mass = 56.1056)*

Mixed Review 95

How many milliliters of **0.225M HCl** would be required to titrate **6.00 g** of KOH? *(KOH molar mass = 56.1056)*

$$HC\,l + KOH \longrightarrow KCl + H_2O$$

$$M_{\mathrm{KOH}} = \frac{6\ \mathrm{g}}{56.1056\ \mathrm{g/mol}} = 0.107\ \mathrm{mol/L}$$

$$\frac{M_{\mathrm{HCl}}V_{\mathrm{HCl}}}{n_{\mathrm{HCl}}} = \frac{M_{\mathrm{KOH}}V_{\mathrm{KOH}}}{n_{\mathrm{KOH}}} \rightarrow \frac{(0.225)(V_{\mathrm{HCl}})}{1} = \frac{(0.107)(1\ \mathrm{mL})}{1}$$

$$V_{\mathrm{HCl}} = \frac{(0.107)}{(0.225)} = \mathbf{475\ mL}$$

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3.4 Neutralization

مكتبة الفكر

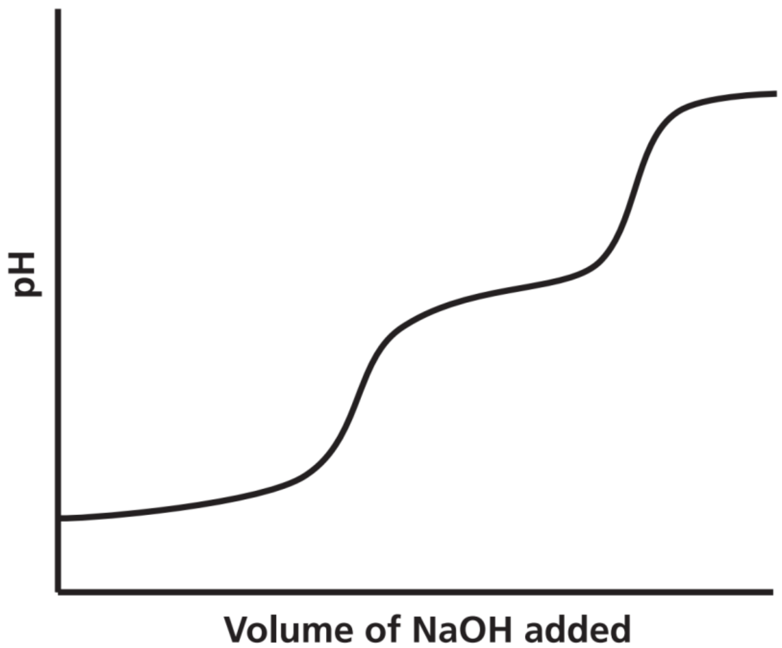
Think Critically 108

Sketch the shape of the approximate pH v. volume curve that would result from titrating a diprotic acid with a 0.10M NaOH solution.

مكتبة الفكر

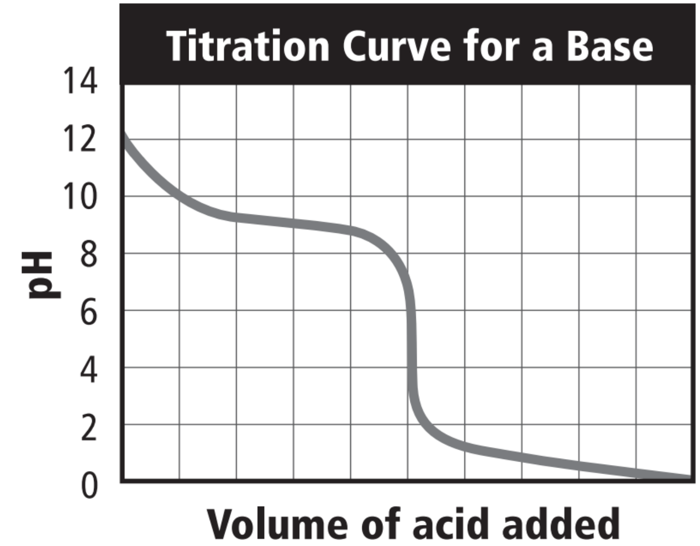
Think Critically 108

Sketch the shape of the approximate pH v. volume curve that would result from titrating a diprotic acid with a 0.10M NaOH solution.



Multiple Choice 1

What is the pH at the equivalence point of this titration?



a) 10

b) 9

c) 5

d) 1

Multiple Choice 1

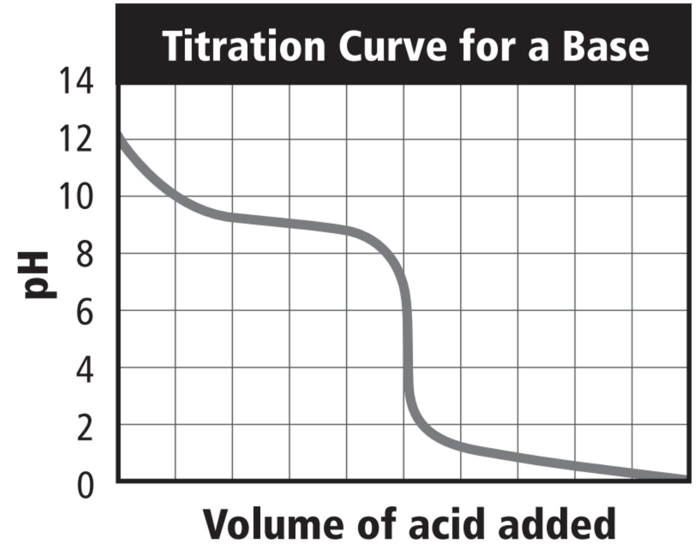
What is the pH at the equivalence point of this titration?

a) 10

b) 9

c) 5

d) 1



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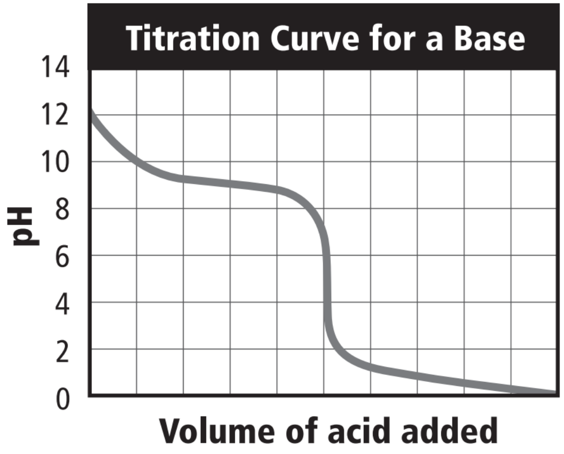
3.4 Neutralization

مكتبة الفكر

Multiple Choice 2

Which indicator would be effective for detecting the end point of this titration?



a) methyl orange, with a range of 3.2-4.4

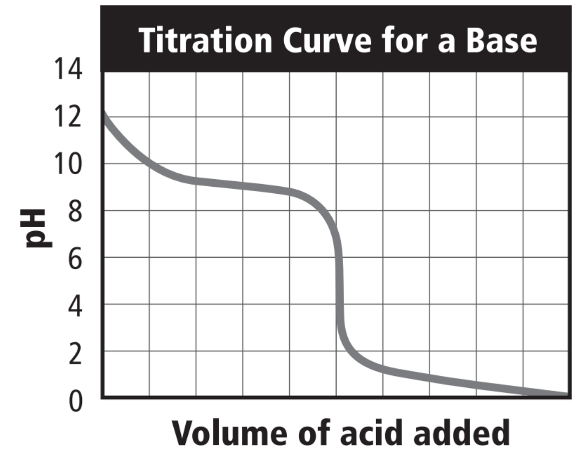
b) phenolphthalein, with a range of 8.2-10

c) bromocresol green, with a range of 3.8-5.4

d) thymol blue, with a range of 8.0-9.6

Multiple Choice 2

Which indicator would be effective for detecting the end point of this titration?



a) methyl orange, with a range of 3.2-4.4

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d) thymol blue, with a range of 8.0-9.6

Chapter 3 – Acids and Bases

Resources

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