CHEMISTRY

12 Advanced

Acids and Bases

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Ions

- **Ions Charges**
  - positive → cation
  - negative → anion
- **Types of ions**
  - monoatomic → one type of atoms
  - polyatomic → two or more types of atoms

Monoatomic ions

+1
- potassium K^+
- rubidium Rb^+
- sodium Na^+
- cesium Cs^+
- lithium Li^+
- silver Ag^+
- hydrogen H^+

+2
- strontium Sr^{2+}
- barium Ba^{2+}
- calcium Ca^{2+}
- zinc Zn^{2+}
- magnesium Mg^{2+}
- cadmium Cd^{2+}

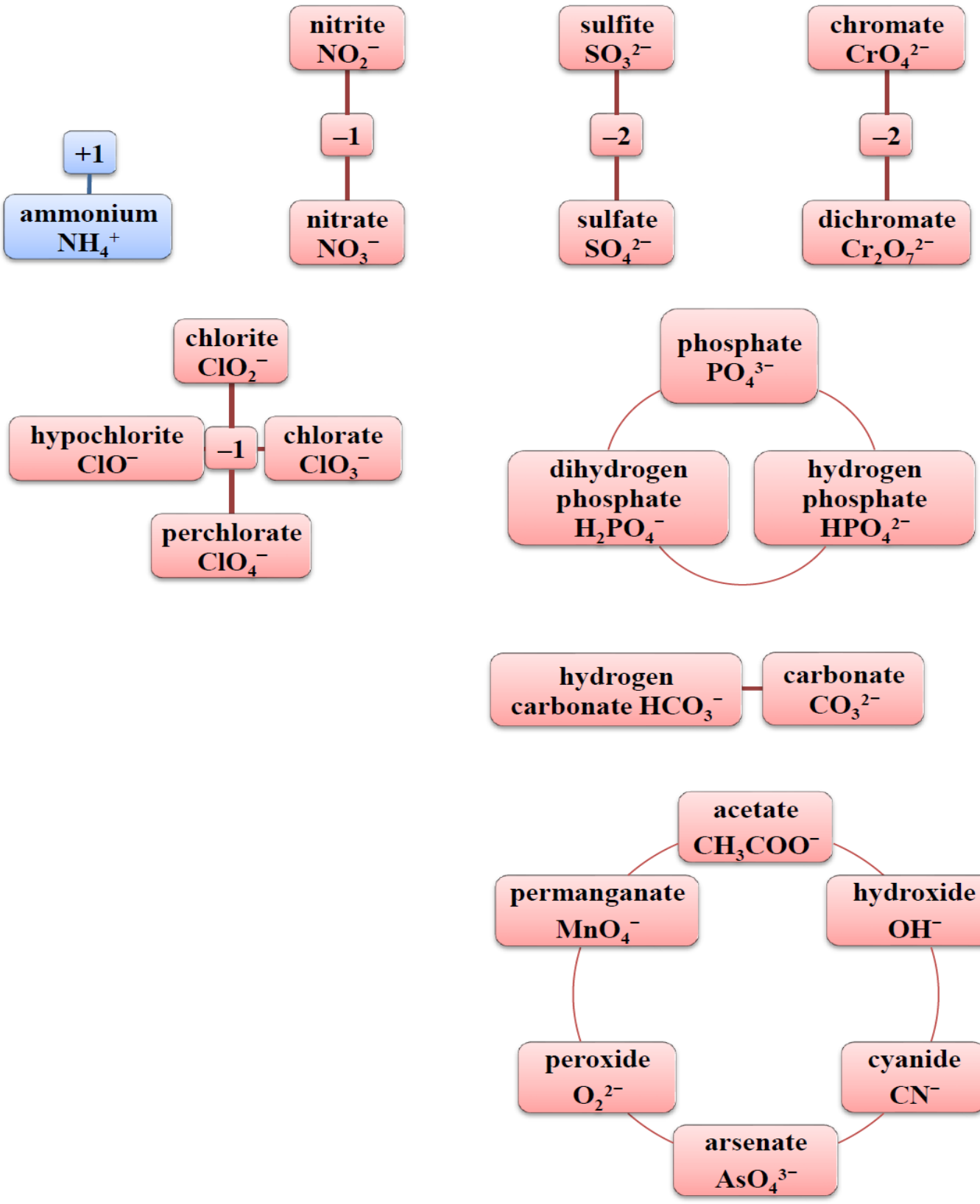
+3
- aluminum Al^{3+}

–1
- chloride Cl^-
- bromide Br^-
- fluoride F^-
- iodide I^-

–2
- oxide O^{2-}
- sulfide S^{2-}

–3
- nitride N^{3-}

Polyatomic ions



Sec. (1) Introduction to Acids and Bases

Acids properties

Methanoic (formic) acid	Ants release it when they sense a threat.
Acid rain	Caves formation in limestone rocks and damage to archaeological sites
Carbonic and phosphoric acids	Added to soft drinks to give it a sour taste
Citric and ascorbic acids	Responsible for the acidic taste in lemon and grapefruit
Acetic acid	Makes vinegar taste acidic
Stomach acid (muriatic) HCl	Digestion of food and industrially used to clean bricks and concrete

- Its solutions have a pungent taste
- Turns litmus paper into red
- Its solutions conduct electricity

Bases properties

Bases	Makes of soaps, household detergents, and antacid tablets
Sodium hydroxide	Opening clogged sewer pipes

- Its solutions have a bitter taste and a slippery feel
- Turns litmus paper into blue
- Its solutions conduct electricity

Why is pure water non-conductive, but acidic and basic aqueous solutions are conductive? → **Because adding an acid or a base produces positive and negative ions that make the product conduct electricity.**

Some plants grow in rich, moist soils such as rosacea.

Some plants grow in less moist and basal soils such as the perennial plant and is known as hens and chicks.

Acids reactions

What results from the reaction of active metals with acid solutions? → **hydrogen gas $H_{2(g)}$**

Inactive metals

- copper Cu
- mercury Hg
- silver Ag
- platinum Pt
- gold Au

active metal + acid → salt + $H_{2(g)}$

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

What results from the reaction of metal carbonates or hydrogen metal carbonates with acid solutions? → **carbon dioxide gas $CO_{2(g)}$**

carbonate (CO_3) + acid → salt + H_2O + $CO_{2(g)}$

When vinegar is added to baking soda, a reaction occurs between the ethanoic acid (acetic) dissolved in the vinegar and $NaHCO_3$ and produces CO_2 gas, which causes bubbles and produce also water, and salt.

$$NaHCO_{3(s)} + HC_2H_3O_{2(aq)} \rightarrow NaC_2H_3O_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

Geologists use a solution of hydrochloric acid to identify limestone (consisting of $CaCO_3$). If a few drops of acid lead to the production of CO_2 gas bubbles, this indicates that the rock contains lime.

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(s)} + H_2O_{(l)} + CO_{2(g)}$$

1) **What gas is produced by the reaction between aluminum and sulfuric acid?**

a. H_2 b. O_2 c. N_2 d. CO_2

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

a. the gas is CO_2 and the rock is magnesium sulfate

b. the gas is H_2 and the rock is magnesium sulfate

c. the gas is CO_2 and the rock is calcium carbonate

d. the gas is H_2 and the rock is calcium carbonate

3) **What is the balanced chemical equation for the reaction of magnesium metal and hydrobromic acid?**

a. $Mg_{(s)} + 2HBr_{(aq)} \rightarrow MgH_{2(aq)} + Br_{2(l)}$

b. $Mg_{(s)} + 2HBr_{(aq)} \rightarrow MgBr_{2(aq)} + 2H^+_{(aq)}$

c. $Mg_{(s)} + 2HBr_{(aq)} \rightarrow MgBr_{2(aq)} + H_{2(g)}$

d. $Mg_{(s)} + 2HBr_{(aq)} \rightarrow MgH_{2(aq)} + 2Br^-_{(aq)}$

Hydronium ions and hydroxide ions

What results from the self-ionization of pure water? → **Equal numbers of H^+ and OH^- ions are produced.**

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

What is produced when water molecules interact together? → **It produces the hydronium ion H_3O^+ and the hydroxide ion OH^-**

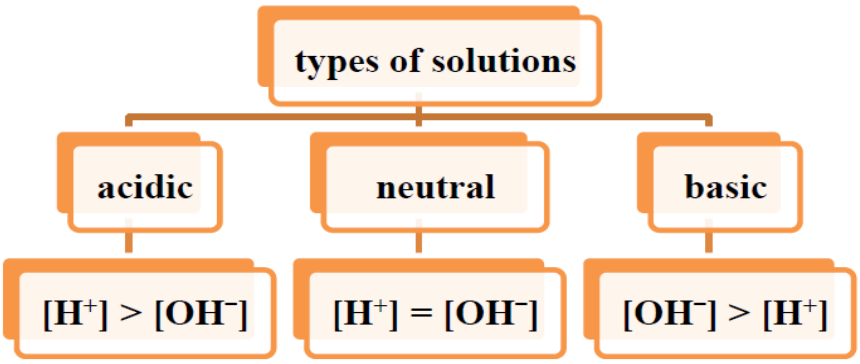
$$H_2O_{(l)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)}$$

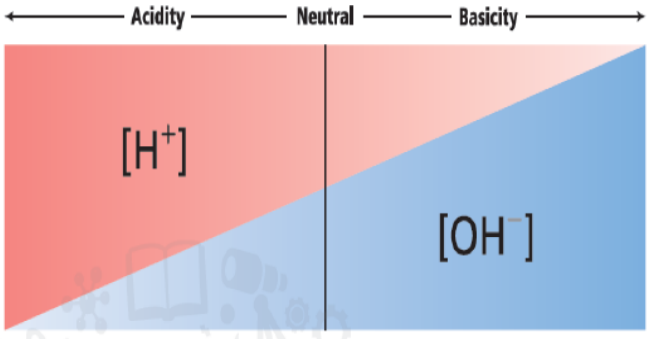
How is the hydronium ion produced? → **If a hydrogen ion bonded to a water molecule with a covalent bond.**

$$H^+_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)}$$

The symbols H^+ and H_3O^+ can be used interchangeably, i.e. placing one in the place of the other.

Aqueous solutions contain H^+ hydrogen ions and OH^- hydroxide ions.





4) **What is the balanced equation that describes the self-ionization of water?**

a. $H_2O_{(l)} + OH^-_{(aq)} \rightleftarrows H_3O^+_{(aq)} + H_2O_{(l)}$

b. $H_2O_{(l)} + H_3O^+_{(aq)} \rightleftarrows H_2O_{(l)} + OH^-_{(aq)}$

c. $H_3O^+_{(aq)} + OH^-_{(aq)} \rightleftarrows H_2O_{(l)} + H_2O_{(l)}$

d. $H_2O_{(l)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)}$

5) **Why are H^+ and H_3O^+ used interchangeably in chemical equations?**

a. **because H_3O^+ is an H^+ ion bonded to a water molecule**

b. **because H_3O^+ is an H^+ ion bonded to KOH**

c. **because H_3O^+ is an OH^- ion bonded to a water molecule**

d. **because H_3O^+ is an OH^- ion bonded to KOH**

6) **What is the relationship between the concentrations of hydrogen ions and hydroxide ions in an acidic solution?**

a. **the concentration of OH^- ions is greater than the concentration of H^+ ions**

b. **the concentration of OH^- ions is equal to the concentration of H^+ ions**

c. **the concentration of H^+ ions is greater than that of OH^- ions**

d. **there is no relationship between the concentrations of H^+ ions and OH^- ions**

Arrhenius model

Arrhenius acid: a substance containing hydrogen that ionizes in aqueous solutions to produce the hydrogen ion H^+

When hydrogen chloride (HCl) gas is dissolved in water, it ionizes to produce H^+ ions, which make the solution acidic: $HCl_{(g)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

Arrhenius base: A substance containing a hydroxide group that dissociates to produce the hydroxide ion, OH^-

When sodium hydroxide is dissolved, NaOH, in water, it dissociates to produce OH^- ions, which make the solution basic: $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

7) Which of the following substances represents Arrhenius acid in aqueous solutions?

a. $Mg(OH)_2$ b. KOH

c. H_2S d. RbOH

8) Which of the following substances represents Arrhenius base in aqueous solutions?

a. HI b. H_2CO_3

c. H_3PO_4 d. LiOH

9) What is the balanced chemical equation for the dissociation of solid magnesium hydroxide in water?

a. $Mg(OH)_{2(s)} \rightarrow Mg^{2+}_{(aq)} + 2OH^-_{(aq)}$

b. $Mg(OH)_{2(s)} \rightarrow Mg^{2-}_{(s)} + 2OH^+_{(s)}$

c. $Mg(OH)_{2(s)} \rightarrow Mg_{(s)} + H_2O_{(l)}$

d. $Mg(OH)_{2(s)} \rightarrow Mg_{(s)} + H_2O_{2(l)}$

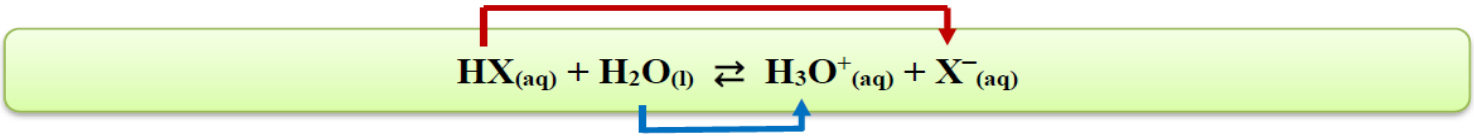
What are the shortcomings of Arrhenius model?

Ammonia NH_3 and Na_2CO_3 sodium carbonate do not contain a hydroxide group but both produce hydroxide ions when dissolved in water, and they are both well-known bases.

Brønsted-Lowry model

Brønsted-Lowry acid: a hydrogen ion donor. — H^+ decrease

Brønsted-Lowry base: a hydrogen ion acceptor. — H^+ increase



Brønsted-Lowry

10) Which of the following statements is true for the reaction?

$$HCl_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + Cl^-_{(aq)}$$

a. HCl is Brønsted-Lowry acid

b. HCl is the Brønsted-Lowry base

c. H_2O is a proton donor

d. HCl is a proton acceptor

11) What equation is H_2O as a hydrogen ion donor?

a. $HI_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + I^-_{(aq)}$

b. $HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

c. $HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + PO_4^{3-}{}_{(aq)}$

d. $C_6H_5NH_{2(aq)} + H_2O_{(l)} \rightleftarrows C_6H_5NH_3^+{}_{(aq)} + OH^-_{(aq)}$

12) Which of the following statements describes the following equation?

$$NH_{3(aq)} + H_2O_{(l)} \rightleftarrows NH_4^+{}_{(aq)} + OH^-_{(aq)}$$

a. H_2O is the Brønsted-Lowry base

b. NH_3 represents Arrhenius acid

c. NH_3 is a proton acceptor

d. NH_3 represents Brønsted-Lowry acid

Conjugate acid: the chemical compound produced when the base receives a hydrogen ion from an acid.

Conjugate base: The chemical compound that is produced when an acid gives off a hydrogen ion.

Conjugate pair: two substances linked together by donating and receiving one hydrogen ion.

$$HX_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + X^-_{(aq)}$$

acid base conjugate acid conjugate base

Conjugate pairs :(HX, X^-), (H_2O, H_3O^+)

13) What are the conjugate pairs in the reaction? $HF_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + F^-_{(aq)}$

a. (HF, H_2O), (F^-, H_3O^+)

b. (HF, F^-), (H_2O, H_3O^+)

c. (H_3O^+, F^-), (H_2O, HF)

d. (H_2O, F^-), (HF, H_3O^+)

14) What are the conjugate pairs in the reaction? $NH_{3(aq)} + H_2O_{(l)} \rightleftarrows NH_4^+{}_{(aq)} + OH^-_{(aq)}$

a. (NH_4^+, H_2O), (OH^-, NH_3)

b. (OH^-, NH_4^+), (H_2O, NH_3)

c. (NH_3, NH_4^+), (H_2O, OH^-)

d. (H_2O, NH_4^+), (NH_3, OH^-)

15) What are the conjugate pairs in the reaction?

$$CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftarrows HCO_3^-{}_{(aq)} + OH^-_{(aq)}$$

a. (OH^-, H_2O), (CO_3^{2-}, HCO_3^-) b. (OH^-, CO_3^{2-}), (HCO_3^-, H_2O)

c. (HCO_3^-, H_2O), (CO_3^{2-}, OH^-) d. (CO_3^{2-}, H_2O), (OH^-, HCO_3^-)

The difference in the conjugate pair between the acid and the base is H^+

To get the conjugate acid, we add H^+

To get the conjugate base, we subtract H^+

16) Complete the following table by writing the conjugate acid or conjugate base.

acid	base
HNO_3	
	F^-
HSO_4^-	
	$H_2PO_4^-$
HCN	
	NH_3
$HC_2H_3O_2$	

17) Which of the following pairs is considered a conjugate pair according to the Brønsted-Lowry model?

a. HCl/ H_3O^+

b. $Na_2O/ NaOH$

c. NH_4^+/ NH_3

d. H_3O^+/ NH_3

18) If the products of an acid-base reaction are SO_4^{2-} and H_3O^+, what is the balanced equation for the reaction?

a. $SO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftarrows HSO_4^-{}_{(aq)} + H_3O^+{}_{(aq)}$

b. $H_2SO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows HSO_4^-{}_{(aq)} + H_3O^+{}_{(aq)}$

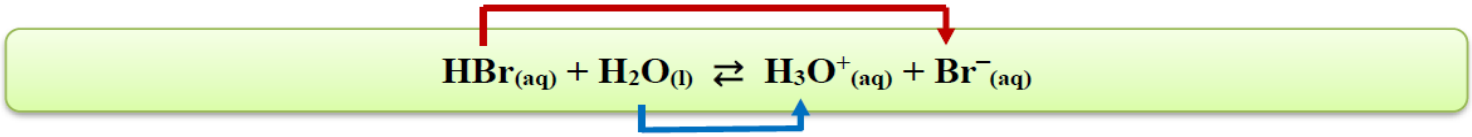
c. $H_2SO_{4(aq)} + H_2O_{(l)} \rightleftarrows SO_4^{2-}{}_{(aq)} + H_3O^+{}_{(aq)}$

d. $HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows SO_4^{2-}{}_{(aq)} + H_3O^+{}_{(aq)}$

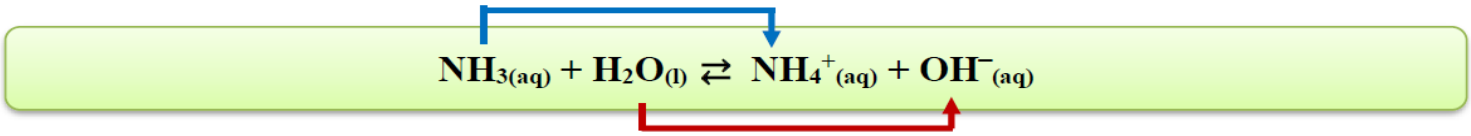
All acids and bases that agree with the Arrhenius definition also agree with the Brønsted-Lowry definition.

However, some substances do not have a hydroxide group, which does not conform to the Arrhenius definition, but it is classified as a base according to the Brønsted-Lowry model.

Amphoteric substance: a substance that can behave like an acid and a base.



acid base
Brønsted-Lowry



base acid
Brønsted-Lowry

Examples: H_2O, NH_3, HS^-, OH^-, HCO_3^-, HSO_4^-, HPO_4^{2-}

Strong acids, weak acids, and strong bases are not amphoteric.

19) Which of the following is an amphoteric substance?

a. SO_3^{2-} b. HSO_3^-

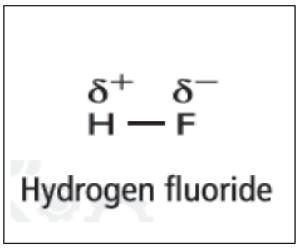
c. H_2SO_3 d. H_2SO_4

20) Which of the following is **not** amphoteric?

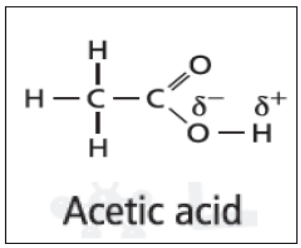
a. H_2O b. OH^-

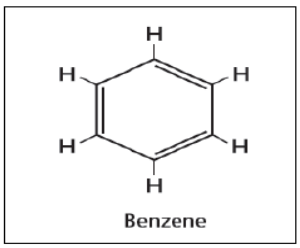
c. $H_2PO_4^-$ d. H_3O^+

What does ionization process mean?	The formation of the ions, and it depends on the polarity of the bond.
When does a hydrogen atom ionize in aqueous solution?	If it associated with a high electronegativity atom.
What atoms have more electronegativity than hydrogen?	Halogens (F,Cl,Br,I) and oxygen.
What results from the ionization of hydrogen in aqueous solution?	Hydronium ion H_3O^+ and negative ion.
What is the resulting solution of hydrogen ionization in aqueous solution?	acidic solution.



Hydrogen fluoride


Acetic acid


Benzene

hydrogen bonds with a highly electronegative atom	hydrogen bonds with a highly electronegative atom	hydrogen does not bond with a highly electronegative atom
hydrogen is ionizable	hydrogen is ionizable	hydrogen is not ionizable
represents acid	represents acid	does not represent acid

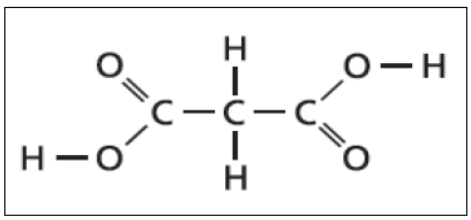
21) In the given structural formula, how many hydrogen atoms are likely to be ionized?

a. 1

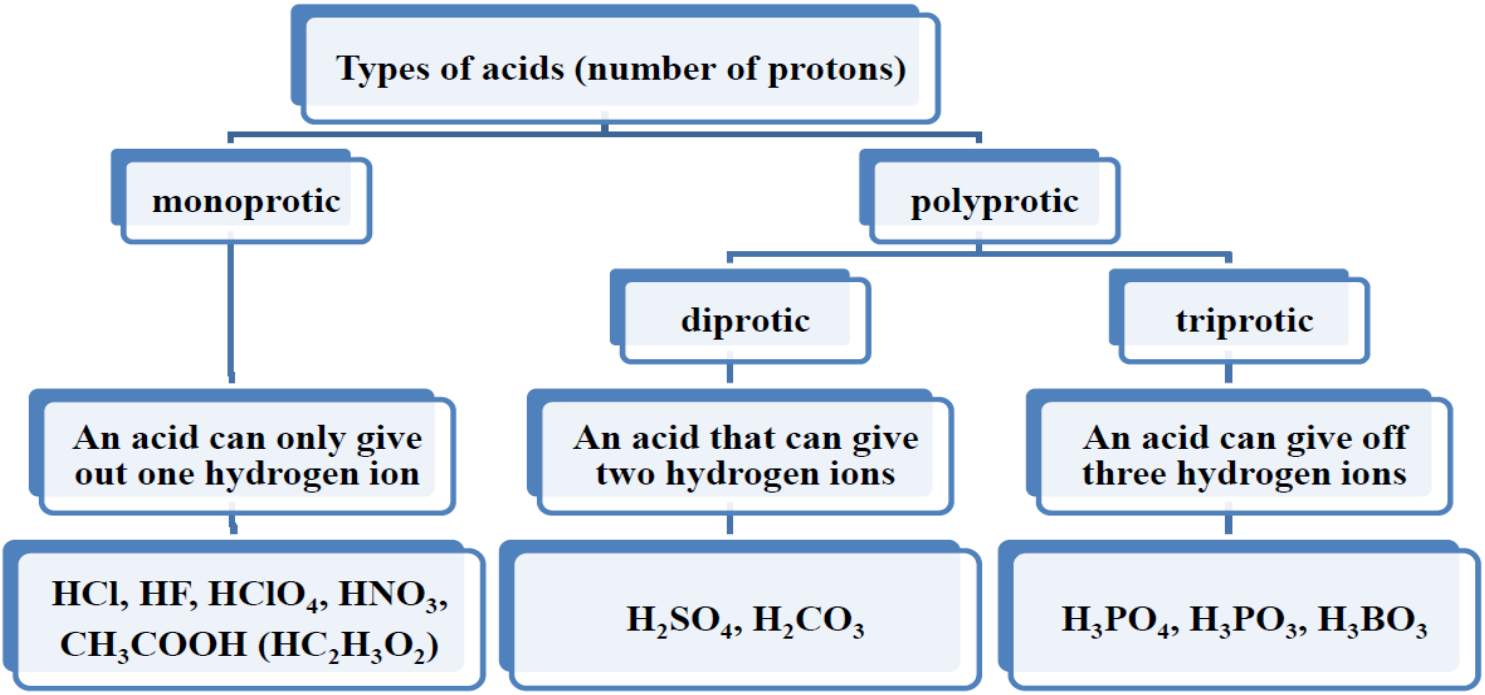
b. 2

c. 3

d. 4



Hydrogen fluoride is used to make various fluorine-containing compounds, by reacting with hydrocarbons to produce the non-stick coating in kitchen utensils.



acid type	monoprotic	diprotic	triprotic
number of hydrogen atoms that can be ionized	1	2	3
number of ionization phases	1	2	3
number of H_3O^+ ions produced by ionization	1	2	3
acid strength	strong or weak	strong or weak	weak

When a strong monoprotic acid ionizes, it produces H_3O^+ and the acid's negative ion

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

When a weak monoprotic acid is ionizes, it produces H_3O^+, the negative ion of the acid, and molecules of the weak acid

$$HF_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + F^-_{(aq)}$$

When a strong diprotic acid ionizes, it produces H_3O^+ and the acid's negative ion

$$H_2SO_{4(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + HSO_4^-{}_{(aq)}$$
$$HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

When a weak diprotic acid is ionizes, it produces H_3O^+, the negative ion of the acid, and molecules of the weak acid

$$H_2CO_{3(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + HCO_3^-{}_{(aq)}$$
$$HCO_3^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + CO_3^{2-}{}_{(aq)}$$

When a weak triprotic acid is ionizes, it produces H_3O^+, the negative ion of the acid, and molecules of the weak acid

$$H_3PO_{4(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + H_2PO_4^-{}_{(aq)}$$
$$H_2PO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + HPO_4^{2-}{}_{(aq)}$$
$$HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + PO_4^{3-}{}_{(aq)}$$

22) Which of the following acids is a triprotic acid?

a. CH_3COOH b. $Al(OH)_3$ c. H_3BO_3 d. HNO_3

23) What is the balanced chemical equation for the ionization of CH_3CH_2COOH propanoic acid in the water?

a. $CH_3CH_2COOH_{(aq)} + H_2O_{(l)} \rightleftarrows CH_3CH_2COOH_{2\,(aq)} + OH^-{}_{(aq)}$

b. $CH_3CH_2COOH_{(aq)} + H_2O_{(l)} \rightleftarrows CH_3CHCOOH_{(aq)} + H_3O^+_{(aq)}$

c. $CH_3CH_2COOH_{(aq)} + H_2O_{(l)} \rightleftarrows CH_2CH_2COOH_{(aq)} + H_3O^+_{(aq)}$

d. $CH_3CH_2COOH_{(aq)} + H_2O_{(l)} \rightleftarrows CH_3CH_2COO^-{}_{(aq)} + H_3O^+_{(aq)}$

24) What is the balanced chemical equation for the second ionization of H_2SO_4 in water?

a. $HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows H_2SO_{4(aq)} + H_3O^+_{(aq)}$

b. $HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows SO_4^{2-}{}_{(aq)} + 2OH^-{}_{(aq)}$

c. $HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows H_2SO_{4(aq)} + OH^-{}_{(aq)}$

d. $HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows SO_4^{2-}{}_{(aq)} + H_3O^+_{(aq)}$

Lewis model

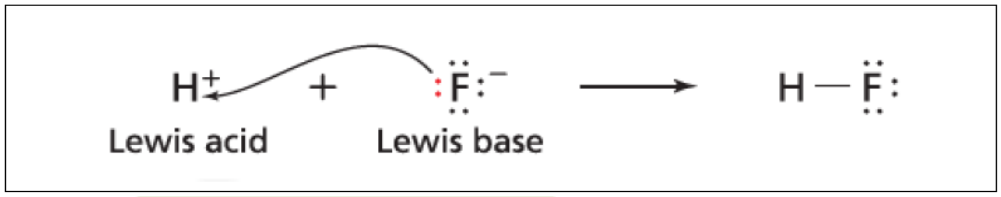
Lewis acid: a substance that accepts a pair of electrons.

A Lewis acid has an empty atomic orbital that can accept (share) a pair of electrons.

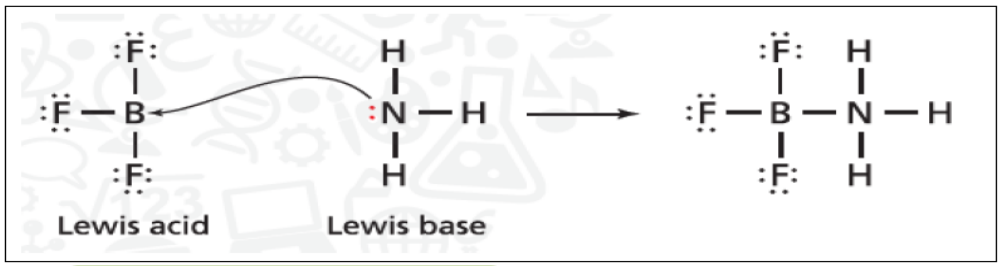
Lewis base: a substance that donates a pair of electrons.

Lewis base has an unshared pair of electrons that it can donate (share).

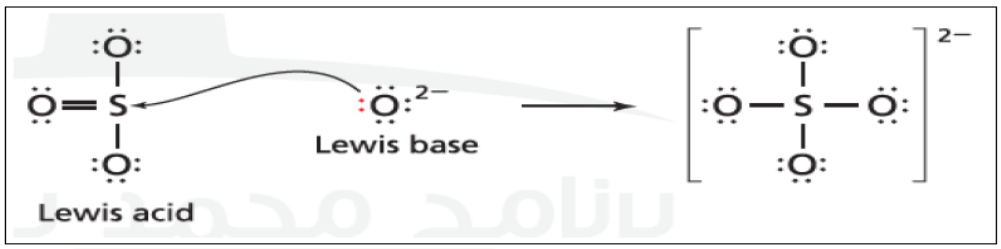
The Lewis model includes all substances classified as acids and bases according to the Brønsted-Lowry model and others.



acceptor donor
electron-pair



acceptor donor
electron-pair



acceptor donor
electron-pair

Lewis acid	Lewis base
electron-pair acceptor (has an empty orbit)	electron-pair donor
positive ion	negative ion
Al, B, S compounds	N, P compounds

25) Which of the following is a Lewis acid?

a. Cl^- b. NH_3 c. $AlCl_3$ d. F^-

26) Which of the following is a Lewis base?

a. NH_3 b. $AlCl_3$ c. BF_3 d. BCl_3

27) Identify acid and Lewis base in the reaction? $H^+ + OH^- \rightleftarrows H_2O$

a. acid: H^+, base: OH^- b. acid: OH^-, base: H^+

c. acid: H^+, base: H_2O d. acid: H^+, base: H_2O

28) Identify acid and Lewis base in the reaction? $Cl^- + BCl_3 \rightleftarrows BCl_4^-$

a. acid: Cl^-, base: BCl_3 b. acid: BCl_3, base: BCl_4^-

c. acid: BCl_4^-, base: Cl^- d. acid: BCl_3, base: Cl^-

29) Identify acid and Lewis base in the reaction? $SO_3 + H_2O \rightleftarrows H_2SO_4$

a. acid: SO_3, base: H_2SO_4 b. acid: SO_3, base: H_2O

c. acid: H_2O, base: SO_3 d. acid: H_2SO_4, base: H_2O

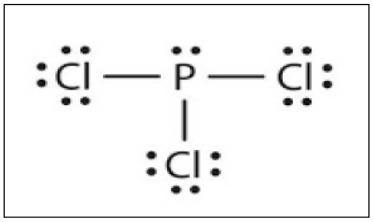
30) Depending on the presence of an unshared pair of electrons on the phosphorous atom in the Lewis structure of PCl_3. What is PCl_3 classified as?

a. Lewis acid

b. Lewis base

c. Arrhenius acid

d. Arrhenius base



The model	Acid	Base
Arrhenius	H^+ producer	OH^- producer
Brønsted-Lowry	H^+ donor	H^+ acceptor
Lewis	electron-pair acceptor	electron-pair donor

life applications

- The reaction of SO_3 with MgO is important because it produces the magnesium sulfate salt $MgSO_4.7H_2O$ known as Epsom salt which is used to relieve muscle pain and act as a plant nutrient.
- MgO is injected into the flue gases of coal-fired power plants, MgO reacts with SO_3 and removes it from the waste gases out into the atmosphere.
- When SO_3 is allowed into the atmosphere, it can combine with water in the atmosphere to form sulfuric acid, which falls to the ground as acid rain.

Connection to Earth Science

- Acidic solutions are produced when nonmetallic oxides are dissolved in water.

$$CO_2 + H_2O \rightarrow H_2CO_3$$

nonmetal oxide + H_2O → acidic solution

- Basic solutions are produced when metallic oxides are dissolved in water.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

metal oxide + H_2O → basic solution

31) Which of the following are properties of acids?

a. feels slippery

b. it tastes bitter

c. turn red litmus paper blue

d. reacts with zinc to produce hydrogen gas

32) Which of the following is correct?

a. in acidic solution $[H^+] > [OH^-]$

b. in acidic solution $[H^+] < [OH^-]$

c. in neutral solution $[H^+] > [OH^-]$

d. in basic solution $[H^+] > [OH^-]$

33) In the reaction equation below, which of the following is true?

$$HX_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + X^-_{(aq)}$$

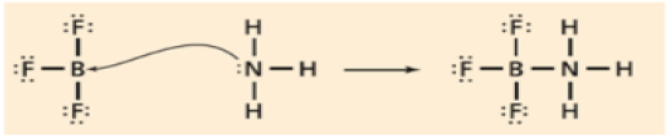
a. HX accepts a hydrogen ion from water H_2O

b. HX donates a hydrogen ion to water H_2O

c. HX is a Brønsted-Lowry base

d. H_2O is a Brønsted-Lowry acid

34) Which of the following is correct?

1	2
	$NH_3(aq) + H_2O(l) \leftrightharpoons NH_4^+(aq) + OH^-(aq)$

a. the ammonia NH_3 in reaction 2 is a Brønsted-Lowry acid

b. the ammonia NH_3 in reaction 2 is an electron pair acceptor

c. the ammonia NH_3 in reaction 1 is a Lewis base

d. the ammonia NH_3 in reaction 1 is a Lewis acid

35) What substance contains hydrogen and ionizes to produce hydrogen ions in aqueous solution?

a. Arrhenius acid

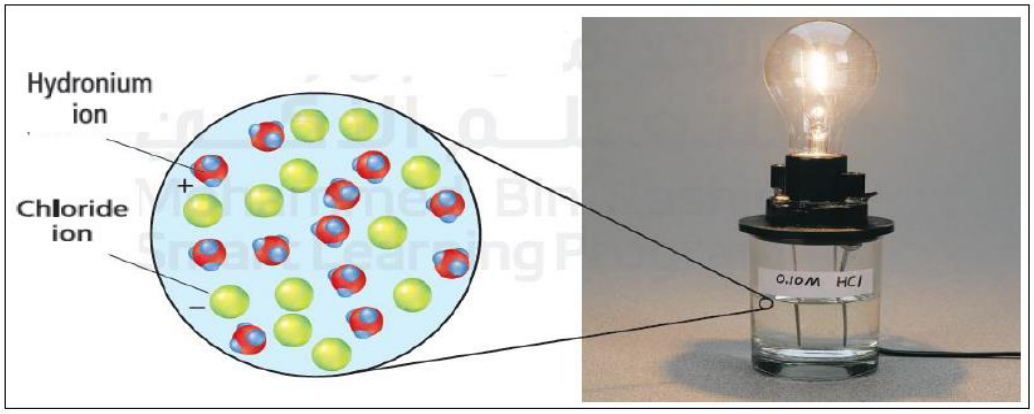
b. Lewis base

c. Arrhenius base

d. Lewis acid

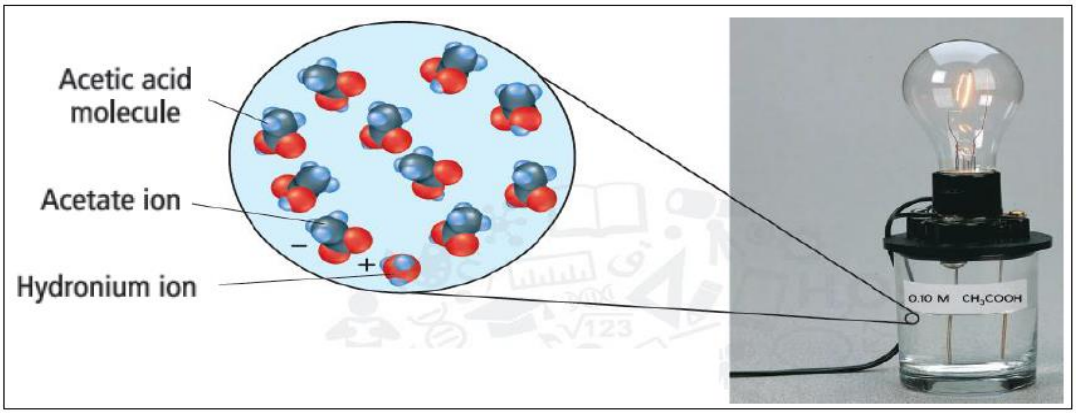
Sec. (2) Strength of Acids and Bases

Compare the electrical conductivity of two acid solutions of the same concentration.



0.1 M aqueous solution of HCl → **More lamp brightness** → **Better electrical conductivity** → **There are ions only** → **Complete ionization strong) (acid**

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$



0.1 M aqueous solution of CH_3COOH → **Less lamp brightness** → **Weaker electrical conductivity** → **There are ions and molecules** → **Incomplete ionization weak) (acid**

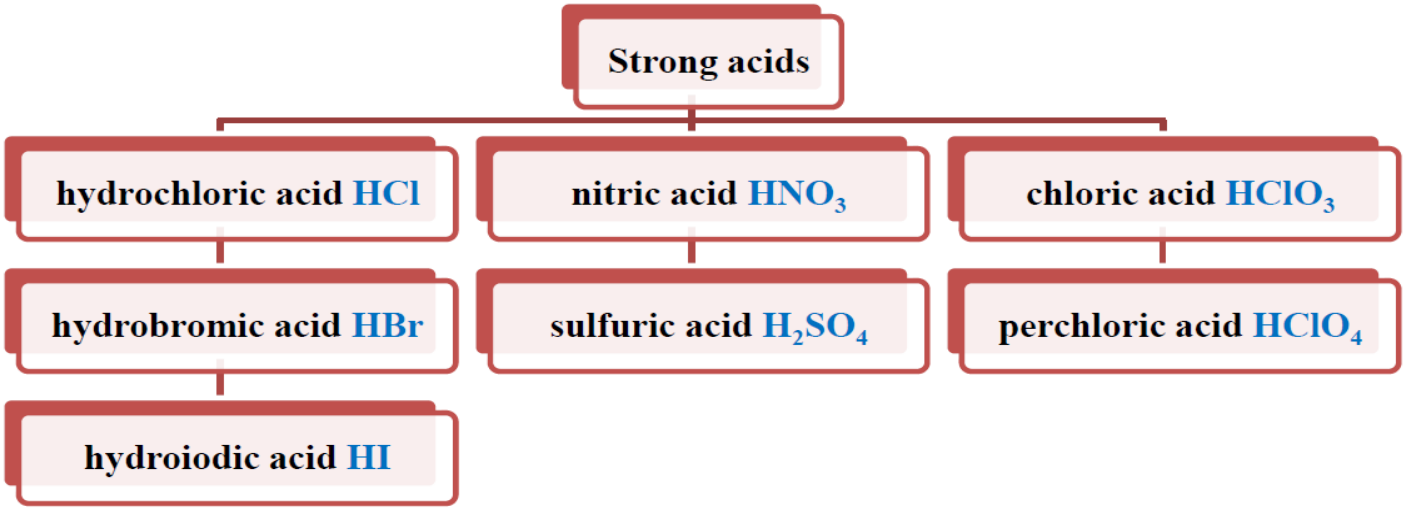
$$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$$

Strong acids: Acids that ionize completely, produce the largest number of ions and are good conductors of electricity.

The HCl molecules in the solution all ionize, forming hydronium ions and chloride ions.

→ Indicates that the reaction is complete, and all molecules ionize to form ions.

Why are strong acids a good conductor of electricity? → Because it is completely ionized to produce ions in the solution, there are no molecules left.



36) What is the content of a dilute aqueous solution of strong acid HI?

a. H_3O^+ only

b. I^- only

c. H_3O^+, I^- only

d. HI, H_3O^+, I^-

37) What is the equation that indicates the ionization of a strong acid?

a. $HClO_{3(aq)} + H_2O_{(l)} \rightleftarrows H_2ClO_3^+{}_{(aq)} + OH^-{}_{(aq)}$

b. $HClO_{3(aq)} + H_2O_{(l)} \rightarrow H_2ClO_3^+{}_{(aq)} + OH^-{}_{(aq)}$

c. $HClO_{4(aq)} + H_2O_{(l)} \rightleftarrows ClO_4^-{}_{(aq)} + H_3O^+{}_{(aq)}$

d. $HClO_{4(aq)} + H_2O_{(l)} \rightarrow ClO_4^-{}_{(aq)} + H_3O^+{}_{(aq)}$

Weak acids: Acids that partially ionize in aqueous solution produce few ions and are poor conductors of electricity.

Not all of the CH_3COOH molecules present in the solution are ionized. After ionization, the ions and molecules are present together.

⇄ Indicates that the reaction is incomplete, the concentration of molecules is greater than the concentration of ions after ionization.

Why are weak acids not a good conductor of electricity? → Because it is incompletely ionized to produce molecules and ions in solution.

Weak acids

- hydrofluoric acid HF
- hydrocyanic acid HCN
- hydrosulfuric acid H_2S
- chlorous acid $HClO_2$
- hypochlorous acid $HClO$
- nitrous acid HNO_2
- sulfurous acid H_2SO_3
- carbonic acid H_2CO_3
- ethanoic (acetic) acid CH_3COOH
- methanoic (formic) acid $HCOOH$
- phosphorous acid H_3PO_3
- phosphoric acid H_3PO_4
- boric acid H_3BO_3

38) What is the contents of a dilute aqueous solution of weak acid HCOOH?

a. H_3O^+ only

b. $HCOO^-$ only

c. H_3O^+, $HCOO^-$ only

d. $HCOOH$, H_3O^+, $HCOO^-$

39) What is the equation that indicates the ionization of a weak acid?

a. $HNO_{2(aq)} + H_2O_{(l)} \rightleftarrows NO_2^-{}_{(aq)} + H_3O^+{}_{(aq)}$

b. $HNO_{2(aq)} + H_2O_{(l)} \rightarrow NO_2^-{}_{(aq)} + H_3O^+{}_{(aq)}$

c. $HNO_{3(aq)} + H_2O_{(l)} \rightleftarrows NO_3^-{}_{(aq)} + H_3O^+{}_{(aq)}$

d. $HNO_{3(aq)} + H_2O_{(l)} \rightarrow NO_3^-{}_{(aq)} + H_3O^+{}_{(aq)}$

Acid strength and the Brønsted-Lowry model

A weak acid has a strong conjugate base.

A strong acid has a weak conjugate base.

The acid-base reactions of Brønsted-Lowry favor the production of the weakest.

The strong acid HX ionizes as in the following equation:

$$HX_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + X^-_{(aq)}$$

strong acid — strong base — weak conjugate acid — weak conjugate base

- strong base → has more ability to attract H^+ ion
- weak conjugate base → has less ability to attract H^+ ion

H_2O is a stronger base (forward reaction) than the conjugate base X^- (reverse reaction)

The attraction of the H_2O base to the H^+ ion is greater than that of the conjugate base X^-

The ionization equilibrium is almost shifts to the right and HX ionizes at 100%

The weak acid HY ionizes as in the following equation:

$$HY_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + Y^-_{(aq)}$$

weak acid — weak base — strong conjugate acid — strong conjugate base

- weak base → has less ability to attract H^+ ion
- strong conjugate base → has more ability to attract H^+ ion

Y^- is a stronger base (reverse reaction) than the base H_2O (forward reaction)

The attraction of the conjugate base Y^- to the H^+ ion is greater than that of the base H_2O

The ionization equilibrium is almost shifts to the left.

40) Which of the following relationships is incorrect for the relationship between the strength of a weak acid and the strength of its conjugate base?

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

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

c. a weak base has a strong conjugate acid

d. a strong acid has a weak conjugate acid

41) If the tendency of a substance to give off protons is large, how is its conjugate?

a. has a large tendency to give protons

b. has a weak tendency to give protons

c. has a large tendency to receive protons

d. has a weak tendency to receive protons

42) For the following balanced reaction, which of the following statements is true?

$$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$$

a. the base $C_2H_3O_2^-$ is stronger than the base H_2O

b. $HC_2H_3O_2$ is a strong acid

c. the base $C_2H_3O_2^-$ is weaker than the base H_2O

d. the ionization equilibrium is shifts to the right

43) For the following balanced reaction, why does the ionization shifts to the left?

$$HF + H_2O \rightleftarrows H_3O^+ + F^-$$

a. the H_2O base has a more attraction to the H^+ ion than the conjugate base F^-

b. the K_a value of the acid is high and it tends towards non-ionizing molecules

c. HF is a strong acid and its conjugate base F^- is weak

d. the conjugate base F^- is stronger than the base H_2O, so it attracts the H^+ ion more than the base H_2O

Acid ionization constants

The Brønsted-Lowry model helps explain the strength of acids, but it does not quantitatively compare the strengths of different acids.

The expression K_{eq} provides a quantitative measure of acid strength.

The ionization equation for HCN and the expression for the equilibrium constant:

$$HCN_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + CN^-_{(aq)} \qquad K_{eq} = \frac{[H_3O^+][CN^-]}{[HCN][H_2O]}$$

The concentration of $H_2O_{(l)}$ is constant, and a new equilibrium constant K_a is used

$$K_{eq}\,[H_2O] = K_a = \frac{[H_3O^+][CN^-]}{[HCN]} = 6.2 \times 10^{-10}$$

Acid ionization constant Ka: The equilibrium constant for the ionization of a weak acid

What is produced if the value of K_a increases?	The concentrations of ions (products) in the numerator increase compared to the concentration of non-ionized molecules (reactants) in the denominator, as in strong acids.
What is produced if the value of K_a decreases?	The concentrations of non-ionizing molecules (reactants) increase in the denominator compared to the concentration of ions (products) in the numerator, as in weak acids.
Why do weak acids have the lowest Ka values?	Because their solutions have the lowest concentrations of ions and the highest concentrations of non-ionized acid molecules.

Most of the polyprotic acids are weakly ionized, and each ionization phase of the polyprotic acid has a different K_a value.

The value of K_a decreases for each subsequent ionization process.

Ionization Constants for Weak Acids		not required to save
Acid	**Ionization Equation**	**K_a (298 K)**
Hydrosulfuric, first ionization	$H_2S \rightleftharpoons H^+ + HS^-$	8.9×10^{-8}
Hydrosulfuric, second ionization	$HS^- \rightleftharpoons H^+ + S^{2-}$	1×10^{-19}
Hydrofluoric	$HF \rightleftharpoons H^+ + F^-$	6.3×10^{-4}
Hydrocyanic	$HCN \rightleftharpoons H^+ + CN^-$	6.2×10^{-10}
Acetic	$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$	1.8×10^{-5}
Carbonic, first ionization	$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$	4.5×10^{-7}
Carbonic, second ionization	$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$	4.7×10^{-11}

44) What is the weakest acid among the acids in the table below?

a. H_2S

b. H_2CO_3

c. HF

d. HCN

acid	K_a
HF	6.3×10^{-4}
H_2S	8.9×10^{-8}
HCN	6.2×10^{-10}
H_2CO_3	4.5×10^{-7}

45) Which of the following relationships represents the acid ionization constant (K_a) in the following equation? $HCOOH_{(aq)} + H_2O_{(l)} \rightleftarrows HCOO^-_{(aq)} + H_3O^+_{(aq)}$

a. $K_a = \frac{[HCOO^-][H_3O^+]}{[HCOOH]}$

b. $K_a = \frac{[HCOO^-][H_3O^+]}{[HCOOH][H_2O]}$

c. $K_a = \frac{[HCOOH][H_2O]}{[HCOO^-]}$

d. $K_a = \frac{[HCOOH][H_2O]}{[HCOO^-][H_3O^+]}$

46) Which of the following choices represents the chemical equation and K_a expression for the ionization of hypochlorous acid in water?

a. $HClO + H_2O \rightarrow H_3O^+ + ClO^-, \quad K_a = \frac{[H_3O^+][ClO^-]}{[HClO][H_2O]}$

b. $HClO + H_2O \rightarrow H_3O^+ + ClO^-, \quad K_a = \frac{[H_3O^+][ClO^-]}{[HClO]}$

c. $HClO + H_2O \rightleftarrows H_3O^+ + ClO^-, \quad K_a = \frac{[H_3O^+][ClO^-]}{[HClO][H_2O]}$

d. $HClO + H_2O \rightleftarrows H_3O^+ + ClO^-, \quad K_a = \frac{[H_3O^+][ClO^-]}{[HClO]}$

47) What is the correct order of the following weak acids in order of their conduction of electricity?

acid	CH_3COOH	HS^-	HCO_3^-	HF
K_a	1.8×10^{-5}	1.0×10^{-19}	4.7×10^{-11}	6.3×10^{-4}

a. least: $HF \rightarrow HCO_3^- \rightarrow HS^- \rightarrow CH_3COOH$ most

b. least: $HF \rightarrow CH_3COOH \rightarrow HCO_3^- \rightarrow HS^-$ most

c. least: $CH_3COOH \rightarrow HS^- \rightarrow HCO_3^- \rightarrow HF$ most

d. least: $HS^- \rightarrow HCO_3^- \rightarrow CH_3COOH \rightarrow HF$ most

48) What is the second ionization equation for the acid H_2SeO_3 in water?

a. $H_2SeO_3 + H_2O \rightarrow H_3O^+ + HSeO_3^-$

b. $H_2SeO_3 + H_2O \rightleftarrows H_3O^+ + HSeO_3^-$

c. $HSeO_3^- + H_2O \rightarrow H_3O^+ + SeO_3^{2-}$

d. $HSeO_3^- + H_2O \rightleftarrows H_3O^+ + SeO_3^{2-}$

49) What is the expression for K_a for the ionization of nitrous acid in water?

a. $K_a = \frac{[H_3O^+][NO_2^-]}{[HNO_2][H_2O]}$

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

c. $K_a = \frac{[HNO_2][H_2O]}{[H_3O^+][NO_2^-]}$

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

50) If the expression for the equilibrium constant for a reaction is: $K_a = \frac{[H_3O^+][AsO_4^{3-}]}{[HAsO_4^{2-}]}$

What is the balanced equation for the reaction?

a. $HAsO_4^{2-} + H_2O \rightleftarrows H_3O^+ + AsO_4^{3-}$

b. $HAsO_4^{2-} + H_2O \rightarrow H_3O^+ + AsO_4^{3-}$

c. $H_3O^+ + AsO_4^{3-} \rightleftarrows HAsO_4^{2-} + H_2O$

d. $H_3O^+ + AsO_4^{3-} \rightarrow HAsO_4^{2-} + H_2O$

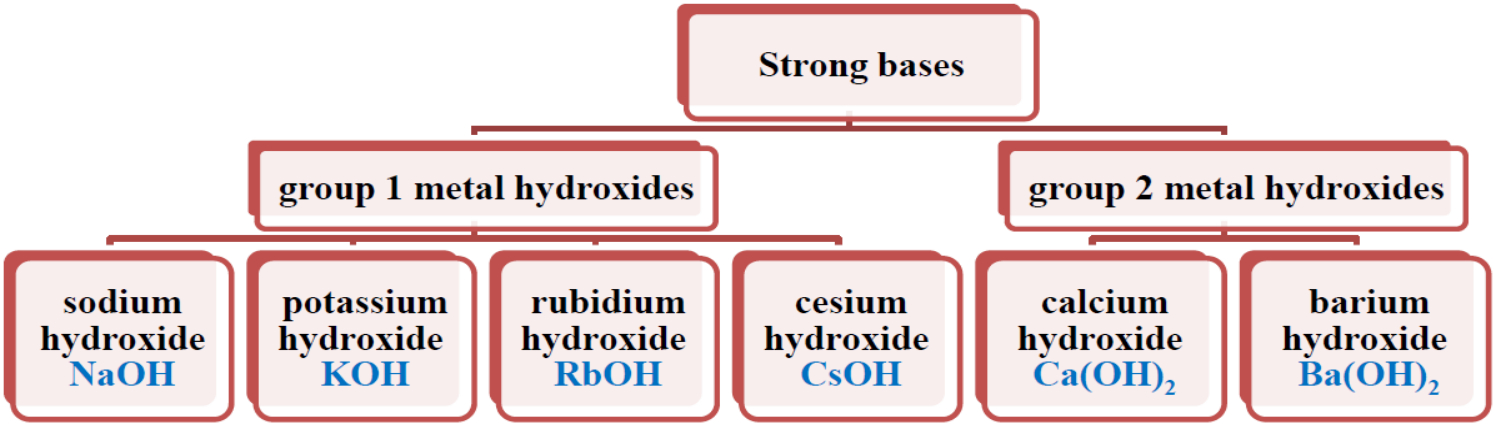
Strengths of bases

What applies to acids also applies to bases, except that OH^- ions are involved instead of H^+

The conductivity of the base depends on the degree to which the base produces OH^- ions in the aqueous solution.

Strong base: A base that completely dissociates to produce metal ions and hydroxide ions OH^-

Dissociation equation for the strong base NaOH: $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$



51) What is in a dilute aqueous solution of most bases?

a. hydroxide ions and cations

b. hydroxide ions and anions

c. hydrogen ions and cations

d. hydrogen ions and anions

52) What is the equation that indicates the ionization of the strong base $Ba(OH)_2$?

a. $Ba(OH)_{2(s)} \rightarrow Ba^{2+}_{(aq)} + OH^-_{(aq)}$

b. $Ba(OH)_{2(s)} \rightleftarrows Ba^{2+}_{(aq)} + OH^-_{(aq)}$

c. $Ba(OH)_{2(s)} \rightarrow Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$

d. $Ba(OH)_{2(s)} \rightleftarrows Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$

Why is calcium hydroxide $Ca(OH)_2$ a poor source of OH^- ions? → **Because calcium hydroxide has poor solubility.**

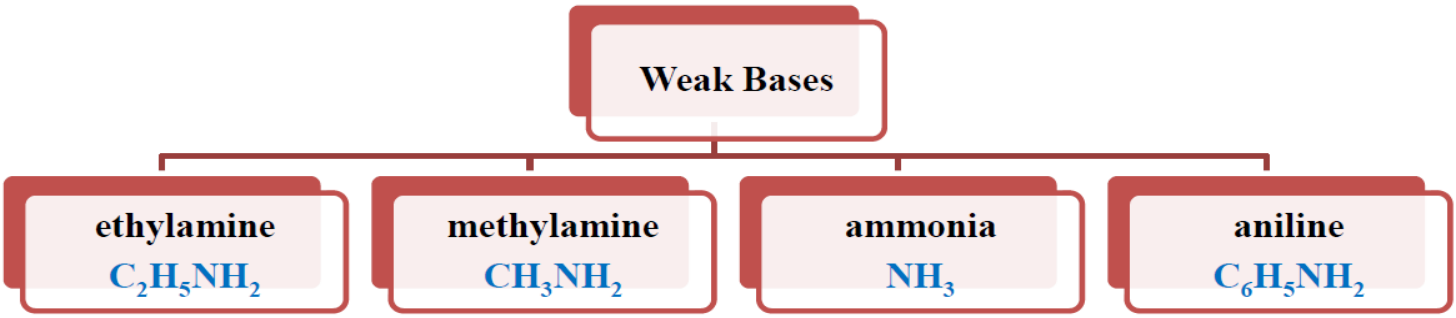
Why calcium hydroxide has poor solubility? → **Because the K_{sp} value of calcium hydroxide is small.**

$$Ca(OH)_{2(s)} \rightleftarrows Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \qquad K_{sp} = 6.5 \times 10^{-6}$$

Why are $Ca(OH)_2$ and other poorly soluble bases considered strong, even though they have a lower solubility in water? → **Because everything that dissolves from the compound dissociates completely.**

Weak Base: A base that partially ionizes in aqueous solutions.

Ionization equation for the weak base NH_3: $NH_{3(aq)} + H_2O_{(l)} \rightleftarrows NH_4^+{}_{(aq)} + OH^-_{(aq)}$



53) What is the reason for the low electrical conductivity of calcium hydroxide even though it is a strong base?

a. it has poor solubility in water

b. no OH^- ions are produced in water

c. partially ionizes in water

d. produces H^+ ions in water

54) What group does aniline belong to?

a. strong base

b. weak base

c. strong acid

d. weak acid

The weak base CH_3NH_2 is ionized as in the following equation:

$$CH_3NH_{2\,(aq)} + H_2O_{(l)} \rightleftarrows CH_3NH_3^+{}_{(aq)} + OH^-{}_{(aq)}$$

weak base	weak acid	strong conjugate acid	strong conjugate base

- CH_3NH_2 has less ability to attract H^+ ion
- $CH_3NH_3^+$ has more ability to attract H^+ ion

OH^- is a stronger base (reverse reaction) than the base CH_3NH_2 (forward reaction)

The attraction of the base OH^- to the H^+ ion is greater than that of the base CH_3NH_2

The ionization equilibrium is almost shifts to the left.

Base ionization constants

The equilibrium constant is a measure of the degree of ionization of the base.

Base ionization constant K_b: Expression of the equilibrium constant for the ionization of a weak base.

Base ionization constant for CH_3NH_2: $K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$

What is produced if the value of K_b decreases? → The concentrations of non-ionizing molecules (reactants) increase in the denominator compared to the concentration of ions (products) in the numerator, as in weak bases.

Ionization Constants of Weak Bases

not required to save

Base	Ionization Equation	K_b (298 K)
Ethylamine	$C_2H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_2H_5NH_3^+(aq) + OH^-(aq)$	5.0×10^{-4}
Methylamine	$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$	4.3×10^{-4}
Ammonia	$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$	2.5×10^{-5}
Aniline	$C_6H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_6H_5NH_3^+(aq) + OH^-(aq)$	4.3×10^{-10}

55) When can a base be considered weak?

a. if its tendency to accept a proton is high

b. if its tendency to donate a proton is high

c. if its tendency to accept a proton is weak

d. if its tendency to donate a proton is weak

56) Which of the following options represents the chemical equation and the ionization expression K_b of ethylamine in water?

a. $C_2H_5NH_2 + H_2O \rightleftarrows C_2H_5NH_3^+ + OH^-$, $K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2][H_2O]}$

b. $C_2H_5NH_2 + H_2O \rightarrow C_2H_5NH_3^+ + OH^-$, $K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2][H_2O]}$

c. $C_2H_5NH_2 + H_2O \rightarrow C_2H_5NH_3^+ + OH^-$, $K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]}$

d. $C_2H_5NH_2 + H_2O \rightleftarrows C_2H_5NH_3^+ + OH^-$, $K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]}$

57) Which of the following options represents the chemical equation and the ionization expression K_b of the carbonate ion CO_3^{2-} in water?

a. $CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$, $K_b = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}]}$

b. $CO_3^{2-} + H_2O \rightleftarrows HCO_3^- + OH^-$, $K_b = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}]}$

c. $CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$, $K_b = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}][H_2O]}$

d. $CO_3^{2-} + H_2O \rightleftarrows HCO_3^- + OH^-$, $K_b = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}][H_2O]}$

58) Which of the following K_a values represents the acid with the strongest conjugate base?

a. 1.8×10^{-5} b. 1×10^{-6}

c. 1.4×10^{-4} d. 3.2×10^{-3}

59) What is an equation for the reversible equilibrium where the base in the forward reaction is PO_4^{3-} and the base in the reverse reaction is OH^-?

a. $HPO_4^{2-}{}_{(aq)} + OH^-{}_{(aq)} \rightarrow PO_4^{3-}{}_{(aq)} + H_2O_{(l)}$

b. $HPO_4^{2-}{}_{(aq)} + OH^-{}_{(aq)} \rightleftarrows PO_4^{3-}{}_{(aq)} + H_2O_{(l)}$

c. $PO_4^{3-}{}_{(aq)} + H_2O_{(l)} \rightarrow HPO_4^{2-}{}_{(aq)} + OH^-{}_{(aq)}$

d. $PO_4^{3-}{}_{(aq)} + H_2O_{(l)} \rightleftarrows HPO_4^{2-}{}_{(aq)} + OH^-{}_{(aq)}$

60) Which of the following options represents the chemical equation and the ionization expression K_b of the hydrogen sulfite ion HSO_3^- in water?

a. $HSO_3^- + H_2O \rightleftarrows H_2SO_3 + OH^-$, $K_b = \frac{[H_2SO_3][OH^-]}{[HSO_3^-][H_2O]}$

b. $HSO_3^- + H_2O \rightarrow H_2SO_3 + OH^-$, $K_b = \frac{[H_2SO_3][OH^-]}{[HSO_3^-][H_2O]}$

c. $HSO_3^- + H_2O \rightleftarrows H_2SO_3 + OH^-$, $K_b = \frac{[H_2SO_3][OH^-]}{[HSO_3^-]}$

d. $HSO_3^- + H_2O \rightarrow H_2SO_3 + OH^-$, $K_b = \frac{[H_2SO_3][OH^-]}{[HSO_3^-]}$

61) What information does a small K_b value (4.3×10^{-10}) of aniline gives you?

a. aniline is strong base

b. aniline is incompletely ionized

c. aniline ionization in water produces only ions

d. its solution is a good conductor of electricity

62) What is the strongest base among the bases in the adjacent table?

a. methylamine

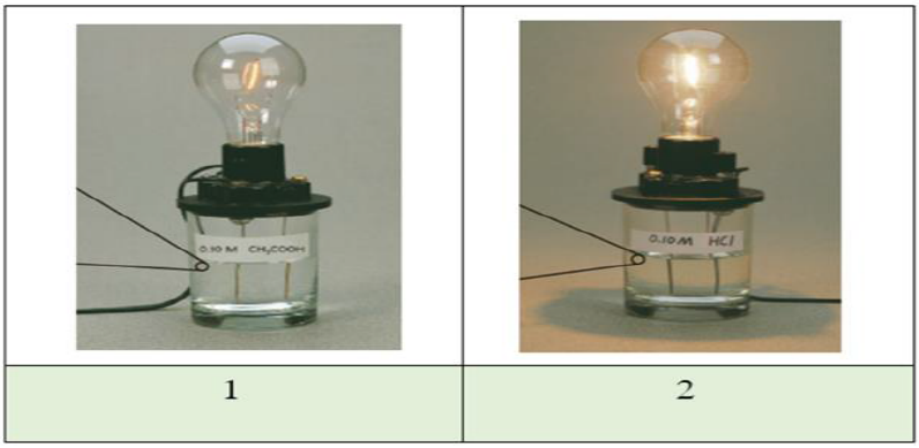
b. ethylamine

c. aniline

d. ammonia

base	K_b (298 K)
ethylamine	5.0×10^{-4}
methylamine	4.3×10^{-4}
ammonia	2.5×10^{-5}
aniline	4.3×10^{-10}

63) Regarding



a. the light glows brightly in 2 because HCl is a strong acid

b. the light is dim in 1 because CH_3COOH is a strong acid

c. the lamp glows brightly in 2 because HCl ionizes only partially

d. the light is dim in 1 because CH_3COOH ionizes completely

64) Which of the following is considered a conjugate acid-base pair?

a. H_2SO_4, SO_4^{2-}

b. H_2O, O^{2-}

c. H_3PO_4, HPO_4^{2-}

d. HNO_3, NO_3^-

65) What is the correct descending order of the acids in the table below according to the concentrations of ions in each solution?

a. $CH_3COOH \rightarrow HF \rightarrow H_2CO_3 \rightarrow H_2S$

b. $H_2S \rightarrow H_2CO_3 \rightarrow HF \rightarrow CH_3COOH$

c. $HF \rightarrow CH_3COOH \rightarrow H_2CO_3 \rightarrow H_2S$

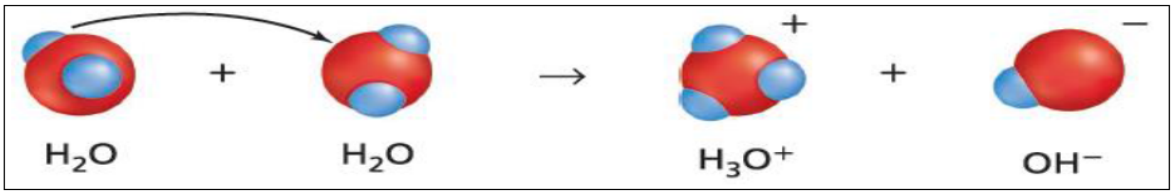
d. $H_2S \rightarrow H_2CO_3 \rightarrow CH_3COOH \rightarrow HF$

ionization constants	acid
8.9×10^{-8}	H_2S
6.3×10^{-4}	HF
1.8×10^{-5}	CH_3COOH
4.5×10^{-7}	H_2CO_3

Sec. (3) Hydrogen ions and pH

Self-ionization of water: pure water contains equal concentrations of H^+ and OH^-

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



In the self-ionization of water, one molecule of water acts as an acid, and the other molecule acts as a base.

Water ionization constant K_w: An expression for the equilibrium constant for the self-ionization of water.

or

The product of the hydrogen ion and hydroxide ion concentrations in dilute aqueous solutions.

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

for the neutral solution

at room temperature (298 K)

$$[H^+] = [OH^-] = 1 \times 10^{-7} \text{ mol/L}$$

$$K_w = [H^+][OH^-] = 1 \times 10^{-14}$$

1 $\quad 1 \times 10^{-14} = [H^+][OH^-]$ $\quad$ 298 K

The K_w value is constant at a constant temperature.

Why does the value of K_w increase when the temperature increases? → Because ionization of water increase as the temperature increase.

K_w and Le Chatelier Principle

What is produced when the concentration of H^+ ions increases? → acidic solution

H^+ reacts with OH^- and the reaction goes to the left to produce water H_2O

As a result, the concentration of H^+ increases and the concentration of OH^- decreases.

$[H^+] > [OH^-]$ acidic solution

H^+

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

K_w no change

What is produced when the concentration of OH^- ions increases? → basic solution

OH^- reacts with H^+ and the reaction goes to the left to produce water H_2O

As a result, the concentration of OH^- increases and the concentration of H^+ decreases.

$[OH^-] > [H^+]$ basic solution

OH^-

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

K_w no change

- types of solutions
  - acidic
    - $[H^+] > [OH^-]$
    - $[H^+] > 1\times10^{-7}$ mol/L
  - neutral
    - $[H^+] = [OH^-]$
    - $[H^+] = [OH^-] = 1\times10^{-7}$ mol/L
  - basic
    - $[OH^-] > [H^+]$
    - $[OH^-] > 1\times10^{-7}$ mol/L

66) The concentration of the H^+ ion in a cup of coffee is 1 x 10^{-5} M at 298 K. What is the concentration of the OH^- ion in the coffee? Is coffee acidic, basic, or neutral?

a. $[OH^-] = 1 \times 10^{-9}$ M, basic

b. $[OH^-] = 1 \times 10^{-9}$ M, acidic

c. $[OH^-] = 1 \times 10^{-24}$ M, basic

d. $[OH^-] = 1 \times 10^{-24}$ M, acidic

67) What is the value of $[H^+]$ in a solution whose concentration of OH^- is 1 x 10^{-3} M?

a. 1×10^{-7} M

b. 1×10^{-17} M

c. 1×10^{-3} M

d. 1×10^{-11} M

68) What is the value of $[OH^-]$ in a solution whose concentration of H^+ is 4×10^{-5} M?

a. 2.5×10^{-10} M

b. 1×10^{-9} M

c. 2.5×10^{-9} M

d. 1×10^{-10} M

69) How many H^+ ions and how many OH^- ions are in 300 mL of pure water at 298 K?

$N_A = 6.022 \times 10^{23}$

a. $[H^+] = [OH^-] = 3 \times 10^{8}$ ions

b. $[H^+] = [OH^-] = 1.8 \times 10^{16}$ ions

c. $[H^+] = [OH^-] = 1.8 \times 10^{6}$ ions

d. $[H^+] = [OH^-] = 3 \times 10^{16}$ ions

70) Use Le Chatelier's principle to determine what happens to equilibrium when a few drops of HCl are added to pure water? $H_2O_{(l)} \rightleftarrows H^+_{(aq)} + OH^-_{(aq)}$

a. the equilibrium shifts to the left and K_w does not change

b. the equilibrium shifts to the left and K_w changes

c. the equilibrium shifts to the right and K_w does not change

d. the equilibrium shifts to the right and K_w changes

71) Use Le Chatelier's principle to determine what happens to $[H^+]$ when drops of NaOH are added to an acetic acid solution? $CH_3COOH_{(aq)} \rightleftarrows CH_3COO^-_{(aq)} + H^+_{(aq)}$

a. $[H^+]$ increases and equilibrium shifts to the right

b. $[H^+]$ decreases and equilibrium shifts to the right

c. $[H^+]$ increases and equilibrium shifts to the left

d. $[H^+]$ decreases and equilibrium shifts to the left

72) If the concentration of H^+ ions decreases in an aqueous solution, what must happen to the concentration of OH^- ions at a constant temperature? And what's the reason?

choice	$[OH^-]$	the reason
a.	decrease	K_w change
b.	decrease	K_w no change
c.	increase	K_w change
d.	increase	K_w no change

73) In the following equilibrium equation for pure water: $H_2O_{(l)} \rightleftarrows H^+_{(aq)} + OH^-_{(aq)}$

Why does the value of K_w not change when other hydrogen ions are added to water?

a. shifting the equilibrium to the right and increasing the concentration of H^+ ions

b. increasing the rate of ionization of water molecules

c. increasing the concentration of OH^- ions in the solution

d. H^+ reacts with OH^- to form more H_2O molecules

pH and pOH

pH: the negative logarithm of hydrogen ion concentration.

2 $pH = -\log [H^+]$

pOH: the negative logarithm of hydroxide ion concentration.

3 $pOH = -\log [OH^-]$

What is the relationship between pH and pOH?

4 $pH + pOH = 14$ 298 K

pH, pOH have no units

74) What is the pH value of the solution that has: $[H^+] = 1.0 \times 10^{-2}$ M, at 298 K?

a. 2

b. 4

c. 12

d. 10

75) What is the pH value of the solution that has: $[H^+] = 0.000084$ M, at 298 K?

a. 10.924

b. 3.075

c. 9.924

d. 4.075

76) What is the pOH value of the solution that has: $[OH^-] = 1.0 \times 10^{-6}$ M, at 298 K?

a. 2

b. 8

c. 12

d. 6

77) What is the pOH value of the solution that has: $[OH^-] = 6.5 \times 10^{-4}$ M, at 298 K?

a. 10

b. 4

c. 10.81

d. 3.18

78) What is the pOH value of the solution that has: $[H^+] = 2.5 \times 10^{-2}$ M, at 298 K?

a. 12.4

b. 1.6

c. 12

d. 2

79) What is the pH value of the solution that has: $[OH^-] = 0.0055$ M, at 298 K?

a. 2.26

b. 11.74

c. 3

d. 11

80) What is the pH value of the neutral solution at 298 K?

a. 14

b. –7

c. 7

d. 0

Calculation of $[H^+]$ and $[OH^-]$ from pH and pOH

5	$[H^+] = 10^{-pH}$
6	$[OH^-] = 10^{-pOH}$

81) What is the value of $[H^+]$ for milk with pH = 6.5?

a. 1×10^{-8} M

b. 1×10^{-7} M

c. 3.16×10^{-8} M

d. 3.16×10^{-7} M

82) What is the value of $[H^+]$ for lemon juice with pOH = 11.6?

a. 2.51×10^{-12} M

b. 3.98×10^{-3} M

c. 2.51×10^{-3} M

d. 3.98×10^{-12} M

83) What is the value of $[OH^-]$ for a solution of magnesia with pOH = 3.5?

a. 3.16×10^{-3} M

b. 3.16×10^{-10} M

c. 3.16×10^{-4} M

d. 3.16×10^{-11} M

84) What is the value of $[OH^-]$ for household ammonia with pH = 11.9?

a. 7.94×10^{-3} M

b. 1.25×10^{-12} M

c. 7.94×10^{-12} M

d. 1.25×10^{-3} M

Molarity and pH of strong acids

A strong acid is 100% ionized, which means it has 100% ions (for monoprotic acids).

$$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$
1 mol/L 1 mol/L 1 mol/L

An acid with a concentration of 1 mol/L produces 1 mol H^+ per liter (for monoprotic acids).

7 $[H^+] = [acid] \times H$ number

Molarity and pH for strong bases

The strong base completely disintegrates.

$$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$$
1 mol/L 1 mol/L 1 mol/L

A base with a concentration of 1 mol/L produces 1 mol OH^- per liter (for monohydroxide bases).

$$Ca(OH)_{2(aq)} \rightarrow Ca^{2+}_{(aq)} + 2OH^-_{(aq)}$$
1 mol/L 1 mol/L 2 mol/L

A base with a concentration of 1 mol/L produces 2 mol OH^- per liter (for dihydroxide bases).

8 $[OH^-] = [base] \times OH$ number

85) What is the pH value of the solution having concentration: 0.02 M HI?

a. 13.30

b. 0.69

c. 12.30

d. 1.69

86) What is the pH value of the solution having concentration: 2.4×10^{-5} M $Mg(OH)_2$?

a. 9.68

b. 4.31

c. 4.61

d. 9.38

87) What is the pOH value of the solution having concentration: 1×10^{-3} M KOH?

a. 2.69

b. 11.30

c. 3

d. 11

88) What is the pOH value of the solution having concentration: 0.05 M HNO_3?

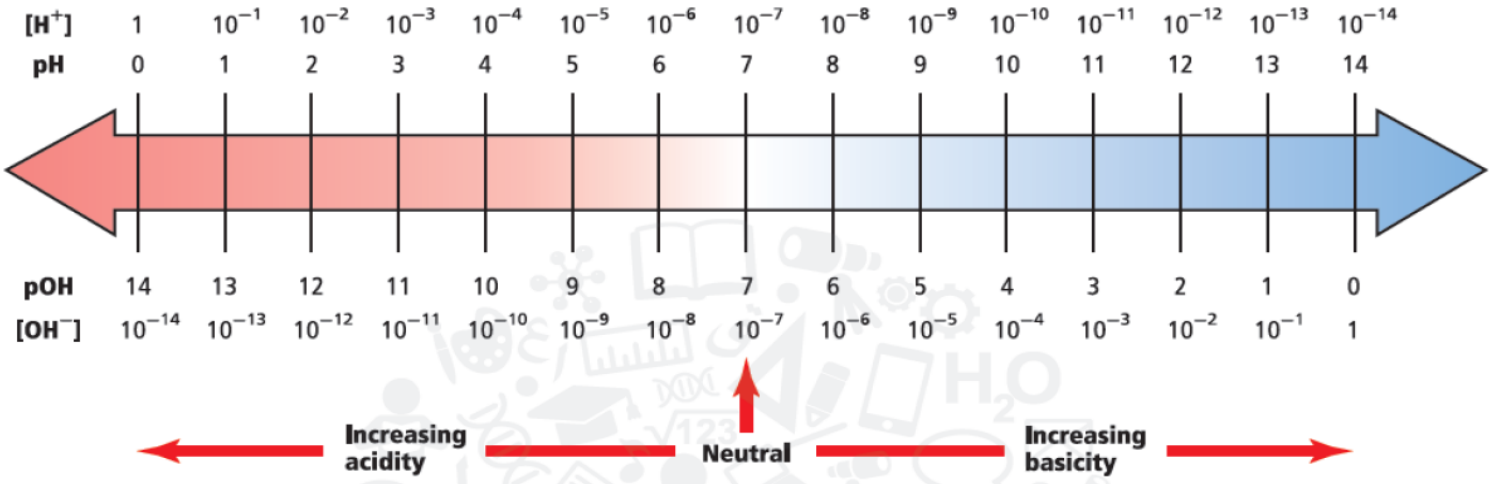
a. 1

b. 13

c. 1.30

d. 12.69

The relationship between pH, pOH, $[H^+]$, $[OH^-]$



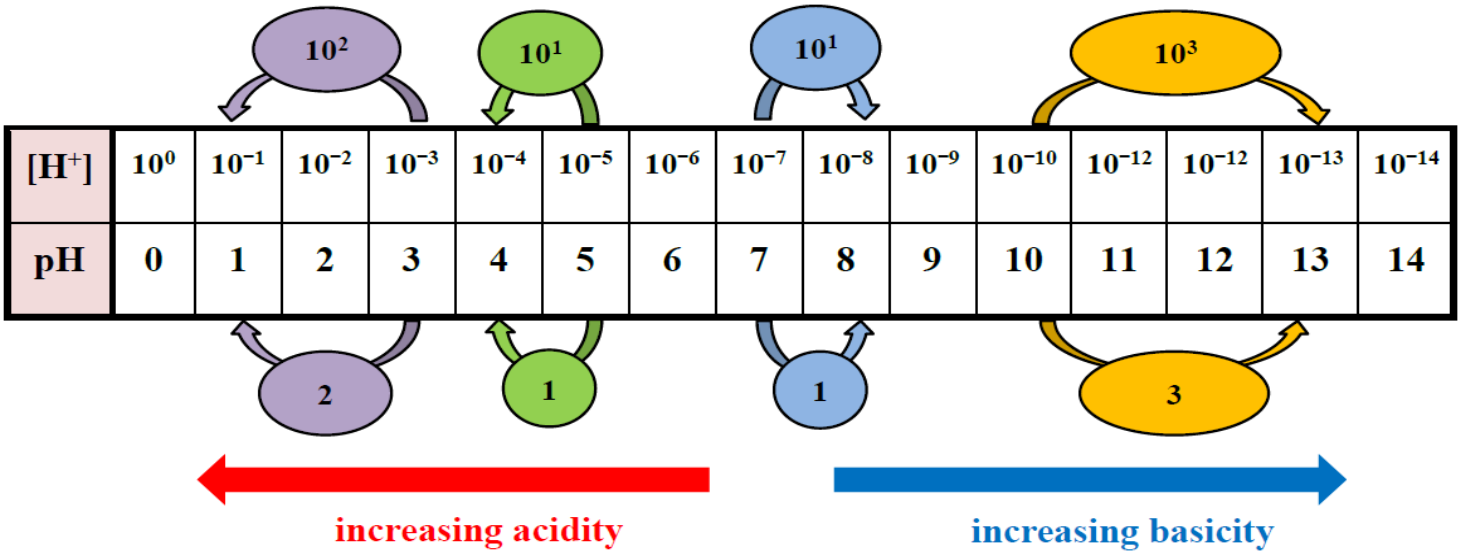
- **types of solutions**
  - **acidic**
    - $[H^+] > [OH^-]$
    - $[H^+] > 1\times10^{-7}$ mol/L
    - pH < 7
    - pH < pOH
  - **neutral**
    - $[H^+] = [OH^-]$
    - $[H^+] = [OH^-] = 1\times10^{-7}$ mol/L
    - pH = pOH = 7
  - **basic**
    - $[OH^-] > [H^+]$
    - $[OH^-] > 1\times10^{-7}$ mol/L
    - pH > 7
    - pH > pOH

As the pH changes by 1, the concentration of the H^+ ion changes by 10

As pOH changes by 1, the concentration of the OH^- ion changes by 10

What is the hydrogen ion concentration when comparing a solution of pH = 3 with a solution of pH = 4?

→ **A solution with a pH of 3 has 10 times more $[H^+]$ than a solution with a pH of 4**



9 $\frac{[H^+]_1}{[H^+]_2} = 10^{(pH_2 - pH_1)}$

10 $\frac{[OH^-]_1}{[OH^-]_2} = 10^{(pOH_2 - pOH_1)}$

89) Based on the following data, which of the following statements is true?

a. the acidity of solution B is 3 times the acidity of solution B

b. the acidity of solution A is 3 times the acidity of solution A

c. the acidity of solution B is 10^3 times the acidity of solution A

d. the acidity of solution A is 10^3 times the acidity of solution B

substance	pH
A	2
B	5

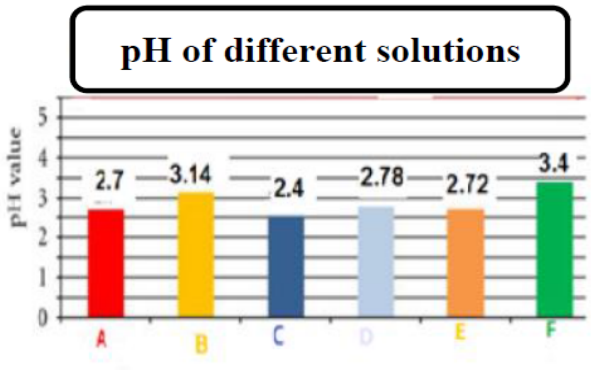
90) Using the adjacent graph, based on the two H^+ ion concentrations, how many times more acidic is the most acidic solution than the least acidic solution?

a. 1000

b. 1

c. 10

d. 100



Calculate K_a from pH and Calculate K_b from pOH

Weak acids and bases ionizes partially, so K_a and K_b values must be used to determine the $[H^+]$ and $[OH^-]$ ions

Why can't $[H^+]$ be obtained directly from the molarity of a weak acid? → **Because a weak acid ionizes partially, one mole of acid does not produce a mole of H^+ ions**

11 $$K_a = \frac{[H^+]^2}{[acid] - [H^+]}$$

12 $$K_b = \frac{[OH^-]^2}{[base] - [OH^-]}$$

91) What is the K_a value of a 0.04 M $HClO_2$ solution with pH = 1.8?

a. 0.01

b. 0.65

c. 0.39

d. 6.27×10^{-3}

92) What is the K_a value of HCOOH, if the pH is 2.38 for a 0.1 M HCOOH solution?

a. 0.0435

b. 1.81×10^{-4}

c. 0.0416

d. 1.73×10^{-4}

93) What is the K_a value of a C_6H_5COOH benzoic acid solution with a concentration of 0.0033 M and pOH = 10.7?

a. 0.179

b. 6.04×10^{-9}

c. 1.20×10^{-19}

d. 8.97×10^{-5}

94) What is the K_a value of a 0.22 M H_3AsO_4 acid solution and pH = 1.5?

a. 4.54×10^{-3}

b. 0.143

c. 0.167

d. 5.30×10^{-3}

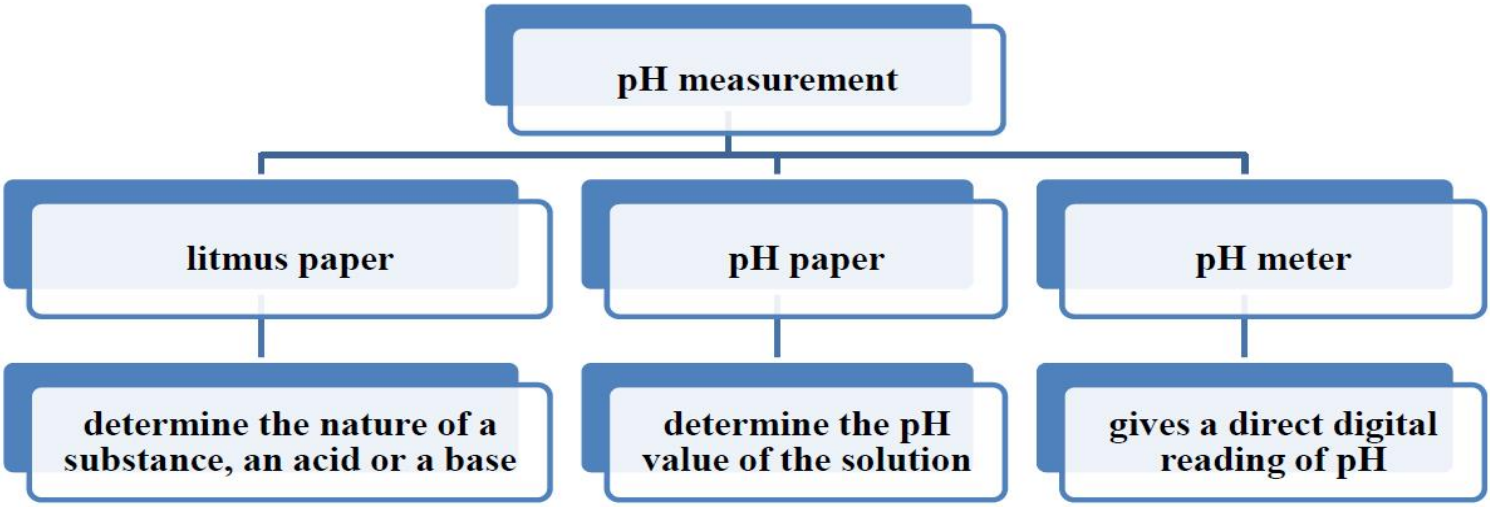
95) What is the K_a value of a 0.1 M HCNO solution and pOH = 11.0?

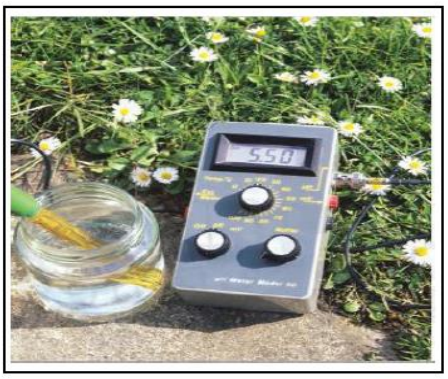
a. 1.01×10^{-5}

b. 1.01×10^{-12}

c. 1.0×10^{-21}

d. 1.0×10^{-10}



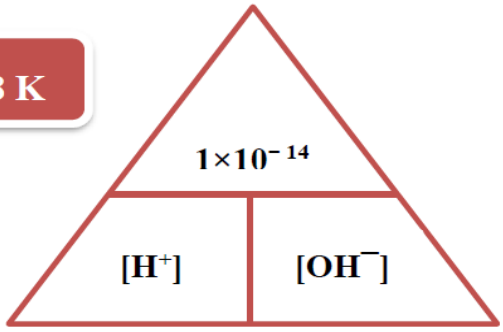


pH papers are treated with one or more substances called indicators.

The pH meter gives a more accurate measurement of pH

pH, pOH calculations

1. $1 \times 10^{-14} = [H^+][OH^-]$ — 298 K



2. $pH = -\log [H^+]$
3. $pOH = -\log [OH^-]$
4. $pH + pOH = 14$ — 298 K
5. $[H^+] = 10^{-pH}$
6. $[OH^-] = 10^{-pOH}$

calculate $[H^+]$, $[OH^-]$ from pH, pOH

7. $[H^+] = [acid] \times H$ number
8. $[OH^-] = [base] \times OH$ number

Only strong acids and strong bases

Calculate the ratio between ion concentrations and pH or pOH

9. $$\frac{[H^+]_1}{[H^+]_2} = 10^{(pH_2 - pH_1)}$$

10. $$\frac{[OH^-]_1}{[OH^-]_2} = 10^{(pOH_2 - pOH_1)}$$

Calculation of K_a for weak acids

11. $$K_a = \frac{[H^+]^2}{[acid] - [H^+]}$$

$$K_a = \frac{(10^{-pH})^2}{[acid] - (10^{-pH})}$$

Calculation of K_b for weak bases

12. $$K_b = \frac{[OH^-]^2}{[base] - [OH^-]}$$

$$K_b = \frac{(10^{-pOH})^2}{[base] - (10^{-pOH})}$$

96) What is the pOH value of a solution of $[H^+] = 0.000033$ M at 298 K?

a. 9.51

b. 4.48

c. 10.51

d. 3.48

97) What is the pH value of a solution having $[OH^-] = 0.0095$ M at 298 K?

a. 10.97

b. 3.02

c. 11.97

d. 2.02

98) What is the value of $[H^+]$ for the blood of a healthy person with a pH of 7.40?

a. 2.51×10^{-8} M

b. 3.98×10^{-7} M

c. 2.51×10^{-7} M

d. 3.98×10^{-8} M

99) What is the value of $[OH^-]$ in a seawater sample where pOH = 5.60?

a. 3.98×10^{-9} M

b. 2.51×10^{-6} M

c. 3.98×10^{-8} M

d. 2.51×10^{-7} M

100) What is the value of $[OH^-]$ for a tomato if the pH of a tomato is 4.50?

a. 3.16×10^{-5} M

b. 3.16×10^{-10} M

c. 3.98×10^{-6} M

d. 2.51×10^{-9} M

101) What is the pH of a solution contains 1.0×10^{-9} mol/L of OH^- ions in the solution?

a. 10

b. 9

c. 4

d. 5

102) What is the pOH value of an aqueous solution containing 1×10^{-3} mol of HCl dissolved in a 5 L solution at 298 K?

a. 3.7

b. 10.3

c. 3.0

d. 11.0

103) What is $[OH^-]$ in an aqueous solution at 298 K such that $[H^+] = 5.40 \times 10^{-3}$ M?

a. 5.40×10^{-3} M

b. 1.85×10^{-12} M

c. 3.42×10^{-10} M

d. 3.16×10^{-17} M

104) What is $[H^+]$ in an aqueous solution at 298 K such that $[OH^-] = 8.2 \times 10^{-6}$ M?

a. 2.51×10^{-9} M

b. 3.98×10^{-5} M

c. 1.21×10^{-9} M

d. 1.21×10^{-23} M

96	a	97	c	98	d	99	b	100	b
101	d	102	b	103	b	104	c		

105) If $[OH^-] = 2.5 \times 10^{-7}$ M in a solution, what is the pH of the solution?

a. 7.4

b. 4.7

c. 6.6

d. 3.3

106) The pH of a 0.2 M solution of HF hydrofluoric acid is 2.15, what is the Ka value of HF acid?

a. 3.2×10^{-9}

b. 2.6×10^{-4}

c. 4.7×10^{-11}

d. 1.8×10^{-5}

107) What is the pH of a 6.5×10^{-2} M solution of calcium hydroxide $Ca(OH)_2$?

a. 7.5

b. 9.8

c. 13.1

d. 4.3

Sec. (4) Neutralization

Neutralization reaction: A reaction between an acid and a base in an aqueous solution to produce a salt and water.

The neutralization reaction is a type of double replacement reaction.

acid + base → salt + water

$$HX + YOH \rightarrow XY + H_2O$$

Salt: An ionic compound composed of a base cation (positive ion) and an anion (negative ion) of an acid.

Antacids relieve indigestion symptoms by neutralizing the acidic solution in the stomach.

A neutralization reaction occurs when $Mg(OH)_2$ reacts with a solution of HCl acid.

$$2HCl_{(aq)} + Mg(OH)_{2(aq)} \rightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$$

A neutralization reaction occurs when NaOH reacts with an acid solution of HCl

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

These compounds exist as ions in aqueous solution:

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

Na^+ and Cl^- are spectator ions.

Net ionic equation:

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

or

$$H_3O^+_{(aq)} + OH^-_{(aq)} \rightarrow 2H_2O_{(l)}$$

108) What is the product of the neutralization reaction?

a. $H_2O_{(l)}$

b. $Ca(OH)_{2(s)}$

c. $HNO_{3(aq)}$

d. $H_3PO_{4(aq)}$

109) What are the two substances produced when $HCl_{(aq)}$ is neutralized with $KOH_{(aq)}$?

a. $KH_{(aq)}$, $HClO_{(aq)}$

b. $KCl_{(aq)}$, $H_2O_{(l)}$

c. $Cl^-_{(aq)}$, $KH_2O^+_{(aq)}$

d. $KCl_{(aq)}$, $H_3O^+_{(aq)}$

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

a. HI, NaOH

b. H_2O, NaI

c. H_2I, NaOH

d. HI, $Na(OH)_2$

111) What substances are produced in the neutralization reaction of $KOH_{(aq)}$ and $HCl_{(aq)}$

a. $KH_{(aq)} + HClO_{(aq)}$

b. $Cl^-_{(aq)} + KH_2O^+_{(aq)}$

c. $H_3O^+_{(aq)} + KCl_{(aq)}$

d. $H_2O_{(l)} + KCl_{(aq)}$

112) What is the net ionic equation for the reaction of HNO_3 with KOH?

a. $H_3O^+_{(aq)} + OH^-_{(aq)} \rightarrow 2H_2O_{(l)}$

b. $K^+_{(aq)} + OH^-_{(aq)} \rightarrow KOH_{(s)}$

c. $H^+_{(aq)} + NO_3^-_{(aq)} \rightarrow HNO_{3(aq)}$

d. $K^+_{(aq)} + NO_3^-_{(aq)} \rightarrow KNO_{3(aq)}$

113) What are the spectator ions produced by neutralizing HCl with $Mg(OH)_2$?

a. H^+, OH^-

b. H^+, Cl^-

c. Mg^{2+}, OH^-

d. Mg^{2+}, Cl^-

Acid-base indicators

Chemists use chemical dyes instead of a pH scale to determine the equivalence point of a titration.

Acid-base indicators: chemical dyes whose colors are affected by acid and base solutions.

Each indicator has its pH range at which the color change occurs (indicator's range)

indicator's range

less than range	in the range	more than range
acid color	endpoint color	base color

Example: phenolphthalein indicator has a range (8-10) and the colors are:

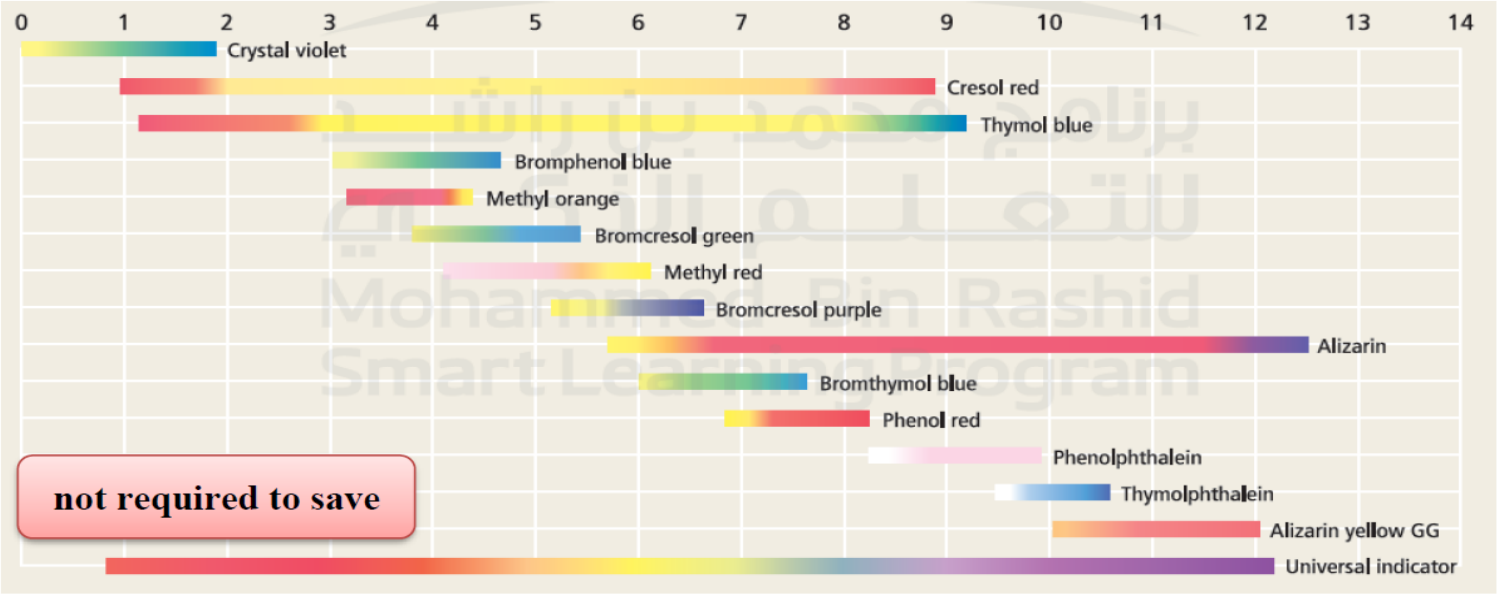
less than 8	8 – 10	more than 10
colorless	pink	purple

8 10

Endpoint: The point at which the indicator used in the titration changes color.

Why does tea color's changes when lemon juice is added to it?

Tea contains polyphenols with ionized hydrogen atoms, so they are weak acids. The addition of acid (lemon juice) slows down the ionization process and the color of the non-ionized polyphenols becomes more pronounced.



not required to save

Titration: A method of concentrating a solution by reacting a known volume of that solution with a solution of known concentration.

titratration solution and the equivalence point	strong acid	weak acid
strong base	neutral (pH = 7)	basic (pH > 7)
weak base	acidic (pH < 7)	no titration

Equivalence point: the point at which moles of the H^+ ion of the acid are equal to the moles of the OH^- ion of the base.

To find the concentration of an acid solution we titrate the acid solution with a base solution of known concentration.

To find the concentration of the base solution we titrate the base solution with an acid solution of known concentration.

Titration steps (acid of unknown concentration - base of known concentration)

1) A known volume of an acidic solution of unknown concentration is placed in a beaker, and the pH is measured using a pH meter.

2) The burette is filled with a base solution of known concentration, called the standard solution or titrant solution.

3) The base is added from the burette to the acid in the beaker slowly with stirring, the pH reading is recorded after each addition, this process continues until the reaction reaches the equivalence point.

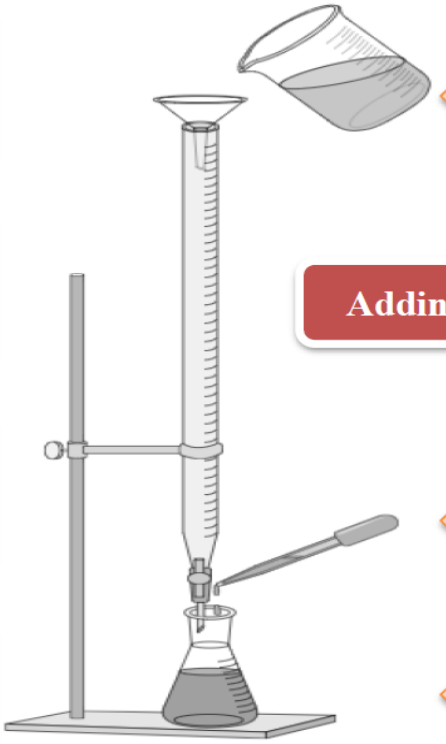
Titration of an acid of unknown concentration - a base of known concentration

4) We open the burette and slowly add the base until we reach the endpoint color

5) We close the burette and the volume of the base used to reach the equivalence point is calculated

6) We use the calculations to calculate the acid concentration used in the titration process

7) The titration process is repeated three times to ensure the accuracy of the calculations



Adding the base to the acid

3) We fill the burette with the base of the known concentration

2) We put 3 drops of the appropriate indicator for titration

1) We put a known volume of acid of unknown concentration

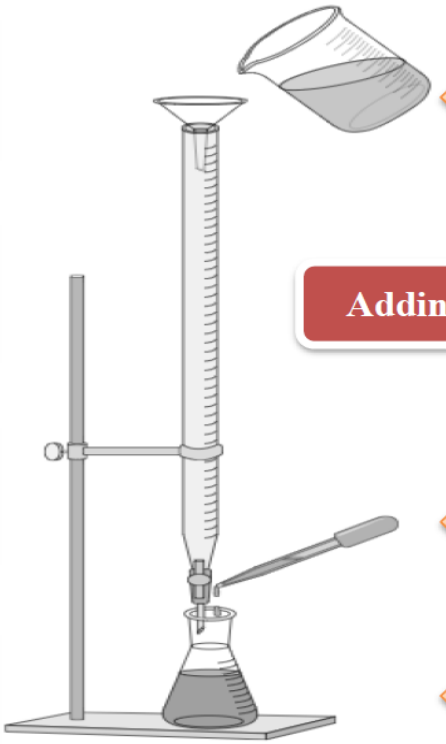
Titration of a base of unknown concentration - an acid of known concentration

4) We open the burette and slowly add the acid until we reach the endpoint color

5) We close the burette and the volume of the acid used to reach the equivalence point is calculated

6) We use the calculations to calculate the base concentration used in the titration process

7) The titration process is repeated three times to ensure the accuracy of the calculations



Adding the acid to the base

3) We fill the burette with the acid of the known concentration

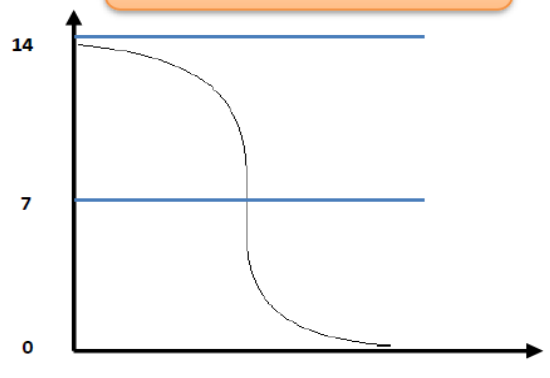
2) We put 3 drops of the appropriate indicator for titration

1) We put a known volume of base of unknown concentration

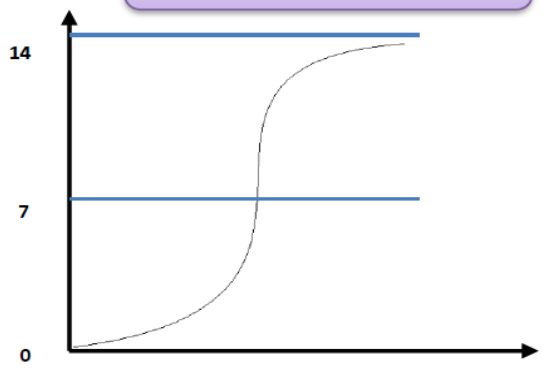
Types of titrations

Strong acid - strong base

add acid to base

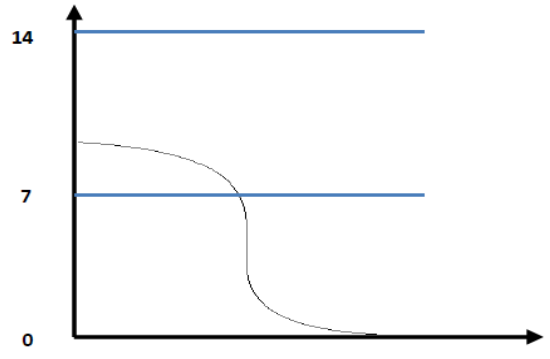


add base to acid

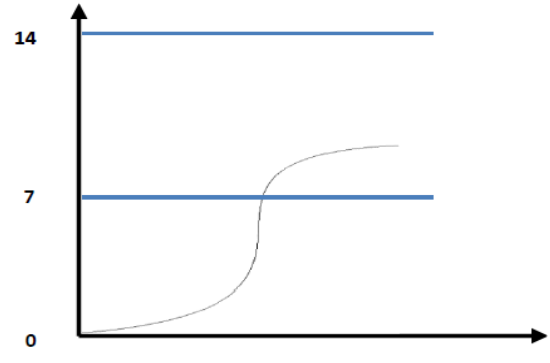


Strong acid - weak base

add acid to base

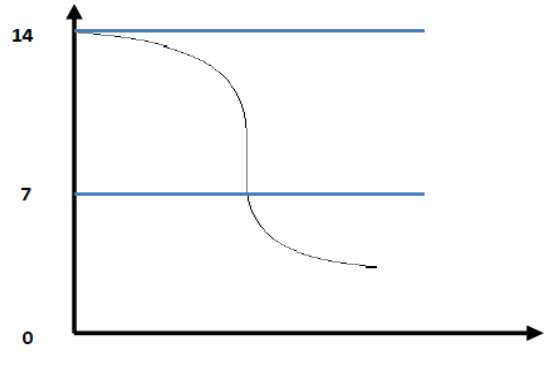


add base to acid

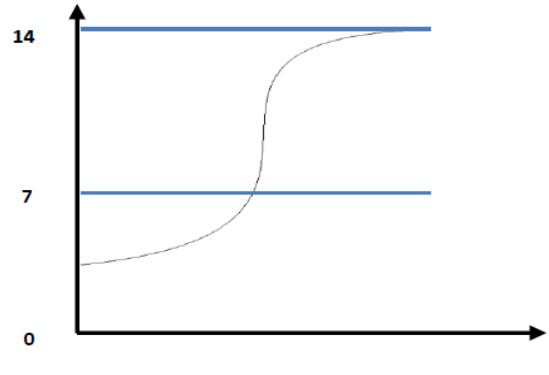


Weak acid - strong base

add acid to base

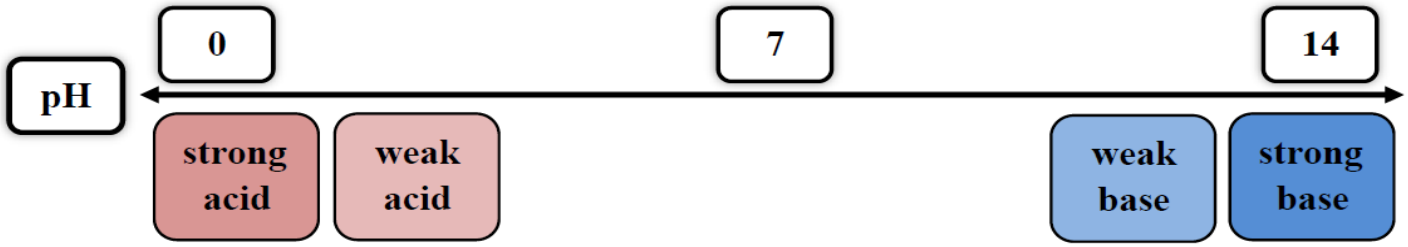


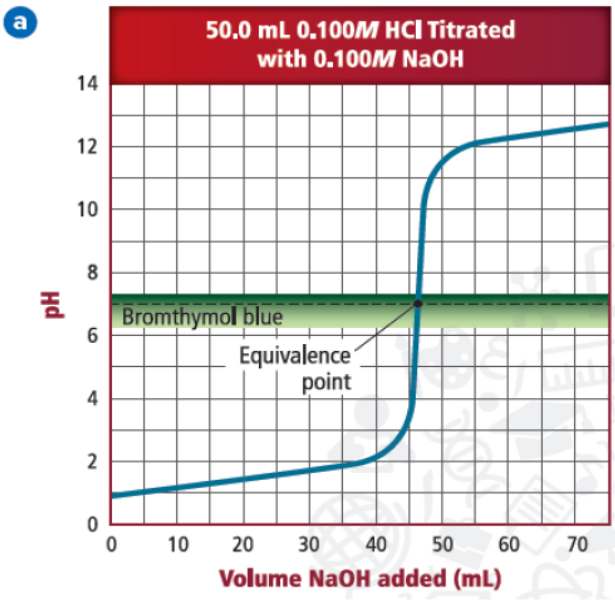
add base to acid

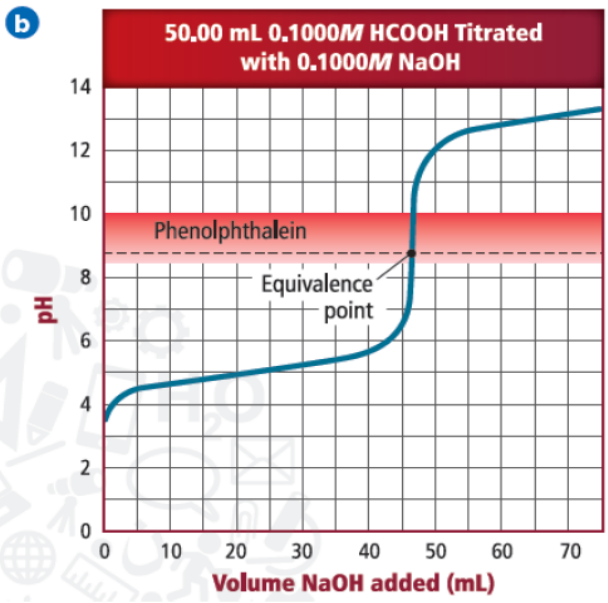


When the base is added to the acid in the titration process, the pH increases dramatically when the equivalence point is reached

When the acid is added to the base in the titration process, the pH decreases dramatically when the equivalence point is reached







114) What is the expected pH value at the equivalence point in a titration of a strong acid and a weak base?

a. 9

b. 7

c. 5

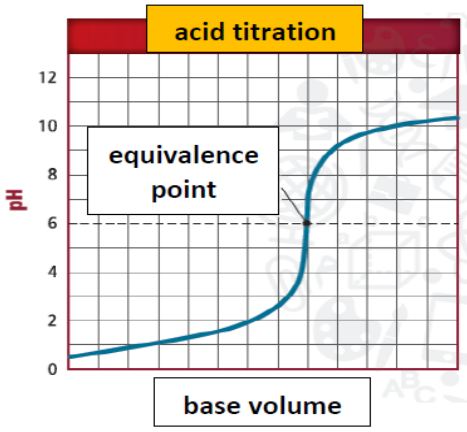
d. 1

115) When acid A reacts with base B, it produces compound C, which has a pH value of less than 7. What is the correct prediction for the strength of A and B?

choice	a.	b.	c.	d.
A	weak	strong	strong	weak
B	strong	weak	strong	weak

116) What acid-base indicator shown in the table will be suitable for a neutralization reaction whose titration curve is shown in figure?

indicator	bromochistol violet	violet crystal	methyl orange	phenolphthalein
range	5.2 – 6.8	0 – 1.9	3.1 – 4.4	8 – 10



a. methyl orange

b. phenolphthalein

c. bromochistol violet

d. violet crystal

Use the corresponding graph to answer the questions (117,118)

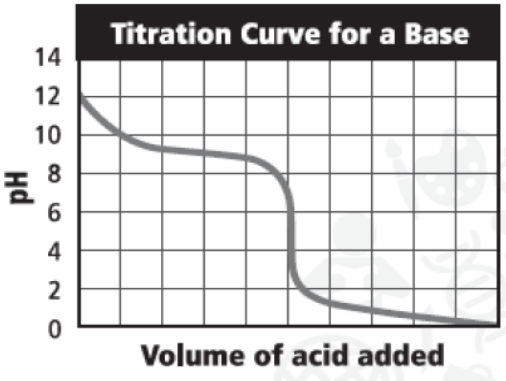
117) What is the pH value at the equivalence point of this titration?

a. 10

b. 9

c. 5

d. 1



118) What indicator would be effective for determining the endpoint of this titration?

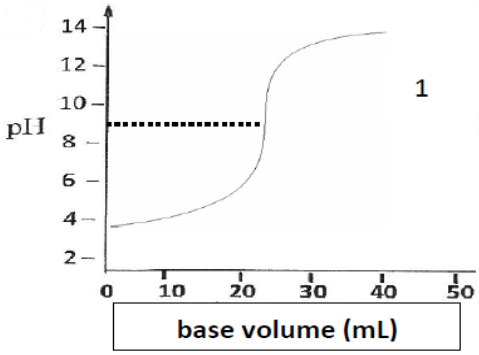
a. methyl orange (range 3.2 - 4.4)

b. bromocresol (range 3.8 - 5.4)

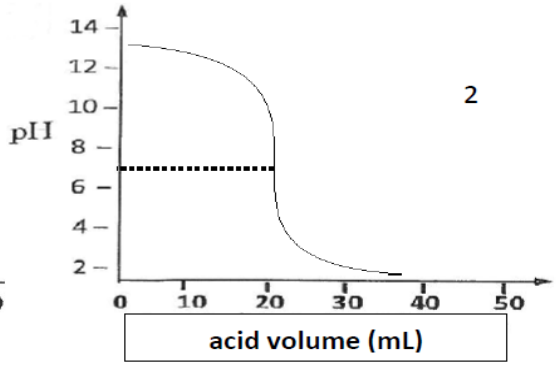
c. phenolphthalein (range 8.2-10)

d. thymol blue (range 8.0 - 9.6)

Using titration curves and indicators table, answer the following questions. (119-122)



1



2

indicator	range
A	3.1 – 4.4
B	6.2 – 7.6
C	8 – 10

119) What type of acid and base are used in titration (1)?

choice	a.	b.	c.	d.
acid	weak	strong	strong	weak
base	strong	weak	strong	weak

120) What is the pH value of the equivalence point of titration (2)?

a. 3 b. 10

c. 13 d. 7

121) What is the appropriate indicator symbol for the titration (1)?

a. C b. A

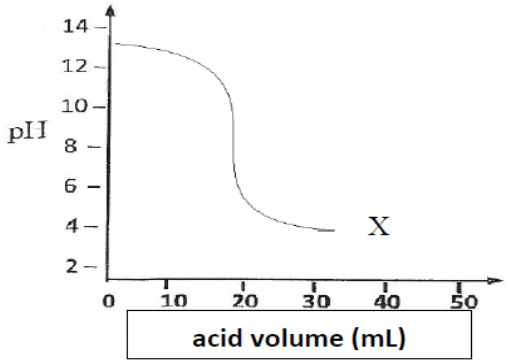
c. B d. all are not suitable

122) What substance is added from the burette in titration (2)?

a. strong base b. weak base

c. strong acid d. weak acid

Study the titration curve and answer the questions. (123 - 125)



123) What is the nature of the excess matter at point X?

a. strong base b. weak base

c. strong acid d. weak acid

124) What is the nature of the material that is gradually added from the burette to the beaker for the titration process?

a. strong base b. weak base

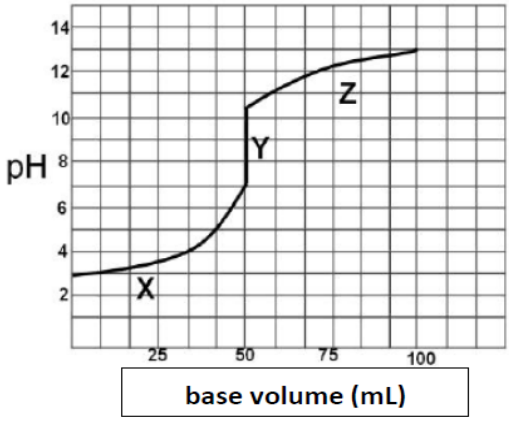
c. strong acid d. weak acid

125) What is the pH value of the equivalence point in this titration?

a. 9 b. 3

c. 7 d. 14

Study the adjacent figure and answer the following questions. (126 - 130)



126) Which of the following symbols represents the equivalence point?

a. X b. Z c. Y

127) Which of the following symbols is the acid in excess?

a. Y b. X c. Z

128) How much volume (mL) does the base need to add to completely neutralize the acid

a. 25 b. 75 c. 50

129) What is the acid and base strength of this titration?

choice	a.	b.	c.	d.
acid	weak	strong	strong	weak
base	strong	weak	strong	weak

130) Which of the following indicators is suitable for this titration?

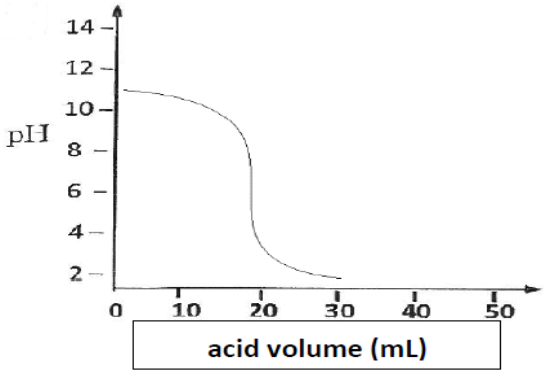
a. bromothymol blue

b. phenolphthalein

c. methyl orange

indicator	range
methyl orange	3.1 – 4.4
bromothymol blue	6.2 – 7.6
phenolphthalein	8 – 10

The adjacent figure represents an acid-base titration curve. Note the relationship between the volume of acid added and the pH values, then answer the questions. (131 - 133)



131) What is the pH value of the equivalence point in this titration?

a. 9.5 **b. 1**

c. 11 **d. 5.5**

132) How can the relationship between the neutralization point and the equivalence point be described in this titration?

a. equivalence point = neutralization point

b. equivalence point > neutralization point

c. equivalence point < neutralization point

133) Which of the following indicators is suitable for this titration?

a. phenol red

b. phenolphthalein

c. methyl orange

indicator	range
methyl orange	3.1 – 4.4
phenol red	6.4 – 8.0
phenolphthalein	8 – 10

Consider the following table and answer the following questions. (134, 135)

indicator	range	color		
		before range	in range	after range
phenolphthalein	8 – 10	colorless	pink	purple
phenol red	6.4 – 8	yellow	light yellow	pink
bromophenol blue	3 – 4.6	yellow	pink	purple

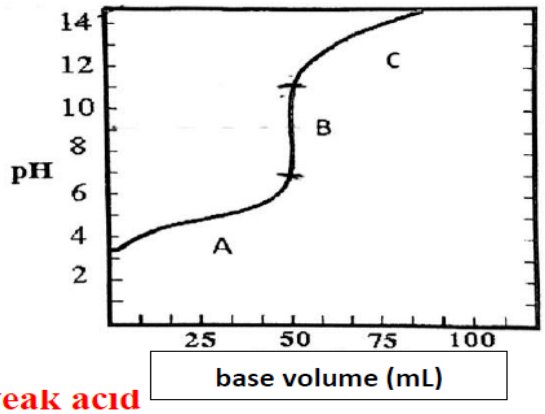
134) What is the appropriate indicator to titrate CH_3COOH with the base NaOH?

a. phenol red **b. phenolphthalein** **c. bromophenol blue**

135) What is the pH value of a solution that gives a purple color with bromophenol blue indicator and a yellow color with phenol red indicator?

a. 4.6 **b. 6.4** **c. 5.5** **d. 7.5**

Study the titration curve and answer the following questions. (136 - 140)



136) What does the symbol (B) on the curve represent?

a. neutralization point

b. end-point

c. equivalence point

137) What is the nature of substance at (C)?

a. strong base b. weak base d. weak acid

138) What is the expected pH value of a salt solution at its equivalence point?

a. 14 b. 7 c. 3 d. 9

139) Which of these pairs of solutions does the titration curve apply to?

a. CH_3COOH, NH_4OH b. HCl, NaOH

c. HCl, NH_4OH d. CH_3COOH, NaOH

140) Which of the following indicators is suitable for this titration?

a. bromothymol blue

b. phenolphthalein

c. methyl orange

indicator	range
methyl orange	3.1 – 4.4
bromothymol blue	6.2 – 7.6
phenolphthalein	8 – 10

Consider the following table and answer the following questions. (141, 142)

indicator	range	acid color	range color	base color
phenolphthalein	8 – 10	colorless	light pink	pink
bromophenol blue	3 – 4.6	yellow	light pink	purple
bromothymol blue	6.2 – 7.6	yellow	light green	purple

141) What is the appropriate indicator to titrate HBr with KOH?

a. bromothymol blue b. phenolphthalein c. bromophenol blue

142) What is the pH value of a solution that gives a purple color with bromophenol blue indicator and is colorless with phenolphthalein indicator?

a. 6.3 b. 2.5 c. 8.7 d. 9.6

Titration problems

First, you must write a balanced chemical equation between the acid and the base to determine the molar ratio.

1) Calculate the number of moles of the substance of known concentration (for the given).

$$n = M \times V$$

2) Calculate the number of moles of the unknown (for the unknown).

$$\text{given mol} \times \frac{\text{unknown mol}}{\text{given mol}}$$

3) Calculate molarity or volume (for the unknown).

$$M = \frac{n}{V} \qquad V = \frac{n}{M}$$

Or use equation

$$\frac{M \times V}{n}\ (\text{acid}) = \frac{M \times V}{n}\ (\text{base})$$

quantity		unit
symbol	meaning	
M	molarity	M (mol/L)
V	volume	L
n	mol number	mol

Acid-base ratios in titration

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

1 mol 1 mol

$$2HCl_{(aq)} + Mg(OH)_{2\ (aq)} \rightarrow MgCl_{2\ (aq)} + 2H_2O_{(l)}$$

2 mol 1 mol

143) If 44 mL of a 0.1 M KOH solution is needed for an equation of 20 mL of nitric acid HNO_3, what is the molarity of the acid solution?

a. 0.11 M

b. 0.22 M

c. 0.02 M

d. 1.14 M

144) In an acid-base titration 46 mL of a sulfuric acid solution is titrated to the endpoint of 74 mL of a 0.4 M NaOH solution, what is the molarity of the H_2SO_4 solution?

a. 0.08 M

b. 0.64 M

c. 0.16 M

d. 0.32 M

145) How many milliliters (volume) of 0.5 M NaOH equal 25 mL of 0.1 M H_3PO_4?

a. 15 mL

b. 45 mL

c. 5 mL

d. 30 mL

146) How many milliliters of 0.225 M HCl are needed to titrate 6.0 g in 1 L of KOH? (KOH = 56 g/mol)

a. 952 mL

b. 238 mL

c. 476 mL

d. 1904 mL

147) In a titration it was found that 25 mL of $Ba(OH)_2$ solution equilibrated with 10 mL of 0.066 M HCl solution to reach the equivalence point. What is the base concentration in mol/L and g/L. $Ba(OH)_2 = 171$ g/mol

choice	$[Ba(OH)_2]$ (mol/L)	$[Ba(OH)_2]$ (g/L)
a.	0.0264	4.51
b.	0.0264	1.54×10^{-4}
c.	0.0132	2.26
d.	0.0132	7.72×10^{-5}

148) If 50 mL of 0.6 M HCl is needed to neutralize 25 mL of NH_4OH ammonia solution used for household cleaning. What is the concentration of ammonia solution?

a. 2.4 M

b. 1.2 M

c. 3.6 M

d. 0.6 M

149) A volume of 18.5 mL of a standard solution of 0.1 M NaOH is required to equalize 25 mL of the HCOOH acid solution. What is the molarity of methanoic acid?

a. 0.296 M

b. 0.025 M

c. 0.222 M

d. 0.074 M

150) For a titration of 118 mL of a H_3PO_4 acid solution, a volume of 114 mL of a 0.8 M NaOH solution is needed, what is the concentration of the acid?

a. 0.26 M

b. 0.78 M

c. 0.086 M

d. 1.04 M

151) If 30 mL of 0.1 M NaOH is required to titrate 25 mL of HBr what is the molarity of the acid when the equivalence point is reached?

a. 1.2 M

b. 0.12 M

c. 2.4 M

d. 0.6 M

152) In a titration experiment, a sample of 0.2 M NaOH solution needed 20 mL of 0.15 M acetic acid CH_3COOH solution, what was the volume of the NaOH sample?

a. 45 mL

b. 60 mL

c. 15 mL

d. 30 mL

153) In a titration, 25 mL of 0.02 M H_2SO_4 solution was added to 100 mL of NaOH solution of unknown concentration to reach the equivalence point. What is the molarity of a basic solution?

a. 1.0 M

b. 2.0 M

c. 0.02 M

d. 0.01 M

154) Calculate the molarity of a solution of HCl if you know that 15 mL of HCl is equivalent to 20 mL of a 1.5×10^{-2} M solution of $Ca(OH)_2$?

a. 0.04 M

b. 0.08 M

c. 0.02 M

d. 0.01 M

151	b	152	c	153	d	154	a		

Salt Hydrolysis

Hydrolysis

dissociated salt cations give hydrogen ions to water

$XH^+_{(aq)} + H_2O_{(l)} \rightleftarrows X_{(aq)} + H_3O^+_{(aq)}$

hydrolysis of the cation (produces an acidic solution)

dissociated salt anions receive hydrogen ions from water

$Y^-_{(aq)} + H_2O_{(l)} \rightleftarrows HY_{(aq)} + OH^-_{(aq)}$

hydrolysis of the anion (produces an basic solution)

Why does hydrolysis happen to weak acids and weak bases? → **Because the ionization is incomplete and the reaction is reversible.**

To find out the acid and base that make up the salt

cation (+) is added to → OH^- → **We get the base**

anion (–) is added to → H^+ → **We get the acid**

Salts that produce basic solutions

Potassium fluoride KF dissociates into K^+, F^- ions in water

$KF_{(s)} \rightarrow K^+_{(aq)} + F^-_{(aq)}$

K^+ does not react with water ← **result from strong base KOH**

result from weak acid HF → **F^- reacts with water**

$F^-_{(aq)} + H_2O_{(l)} \rightleftarrows HF_{(aq)} + OH^-_{(aq)}$

It produces OH^- ions, making the solution basic.

Salts that produce acidic solutions

Ammonium chloride NH_4Cl dissociates into NH_4^+, Cl^- ions in water

$$NH_4Cl_{(s)} \rightarrow NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$$

- NH_4^+ reacts with water ← result from weak base NH_4OH
- result from strong acid HCl → Cl^- does not react with water

$$NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftarrows NH_{3(aq)} + H_3O^+{}_{(aq)}$$

H_3O^+ ions are produced, making the solution acidic.

Salts that produce neutral solutions

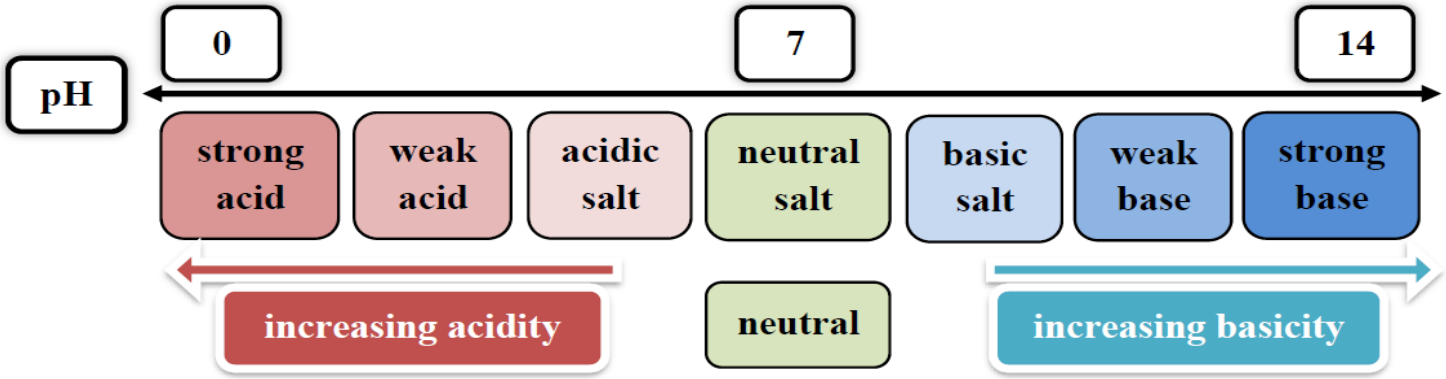
Sodium nitrate $NaNO_3$ decomposes into Na^+, NO_3^- ions in water

$$NaNO_{3(s)} \rightarrow Na^+{}_{(aq)} + NO_3^-{}_{(aq)}$$

- Na^+ does not react with water ← result from strong base NaOH
- result from strong acid HNO_3 → NO_3^- does not react with water

Little or no hydrolysis of this salt occurs.

The resulting salt solution is neutral.



155) Complete the table by writing the type of acid and base in terms of strength or weakness when the salt dissolves in water.

What is the type of salt (acidic, basic, or neutral).

Salt	Ions	Acid (H^+)		Base (OH^-)		Salt type
		formula	strengh	formula	strengh	
NaCl	Na^+ , Cl^-	$H^+ + Cl^-$ HCl		$Na^+ + OH^-$ NaOH		
CaS	Ca^{2+} , S^{2-}	$H^+ + S^{2-}$ H_2S		$Ca^{2+} + OH^-$ $Ca(OH)_2$		
NH_4NO_3	NH_4^+ , NO_3^-	$H^+ + NO_3^-$ HNO_3		$NH_4^+ + OH^-$ NH_4OH		
$KHCO_3$	K^+ , HCO_3^-	$H^+ + HCO_3^-$ H_2CO_3		$K^+ + OH^-$ KOH		
NH_4Br	NH_4^+ , Br^-	$H^+ + Br^-$ HBr		$NH_4^+ + OH^-$ NH_4OH		
K_2SO_4	K^+ , SO_4^{2-}	$H^+ + SO_4^{2-}$ H_2SO_4		$K^+ + OH^-$ KOH		

156) Which of the following ions undergoes hydrolysis in aqueous solution?

a. PO_4^{3-} b. NO_3^-

c. SO_4^{2-} d. K^+

157) What kind of reaction takes place in an aqueous solution when a salt of a weak acid and a strong base is dissolved?

a. hydrolysis of water

b. hydrolysis of cation

c. hydrolysis of anion

d. hydrolysis of cation and anion

158) Which of the following salts undergoes hydrolysis for the cation only?

a. CH_3COONH_4

b. CH_3COOK

c. $(NH_4)_2SO_4$

d. $Al_2(SO_4)_3$

159) Which of the following solutions of salts does not hydrate any of the ions?

a. KF

b. Na_2S

c. NH_4Br

d. Na_2SO_4

160) Which of the following solutions of salts has a basic effect?

a. NaCl

b. Na_2CO_3

c. KNO_3

d. K_2SO_4

161) Which of the following solutions of salts does not have a pH value of 7?

a. $LiNO_3$

b. $KClO_4$

c. NaCl

d. NH_4Cl

162) Which of the following equations describes the hydrolysis of NH_4NO_3 in water?

a. $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftarrows NH_{3(aq)} + H_3O^+{}_{(aq)}$

b. $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftarrows NH_5^{2+}{}_{(aq)} + OH^-{}_{(aq)}$

c. $NO_3^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows HNO_{3(aq)} + H_3O^+{}_{(aq)}$

d. $NO_3^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows HNO_{3(aq)} + OH^-{}_{(aq)}$

163) Which of the following equations describes the hydrolysis of $CaCO_3$ in water?

a. $Ca^{2+}{}_{(aq)} + H_2O_{(l)} \rightleftarrows Ca(OH)_{2(aq)} + H_3O^+{}_{(aq)}$

b. $Ca^{2+}{}_{(aq)} + H_2O_{(l)} \rightleftarrows Ca(OH)_{2(aq)} + OH^-{}_{(aq)}$

c. $CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftarrows HCO_3^-{}_{(aq)} + H_3O^+{}_{(aq)}$

d. $CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftarrows HCO_3^-{}_{(aq)} + OH^-{}_{(aq)}$

164) Which of the following salt solutions does not hydrate in water?

a. $(NH_4)_2SO_4$

b. K_2SO_4

c. K_2CO_3

d. Na_2CO_3

165) What is the pH value and type of solution produced by titrating NH_4OH with HBr?

a. pH > 7, the salt solution is acidic

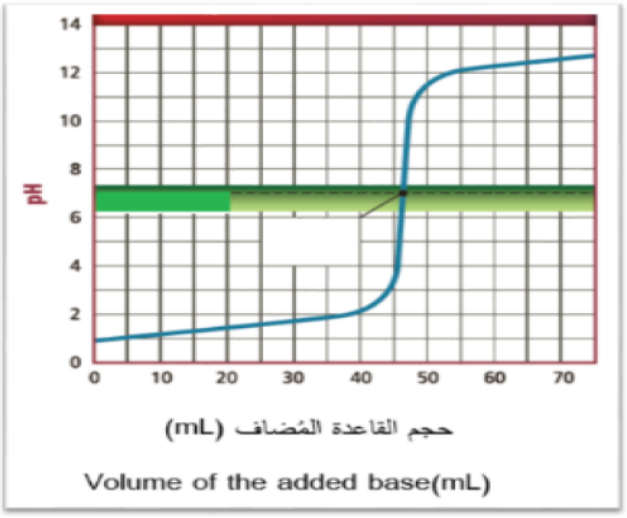
b. pH > 7, the salt solution is basic

c. pH < 7, the salt solution is acidic

d. pH < 7, the salt solution is basic

166) Which of the following is true regarding the titration curve below?

pH values at which the indicator's color changes	indicator
3.1–4.7	Bromophenol blue
3.2–4.6	Methyl orange
4.2–6.2	Methyl red
6.0–7.6	Bromothymol blue



a. the acid is weak, and the base is strong and the suitable indicator is Methyl orange

b. the acid is strong, and the base is weak and the suitable indicator is Methyl red

c. the acid is strong, and the base is strong and the suitable indicator is Bromothymol blue

d. the acid is weak, and the base is weak and the suitable indicator is Bromophenol blue

167) In an acid-base titration, 25.8 mL of a solution of sulfuric acid H_2SO_4 is titrated to the end point with 54.7 mL of 0.65 M potassium hydroxide KOH solution. What is the molarity of the H_2SO_4 solution? $H_2SO_{4(aq)} + 2KOH_{(aq)} \rightarrow K_2SO_{4(aq)} + 2H_2O_{(l)}$

a. 1.2 M

b. 0.6 M

c. 0.7 M

d. 1.4 M

168) Which of the following salts produces an acidic solution when dissolves in water?

a. rubidium acetate $RbC_2H_3O_2$

b. calcium carbonate $CaCO_3$

c. ammonium nitrate NH_4NO_3

d. potassium fluoride KF