

CHEMISTRY

11 ADVANCED SCENARIO 2

XXX



أ. طارق محمد
معلم مادة الكيمياء



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TERM 3 BOOKLET

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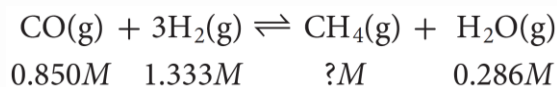




Chapter: Chemical Equilibrium

Lesson 3: Using Equilibrium constants

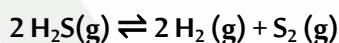
Calculating Equilibrium Concentrations



The K_{eq} for the reaction is 3.933 at 1200 K. calculate the concentration of CH_4 .

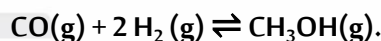
Write the constant equilibrium expression for this reaction. Then solve for CH_4 .

At a temperature of 1405 K, hydrogen sulfide, which has a foul odor resembling rotten eggs, decomposes to form hydrogen and a diatomic sulfur molecule, S_2 . The equilibrium constant for the reaction is 2.27×10^{-3} .



What is the concentration of hydrogen gas if $[\text{S}_2] = 0.0540 \text{ mol/L}$ and $[\text{H}_2\text{S}] = 0.184 \text{ mol/L}$?

At a certain temperature, $K_{eq} = 10.5$ for the equilibrium



Calculate the following concentrations:

- $[\text{CO}]$ in an equilibrium mixture containing 0.933 mol/L H_2 and $1.32 \text{ mol/L CH}_3\text{OH}$
- $[\text{H}_2]$ in an equilibrium mixture containing 1.09 mol/L CO and $0.325 \text{ mol/L CH}_3\text{OH}$
- $[\text{CH}_3\text{OH}]$ in an equilibrium mixture containing 0.0661 mol/L H_2 and 3.85 mol/L CO

CHALLENGE In a generic reaction $\text{A} + \text{B} \rightleftharpoons \text{C} + \text{D}$, 1.00 mol of A and 1.00 mol of B are allowed to react in a 1-L flask until equilibrium is established. If the equilibrium concentration of A is 0.450 mol/L , what is the equilibrium concentration of each of the other substances? What is K_{eq} ?



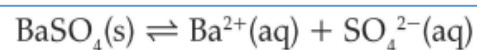
The Solubility Product Constant

Some ionic compounds such as sodium chloride, dissolve readily in water and some, such as barium sulfate (BaSO_4) barely dissolve.

Write the ionic equation for NaCl in water:

Sometimes low solubility is also important.

At equilibrium, the solution is saturated, the concentrations of ions are small.



Although barium ions are toxic to humans, patients must ingest barium sulfate prior to having an X-ray of the digestive tract taken.

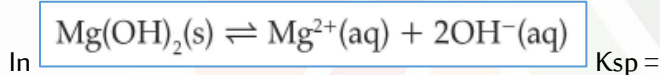
Can patients safely ingest BaSO_4 ?

Writing solubility product constant expressions

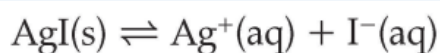
The **solubility product constant (K_{sp})** expression is the product of the concentrations of the dissolved ions, each raised to the power equal to the coefficient of the ion in the chemical equation.

$$K_{sp} = [\text{Ba}^{2+}][\text{SO}_4^{2-}] = 1.1 \times 10^{-10}$$

The small value of K_{sp} for BaSO_4 indicates what?



Using solubility product constant



$$K_{sp} = [\text{Ag}^{+}][\text{I}^{-}] = 8.5 \times 10^{-17} \text{ at } 298 \text{ K}$$

$$[\text{Ag}^{+}][\text{I}^{-}] = (s)(s) = s^2 = 8.5 \times 10^{-17}$$

$$s = \sqrt{8.5 \times 10^{-17}} = 9.2 \times 10^{-9} \text{ mol/L}$$

Calculating Molar Solubility

If $K_{sp} = 2.5 \times 10^{-10}$. calculate the solubility in mol/L of copper(II) carbonate (CuCO_3) at 298 K.

Question At 298 K, K_{sp} for lead(II) iodide is 9.8×10^{-9} . What is the molar solubility of PbI_2 at 298 K?

CHALLENGE The K_{sp} of lead(II) carbonate (PbCO_3) is 7.40×10^{-14} at 298 K. What is the solubility of lead(II) carbonate in g/L?

Molar mass of $\text{PbCO}_3 = 267.2 \text{ g/mol}$





Calculating Ion Concentration

Calculate the concentration of $[\text{OH}^-]$ in a saturated solution of $\text{Mg}(\text{OH})_2$ at 298 K. The K_{sp} equals 5.6×10^{-12} .

Calculate the concentration of $[\text{Ag}^+]$ in a solution of AgBr at equilibrium. $K_{\text{sp}} = 5.4 \times 10^{-13}$.

Calculate the concentration of $[\text{F}^-]$ in a saturated solution of CaF_2 . $K_{\text{sp}} = 3.5 \times 10^{-11}$.

Calculate the concentration of $[\text{Ag}^+]$ in a solution of Ag_2CrO_4 at equilibrium 1.1×10^{-12} .

Calculate the solubility of Ag_3PO_4 ($K_{\text{sp}} = 2.6 \times 10^{-18}$).

THE GARDEN ACADEMY
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CHALLENGE The solubility of silver chloride (AgCl) is $1.86 \times 10^{-4} \text{ g/100 g of H}_2\text{O}$ at 298 K. Calculate the K_{sp} for AgCl .

molar mass of $\text{AgCl} = 143.3 \text{ g/mol}$





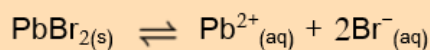
Extra Final Exam Questions

What is the solubility in mol/L of lead bromide PbBr_2 at 298 K?

ما ذائبية بروميد الرصاص PbBr_2 عند 298 K (بوحدة mol/L)؟

if $K_{sp} = 6.6 \times 10^{-6}$

إذا كان $K_{sp} = 6.6 \times 10^{-6}$



0.024

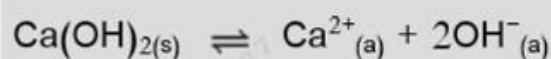
0.018

0.030

0.012

If the K_{sp} of calcium hydroxide Ca(OH)_2 is 5.32×10^{-6} at 298 K. What is the solubility of calcium hydroxide in mol/L?

إذا كانت قيمة K_{sp} لهيدروكسيد الكالسيوم Ca(OH)_2 تساوي 5.32×10^{-6} عند 298 K. فما ذائبية هيدروكسيد الكالسيوم بوحدة mol/L؟



3.30×10^{-8}

1.60×10^{-3}

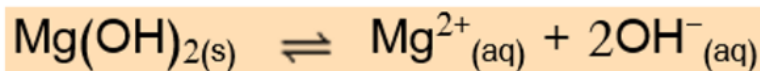
2.80×10^{-7}

1.10×10^{-2}



If the K_{sp} of magnesium hydroxide $Mg(OH)_2$ is 5.60×10^{-12} at 298 K. What is the solubility of magnesium hydroxide in mol/L?

إذا كانت قيمة K_{sp} لهيدروكسيد المغنيسيوم $Mg(OH)_2$ تساوي 5.60×10^{-12} عند 298 K . فما ذائبية هيدروكسيد المغنيسيوم بوحدة mol/L ؟



3.45×10^{-5}



1.12×10^{-4}



4.73×10^{-6}

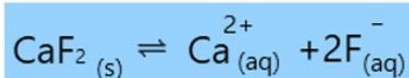


2.52×10^{-4}



What is the value of k_{sp} for CaF_2 compound if the solubility of calcium fluoride CaF_2 is 2.06×10^{-4} M at 298 K?

ما قيمة k_{sp} للمركب CaF_2 إذا كانت ذائبية فلوريد الكالسيوم CaF_2 تساوي 2.06×10^{-4} M عند درجة حرارة 298 K ؟



4.2×10^{-4}

1.8×10^{-7}

8.8×10^{-12}

3.5×10^{-11}



The reaction : $\text{COCl}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{Cl}_2(\text{g})$

reaches equilibrium at 900 K.

$$K_{\text{eq}} = 8.20 \times 10^{-2}$$

If the equilibrium concentrations of CO and Cl_2 are 0.150 mol/L,

what is the equilibrium concentration of COCl_2 ?

التفاعل : $\text{COCl}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{Cl}_2(\text{g})$

يصل إلى حالة الاتزان عند درجة حرارة 900 K .

$$K_{\text{eq}} = 8.20 \times 10^{-2}$$

إذا كانت تراكيز الاتزان لـ CO و Cl_2 هي 0.150 mol/L ،

فما تركيز الاتزان لـ COCl_2 ؟

$$0.274 \text{ mol/L}$$

$$0.183 \text{ mol/L}$$

$$3.65 \text{ mol/L}$$

$$0.550 \text{ mol/L}$$

What is the concentration of silver ion $[\text{Ag}^+]$ in Ag_2CO_3 solution at equilibrium if the $K_{\text{sp}} = 8.52 \times 10^{-12}$ at 298 K?

ما تركيز أيون الفضة $[\text{Ag}^+]$ في محلول Ag_2CO_3 عند الاتزان إذا كان

$K_{\text{sp}} = 8.52 \times 10^{-12}$ عند 298 K ؟

$$3.24 \times 10^{-2} \text{ M}$$

$$8.81 \times 10^{-4} \text{ M}$$

$$2.57 \times 10^{-4} \text{ M}$$

$$1.29 \times 10^{-4} \text{ M}$$



Chapter: Acids and Bases

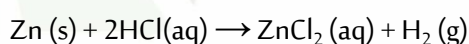
Lesson 1: Introduction to acids and bases

Properties of Acids and Bases

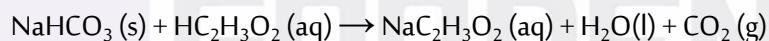
Acids	Bases
<u>Physical properties:</u> - Carbonic and phosphoric acids give carbonated beverages their sharp taste. - Citric and ascorbic acids give lemons their tartness. - Acetic acid makes vinegar taste sour.	<u>Physical properties:</u> - Taste bitter. - Soap becomes slippery when it gets wet.
<u>Electrical conductivity:</u> 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**.

Acids Reactions with metal carbonates

Metal carbonates and hydrogen carbonates react with aqueous solutions of acids to produce **carbon dioxide (CO₂) gas and water**.



Geologists identify rocks as limestone (CaCO₃) by using a hydrochloric acid solution. If a few drops of the acid produce bubbles of CO₂, the rock contains limestone.

Write balanced equations for the reactions between the following.

- aluminum and sulfuric acid
- calcium carbonate and hydrobromic acid

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



For each description below, write *acid* if it tells about a property of an acid or *base* if it tells about a property of a base. If the property does not apply to either an acid or a base, write *neither*. If it applies to both an acid and a base, write *both*.

- _____ 1. Can turn litmus paper a different color
- _____ 2. Reacts with certain metals
- _____ 3. Contains more hydrogen ions than hydroxide ions
- _____ 4. Feels slippery
- _____ 5. Reacts with carbonates
- _____ 6. Feels rough
- _____ 7. Contains equal numbers of hydrogen and hydroxide ions
- _____ 8. Tastes bitter
- _____ 9. Tastes sour

Final Exam questions

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؟

CO₂

H₂

O₂

N₂

Which of the following is a property of basic solutions?

أي مما يأتي من خصائص محاليل القواعد؟

React with metals like zinc to produce hydrogen gas

تتفاعل مع الفلزات مثل الخارصين لإنتاج غاز الهيدروجين

React with metal carbonates to produce carbon dioxide (CO₂) gas

تتفاعل مع كربونات الفلزات لإنتاج غاز ثاني أكسيد الكربون (CO₂)

Taste sour

طعمها لاذع

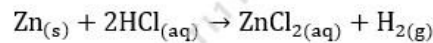
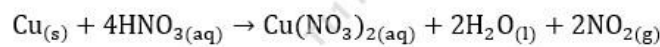
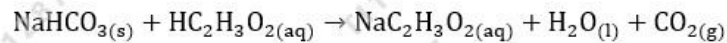
Taste bitter and feel slippery

مرة المذاق وزلقة الملمس



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

أي المعادلات الكيميائية الآتية تمثل التفاعل الذي يستخدمه الجيولوجيين للتعرف على الصخور الجيرية من بقية الصخور؟



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

زلفة الملمس



React with zinc to produce hydrogen gas

تتفاعل مع الزنك لتنتج غاز الهيدروجين



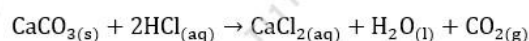
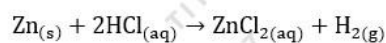
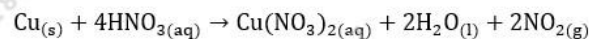
It tastes bitter

طعمها مر



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

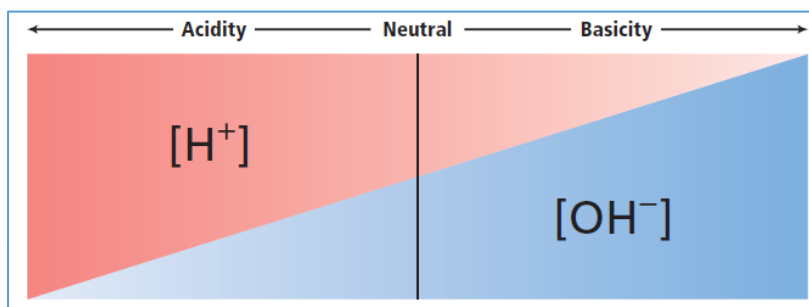
أي المعادلات الكيميائية الآتية تمثل تفاعل بين المحلول المائي لحمض وكربونات الفلز الهيدروجينية؟





Hydronium and hydroxide ions

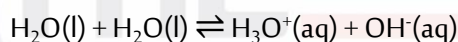
All water solutions contain hydrogen ions (H^+) and hydroxide ions (OH^-).



Acidic solution	Basic solution	Neutral solution
contains more hydrogen ions than hydroxide ions	contains more hydroxide ions than hydrogen ions	contains equal concentrations of hydroxide and hydrogen ions
$[H^+] > [OH^-]$	$[H^+] < [OH^-]$	$[H^+] = [OH^-]$

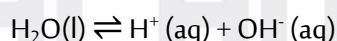
Self-ionization of water

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.



Water molecules $\rightleftharpoons$ Hydronium ion + 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.



Which of the following is correct?

أي مما يأتي صحيح؟

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

$[H^+] > [OH^-]$ في المحلول القاعدي يكون



In neutral solution $[H^+] > [OH^-]$

$[H^+] > [OH^-]$ في المحلول المتعادل يكون



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

$[H^+] > [OH^-]$ في المحلول الحمضي يكون



In acidic solution $[H^+] < [OH^-]$

$[H^+] < [OH^-]$ في المحلول الحمضي يكون



The Arrhenius Model (H^+ and OH^-)

Arrhenius acid(H^+)	Arrhenius base(OH^-)
a substance that contains hydrogen and ionizes to produce hydrogen ions in aqueous solution.	a substance that contains a hydroxide group and dissociates to produce a hydroxide ion in aqueous solution.
$HCl(g) \rightarrow \dots + \dots$	$NaOH(s) \rightarrow \dots + \dots$

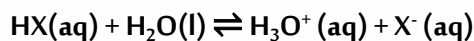
The shortcomings of Arrhenius model:

Ammonia (NH_3) and sodium carbonate (Na_2CO_3) do not contain a hydroxide group, yet both substances produce hydroxide ions in solution and are well-known bases.

The Bronsted-Lowry Model (H^+)

Acid	Base
hydrogen-ion donor	hydrogen ion acceptor

Use this equation to answer the following questions:



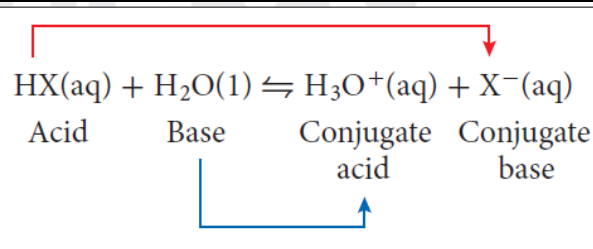
Which substance is the acid? Why?

The water molecule acts as a because

In the reverse reaction there is a conjugate acid and a conjugate base.

Conjugate acid	Conjugate base
the species produced after a base accepts a hydrogen ion	the species that results after an acid donates a hydrogen ion
In this example it's	In this example it's

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



First pair (acid-conjugate base)	Second pair (base-conjugate acid)

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

.....

.....

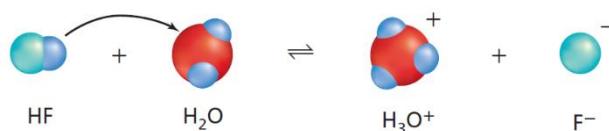
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Hydrogen fluoride—a Brønsted-Lowry acid

Hydrogen fluoride is an acid. Why?



Which species is the conjugate base of hydrogen fluoride?

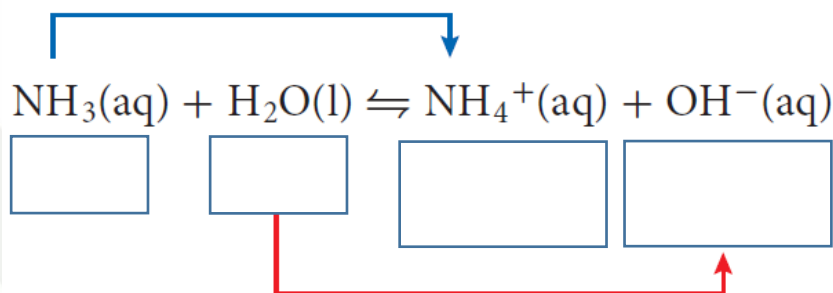
What is the other conjugate acid-base pair?

What are the acid and base in the reverse reaction?

Ammonia—a Brønsted-Lowry base

Ammonia does not fit the Arrhenius model of bases

because



Label the next equation:

Water—a Brønsted-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.

$\text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$			
Acid	Conjugate base	Base	Conjugate acid
$\text{HBr}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{Br}^-(\text{aq})$			
Acid	Conjugate base	Base	Conjugate acid
$\text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HCO}_3^-(\text{aq}) + \text{OH}^-(\text{aq})$			
Acid	Conjugate base	Base	Conjugate acid

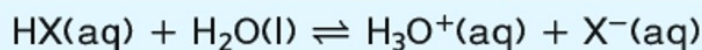
Challenge The products of an acid-base reaction are H_3O^+ and SO_4^{2-} . Write a balanced equation for the reaction and identify the conjugate acid-base pairs.



In the reaction equation below, which of the following

في معادلة التفاعل أدناه، أي مما يأتي صحيح؟

is true?



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



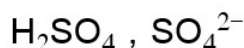
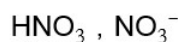
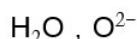
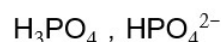
HX accepts a hydrogen ion from water H_2O

يستقبل HX أيون هيدروجين من الماء H_2O



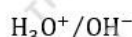
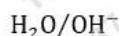
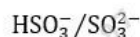
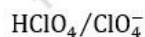
Which of the following is considered a conjugate acid -base pair?

أي مما يأتي يُعتبر زوج حمض قاعدة مرافق؟



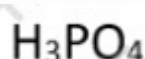
Which of the following is **not** a conjugate acid- base pair?

أي مما يلي **ليس** زوج حمض قاعدة مرافق؟



Which of the following is amphoteric substance?

أي مما يلي يُعتبر مادة أمفوتيرية؟





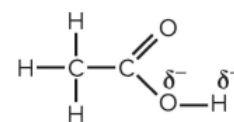
Monoprotic Acid and polyprotic acids

Monoprotic acid
An acid that can donate only one hydrogen ion.
Examples:

Polyprotic	
It has more than one ionizable hydrogen atoms.	
Diprotic	Triprotic
Acids that contain two ionizable hydrogen atoms per molecule.	Acids with three hydrogen ions to donate.
Examples:	Examples:

Ionizable hydrogen atoms

The formula of acetic acid is often written $\text{HC}_2\text{H}_3\text{O}_2$. why?



Acetic acid

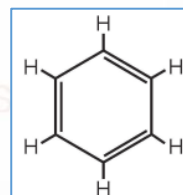
Explain the difference between acetic acid's ionizable hydrogen atom and the other three hydrogen atoms.

Hydrogen fluoride (HF) is an acid in solution. Explain.



Hydrogen fluoride

Explain why benzene (C_6H_6) is not an acid.



Benzene

Write the three ionizations of phosphoric acid (H_3PO_4).



The Lewis Model

Lewis acid	Lewis base
an ion or molecule with a vacant atomic orbital that can accept (share) an electron pair .	an ion or molecule with a lone electron pair that it can donate (share).

Lewis acid Lewis base	The H^+ ion is the Lewis acid because The fluoride ion F^- is the Lewis base because
	The acid is Because The base is Because
Lewis acid Lewis base	Another Lewis acid-base reaction occurs when gaseous sulfur trioxide (SO_3) is brought into contact with solid magnesium oxide (MgO). $SO_3(g) + MgO(s) \rightarrow MgSO_4(s)$

This reaction between SO_3 and MgO is important for some reasons:

1. A heptahydrate known as Epsom salt ($MgSO_4 \cdot 7H_2O$). It's useful in **soothing sore muscles** and **acting as a plant nutrient**.
2. MgO reacts with SO_3 , that can combine with water in the air to form sulfuric acid, which falls to Earth as **acid precipitation**.

Anhydrides

Nonmetallic oxides (acid anhydride)	Metallic oxides (base anhydride)
Nonmetallic oxides that can combine with water to form an acids	Metallic oxides combine with water to form bases
CO_2 will form	CaO will form

Table 2 Three Models for Acids and Bases

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





Final Exam questions

Which of the following is correct about to the reaction below?	أي العبارات التالية صحيحة بالنسبة للتفاعل أدناه؟
$\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$	
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

Which of the following is correct about to the reaction below?	أي العبارات التالية صحيحة بالنسبة للتفاعل أدناه؟
$\text{H}^+ + \text{F}^- \rightarrow \text{H} - \ddot{\text{F}}:$	
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 true?

أي مما يأتي صحيح؟

	$\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$
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

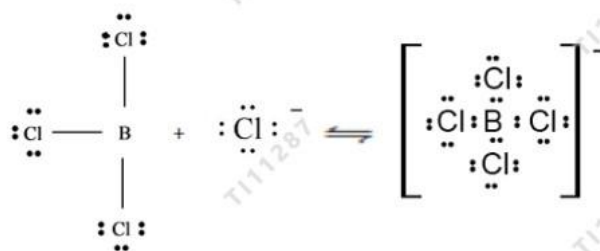
The ammonia NH_3 in reaction **1** is a Lewis acid

تُعتبر الأمونيا NH_3 في التفاعل **1** حمض لويس



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^-

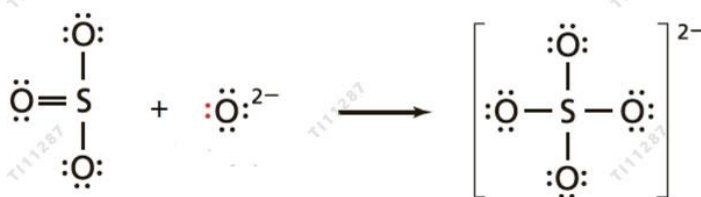
لأنه مانح لزوج إلكترونات إلى القاعدة Cl^-

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 بروتوناً من SO_3

Because it donated a proton to SO_3

لأنها منحت بروتوناً إلى SO_3

Because it donated a pair of electrons to SO_3

لأنها منحت زوجاً من الإلكترونات إلى SO_3

Because it accepted a pair of electrons from SO_3

لأنها استقبلت زوجاً من الإلكترونات من SO_3

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

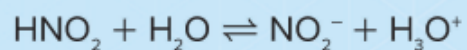
Arrhenius base

قاعدة أرهينيوس



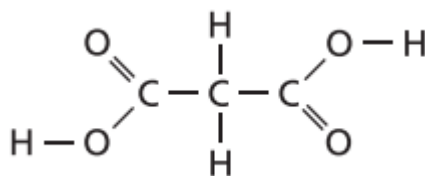
Review and assessment

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



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

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



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

H_2S		$\text{Mg}(\text{OH})_2$	
RbOH		H_3PO_4	

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

Write a balanced chemical equation for each of the following.

- The dissociation of solid magnesium hydroxide in water
- The reaction of magnesium metal and hydrobromic acid
- The ionization of propanoic acid ($\text{CH}_3\text{CH}_2\text{COOH}$) in water
- The second ionization of sulfuric acid in water



Chapter: Acids and Bases

Lesson 2: Strengths of Acids and Bases

Strengths of Acids

Figure 9 The light glows brightly when electrodes are placed in 0.10M hydrochloric acid solution because all of the HCl is in the form of hydronium ions and chloride ions.

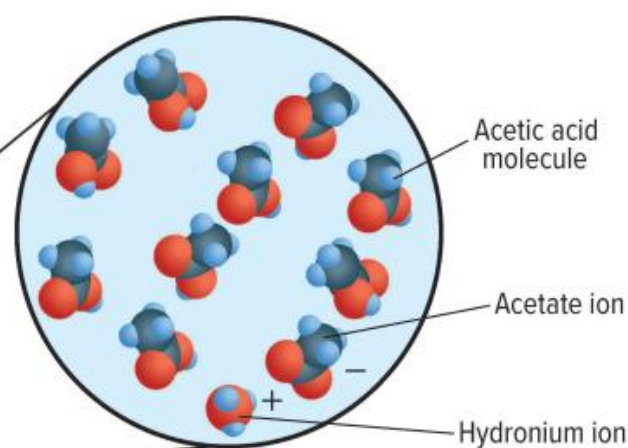
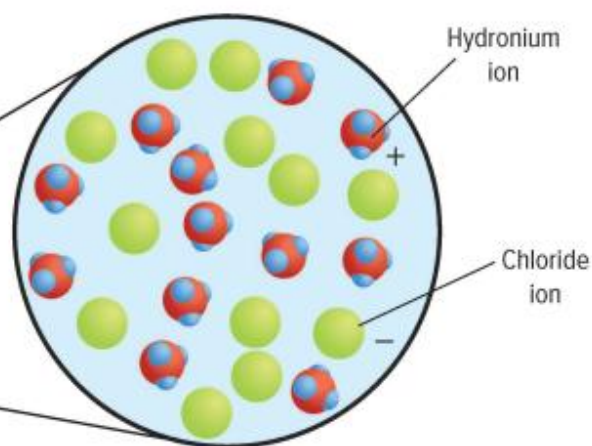


Figure 10 When electrodes are placed in 0.10M acetic acid solution, the light is dim. Compare this illustration with **Figure 9**. Explain the difference in the brightness of the bulbs in terms of the concentration of ions in solution.



Strong acids	Weak acids
Acids that ionize completely	Acids that ionize only partially
All the molecules in the solution are ionized completely into ions (no molecules are left)	The solution contains molecules and ions
They produce the maximum number of ions	They produce fewer ions
They are good conductors of electricity (bright light)	They are poor conductors of electricity (dim light)
The ionization equation uses a single arrow (completion)	The ionization equation uses a double arrow (equilibrium)

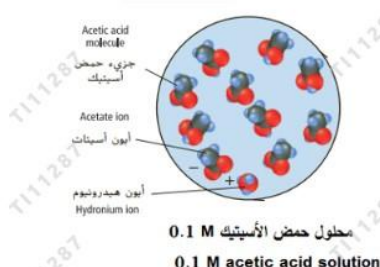
Table 3 Ionization Equations

Strong Acids		Weak Acids	
Name	Ionization Equation	Name	Ionization Equations
Hydrochloric	$\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$	Hydrofluoric	$\text{HF} \rightleftharpoons \text{H}^+ + \text{F}^-$
Hydroiodic	$\text{HI} \rightarrow \text{H}^+ + \text{I}^-$	Acetic	$\text{HC}_2\text{H}_3\text{O}_2 \rightleftharpoons \text{H}^+ + \text{C}_2\text{H}_3\text{O}_2^-$
Perchloric	$\text{HClO}_4 \rightarrow \text{H}^+ + \text{ClO}_4^-$	Hydrosulfuric	$\text{H}_2\text{S} \rightleftharpoons \text{H}^+ + \text{HS}^-$
Nitric	$\text{HNO}_3 \rightarrow \text{H}^+ + \text{NO}_3^-$	Carbonic	$\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$
Sulfuric	$\text{H}_2\text{SO}_4 \rightarrow \text{H}^+ + \text{HSO}_4^-$	Hypochlorous	$\text{HClO} \rightleftharpoons \text{H}^+ + \text{ClO}^-$

Final exam questions

What is the difference between the two figures below?

ما وجه الاختلاف بين الشكلين أدناه؟



HCl acid solution is weak conductors of electricity while the **HC₂H₃O₂** acid solution is good conductors of electricity

محلول حمض **HCl** من الموصلات الضعيفة للكهرباء بينما محلول حمض **HC₂H₃O₂** من الموصلات الجيدة للكهرباء

The **HCl** acid molecules contained in the solution are ionized partially while the **HC₂H₃O₂** acid molecules contained in the solution are ionized completely

تتأين جزيئات حمض **HCl** التي يحتويها المحلول جزئياً بينما تتأين جزيئات حمض **HC₂H₃O₂** التي يحتويها المحلول تماماً

HCl acid solution produces a maximum number of ions while **HC₂H₃O₂** acid solution produces fewer ions

ينتج محلول حمض **HCl** أقصى عدد من الأيونات بينما ينتج محلول حمض **HC₂H₃O₂** أيونات أقل

HCl acid solution produces fewer ions while **HC₂H₃O₂** acid solution produces a maximum number of ions

ينتج محلول حمض **HCl** أيونات أقل بينما ينتج محلول حمض **HC₂H₃O₂** أقصى عدد من الأيونات



Which of the following substances ionize completely in aqueous solutions producing hydronium ions H_3O^+ ?

أي من المواد التالية تتأين تمامًا في المحاليل المائية وتنتج أيونات الهيدرونيوم H_3O^+ ؟

I.	HCl
II.	$\text{HC}_2\text{H}_3\text{O}_2$
III.	H_2SO_4
IV.	HClO

A. I and II	A. I و II
B. II and III	B. II و III
C. I and III	C. I و III
D. I, II and IV	D. I و II و IV

The bulb is connected to a solution of 0.1 M HCl in figure 1, while the bulb is connected to a solution of 0.1M $\text{HC}_2\text{H}_3\text{O}_2$ in figure 2.

المصباح موصل بمحلول 0.1 M HCl في الشكل 1 ، بينما المصباح موصل بمحلول 0.1 M $\text{HC}_2\text{H}_3\text{O}_2$ في الشكل 2 .

What is the reason for the difference in the brightness of the bulb in the two figures below?

ما سبب الاختلاف في سطوع المصباح في الشكلين أدناه ؟



2



1

$\text{HC}_2\text{H}_3\text{O}_2$ is a strong acid and completely ionizes in aqueous solution

الحمض $\text{HC}_2\text{H}_3\text{O}_2$ حمض قوي ويتأين بشكل تام في المحلول المائي

The number of ions in HCl solution is less than the number of ions in $\text{HC}_2\text{H}_3\text{O}_2$ solution

عدد الأيونات في المحلول HCl أقل من عدد الأيونات في المحلول $\text{HC}_2\text{H}_3\text{O}_2$

The number of ions in HCl solution is more than the number of ions in $\text{HC}_2\text{H}_3\text{O}_2$ solution

عدد الأيونات في المحلول HCl أكثر من عدد الأيونات في المحلول $\text{HC}_2\text{H}_3\text{O}_2$

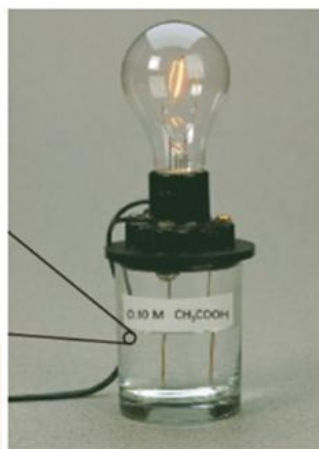
HCl is a weak acid and only partially ionizes in aqueous solution

الحمض HCl حمض ضعيف ويتأين جزئيًا فقط في المحلول المائي



Regarding the figure below, which of the following is correct?

فيما يتعلق بالشكل أدناه، أي مما يأتي صحيح؟



1



2

The light is dim in **1** because CH_3COOH is a strong acid

يكون ضوء المصباح باهتًا في **1** لأن CH_3COOH حمض قوي

The light glows brightly in **2** because HCl ionizes only partially

يتوهج المصباح توهجًا ساطعًا في **2** لأن حمض HCl يتأين جزئيًا فقط

The light glows brightly in **2** because HCl is a strong acid

يتوهج المصباح توهجًا ساطعًا في **2** لأن حمض HCl قوي

The light is dim in **1** because CH_3COOH ionizes completely

يكون ضوء المصباح باهتًا في **1** لأن حمض CH_3COOH يتأين تمامًا

ALNADIV
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Acid strength and the Bronsted-Lowry model

In the strong acids:

HX represents a **strong acid**, and its **conjugate base** (X^-) is **weak**. It's 100% ionized

The base H_2O has a much **greater attraction for the H^+ ion** than does the base X^- .

Think of this as the battle of the bases: Which of the two (H_2O or X^-) has a greater attraction for the hydrogen ion?

In the case of all strong acids, water is the stronger base. Therefore, the ionization equilibrium lies almost completely to the **right**.

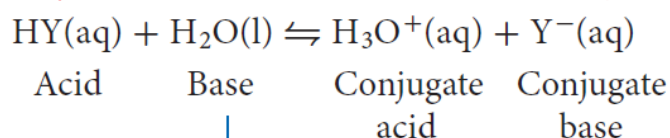
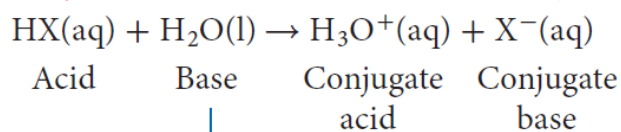
In the weak acids:

HY represents a **weak acid**, and its **conjugate base** (Y^-) is **strong**.

The **conjugate base** Y^- has a **greater attraction** for the H^+ ion than does the base H_2O .

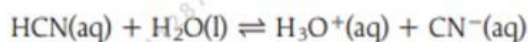
It captures the H^+ and does the reverse reaction.

The ionization equilibrium lies far to the **left**.



Final exam questions

Which of the following statements is **correct** according to the following ionization equation?



The equilibrium lies far to the right because the conjugate base CN^- has a greater attraction for the H^+ ion than does the base H_2O

The equilibrium lies far to the left because the conjugate base CN^- has a greater attraction for the H^+ ion than does the base H_2O

The equilibrium lies far to the right because the conjugate base CN^- has less attraction for the H^+ ion than does the base H_2O

The equilibrium lies far to the left because the conjugate base CN^- has less attraction for the H^+ ion than does the base H_2O

أي العبارات التالية **صحيحة** فيما يتعلق بمعادلة التأيين التالية؟

يتجه الاتزان بعيداً إلى اليمين لأن القاعدة المرافقة CN^- تمتلك جذباً للأيون H^+ أكبر من القاعدة H_2O

يتجه الاتزان بعيداً إلى اليسار لأن القاعدة المرافقة CN^- تمتلك جذباً للأيون H^+ أكبر من القاعدة H_2O

يتجه الاتزان بعيداً إلى اليمين لأن القاعدة المرافقة CN^- تمتلك جذباً للأيون H^+ أقل من القاعدة H_2O

يتجه الاتزان بعيداً إلى اليسار لأن القاعدة المرافقة CN^- تمتلك جذباً للأيون H^+ أقل من القاعدة H_2O



Regarding the two reactions (1) , (2) in the table

فيما يتعلق بالتفاعلين (1) و (2) في الجدول أدناه. أي مما يأتي

below. Which of the following is **correct**?

صحيح؟

التفاعل (2) Reaction (2)	التفاعل (1) Reaction (1)
$\text{HY(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{Y}^-(\text{aq})$	$\text{HX(aq)} + \text{H}_2\text{O(l)} \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{X}^-(\text{aq})$

In reaction (1) the ionization equilibrium lies almost completely to the left because the base H_2O has a much greater attraction for the H^+ ion than does the base X^-

في التفاعل (1) يتجه اتزان التأين كله تقريبًا إلى اليسار لأن القاعدة H_2O تمتلك جذبًا أكبر بكثير بالنسبة لأيون H^+ مما تمتلكه القاعدة X^-

In reaction (1) the ionization equilibrium lies almost completely to the right because the base H_2O has a smaller attraction for the H^+ ion than does the base X^-

في التفاعل (1) يتجه اتزان التأين كله تقريبًا إلى اليمين لأن القاعدة H_2O تمتلك جذبًا أقل بكثير بالنسبة لأيون H^+ مما تمتلكه القاعدة X^-

In reaction (2) the ionization equilibrium lies almost completely to the right because the conjugate base Y^- has a smaller attraction for the H^+ ion than does the base H_2O

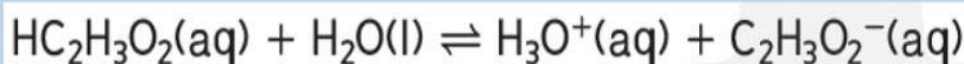
في التفاعل (2) يتجه اتزان التأين بعيدًا إلى اليمين لأن القاعدة المرافقة Y^- تمتلك جذبًا لأيون H^+ أقل من القاعدة H_2O

In reaction (2) the ionization equilibrium lies almost completely to the left because the conjugate base Y^- has a much greater attraction for the H^+ ion than does the base H_2O

في التفاعل (2) يتجه اتزان التأين بعيدًا إلى اليسار لأن القاعدة المرافقة Y^- تمتلك جذبًا لأيون H^+ أكبر من القاعدة H_2O

Which of the following statements is **correct** about the reaction shown below?

أي العبارات التالية **صحيحة** بالنسبة للتفاعل أدناه؟

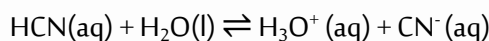


A. The acid $\text{HC}_2\text{H}_3\text{O}_2$ is strong and the conjugate base $\text{C}_2\text{H}_3\text{O}_2^-$ is weak	A. $\text{HC}_2\text{H}_3\text{O}_2$ حمض قوي و القاعدة المرافقة $\text{C}_2\text{H}_3\text{O}_2^-$ ضعيفة
B. The base $\text{C}_2\text{H}_3\text{O}_2^-$ is weak than H_2O base	B. القاعدة $\text{C}_2\text{H}_3\text{O}_2^-$ أضعف من القاعدة H_2O
C. The conjugate base $\text{C}_2\text{H}_3\text{O}_2^-$ has greater attraction for H^+ ion than does the base H_2O	C. القاعدة المرافقة $\text{C}_2\text{H}_3\text{O}_2^-$ تمتلك جذبًا لأيون H^+ أقوى مما تمتلكه القاعدة H_2O
D. The equilibrium lies far to the right	D. يتجه الاتزان بعيدًا إلى اليمين

**Acid ionization constants**

Any weak acid produces an equilibrium mixture of molecules and ions in aqueous solutions.

The equilibrium constant K_{eq} provides the quantitative measure of acid strength.



The concentration of liquid H_2O is considered to be constant in dilute aqueous solutions, so it can be combined with K_{eq} to give a new equilibrium constant, K_a .

$$K_a = \text{_____} = 6.2 \times 10^{-10}$$

Acid ionization constant (K_a) is the value of the equilibrium constant expression for the ionization of a weak acid.

The weakest acids have the smallest K_a values. Explain.

Note that each ionization of a polyprotic acid has a K_a value, and the values decrease for each successive ionization.

Acid	Ionization Equation	K_a (298 K)
Hydrosulfuric, first ionization	$\text{H}_2\text{S} \rightleftharpoons \text{H}^+ + \text{HS}^-$	8.9×10^{-8}
Hydrosulfuric, second ionization	$\text{HS}^- \rightleftharpoons \text{H}^+ + \text{S}^{2-}$	1×10^{-19}

PRACTICE Problems

Write ionization equations and acid ionization constant expressions for each acid.

a. HClO_2

b. HNO_2

c. HIO

Write the first and second ionization equations for H_2SeO_3 .

Given the expression $K_a = \frac{[\text{AsO}_4^{3-}][\text{H}_3\text{O}^+]}{[\text{HAsO}_4^{2-}]}$, write the balanced equation for the corresponding reaction.



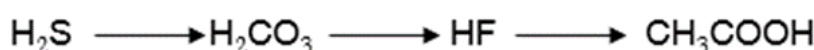


Final exam questions

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

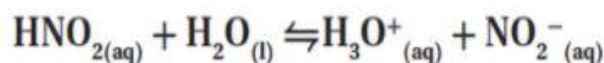
ما الترتيب **التنازلي** الصحيح للأحماض الواردة في الجدول أدناه وفقاً لتراكيز الأيونات في محلول كل منها؟

ثوابت التأين Ionization Constants	Acid الحمض
8.9×10^{-8}	H_2S
6.3×10^{-4}	HF
1.8×10^{-5}	CH_3COOH
4.5×10^{-7}	H_2CO_3



What is the acid ionization constant of the equation shown below?

ما تعبير ثابت تأين الحمض للمعادلة المبينة أدناه؟



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

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

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

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



Which of the following statements is **correct** regarding the following ionization equations?

أي العبارات التالية **صحيحة** فيما يتعلق بمعادلات التأين التالية ؟

K_a (298 K)	معادلة التأين Ionization equation	الحمض Acid
8.9×10^{-8}	$H_2S \rightleftharpoons H^+ + HS^-$	الهيدروكبريتيك، التأين الأول Hydrosulfuric, first ionization
1×10^{-19}	$HS^- \rightleftharpoons H^+ + S^{2-}$	الهيدروكبريتيك، التأين الثاني Hydrosulfuric, second ionization

The acid in the first ionization is weaker than the acid in the second ionization

الحمض في التأين الأول أكثر ضعفًا من الحمض في التأين الثاني

The concentrations of ions produced by the second ionization are greater than the concentrations of ions produced by the first ionization

تركيز الأيونات الناتجة من التأين الثاني أكبر من تراكيز الأيونات الناتجة من التأين الأول

Hydrosulfuric acid is a strong acid because it is a polyprotic

حمض الهيدروكبريتيك حمض قوي لأنه متعدد البروتون

The acid in the second ionization is weaker than the acid in the first ionization

الحمض في التأين الثاني أكثر ضعفًا من الحمض في التأين الأول

Which of the following statements is **correct** according to the data in the table below?

أي العبارات التالية **صحيحة** فيما يتعلق بالبيانات الواردة بالجدول أدناه؟

K_a (298 K)	معادلة التأين Ionization equation	الحمض Acid
4.5×10^{-7}	$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$	الكربونيك، التأين الأول Carbonic, first ionization
4.7×10^{-11}	$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$	الكربونيك، التأين الثاني Carbonic, second ionization

Carbonic acid is a strong acid because it is a polyprotic

حمض الكربونيك حمض قوي لأنه متعدد البروتون

The concentrations of ions produced by the second ionization are greater than the concentrations of ions produced by the first ionization

تركيز الأيونات الناتجة من التأين الثاني أكبر من تراكيز الأيونات الناتجة من التأين الأول

The acid in the first ionization is weaker than the acid in the second ionization

الحمض في التأين الأول أضعف من الحمض في التأين الثاني

The acid in the second ionization is weaker than the acid in the first ionization

الحمض في التأين الثاني أضعف من الحمض في التأين الأول



Strong Bases

The conductivity of a base depends on the extent to which the base produces OH^- ions.

A base that dissociates entirely into metal ions and hydroxide ions is known as a **strong base**.

Table 5 Dissociation Equations for Strong Bases

$\text{NaOH(s)} \rightarrow \text{Na}^+(\text{aq}) + \text{OH}^-(\text{aq})$
$\text{KOH(s)} \rightarrow \text{K}^+(\text{aq}) + \text{OH}^-(\text{aq})$
$\text{RbOH(s)} \rightarrow \text{Rb}^+(\text{aq}) + \text{OH}^-(\text{aq})$
$\text{CsOH(s)} \rightarrow \text{Cs}^+(\text{aq}) + \text{OH}^-(\text{aq})$
$\text{Ca(OH)}_2(\text{s}) \rightarrow \text{Ca}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})$
$\text{Ba(OH)}_2(\text{s}) \rightarrow \text{Ba}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})$

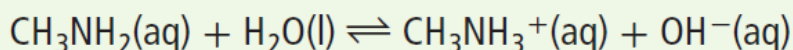
Some metallic hydroxides, such as calcium hydroxide (Ca(OH)_2) have low solubility and thus are poor sources of OH^- ions.



Nevertheless, they are considered strong bases because all of the compound that dissolves is completely dissociated.

Weak Bases

A **weak base** ionizes only partially in dilute aqueous solution.



This equilibrium lies far to the left. Explain.

Final exam questions

Which of the following substances dissociate completely in aqueous solutions producing hydroxide ions OH^- ?

أي من المواد التالية تتفكك تمامًا في المحاليل المائية وتنتج أيونات الهيدروكسيد OH^- ؟

I.	NaOH
II.	NH_3
III.	Ca(OH)_2
IV.	CH_3NH_2

A. I and II

A. I و II

B. I and III

B. I و III

C. II and III

C. II و III

D. I, III and IV

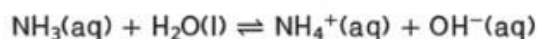
D. I و III و IV





Which of the following statements is **correct** regarding the following ionization equation?

أي العبارات التالية **صحيحة** فيما يتعلق بمعادلة التأين التالية ؟



The equilibrium lies far to the left because the base NH_3 is strong, and the conjugate base OH^- is weak

يتجه الاتزان بعيداً إلى اليسار لأن القاعدة NH_3 قوية والقاعدة المرافقة OH^- ضعيفة

The equilibrium lies far to the left because the base NH_3 is weak, and the conjugate base OH^- is strong

يتجه الاتزان بعيداً إلى اليسار لأن القاعدة NH_3 ضعيفة والقاعدة المرافقة OH^- قوية

The equilibrium lies far to the right because the base NH_3 is weak, and the conjugate base OH^- is strong

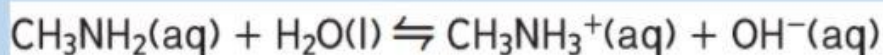
يتجه الاتزان بعيداً إلى اليمين لأن القاعدة NH_3 ضعيفة والقاعدة المرافقة OH^- قوية

The equilibrium lies far to the right because the base NH_3 is strong, and the conjugate base OH^- is weak

يتجه الاتزان بعيداً إلى اليمين لأن القاعدة NH_3 قوية والقاعدة المرافقة OH^- ضعيفة

Which of the following statements is **correct** about the reaction shown below?

أي العبارات التالية **صحيحة** بالنسبة للتفاعل أدناه؟



A. The base CH_3NH_2 is weak and the conjugate base OH^- is strong

A. القاعدة CH_3NH_2 ضعيفة والقاعدة المرافقة OH^- قوية

B. The base CH_3NH_2 is strong and the conjugate base OH^- is weak

B. القاعدة CH_3NH_2 قوية والقاعدة المرافقة OH^- ضعيفة

C. OH^- ion has lowest attraction for H^+ ion than has a molecule of CH_3NH_2

C. أيون OH^- يمتلك جذباً لأيون H^+ أقل مما يمتلكه جزيء CH_3NH_2

D. The equilibrium lies far to the right

D. يتجه الاتزان بعيداً إلى اليمين

**Base ionization constants**

It is the value of the equilibrium constant expression for the ionization of a base.

The smaller the value of K_b , the weaker the base. Explain.

Table 6 Ionization Constants of Weak Bases

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}

PRACTICE Problems

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

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

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

c. propylamine ($C_3H_7NH_2$)

d. hydrogen sulfite ion (HSO_3^-)

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



Final exam question

Which of the following is **correct** according to the bases in the table below?

أي مما يأتي **صحيح** فيما يتعلق بالقواعد الواردة في الجدول أدناه؟

K_b (298 K)	Ionization Equation	معادلة التآين	القاعدة Base
2.5×10^{-5}	$\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$		Ammonia الأمونيا
5.0×10^{-4}	$\text{C}_2\text{H}_5\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_2\text{H}_5\text{NH}_3^+(\text{aq}) + \text{OH}^-(\text{aq})$		Ethylamine إيثيل أمين
4.3×10^{-4}	$\text{CH}_3\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{NH}_3^+(\text{aq}) + \text{OH}^-(\text{aq})$		Methylamine الميثيل أمين
4.3×10^{-10}	$\text{C}_6\text{H}_5\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_6\text{H}_5\text{NH}_3^+(\text{aq}) + \text{OH}^-(\text{aq})$		Aniline الأنيلين

Ammonia solution produces the maximum number of ions

يُنتج محلول الأمونيا أقصى عدد من الأيونات

Ethylamine solution produces the maximum number of ions

يُنتج محلول إيثيل أمين أقصى عدد من الأيونات

Aniline solution contains lower concentrations of the un-ionized molecules

يحتوي محلول الأنيلين على أقل تراكيز من الجزيئات غير المؤينة

Methylamine solution contains higher concentrations of the un-ionized molecules

يحتوي محلول الميثيل أمين على أعلى تراكيز من الجزيئات غير المؤينة

Important tables

Strong acids	
HCl	Hydrochloric acid
HBr	Hydrobromic acid
HI	Hydroiodic acid
HNO_3	Nitric acid
H_2SO_4	Sulfuric acid
HClO_4	Perchloric acid
HClO_3	Chloric acid

Strong bases	
NaOH	Sodium hydroxide
KOH	Potassium hydroxide
RbOH	Rubidium hydroxide
CsOH	Cesium hydroxide
LiOH	Lithium hydroxide
$\text{Ca}(\text{OH})_2$	Calcium hydroxide
$\text{Ba}(\text{OH})_2$	Barium hydroxide
$\text{Sr}(\text{OH})_2$	Strontium hydroxide

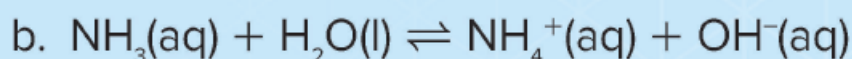
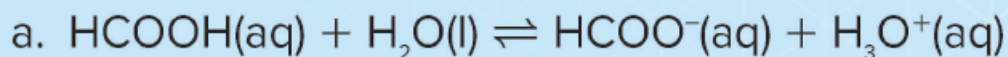


Review and assessment

Describe the contents of dilute aqueous solutions of the strong acid HI and the weak acid HCOOH.

HI	HCOOH

Identify the conjugate acid-base pairs in each equation.



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

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

Write the chemical equation and the K_b expression for the ionization of aniline ($\text{C}_2\text{H}_5\text{NH}_2$) in water. Aniline is a weak base.

A fictional weak base, ZaH_2 , reacts with water to yield a solution with a OH^- ion concentration of $2.68 \times 10^{-4} \text{ mol/L}$. The chemical equation for the reaction is $\text{ZaH}_2(\text{aq}) + \text{H}_2\text{O(l)} \rightleftharpoons \text{ZaH}_3^+(\text{aq}) + \text{OH}^-(\text{aq})$. If $[\text{ZaH}_2]$ at equilibrium is 0.0997 mol/L , what is the value of K_b for ZaH_2 ?



Chapter: Acids and Bases

Lesson 3: Hydrogen ions and pH

Ion Product Constant for Water

Pure water contains equal concentrations of H^+ and OH^- ions produced by self-ionization.

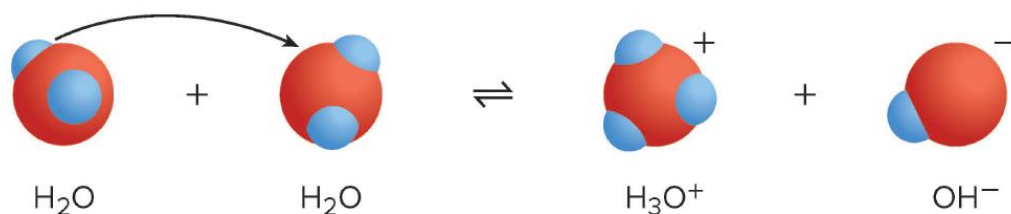
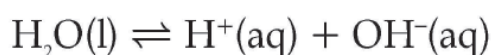


Figure 11 In the self-ionization of water, one water molecule acts as an acid, and the other acts as a base.

The numbers of hydronium and hydroxide ions formed are

The equation for the equilibrium can be simplified as follows

Writing K_w

The Ion Product of Water

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

K_w is the ion product constant for water. $[H^+]$ represents the concentration of the hydrogen ion. $[OH^-]$ represents the concentration of the hydroxide ion.

The **ion product constant for water (K_w)** is the value of the equilibrium constant expression for the self-ionization of water.

$[H_2O]$ does not appear in the denominator. Why?

Experiments show that in pure water at 298 K, $[H^+]$ and $[OH^-]$ are both equal to $1.0 \times 10^{-7} M$.

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

$$K_w = 1.0 \times 10^{-14}$$

 K_w and Le Châtelier's Principle

The product of $[H^+]$ and $[OH^-]$ always equals

If the concentration of H^+ increases, the concentration of OH^-

Le Châtelier's principle.

Adding extra hydrogen ions is a stress, the system reacts in a way to relieve that stress. The added H^+ ions react with OH^- ions to form more water molecules. Thus, the concentration of OH^- decreases.



Final exam question

In the self-ionization reaction of water shown below.

في تفاعل التأين الذاتي للماء الموضح أدناه. ماذا يحدث إذا زاد

What happens if the concentration of H^+ ions

تركيز أيونات الهيدروجين H^+ ؟

increases?



The concentration of OH^- ions increases
and K_w value increases

يزداد تركيز أيونات الهيدروكسيد OH^- وتزداد قيمة K_w

The concentration of OH^- ions decreases
and K_w value does not change

يقل تركيز أيونات الهيدروكسيد OH^- وتبقى قيمة K_w دون تغيير

The concentration of OH^- ions increases
and K_w value does not change

يزداد تركيز أيونات الهيدروكسيد OH^- وتبقى قيمة K_w دون
تغيير

The concentration of OH^- ions decreases
and K_w value decreases

يقل تركيز أيونات الهيدروكسيد OH^- وتقل قيمة K_w



Calculate $[H^+]$ and $[OH^-]$ Using K_w

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

The concentration of either the H^+ ion or the OH^- ion is given for four aqueous solutions at 298 K. For each solution, calculate $[H^+]$ or $[OH^-]$. State whether the solution is acidic, basic, or neutral.

	Calculate H^+ or OH^- to compare	acidic-basic-neutral
a. $[H^+] = 1.0 \times 10^{-13} M$		
b. $[OH^-] = 1.0 \times 10^{-7} M$		
c. $[OH^-] = 1.0 \times 10^{-3} M$		
d. $[H^+] = 4.0 \times 10^{-5} M$		

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



Final exam questions

Which of the following solutions is **basic**?

أي المحاليل التالية قاعدي؟

(Concentrations at 298 K)

(التركيزات عند 298 K)

عصير الليمون Lemon juice	ماء البحر Seawater	ماء نقي Pure water	فنجان قهوة Coffee cup
$[H^+] = 6.0 \times 10^{-3}$	$[OH^-] = 1.0 \times 10^{-6}$	$[OH^-] = 1.0 \times 10^{-7}$	$[H^+] = 1.0 \times 10^{-5}$

Pure water

ماء نقي

Lemon juice

عصير الليمون

Seawater

ماء البحر

Coffee cup

فنجان قهوة

Which of the following aqueous solutions is acidic?

أي المحاليل المائية التالية حمضي؟

(Concentrations at 298 K)

(التركيزات عند 298 K)

المحلول D Solution D	المحلول C Solution C	المحلول B Solution B	المحلول A Solution A
$[H^+] = 4.0 \times 10^{-4}$	$[OH^-] = 1.0 \times 10^{-7}$	$[OH^-] = 1.0 \times 10^{-3}$	$[H^+] = 1.0 \times 10^{-13}$

Solution A

المحلول A

Solution B

المحلول B

Solution D

المحلول D

Solution C

المحلول C





What is the number of hydroxide ions (OH^-)?
in **0.750 L** of pure water at **298 k**?

ما عدد أيونات الهيدروكسيد (OH^-) في **0.750 L** من الماء النقي عند
298 k؟

$$6.02 \times 10^{23}$$

عدد أفوجادرو

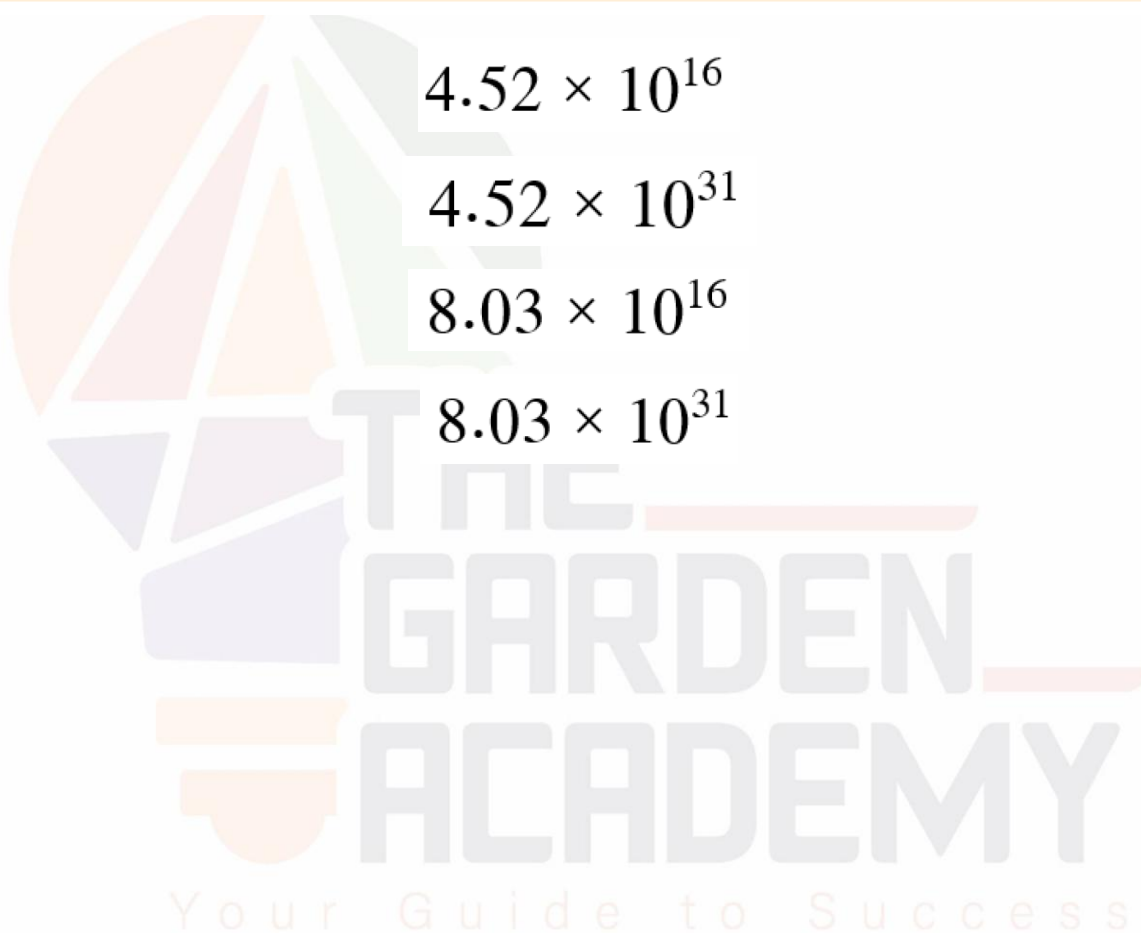
Avogadro's number

$$4.52 \times 10^{16}$$

$$4.52 \times 10^{31}$$

$$8.03 \times 10^{16}$$

$$8.03 \times 10^{31}$$



**What is pH?**

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

The **pH** of a solution is the negative logarithm of the hydrogen ion concentration.

Acidic solutions have pH values below 7. Basic solutions have pH values above 7.

A solution with a pH of 0.0 is strongly

A solution with a pH of 14.0 is strongly

Practice: Calculate the pH of solutions having the following ion concentrations.

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

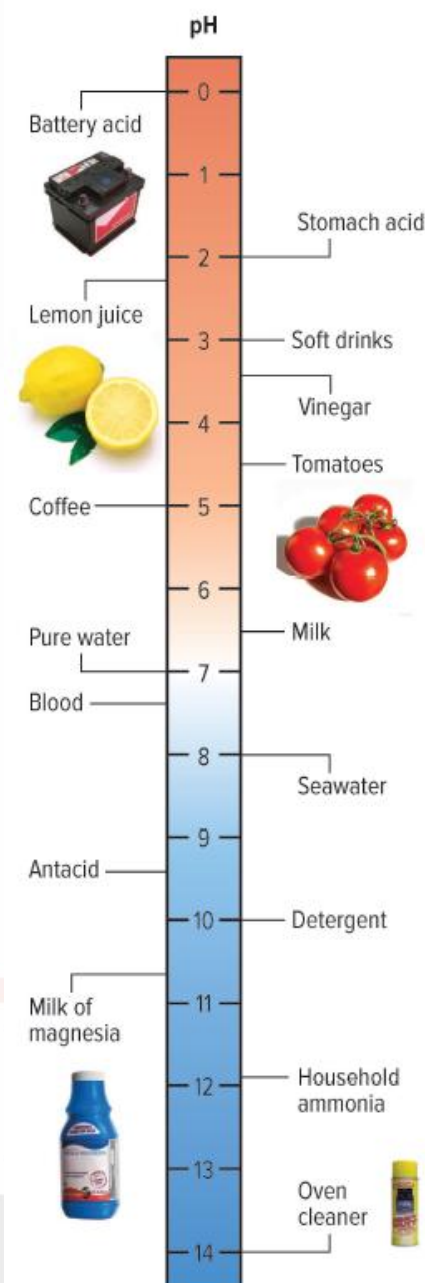
b. $[\text{H}^+] = 3.0 \times 10^{-6} \text{ M}$

c. $[\text{H}^+] = 0.0055 \text{ M}$

d. $[\text{H}^+] = 0.000084 \text{ M}$

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

Important: A change of one pH unit represents a **tenfold** change in ion concentration.



pH	Hydrogen ion concentration $[\text{H}^+]$	pH	Hydrogen ion concentration $[\text{H}^+]$
1	1×10^{-1}	8	1×10^{-8}
2	1×10^{-2}	9	1×10^{-9}
3	1×10^{-3}	10	1×10^{-10}
4	1×10^{-4}	11	1×10^{-11}
5	1×10^{-5}	12	1×10^{-12}
6	1×10^{-6}	13	1×10^{-13}
7	1×10^{-7}	14	1×10^{-14}

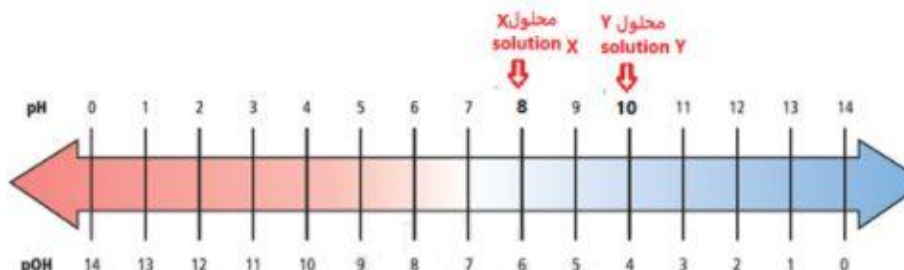
Determine whether seawater (pH=8) or detergent (pH=10) has a higher concentration of H^+ ions. How many times higher?



Final exam questions

How many times increases the concentration of hydrogen ions $[H^+]$ in the solution **X** than in the solution **Y** according to the figure below?

كم مرة يزيد تركيز أيون الهيدروجين $[H^+]$ في المحلول **X** عن المحلول **Y** حسب الرسم أدناه؟



A. 2 times

B. 10 times

C. 100 times

D. 1000 times

A. 2 (مرتان)

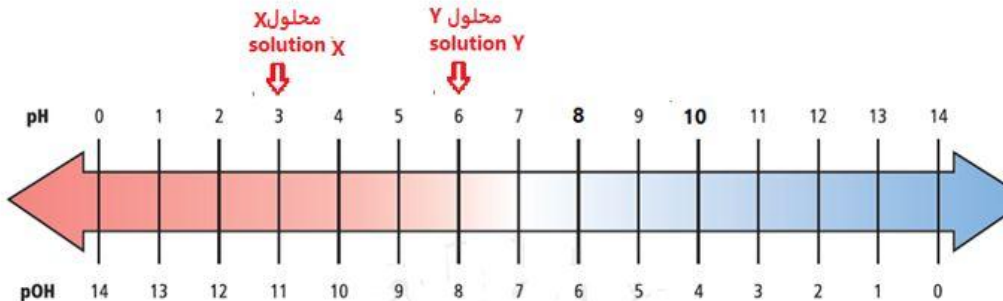
B. 10 مرات

C. 100 مرة

D. 1000 مرة

How many times increases the concentration of hydrogen ions $[H^+]$ in the solution **X** than in the solution **Y** according to the figure below?

كم مرة يزيد تركيز أيون الهيدروجين $[H^+]$ في المحلول **X** عن المحلول **Y** حسب الرسم أدناه؟



A. 2 times

B. 10 times

C. 100 times

D. 1000 times

A. 2 (مرتان)

B. 10 مرات

C. 100 مرة

D. 1000 مرة

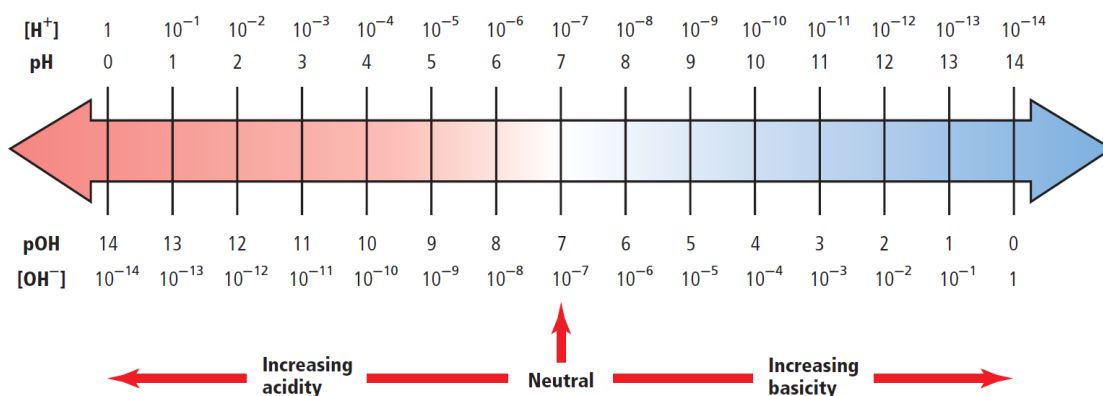
Challenge Calculate the pH of a solution having $[OH^-] = 8.2 \times 10^{-6} M$.

**What is pOH?**

The **pOH** of a solution is the negative logarithm of the hydroxide ion concentration.

$$\text{pOH} = -\log [\text{OH}^-]$$

$$\text{pH} + \text{pOH} = 14.00$$



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

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

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

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

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

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

e. $[\text{OH}^-] = 0.000033 \text{ M}$

f. $[\text{H}^+] = 0.0095 \text{ M}$

Challenge Calculate pH and pOH for an aqueous solution containing $1.0 \times 10^{-3} \text{ mol}$ of HCl dissolved in 5.0 L of solution.



Calculating ion concentrations from pH

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

$$[OH^-] =$$

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

a. Milk, pH = 6.50.

c. Milk of magnesia, pH = 10.50

b. Lemon juice, pH = 2.37

d. Household ammonia, pH = 11.90

e. Blood, pH = 7.40

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

Final exam questions

If $[OH^-] = 2.5 \times 10^{-7} M$ in a solution.إذا كان $[OH^-] = 2.5 \times 10^{-7} M$ في محلول ما.

What is the pH of the solution?

فما قيمة pH للمحلول؟

4.7



6.6



7.4



3.5





Which is the correct arrangement according to the **pOH values** of the solutions (X), (Y), and (Z) which have the following characteristic?

ما الترتيب التصاعدي الصحيح حسب قيمة **pOH** للمحاليل (X) و (Y) و (Z) ذات الخصائص التالية؟

$$(X): \text{pH} = 10.5$$

$$(Y): [\text{H}^+] = 10^{-12}$$

$$(Z): [\text{OH}^-] = 10^{-9}$$

A. (lowest) (Y) → (X) → (Z) (highest)

A. (الأقل) (Y) ← (X) ← (Z) (الأكثر)

B. (lowest) (X) → (Y) → (Z) (highest)

B. (الأقل) (X) ← (Y) ← (Z) (الأكثر)

C. (lowest) (Z) → (X) → (Y) (highest)

C. (الأقل) (Y) ← (X) ← (Z) (الأكثر)

D. (lowest) (X) → (Z) → (Y) (highest)

D. (الأقل) (Y) ← (Z) ← (X) (الأكثر)

Which is the correct arrangement according to the **pH values** of the solutions (X), (Y), and (Z) which have the following characteristic?

ما الترتيب التصاعدي الصحيح حسب قيمة **pH** لكل من المحاليل (X) و (Y) و (Z) ذات الخصائص التالية؟

$$(X): \text{pOH} = 9.5$$

$$(Y): [\text{H}^+] = 10^{-9}$$

$$(Z): [\text{OH}^-] = 10^{-6}$$

A. (lowest) (Y) → (X) → (Z) (highest)

A. (الأقل) (Y) ← (X) ← (Z) (الأكثر)

B. (lowest) (X) → (Y) → (Z) (highest)

B. (الأقل) (X) ← (Y) ← (Z) (الأكثر)

C. (lowest) (Z) → (X) → (Y) (highest)

C. (الأقل) (Y) ← (X) ← (Z) (الأكثر)

D. (lowest) (X) → (Z) → (Y) (highest)

D. (الأقل) (Y) ← (Z) ← (X) (الأكثر)

Which of the following solution is the **most** acidic?

أي المحاليل التالية هو **الأعلى** حمضية؟

$$[\text{H}_3\text{O}^+] = 1 \times 10^{-4}, \quad \text{pOH} = 13, \quad [\text{OH}^-] = 1 \times 10^{-9}, \quad \text{pH} = 3$$



What is the **correct** ascending order according to the **pH** value for each of the following solutions?

ما الترتيب التصاعدي **الصحيح** حسب قيمة **pH** لكل من المحاليل التالية ؟

الأمونيا المنزلية Household ammonia	عصير الليمون Lemon juice	حليب المغنيسيا Milk of magnesia	الحليب Milk
pOH= 2.10	pH= 2.37	$[\text{OH}^-] = 3.2 \times 10^{-4}$	$[\text{H}^+] = 3.2 \times 10^{-7}$

Milk of magnesia → milk → lemon juice → household ammonia

حليب المغنيسيا ← الحليب ← عصير الليمون ← الأمونيا المنزلية

Milk → household ammonia → lemon juice → milk of magnesia

الحليب ← الأمونيا المنزلية ← عصير الليمون ← حليب المغنيسيا

Household ammonia → lemon juice → milk → milk of magnesia

الأمونيا المنزلية ← عصير الليمون ← الحليب ← حليب المغنيسيا

Lemon juice → milk → milk of magnesia → household ammonia

عصير الليمون ← الحليب ← حليب المغنيسيا ← الأمونيا المنزلية

What is the **correct** ascending order according to the **$[\text{OH}^-]$** value for each of the following solutions?

ما الترتيب التصاعدي **الصحيح** حسب قيمة **$[\text{OH}^-]$** لكل من المحاليل التالية ؟

المحلول D Solution D	المحلول C Solution C	المحلول B Solution B	المحلول A Solution A
$[\text{H}^+] = 2.5 \times 10^{-2} \text{M}$	$[\text{OH}^-] = 4.0 \times 10^{-3} \text{M}$	pH= 7.40	pOH= 5.60

Solution **D** → solution **B** → solution **A** → solution **C**

المحلول **D** ← المحلول **B** ← المحلول **A** ← المحلول **C**

Solution **B** → solution **C** → solution **D** → solution **A**

المحلول **B** ← المحلول **C** ← المحلول **D** ← المحلول **A**

Solution **C** → solution **A** → solution **B** → solution **D**

المحلول **C** ← المحلول **A** ← المحلول **B** ← المحلول **D**

Solution **A** → solution **B** → solution **C** → solution **D**

المحلول **A** ← المحلول **B** ← المحلول **C** ← المحلول **D**



Molarity and the pH of strong acids and bases

Strong acids and bases are essentially 100% in the form of ions in solution.

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

Strong polyprotic acid and Multiple OH^-

The concentration of hydroxide ions in a $7.5 \times 10^{-4} M$ solution of $Ca(OH)_2$ is

pOH = ... pH = ...



Figure 15 The label on a bottle of a strong acid or a strong base tells you the concentration of hydrogen ions or hydroxide ions in the solution. That is because, in solution, strong acids and bases exist entirely as ions.

Final exam question

What is the pH value of $6.50 \times 10^{-2} M$ calcium hydroxide $Ca(OH)_2$ solution?

ما قيمة pH لمحلول هيدروكسيد الكالسيوم $Ca(OH)_2$ تركيزه $6.50 \times 10^{-2} M$ ؟

9.8

☐

7.5

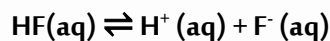
☐

4.3

☐

13.1

☐

Calculating K_a from pHWrite the K_a expression forCalculate K_a for HF if the pH of 0.100M solution is 3.20.

$$[\text{H}^+] = [\text{F}^-] = \dots\dots\dots$$

$$[\text{HF}] = 0.100\text{M} - \dots\dots\dots = \dots\dots\dots$$

The pH of a 0.100M solution of formic acid (HCOOH) is 2.38. What is K_a for HCOOH ?

$$1.8 \times 10^{-4}$$

Calculate the K_a for a 0.220M solution of H_3AsO_4 , pH = 1.50

$$5.4 \times 10^{-3}$$

Calculate the K_a for a 0.0400M solution of HClO_2 , pH = 1.80

$$1.1 \times 10^{-2}$$





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

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

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

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

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

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

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

Challenge Calculate the K_a of a 0.0091M solution of an unknown acid (HX) having a pOH of 11.32.

$$6.3 \times 10^{-4} (HF)$$





Final exam question

The pH of a 0.200 M solution of hydrofluoric acid HF is 2.15. What is the K_a value of HF acid?
الرقم الهيدروجيني pH لمحلول 0.200 M من حمض الهيدروفلوريك HF هو 2.15 . ما قيمة K_a لحمض HF؟

$$4.7 \times 10^{-11}$$

$$3.2 \times 10^{-9}$$

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

$$2.6 \times 10^{-4}$$

What is the value of K_a of 0.0400 M solution of acid HClO_2 with pH=1.80?

ما قيمة K_a لمحلول حمض HClO_2 تركيزه 0.0400 M و pH=1.80؟

$$4.9 \times 10^{-9}$$

$$5.8 \times 10^{-3}$$

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

$$2.6 \times 10^{-4}$$

What is the value of K_a of 0.0044 M solution of acid $\text{C}_6\text{H}_5\text{COOH}$ with pH=3.30?

ما قيمة K_a لمحلول حمض $\text{C}_6\text{H}_5\text{COOH}$ تركيزه 0.0044 M و pH=3.30؟

$$3.8 \times 10^{-2}$$

$$2.6 \times 10^{-4}$$

$$6.5 \times 10^{-5}$$

$$4.9 \times 10^{-9}$$





Measuring pH



Figure 16 The approximate pH of a solution can be obtained by wetting a piece of pH paper with the solution and comparing the color of the wet paper with a set of standard colors as shown in **a**. The portable pH meter in **b**, which is being used to measure the pH of rain water, provides a more accurate measurement in the form of a digital display of the pH.





Extra practice

1. **Explain**, Using Le Châtelier's principle, what happens to the $[H^+]$ of a $0.10M$ solution of acetic acid when a drop of $NaOH$ solution is added.

.....
.....

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

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

4. **Calculate** the pH of the following solutions.

a. $1.0M$ HI

b. $0.050M$ HNO_3

c. $1.0M$ KOH

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

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





6. Use Le Châtelier's principle to explain what happens to the equilibrium $\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$ when a few drops of HCl are added to pure water.

.....

.....

7. Use the data in the table to answer the following questions(a to e).

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

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

8. What is $[\text{OH}^-]$ in an aqueous solution at 298 K in which $[\text{H}^+] = 5.40 \times 10^{-3} \text{ M}$?

9. What are the pH and pOH for the solution described in Question 8?

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

11. Given two solutions, 0.10M HCl and 0.10M HF, which solution has the greater concentration of H^+ ions?

Calculate pH values for the two solutions, given that $[\text{H}^+] = 7.9 \times 10^{-3} \text{ M}$ in the 0.10M HF.





Chapter: Acids and Bases

Lesson 4: Neutralization

Reactions Between Acids and Bases

A **neutralization reaction** is in which an **acid** and a **base** in an aqueous solution react to produce **salt** and **water**.

A **salt** is an ionic compound made up of a cation (positive ion) from a base and an anion (negative acid) from an acid.

Writing neutralization equations

What kind of reaction occurs when magnesium hydroxide ($\text{Mg}(\text{OH})_2$), the active ingredient in milk of magnesia, contacts hydrochloric acid (HCl) solution produced by the stomach?

For the reaction between hydrochloric (HCl) acid and sodium hydroxide (NaOH).

Formula equation
Complete ionic equation
Eliminate the spectator ions and write the net ionic equation

In an aqueous solution, a H^+ ion exists as a H_3O^+ ion, so the net ionic equation for an acid-base neutralization reaction is

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

Formula equation
Complete ionic equation
Eliminate the spectator ions and write the net ionic equation





Acid-base titration

Titration is a method for determining the concentration of a solution by reacting a known volume of that solution with a solution of known concentration.

Titration procedure How is an acid-base titration performed?

- 1- A measured volume of an acidic or basic solution of unknown concentration is placed in a beaker, and the initial pH of the solution is read and recorded.
- 2- A buret is filled with the titrating solution of known concentration. This is called the standard solution, or **titrant**.
- 3- Measured volumes of the standard solution are added slowly and mixed into the solution in the beaker. The pH is read and recorded after each addition. This process continues until the reaction reaches the **equivalence point**, which is the point at which moles of H^+ ion from the acid equal moles of OH^- ion from the base.

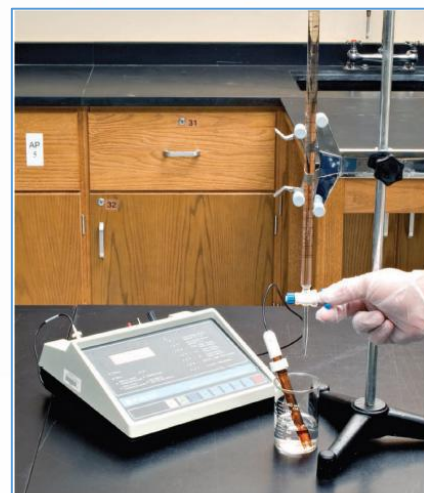


Figure 19 In the titration of an acid by a base, the pH meter measures the pH of the acid solution in the beaker as a solution of a base with a known concentration is added from the buret.

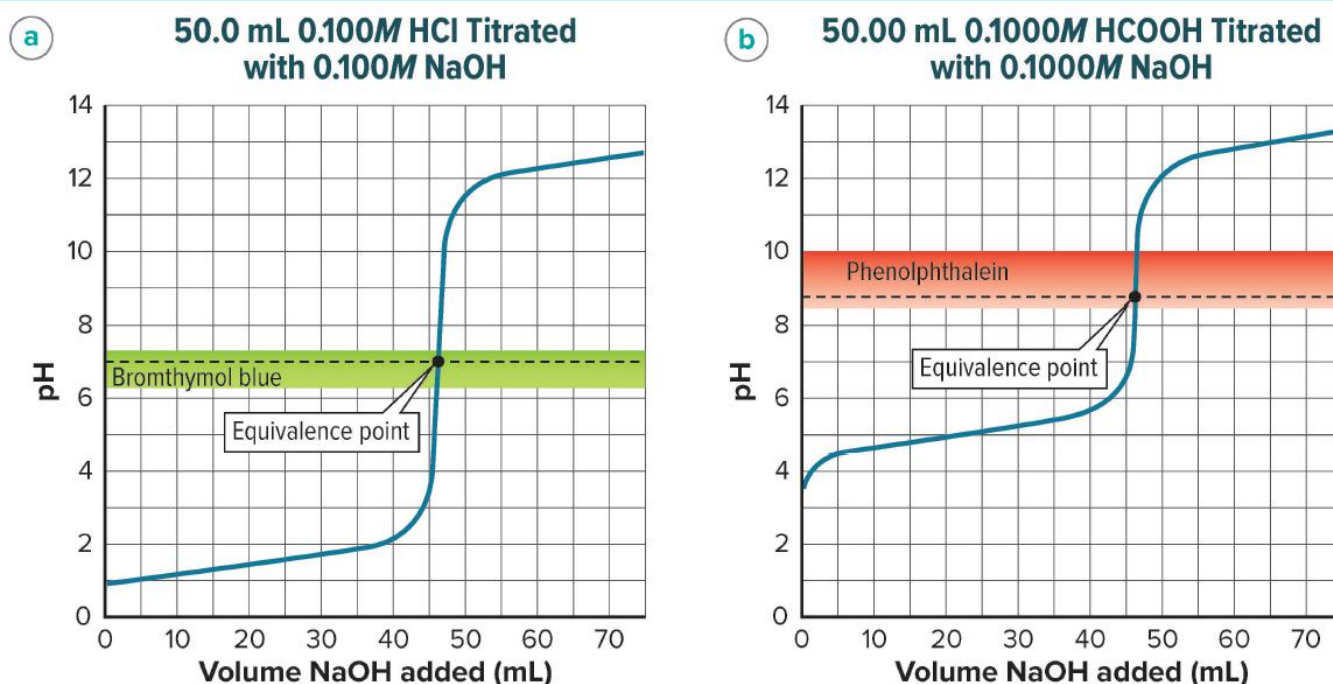


Figure 20 Graph **a** shows the titration of a strong acid with a strong base. Graph **b** shows the titration of a weak acid with a strong base. In each titration curve, a steep rise in the pH of the solution indicates that all of the H^+ ions from the acid have been neutralized by the OH^- ions of the base. The point at which the curve flexes (at its intersection with the dashed line) is the equivalence point of the titration.

Compare Identify two ways in which the graphs differ.

Question: The equivalence point is not always at a pH of 7. Explain.



Acid-base indicators

Chemical dyes whose colors are affected by acidic and basic solutions are called **acid-base indicators**.



Figure 21 The familiar dark color of tea becomes lighter when lemon juice is added. A substance contained in tea is an indicator. Most indicators are large molecules that act as weak acids. Slight differences in bonding patterns when an indicator molecule is ionized or un-ionized account for the color changes.

Tea contains compounds called polyphenols that have slightly ionizable hydrogen atoms. Adding acid to a cup of tea depresses the ionization according to Le Chatelier's principle, and the color of the un-ionized polyphenols becomes more apparent.

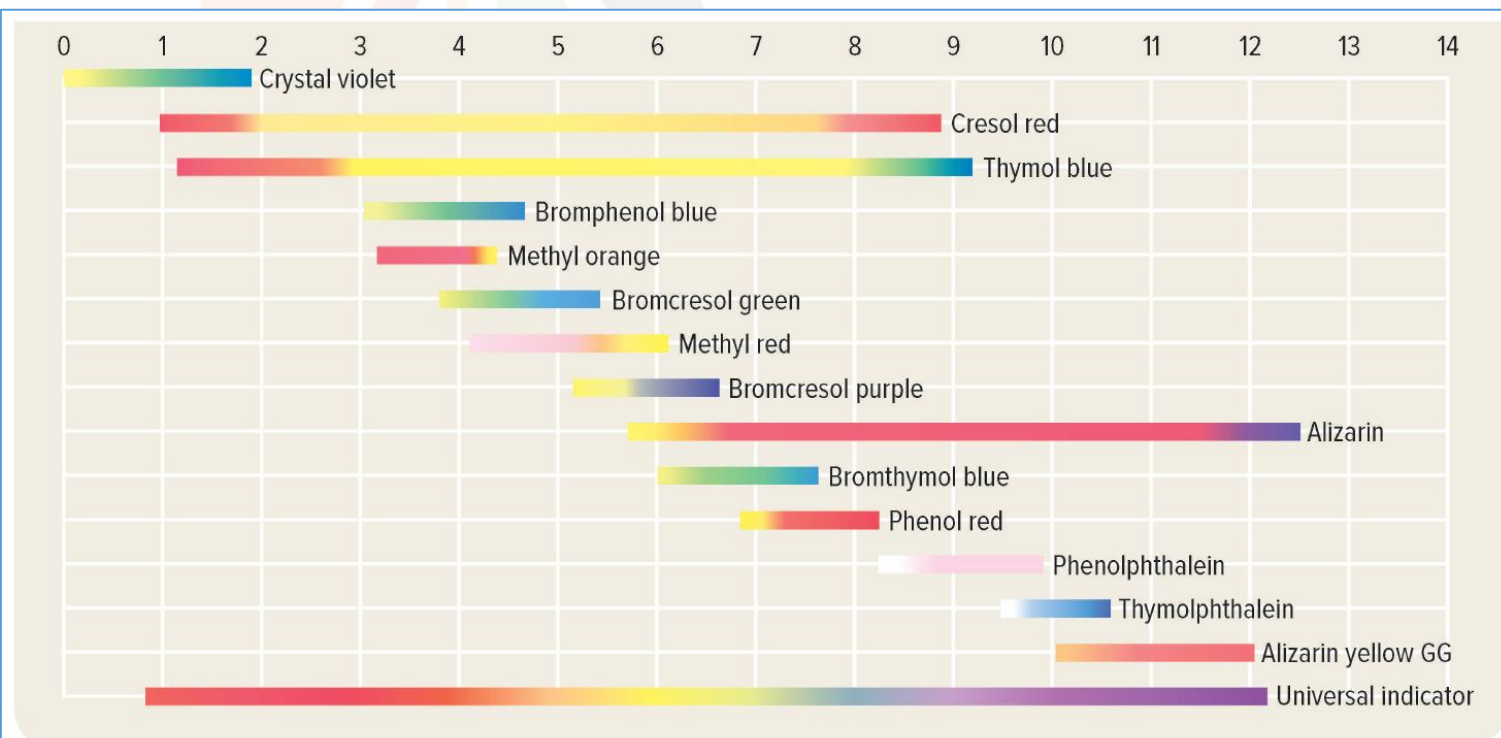


Figure 22 Choosing the right indicator is important. The indicator must change color at the equivalence point of the titration, which is not always at pH 7.

Choose some indicators that may be used for a titration of a **strong acid** with a **strong base**.

Choose some indicators that may be used for a titration of a **weak acid** with a **strong base**.

Choose some indicators that may be used for a titration of a **strong acid** with a **weak base**.



Indicators and titration end point

Indicators used for titration are weak acids. Each has its own particular pH or pH ranges over which it changes color.

The point at which the indicator used in a titration changes color is called the **end point**.

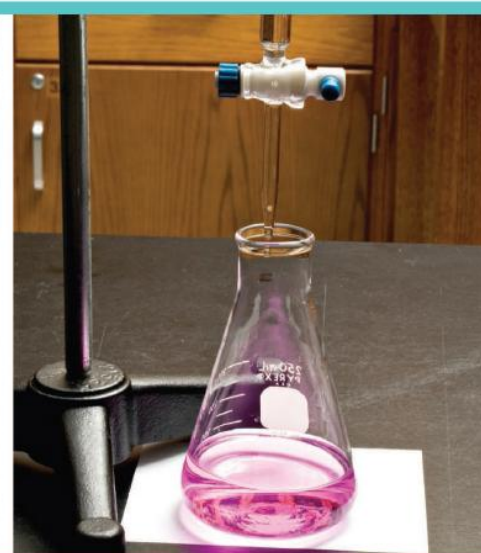
The indicator for a titration should change color at the equivalence point of the titration.



The buret contains the standard solution (0.1000M NaOH), and the flask contains 25.00 mL HCOOH solution along with a small amount of phenolphthalein indicator.



The standard solution is added slowly to the acid solution. The phenolphthalein indicator turns pink, but the color disappears upon mixing, until the end point is reached.



The end point of the titration is marked by a permanent, but very light, pink color. A careful reading of the buret reveals that 18.28 mL 0.1000M NaOH has been added.

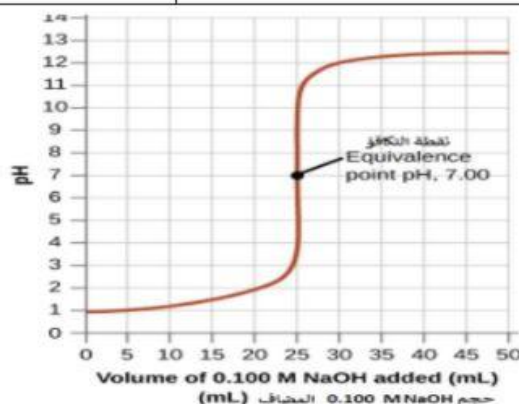
Figure 23 Titration is a precise procedure requiring practice. The white paper under the flask provides a background for viewing the indicator color change.

Final exam questions

Which of the following statements is **correct** according to the titration curve and indicator table shown below?

أي العبارات التالية **صحيحة** فيما يتعلق بمنحنى المعايرة وجدول الكواشف الموضحة أدناه؟

مدي الكاشف Indicator range	الكاشف Indicator
8.2-10	فينولفثالين Phenolphthalein
6.0-7.6	ازرق البروموثيمول Bromthymol blue



A. The acid is weak, and Phenolphthalein is the suitable indicator to use in this titration

A. الحمض ضعيف والكاشف المناسب استخدامه في هذه المعايرة هو الفينولفثالين

B. The acid is strong, and Bromothymol blue is the suitable indicator to use in this titration

B. الحمض قوي والكاشف المناسب استخدامه في هذه المعايرة هو ازرق البروموثيمول

C. The acid is strong, and Phenolphthalein is the suitable indicator to use in this titration

C. الحمض قوي والكاشف المناسب استخدامه في هذه المعايرة هو الفينولفثالين

D. The acid is weak, and Bromothymol blue is the suitable indicator to use in this titration

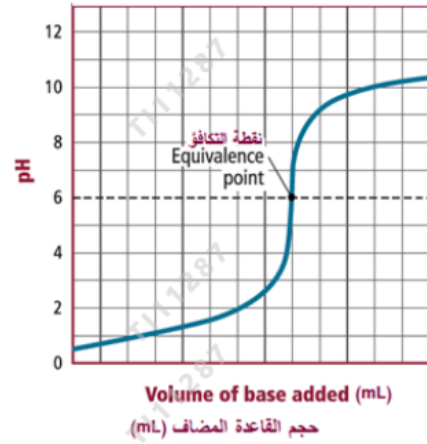
D. الحمض ضعيف والكاشف المناسب استخدامه في هذه المعايرة هو ازرق البروموثيمول



Which of the following statements is **correct** according to the titration curve and indicator table shown below?

أي العبارات التالية **صحيحة** فيما يتعلق بمنحنى المعايرة وجدول الكواشف الموضحة أدناه؟

مدى الكاشف Indicator range	الكاشف Indicator
5.2-6.8	بنفسجي برومو كريزول Bromocresol purple
8.2-10.0	الفينولفثالين Phenolphthalein



The base is NH_4OH , and phenolphthalein is the suitable indicator

القاعدة NH_4OH ، والكاشف المناسب هو الفينولفثالين

The base is NH_4OH ,and bromocresol purple is the suitable indicator

القاعدة NH_4OH ، والكاشف المناسب هو بنفسجي برومو كريزول

The base is KOH ,and bromocresol purple is the suitable indicator

القاعدة KOH ، والكاشف المناسب هو بنفسجي برومو كريزول

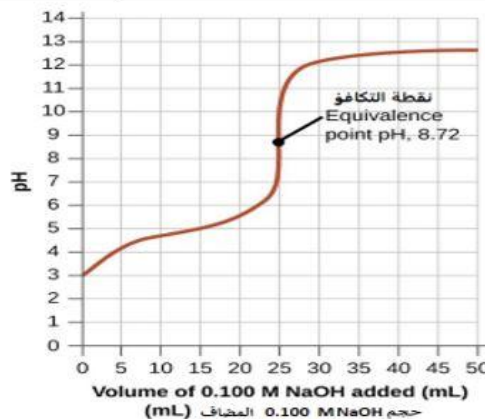
The base is KOH ,and phenolphthalein is the suitable indicator

القاعدة KOH ، والكاشف المناسب هو الفينولفثالين

Which of the following statements is **correct** according to the titration curve and indicator table shown below?

أي العبارات التالية **صحيحة** فيما يتعلق بمنحنى المعايرة وجدول الكواشف الموضحة أدناه؟

مدى الكاشف Indicator range	الكاشف Indicator
8.2-10	فينولفثالين Phenolphthalein
4.2-6.2	أحمر الميثيل Methyle orange



- A. The acid is weak, and Phenolphthalein is the suitable indicator to use in this titration
- B. The acid is strong and Methyl orange is the suitable indicator to use in this titration
- C. The acid is strong and Phenolphthalein suitable indicator to use in this titration
- D. The acid is weak and Methyl orange suitable indicator to use in this titration

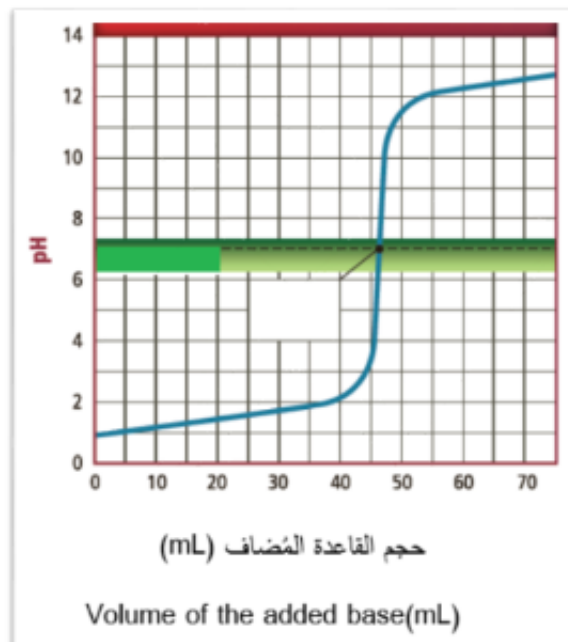
- A. الحمض ضعيف والكاشف المناسب استخدامه في هذه المعايرة هو الفينولفثالين
- B. الحمض قوي والكاشف المناسب استخدامه في هذه المعايرة هو أحمر الميثيل
- C. الحمض قوي والكاشف المناسب استخدامه في هذه المعايرة هو الفينولفثالين
- D. الحمض ضعيف والكاشف المناسب استخدامه في هذه المعايرة هو أحمر الميثيل



Which of the following is true regarding the titration

أي مما يأتي صحيح فيما يتعلق بمنحنى المعايرة أدناه؟

curve below?



أزرق بروموثيمول Bromothymol blue	أحمر الميثيل Methyl red	الميثيل البرتقالي Methyl orange	أزرق البروموفينول Bromophenol blue	الكاشف The indicator
6.0 - 7.6	4.2 - 6.2	3.2 - 4.6	3.1 - 4.7	قيم pH التي يتغير عندها لون الكاشف pH values at which the indicator's color changes

The acid is weak, and the base is weak
and the suitable indicator is Bromophenol blue

الحمض ضعيف والقاعدة ضعيفة والكاشف الملائم هو أزرق
البروموفينول

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

الحمض قوي والقاعدة ضعيفة والكاشف الملائم هو أحمر الميثيل

The acid is strong, and the base is strong
and the suitable indicator is Bromothymol blue

الحمض قوي والقاعدة قوية والكاشف الملائم هو أزرق بروموثيمول

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

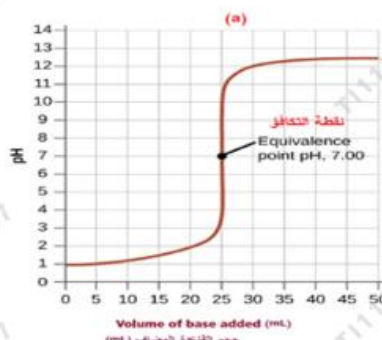
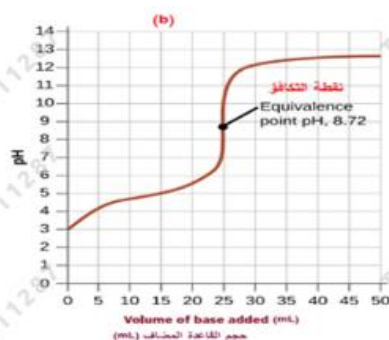
الحمض ضعيف والقاعدة قوية والكاشف الملائم هو برتقالي الميثيل



Which of the following is **correct** for both (a, and b) curves

أي مما يلي **صحيح** لكل من منحنى (a و b) الواردين أدناه؟

shown below?



أزرق البروموثيمول Bromothymol blue	أحمر الميثيل Methyl red	الكاشف Indicator
6.0-7.6	4.1-6.2	مدى الكاشف Indicator range

In curve **b** the acid is strong, and Methyl red

في المنحنى **b** الحمض قوي، والكاشف المناسب هو أحمر الميثيل

is the suitable indicator

In curve **b** the acid is weak, and Bromothymol blue

في المنحنى **b** الحمض ضعيف، والكاشف المناسب هو أزرق البروموثيمول

is the suitable indicator

In curve **a** the acid is weak, and Methyl red

في المنحنى **a** الحمض ضعيف، والكاشف المناسب هو أحمر الميثيل

is the suitable indicator

In curve **a** the acid is strong, and Bromothymol blue

في المنحنى **a** الحمض قوي، والكاشف المناسب هو أزرق البروموثيمول

is the suitable indicator

Your Guide to Success



Calculating Molarity from Titration

The balanced equation for a titration reaction is the key to calculating the unknown molarity.

Practice: Use the acid and base given to write a balanced neutralization equation

HCl	KOH	
H ₂ SO ₄	Mg(OH) ₂	
H ₃ PO ₄	NaOH	
HNO ₃	Fe(OH) ₃	
H ₃ PO ₄	Ca(OH) ₂	

Then use the following relationship to calculate the unknown concentration

$$\frac{Ma Va}{na} = \frac{Mb Vb}{nb}$$

M is molarity, **V** is volume, **n** is the number of moles (coefficient from the equation), **a** is for acid, **b** is for base

Practice problems:

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

What is the molarity of a nitric acid solution(**HNO₃**) if 43.33 mL of 0.1000M **KOH** solution is needed to neutralize 20.00 mL of the acid solution?





What is the concentration of a household ammonia cleaning solution (NH_4OH) if 49.90 mL of 0.5900M HCl is required to neutralize 25.00 mL of the solution?

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

Final exam questions

A **25.00 mL** sample of lithium hydroxide solution LiOH , is titrated by **0.425M** sulfuric acid H_2SO_4 solution, **20.25 mL** of the acid solution is required to reach the end point. **What is the molarity** of the LiOH solution?

تتم معايرة عينة قدرها **25.00 mL** من هيدروكسيد الليثيوم LiOH بمحلول حمض الكبريتيك H_2SO_4 تركيزه **0.425 M** ووجد أنه يلزم **20.25 mL** من محلول الحمض للوصول إلى نقطة نهاية المعايرة .
ما مولارية محلول هيدروكسيد الليثيوم LiOH ؟

0.6885 M

0.3443 M

0.5275 M

0.4550 M





What is the molarity of H_3PO_4 solution if 15.00 mL

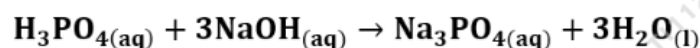
ما مولارية محلول H_3PO_4 إذا لزم 15.00 mL

of 0.500 M NaOH solution is needed

من 0.500 M محلول NaOH لمعادلة 25.00 mL

to neutralize 25.00 mL of the acid solution?

من محلول الحمض؟



0.0075 M

0.0025 M

0.1 M

0.200 M

What is the molarity of H_2SO_4 solution

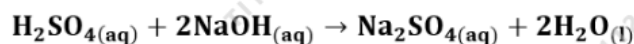
ما مولارية محلول H_2SO_4 إذا لزم 74.30 mL من

if 74.30 mL of 0.4388 M NaOH solution is needed

0.4388 M محلول NaOH لمعادلة 45.78 mL من

to neutralize 45.78 mL of the acid solution?

محلول الحمض؟



0.2320 M

0.4211 M

0.1569 M

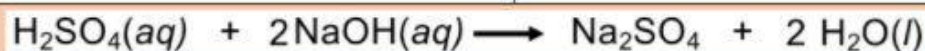
0.3561 M





What is the molarity of sulfuric acid H_2SO_4 solution if 68.4 mL of 0.333 M NaOH solution is needed to neutralize 49.0 mL of the acid solution?

ما مولارية محلول حمض الكبريتيك H_2SO_4 إذا لزم 68.4 mL من محلول 0.333 M NaOH لمعادلة 49.0 mL من محلول الحمض؟



0.465 M

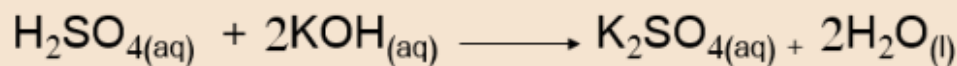
0.116 M

0.880 M

0.232 M

In an acid-base titration, 25.80 mL of a sulfuric acid solution H_2SO_4 is titrated to the end point by 54.70 mL of 0.6500 M potassium hydroxide KOH solution. What is the molarity of the H_2SO_4 solution?

في معايرة الحمض - القاعدة، تتم معايرة 25.80 mL من محلول حمض الكبريتيك H_2SO_4 حتى نقطة النهاية بمقدار 54.70 mL من محلول 0.6500 M هيدروكسيد البوتاسيوم KOH. فما مولارية محلول H_2SO_4 ؟



0.7 M

0.6 M

1.2 M

1.4 M