Lesson 1: Introduction to Acids and Bases

Properties of Acids and Bases

Acids	Bases
Physical properties: • Carbonic and phosphoric acids give carbonated beverages their **sharp** taste. • Citric and ascorbic acids give lemons their **tartness**. • Acetic acid makes vinegar taste **sour**.	**Physical properties:** • Taste **bitter**. • Soap becomes **slippery** when it gets wet.
Electrical conductivity: Acids and bases produce ions that cause the resulting solution to become a conductor.	
Acids cause blue litmus paper to **turn red**.	Bases cause red litmus paper to **turn blue**.

Acids Reactions with metals

Magnesium and zinc react with aqueous solutions of acids to produce **hydrogen gas**.

$$Zn\ (s) + 2HCL(aq) \longrightarrow ZnCl_2\ (aq) + H_2\ (g)$$

Acids Reactions with metal carbonates

Metal carbonates react with aqueous solutions of acids to produce **carbon dioxide (CO_2) gas and water**.

$$NaHCO_3\ (s) + HC_2H_3O_2\ (aq) \longrightarrow NaC_2H_3O_2\ (aq) + H_2O(l) + CO_2\ (g)$$

Geologists identify rocks as limestone ($CaCO_3$) by using a hydrochloric acid solution. If a few drops of the acid produce bubbles of CO_2, the rock contains limestone.

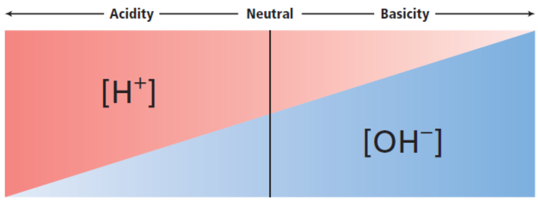
Write balanced equations for the reactions between the following.

a. aluminum and sulfuric acid

b. calcium carbonate and hydrobromic acid

Challenge Write the net ionic equation for the reaction between calcium carbonate and hydrobromic acid.

Hydronium and hydroxide ions



All water solutions contain hydrogen ions (H^+) and hydroxide ions (OH^-).

An **acidic solution** contains more hydrogen ions than hydroxide ions.

A **basic solution** contains more hydroxide ions than hydrogen ions.

Neutral solution is neither acidic nor basic. It contains equal concentrations of hydrogen ions and hydroxide ions.

Pure water produces equal numbers of H^+ ions and OH^- ions in a process called **self-ionization**, in which water molecules react to form a hydronium ion (H_3O^+) and a hydroxide ion.

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

$$\text{Water molecules} \rightleftharpoons \text{Hydronium ion} + \text{Hydroxide ion}$$

The **hydronium ion** is a hydrogen ion which has a water molecule attached to it by a covalent bond. The symbols H^+ and H_3O^+ can be used interchangeably, as this simplified self-ionization equation shows.

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The Arrhenius Model

An **acid** is a substance that contains hydrogen and ionizes to produce hydrogen ions in aqueous solution.

A **base** is a substance that contains a hydroxide group and dissociates to produce a hydroxide ion in aqueous solution.

When hydrogen chloride gas dissolves in water. HCl molecules ionize to form H^+ ions, which make the solution acidic. $HCl(g) \longrightarrow$ .... + ...

When the ionic compound sodium hydroxide (NaOH) dissolves in water, it dissociates to produce OH^- ions, which make the solution basic. $NaOH(s) \longrightarrow$ .... + ...

<u>The shortcomings of Arrhenius model:</u>

Ammonia (NH_3) and sodium carbonate (Na_2CO_3), can they considered as Arrhenius bases? Why?

....

Yet both substances produce hydroxide ions in solution and are well-known bases.

Which of the following is correct?	أي مما يأتي صحيح؟
In basic solution $[H^+] > [OH^-]$	في المحلول القاعدي يكون $[H^+] > [OH^-]$ ○
In neutral solution $[H^+] > [OH^-]$	في المحلول المتعادل يكون $[H^+] > [OH^-]$ ○
In acidic solution $[H^+] > [OH^-]$	في المحلول الحمضي يكون $[H^+] > [OH^-]$ ○
In acidic solution $[H^+] < [OH^-]$	في المحلول الحمضي يكون $[H^+] < [OH^-]$ ○

The Bronsted-Lowry Model

An **acid** is a hydrogen-ion donor. A **base** is a hydrogen ion acceptor.

Hydrogen ion donors and acceptors

Use this equation to answer the following questions: $HX(aq) + H_2O(l) \rightleftharpoons H_3O^+ (aq) + X^- (aq)$

Which substance is the acid? .... Why? ....

The water molecule acts as a .... because ....

A **conjugate acid** is the species produced when a base accepts a hydrogen ion. (In this example it's ....)

A **conjugate base** is the species that results when an acid donates a hydrogen ion. (In this example it's ....)

The hydronium ion (H_3O^+) is the conjugate acid of the base H_2O.

The X^- ion is the conjugate base of the acid HX.

A **conjugate acid-base pair** consists of two substances related to each other by the donating and accepting of a single hydrogen ion.

$$\underset{\text{Acid}}{HX(aq)} + \underset{\text{Base}}{H_2O(l)} \rightleftharpoons \underset{\text{Conjugate acid}}{H_3O^+(aq)} + \underset{\text{Conjugate base}}{X^-(aq)}$$

Explain how the ion HCO_3^- can be both an acid and a base.

....

Hydrogen fluoride—a Bronsted-Lowry acid

Hydrogen fluoride is an acid. Why?

....

Which species is the conjugate base of hydrogen fluoride? ....

What is the other conjugate acid-base pair? ....

What are the acid and base in the reverse reaction? ....

Hydrogen fluoride is used to manufacture a variety of fluorine-containing compounds, such as the nonstick coating on the kitchenware. It is an acid according to both the Arrhenius and Brønsted-Lowry definitions.

Ammonia—a Brønsted-Lowry base

Ammonia does not fit the Arrhenius model of bases because ....

....

Label the next equation:

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

Water—a Bronsted-Lowry acid and base

When HF dissolves in water, water acts as a ………………….; when NH_3 dissolves in water, water acts as an ……………………..

Water and other substances that can act as both acids and bases are said to be **amphoteric**.

PRACTICE Problems

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

	Acid	Conjugate base	Base	Conjugate acid
a.				
b.				
c.				

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.

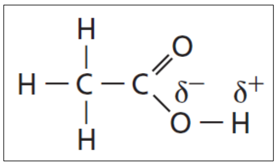
………

………

Monoprotic Acids

An acid that can donate only one hydrogen ion is called a **monoprotic** acid. (Examples: …………………………………………)

The formula of acetic acid is often written $HC_2H_3O_2$.why.



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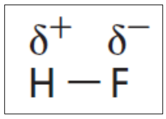
Ionizable hydrogen atoms

Explain the difference between acetic acid's ionizable hydrogen atom and the other three hydrogen atoms.

………

………

Hydrofluoric acid (HF) is an acid in solution. Explain.



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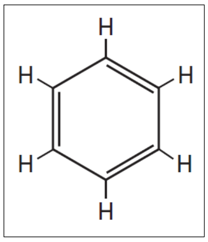
Explain why benzene is not an acid.



………

………

Polyprotic Acids

Any acid that has more than one ionizable hydrogen atom.

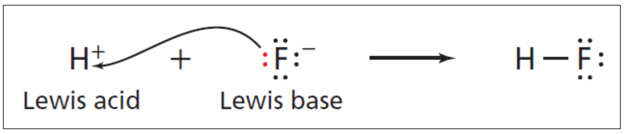
diprotic acids	triprotic acids
Acids that contain two ionizable hydrogen atoms.	Acids with three hydrogen ions to donate.
Examples:	Examples:

Write the three ionizations of phosphoric acid.

The Lewis Model

Lewis acid is an ion or molecule with a vacant atomic orbital that can **accept** (share) an **electron pair**.

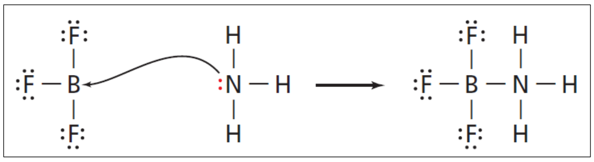
Lewis base is an ion or molecule with a lone **electron pair** that it can **donate** (share).



The H^+ ion is the Lewis acid because ....

The fluoride ion is the Lewis base ....

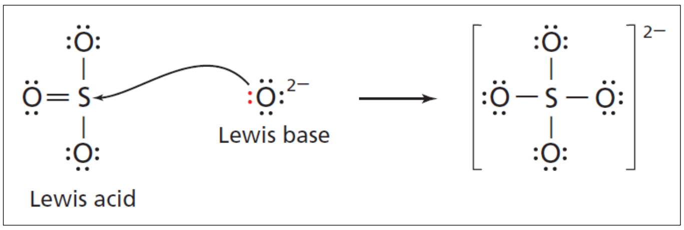
In this reaction:



What is the Lewis acid? ....

What is the Lewis base? ....

Another Lewis acid-base reaction occurs when gaseous sulfur trioxide (SO_3) is brought into contact with solid magnesium oxide (MgO).



$$SO_3\,(g) + MgO(s) \longrightarrow MgSO_4\,(s)$$

This reaction is important for some reasons:

- Magnesium sulfate forms the heptahydrate known as Epsom salt ($MgSO_4{\cdot}7H_2O$). Epsom salt has many uses, including **soothing sore muscles** and **acting as a plant nutrient**.
- In environmental applications. When MgO is injected into the flue gases of coal-fired power plants, it reacts with and removes SO_3, which can combine with water in the air to form sulfuric acid, which falls to Earth as acid precipitation.

Anhydrides

An acid anhydride is an oxide that can combine with water to form an acid. (example: CO_2)

Other oxides combine with water to form bases. (example: CaO)

CO_2 will form .... CaO will form ....

In general, oxides of metallic elements form bases, oxides of nonmetals form acids.

Assessment

Which of the following refers to a basic solution?

- $[\,H^+\,] > [\,OH^-\,]$
- $[\,H^+\,] < [\,OH^-\,]$
- $[\,H^+\,] = [\,OH^-\,]$
- $[\,H^+\,]\,[\,OH^-\,] = 1 \times 10^{-7}M$

Which of the following is correct about to the reaction below?	أي العبارات التالية صحيحة بالنسبة للتفاعل أدناه؟
$NH_3(aq) + H_2O(l) \leftrightharpoons NH_4^+(aq) + OH^-(aq)$	
A. NH_3 is considered as Arrhenius base	A. تُعتبر NH_3 قاعدة أرهينوس
B. H_2O is considered as a Bronsted - Lowry acid	B. يُعتبر H_2O حمض برونشتد - لوري
C. NH_3 accepts an electron pair from H_2O	C. NH_3 تستقبل زوج إلكترونات من H_2O
D. H_2O accepts H^+ ion in the forward reaction	D. H_2O يستقبل أيون H^+ في التفاعل الأمامي

What gas is produced during the reaction between sodium carbonate and acetic acid solution	ما الغاز الناتج خلال تفاعل كربونات الصوديوم الهيدروجينية مع المحلول المائي لحمض الأسيتيك؟

CO_2

H_2

O_2

N_2

Which of the following is correct about to the reaction below?	أي العبارات التالية صحيحة بالنسبة للتفاعل أدناه؟
$$H^+ + F^- \rightarrow H - \ddot{F}:$$	
A. F^- ion accepts an electron pair	A. يستقبل أيون F^- زوج إلكترونات
B. F^- ion is considered as acceptor of hydrogen ion	B. يُعتبر F^- مستقبل لأيون الهيدروجين
C. H^+ ion is considered as Arrhenius base	C. يُعتبر أيون H^+ قاعدة أرهينوس
D. H^+ ion donates an electron pair to F^- ion	D. يمنح أيون H^+ زوج من الإلكترونات إلى أيون F^-

Which of the following is a property of **acids**? — أي مما يأتي تُعتبر من خصائص **الأحماض**؟

- Turn red litmus paper blue — تُحول ورقة تباع الشمس الحمراء إلى اللون الأزرق
- Feel slippery — زلقة الملمس
- React with zinc to produce hydrogen gas — تتفاعل مع الخارصين لتُنتج غاز الهيدروجين
- It tastes bitter — طعمها مر

What is the substance that contains hydrogen, and ionizes to produce hydrogen ions in aqueous solution? — ما المادة التي تحتوي على هيدروجين وتتأين لإنتاج أيونات الهيدروجين في المحلول المائي؟

- Lewis acid — حمض لويس
- Lewis base — قاعدة لويس
- Arrhenius acid — حمض أرهينيوس
- Arrhenius base — قاعدة أرهينيوس

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

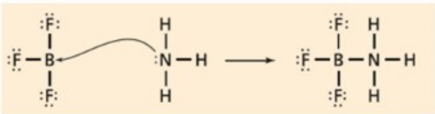
في معادلة التفاعل أدناه، أي مما يأتي صحيح؟

$$HX(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + X^-(aq)$$

- HX donates hydrogen ion to water H_2O — يمنح HX أيون هيدروجين للماء H_2O
- H_2O is a Bronsted–Lowry acid — يُعتبر H_2O من أحماض برونشتد – لوري
- HX is a Bronsted–Lowry base — يُعتبر HX من قواعد برونشتد – لوري
- HX accepts a hydrogen ion from water H_2O — يستقبل HX أيون هيدروجين من الماء H_2O

Which of the following is true?

أي مما يأتي صحيح؟

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

- The ammonia NH_3 in reaction **2** is an electron pair acceptor — تُعتبر الأمونيا NH_3 في التفاعل **2** مستقبل زوج إلكترونات
- The ammonia NH_3 in reaction **1** is a Lewis base — تُعتبر الأمونيا NH_3 في التفاعل **1** قاعدة لويس
- The ammonia NH_3 in reaction **2** is a Bronsted–Lowry acid — تُعتبر الأمونيا NH_3 في التفاعل **2** حمض برونشتد – لوري
- The ammonia NH_3 in reaction **1** is a Lewis acid — تُعتبر الأمونيا NH_3 في التفاعل **1** حمض لويس

Which of the following is considered a conjugate acid –base pair?

أي مما يأتي يُعتبر زوج حمض قاعدة مرافق؟

- H_3PO_4 , HPO_4^{2-}
- H_2O , O^{2-}
- HNO_3 , NO_3^-
- H_2SO_4 , SO_4^{2-}

Which of the following chemical equations represents a reaction between the aqueous solution of an acid and metal hydrogen carbonate?

أي المعادلات الكيميائية التالية تُمثل تفاعل بين المحلول المائي لحمض وكربونات الفلز الهيدروجينية ؟

$Cu_{(s)} + 4HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2H_2O_{(l)} + 2NO_{2(g)}$

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

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

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

Which of the following is not a conjugate acid– base pair?

أي مما يلي ليس زوج حمض قاعدة مرافق؟

$HClO_4/ClO_4^-$

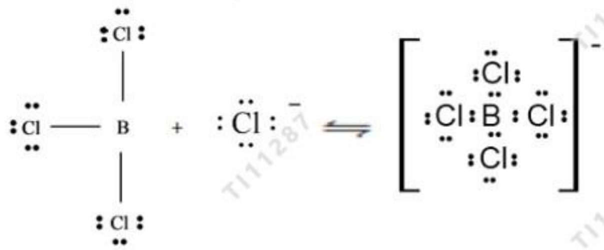
HSO_3^-/SO_3^{2-}

H_2O/OH^-

H_3O^+/OH^-

Why does **BCl_3** represent Lewis's acid in the following reaction?

لماذا يُمثل **BCl_3** حمض لويس في التفاعل التالي؟



Because it is proton acceptor from the base Cl^- — لأنه مستقبل للبروتون من القاعدة Cl^-

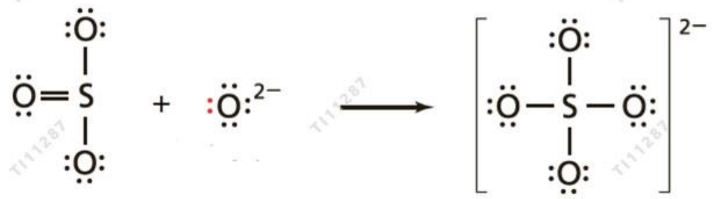
Because it is proton donor to the base Cl^- — لأنه مانح للبروتون إلى القاعدة Cl^-

Because it is an electron pair donor to the base Cl^- — لأنه مانح لزوج إلكترونات إلى القاعدة Cl^-

Because it is an electron pair acceptor from the base Cl^- — لأنه مستقبل لزوج إلكترونات من القاعدة Cl^-

Why does O^{2-} represent Lewis's base in the following reaction?

لماذا تُمثل O^{2-} قاعدة لويس في التفاعل التالي؟



- Because it accepted a proton from SO_3 — لأنها استقبلت بروتونًا من SO_3
- Because it donated a proton to SO_3 — لأنها منحت بروتونًا إلى SO_3
- Because it donated a pair of electrons to SO_3 — لأنها منحت زوجًا من الإلكترونات إلى SO_3
- Because it accepted a pair of electrons from SO_3 — لأنها استقبلت زوجًا من الإلكترونات من SO_3

Which of the following is amphoteric substance?

أي مما يلي يُعتبر مادة أمفوتيرية؟

- HPO_4^{2-}
- H^+
- H_3PO_4
- PO_4^{2-}

Which of the following chemical equations represents the reaction that geologists use to identify limestone rocks from other rocks?

أي المعادلات الكيميائية الاتية تمُثل التفاعل الذي يستخدمه الجيولوجيين للتعرف على الصخور الجيرية من بقية الصخور؟

- $CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
- $NaHCO_{3(s)} + HC_2H_3O_{2(aq)} \rightarrow NaC_2H_3O_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
- $Cu_{(s)} + 4HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2H_2O_{(l)} + 2NO_{2(g)}$
- $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$