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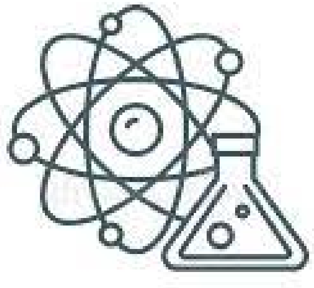


Chemistry

preparing students for exams

Ana Oliveira | June, 2025

Integrated Masters in Medicine
Model Exam | Access for International Students | 2025/2026

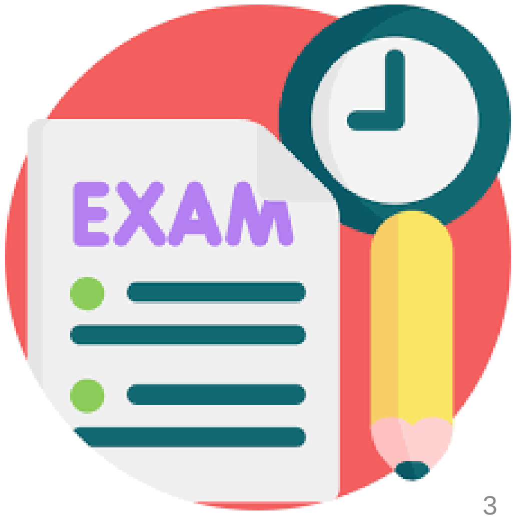
General instructions:

- The exam is evaluated from 0 to 200 points
- The exam is based on 20 questions, 15 multiple-choice and 5 essay questions
- Each multiple-choice question is marked out of 10.0 points and each essay question is also marked out of 10.0 points
- Only a blue or black pen may be used
- The use of a broker is not allowed
- All questions must be answered on the exam sheet
- The use of a scientific calculator is allowed
- The exam lasts 90 minutes

Exam structure:

Type of knowledge and skills		Quote	
Chemistry	Atomic structure, chemical bonding and Lewis's notation	40.0 points	200.0 points
	Solutions and solution preparation	30.0 points	
	Chemical reactions, writing and correcting reactions	30.0 points	
	Chemical equilibrium	40.0 points	
	Acid-base equilibrium	40.0 points	
	Oxidation-reduction equilibrium	20.0 points	

Exam date: 20/06/2025 (Friday) at 10:00 am



Model Exam resolution

Model Exam resolution

Group I

(15 multiple-choice questions)

1. The table shows the approximate melting and boiling temperatures of two thermometric substances at normal pressure.

Thermometric substance	Melting temperature / ºC	Boiling temperature / ºC
Water	0	100
Ethanol	-114	78

An advantage of using ethanol as a thermometric substance, compared to water, is that it allows the measurement of temperatures (at normal pressure)

(A) between -114ºC and 0ºC.

(B) below -114ºC.

(C) between 78ºC and 100ºC.

(D) above 100ºC.

To know

- **Ethanol** has a much lower freezing point (about **−114 °C**) compared to water (**0 °C**), which means it remains in liquid form at much colder temperatures
- This makes ethanol suitable for **measuring temperatures in cold environments** where water would freeze and become unusable in thermometers

Learn more

Thermometric Liquids – Ethanol vs. Mercury vs. Water
https://www.youtube.com/watch?v=7vYOIT3cLQk

Why Use Alcohol in Thermometers?
https://www.youtube.com/watch?v=krVZ2ZyE_kA

Properties of Thermometric Liquids (Educational Science Video)
https://www.youtube.com/watch?v=KsyyMfWeHlM

2. Which statement about the noble gases is correct?

(A) Noble gases are diatomic molecules.

(B) Noble gases are reactive gases.

(C) Noble gases have full outer electron shells.

(D) The noble gases are found on the left-hand side of the Periodic Table.

To know

- Noble gases (like helium, neon, argon, krypton, xenon, and radon) are chemically stable because their outermost energy levels (electron shells) are completely filled with electrons
- For most noble gases (like Ne, Ar, etc.), this means having 8 electrons in their outer shell – a condition known as the octet
- For helium (He), the outer shell only needs 2 electrons to be full, and helium has exactly 2 electrons

Learn more

[Electron Configuration of the Noble Gases – YouTube]
This video walks through the electron configurations of each noble gas, highlighting their complete outer shells

[Noble Gases – YouTube]
This tutorial provides an overview of the noble gases, their electron configurations, and why they are unreactive

Learn more about the periodic table

Periodic Table Song

Periodic Table of Elements | Groups, Periods, Chemistry

This video provides a comprehensive overview of the periodic table, detailing the arrangement of elements into groups and periods, and explaining the significance of each

Groups of the Periodic Table

This video focuses on the different groups within the periodic table, such as alkali metals, alkaline earth metals, halogens, and noble gases, highlighting their unique properties

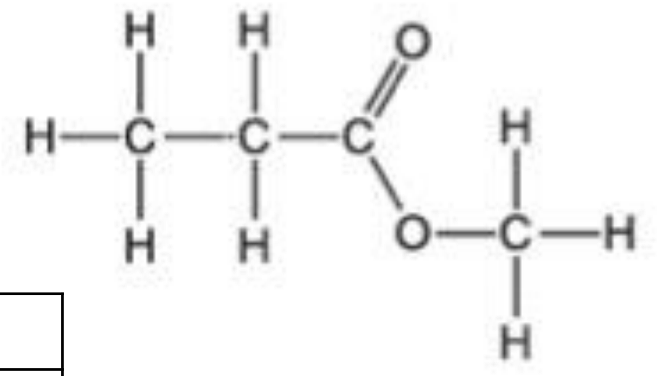
Atomic Radius, Ionization Energy, and Electronegativity

This video explains key periodic trends such as atomic radius, ionization energy, and electronegativity, and how they vary across the periodic table

How Does The Periodic Table Work | Properties of Matter

This video provides a basic understanding of how the periodic table functions and how it relates to the properties of matter

3. The structure of ester W is shown.

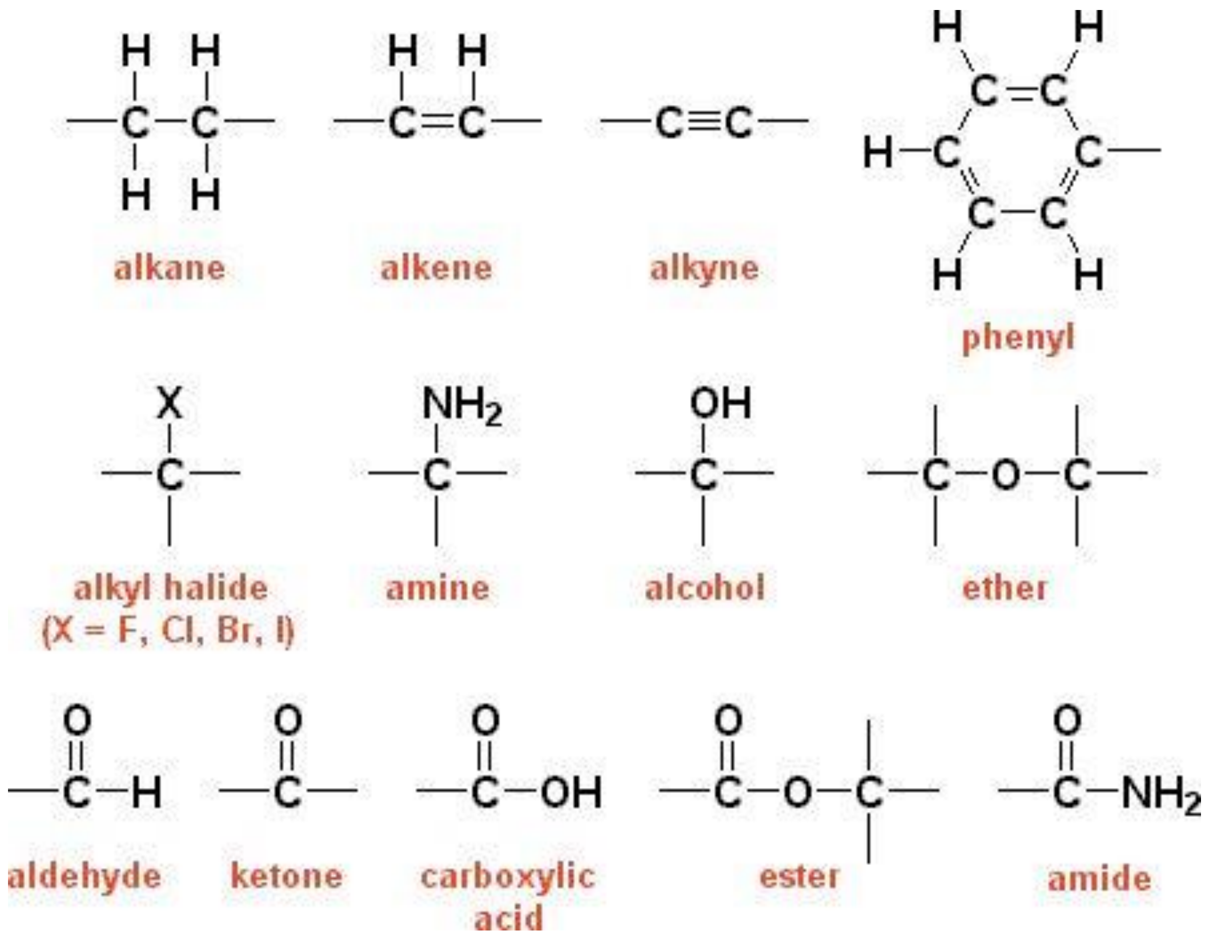


Which row gives the names of ester W and the carboxylic acid and alcohol from which it is made?

	Name of ester W	Carboxylic acid	Alcohol
(A)	propyl methanoate	propanoic acid	methanol
(B)	propyl methanoate	methanoic acid	propanol
(C)	methyl propanoate	propanoic acid	methanol
(D)	methyl propanoate	methanoic acid	propanol

To know

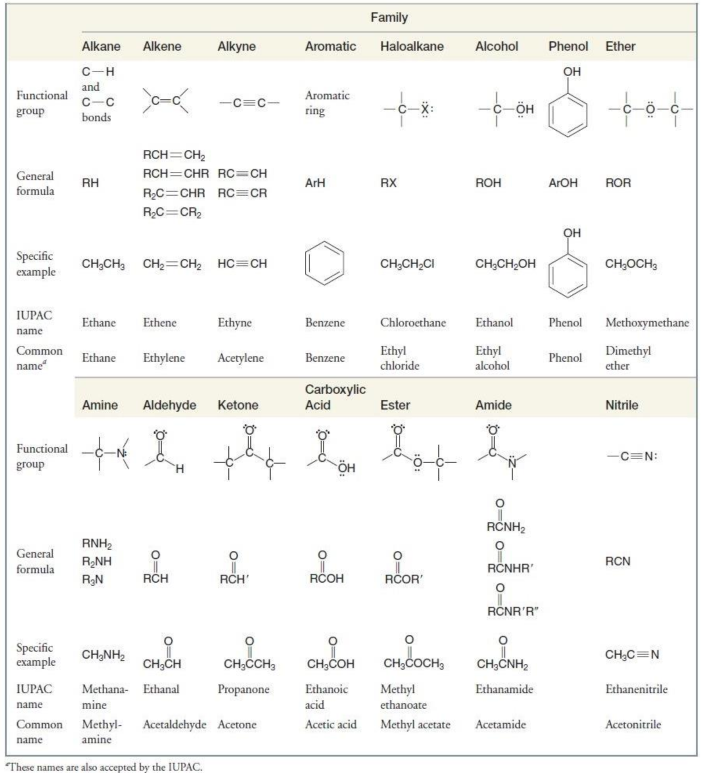
ORGANIC CHEMISTRY families



- Amide
- Amine
- Alcohol
- Aldehyde
- Carboxylic acid
- Ether
- Ester
- Hydrocrabons
- Ketone
- Phenyl

To know

HYDROCARBONS families



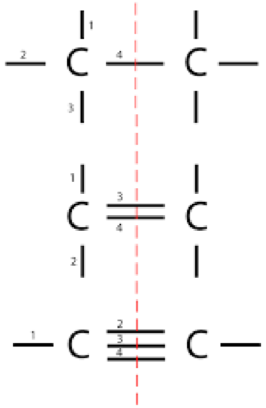
	Family							
	Alkane	Alkene	Alkyne	Aromatic	Haloalkane	Alcohol	Phenol	Ether
Functional group	C—H and C—C bonds	C=C	—C≡C—	Aromatic ring	—C—X:	—C—OH	Benzene ring with OH	—C—O—C—
General formula	RH	RCH=CH₂ / RCH=CHR / R₂C=CHR / R₂C=CR₂	RC≡CH / RC≡CR	ArH	RX	ROH	ArOH	ROR
Specific example	CH_3CH_3	$CH_2{=}CH_2$	$HC{\equiv}CH$	Benzene ring	CH_3CH_2Cl	CH_3CH_2OH	Benzene ring with OH	CH_3OCH_3
IUPAC name	Ethane	Ethene	Ethyne	Benzene	Chloroethane	Ethanol	Phenol	Methoxymethane
Common name[a]	Ethane	Ethylene	Acetylene	Benzene	Ethyl chloride	Ethyl alcohol	Phenol	Dimethyl ether
	Amine	Aldehyde	Ketone	Carboxylic Acid	Ester	Amide		Nitrile
Functional group	—C—N:	C(=O)—H	—C—C(=O)—C—	C(=O)—OH	C(=O)—O—C—	C(=O)—N:		—C≡N:
General formula	RNH_2 / R_2NH / R_3N	RCH (C=O)	RCH′ (C=O)	RCOH (C=O)	RCOR′ (C=O)	$RCNH_2$ / RCNHR′ / RCNR′R″ (C=O)		RCN
Specific example	CH_3NH_2	CH_3CH (C=O)	CH_3CCH_3 (C=O)	CH_3COH (C=O)	CH_3COCH_3 (C=O)	CH_3CNH_2 (C=O)		$CH_3C{\equiv}N$
IUPAC name	Methanamine	Ethanal	Propanone	Ethanoic acid	Methyl ethanoate	Ethanamide		Ethanenitrile
Common name	Methylamine	Acetaldehyde	Acetone	Acetic acid	Methyl acetate	Acetamide		Acetonitrile

[a]These names are also accepted by the IUPAC.

Alkane

Alkene

Alkyne



Hydrocarbons "families“:

- **Alkanes** (single bond) C_nH_{2n+2}
- **Alkenes** (double bond) C_nH_{2n}
- **Alkynes** (triple bond) C_nH_{2n-2}

Learn more [IUPAC names and rules]

4. The presence of ethanol, CH_3CH_2OH (M = 46.08 g mol^{-1}), in a person can be determined using a breathalyzer. In the breathalyzer, the ethanol present in exhaled air reacts with dioxygen, O_2, present in the air, being converted into ethanoic acid, CH_3COOH. This reaction can be translated as:

$$CH_3CH_2OH\ (g) + O_2\ (g) \longrightarrow CH_3COOH\ (g) + H_2O\ (g)$$

4.1. Consider that air contains 21% by volume of O_2 and assume that the molar volume of a gas at the temperature and pressure at which the reaction occurs is 24.0 $dm^3\ mol^{-1}$. Which of the following expressions allows you to calculate, in dm^3, the volume of air required for the complete reaction of 0.0275 g of CH_3CH_2OH?

(A) $V = \frac{21 \times 0.0275 \times 24.0}{100 \times 46.08}\ dm^3$

(B)) $V = \frac{100 \times 0.0275 \times 24.0}{21 \times 46.08}\ dm^3$

(C) $V = \frac{21 \times 0.0275}{100 \times 46.08 \times 24.0}\ dm^3$

(D) $V = \frac{100 \times 0.0275}{21 \times 46.08 \times 24.0}\ dm^3$

Resolution steps:

Exercise data:

$M(CH_3CH_2OH) = 46.08\ g\ mol^{-1}$

$m(CH_3CH_2OH) = 0.0275\ g$

$V_m = 24\ dm^3\ mol^{-1}$

$21\%\ O_2$

1) Calculate the number of moles of CH_3CH_2OH

$$M = \frac{m}{n} \Leftrightarrow n(CH_3CH_2OH) = \frac{0.0275}{46.08}\ mol$$

2) Using the stoichiometry of the reaction, determine the number of moles of O_2

1 mol CH_3CH_2OH ——— 1 mol O_2

$\frac{0.0275}{46.08}\ mol$ ——— x

$$x = \frac{0.0275}{46.08}\ mol\ O_2$$

Resolution steps:

3) Calculate the volume of O_2

$$V_m = \frac{V}{n} \Leftrightarrow 24 = \frac{V}{\frac{0.0275}{46.08}} \Leftrightarrow V = \frac{24 \times 0.0275}{46.08}\ dm^3 O_2$$

2) Since air contains 21% by volume of O_2

21% ———— $\frac{24 \times 0.0275}{46.08}\ dm^3\ O_2$

100% ———— x

$$x = \frac{100 \times 24 \times 0.0275}{21 \times 46.08}\ dm^3\ O_2$$

4.2. The first practical device for detecting alcohol in the human body was known as the “balloon test”. The presence of CH_3CH_2OH in exhaled air was detected by a change in color, due to the reaction translated into

$$2\ Cr_2O_7^{\ 2-} + 16\ H^+ + 3\ CH_3CH_2OH \longrightarrow 4\ Cr^{3+} + 3\ CH_3COOH + 11\ H_2O$$

(orange) *(green)*

In the presence of CH_3CH_2OH, the ________ color is observed, with $Cr_2O_7^{2-}$ being the ________ species.

(A) orange... oxidant

(B) orange ... reducing

(C) green ... reducing

(D) green... oxidizing

$$2\,Cr_2O_7^{\,2-} + 16\,H^+ + 3\,CH_3CH_2OH \longrightarrow 4\,Cr^{3+} + 3\,CH_3COOH + 11\,H_2O$$

(orange) *(green)*

$$2x + 7 \times (-2) = -2 \Leftrightarrow x = +6$$

nox(Cr) = +6 nox(Cr) = +3

Reduction → $Cr_2O_7^{2-}$ oxidizing species

In the presence of CH_3CH_2OH, the **green** color is observed, with $Cr_2O_7^{2-}$ being the **oxidizing** species.

Learn more

Redox Equilibria – A Level | CAPE Chemistry Unit 1
This educational video delves into redox equilibria concepts, suitable for advanced high school or early college-level students

Standard Potential, Free Energy, and the Equilibrium Constant – Khan Academy
This video explains the relationship between standard electrode potentials, Gibbs free energy, and equilibrium constants in redox reactions

Find Equilibrium Constant of Redox Reaction
This tutorial walks through the process of calculating the equilibrium constant for a redox reaction, providing practical exemples

Oxidation and Reduction In Terms of Change in Oxidation State
This video explains redox reactions by focusing on changes in oxidation states, a fundamental concept in understanding redox equilibrium

To know

Oxidation numbers

- The oxidation number is a positive or negative number that is assigned to an atom to indicate its degree of oxidation or reduction
- In oxidation-reduction processes, the driving force for chemical change is in the exchange of electrons between chemical species
- Six rules for determining oxidation numbers:

1) For free elements (uncombined state), each atom has an oxidation number of zero, H_2, Br_2, Na, Be, K, O_2, P_4, all have an oxidation number of 0.

To know

Oxidation numbers

2) Monatomic ions have oxidation numbers equal to their charge, for exemple, Li^{+}=+1, Ba^{2+}=+2, Fe^{3+}=+3, I^{-}=−1, O^{2-}=−2, etc. Alkali metal oxidation numbers =+1. Alkaline earth oxidation numbers =+2. Aluminum =+3 in all of its compounds. Oxygen's oxidation number =−2 *except* when in hydrogen peroxide (H_2O_2), or a peroxide ion (O_2^{-2}) where it is −1.

3) Hydrogen's oxidation number is +1, except for when bonded to metals as the hydride ion forming binary compounds. In LiH, NaH, and CaH_2, the oxidation number is −1.

4) Fluorine has an oxidation number of −1 in all of its compounds.

To know

OXIDATION NUMBERS

5) Halogens (Cl, Br, I) have negative oxidation numbers when they form halide compounds. When combined with oxygen, they have positive numbers. In the chlorate ion (ClO^{-3}), the oxidation number of Cl is +5, and the oxidation number of O is −2.

6) In a neutral atom or molecule, the sum of the oxidation numbers must be 0. In a polyatomic ion, the sum of the oxidation numbers of all the atoms in the ion must be equal to the charge on the ion.

5. The ion $^{23}_{11}Na^{+}$ contains:

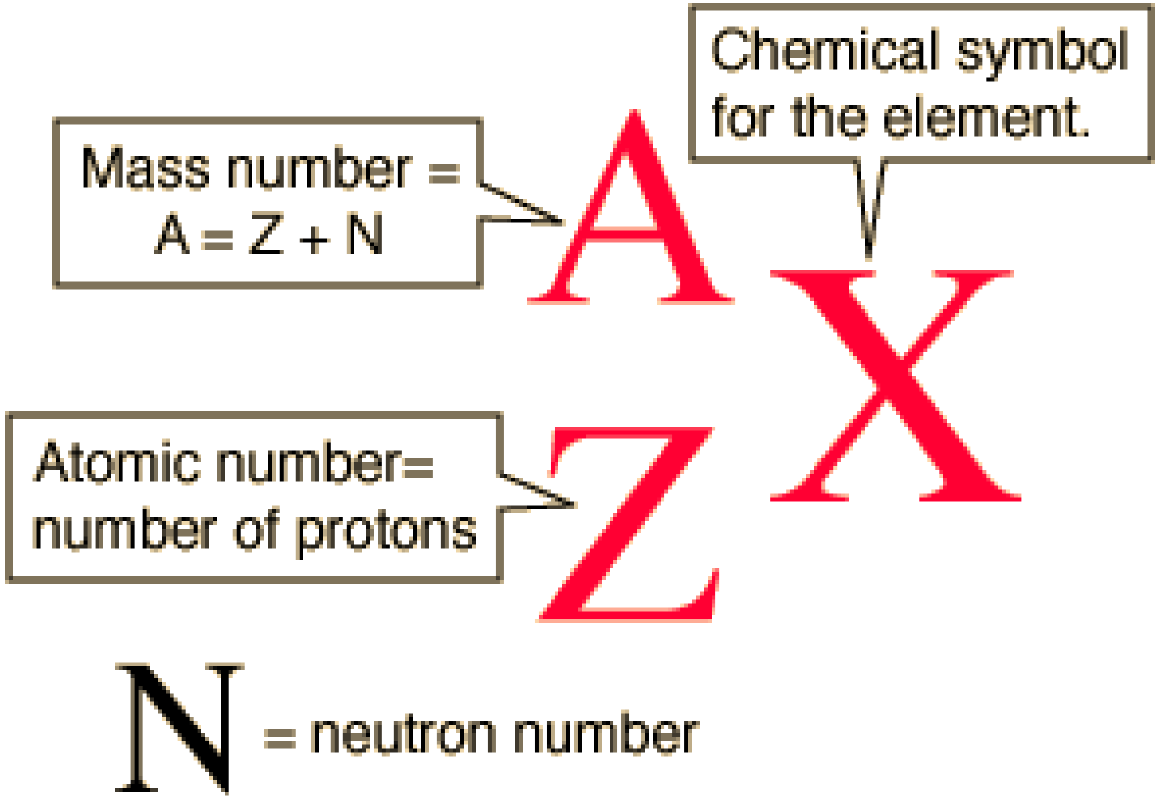
(A) 11 protons, 11 electrons, and 23 neutrons

(B) 11 protons, 10 electrons, and 12 neutrons

(C) 23 protons, 10 electrons, and 11 neutrons

(D) 23 protons, 11 electrons, and 10 neutrons

To know



Learn more **Atomic Symbols**

6. The equation for the manufacture of ammonia in the Haber process is shown.

$$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3\ (g)$$

The forward reaction is exothermic.

Which row describes the effect of the stated change on the reaction rate and the yield of ammonia?

	Change	Effect on reaction rate	Effect on yield of ammonia
(A)	decrease pressure	increases	decreases
(B)	decrease temperature	decreases	increases
(C)	increase pressure	increases	decreases
(D)	increase temperature	increases	increases

$$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3\ (g)$$

The forward reaction is exothermic

$$\Delta H < 0 \Longrightarrow Exothermic\ reaction$$

According to Le Châtelier's Principle, lowering the temperature favors the exothermic forward reaction, resulting in a higher concentration of ammonia (NH_3). However, the rate of the reaction decreases due to the reduced kinetic energy of the particles.

Learn more

https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Equilibria/Le_Chateliers_Principle

https://www.youtube.com/watch?v=XmgRRmxS3is

7. Lumps of calcium carbonate react with dilute hydrochloric acid as shown.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

Which change in conditions decreases the rate of the reaction?

(A) Increasing the concentration of the acid.

(B) Increasing the volume of the acid.

(C) Increasing the temperature.

(D Increasing the size of the lumps of calcium carbonate.

To know

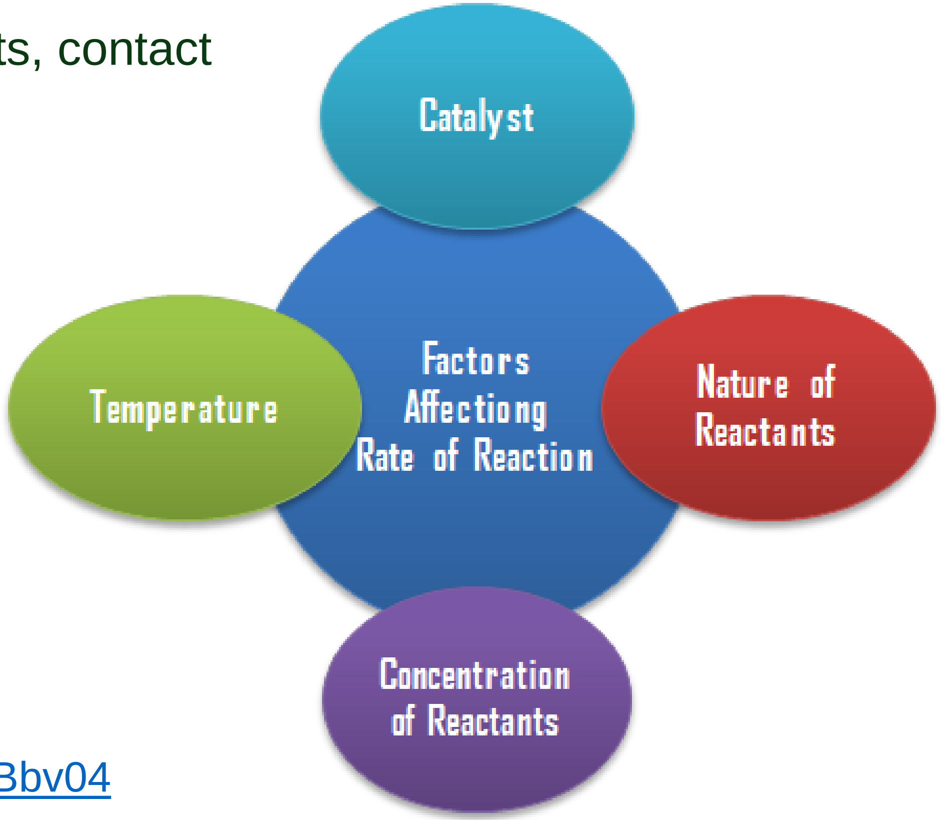
Several factors influence the speed (rate) of a chemical reaction:

1. **Temperature**: Increasing the temperature raises the kinetic energy of molecules, leading to more frequent and energetic collisions, which can increase the reaction rate
2. **Concentration**: Higher concentration of reactants leads to more collisions per unit time, thus potentially increasing the reaction rate
3. **Surface Area**: For reactions involving solids, increasing the surface area (e.g., by grinding into a powder) exposes more particles to react, enhancing the reaction rate
4. **Catalysts**: Catalysts provide an alternative pathway with a lower activation energy, increasing the reaction rate without being consumed in the process
5. **Pressure**: In reactions involving gases, increasing the pressure effectively increases the concentration of gas molecules, leading to a higher reaction rate
6. **Nature of Reactants**: Some substances react more readily than others due to their chemical nature
7. **Light (for photochemical reactions)**: Light can provide energy to reactants, initiating or accelerating certain reactions

To know

REACTIONS RATE

- Factors that influence the rate of reactions: concentration of reactants, contact surface of reactants, temperature and presence of catalyst



Learn more https://www.youtube.com/watch?v=-4HXaUBbv04

8. In the synthesis of acetylsalicylic acid, salicylic acid, $C_7H_6O_3$ (M = 138.13 g mol^{-1}), reacts with acetic anhydride, $C_4H_6O_3$ (M = 102.10 g mol^{-1} e ρ = 1.08 g cm^{-3}), giving rise to acetylsalicylic acid, $C_9H_8O_4$ (M = 180.17 g mol^{-1}), and acetic acid, $C_2H_4O_2$ (M = 60.05 g mol^{-1}). This reaction is catalyzed by sulfuric acid.

In a laboratory, 40.0 g of $C_7H_6O_3$ were added to excess acetic anhydride and 45.0 g of $C_9H_8O_4$ were obtained.

The yield of the reaction can be calculated as follows:

(A) $\eta = \frac{45 \times 138.13}{180.17 \times 40} \times 100\ \%$

(B) $\eta = \frac{40 \times 180.17}{138.13 \times 45} \times 100\ \%$

(C) $\eta = \frac{180.17}{40 \times 138.13} \times 100\ \%$

(D) $\eta = \frac{138.13}{180.17 \times 45} \times 100\ \%$

Resolution steps:

1) Write the reaction

$$C_7H_6O_3 + C_4H_6O_3 \longrightarrow C_9H_8O_4 + C_2H_4O_2$$

2) Calculate the number of moles of $C_7H_6O_3$

$$M = \frac{m}{n} \Leftrightarrow n(C_7H_6O_3) = \frac{40.0}{138.13}\ mol$$

Exercise data:

$M(C_7H_6O_3) = 138.13\ g\ mol^{-1}$

$M(C_4H_6O_3) = 102.10\ g\ mol^{-1}$

$\rho(C_4H_6O_3) = 1.08\ gcm^{-3}$

$M(C_9H_8O_4) = 180.17\ g\ mol^{-1}$

$M(C_2H_4O_2) = 60.05\ g\ mol^{-1}$

$m(C_7H_6O_3) = 45.0g$

$m(C_9H_8O_4) = 40.0g$

Resolution steps:

3) Calculate the number of moles of $C_9H_8O_4$

$$M = \frac{m}{n} \Leftrightarrow n(C_9H_8O_4) = \frac{45.0}{180.17}\ mol$$

4) Calculate reaction yield

$$\eta = \frac{actual\ yield}{theoretical\ yield} \times 100 = \frac{n(C_9H_8O_4)}{n(C_7H_6O_3)} \times 100 = \frac{45.0 \times 138.13}{40 \times 180.17} \times 100$$

Exercise data:

$M(C_7H_6O_3) = 138.13\ g\ mol^{-1}$

$M(C_4H_6O_3) = 102.10\ g\ mol^{-1}$

$\rho(C_4H_6O_3) = 1.08\ gcm^{-3}$

$M(C_9H_8O_4) = 180.17\ g\ mol^{-1}$

$M(C_2H_4O_2) = 60.05\ g\ mol^{-1}$

$m(C_7H_6O_3) = 45.0g$

$m(C_9H_8O_4) = 40.0g$

To know

$$Percent\ yield\ of\ a\ reaction\ (\%):\ \ \eta = \frac{actual\ yield}{theoretical\ yield} \times 100$$

Learn more

https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Introductory_Chemistry_(CK-12)/12%3A_Stoichiometry/12.09%3A_Theoretical_Yield_and_Percent_Yield

To know

$$Concentration\ (mol\ dm^{-3}):\ \ [X] = \frac{n}{V}$$

$$Molar\ mass\ (g\ mol^{-1}):\ M = \frac{m}{n}$$

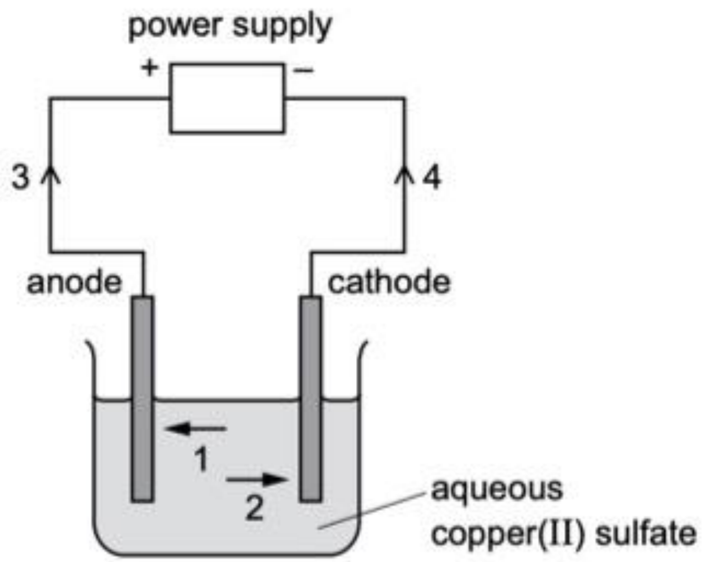
$$Density\ (g\ cm^{-3}):\ \ \rho = \frac{m}{V}$$

Learn more

https://chem.libretexts.org/Courses/Prince_Georges_Community_College/CHEM_2000%3A_Chemistry_for_Engineers_(Sinex)/Unit_4%3A_Nomenclature_and_Reactions/Chapter_12%3A_Aqueous_Reactions/Chapter_12.1%3A_Preparing_Solutions

9. The diagram shows a circuit used to electrolyse aqueous copper(II) sulfate.

Which arrows indicate the movement of the copper ions in the electrolyte and of the electrons in the external circuit?



	Copper ions	Electrons
(A)	1	3
(B)	1	4
(C)	2	3
(D)	2	4

$$Cu^{2+} + 2e^{-} \rightarrow Cu$$

Reduction / Cathode

To know

What Happens in an Electrolysis Cell?

In an electrolysis cell, electrical energy is used to drive a chemical reaction

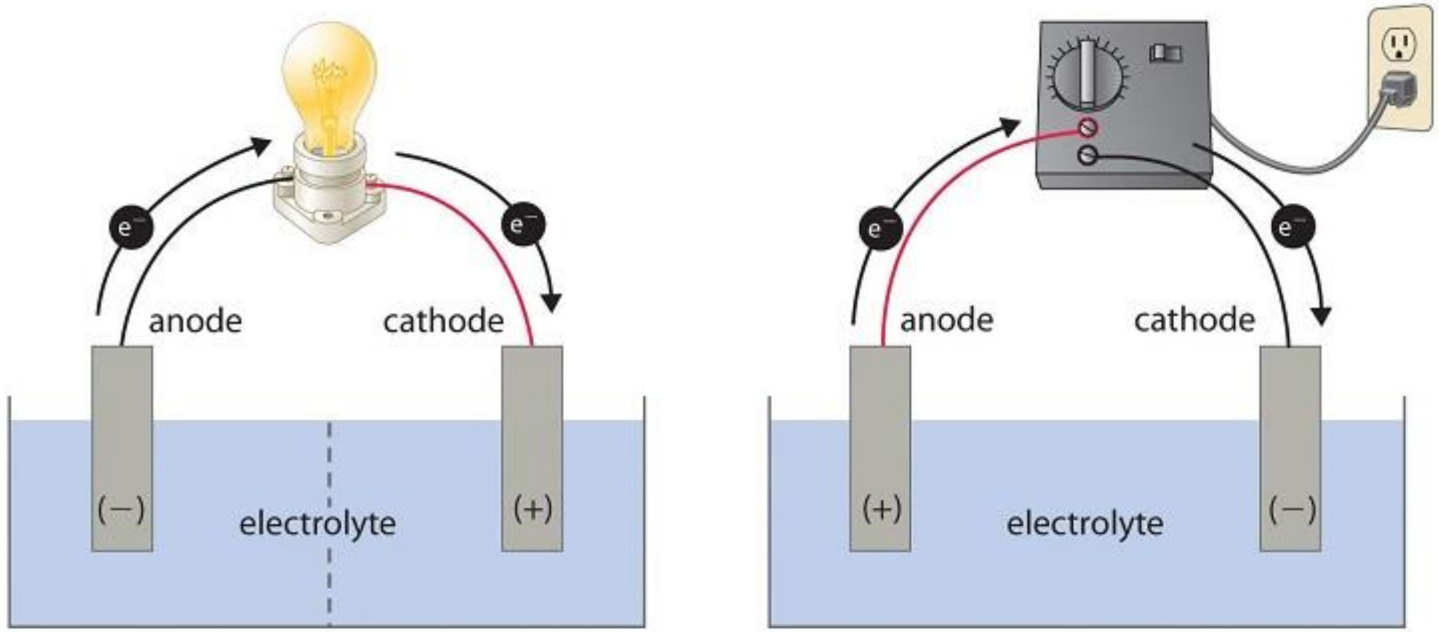
The cell has two electrodes: the **anode** (positive) and the **cathode** (negative), placed in an electrolyte, a liquid that contains **ions**

- **Electrons** are provided by a power source (like a battery) and move through wires from the **anode** to the **cathode**
- **Positive ions** in the electrolyte move **toward the cathode** to gain electrons (this is called **reduction**).
- **Negative ions** move **toward the anode** to lose electrons (this is called **oxidation**)

In sum:

- **Electrons flow** through the wire from anode to cathode
- **Ions move** through the solution: positive ions to the cathode, negative ions to the anode

To know



GALVANIC CELL

Energy released by spontaneous redox reaction is converted to electrical energy.

Oxidation half-reaction:
$Y \rightarrow Y^{+} + e^{-}$

Reduction half-reaction:
$Z^{+} + e^{-} \rightarrow Z$

Overall cell reaction:
$Y + Z \rightarrow Y^{+} + Z^{-}$ $(G < 0)$

ELECTROLYTIC CELL

Electrical energy is used to drive nonspontaneous redox reaction.

Oxidation half-reaction:
$Z^{-} \rightarrow Z + e^{-}$

Reduction half-reaction:
$Y^{+} + e^{-} \rightarrow Y$

Overall cell reaction:
$Y^{+} + Z^{-} \rightarrow Y + Z$ $(G > 0)$

Learn more

Electrolysis | Reactions | Chemistry | FuseSchool

A clear, student-friendly explanation of electrolysis with animations

Crash Course Chemistry – Electrochemistry

More detailed explanation

Galvanic Cell vs Electrolytic Cell Animation

An animated explanation highlighting the similarities and differences between galvanic and electrolytic cells

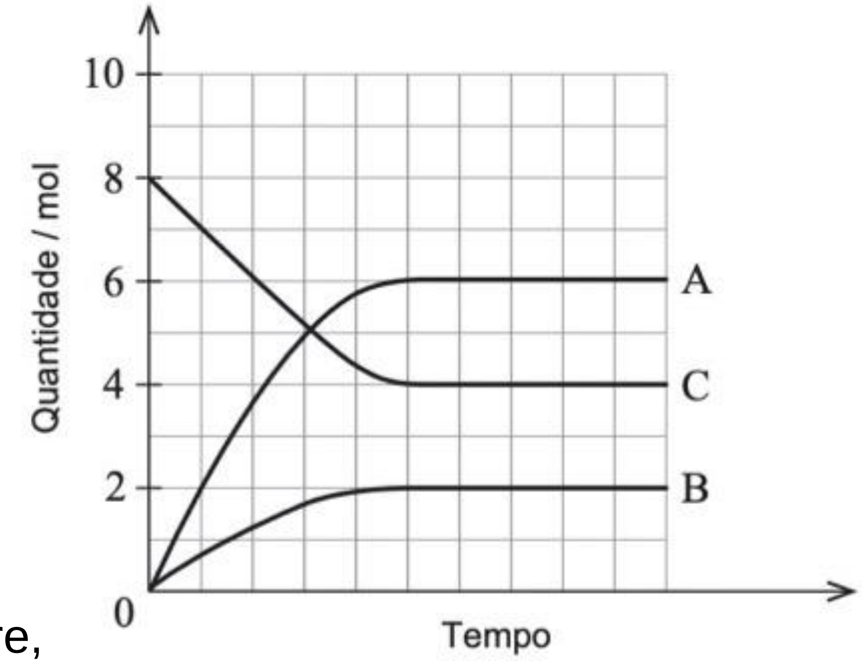
Galvanic Cell Vs Electrolytic Cell Differences

This video focuses on the distinctions between galvanic and electrolytic cells

10. Consider a closed gaseous system in which species A, B and C are involved in a chemical reaction and x, y and z correspond to their stoichiometric coefficients.

This reaction can be translated as: $z\,C(g) \rightleftharpoons x\,A(g) + y\,B(g)$

The figure shows the graph that reflects the evolution, over time, of the quantity of each of the species, A, B and C, until the equilibrium state is reached, at temperature T.



10.1. According to the figure, the stoichiometric coefficients x, y and z are, respectively,

(A) 3, 1 and 2

(B) 3, 2 and 1

(C) 2, 1 and 3

(D) 2, 3 and 1

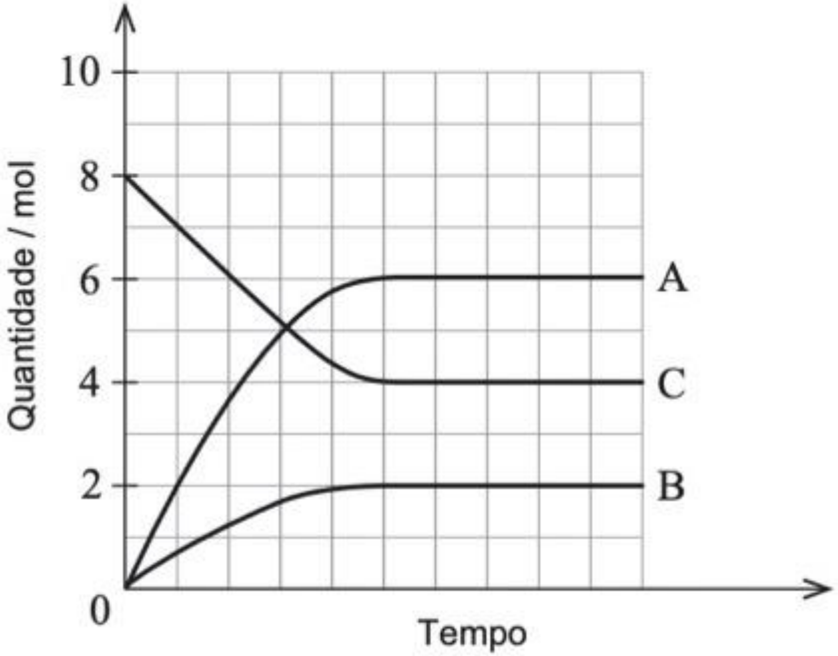
10.2. To study the effect of using a catalyst on the reaction, the same amount of species C was introduced into two identical reactors, under the same pressure and temperature conditions. The catalyst was also added to one of the reactors. Consider that the temperature, T, remained constant in both reactors. In the reactor to which the catalyst was added, it increased the

(A) reaction extent.

(B) equilibrium constant, Kc, at temperature T.

(C) percentage of A and B in the equilibrium reaction mixture.

(D) reaction rate.



To know

Factors Affecting Chemical Equilibrium:

1. **Concentration:** Altering the concentration of reactants or products shifts the equilibrium to oppose the change. For example, increasing the concentration of reactants drives the reaction forward, producing more products. Conversely, increasing the concentration of products shifts the equilibrium backward, forming more reactants

2. **Pressure (for gases):** Changing the pressure affects equilibria involving gaseous reactants or products. Increasing pressure shifts the equilibrium toward the side with fewer gas molecules, while decreasing pressure favors the side with more gas molecules

3. **Temperature:** Temperature changes can shift the equilibrium depending on whether the reaction is exothermic or endothermic. Increasing temperature favors the endothermic direction (absorbing heat), while decreasing temperature favors the exothermic direction (releasing heat)

4. **Catalysts:** Catalysts speed up both the forward and reverse reactions equally, thus they do not affect the position of equilibrium but help the system reach equilibrium faster

Learn more

- **Le Chatelier's Principle**

A video tutorial offering a basic introduction to Le Châtelier's Principle of chemical equilibrium

- **Equilibrium: Crash Course Chemistry #28**

An engaging video that discusses chemical equilibrium and its significance in chemistry

- **Le Châtelier's principle | Reaction rates and equilibrium**

This video explains how chemical systems at equilibrium respond to changes in conditions

11. The figure below shows the titration curve of 10.00 cm^3 of a sulfuric acid solution with a standard sodium hydroxide solution of concentration 5.00x10^{-2} mol dm^{-3}. The reaction that occurs can be translated as

H_2SO_4 (aq) + 2 NaOH (aq) → Na_2SO_4 (aq) + 2 H_2O (l)

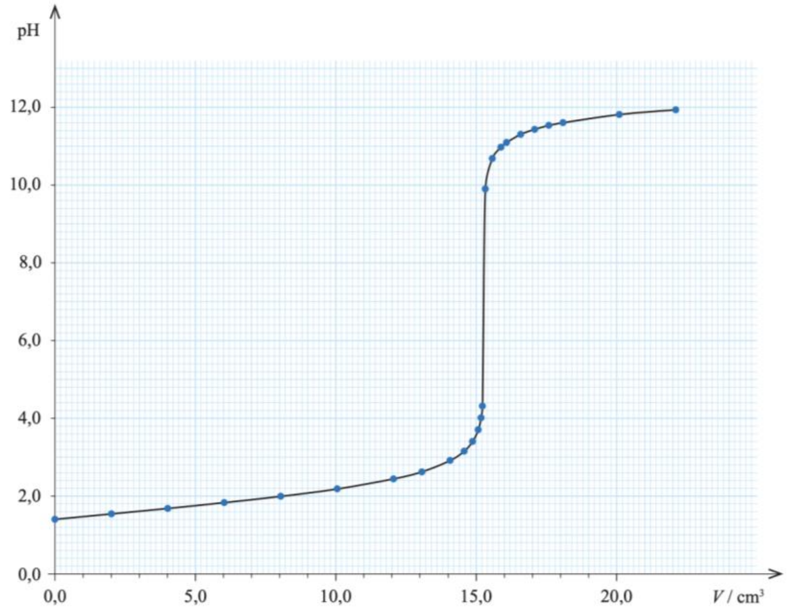
11.1. The concentration of the sulfuric acid solution can be calculated using the following expression:

(A) $[H_2SO_4] = \frac{5\times10^{-2}\times15.1}{10}$ mol dm^{-3}

(B) $[H_2SO_4] = \frac{5\times10^{-2}\times10}{2\times15.1}$ mol dm^{-3}

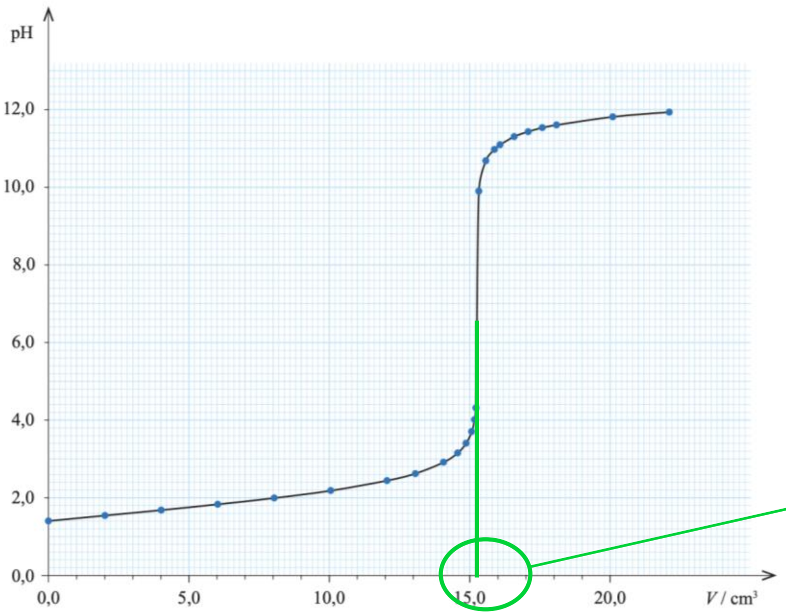
(C) $[H_2SO_4] = \frac{5\times10^{-2}\times15.1}{2\times10}$ mol dm^{-3}

(D) $[H_2SO_4] = \frac{5\times10^{-2}\times10}{15.1}$ mol dm^{-3}



Acid (a) – H_2SO_4

Base (b) – NaOH



Exercise data:

$V_a = 10.00\ cm^3$

$[NaOH] = 5.02 \times 10^{-2}\ mol\ dm^{-3}$

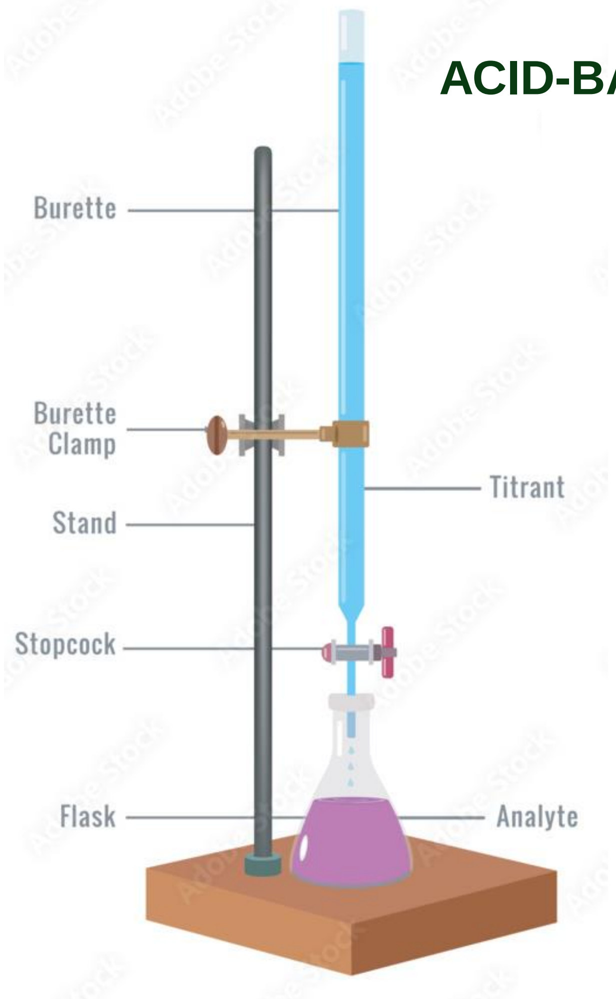
$V_b = 15.10\ cm^3$

Neutralization Reaction: $2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$

$$\frac{[acid] \times V_a}{n_a} = \frac{[base] \times V_b}{n_b}$$

$$\frac{[H_2SO_4] \times 10.00}{1} = \frac{5.02 \times 10^{-2} \times 15.1}{2} \Leftrightarrow [H_2SO_4] = \frac{5.02 \times 10^{-2} \times 15.1}{10.00 \times 2}\ mol\ dm^{-3}$$

To know



ACID-BASE TITRATION

at the equivalente point:

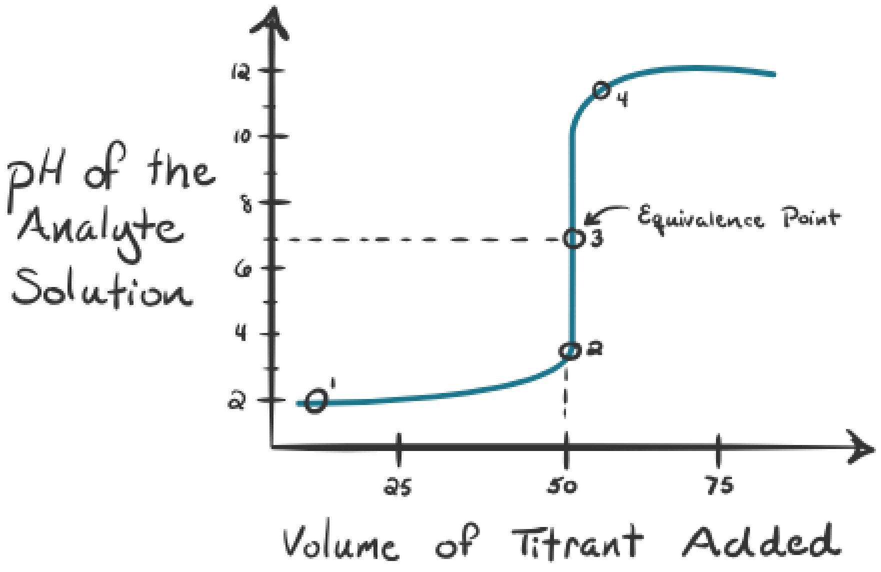
$$\frac{[acid] \times V_a}{n_a} = \frac{[base] \times V_b}{n_b}$$

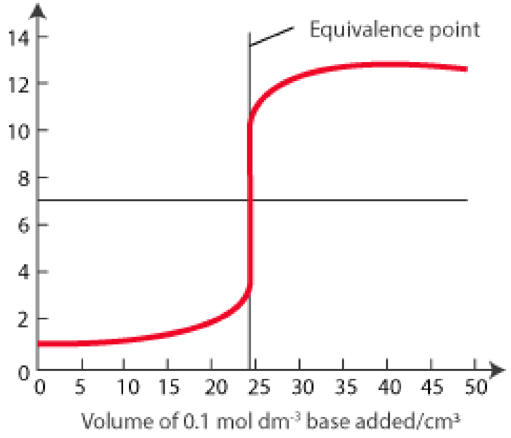
n = number of moles from the balanced equation

To know

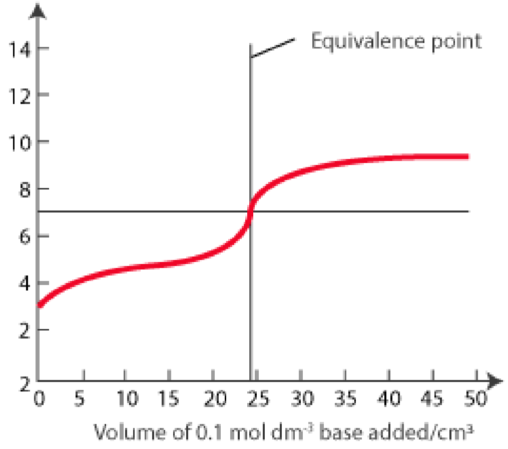
TITRATION CURVE

Typical Titration Curve

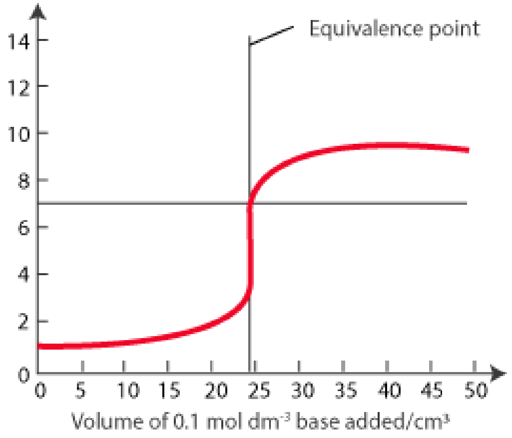




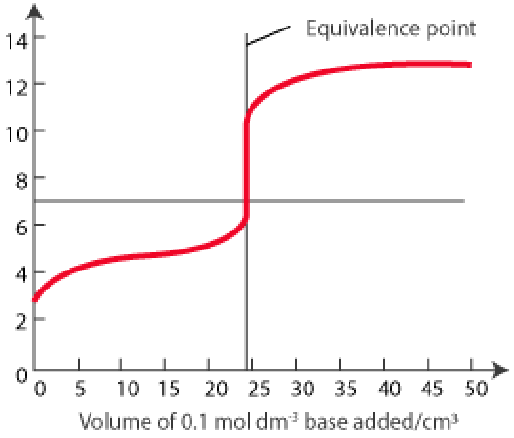
(Strong acid and strong base)



(Strong acid and weak base)



(Weak acid and weak base)



(Weak acid and strong base)

Learn more

Acid Base Titration with Sulfuric Acid and Sodium Hydroxide - YouTube
Step-by-step titration example with H_2SO_4 and NaOH

Titration Calculations Made Easy - YouTube
A basic tutorial with calculation examples

Khan Academy: Titration example with strong acid and base
Focuses on strong acid–strong base titration logic

Acid Base Titration Problems, Basic Introduction, Calculations
This video provides a basic introduction to acid-base titrations, including step-by-step calculations

How To Do Titration Calculations | Chemistry | FuseSchool
An educational video explaining how to perform titration calculations in chemistry

Determining Solute Concentration by Acid–Base Titration | Khan Academy
A tutorial on determining solute concentration through acid-base titration

11.2. Consider the following statements regarding the previous text and figure:

I. According to Arrhenius, the dissociation reaction of NaOH is: NaOH (aq) $\rightarrow$ Na^+ (aq) + OH^- (aq)

II. The conjugate pair of H_2SO_4 is SO_4^{2-}.

III. The basicity constant, K_b, of the dissociation of NaOH is given by por $K_b = \frac{[NaOH]}{[Na^+]\cdot[OH^-]}$.

IV. Methyl orange indicator (3.1 – 4.4 turning point) should be used in the titration.

V. The conjugate base of H_2SO_4 is strong.

The true statements are:

(A) I and II

(B) I and III

(C) III and IV

(D) II, IV and V

✓ I. According to Arrhenius, the dissociation reaction of NaOH is: NaOH (aq) → Na^+ (aq) + OH^- (aq)

✓ II. The conjugate pair of H_2SO_4 is SO_4^{2-}

✗ III. The basicity constant, K_b, of the dissociation of NaOH is given by por $K_b = \frac{[NaOH]}{[Na^+]\cdot[OH^-]}$

Dissociation reaction: NaOH → Na^+ + OH^-

Thus, the basicity constant (K_b) is given by:

$$K_b = \frac{[Na^+]\cdot[OH^-]}{[NaOH]}$$

✗ IV. Methyl orange indicator (3.1 – 4.4 turning point) should be used in the titration

At equilibrium, the pH is 7; therefore, the pH range of the indicator must include this value to accurately signal the endpoint of the reaction

✗ V. The conjugate base of H_2SO_4 is strong

Since H_2SO_4 is a strong acid, its conjugate base (HSO_4^-) is correspondingly weak and exhibits minimal tendency to accept protons

To know

ACID-BASE EQUILIBRIUM

Acidity constant (K_a)

$$aHA + H_2O \rightleftharpoons bA^- + cH_3O^+$$

$$K_a = \frac{[A^-]^b \cdot [H_3O^+]^c}{[HA]^a}$$

Basicity constant (K_b)

$$aBOH \rightleftharpoons bB^- + cOH^-$$

$$K_b = \frac{[B^-]^b \cdot [OH^-]^c}{[BOH]^a}$$

Conjugate acid/base pair

$$K_a \cdot K_b = K_W$$

Learn more

https://www.youtube.com/watch?v=pkqDTi2K-5g

To know

Acid-Base Equilibrium

$$pOH = -log[OH^-] \Leftrightarrow [OH^-] = 10^{-pOH}$$

$$pH = -log[H^+] \Leftrightarrow [H^+] = 10^{-pH}$$

or

$$pH = -log[H_3O^+] \Leftrightarrow [H_3O^+] = 10^{-pH}$$

Learn more

https://www.youtube.com/watch?v=R07zGPMAni0

$$at\ 25°C:\quad pH + pOH = 14 \longrightarrow K_w = [H_3O^+] \cdot [OH^-] = 1 \times 10^{-14}$$

12. Which of the following electronic configurations could correspond to a carbon atom, $_6C$, in the ground-state?

(A) $1s^2\ 2s^1\ 2p_x^1\ 2p_y^1\ 2p_z^1$

(B) $1s^2\ 2s^2\ 2p_x^1\ 2p_y^0\ 2p_z^1$

(C) $1s^2\ 2s^1\ 2p_x^2$

(D) $1s^2\ 2s^1\ 2p_x^2\ 2p_y^1$

To know

Electron configuration refers to the arrangement of electrons in an atom's energy levels, sublevels, and orbitals. Electrons occupy orbitals in a manner that minimizes the atom's energy, following specific principles:

1. **Aufbau Principle**: Electrons fill orbitals starting from the lowest energy level to higher ones
2. **Pauli Exclusion Principle**: An orbital can hold a maximum of two electrons with opposite spins
3. **Hund's Rule**: Electrons will singly occupy degenerate orbitals (orbitals of the same energy) before pairing up

Learn more

- **[Electron Configuration - Basic Introduction]**
This video provides a foundational overview of electron configurations, including practice problems to reinforce learning

- **[Electron Configuration Diagrams | Properties of Matter | FuseSchool]**
An animated explanation focusing on electron configuration diagrams, ideal for visual learners

- **[Introduction to Electron Configurations | Khan Academy]**
A comprehensive tutorial that delves into the principles governing electron configurations

- **[Electron Configurations with the Periodic Table | Khan Academy]**
This video demonstrates how to use the periodic table as a tool to determine electron configurations

Model Exam resolution

Group II

(5 essay questions)

13. Nitrogen oxides, which are mainly produced by combustion in automobile engines and thermal power plants, contribute to the formation of several chemical species that have an impact on the environment. Nitrogen oxides are formed by nitrogen and oxygen atoms.

In the atmosphere, nitrogen oxides can produce nitric acid, HNO_3, a strong acid, and nitrous acid, HNO_2, a weak acid, which contribute to the acidification of rainwater.

Consider two aqueous solutions, one of HNO_3, with pH 1.00, and the other of HNO_2, with pH 2.16, both with the same concentration and temperature.

13.1. Determine the acidity constant, K_a, of HNO_2 for the temperature considered.

Present all calculations performed.

RESOLUTION STEPS:

- Calculate the concentration of the HNO_3 solution (1.000×10^{-1} mol dm^{-3})
- Calculate the concentration of HNO_2 at equilibrium (9.308×10^{-2} mol dm^{-3})
- Calculate the acidity constant, K_a, of HNO_2 (5.14×10^{-4})

Resolution steps:

1) Write the reaction of HNO_3, taking into account is is a strong acid

$$HNO_3 \rightleftarrows H^+ + NO_2^-$$

2) Calculate the concentration of H^+

$$pH = [H^+] \Leftrightarrow [H^+] = 10^{-pH} = 10^{1.00} = 0.10\ mol\ dm^{-3}$$

3) Initially both acids have the same concentration, as described in the exercise statement

$[HNO_3] = [HNO_2] = 0.10$ mol dm^{-3}

Exercise data:

HNO_3: pH = 1.00

HNO_2: pH = 2,16

initially: $[HNO_3] = [HNO_2]$

Resolution steps:

4) Calculate the concentration of H^+ in HNO_2

$$pH = [H^+] \Leftrightarrow [H^+] = 10^{-pH} = 10^{2.16} = 0.00692\,mol\,dm^{-3}$$

5) Calculate the equilibrium concentrations

	HNO_2	$\rightleftharpoons$	H^+	+	NO_2^-
beginning:	0.10		0		0
at equilibrium:	0.10 – 0.00692 0.09308		0.00692		0.00692

Exercise data:

HNO_3: pH = 1.00

HNO_2: pH = 2,16

initially: $[HNO_3] = [HNO_2]$

Resolution steps:

6) Calculate the equilibrium constant (K_a)

$$K_a = \frac{[H^+]_e \cdot [NO_2^-]_e}{[HNO_2]_e} = \frac{0.00692 \times 0.00692}{0.09308} = 5.4 \times 10^{-4}$$

Exercise data:

HNO_3: pH = 1.00

HNO_2: pH = 2,16

initially: $[HNO_3] = [HNO_2]$

13.2. Solutions of HNO_3 and HNO_2, of the same volume, were titrated with an aqueous solution of a strong base, NaOH, at a temperature of 25ºC, until reaching the equivalence point.

13.2.1. The volume of NaOH used to titrate the HNO_2 solution is ____ to the volume of NaOH used to titrate the HNO_3 solution, and the pH at the equivalence point for the HNO_2 titration is ____ then 7.

Fill in the blanks with the words “equal”, “lower” or “higher”.

The volume of NaOH used to titrate the HNO_2 solution is **equal** to the volume of NaOH used to titrate the HNO_3 solution, and the pH at the equivalence point for the HNO_2 titration is **greater** then 7.

13.2.2. Indicate the type of titration and identify the titrant and the titrated (ANALYTE).

Acid-base titration

Titrant is NaOH

Titrated is HNO_3 or HNO_2

14. Phosphorus pentachloride, PCl_5, can decompose in the gas phase, yielding phosphorus trichloride, PCl_3, and chlorine, Cl_2. This reaction can be translated as:

$$PCl_5\ (g) \rightleftharpoons PCl_3\ (g) + Cl_2\ (g)$$

A variable volume reactor initially contains only 3.00 mol of PCl_5 (g) and 0.80 mol of PCl_3 (g). The system reaches equilibrium at temperature T. Consider that the volume of the reactor is 2.5 dm^3 and that 90% of the initial amount of PCl_5 (g) has not reacted.

14.1. Calculate the equilibrium constant, K_c, of the decomposition reaction considered, at temperature T. Present all calculations carried out.

RESOLUTION STEPS

- Calculate the amount of Cl_2 (g) in the equilibrium state (0.30 mol)
- Calculate the amount of PCl_3 (g) in the equilibrium state (1.10 mol)
- Calculate the equilibrium constant, K_c, of the decomposition reaction considered, at temperature T (4.9×10^{-2})

Resolution steps:

1) Calculate the equilibrium amounts

	PCl_5	$\rightleftharpoons$	PCl_3	+	Cl_2
beginning:	3.00		0.80		0
amount that react:	3.00x10% = 0.30				
at equilibrium:	3.00 – 0.30 = 2.7		0.80 + 0.30		0.30

2) Calculate the equilibrium concentrations

$$[PCl_5]_e = \frac{n}{V} = \frac{2.7}{2.5} = 1.08\ mol\ dm^{-3}$$

$$[Cl_2]_e = \frac{n}{V} = \frac{0.30}{2.5} = 0.12\ mol\ dm^{-3}$$

$$[PCl_3]_e = \frac{n}{V} = \frac{0.80 + 0.30}{2.5} = \frac{1.10}{2.5} = 0.44\ mol\ dm^{-3}$$

Exercise data:

$n(PCl_5)$ = 3.00 mol

$n(PCl_3)$ = 0.80 mol

V = 2.5 dm^3

90% of the initial amount of PCl5 (g) has not reacted

Resolution steps:

3) Calculate the equilibrium constant (Kc)

$$K_c = \frac{[PCl_3]_e \cdot [Cl_2]_e}{[PCl_5]_e} = \frac{0.44 \times 0.12}{1.08} = 0.04(8) = 4.9 \times 10^{-2}$$

Exercise data:

$n(PCl_5)$ = 3.00 mol

$n(PCl_3)$ = 0.80 mol

V = 2.5 dm^3

90% of the initial amount of PCl5 (g) has not reacted

To know

EQUILIBRIUM

$$aA + bB \rightleftharpoons cC + dD$$

$$K_c = \frac{[C]^c \cdot [D]^d}{[A]^a \cdot [B]^b}$$

Learn more

https://www.youtube.com/watch?v=J4WJCYpTYj8

https://www.youtube.com/watch?v=XsDWeS5nzi0&list=PLCqaWwIFjceo0X3tPf2Mw9yrz8C4rLt3-

https://www.youtube.com/watch?v=1GiZzCzmO5Q

https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Chemistry_for_Allied_Health_(Soult)/08%3A_Properties_of_Solutions/8.02%3A_Chemical_Equilibrium

14.2. Consider that, with the system in equilibrium, the reactor volume decreases at temperature T. Predict, with reasons, how the amount of PCl_5 will vary.

Resolution Steps

$$PCl_5\ (g) \rightleftharpoons PCl_3\ (g) + Cl_2\ (g)$$

According to Le Chatelier's Principle:

- decrease in volume, consequent increase in pressure and favoring the reaction that generates fewer molecules

OR decrease in volume, consequent increase in concentrations of reactants and reaction products and increase in the reaction quotient

- favoring the reverse reaction and increasing the amount of PCl_5

Chemistry Exam

QUESTIONS?