

## End of Term 3 Revision Answers



### تم تحميل هذا الملف من موقع المناهج الإماراتية

موقع المناهج ← المناهج الإماراتية ← الصف الحادي عشر المتقدم ← كيمياء ← الفصل الثالث ← ملفات متنوعة ← الملف

تاريخ إضافة الملف على موقع المناهج: 18:55:59 2026-06-15

ملفات اكتب للمعلم اكتب للطالب | اختبارات الكترونية | اختبارات | حلول | عروض بوربوينت | أوراق عمل  
منهج انجليزي | ملخصات وتقارير | مذكرات وبنوك | الامتحان النهائي | للمدرس

المزيد من مادة  
كيمياء:

إعداد: عبدالرحمن الشناوي

### التواصل الاجتماعي بحسب الصف الحادي عشر المتقدم



صفحة المناهج  
الإماراتية على  
فيسبوك

الرياضيات

اللغة الانجليزية

اللغة العربية

التربية الاسلامية

المواد على تلغرام

### المزيد من الملفات بحسب الصف الحادي عشر المتقدم والمادة كيمياء في الفصل الثالث

1 P Adv 11 Grade Chemistry Revision 3 Term of End إجابات

1

End of Term 3 Revision

2

مراجعة هيكل الامتحان كراسة تدريبية

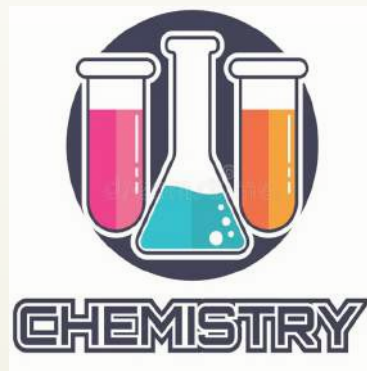
3

EOT3 - CHEMISTRY - ACIDS AND BASES - CHEMICAL EQUILIBRIUM

4

مواصفات امتحان مادة الكيمياء

5



# BE

# READY

# END OF TERM 3 REVISION CHEMISTRY GRADE 11 ADV P 1 ANSWERS

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حمدة العامري

|   |                                                                                                                                                                                                                                                                                            |
|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | CHM.5.3.05.007.02 Identify components of a voltaic or galvanic cell (anode, cathode, salt bridge or porous barrier, wires, electrolyte compartments); while explaining the role of each component, when does the reaction start and determining the direction of electron and current flow |
| 2 | CHM.5.3.05.007.05 Use the half-cell standard reduction potentials to calculate the electrochemical cell standard potential, while determining whether the redox reactions are spontaneous or non-spontaneous.                                                                              |
| 3 | CHM.5.3.05.007.04 Write the cell notation and the overall chemical equation for a redox reaction occurring in a voltaic cell potential                                                                                                                                                     |
| 4 | CHM.5.3.05.011.03 Compare between electrolytic cell and voltaic cell in terms of identifying where will reduction and oxidation processes take place, anode, cathode, direction of electron flow and current flow and spontaneity of the reaction occurring                                |
| 5 | CHM.5.3.05.011.05 Define electroplating while describing how it works, identifying anode, cathode and electrolyte needed for an electrolytic cell in which a selected metal is to be plated on an object (car or spoon,... etc)                                                            |

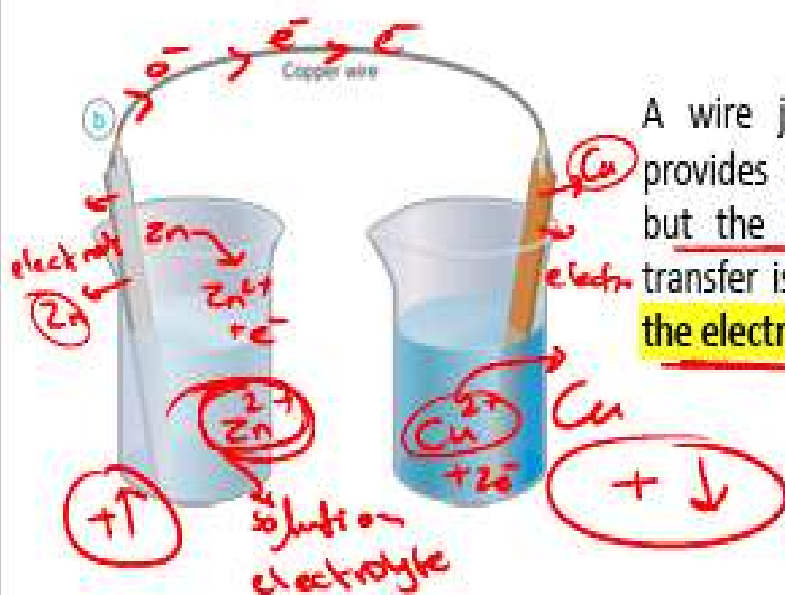
## Redox in Electrochemistry

- Electrochemistry** is the study of the redox processes by which **chemical energy** is converted to **electrical energy** and vice versa.
- Redox reactions involve a transfer of electrons from the species that is oxidized to the species that is reduced.



## Redox in Electrochemistry

- A **voltaic cell** is a type of electrochemical cell that **converts chemical energy to electrical energy** by a **spontaneous** redox reaction.

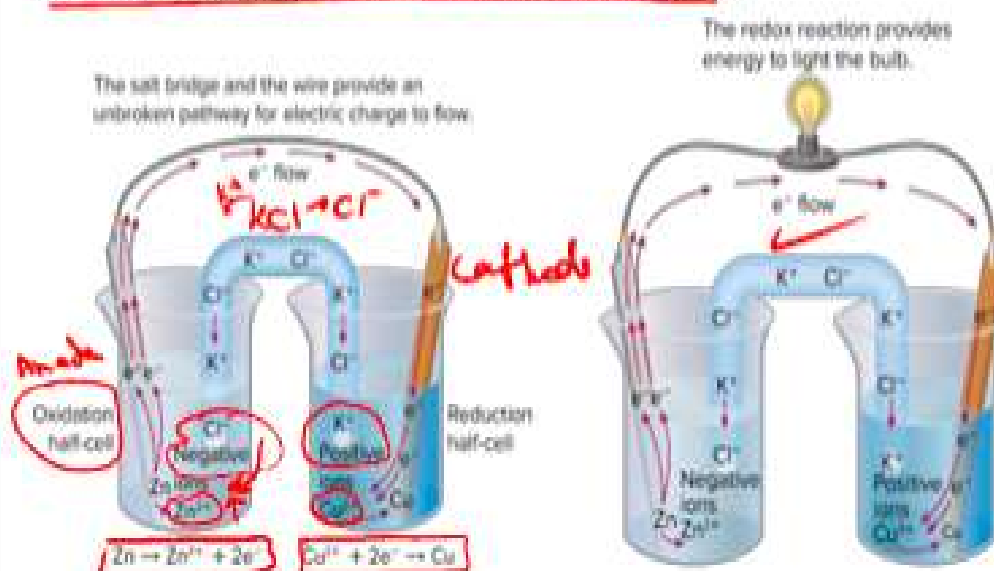


A wire joining the zinc and copper strips provides a pathway for the flow of electrons, but the pathway is not complete. Electron transfer is still not possible. (Ions build up on the electrodes.)

How to fix this? Use a **Salt Bridge**

## Redox in Electrochemistry

- A **voltaic cell** is a type of electrochemical cell that **converts chemical energy to electrical energy** by a **spontaneous** redox reaction.
- A **salt bridge** is a pathway to allow the passage of ions from one side to another, so that ions do not build up around the electrodes.



The addition of a salt bridge completes the pathway. Negative ions move through the salt bridge to the zinc side. Positive ions move through the bridge to the copper side. **Real**

## Quiz

1. Which is a pathway to allow the passage of ions from one side of a redox process to the other?

- 1 voltaic cell
- 2 half-cell
- 3 salt bridge **CORRECT**
- 4 standard hydrogen electrode

## Quiz

2. Which is an apparatus that uses a redox reaction to produce electrical energy or uses electrical energy to cause a chemical reaction?

- A salt bridge
- C standard hydrogen electrode
- B half-cell
- D electrochemical cell

## Quiz

3. Which is a type of electrochemical cell that converts chemical energy to electrical energy by a spontaneous redox reaction?

**A** voltaic cell

**C** half-cell

**B** salt cell

**D** oxidation cell

## Chemistry of Voltaic Cells: Main points

- An electrochemical cell consists of two parts called half-cells, in which the separate oxidation and reduction reactions take place.
- The electrode where oxidation takes place is called the anode.
- The cathode is the electrode where reduction occurs.
- - Salt bridge: It is a pathway to maintain solution neutrality by allowing the passage of ions from one side to another, where anions migrate towards anode and cations migrate towards cathode.
- It usually contains a conducting neutral soluble solution as KCl, NaCl or NaNO<sub>3</sub>.  
 $K^+ Cl^- Na^+ NO_3^-$
- - The spontaneous reaction starts when the connecting metal wire and salt bridge are in place

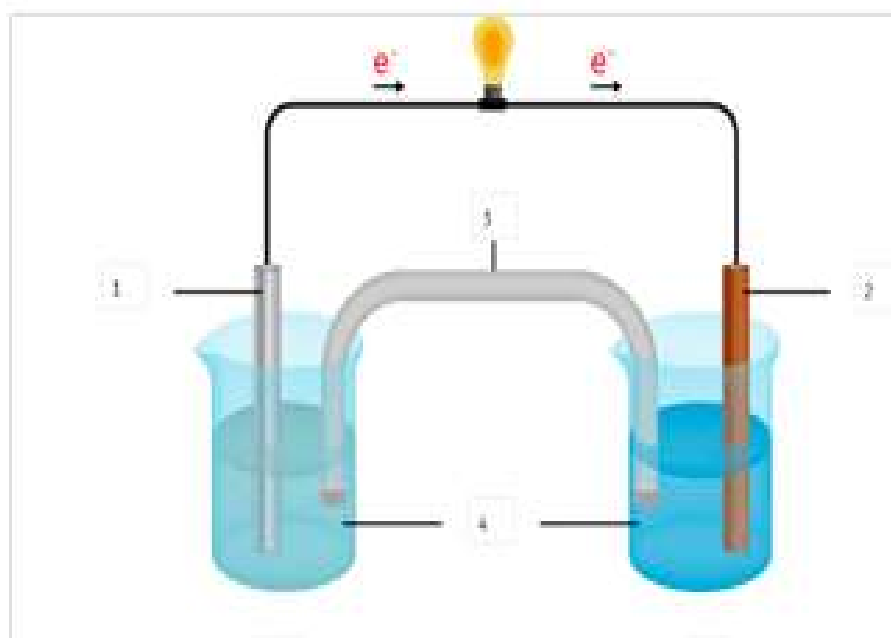
## Chemistry of Voltaic Cells: Main points

- Electrons flow through the wire from the oxidation-half reaction (anode) to the reduction-half reaction (cathode) while positive and negative ions move through the salt bridge
- ~~Current flows from cathode to anode~~
- ✓ - The flow of electrons through the wire and the flow of ions through the salt bridge make up the electric current
- *Electric potential energy* is a measure of the amount of current that can be generated from a voltaic cell to do work.

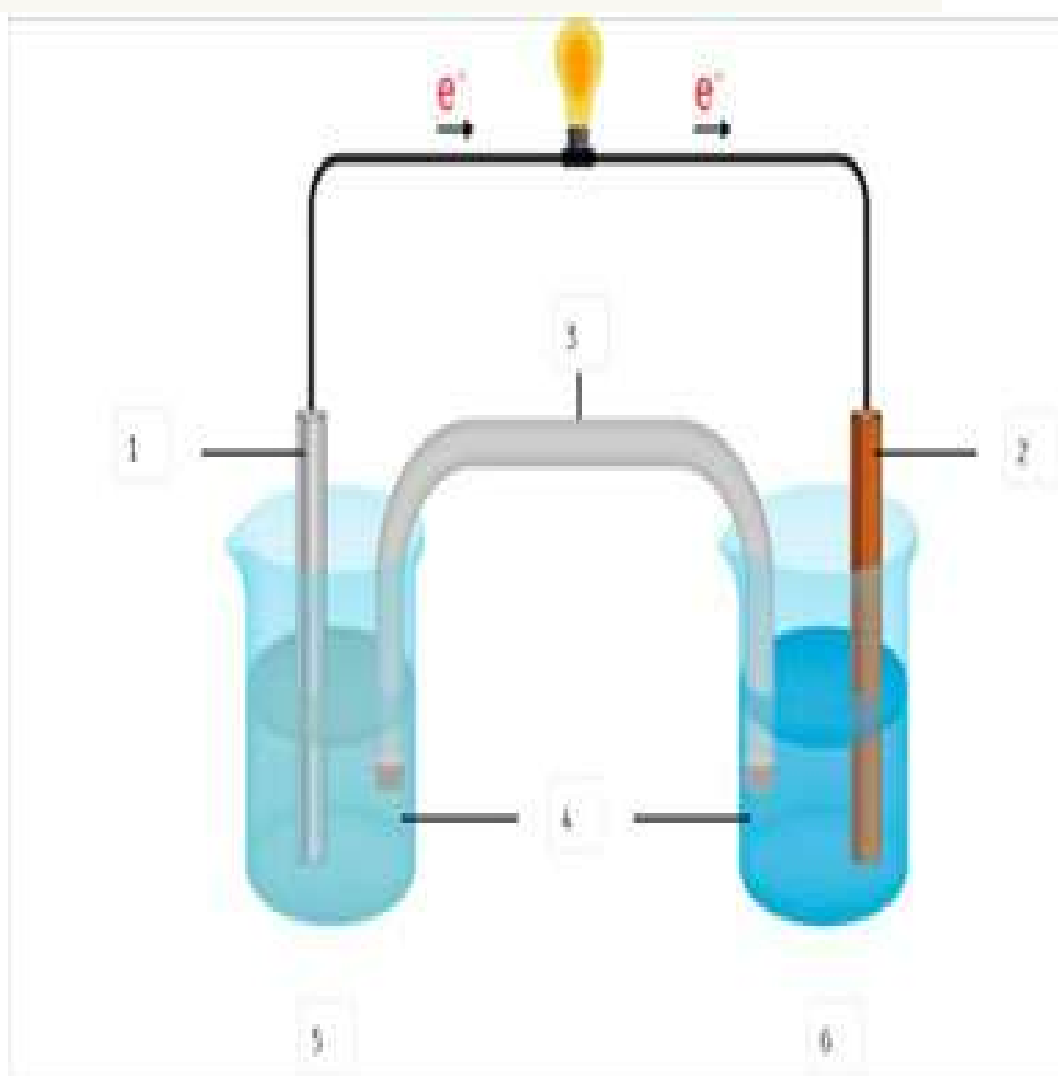
## Check Point (Paired Activity)

Assign the components to the numbers in the image.

- \*Cathode
- \*Anode
- \*Oxidation-half cell
- \*Reduction-half cell
- \*Salt bridge
- \*electrolyte



1. anode
2. cathode
3. salt bridge
4. electrolyte
5. oxidation half-cell
6. reduction half-cell



|   |                                                                                                                                                                                                                  |
|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3 | CHM.5.1.05.007.04 Use the half-cell standard reduction potentials to calculate the electrochemical cell standard potential, while determining whether the redox reactions are spontaneous or non-spontaneous     |
| 4 | CHM.5.1.05.007.04 Write the cell notation and the overall chemical equation for a redox reaction occurring in a voltaic cell                                                                                     |
| 5 | CHM.5.1.05.008.01 Use the standard reduction potentials to predict if a reaction occurs or not, while identifying the strongest reducing or oxidizing agent and the substance that is easily oxidized or reduced |

*Anode or cathode*

## What is "Standard Electrode Potential" $E^0$ ?

**Standard electrode potential ( $E^0$ )** is the potential or voltage developed by a metal or other material immersed in an electrolyte solution relative to the **potential of the hydrogen electrode which is zero.**

Why is the standard potential of hydrogen ( $H_2$ ) zero??

✓ **Because it is used as the reference point of the scale.**

Example from table 1 in the book (**Standard Reduction potentials  $E^0$** )

*The higher the number  $E^0$  the more likely reduction will happen*

*oxidation*

**Table 1 Standard Reduction Potentials**

| Half-Reaction                                 | $E^0$ (V) | Half-Reaction                                        | $E^0$ (V) |
|-----------------------------------------------|-----------|------------------------------------------------------|-----------|
| $Li^+ + e^- \rightleftharpoons Li$            | -3.0401   | $Cu^{2+} + e^- \rightleftharpoons Cu^+$              | +0.153    |
| $Ca^{2+} + 2e^- \rightleftharpoons Ca$        | -2.868    | $Cu^{2+} + 2e^- \rightleftharpoons Cu$               | +0.3419   |
| $Na^+ + e^- \rightleftharpoons Na$            | -2.71     | $O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$        | +0.401    |
| $Mg^{2+} + 2e^- \rightleftharpoons Mg$        | -2.372    | $I_2 + 2e^- \rightleftharpoons 2I^-$                 | +0.5355   |
| $Be^{2+} + 2e^- \rightleftharpoons Be$        | -1.847    | $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$           | +0.771    |
| $Al^{3+} + 3e^- \rightleftharpoons Al$        | -1.662    | $NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2 + H_2O$ | +0.775    |
| $Mn^{2+} + 2e^- \rightleftharpoons Mn$        | -1.185    | $Hg_2^{2+} + 2e^- \rightleftharpoons 2Hg$            | +0.7973   |
| $Cr^{2+} + 2e^- \rightleftharpoons Cr$        | -0.913    | $Ag^+ + e^- \rightleftharpoons Ag$                   | +0.7996   |
| $2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$ | -0.8277   | $Hg^{2+} + 2e^- \rightleftharpoons Hg$               | +0.851    |
| $Zn^{2+} + 2e^- \rightleftharpoons Zn$        | -0.7618   | $2Hg^{2+} + 2e^- \rightleftharpoons Hg_2^{2+}$       | +0.920    |

*reducing agent*

*oxidizing agent*

*(stronger oxidizing agent)*

*reduction*

Standard  
 Hydrogen  
 Electrode  
 "SHE"  
 "SHE"

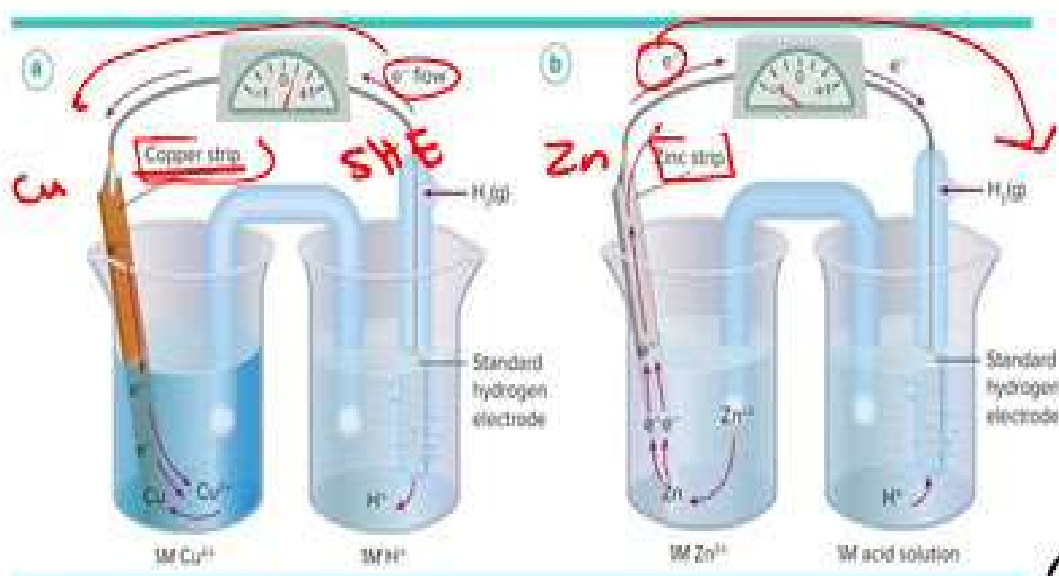
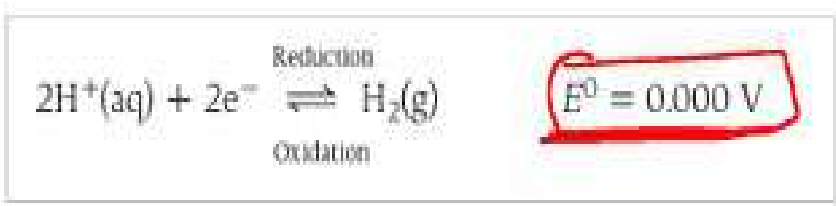


Figure 6 a. When a  $Cu^{2+} | Cu$  electrode is connected to the hydrogen electrode, electrons flow toward the copper strip and reduce  $Cu^{2+}$  ions to  $Cu$  atoms. b. When a  $Zn | Zn^{2+}$  electrode is connected to the hydrogen electrode, electrons flow away from the zinc strip and zinc atoms are oxidized to  $Zn^{2+}$  ions.

a. Cu cathode  
 SHE anode  
 b. Zn anode  
 SHE cathode  
 oxidized  
 reduced  
 oxidizing agent  
 reducing agent

Example from table 1 in the book (Standard Reduction potentials  $E^0$ )

| Table 1 Standard Reduction Potentials                                            |           |                                                                                                |           |
|----------------------------------------------------------------------------------|-----------|------------------------------------------------------------------------------------------------|-----------|
| Half-Reaction                                                                    | $E^0$ (V) | Half-Reaction                                                                                  | $E^0$ (V) |
| $\text{Li}^+ + \text{e}^- \rightleftharpoons \text{Li}$                          | -3.0401   | $\text{Cu}^{2+} + \text{e}^- \rightleftharpoons \text{Cu}^+$                                   | +0.153    |
| $\text{Ca}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ca}$                      | -2.868    | $\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu}$                                    | +0.3419   |
| $\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na}$                          | -2.71     | $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightleftharpoons 4\text{OH}^-$               | +0.401    |
| $\text{Mg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mg}$                      | -2.372    | $\text{I}_2 + 2\text{e}^- \rightleftharpoons 2\text{I}^-$                                      | +0.5355   |
| $\text{Ba}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ba}$                      | -1.847    | $\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$                                | +0.771    |
| $\text{Al}^{3+} + 3\text{e}^- \rightleftharpoons \text{Al}$                      | -1.662    | $\text{NO}_3^- + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{NO}_2 + \text{H}_2\text{O}$ | +0.775    |
| $\text{Mn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mn}$                      | -1.185    | $\text{Hg}_2^{2+} + 2\text{e}^- \rightleftharpoons 2\text{Hg}$                                 | +0.7973   |
| $\text{Cr}^{3+} + 2\text{e}^- \rightleftharpoons \text{Cr}$                      | -0.913    | $\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}$                                        | +0.7996   |
| $2\text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{H}_2 + 2\text{OH}^-$ | -0.8277   | $\text{Hg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Hg}$                                    | +0.851    |
| $\text{Zn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Zn}$                      | -0.7618   | $2\text{Hg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Hg}_2^{2+}$                            | +0.920    |

Calculating Electrochemical Cell Potentials

- Formula for Cell Potential

$$E_{\text{cell}}^0 = E_{\text{reduction}}^0 - E_{\text{oxidation}}^0$$

or

$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0$$

- The standard potential of a cell is the standard potential of the reduction half-cell minus the standard potential of the oxidation half-cell.

If  $E^0_{\text{cell}}$  is positive ( $>0$ ), the redox reaction is spontaneous (تلقائي)

If  $E^0_{\text{cell}}$  is negative ( $<0$ ), the redox reaction is nonspontaneous (غير تلقائي)

$E_{\text{cell}}^0 =$   
 $= 0.23 - (-0.5)$   
 $= +0.73$   
 Y

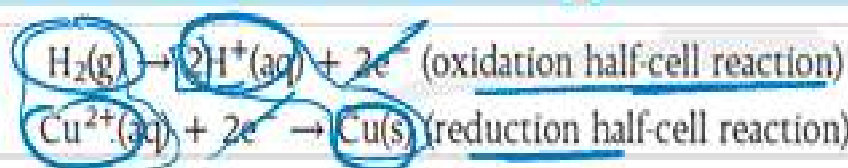
$E_{\text{cath}}^0 = 0.23$   
 $E_{\text{anode}}^0 = -0.5$   
 anode (ox)



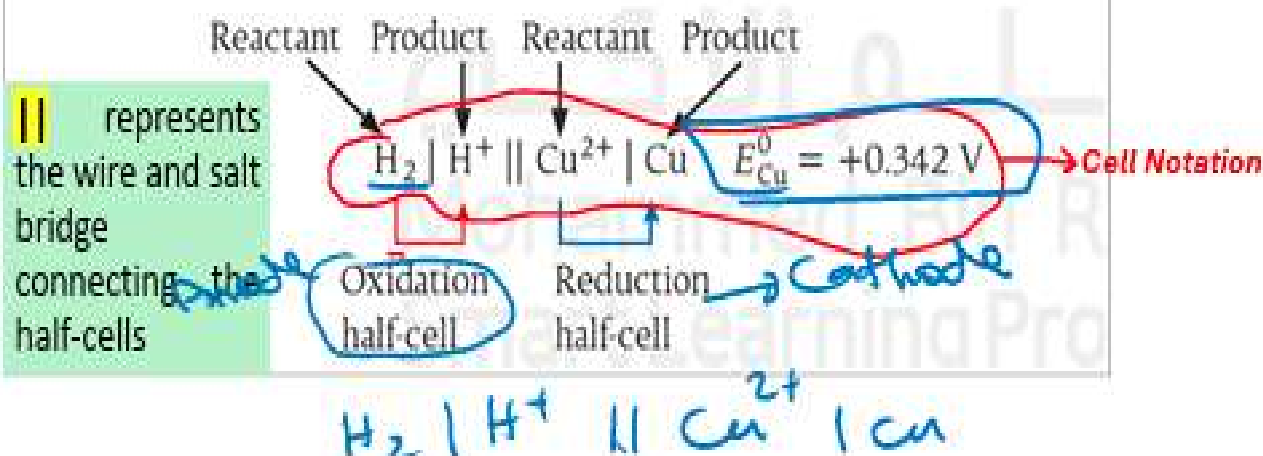
Table 1 Standard Reduction Potentials

| Half-Reaction                                                                        | $E^{\circ}$ (V) | Half-Reaction                                                                                        | $E^{\circ}$ (V) |
|--------------------------------------------------------------------------------------|-----------------|------------------------------------------------------------------------------------------------------|-----------------|
| $\text{Li}^{+} + \text{e}^{-} \rightleftharpoons \text{Li}$                          | -3.0401         | $\text{Cu}^{2+} + \text{e}^{-} \rightleftharpoons \text{Cu}^{+}$                                     | +0.153          |
| $\text{Ca}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Ca}$                        | -2.868          | $\text{Cu}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Cu}$                                        | +0.3419         |
| $\text{Na}^{+} + \text{e}^{-} \rightleftharpoons \text{Na}$                          | -2.71           | $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^{-} \rightleftharpoons 4\text{OH}^{-}$                 | +0.401          |
| $\text{Mg}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Mg}$                        | -2.372          | $\text{I}_2 + 2\text{e}^{-} \rightleftharpoons 2\text{I}^{-}$                                        | +0.5355         |
| $\text{Be}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Be}$                        | -1.847          | $\text{Fe}^{3+} + \text{e}^{-} \rightleftharpoons \text{Fe}^{2+}$                                    | +0.771          |
| $\text{Al}^{3+} + 3\text{e}^{-} \rightleftharpoons \text{Al}$                        | -1.662          | $\text{NO}_3^{-} + 2\text{H}^{+} + \text{e}^{-} \rightleftharpoons \text{NO}_2 + \text{H}_2\text{O}$ | +0.775          |
| $\text{Mn}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Mn}$                        | -1.185          | $\text{Hg}_2^{2+} + 2\text{e}^{-} \rightleftharpoons 2\text{Hg}$                                     | +0.7973         |
| $\text{Cr}^{3+} + 3\text{e}^{-} \rightleftharpoons \text{Cr}$                        | -0.993          | $\text{Ag}^{+} + \text{e}^{-} \rightleftharpoons \text{Ag}$                                          | +0.7996         |
| $2\text{H}_2\text{O} + 2\text{e}^{-} \rightleftharpoons \text{H}_2 + 2\text{OH}^{-}$ | -0.8277         | $\text{Hg}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Hg}$                                        | +0.851          |
| $\text{Zn}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Zn}$                        | -0.7618         | $2\text{Hg}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Hg}_2^{2+}$                                | +0.920          |

Write the cell notation and the overall chemical equation for a redox reaction occurring in a voltaic cell. **Page 184**



This reaction can be written in a form called cell notation.



## Calculate a Cell Potential

### IN-CLASS EXAMPLE

Use with Example Problem 1.

#### Problem

The following reduction half-reactions represent the half-cells of a voltaic cell.



Determine the **overall cell reaction** and the **standard cell potential**. Describe the cell using **cell notation**.

#### KNOWN

Standard reduction potentials for the half-cells

$$E_{\text{cell}}^0 = E_{\text{reduction}}^0 - E_{\text{oxidation}}^0$$

Given to you in the exam

The standard reduction potentials of each half-reaction in Table 1.



First, which one is oxidized, and which one is reduced?

The half reaction with the **higher  $E^0$**  is **reduced**

#### UNKNOWN

overall cell reaction = ?

$$E_{\text{cell}}^0 = ?$$

cell notation = ?

## Calculate a Cell Potential

### IN-CLASS EXAMPLE

Given to you in the exam

The standard reduction potentials of each half-reaction in Table 1.



The half reaction with the **higher  $E^0$**  is **reduced**

cathode (Red)

Anode (OX)

spontaneous

$$① E_{\text{cell}}^0 = E_{\text{cath}}^0 - E_{\text{anode}}^0 = 0.536 - (-0.447) = +0.983$$

② overall Reaction



③ cell notation



## Calculate a Cell Potential

### IN-CLASS EXAMPLE

SOLVE FOR THE UNKNOWN (continued)

- Rewrite the iron half-reaction in the correct direction.



- Add the two equations.



Calculate the standard cell potential.

- State the formula for cell potential.

$$E_{\text{cell}}^0 = E_{\text{reduction}}^0 - E_{\text{oxidation}}^0$$

- Substitute  $E_{I_2|I^-}^0$  and  $E_{Fe^{2+}|Fe}^0$  in the generic equation.

$$E_{\text{cell}}^0 = E_{I_2|I^-}^0 - E_{Fe^{2+}|Fe}^0$$

## Calculate a Cell Potential

### IN-CLASS EXAMPLE



$$E_{\text{cell}}^0 = +0.536 \text{ V} - (-0.447 \text{ V})$$

$$E_{\text{cell}}^0 = +0.983 \text{ V}$$

Describe the cell using cell notation.

- First, write the oxidation half-reaction using cell notation: **reactant then product**.



- Next, write the reduction half-reaction to the right. Separate the half-cells by a double vertical line.



Cell notation:  $Fe | Fe^{2+} || I_2 | I^-$

## Calculate a Cell Potential

### IN-CLASS EXAMPLE



$$E_{\text{cell}}^0 = +0.536 \text{ V} - (-0.447 \text{ V})$$

$$E_{\text{cell}}^0 = +0.983 \text{ V}$$

Is this reaction spontaneous or nonspontaneous?

**It is spontaneous because the cell potential  $E_{\text{cell}}^0$  is positive**

### PRACTICE Problems

### ADDITIONAL PRACTICE

For each of these pairs of half-reactions, write the balanced equation for the overall cell reaction, and calculate the standard cell potential. Describe the reaction using cell notation. Refer to the module on redox reactions to review writing and balancing redox equations.



4. **CHALLENGE** Write the balanced equation for the cell reaction and calculate the standard cell potential for the reaction that occurs when these half-cells are connected. Describe the reaction using cell notation.



$$E_{\text{red}}^0 = +1.18 \text{ V}$$



$$E_{\text{red}}^0 = -0.1375 \text{ V}$$



$$E_{\text{red}}^0 = -0.28 \text{ V}$$



$$E_{\text{red}}^0 = -0.744 \text{ V}$$



$$E_{\text{red}}^0 = +0.851 \text{ V}$$



$$E_{\text{red}}^0 = -0.913 \text{ V}$$



$$E_{\text{red}}^0 = +0.957 \text{ V}$$



$$E_{\text{red}}^0 = +0.401 \text{ V}$$

# PRACTICE Problems

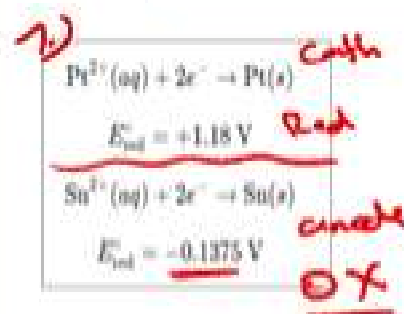
For each of these pairs of half-reactions, write the balanced equation for the overall cell reaction, and calculate the standard cell potential. Describe the reaction using cell notation. Refer to the module on redox reactions to review writing and balancing redox equations.



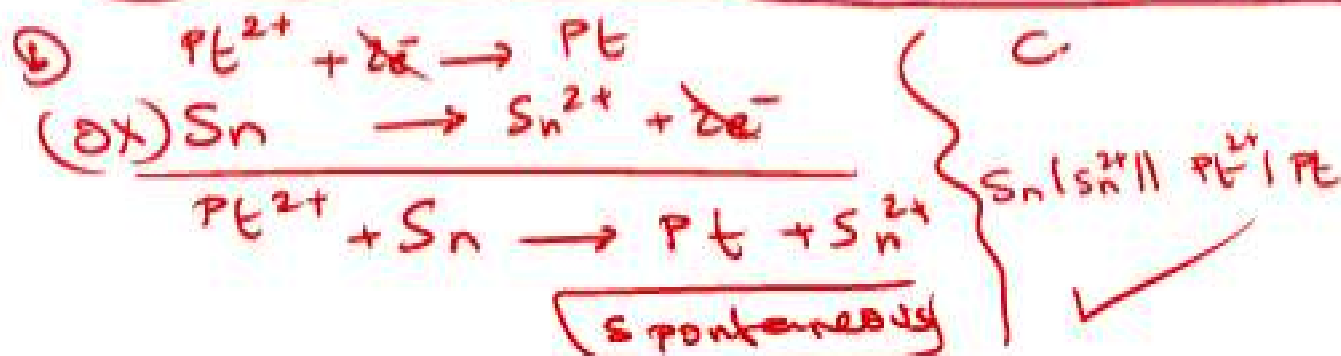
4. **CHALLENGE** Write the balanced equation for the cell reaction and calculate the standard cell potential for the reaction that occurs when these half-cells are connected. Describe the reaction using cell notation.



# ADDITIONAL PRACTICE



1.) a)  $E_{\text{cell}} = E_{\text{cath}} - E_{\text{anode}} = 1.18 - (-0.1375)$   
 $= +1.3175 \text{ V}$



# PRACTICE Problems

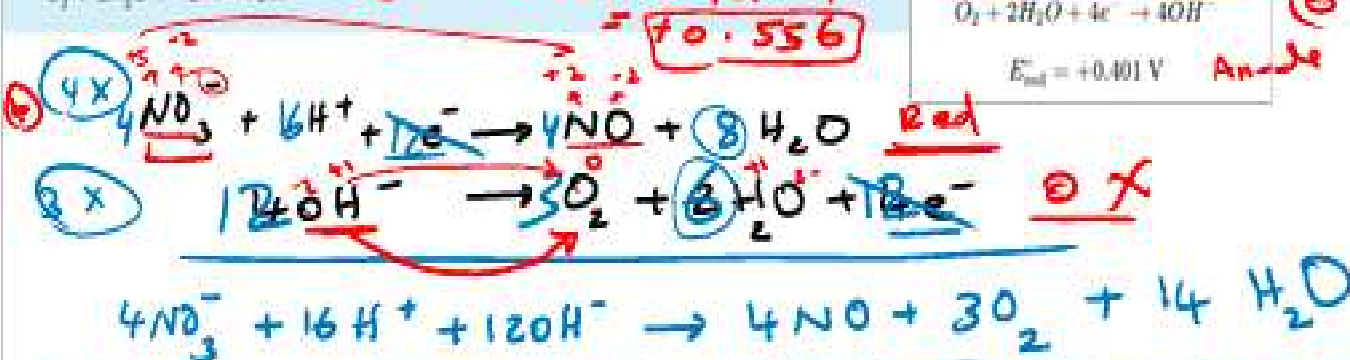
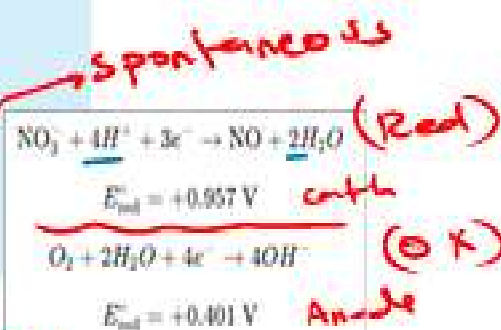
For each of these pairs of half-reactions, write the balanced equation for the overall cell reaction, and calculate the standard cell potential. Describe the reaction using cell notation. Refer to the module on redox reactions to review writing and balancing redox equations.



4. **CHALLENGE** Write the balanced equation for the cell reaction and calculate the standard cell potential for the reaction that occurs when these half-cells are connected. Describe the reaction using cell notation.



$E_{\text{cell}}^{\circ} = E_{\text{cath}}^{\circ} - E_{\text{anode}}^{\circ}$   
 $= 0.957 - 0.401$   
 $= +0.556$



notation

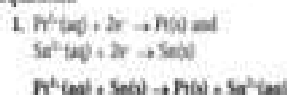




### Practice Problems

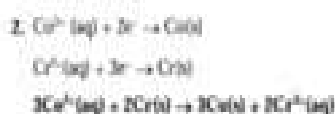
page 611

For each of these pairs of half reactions, write the balanced equation for the overall cell reaction and calculate the standard cell potential. Express the reaction using cell notation. Refer to the chapter on redox reactions to review writing and balancing redox equations.



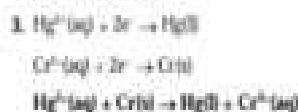
$$E_{\text{cell}}^{\circ} = +1.18 \text{ V} - (-0.1375 \text{ V})$$

$$E_{\text{cell}}^{\circ} = +1.32 \text{ V}$$



$$E_{\text{cell}}^{\circ} = -0.28 \text{ V} - (-0.744 \text{ V})$$

$$E_{\text{cell}}^{\circ} = +0.46 \text{ V}$$



$$E_{\text{cell}}^{\circ} = +0.851 \text{ V} - (-0.813 \text{ V})$$

$$E_{\text{cell}}^{\circ} = +1.664 \text{ V}$$



4. **Challenge** Write the balanced equation for the cell reaction and calculate the standard cell potential for the reaction that occurs when these half-cells are connected. Describe the reaction using cell notation.



$$E_{\text{cell}}^{\circ} = +0.957 \text{ V} - (+0.401 \text{ V})$$

$$E_{\text{cell}}^{\circ} = +0.556 \text{ V}$$



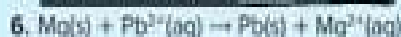
### PRACTICE Problems

### ADDITIONAL PRACTICE

Calculate the cell potential to determine if each of the following balanced redox reactions is spontaneous as written. Use Table 1 to help you determine the correct half-reactions.



overall is ready



9. **CHALLENGE** Using Table 1, write the equation and determine the cell voltage ( $E^{\circ}$ ) for the following cell. Is the reaction spontaneous?



$$E_{\text{red}}^{\circ} = +0.3419 \text{ V}$$



$$E_{\text{red}}^{\circ} = -0.1375 \text{ V}$$



$$E_{\text{red}}^{\circ} = -0.1262 \text{ V}$$



$$E_{\text{red}}^{\circ} = -2.372 \text{ V}$$



$$E_{\text{red}}^{\circ} = +0.920 \text{ V}$$



$$E_{\text{red}}^{\circ} = +1.507 \text{ V}$$



$$E_{\text{red}}^{\circ} = -0.28 \text{ V}$$



$$E_{\text{red}}^{\circ} = +2.010 \text{ V}$$



$$E_{\text{red}}^{\circ} = +0.920 \text{ V}$$



$$E_{\text{red}}^{\circ} = -1.662 \text{ V}$$

we will not use the values of  $E^{\circ}$  to determine cath or anode

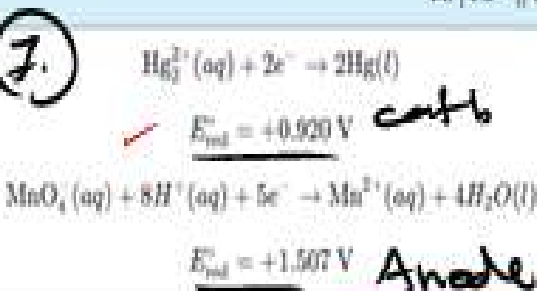
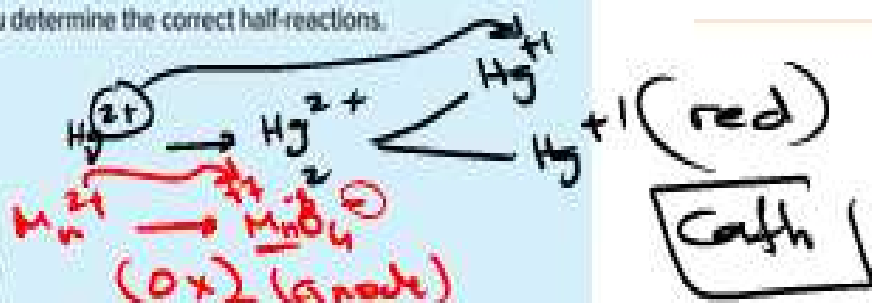
# PRACTICE Problems

# ADDITIONAL PRACTICE

Calculate the cell potential to determine if each of the following balanced redox reactions is spontaneous as written. Use Table 1 to help you determine the correct half-reactions.



9. **CHALLENGE** Using Table 1, write the equation and determine the cell voltage ( $E^\circ$ ) for the following cell. Is the reaction spontaneous?



$$E_{\text{cell}}^{\circ} = 0.92 - 1.507$$

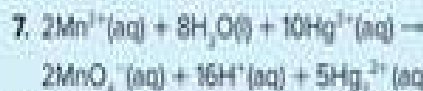
$$-0.587$$

non spontaneous

# PRACTICE Problems

# ADDITIONAL PRACTICE

Calculate the cell potential to determine if each of the following balanced redox reactions is spontaneous as written. Use Table 1 to help you determine the correct half-reactions.



9. **CHALLENGE** Using Table 1, write the equation and determine the cell voltage ( $E^\circ$ ) for the following cell. Is the reaction spontaneous?



$$E_{\text{red}}^{\circ} = +0.3419 \text{ V}$$



$$E_{\text{red}}^{\circ} = -0.1375 \text{ V}$$

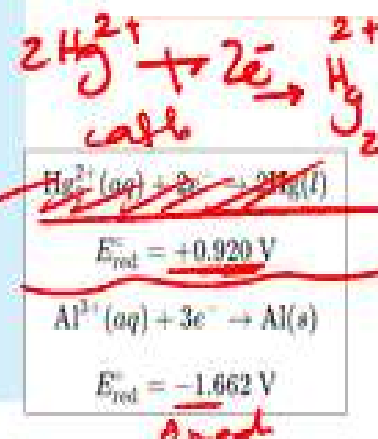
# PRACTICE Problems

# ADDITIONAL PRACTICE

Calculate the cell potential to determine if each of the following balanced redox reactions is spontaneous as written. Use Table 1 to help you determine the correct half-reactions:

5.  $\text{Sn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{Cu(s)}$
6.  $\text{Mg(s)} + \text{Pb}^{2+}(\text{aq}) \rightarrow \text{Pb(s)} + \text{Mg}^{2+}(\text{aq})$
7.  $2\text{Mn}^{2+}(\text{aq}) + 8\text{H}_2\text{O(l)} + 10\text{Hg}_2^{2+}(\text{aq}) \rightarrow 2\text{MnO}_4^{-}(\text{aq}) + 16\text{H}^{+}(\text{aq}) + 5\text{Hg}_2^{2+}(\text{aq})$
8.  $2\text{SO}_4^{2-}(\text{aq}) + \text{Co}^{3+}(\text{aq}) \rightarrow \text{Co(s)} + \text{S}_2\text{O}_8^{2-}(\text{aq})$

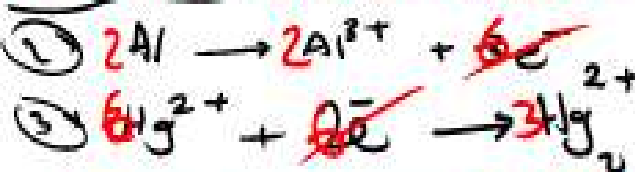
9. **CHALLENGE** Using Table 1, write the equation and determine the cell voltage ( $E^\circ$ ) for the following cell. Is the reaction spontaneous?



$$E^\circ_{\text{cell}} = E^\circ_{\text{cath}} - E^\circ_{\text{anode}} = 0.92 - (-1.662)$$

$$= +2.582$$

spontaneous



Calculate the cell potential to determine if each of the following balanced redox reactions is spontaneous as written. Use Table 1 to help you determine the correct half-reactions.

5.  $\text{Sn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{Cu(s)}$

$$E_{\text{cell}}^\circ = +0.3419 \text{ V} - (-0.1375 \text{ V})$$

$$E_{\text{cell}}^\circ = +0.4794 \text{ V}$$

$$E_{\text{cell}}^\circ > 0; \text{spontaneous}$$

6.  $\text{Mg(s)} + \text{Pb}^{2+}(\text{aq}) \rightarrow \text{Pb(s)} + \text{Mg}^{2+}(\text{aq})$

$$E_{\text{cell}}^\circ = -0.1262 \text{ V} - (-2.372 \text{ V})$$

$$E_{\text{cell}}^\circ = +2.246 \text{ V}$$

$$E_{\text{cell}}^\circ > 0; \text{spontaneous}$$

7.  $2\text{Mn}^{2+}(\text{aq}) + 8\text{H}_2\text{O(l)} + 10\text{Hg}_2^{2+}(\text{aq}) \rightarrow 2\text{MnO}_4^{-}(\text{aq}) + 16\text{H}^{+}(\text{aq}) + 5\text{Hg}_2^{2+}(\text{aq})$

$$E_{\text{cell}}^\circ = 0.920 \text{ V} - (-1.507 \text{ V})$$

$$E_{\text{cell}}^\circ = -0.587 \text{ V}$$

$$E_{\text{cell}}^\circ < 0; \text{not spontaneous}$$

8.  $2\text{SO}_4^{2-}(\text{aq}) + \text{Co}^{3+}(\text{aq}) \rightarrow \text{Co(s)} + \text{S}_2\text{O}_8^{2-}(\text{aq})$

$$E_{\text{cell}}^\circ = -0.28 \text{ V} - (+2.010 \text{ V})$$

$$E_{\text{cell}}^\circ = -2.29 \text{ V}$$

$$E_{\text{cell}}^\circ < 0; \text{not spontaneous}$$

9. **Challenge** Using Table 1, write the equation and determine the cell voltage ( $E^\circ$ ) for the following cell. Is the reaction spontaneous?



$$E_{\text{cell}}^\circ = 0.920 \text{ V} - (-1.662 \text{ V}) = 2.582 \text{ V}$$

The reaction is spontaneous.

## Check Your Progress

### Summary

- In a voltaic cell, oxidation and reduction take place at electrodes separated from each other.
- The standard potential of a half-cell reaction is its voltage when paired with a standard hydrogen electrode under standard conditions.
- The reduction potential of a half-cell is negative if it undergoes oxidation when connected to a standard hydrogen electrode. The reduction potential of a half-cell is positive if it undergoes reduction when connected to a standard hydrogen electrode.
- The standard potential of a voltaic cell is the difference between the standard reduction potentials of the half-cell reactions.

### Demonstrate Understanding

- Describe the conditions under which a redox reaction causes an electric current to flow through a wire.
- Identify the components of a voltaic cell. Explain the role of each component in the operation of the cell.
- Write the balanced equation for the spontaneous cell reaction that occurs in a cell with these reduction half-reactions.
  - $\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$  and  $\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$
  - $\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg}(\text{s})$  and  $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$
  - $\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$  and  $\text{Fe}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$
  - $\text{PbI}_2(\text{s}) + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s}) + 2\text{I}^-(\text{aq})$  and  $\text{Pt}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Pt}(\text{s})$
- Determine the standard potential for electrochemical cells in which each equation represents the overall cell reaction. Identify the reactions as spontaneous or nonspontaneous as written.
  - $2\text{Al}^{3+}(\text{aq}) + 3\text{Cu}(\text{s}) \rightarrow 3\text{Cu}^{2+}(\text{aq}) + 2\text{Al}(\text{s})$
  - $\text{Hg}^{2+}(\text{aq}) + 2\text{Cu}(\text{aq}) \rightarrow 2\text{Cu}^{2+}(\text{aq}) + \text{Hg}(\text{l})$
  - $\text{Cd}(\text{s}) + 2\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) \rightarrow \text{Cd}^{2+}(\text{aq}) + 2\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
- Design a concept map for Lesson 1, starting with the term electrochemical cell. Incorporate all the new vocabulary terms in your map.

## Check Your Progress

### Summary

- In a voltaic cell, oxidation and reduction take place at electrodes separated from each other.

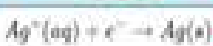
### Demonstrate Understanding

- Describe the conditions under which a redox reaction causes an electric current to flow through a wire.
- Identify the components of a voltaic cell. Explain the role of each component in the operation of the cell.



12. Write the balanced equation for the spontaneous cell reaction that occurs in a cell with these reduction half-reactions.

- a.  $\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$  and  $\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$   
b.  $\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg}(\text{s})$  and  $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$   
c.  $\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$  and  $\text{Fe}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$   
d.  $\text{PbI}_2(\text{s}) + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s}) + 2\text{I}^-(\text{aq})$  and  $\text{Pt}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Pt}(\text{s})$



$E_{\text{red}} = +0.799 \text{ V}$



$E_{\text{red}} = -0.250 \text{ V}$



$E_{\text{red}} = -2.372 \text{ V}$



$E_{\text{red}} = 0.000 \text{ V}$



$E_{\text{red}} = -0.1375 \text{ V}$



$E_{\text{red}} = -0.036 \text{ V}$



$E_{\text{red}} = -0.365 \text{ V}$



$E_{\text{red}} = +1.18 \text{ V}$

13. Determine the standard potential for electrochemical cells in which each equation represents the overall cell reaction. Identify the reactions as spontaneous or nonspontaneous as written.

- a.  $2\text{Al}^{3+}(\text{aq}) + 3\text{Cu}(\text{s}) \rightarrow 3\text{Cu}^{2+}(\text{aq}) + 2\text{Al}(\text{s})$   
b.  $\text{Hg}^{2+}(\text{aq}) + 2\text{Cu}^+(\text{aq}) \rightarrow 2\text{Cu}^{2+}(\text{aq}) + \text{Hg}(\text{l})$   
c.  $\text{Cd}(\text{s}) + 2\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) \rightarrow \text{Cd}^{2+}(\text{aq}) + 2\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$



$E_{\text{red}} = -1.662 \text{ V}$



$E_{\text{red}} = +0.3419 \text{ V}$



$E_{\text{red}} = +0.851 \text{ V}$



$E_{\text{red}} = +0.153 \text{ V}$



$E_{\text{red}} = +0.775 \text{ V}$



$E_{\text{red}} = -0.4030 \text{ V}$

$E_{\text{cell}} = -1.662 - 0.3419$   
 $= -2.004 \text{ V}$   
non spontaneous

## Lesson 1 Check Your Progress

page 832

10. Describe the conditions under which a redox reaction causes an electric current to flow through a wire.

An electrochemical cell in which an oxidation half-reaction and a reduction half-reaction are connected by a salt bridge and a conducting wire results in a flow of electrons (electric current) through the conducting wire.

11. Identify the components of a voltaic cell. Explain the role of each component in the operation of the cell.

A voltaic cell consists of an anode, a cathode, a salt bridge, and a connecting wire between the two electrodes. Oxidation takes place at the anode, reduction takes place at the cathode, the salt bridge allows movement of ions from one solution to the other, and the wire allows the passage of electrons from the anode to the cathode.

12. Write the balanced equation for the spontaneous reaction that occurs in a cell with these reduction half-reactions.



13. Determine the standard potential for electrochemical cells in which each equation represents the overall cell reaction. Identify the reactions as spontaneous or nonspontaneous as written.



$E_{\text{cell}}^{\circ} = -1.662 \text{ V} - (-0.3419 \text{ V}) = -2.004 \text{ V}$

nonspontaneous



$E_{\text{cell}}^{\circ} = +0.851 \text{ V} - (+0.153 \text{ V}) = +0.698 \text{ V}$

spontaneous



$E_{\text{cell}}^{\circ} = -0.775 \text{ V} - (-0.4400 \text{ V}) = +1.178 \text{ V}$

spontaneous

# Electrolysis

## • Reversing Redox Reaction

• The use of electrical energy to bring about a chemical reaction is called electrolysis.

• An electrochemical cell in which electrolysis occurs is called an electrolytic cell.

• For example, when a secondary battery is recharged, it is acting as an electrolytic cell.

## Reversing Redox Reactions

- The use of electrical energy to bring about a chemical reaction is called **electrolysis**.
- An electrochemical cell in which electrolysis occurs is called an **electrolytic cell**.

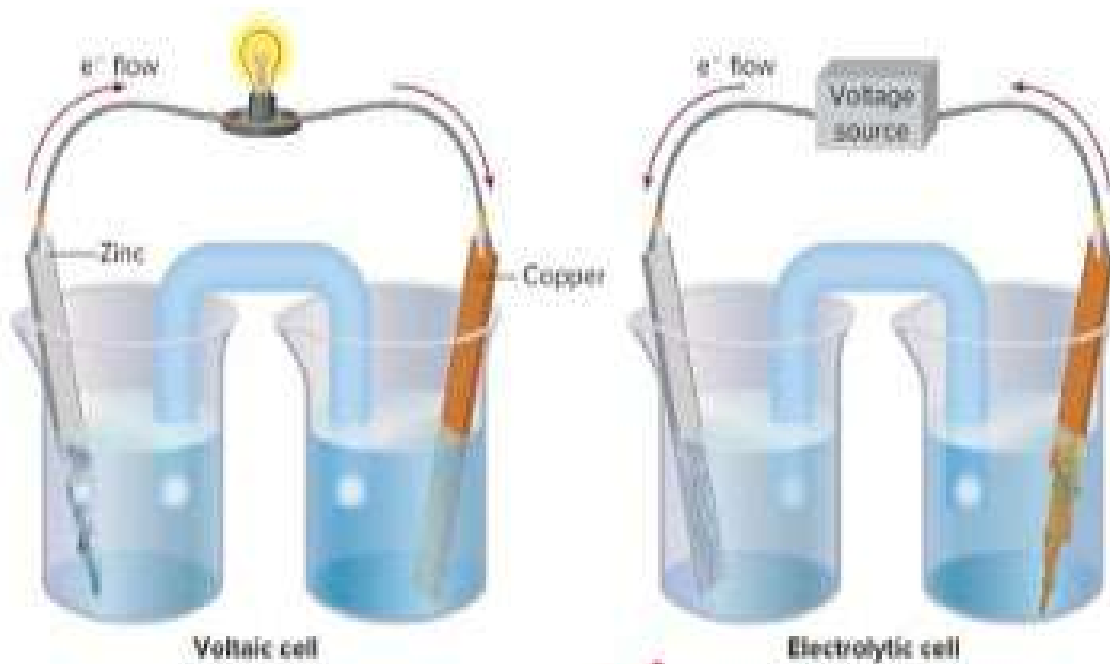
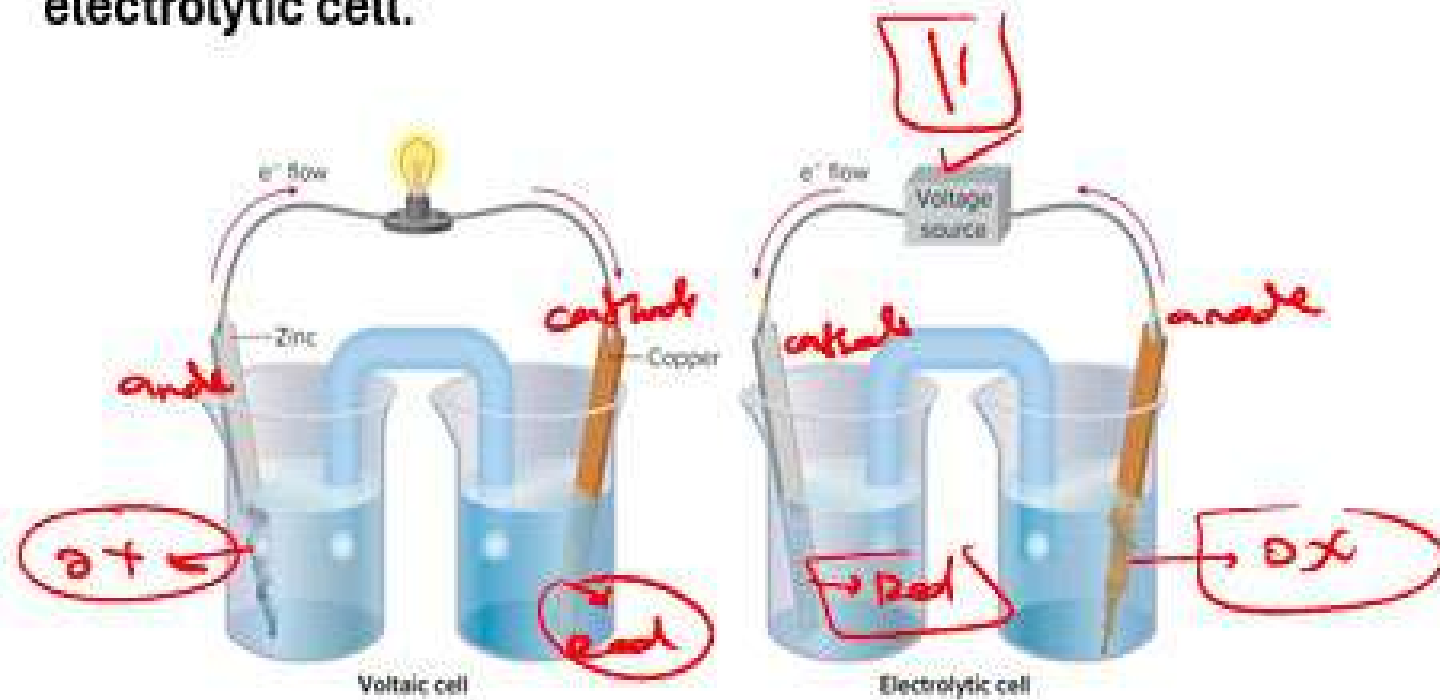


Figure 18 The zinc-copper electrochemical cell can be a voltaic cell or an electrolytic cell.

Infer: In each electrochemical cell, which metal is oxidized? What is reduced?

## Quiz

1. Which is the use of electrical energy to bring about a chemical reaction?

- 1 reduction
- 2 galvanization
- 3 electrolysis **CORRECT**
- 4 oxidation

## Quiz

2. Which is an electrochemical cell in which electrolysis occurs?

- A a voltaic cell
- B a fuel cell
- C a half-cell
- D an electrolytic cell

**CORRECT**

## Differences between voltaic cells and electrolyt cells

| Voltaic Cell                                                                                                    | Electrolytic Cell                                                                               |
|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Chemical energy → Electrical energy                                                                             | Electrical energy → Chemical energy                                                             |
| Voltaic cells convert chemical energy to electrical energy as a result of a <b>spontaneous redox reaction</b> . | Electrolytic cells use electrical energy to drive a <b>nonspontaneous reaction</b> .            |
| In these electrochemical cells, the <b>anode is negatively charged</b> , and the cathode is positively charged. | These cells feature a <b>positively charged anode</b> and a <b>negatively charged cathode</b> . |
| The electrons originate from the <u>species that undergoes oxidation</u> .                                      | Electrons originate from an <u>external source (such as a battery)</u> .                        |

**NOTE:** Cathode is ALWAYS where Reduction happens regardless if the cell is voltaic or Electrolytic.

Anode is Always where oxidation happens regardless if the cell is Voltaic or Electrolytic.

### Activity: concept check

- What type of electrochemical cell is this?

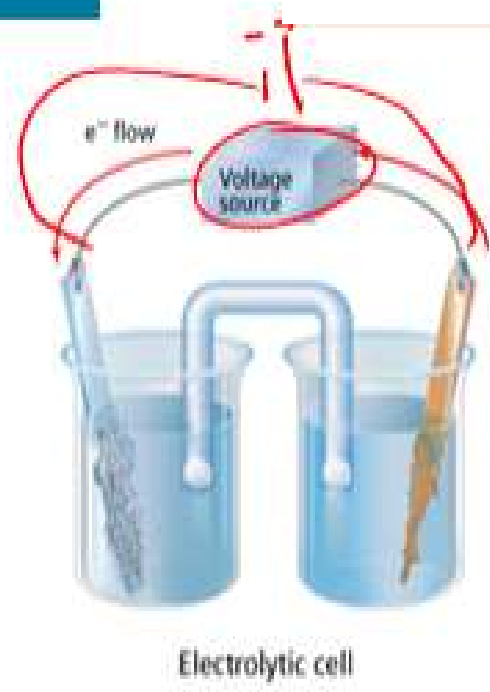
Electrolytic cell

- What is the charge on anode and cathode?

Anode is positive and cathode is negative

- Is the cell reaction spontaneous or nonspontaneous?

Nonspontaneous



# Electroplating coating with a metal

Objects are electroplated when a uniform coating is deposited usually as a protective or decorative layer. The substance used is typically a metal. Electroplating with a metal such as silver is accomplished with a method similar to that used to refine copper. The object to be silver-plated is the cathode of an electrolytic cell. The anode is a silver bar or sheet, as shown in Figure 22.

At the anode, silver is oxidized to silver ions as electrons are removed by the power source. At the cathode, the silver ions are reduced to silver metal by electrons from the external power source. The silver forms a thin coating over the object being plated. Current passing through the cell must be carefully controlled in order to get a smooth, even metal coating.

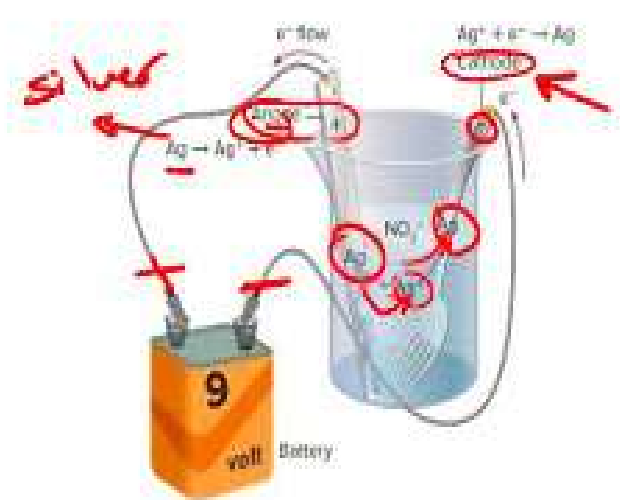
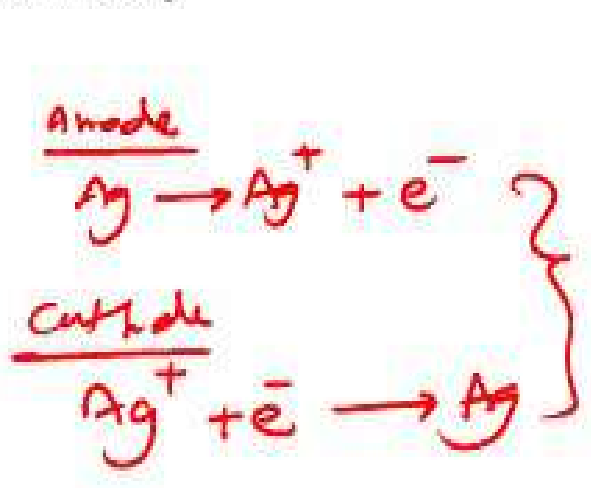
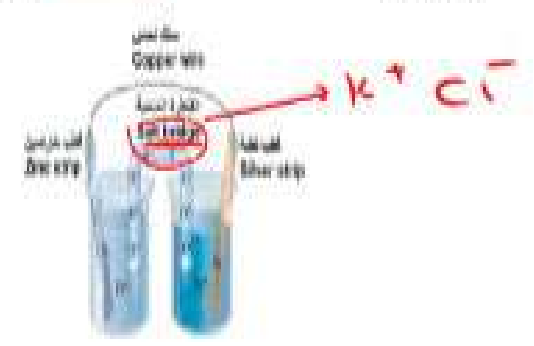


Figure 22. Power is needed to oxidize silver at the anode and reduce silver at the cathode. In an electrolytic cell used for silver plating, the object to be plated is the cathode, where silver ions in the electrolyte solution are reduced to silver metal and deposited on the object.

في الخلية الكهروكيميائية أدناه، أين تتحرك الأيونات من جانب إلى آخر؟  
 In the cell shown below, where are the ions moving from one side to another?



- |                           |                                         |
|---------------------------|-----------------------------------------|
| Through the silver strip  | <input type="radio"/> خلال القطب الفضي  |
| ✓ Through the salt bridge | <input type="radio"/> خلال الجسر الملحي |
| Through the copper wire   | <input type="radio"/> خلال سلك النحاس   |
| Through the zinc strip    | <input type="radio"/> خلال القطب الزنك  |

What number represents the part that prevents ions build up around the electrodes in the voltaic cell shown below?

ما الرقم الذي يمثل الجزء الذي يمنع تراكم الأيونات حول القطبين في الخلية الجلفانية الموضحة أدناه؟

|   |   |
|---|---|
| 1 | 0 |
| 2 | 0 |
| 3 | 0 |
| 4 | 0 |

The following reaction takes place in a voltaic cell:

يحدث التفاعل التالي في خلية جلفانية:

$$\text{Zn} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu}$$

Which of the following takes place at the anode?

أي مما يلي يحدث عند الأنود؟

**OX**

|                               |                         |   |
|-------------------------------|-------------------------|---|
| Reduction of $\text{Cu}^{2+}$ | اختزال $\text{Cu}^{2+}$ | 0 |
| Reduction of $\text{Zn}^{2+}$ | اختزال $\text{Zn}^{2+}$ | 0 |
| Oxidation of Cu               | أكسدة Cu                | 0 |
| Oxidation of Zn               | أكسدة Zn                | 0 |

In the voltaic cell shown below, where are electrons located?

في الخلية الجلفانية الموضحة أدناه، أين تقع الإلكترونات؟

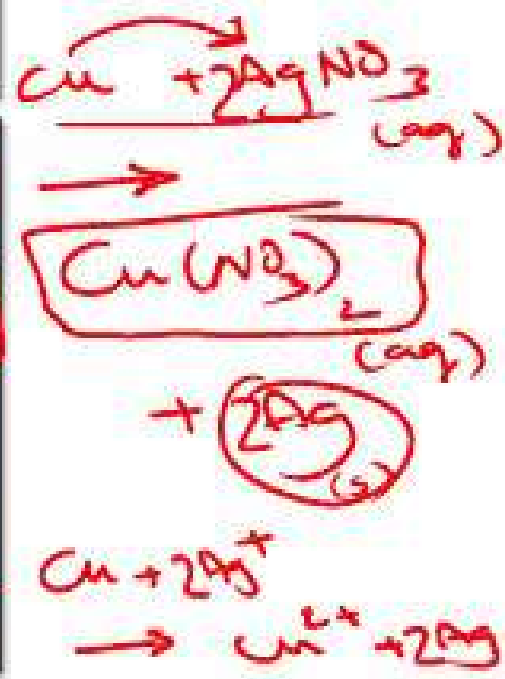
|                 |                  |   |
|-----------------|------------------|---|
| At zinc strip   | عند قطب الزنك    | 0 |
| At salt bridge  | عند الجسر الملحي | 0 |
| At both strips  | عند كلا القطبين  | 0 |
| At copper strip | عند قطب النحاس   | 0 |

When a solid copper wire is put into a solution of silver nitrate, a substance precipitates on the copper wire and the solution turns blue. Which of the following is correct?

عند وضع سلك من النحاس الصلب في محلول نترات الفضة، تترسب مادة على سطح النحاس ويكون المحلول أزرق اللون. أي مما يلي صحيح؟

correct?

| المحلول الأزرق<br>The blue solution     | تفاعل الاختزال<br>Reduction - half-reaction | تفاعل التأكسد<br>Oxidation - half-reaction | الناتج المتساقط من السلك<br>Solid deposited on the wire |   |
|-----------------------------------------|---------------------------------------------|--------------------------------------------|---------------------------------------------------------|---|
| نترات النحاس (II)<br>Copper(II) nitrate | $Ag^+ + e^- \rightarrow Ag$                 | $Cu \rightarrow Cu^{2+} + 2e^-$            | فضة<br>Silver                                           | 1 |
| نترات الفضة<br>Silver nitrate           | $Cu^{2+} + 2e^- \rightarrow Cu$             | $Ag \rightarrow Ag^+ + e^-$                | نحاس<br>Copper                                          | 2 |
| نترات النحاس (II)<br>Copper(II) nitrate | $Cu^{2+} + 2e^- \rightarrow Cu$             | $Ag + e^- \rightarrow Ag^+$                | فضة<br>Silver                                           | 3 |
| نترات الفضة<br>Silver nitrate           | $Ag + e^- \rightarrow Ag^+$                 | $Cu^{2+} + 2e^- \rightarrow Cu$            | نحاس<br>Copper                                          | 4 |



$Cu^{2+} + 2e^- \rightarrow Cu \quad E^0(V) = +0.3419$   
 $Zn^{2+} + 2e^- \rightarrow Zn \quad E^0(V) = -0.7618$

$E^0_{cell} = 0$

هذا الخزان القياسي ( $E^0$ ) لقطب الهيدروجين يساوي 1.14 V  
 هذا الخزان القياسي ( $E^0$ ) لقطب الهيدروجين يساوي 1.000 V

The standard reduction potential ( $E^0$ ) of the standard hydrogen electrode is defined as 1.14 V  
 The standard reduction potential ( $E^0$ ) of the standard hydrogen electrode is defined as 1.000 V

It will be a cathode when connected to  $Cu|Cu^{2+}$  electrode  
 يكون أنوداً عند توصله مع قطب  $Cu|Cu^{2+}$

It will be an anode when connected to  $Zn|Zn^{2+}$  electrode  
 يكون أنوداً عند توصله مع قطب  $Zn|Zn^{2+}$

A voltaic cell consists of the following half-reduction reactions, which of the following is correct?

تتكون خلية فولتية من تفاعلات الاختزال النصفية التالية، أي مما يأتي؟  
 مسيحي



$E^\circ_{\text{cell}}$   
 $= 0.7996$   
 $- (-0.744)$   
 $= \boxed{+1.54}$

|          | الأنود<br>Anode | الكاثود<br>Cathode | جهد الخلية ( $E^\circ$ )<br>Electrochemical Cell Potential ( $E^\circ$ ) | نوع التفاعل<br>Reaction Type |
|----------|-----------------|--------------------|--------------------------------------------------------------------------|------------------------------|
| <b>A</b> | Cr              | Ag                 | + 1.54 V                                                                 | تلقائي<br>Spontaneous        |
| B        | Ag              | Cr                 | + 0.0556 V                                                               | تلقائي<br>Spontaneous        |
| C        | Cr              | Ag                 | - 1.54 V                                                                 | غير تلقائي<br>Nonspontaneous |
| D        | Ag              | Cr                 | - 0.0556 V                                                               | غير تلقائي<br>Nonspontaneous |

A voltaic cell consists of the following half-reduction reactions, which of the following is correct?

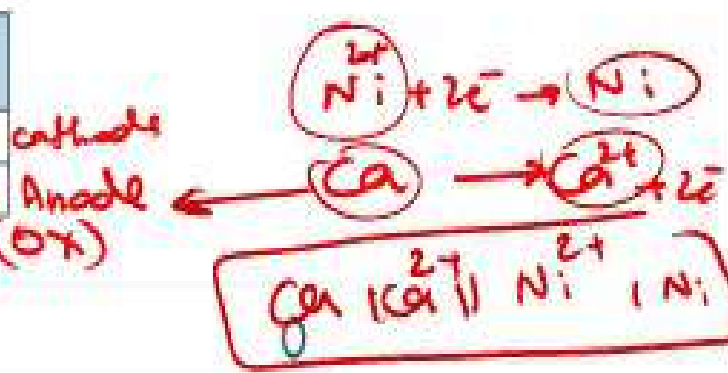
تتكون خلية فولتية من تفاعلات الاختزال النصفية التالية، أي مما يأتي؟  
 مسيحي



|   | الأنود<br>Anode | الكاثود<br>Cathode | جهد الخلية ( $E^\circ$ )<br>Electrochemical Cell Potential ( $E^\circ$ ) | نوع التفاعل<br>Reaction Type |
|---|-----------------|--------------------|--------------------------------------------------------------------------|------------------------------|
| A | Cr              | Ag                 | + 1.54 V                                                                 | تلقائي<br>Spontaneous        |
| B | Ag              | Cr                 | + 0.0556 V                                                               | تلقائي<br>Spontaneous        |
| C | Cr              | Ag                 | - 1.54 V                                                                 | غير تلقائي<br>Nonspontaneous |
| D | Ag              | Cr                 | - 0.0556 V                                                               | غير تلقائي<br>Nonspontaneous |

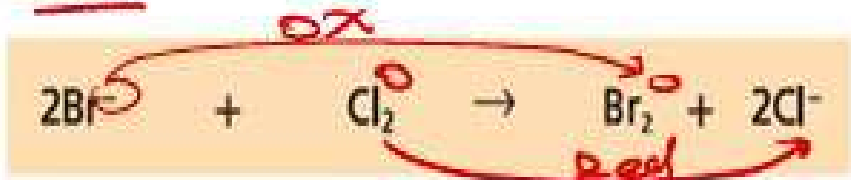
Which of the following represents the cell notation for the voltaic cell consisting of nickel and calcium electrodes?  
 أي مما يلي يمثل لرميز الخلية الفولتية التي تتكون من أقطاب النيكل والكالسيوم؟

| النصف التأكسدي<br>Half-Reaction   | $E^{\circ}(V)$ |
|-----------------------------------|----------------|
| $Ni^{2+} + 2e^{-} \rightarrow Ni$ | -0.257         |
| $Ca^{2+} + 2e^{-} \rightarrow Ca$ | -2.868         |



- $Ca^{2+} | Ca || Ni | Ni^{2+}$
- $Ni^{2+} | Ni || Ca^{2+} | Ca$  0
- $Ni || Ni^{2+} || Ca^{2+} | Ca$  0
- $Ca | Ca^{2+} || Ni^{2+} | Ni$  0

In the redox reaction below, What represents  
 the oxidation half-reaction and the reduction half-reaction?  
 في تفاعل الأكسدة والاختزال أدناه، ما الذي يمثل نصف تفاعل الأكسدة والاختزال؟



| نصف تفاعل الاختزال<br>Reduction half-reaction             | نصف تفاعل الأكسدة<br>Oxidation Half-Reaction              |   |
|-----------------------------------------------------------|-----------------------------------------------------------|---|
| $2Br^{-} + 2e^{-} \rightarrow Br_2$                       | $Cl_2 \rightarrow 2Cl^{-} + 2e^{-}$                       | X |
| <del><math>Cl_2 \rightarrow 2Cl^{-} + 2e^{-}</math></del> | <del><math>2Br^{-} + 2e^{-} \rightarrow Br_2</math></del> | X |
| <del><math>2Br^{-} \rightarrow Br_2 + 2e^{-}</math></del> | <del><math>Cl_2 + 2e^{-} \rightarrow 2Cl^{-}</math></del> | X |
| $Cl_2 + 2e^{-} \rightarrow 2Cl^{-}$                       | $2Br^{-} \rightarrow Br_2 + 2e^{-}$                       | ✓ |

|                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Which of the following is <u>true</u> for the two cells below?                                                                                                                                                                                                                                                            | أي مما يلي <u>صحيح</u> فيما يتعلق بالخلايتين أدناه؟                                                                                                                                                                                      |
|                                                                                                                                                                                                                                          |                                                                                                                                                        |
| <del>A- The Cell number (1) converts the electrical energy into chemical energy</del><br>✓ B- A spontaneous redox reaction occurs in the cell number (1)<br><del>C- The cell number (2) converts chemical energy into electrical energy</del><br><del>D- A spontaneous redox reaction occurs in the cell number (2)</del> | A- تحول الخلية رقم (1) الطاقة الكهربائية إلى طاقة كيميائية<br>B- يحدث في الخلية رقم (1) تفاعل أكسدة واختزال تلقائي<br>C- تحول الخلية رقم (2) الطاقة الكيميائية إلى طاقة كهربائية<br>D- يحدث في الخلية رقم (2) تفاعل أكسدة واختزال تلقائي |

|                                                                                                                                                                                                                                              |                                                                                                                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                           |                                                                                              |
| <del>In cell 1 the reaction is spontaneous</del><br>In cell 2 the reaction continues until the zinc strip is used up and then the reaction stops<br><del>2 is an electrolytic cell and converts chemical energy into electrical energy</del> | في الخلية 1 يكون التفاعل تلقائياً<br>في الخلية 2 يستمر التفاعل حتى يستهلك قضيب الزنك ثم يتوقف التفاعل<br>الخلية 2 هي خلية كهروكيميائية وتحول الطاقة الكيميائية إلى طاقة كهربائية |

What is the similarity between the two cells below?

ما وجه الشبه بين الخليتين أدناه؟



- |                                                                            |                                                |
|----------------------------------------------------------------------------|------------------------------------------------|
| <input checked="" type="checkbox"/> A spontaneous reaction occurs          | <input type="radio"/> حدوث تفاعل غير تلقائي    |
| <input checked="" type="checkbox"/> An oxidation-reduction reaction occurs | <input type="radio"/> حدوث تفاعل أكسدة واختزال |
| <input checked="" type="checkbox"/> A neutralization reaction occurs       | <input type="radio"/> حدوث تفاعل تعادل         |
| <input checked="" type="checkbox"/> A spontaneous reaction occurs          | <input type="radio"/> حدوث تفاعل تلقائي        |

Which of the following is true for the two cells below?

أي مما يلي صحيح فيما يتعلق بالخليتين أدناه؟



- |                                                                                                     |                                                         |
|-----------------------------------------------------------------------------------------------------|---------------------------------------------------------|
| <input checked="" type="checkbox"/> In cell number (1), the <u>electrons flow from Cu to Zn</u>     | في الخلية رقم (1) تتدفق الإلكترونات من <u>Cu إلى Zn</u> |
| <input checked="" type="checkbox"/> In cell number (1), the <u>anode produces electrons from Zn</u> | في الخلية رقم (1) ينتج الأنود الإلكترونات من <u>Zn</u>  |
| <input checked="" type="checkbox"/> In cell number (2), the <u>anode produces electrons from Zn</u> | في الخلية رقم (2) ينتج الأنود الإلكترونات من <u>Zn</u>  |
| <input checked="" type="checkbox"/> In cell number (2), the <u>electrons flow from Zn to Cu</u>     | في الخلية رقم (2) تتدفق الإلكترونات من <u>Zn إلى Cu</u> |

Electroplating Al with gold

Handwritten notes and diagrams:

- Anode (Au):**  $Au \rightarrow Au^{3+} + 3e^-$
- Cathode (Al):**  $Au^{3+} + 3e^- \rightarrow Au$
- Solution:**  $Au^{3+}$

| التركيب المستخدم<br>Used electrode        | تفاعل الكاثود<br>Cathode reaction | تفاعل الأنود<br>Anode reaction  | العملية<br>Owing it mass<br>of deposited metal |
|-------------------------------------------|-----------------------------------|---------------------------------|------------------------------------------------|
| يحتوي على $Au^{3+}$<br>Contains $Au^{3+}$ | $Au^{3+} + 3e^- \rightarrow Au$   | $Au \rightarrow Au^{3+} + 3e^-$ | تزداد / Increases ✓                            |
| يحتوي على $Al^{3+}$<br>Contains $Al^{3+}$ | $Al^{3+} + 3e^- \rightarrow Al$   | $Al \rightarrow Al^{3+} + 3e^-$ | تزداد / Increases ✓                            |
| يحتوي على $Au^{3+}$<br>Contains $Au^{3+}$ | $Al^{3+} + 3e^- \rightarrow Al$   | $Al \rightarrow Al^{3+} + 3e^-$ | تقل / Decreases ✗                              |
| يحتوي على $Al^{3+}$<br>Contains $Al^{3+}$ | $Au^{3+} + 3e^- \rightarrow Au$   | $Au \rightarrow Au^{3+} + 3e^-$ | تزداد / Increases ✓                            |

Recharging the cell in the figure below. Which of the following is correct?

Handwritten notes and diagrams:

- Voltagge source / مصدر كهربائي**
- Cathode / كاثود (Zinc)**
- Anode / أنود (Copper)**

Reactions:

- Anode:**  $Zn \rightarrow Zn^{2+} + 2e^-$
- Cathode:**  $Cu^{2+} + 2e^- \rightarrow Cu$

Explanations:

- The reaction continues until the zinc strip is used up, and then the reaction stops.
- Oxidation takes place at zinc electrode.
- The external power supply (voltage) works on cell regeneration and the cell returns to almost its original strength.

Arabic notes:

- يستمر التفاعل حتى يستهلك القطب الزنك، ثم يتوقف التفاعل.
- تحدث عملية أكسدة عند القطب الزنك.
- يعمل مصدر الطاقة (المصدر الكهربائي) الخارجي على تجديد الخلية ويعود الخلية إلى قوتها الأصلية تقريباً.



|                                       |                                                  |                                          |
|---------------------------------------|--------------------------------------------------|------------------------------------------|
| <input checked="" type="checkbox"/> X | The object to be plated is the anode             | يكون الجسم المراد طلائه هو الأنود        |
| <input checked="" type="checkbox"/> X | metal used for coating is the cathode            | يكون المعدن المراد طلائه به هو الكاثود   |
| <input checked="" type="checkbox"/> X | Silver is oxidized to silver ions at the cathode | تأكسد الفضة إلى أيونات الفضة عند الكاثود |
| <input checked="" type="checkbox"/>   | Silver is oxidized to silver ions at the anode   | تأكسد الفضة إلى أيونات الفضة عند الأنود  |

The figure below shows a picture of a key being electroplated with copper in an electrolytic cell. Which of the following statements is **true**?

- ☒ X copper is oxidized to  $\text{Cu}^{2+}$  ions at the cathode
- ☒ X reduction of copper ions occurs on the anode electrode
- ☒ X the mass of the copper electrode increases
- ☒ d. electrical energy is used to cause a redox reaction



Electrolytic cell

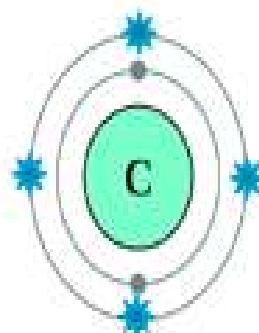
- |   |                                                                                                                                                  |
|---|--------------------------------------------------------------------------------------------------------------------------------------------------|
| 6 | CHM.5.6.01.001.07 Explain why carbon forms many compounds<br>CHM.5.6.01.003.14 Identify the main (general) characteristic of an organic compound |
|---|--------------------------------------------------------------------------------------------------------------------------------------------------|

- |   |                                                                                                                                    |
|---|------------------------------------------------------------------------------------------------------------------------------------|
| 7 | CHM.5.6.01.001.09 Explain, using Lewis diagram and ball-stick model, the difference between saturated and unsaturated hydrocarbons |
|---|------------------------------------------------------------------------------------------------------------------------------------|

- |   |                                                                                                                                         |
|---|-----------------------------------------------------------------------------------------------------------------------------------------|
| 8 | CHM.5.6.01.005.07 Describe the process used to separate petroleum compounds by explaining the physical property used during the process |
|---|-----------------------------------------------------------------------------------------------------------------------------------------|

## Why can **Carbon atom** form so many different organic compounds?

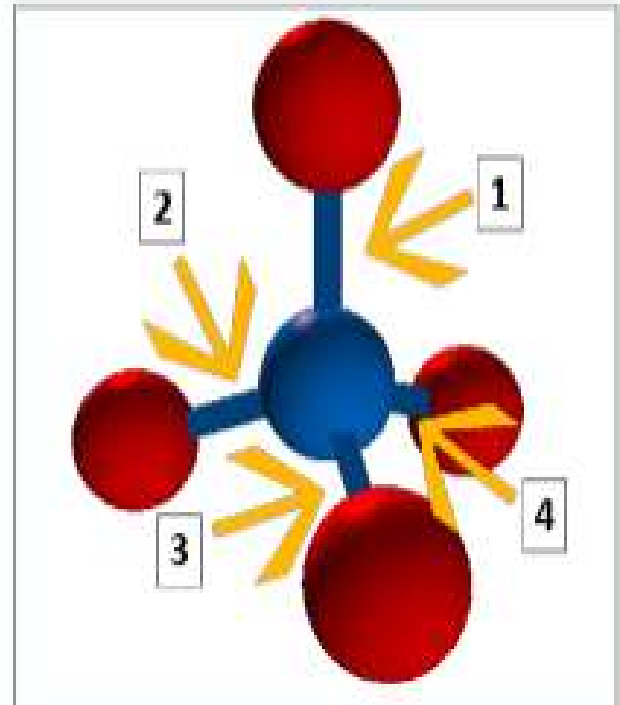
- 1. a carbon atom has four electrons in its outer energy level (**4 valence electrons**).
- Carbon can share **4 valence electrons**, thus it can make a total of 4 covalent bonds



## Why can Carbon atom form so many different organic compounds?

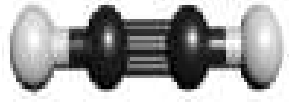
- 2. a carbon atom can form **four covalent bonds** with atoms of carbon or with other elements **because it has 4 valence electrons.**

Recall: covalent bond is formed when two atoms share pair of electrons.



## Why can Carbon atom form so many different organic compounds?

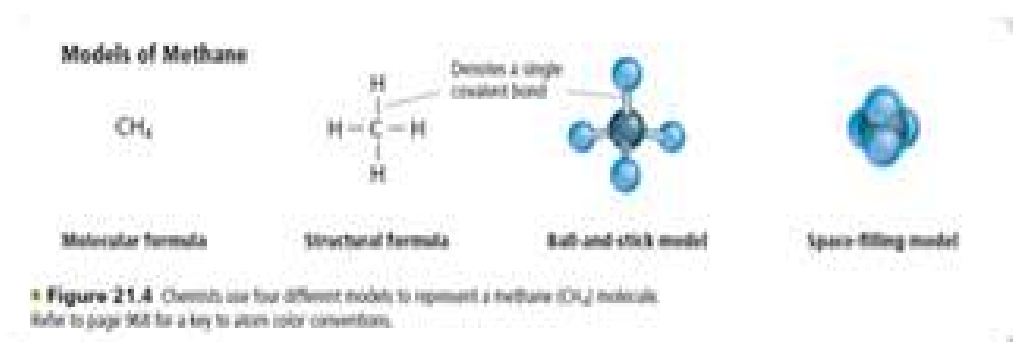
- 3. Carbon can form single, double, or triple covalent bonds.

| Type of bonding | Bond structure                                            | Example                                                                                                        | 3D plo                                                                                |
|-----------------|-----------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Single          | $\begin{array}{c}   \\ -C- \\   \end{array}$              | Methane<br>$\begin{array}{c} H \\   \\ H-C-H \\   \\ H \end{array}$                                            |  |
| Double          | $\begin{array}{c} \diagup \\ C= \\ \diagdown \end{array}$ | Ethene<br>$\begin{array}{c} H & H \\ & \diagdown \diagup \\ & C=C \\ & \diagup \diagdown \\ H & H \end{array}$ |  |
| Triple          | $-C\equiv$                                                | Ethyne<br>$H-C\equiv C-H$                                                                                      |  |

14

|           |         |
|-----------|---------|
| 6         | C       |
| Carbon    | 12.011  |
| 14        | Si      |
| Silicon   | 28.086  |
| 32        | Ge      |
| Germanium | 72.64   |
| 50        | Sn      |
| Tin       | 118.710 |
| 82        | Pb      |
| Lead      | 207.2   |

**Figure 2** Carbon can bond to four other elements and form thousands of different compounds.

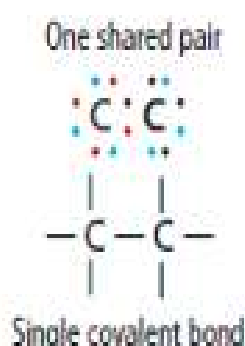


**Models and hydrocarbons** Chemists represent organic molecules in a variety of ways. Figure 21.4 shows four different ways to represent a methane molecule. Covalent bonds are represented by a single straight line, which denotes two shared electrons. Most often, chemists use the type of model that best shows the information they want to highlight.

As shown in Figure 21.4, **molecular formulas** give no information about the geometry of the molecule. **A structural formula** shows the general arrangement of atoms in the molecule but not the exact, three dimensional geometry. **The ball-and-stick model** demonstrates the geometry of the molecule clearly, but the **space-filling model** gives a more realistic picture of what a molecule would look like if you could see it. Keep in mind as you look at the models that the atoms are held closely together by electron-sharing bonds.

## Lewis structures and structural formulas

- Carbon can bond to other carbon atoms in double and triple bonds. These **Lewis structures** and **structural formulas** show two ways to denote double and triple bonds



- and • = carbon electrons
- = electron from another atom

## Hydrocarbons

### → Bonding in hydrocarbons:

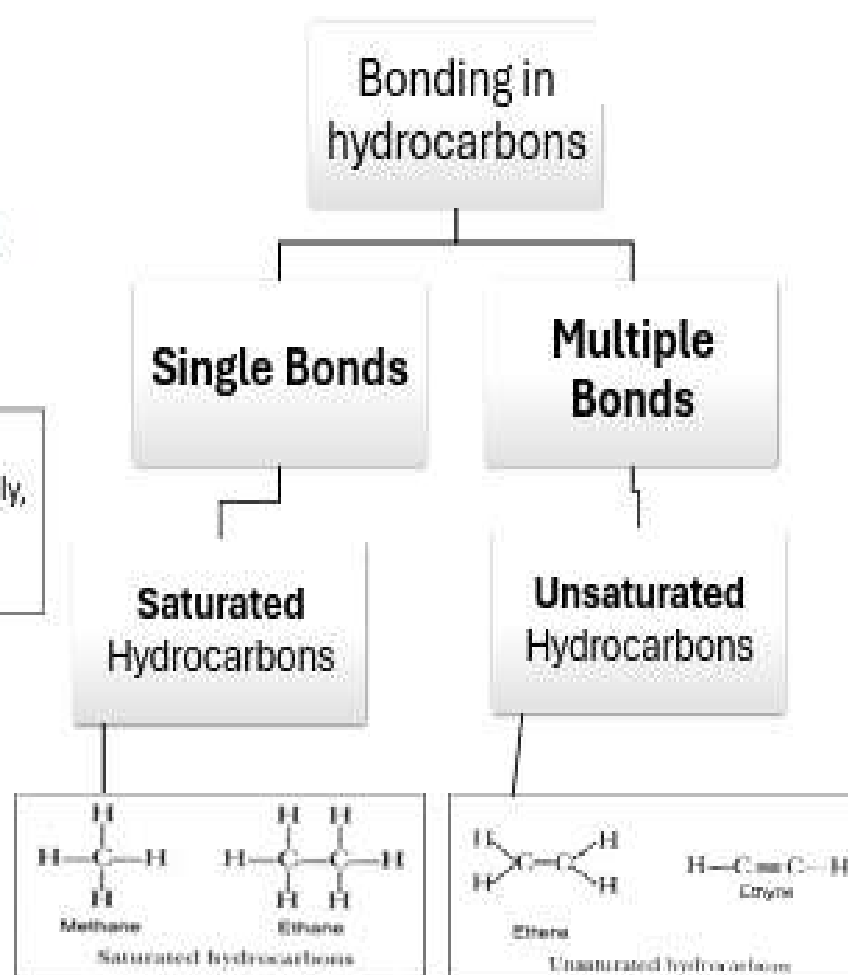
- Saturated
- unsaturated

#### Note:

the ending *-ane* indicates a single bonds only,  
 The ending *-ene* indicates a double bond,  
 and *-yne* indicates a triple bond.

#### Note:

the term "unsaturated" means more  
 hydrogen atoms may be added to  
 the hydrocarbon to make it saturated.



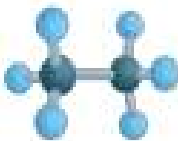
## Reacting with Bromine: Double and triple bonds (Unsaturated hydrocarbons)

## Not reacting with bromine (single bonds): saturated hydrocarbons

|    |                                                                                                                                                                                  |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 9  | CHM.5.6.(01.0)13.02 Use IUPAC system to name aliphatic alkanes (straight chain, branched, non-substituted and substituted)                                                       |
| 10 | CHM.5.6.(01.0)13.03 Use IUPAC system to name cycloalkanes (non-branched, branched, non-substituted and substituted)                                                              |
| 11 | CHM.5.6.(01.0)16 Use the structures and functional groups to interpret the physical properties of organic compounds (e.g. melting point, boiling point and solubility in water). |

## Straight-Chain Alkanes

**Alkanes** are **hydrocarbons** that have only single bonds between atoms.

|                                             | Structural formula                                                                                                                                                                                                                                                         | Ball & Stick Model                                                                  | Space Filling Model                                                                   |
|---------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Ethane<br>(C <sub>2</sub> H <sub>6</sub> )  | $  \begin{array}{c}  \text{H} \quad \text{H} \\    \quad   \\  \text{H}-\text{C}-\text{C}-\text{H} \\    \quad   \\  \text{H} \quad \text{H}  \end{array}  $                                                                                                               |  |  |
| Propane<br>(C <sub>3</sub> H <sub>8</sub> ) | $  \begin{array}{c}  \text{H} \quad \text{H} \quad \text{H} \\    \quad   \quad   \\  \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\    \quad   \quad   \\  \text{H} \quad \text{H} \quad \text{H}  \end{array}  $                                                        |  |  |
| Butane<br>(C <sub>4</sub> H <sub>10</sub> ) | $  \begin{array}{c}  \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\    \quad   \quad   \quad   \\  \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\    \quad   \quad   \quad   \\  \text{H} \quad \text{H} \quad \text{H} \quad \text{H}  \end{array}  $ |  |  |

## Straight-Chain Alkanes

- The names of **alkanes** end in **-ane**.
- Alkanes **with five or more carbons** in a chain have names that use a prefix derived from the Greek or Latin word for the number of carbons in each chain.
  - Example: *pentane*

Table 2 First Ten of the Alkane Series

| Name    | Molecular Formula            | Condensed Structural Formula                                                    |
|---------|------------------------------|---------------------------------------------------------------------------------|
| Methane | $\text{CH}_4$                | $\text{CH}_4$                                                                   |
| Ethane  | $\text{C}_2\text{H}_6$       | $\text{CH}_3\text{CH}_3$                                                        |
| Propane | $\text{C}_3\text{H}_8$       | $\text{CH}_3\text{CH}_2\text{CH}_3$                                             |
| Butane  | $\text{C}_4\text{H}_{10}$    | $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$                                  |
| Pentane | $\text{C}_5\text{H}_{12}$    | $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$                       |
| Hexane  | $\text{C}_6\text{H}_{14}$    | $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$            |
| Heptane | $\text{C}_7\text{H}_{16}$    | $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ |
| Octane  | $\text{C}_8\text{H}_{18}$    | $\text{CH}_3(\text{CH}_2)_6\text{CH}_3$                                         |
| Nonane  | $\text{C}_9\text{H}_{20}$    | $\text{CH}_3(\text{CH}_2)_7\text{CH}_3$                                         |
| Decane  | $\text{C}_{10}\text{H}_{22}$ | $\text{CH}_3(\text{CH}_2)_8\text{CH}_3$                                         |

Alkanes  $C_nH_{2n+2}$

substituent groups

Table 3 Common Alkyl Groups  $C_n H_{2n+1}$ 

| Name                         | Methyl                                                                          | Ethyl                                                                                                              | Propyl                                                                                                                                                | Isopropyl                                                                                                                                                 | Butyl                                                                                                                                                                                    |
|------------------------------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Condensed structural formula | $\text{CH}_3-$                                                                  | $\text{CH}_3\text{CH}_2-$<br>$\text{C}_2\text{H}_5-$                                                               | $\text{CH}_3\text{CH}_2\text{CH}_2-$<br>$\text{C}_3\text{H}_7$                                                                                        | $\text{CH}_3\text{CH}(\text{CH}_3)-$<br>$\text{C}_3\text{H}_7$                                                                                            | $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2-$<br>$\text{C}_4\text{H}_9$                                                                                                                |
| Structural formula           | $\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \end{array}$ | $\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \end{array}$ | $\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \end{array}$ | $\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ -\text{C}-\text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H} \end{array}$ | $\begin{array}{c} \text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \\ \text{H}-\text{C}-\text{H} \\   \end{array}$ |

$\text{CH}_3\text{CH}_2\text{CH}_2$

$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2$  } —————  
                  |  
 $\text{CH}_3\text{CH}_2\text{CH}_2$

## Straight-Chain Alkanes

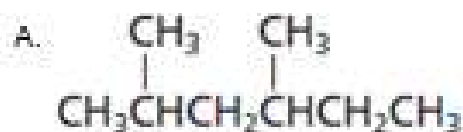
- A series of compounds that differ from one another by a repeating unit is called a **homologous series**.
- A homologous series has a fixed numerical relationship among the numbers of atoms. For alkanes, the relationship between the numbers of carbon and hydrogen atoms can be expressed as  $C_nH_{2n+2}$ , where  $n$  is equal to the number of carbon atoms in the alkane.
- For example, heptane has seven carbon atoms, so its formula is  $C_7H_{2(7)+2}$ , or  $C_7H_{18}$ .

## Branched Chain Alkanes

- Carbon atoms can bond to one, two, three, or four other carbon atoms, making a variety of branched-chain alkanes possible.
- A straight-chain and a branched-chain alkane can have the same molecular formula, but their structural arrangements are different.
- The order and arrangement of atoms in an organic molecule determine its identity.

## Your Turn!

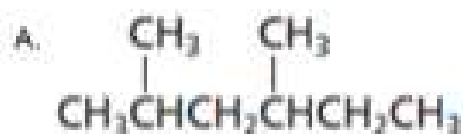
- Use the IUPAC rules to name the following structures.



**2,4-dimethylhexane**

## Your Turn!

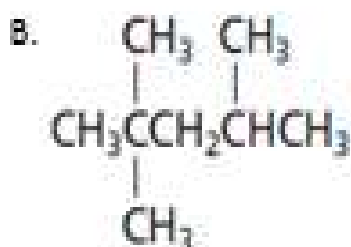
- Use the IUPAC rules to name the following structures.



**2,4-dimethylhexane**

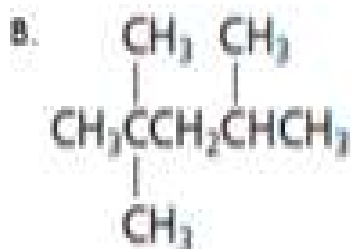
## Your Turn!

- Use the IUPAC rules to name the following structures.



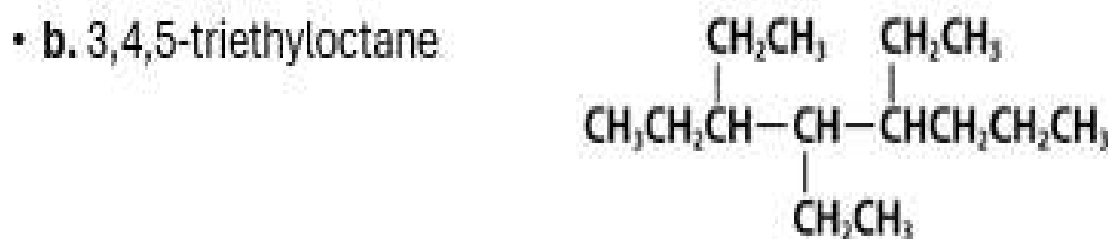
## Your Turn!

- Use the IUPAC rules to name the following structures.



# Plenary Page 224

Draw the structures of the following branched-chain alkanes.

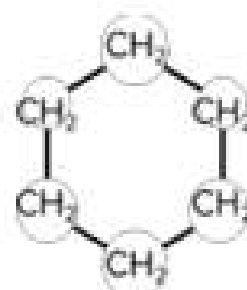


## Cycloalkanes

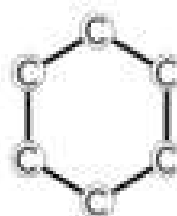
- An organic compound that contains a hydrocarbon ring is called a **cyclic hydrocarbon**. (Cyclic = ring-like structure)
- Cyclic hydrocarbons that contain **only single bonds** are called **cycloalkanes**. Example: cyclohexane
- The relationship between numbers of carbon and hydrogen atoms in cycloalkanes can be expressed as: **C<sub>n</sub>H<sub>2n</sub>**

## Cycloalkanes

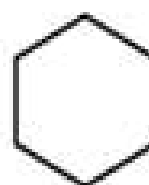
Cyclic hydrocarbons such as cyclohexane are represented by **condensed**, **skeletal**, and **line structures**.



Condensed structural formula

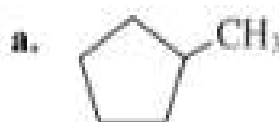


Skeletal structure

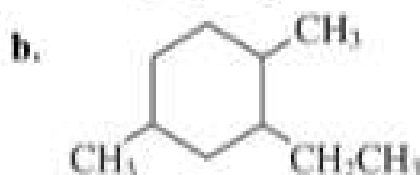


Line structure

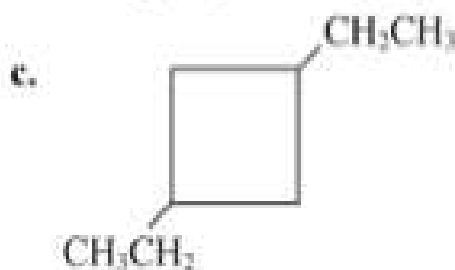
## Activity (Practice Problems page 22



methylcyclopentane



2-ethyl-1,4-dimethylcyclohexane



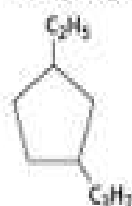
1,3-diethylcyclobutane

## 11. CHALLENGE Draw the structures of the following cycloalkanes.

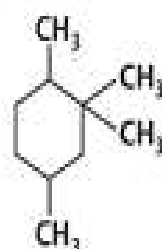
- 1-ethyl-3-propylcyclopentane
- 1,2,2,4-tetramethylcyclohexane

### 11. Challenge Draw the structures of the following cycloalkanes.

- 1-ethyl-3-propylcyclopentane



- 1,2,2,4-tetramethylcyclohexane



## Properties of Alkanes

- The structure of a molecule affects its properties.
- Alkanes are nonpolar. They have little intermolecular attraction and do not form hydrogen bonds like water.
- As a result, **they boil and melt at lower temperatures than water.**
- Also, they are more soluble in solvents composed of nonpolar molecules than in water.

Table 4 Comparing Physical Properties

| Substance and formula     | Water (H <sub>2</sub> O) | Methane (CH <sub>4</sub> ) |
|---------------------------|--------------------------|----------------------------|
| Molecular mass            | 18 amu                   | 16 amu                     |
| State at room temperature | liquid                   | gas                        |
| Boiling point             | 100°C                    | -162°C                     |
| Melting point             | 0°C                      | -182°C                     |

# Properties of Alkanes: Chemical properties

- The main chemical property of alkanes is their **low reactivity**. Why?
- Molecules such as alkanes, in which atoms are connected by **nonpolar bonds**, have no charge. As a result, they have little attraction for ions or polar molecules.
- The low reactivity of alkanes can also be attributed to the **relatively strong C–C and C–H bonds**.



■ **Figure 21.11** Many solvents—used as thinners for paints, coatings, waxes, photocopier toners, adhesives, and printer press inks—contain alkanes and cycloalkanes.



## Check Your Progress

### Summary

- Alkanes contain only single bonds between carbon atoms.
- Alkanes and other organic compounds are best represented by structural formulas and can be named using systematic rules determined by the International Union of Pure and Applied Chemistry (IUPAC).
- Alkanes that contain hydrocarbon rings are called cyclic alkanes.

### Demonstrate Understanding

- Describe the main structural characteristics of alkane molecules.
- Name the following structures using IUPAC rules.
 

a.

$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH}_3\text{CHCH}_2\text{CH}_2\text{CH}_3 \end{array}$$

b.

$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH}_2\text{CCH}_3 \\ | \\ \text{CH}_3 \end{array}$$

c.
- Describe the general properties of alkanes.
- Draw the molecular structure for each of the following.
 

a. 3,4-diethylheptane

c. 1-ethyl-4-methylcyclohexane

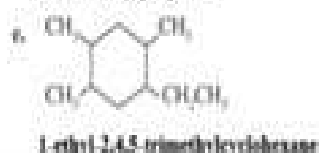
b. 4-isopropyl-3-methyldecane

d. 1,2-dimethylcyclopropane
- Interpret Chemical Structures** Why is the name 3-butylpentane incorrect? Based on this name, write the structural formula for the compound. What is the correct IUPAC name for 3-butylpentane?

- Describe the main structural characteristics of alkane molecules.

Alkanes are chain or ring hydrocarbons containing only single carbon-carbon covalent bonds.

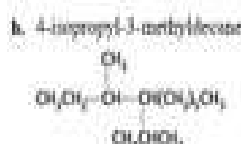
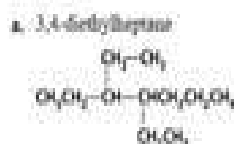
- Name the following structures using IUPAC rules.



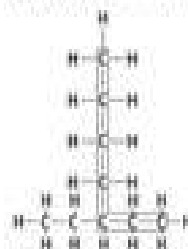
- Describe the general properties of alkanes.

The C-C and C-H bonds are nonpolar, making alkanes insoluble in water, a polar solvent. Alkanes are good solvents for other nonpolar substances. The bonds are also strong and stable, making alkanes relatively unreactive.

- Draw the molecular structure for each of the following.



- Interpret Chemical Structures** Why is the name 3-butylpentane incorrect? Based on this name, write the structural formula for the compound. What is the correct IUPAC name for 3-butylpentane?



The longest continuous carbon chain contains seven carbon atoms, not five carbon atoms. Parent chain has seven carbon atoms with an ethyl group on carbon 3: 3-ethylheptane.

- |    |                                                                                                                |
|----|----------------------------------------------------------------------------------------------------------------|
| 12 | CHM.5.6.01.013.08 Draw the structure of an alkene given its IUPAC name                                         |
| 13 | CHM.5.6.01.013.06 Use IUPAC system to name alkenes (straight chain, branched, non-substituted and substituted) |
| 14 | CHM.5.6.01.013.07 Use IUPAC system to name alkynes (straight chain and branched)                               |

## Alkenes

- Alkenes are hydrocarbons that contain **at least one double bond**.

Because an alkene must have a double bond between carbon atoms, there is no 1-carbon alkene.

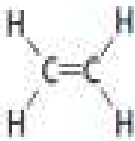
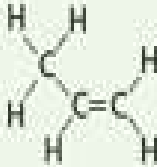
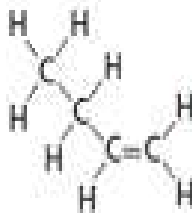
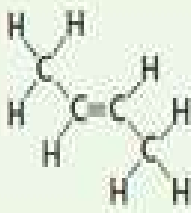
The simplest alkene has two carbon atoms double bonded to each other.

The remaining four electrons—two from each carbon atom—are shared with four hydrogen atoms to give the molecule ethene ( $C_2H_4$ ).



The smallest Alkene  
"Ethene"

## Examples of Alkenes

| Name                         | Ethene                                                                            | Propene                                                                           | 1-Butene                                                                           | 2-Butene                                                                            |
|------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Molecular formula            | $C_2H_4$                                                                          | $C_3H_6$                                                                          | $C_4H_8$                                                                           | $C_4H_8$                                                                            |
| Structural formula           |  |  |  |  |
| Condensed structural formula | $CH_2=CH_2$                                                                       | $CH_3CH=CH_2$                                                                     | $CH_3CH_2CH=CH_2$                                                                  | $CH_3CH=CHCH_3$                                                                     |

You can conclude from the table; you will see that each molecular formulas for the substances shown in the table, has twice as many hydrogen atoms as carbon atoms,

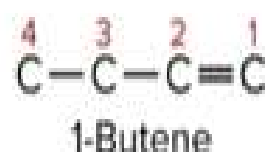
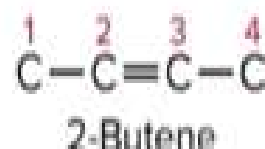
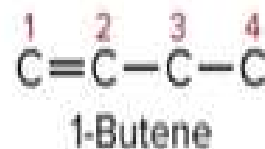
The general formula for the series is  $C_nH_{2n}$ . **This formula is true for alkenes with only one double bond.**

## Alkenes

- Unsaturated hydrocarbons that contain one or more double covalent bonds between carbon atoms in a chain are called **alkenes**.
- For alkenes with only one double bond**, the relationship between the numbers of carbon and hydrogen atoms can be expressed as:  
 $C_nH_{2n}$

## Naming Alkenes (with 4 or more c

- To name alkenes with **four or more carbons** in the chain, it is necessary to **specify the location of the double bond**, fig. 21.12.
- This is done by **numbering the carbons in the parent chain**, starting at the end of the chain that will give the first carbon in the **double bond the lowest number**. Then, use only that number in the name.



a. Straight-chain alkenes

## Naming Alkenes (Cyclic Alkenes)

- Cyclic alkenes or cycloalkenes** are named in much the same way as cyclic alkanes; however, **carbon number 1 must be one of the carbons connected by the double bond**. In the figure, note the numbering in the compound.



b. Cyclic alkenes

- The name of this compound is **1,3-dimethylcyclopentene**.

## Naming branched-chain alkenes

When naming branched chain alkenes, follow the IUPAC rules for naming branched-chain alkanes, but with two exceptions:

1. First, in alkenes, **the parent chain is always the longest chain that contains the double bond**, whether or not it is the longest chain of carbon atoms.
2. Second, **the position of the double bond**, not the branches, determines how the chain is numbered.

The positions of the double bonds in alkenes are numbered in a way that gives the lowest set of numbers. This is true of both branched and straight chain alkenes.



2-methylbutene

a. Single double bond



or



2,4-heptadiene

b. Two double bonds

## Naming branched-chain alkenes

- For alkenes with **more than one double bond**, you must indicate the position of the double bond(s) using a prefix (**di-, tri-, etc.**) before the suffix **-ene**.

Example: 2,4-heptadiene

- The positions of the bonds are numbered to give the lowest set of numbers.

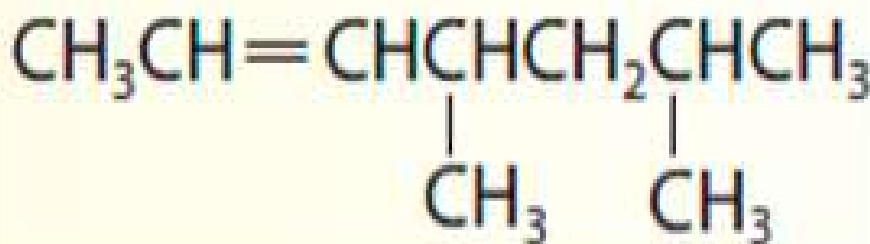
## NAMING BRANCHED-CHAIN ALKENES (Page 231)

### IN-CLASS EXAMPLE

Use with Example Problem 3.

#### Problem

Name the alkene shown.



## NAMING BRANCHED-CHAIN ALKENES (Page 231)

### IN-CLASS EXAMPLE

Use with Example Problem 3.

#### Problem

Name the alkene shown.



#### Response

##### ANALYZE THE PROBLEM

You are given a branched-chain alkene that contains one double bond and two alkyl groups. Follow the IUPAC rules to name the organic compound.

##### SOLVE FOR THE UNKNOWN

Step 1. The longest continuous-carbon chain that includes the double bond contains seven carbons. The 7-carbon alkane is heptane, but the name is changed to heptene because a double bond is present.

- **Heptene parent chain**



Step 2. Number the chain to give the lowest number to the double bond.

- **2-heptene parent chain**



## NAMING BRANCHED-CHAIN ALKENES

### IN-CLASS EXAMPLE

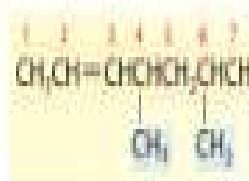
Step 3. Name each substituent.

- Each substituent is a methyl group.



Step 4. Determine how many of each substituent is present, and assign the correct prefix to represent that number. Then, include the position numbers to get the complete prefix.

- 2-heptene parent chain
- Two methyl groups at Positions 4 and 6
- Prefix is 4,6-dimethyl



Step 5. The names of substituents do not have to be alphabetized because they are the same. Apply the complete prefix to the name of the parent alkene chain. Use commas between numbers, and hyphens between numbers and words. Write the name 4,6-dimethyl-2-heptene.

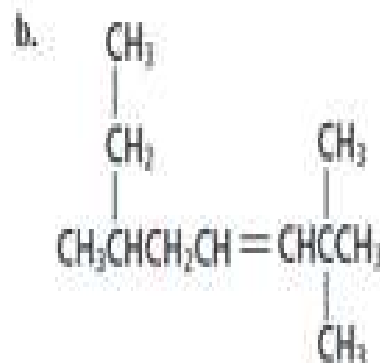
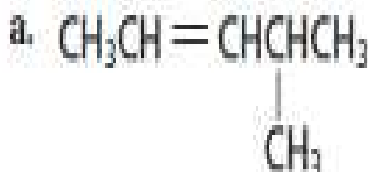
### EVALUATE THE ANSWER

The longest carbon chain includes the double bond, and the position of the double bond has the lowest possible number.

Correct prefixes and alkyl group names designate the branches.

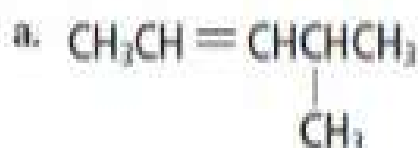
## Practice Problems Page 232

Use the IUPAC rules to name the following structures.

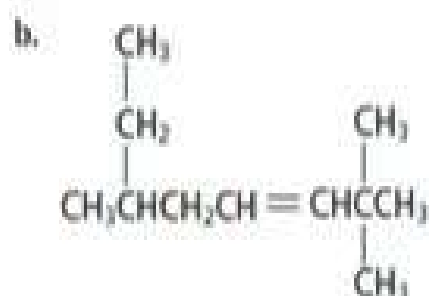


## Practice Problems Page 232

Use the IUPAC rules to name the following structures.



**4-methyl-2-pentene**



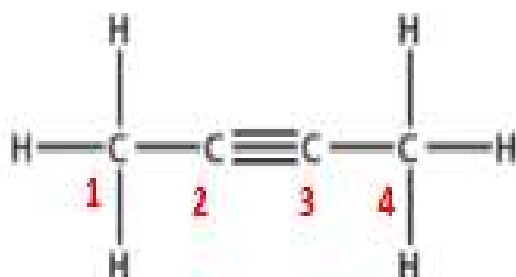
**2,2,6-trimethyl-3-octene**

### Table 6 Examples of Alkynes

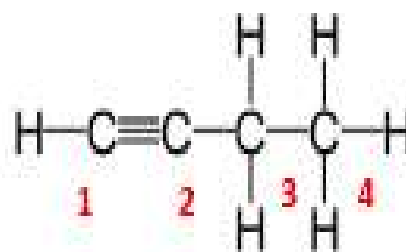
| Name     | Molecular Formula | Structural Formula                                                                                                                      | Condensed Structural Formula |
|----------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| Ethyne   | $C_2H_2$          | $H-C \equiv C-H$                                                                                                                        | $CH \equiv CH$               |
| Propyne  | $C_3H_4$          | $  \begin{array}{c}  H \\    \\  H-C \equiv C-C-H \\    \\  H  \end{array}  $                                                           | $CH \equiv CCH_3$            |
| 1-Butyne | $C_4H_6$          | $  \begin{array}{c}  H \quad H \\    \quad   \\  H-C \equiv C-C-C-H \\    \quad   \\  H \quad H  \end{array}  $                         | $CH \equiv CCH_2CH_3$        |
| 2-Butyne | $C_4H_6$          | $  \begin{array}{c}  H \quad \quad H \\    \quad \quad   \\  H-C-C \equiv C-C-H \\    \quad \quad   \\  H \quad \quad H  \end{array}  $ | $CH_3C \equiv CCH_3$         |

## Naming alkynes

- Straight-chain alkynes and branched-chain alkynes are named in the same way as alkenes. The only difference is that the name of the parent chain ends in **-yne** rather than **-ene**.
- Alkynes with **one triple covalent bond** form a homologous series with the general formula  $C_nH_{2n-2}$ .



2-Butyne

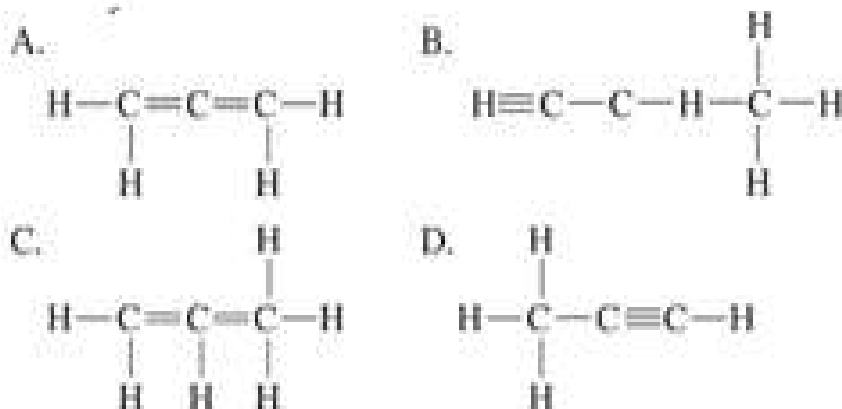


1-Butyne

## Check

- What is the name of the alkyne with the formula  $C_2H_2$ ?
  - ethane
  - ethene
  - ethyne**
  - ethylene

## Check



Which of the figures above is the structural formula for **propyne**?

- A  
B  
C  
**D**

## Check

- What is the name of this hydrocarbon?



**2,5-dimethyl-3-hexyne**

|    |                                                                                                                |
|----|----------------------------------------------------------------------------------------------------------------|
| 15 | CHM.5.6.01.011.01 Compare and contrast structural and geometric isomers                                        |
| 16 | CHM.5.6.01.011.02 Describe the difference between cis- and trans- isomers in terms of geometrical arrangements |

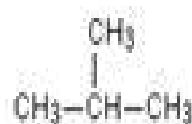
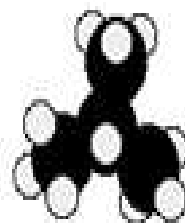
## • **Hydrocarbon Isomers:** Introduction

- Some hydrocarbons have the same molecular formula but have different molecular structures.

Have you ever met a **pair of identical twins**?

Identical twins have the same genetic makeup, yet they are two separate individuals with different personalities.

**Isomers** are similar to twins—they have the same molecular formula, but different molecular structures and properties.



## Structural Isomers

**Isomers** are two or more compounds that have the same molecular formula but different molecular structures.

There are two main classes of isomers:

- **structural isomers**
- **Stereoisomers**
  - **Geometric Isomers**
  - **Optical Isomers**

1. What is the name of two or more compounds with the same molecular formulas but different molecular structures?

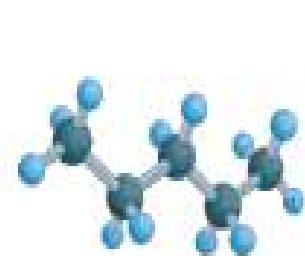
 telomeres

 chiral molecules

 isomers **CORRECT**

 Compounds with the same molecular formulas never have different molecular structures.

- **Structural isomers** have the same chemical formula, but their atoms are bonded in different arrangements.
- Structural isomers have different chemical and physical properties.
- The structure of a substance determines its properties.



Pentane  
bp = 36°C



2-Methylbutane  
bp = 28°C



2,2-Dimethylpropane  
bp = 9°C

2. What is the best name for the molecules shown below?



Pentane  
bp = 36°C



2-Methylbutane  
bp = 28°C



2,2-Dimethylpropane  
bp = 9°C

1 isomers

3 stereoisomers

2 Structural isomers

4 geometric isomers

# Check

- Which of the following compounds cannot have different structural isomers?



## Pentane

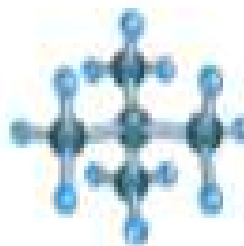
Figure 17 These compounds with the same molecular formula,  $C_5H_{12}$ , are structural isomers. Note how their boiling points differ.



Pentane  
bp = 36°C

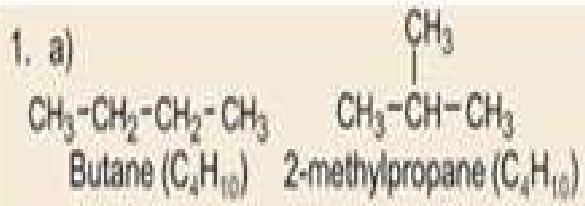


2-Methylbutane  
bp = 28°C



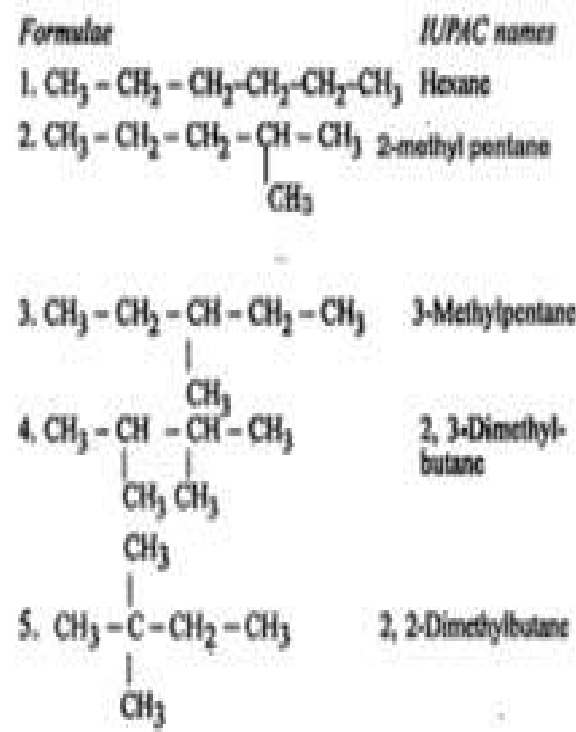
2,2-Dimethylpropane  
bp = 9°C

### Butane

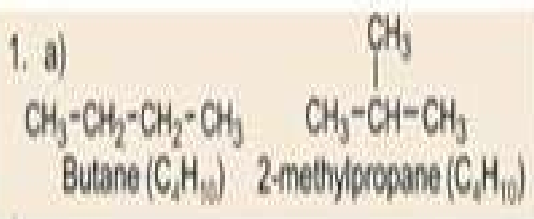


### Pentane

Figure 17 These compounds with the same molecular formula,  $\text{C}_5\text{H}_{12}$ , are structural isomers. Note how they differ from pentane.

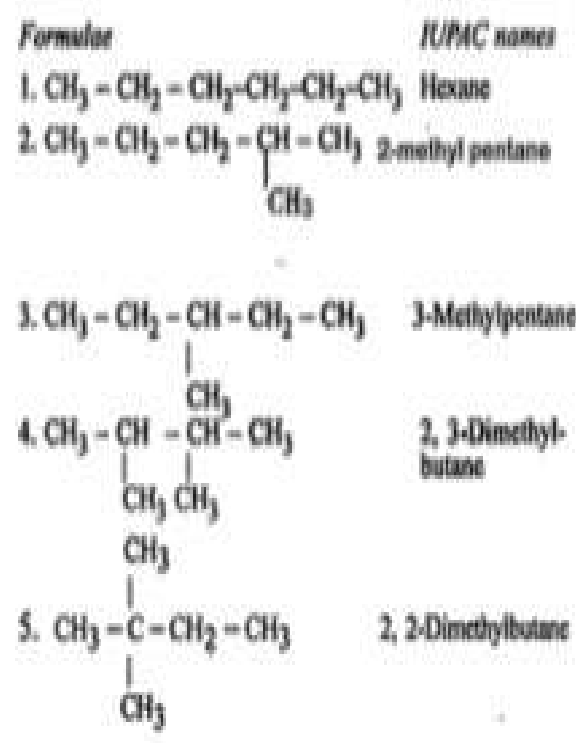


### Butane



### Pentane

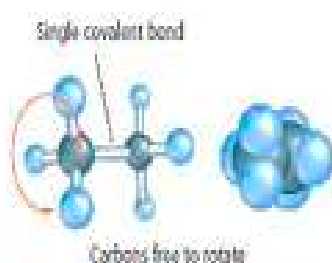
Figure 17 These compounds with the same molecular formula,  $\text{C}_5\text{H}_{12}$ , are structural isomers. Note how they differ from pentane.



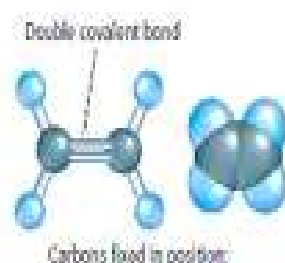
# Stereoisomers

- are isomers in which all atoms are bonded in the same order **but are arranged differently in space.**
- There are two types of stereoisomers:
  - Geometric isomers.**
  - Optical Isomers: "Chirality", mirror images (right- and left-handed form).

The **single-bonded carbons** in ethane are free to rotate around the bond.



Ethane

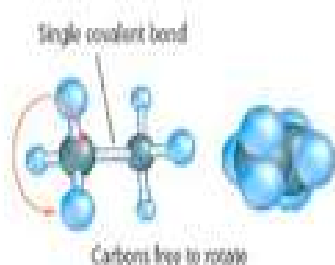


Ethene

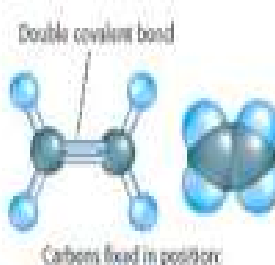
The **double-bonded carbons** in ethene resist being rotated.

# Stereoisomers

- here are two types of stereoisomers:
- One type occurs in **alkenes**, which contain **double bonds**. Two carbon atoms with a single bond between them can rotate freely in relationship to each other.
- However, when a second covalent bond (**double bond**) is **present**, the carbons can no longer rotate; they are locked in place.



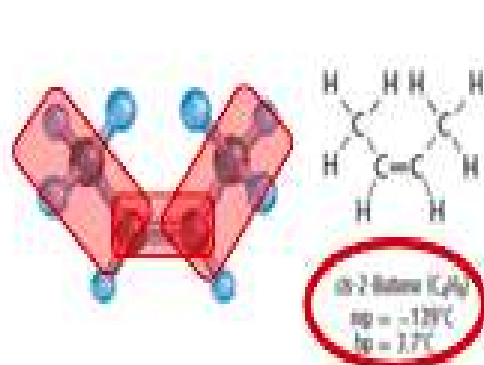
Ethane



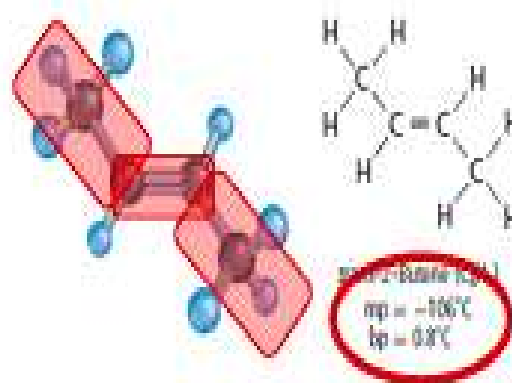
Ethene

# Geometric isomers

Isomers resulting from different arrangements of groups around a double bond are called **geometric isomers**.



*cis-*



*trans-*

3. Which term that means *across from* is used to describe and name stereoisomers?

**A** trans

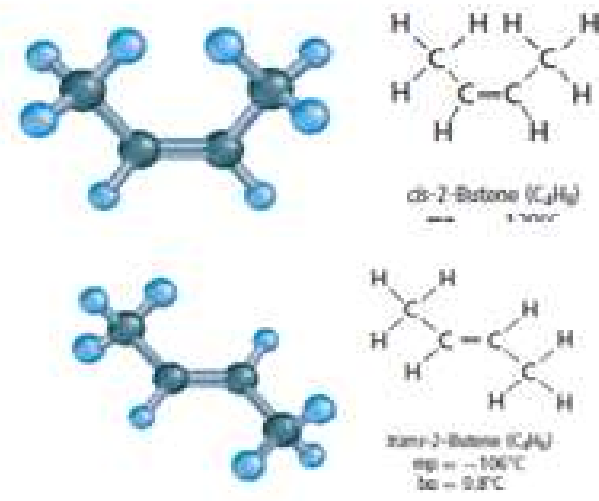
**C** levo

**B** levo

**D** cis

Isomers resulting from different arrangements of groups around a double bond are called **geometric isomers**.

- **Cis** means the branches are on the same side of the double bond
- **trans** means the branches are across from each other.



Geometric isomers have different physical and chemical properties.

Figure 18: The single-bonded carbons in ethane are free to rotate around the bond. The double-bonded carbons in ethene result being rotated.

**Explain:** How do you think this difference in ability to rotate would affect atoms or groups of atoms bonded to single-bonded and double-bonded carbon atoms?

Single covalent bond

Carbons free to rotate

**Ethane**

Double covalent bond

Carbons fixed in position; no rotation possible

**Ethene**

Double-bonded compounds only:  
 cis-trans isomerism

Figure 19: These isomers of 2-butene differ in the arrangement in space of the two methyl groups at the ends. The double-bonded carbon atoms cannot rotate with respect to each other, so the methyl groups are fixed in one of these two arrangements:

**cis-2-Butene ( $C_4H_8$ )**  
 $mp = -139^\circ C$   
 $bp = 3.7^\circ C$

**trans-2-Butene ( $C_4H_8$ )**  
 $mp = -106^\circ C$   
 $bp = 0.8^\circ C$

|    |                                                                                        |
|----|----------------------------------------------------------------------------------------|
| 17 | CHM.5.6.01.009-04 Distinguish among aliphatic and aromatic hydrocarbons                |
| 18 | CHM.5.6.01.003-26 Describe the structure of benzene and its reactivity                 |
| 19 | Identifies the health risks of exposure to aromatic compounds (carcinogenic compounds) |

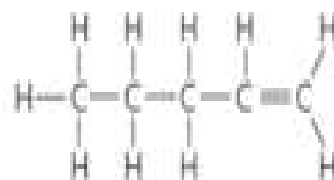
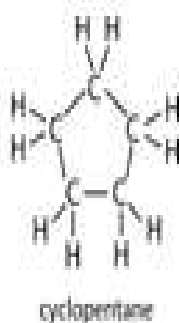
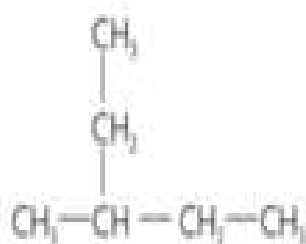
## Starter

Match each keyword with its proper structure below

Ring/cyclic

Straight-chain

Branched chain



## EXPAND YOUR THINKING

To which family of hydrocarbons do you think “ $C_6H_6$ ” belongs to?

What is its name?

Which structure does it have?

## The Structure of Benzene

- Benzene molecule  $C_6H_6$

Because the benzene molecule had so few hydrogen atoms, chemists reasoned that it must be unsaturated; that is, it must have several double or triple bonds, or a combination of both. They proposed many different structures, including this one suggested in 1860.



## The Structure of Benzene

- Benzene molecule  $C_6H_6$

Although this structure has a molecular formula of  $C_6H_6$ , such a hydrocarbon would be **unstable and extremely reactive** because of its many double bonds.

However, **benzene was fairly unreactive**, and it did not react in the ways that alkenes and alkynes usually react.

For that reason, chemists reasoned that structures such as the one shown below must be **incorrect**.



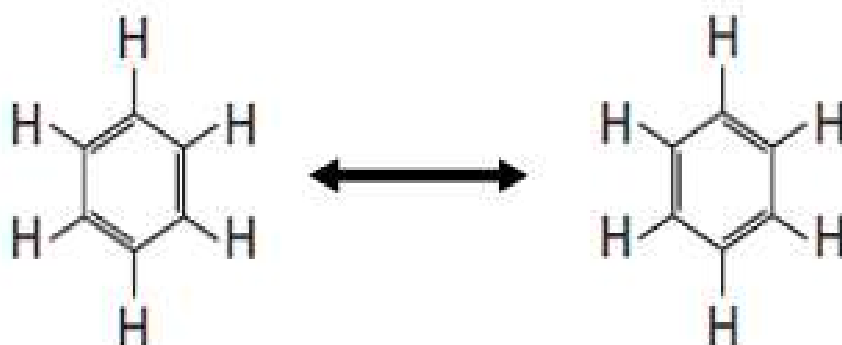
# The Structure of Benzene

- **Kekulé's dream:** Kekulé proposed a different kind of structure for benzene— a **hexagon of carbon atoms with alternating single and double bonds**.
- Kekulé claimed that benzene's structure came to him in a dream.
- The flat, hexagonal structure Kekulé proposed explained some of the properties of benzene, but it did not explain benzene's lack (افتقاد) of reactivity!!!



What can explain why Kekulé  
model of  $C_6H_6$  (Benzene) lack high  
reactivity???

## Kekulé Structure (Isomers)



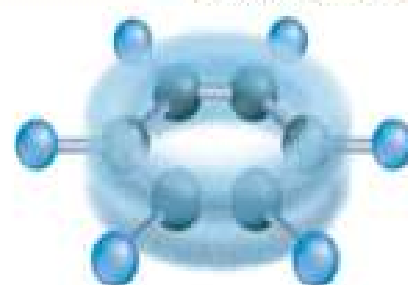
What is the difference between both structures?

**Alternating single and double bonds.**

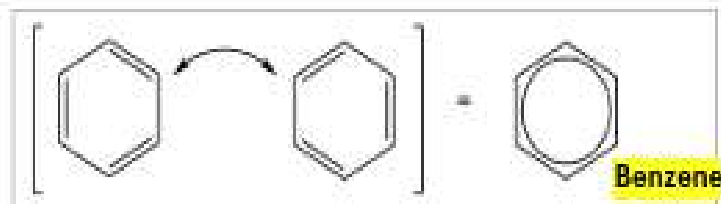
**The double bonds are changing their places.**

## The Structure of Benzene

- Linus Pauling's hybrid orbital theory **explained** benzene's lack of reactivity.
- This theory predicts that the **pairs of electrons that form the second bond of each of benzene's double bonds are shared among all six carbons' nuclei in the ring.**
- This makes benzene chemically stable **because electrons shared by six carbon nuclei are hard to pull away.**



■ **Figure 25** Benzene's bonding electrons spread evenly in a double-donut shape around the ring instead of remaining near individual atoms.



<https://edushare.moe.gov.ae/Uploads/Resources/e476687b-8a7a-4492-b19e-ef8ee41958f3/6666872112021504/index.html>

Page 5 video

## Quiz

1. What did Friedrich Kekulé's proposed structure of benzene fail to explain?

- ☐ A its reactivity
- ☒ B its lack of reactivity
- ☐ C its boiling point
- ☐ D its melting point

## Quiz

2. Which of the following best describes the structure of benzene as it is understood today?

- ☐ A It is a ring structure.
- ☐ B It is a linear structure.
- ☐ C It is a ring structure with six carbon atoms.
- ☒ D It is a ring structure in which electrons are shared by six carbon nuclei.

## Check Your Understanding

Select the correct answer.

Which of the following statements applies to benzene?

- I: contains 12 hydrogen atoms
- II: unsaturated hydrocarbon
- III: undergoes addition reactions

☐ only I and II

☐ only II and III

☐ I only

☒ II only

## Aromatic Compounds vs. Aliphatic Compounds

Aromatic  
compounds

Organic compounds  
that **contain**  
**benzene rings** as  
part of their  
structures

Aliphatic  
compounds

Hydrocarbons such  
as the alkanes,  
alkenes, and  
alkynes. **NO**  
**benzene rings**

## Aromatic Compounds

- Organic compounds that contain benzene rings are called **aromatic compounds**.
- The term aromatic was originally used because many of the benzene-related compounds known in the nineteenth century were found in pleasant-smelling oils that came from spices, fruits, and other plant parts.

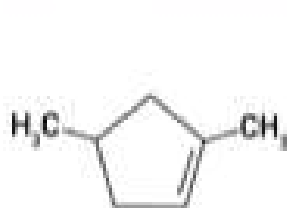
## Aromatic Compounds

- Hydrocarbons such as the alkanes, alkenes, and alkynes are called **aliphatic compounds** to distinguish them from aromatic compounds.
- The term aliphatic comes from the Greek word for *fat* because the compounds were obtained by heating animal fat.

## Check Your Understanding

Select the **CORRECT** answer.

Study the four structures below. Which of the compounds is aromatic?



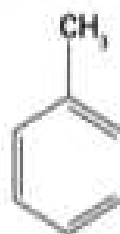
compound A



compound B



compound C



compound D

A, C, and D

☐ A, B, C, and D

C and D

☒ only D

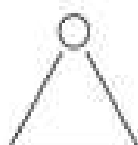
## Check Your Understanding

Select the **CORRECT** answer.

Study the four structures below. Which of the compounds is aliphatic?



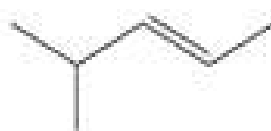
compound A



compound B



compound C



compound D

A, C, and D

☒ A, B, C, and D

C and D

☐ only D

All of the compounds are aliphatic as none consist of benzene rings.

## Carcinogens (Chemicals that cause cancer)

- Many **aromatic compounds**, particularly benzene, toluene, and xylene, were once commonly used as industrial and laboratory solvents.
- However, tests have shown that the use of such compounds should be limited because they can affect the health of people who are exposed to them regularly.



## Carcinogens

### Health risks linked to aromatic compounds include:-

- respiratory ailments.
- liver problems.
- and damage to the nervous system.



- Beyond these hazards, some aromatic compounds are **carcinogens**, which are substances that can cause cancer.

## Carcinogens: benzopyrene

- The first known carcinogen was an aromatic substance discovered around the turn of the twentieth century in chimney soot.
- Chimney sweeps in Great Britain were known to have abnormally high rates of cancer.
- Scientists discovered that the cause of the cancer was the aromatic compound benzopyrene, see next slide.

## Carcinogens: benzopyrene

■ **Figure** Benzopyrene is a cancer-causing chemical that is found in soot, cigarette smoke, and car exhaust.



20 CHM.5.6.01.013.19 Identify general formula, molecular formula, structural formula and functional group for different families of organic compounds

21 CHM.5.6.01.013.12 Write the IUPAC name of alkyl halides and aryl halides

22 CHM.5.6.01.016.01 Explain why the densities and the boiling points of alkyl halides increase in order of going down the column of halides in the periodic table, from fluorine to iodine

## Functional Groups

- In an organic molecule, a **functional group** is an atom or group of atoms that always reacts in a certain way.
- Addition of a functional group to a hydrocarbon always produces a substance with different chemical and physical properties.

- Double and triple bonds between carbon atoms are considered functional groups.



Select the correct answer.

What is the name given to an atom or group of atoms that gives an organic molecule its chemical properties?

- ☐ variable side chain
- ☐ functional group
- ☐ alkyl group
- ☐ cycloalkyl substituent

$C_nH_{2n-1}$   
 $CH_3$  methyl  
 $CH_2CH_3$  ethyl  
 propyl  $CH_3CH_2CH_2$

cycloalkyl as a branch  
 cycloalkane  $\Delta$ , but if it is a branch  
 it is cycloalkyl  
 $\Delta$  cyclopropane  
 $\Delta$  cyclopropyl

M 20  
 Compound  
 Types  
 Alkane C-C  
 Alkene C=C  
 Alkyne C $\equiv$ C

Table 1 Organic Compounds and Their Functional Groups

| Compound Type   | General Formula                                    | Functional Group                                                                     |
|-----------------|----------------------------------------------------|--------------------------------------------------------------------------------------|
| Halocarbon      | $R-X$ (X = F, Cl, Br, I)                           | Halogen $-X$                                                                         |
| Alcohol         | $R-OH$                                             | Hydroxyl $-OH$                                                                       |
| Ether           | $R-O-R'$                                           | Ether $-O-$                                                                          |
| Amine           | $R-NH_2$                                           | Amino $-NH_2$ or $-NH$ or $-N$                                                       |
| Aldehyde        | $\begin{array}{c} O \\    \\ R-C-H \end{array}$    | Carbonyl $\begin{array}{c} O \\    \\ -C- \end{array}$ CO                            |
| Ketone          | $\begin{array}{c} O \\    \\ R-C-R' \end{array}$   | Carbonyl $\begin{array}{c} O \\    \\ -C- \end{array}$ CO                            |
| Carboxylic acid | $\begin{array}{c} O \\    \\ R-C-OH \end{array}$   | Carboxyl $\begin{array}{c} O \\    \\ -C-OH \end{array}$ Hydroxyl + Carbonyl<br>COOH |
| Ester           | $\begin{array}{c} O \\    \\ R-C-O-R' \end{array}$ | Ester $\begin{array}{c} O \\    \\ -C-O- \end{array}$ COO                            |
| Amide           | $\begin{array}{c} O \\    \\ R-C-NH_2 \end{array}$ | Amide $\begin{array}{c} O \\    \\ -C-N- \end{array}$ CON                            |

- The symbols R and R' in the general formulas represent carbon chains or rings bonded to the functional group.



- An asterisk (\*) represents a hydrogen atom, carbon chain, or carbon ring.

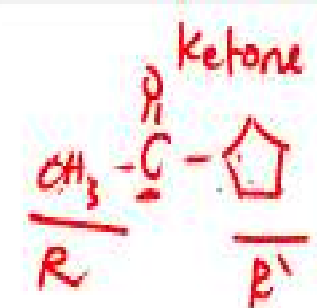
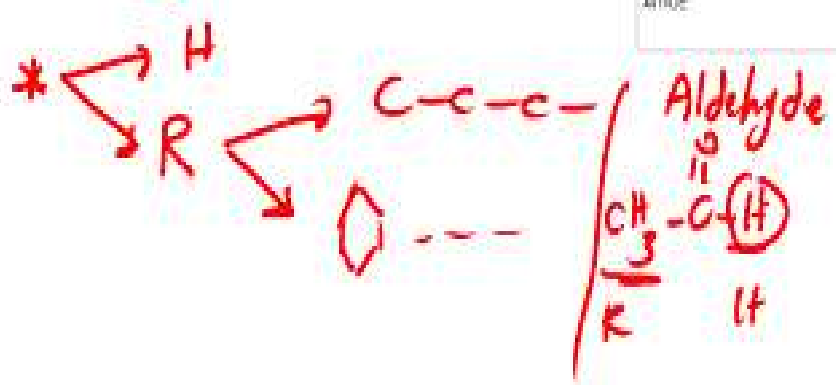


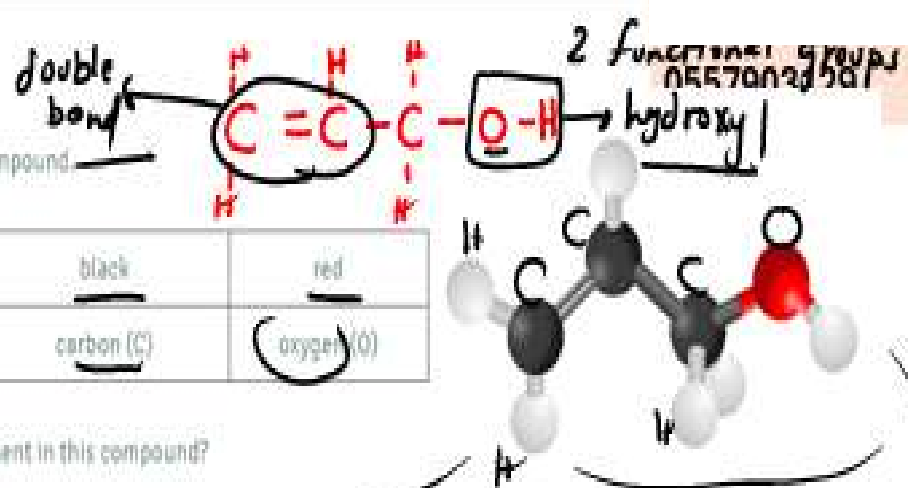
Table 1 Organic Compounds and Their Functional Groups

| Compound Type   | General Formula                  | Functional Group |
|-----------------|----------------------------------|------------------|
| Halocarbon      | $R-X$ (X = F, Cl, Br, I)         | Halogen          |
| Alcohol         | $R-OH$                           | Hydroxyl         |
| Ether           | $R-O-R'$                         | Ether            |
| Amine           | $R-NH_2$                         | Amino            |
| Aldehyde        | $R-\overset{O}{\parallel}C-H$    | Carbonyl         |
| Ketone          | $R-\overset{O}{\parallel}C-R'$   | Carbonyl         |
| Carboxylic acid | $R-\overset{O}{\parallel}C-OH$   | Carboxyl         |
| Ester           | $R-\overset{O}{\parallel}C-O-R'$ | Ester            |
| Amide           | $R-\overset{O}{\parallel}C-NH_2$ | Amide            |

Select the correct answer.

Study the ball-and-stick model of an organic compound.

|           |              |            |            |
|-----------|--------------|------------|------------|
| Color Key | white        | black      | red        |
| Element   | hydrogen (H) | carbon (C) | oxygen (O) |



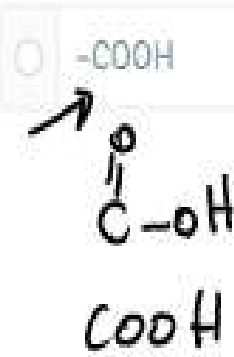
Which option represents a functional group present in this compound?

- ☐ ether group  $\begin{matrix} R-O-R \\ | \\ C-O-C \end{matrix}$
- ☒ C=C double bond
- ☐ carbonyl group  $\begin{matrix} O \\ || \\ C \end{matrix}$
- ☐ ester group  $\begin{matrix} O \\ || \\ C-O \end{matrix}$

Select the correct answer.

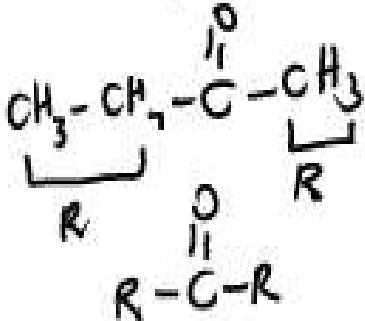
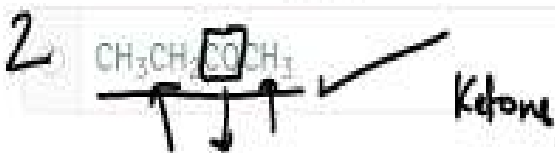
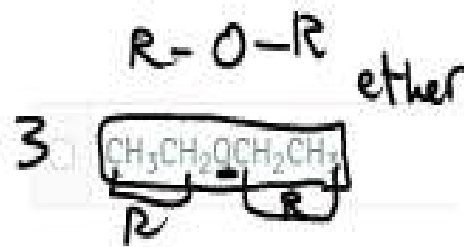
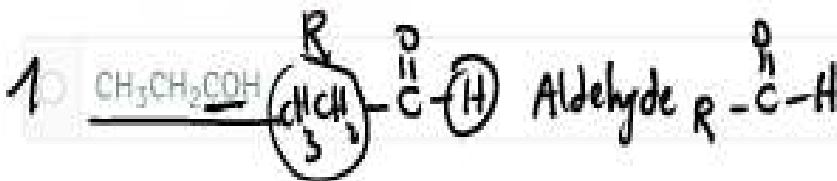
Ethyl ethanoate is an ester used in glues. Which functional group is present in ethyl ethanoate?

ester



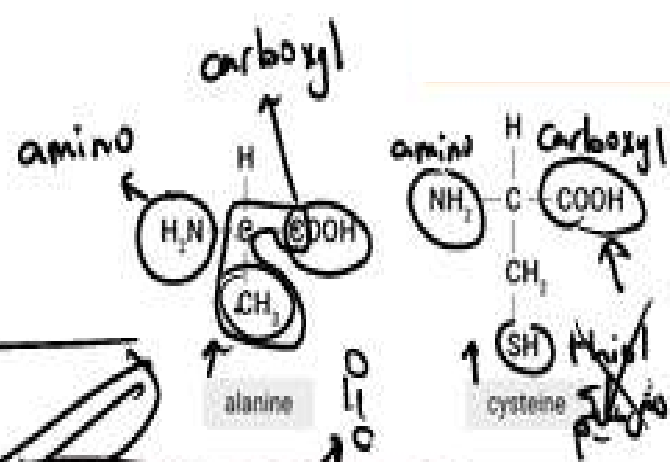
Select the correct answer.

Which compound is a ketone?



Select the correct answer.  
 Study the structures of alanine and cysteine.

Which statement does NOT apply to these compounds?



- ☐ Cysteine contains an amino functional group. ✓
  - ☒ Cysteine contains a carbonyl functional group. ✓
  - ☐ Alanine contains a methyl group. ✓
  - ☐ Alanine contains a carboxyl functional group. ✓
- Handwritten notes below the options:
- Next to the methyl group option: CH3
  - Next to the carboxyl group option: only carboxyl with a structure O=C(OH)

**Halogens (X)**

$R-X$  17

**Halo Carbons**

|      |          |
|------|----------|
| 9    | 19.0     |
| ✓ F  | Fluorine |
| 17   | 35.5     |
| ✓ Cl | Chlorine |
| 35   | 79.9     |
| ✓ Br | Bromine  |
| 53   | 126.9    |
| ✓ I  | Iodine   |

## Halocarbons

Any organic compound that contains a **halogen substituent (X)** is called a **halocarbon**.

The first four halogens—

X

|    |          |
|----|----------|
| 9  | 18.998   |
| F  | Fluorine |
| 17 | 35.45    |
| Cl | Chlorine |
| 35 | 79.90    |
| Br | Bromine  |
| 53 | 126.9    |
| I  | Iodine   |

### Halocarbons

Aliphatic

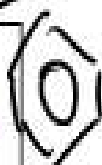
No benzene

**Alkyl Halides**

Aromatic

benzene

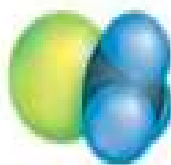
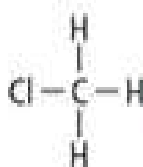
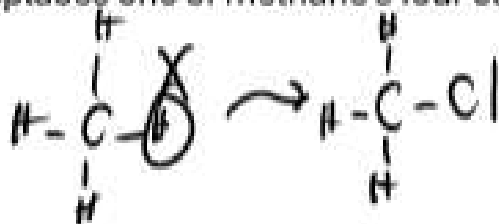
**Aryl Halides**



## Alkyl Halides and Aryl Halides

- An **alkyl halide** is an organic compound containing a halogen atom covalently bonded to an **aliphatic carbon atom**.

- For example, **chloromethane** is the alkyl halide formed when a chlorine atom replaces one of methane's four carbon atoms.



Chloromethane

**Chloromethane** is an alkyl halide that is used in the manufacturing process for **silicone products**, such as window and door sealants.

# Alkyl Halides and Aryl Halides

- An **aryl halide** is an organic compound containing a **halogen atom** bonded to a **benzene ring** or other aromatic group.



- The structural formula for an aryl halide is created by first drawing the aromatic structure and then replacing its hydrogen atoms with the halogen atoms specified.



## Quiz

An alkyl halide has a halogen bonded to a(n) \_\_\_\_\_.

- ☒ A aliphatic carbon atom
- ☐ B aromatic group
- ☐ C halogen
- ☐ D salt

## Quiz

2. What term refers to an organic compound with a halogen bonded to an aromatic group?

A halocarbon

B alkyl halide

C aryl halide

D plastic

Aryl

benzene

## Naming of Halo carbons

we follow the same rules of module 20, Halogens  
 we treat them as branches like  $\text{CH}_3$  (methyl)  
 $\text{CH}_2\text{CH}_3$  (ethyl)

F: fluorine  $\Rightarrow$  Fluoro-

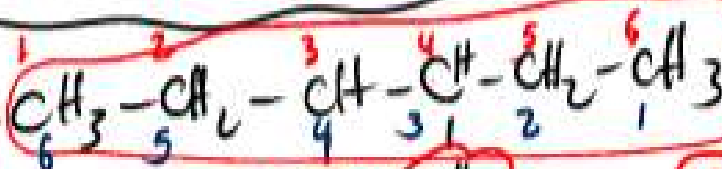
Cl: Chlorine  $\Rightarrow$  Chloro-

I: Iodine  $\Rightarrow$  Iodo-

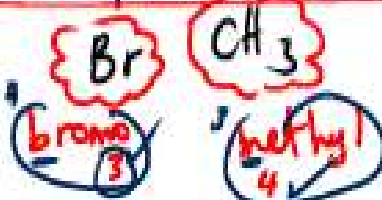
Br: Bromine  $\Rightarrow$  Bromo-



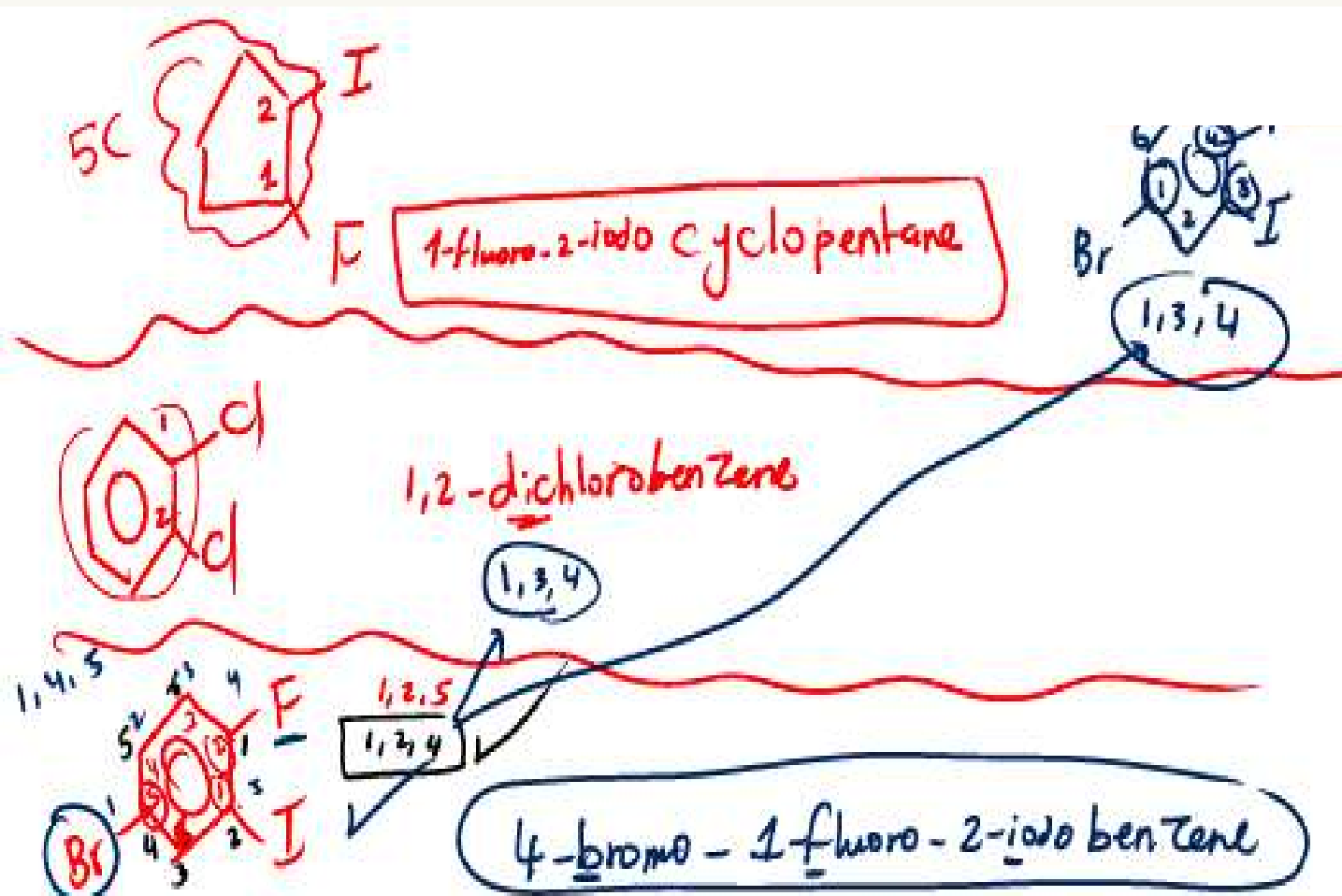
Example



name this compound



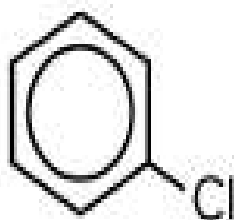
3-bromo-4-methylhexane



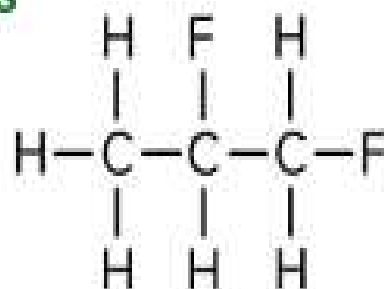
## Naming halocarbons

- a **prefix** indicates which **halogen is present**. The prefixes are formed by changing the *-ine* at the end of each halogen name to *-o*. Thus, the prefix for **fluorine is fluoro-**, chlorine is *chloro-*, **bromine is bromo-**, and **iodine is iodo-**.
- If more than one kind of halogen atom is present in the same molecule, the atoms are listed **alphabetically in the name**.
- The chain also must be numbered in a way that gives **the lowest position number** to the substituent that comes **first in the alphabet**.
- Similarly, the **benzene ring** in an aryl halide **is numbered to give each substituent the lowest position number possible**.

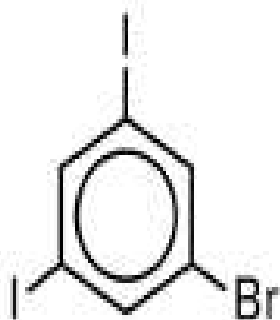
## Organic Compounds Containing Halogens



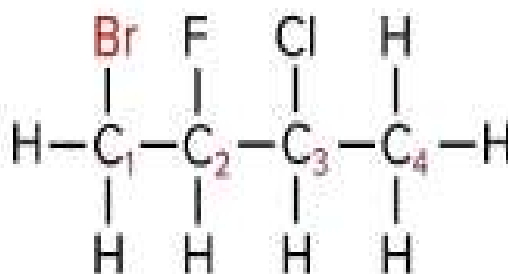
Chlorobenzene



1,2-Difluoropropane



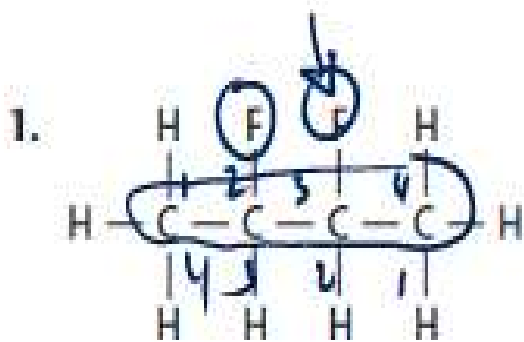
1-Bromo-3,5-diiodobenzene



1-Bromo-3-chloro-2-fluorobutane

## Activity

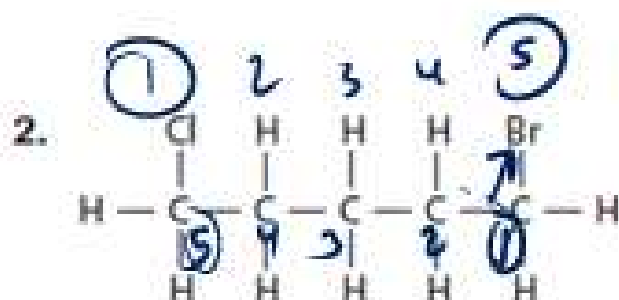
Name the alkyl or aryl halide whose structure is shown.



2,3-difluorobutane

## Activity

Name the alkyl or aryl halide whose structure is shown.

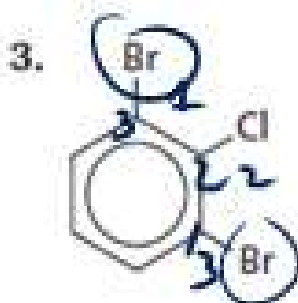


**1-bromo-5-chloropentane**



## Activity

Name the alkyl or aryl halide whose structure is shown.



**1,3-dibromo-2-chlorobenzene**

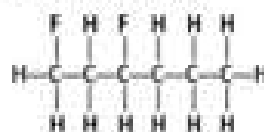
4. **Compare and contrast** alkyl halides and aryl halides.
5. **Draw** structures for the following molecules.
  - a. 2-chlorobutane
  - b. 1,3-difluorohexane
  - c. 1,1,1-trichloroethane
  - d. 1-bromo-4-chlorobenzene

7. **Evaluate** How would you expect the boiling points of propane and 1-chloropropane to compare? Explain your answer.

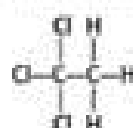
4. **Compare and contrast** alkyl halides and aryl halides.

An alkyl halide is a substituted hydrocarbon that is covalently bonded to an aliphatic carbon atom.  
 An aryl halide is a substituted hydrocarbon that contains a halogen bonded to a benzene ring or other aromatic compound.

b. 1,3-difluorohexane



c. 1,1,1-trichloroethane



d. 1-chloro-4-bromobenzene



5. **Draw** structures for the following molecules.

a. 2-chlorobutane



7. **Evaluate** How would you expect the boiling points of propane and 1-chloropropane to compare? Explain your answer.

The boiling point of 1-chloropropane should be higher than that of propane. The molecules in 1-chloropropane should form more temporary dipoles than the molecules in propane.

## Organic Compounds Containing Halogens

Table 2 A Comparison of Alkyl Halides and Their Parent Alkanes

| Structure                                                          | Name            | Boiling Point (°C) | Density (g/mL) in Liquid State  |
|--------------------------------------------------------------------|-----------------|--------------------|---------------------------------|
| $\text{CH}_4$                                                      | methane         | -162               | 0.423 at -162°C (boiling point) |
| $\text{CH}_3\text{Cl}$                                             | chloromethane   | -24                | 0.911 at 25°C (under pressure)  |
| $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$          | pentane         | 36                 | 0.626                           |
| $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{F}$  | 1-fluoropentane | 62.8               | 0.791                           |
| $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}$ | 1-chloropentane | 108                | 0.882                           |
| $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$ | 1-bromopentane  | 130                | 1.218                           |
| $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{I}$  | 1-iodopentane   | 155                | 1.516                           |

17

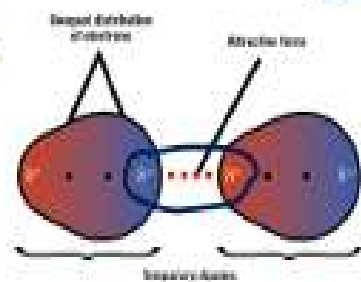
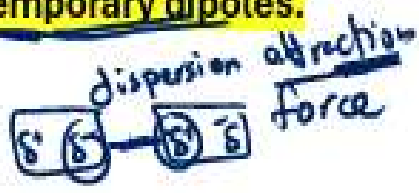
|    |          |
|----|----------|
| 9  | 19.0     |
| F  | Fluorine |
| 17 | 35.3     |
| Cl | Chlorine |
| 35 | 79.9     |
| Br | Bromine  |
| 53 | 126.9    |
| I  | Iodine   |

## Organic Compounds Containing Halogen... Halocarbons

- The trend of increasing the boiling points and densities as the halogen changes from fluorine to chlorine, bromine, and iodine was observed in the table. **WHY??**

☐ **because** the halogens from **fluorine to iodine** have increasing numbers of **electrons** that lie farther from the halogen nucleus.

- These **electrons** shift position easily and, as a result, the halogen-substituted hydrocarbons have an increasing tendency to form **temporary dipoles**.



17

|    |          |
|----|----------|
| 9  | 19.0     |
| F  | Fluorine |
| 17 | 35.3     |
| Cl | Chlorine |
| 35 | 79.9     |
| Br | Bromine  |
| 53 | 126.9    |
| I  | Iodine   |

## Organic Compounds Containing Halogen

### Halocarbons

17

|    |          |
|----|----------|
| 9  | 19.0     |
| F  | Fluorine |
| 17 | 35.5     |
| Cl | Chlorine |
| 35 | 79.9     |
| Br | Bromine  |
| 53 | 126.9    |
| I  | Iodine   |

- Because the **dipoles attract each other**, the energy needed to separate the molecules also increases.
- Thus, the boiling points of halogen-substituted alkanes increase as the size of the halogen atom increases. *as the number of electrons increases*

Select the correct .

Which alkyl halide has the highest boiling point?

1 an alkyl halide with a fluorine atom

2 an alkyl halide with an iodine atom ✓

3 an alkyl halide with a chlorine atom

4 an alkyl halide with a bromine atom

|    |          |
|----|----------|
| 9  | 19.0     |
| F  | Fluorine |
| 17 | 35.5     |
| Cl | Chlorine |
| 35 | 79.9     |
| Br | Bromine  |
| 53 | 126.9    |
| I  | Iodine   |

|    |                                                                                                                                                                                                          |
|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 23 | CHM.5.6.02.005.04 Define substitution reaction while writing the equation for the substitution reaction including halogenation of alkanes, alkyl halide-alcohol reaction and alkyl halide-amine reaction |
| 24 | CHM.5.6.01.013.14 Use the IUPAC system to name alcohols                                                                                                                                                  |
| 25 | CHM.5.6.01.013.17 Use the IUPAC system to name ethers                                                                                                                                                    |
| 26 | CHM.5.6.01.016.03 Compare and contrast properties of ether and alcohol of similar size and mass (volatility, boiling point, solubility in water)                                                         |
| 27 | CHM.5.6.01.015.03 Define an amine while classifying it into primary, secondary and tertiary amine                                                                                                        |

## Alcohols

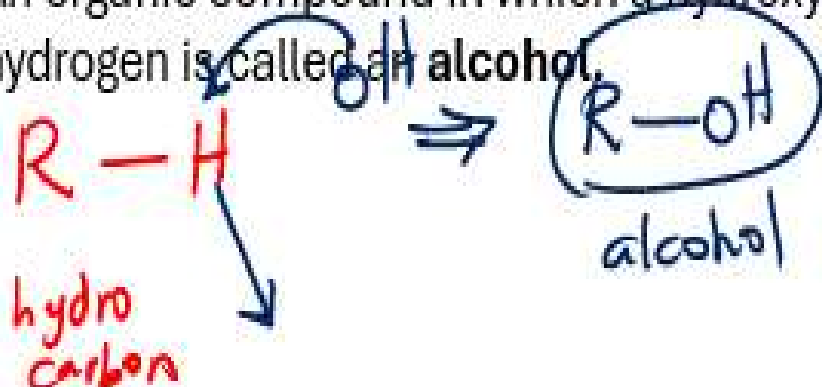
- Oxygen commonly forms two covalent bonds to form a stable octet.



- An oxygen-hydrogen group covalently bonded to a carbon atom is called a **hydroxyl group**.



- An organic compound in which a hydroxyl group replaces a hydrogen is called an **alcohol**.



## Alcohols

### Table 3 Alcohols

| General Formula                                                                                                          | Simple Alcohol and Simple Hydrocarbon                                                      |
|--------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| $R-OH$<br><u>ROH</u><br>$\underline{R}-O-H$<br><u>R represents carbon chains or rings bonded to the functional group</u> | <br><u>Methane</u> ( $CH_4$ ) <u>Methanol</u> ( $CH_3OH$ )<br><b>Alkane</b> <b>Alcohol</b> |

## Alcohols

- Like water molecules, the hydroxyl groups of alcohol molecules are moderately polar and form hydrogen bonds.
  - As a result, alcohols are miscible with water and are good solvents for other polar substances.
  - Alcohols have relatively high boiling points.
- Handwritten notes and diagrams:
- Alcohols:  $-O-H$  or  $-OH$
  - Diagram of a water molecule ( $H_2O$ ) showing hydrogen bonds between the  $\delta^-$  oxygen of one molecule and the  $\delta^+$  hydrogen of another. The  $O-H$  bond is labeled "Hydrogen bond" and "O-H".
  - Diagram of ethanol ( $CH_3CH_2OH$ ) showing the polar hydroxyl group with  $\delta^-$  on oxygen and  $\delta^+$  on hydrogen. A note says "because of the hydrogen bonds".
  - Diagram of two ethanol molecules showing hydrogen bonding between their hydroxyl groups, labeled "Hydrogen bonding".
  - Ball-and-stick models of ethanol and water are shown at the bottom.

## Naming Alcohols

super easy

- Alcohol names are based on the alkane names, with the ending -ol. There can be one or more hydroxyl groups; positions are specified with numbers.

$CH_3CH_2CH_2$  branch -ol

- Methanol, or wood alcohol, is the simplest alcohol.

$CH_3CH_3$   
ethane

$CH_3CH_2OH$   
ethanol

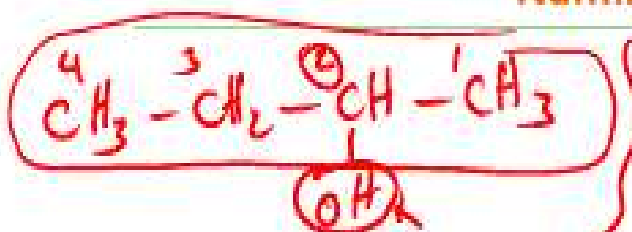
- Ethanol is the kind of alcohol found in alcoholic drinks.

- Denatured alcohol** is ethanol with small amounts of noxious materials added to it.

ethanol + other substances

## Naming Alcohols

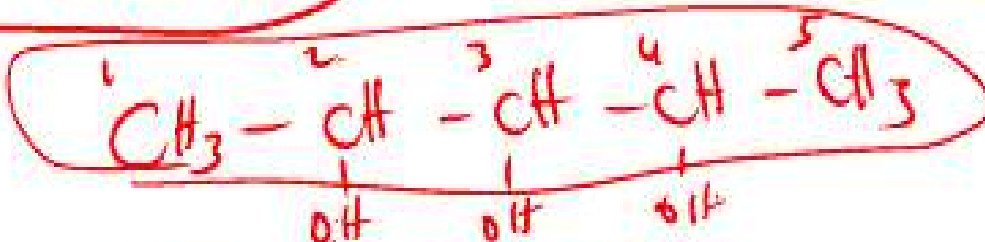
2 twi



same  
2-butanol  
butan-2-ol



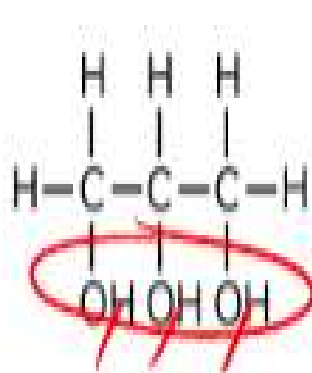
tri  
tetra  
don't remove  
e



2,3,4-pentanetriol

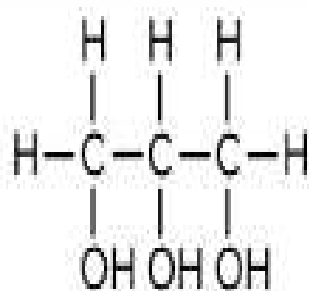
## Naming Alcohols

- A carbon chain can also have more than one hydroxyl group. To name these compounds, prefixes such as **di-**, **tri-**, and **tetra-** are used before the **-ol** to indicate the number of hydroxyl groups present.

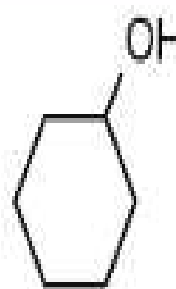


1,2,3 - propanetriol

## Naming Alcohols



1,2,3-Propanetriol (glycerol)



Cyclohexanol

## Practice

Draw the structure for each molecule.

A. 1-propanol

B. 1,3-cyclopentanediol

## Practice

Draw the structure for each molecule.

A. <sup>3C</sup> 1-propanol Alcohol (OH)



B. 1,3-cyclopentanediol



## Check

1. An alcohol is an organic compound in which a(n) \_\_\_\_\_ replaces a hydrogen atom of a hydrocarbon.

- ☒ A halogen
- ☒ B hydroxyl group
- ☒ C amino group
- ☒ D oxygen atom

## Check

1. An alcohol is an organic compound in which a(n) \_\_\_\_\_ replaces a hydrogen atom of a hydrocarbon.

☒ halogen

CORRECT

☒ B hydroxyl group - OH

☒ amino group

☒ oxygen atom

Select the correct answer.

Which of the following line structures represents an alcohol molecule?



compound A

compound B

compound C

compound D

☐ compound D

☐ compound A

☐ compound B

☐ compound C

Select the correct answer.

Which of the following line structures represents an alcohol molecule?



compound A

compound B

compound C

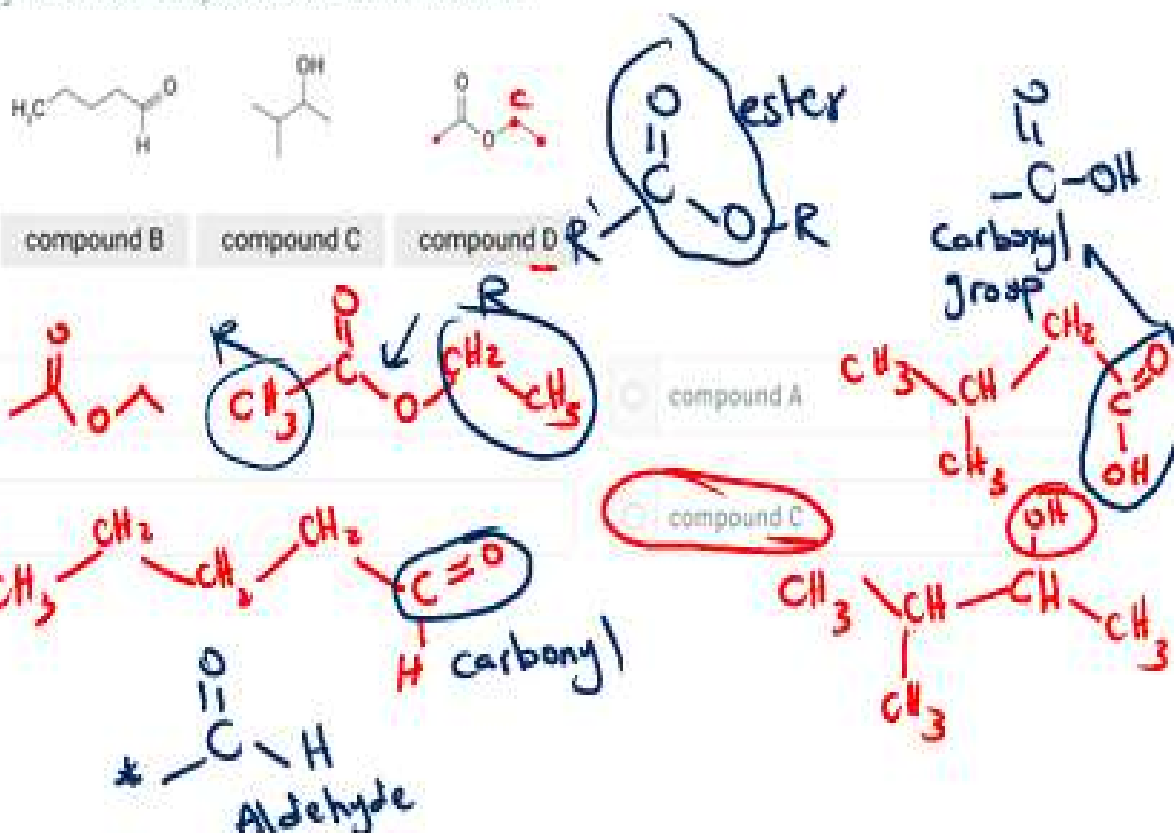
compound D

☐ compound D

☐ compound A

☐ compound B

☒ compound C



[Go Back](#) [Refresh](#)

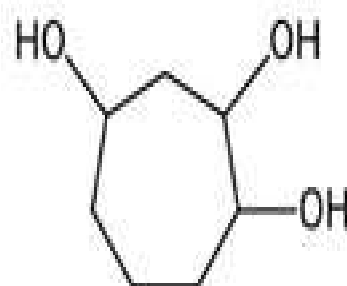
Select the correct answers from the drop-down menus.

Study the line structure of a cyclic alcohol.

The lowest position numbers for the hydroxyl groups are:

The prefix that indicates the number of hydroxyl groups is:

The IUPAC name of this compound is:



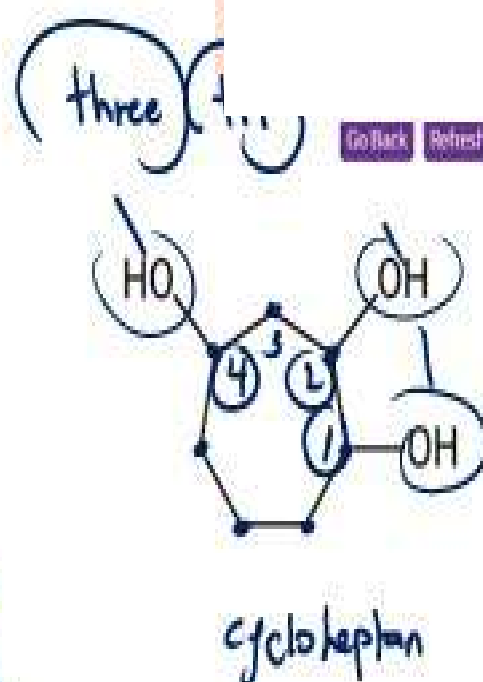
Select the correct answers from the drop-down menus.

Study the line structure of a cyclic alcohol.

The lowest position numbers for the hydroxyl groups are:

The prefix that indicates the number of hydroxyl groups is:

The IUPAC name of this compound is:



[Go Back](#) [Refresh](#)

Select the correct answer.

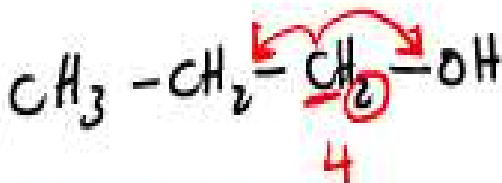
Which condensed structural formula represents an alcohol molecule?

☐  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$

☐  $\text{CH}_3\text{CH}_2\text{COOH}$

☐  $\text{CH}_3\text{COOCH}_3$

☐  $\text{CH}_3\text{CH}_2\text{COH}$



Select the correct answer.

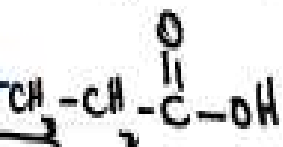
Which condensed structural formula represents an alcohol molecule?

☒  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$

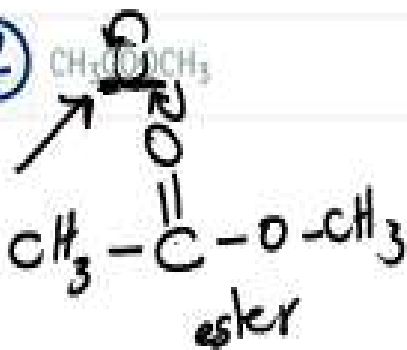
alcohol

☐  $\text{CH}_3\text{CH}(\text{COOH})$

carboxylic acid

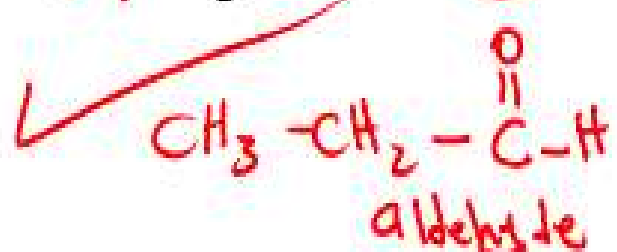
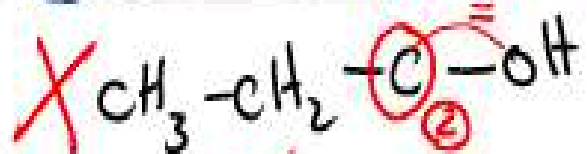


☐  $\text{CH}_3\text{COOCH}_3$



☐  $\text{CH}_3\text{CH}_2\text{COH}$

Needs 4 bonds



Select the correct answer to complete the sentence.

Alcohols are polar compounds. They interact with other molecules through hydrogen bonding except with \_\_\_\_\_

☐ polar molecules

☐ water molecules

☐ alcohol molecules

☐ non-polar molecules

Select the correct answer to complete the sentence.

Alcohols are polar compounds. They interact with other molecules through hydrogen bonding except with \_\_\_\_\_

① polar molecules ✓

③ water molecules ✓

② ✓ alcohol molecules

④ non-polar molecules

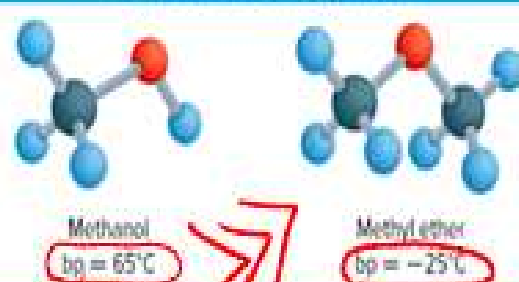
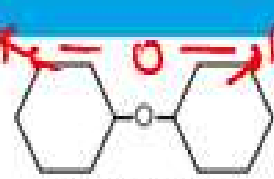
polar dissolves polar

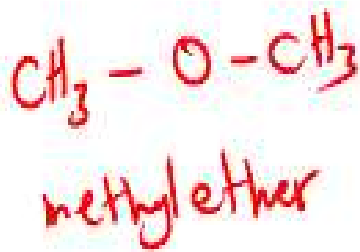
non-polar dissolves non-polar

## Ethers

An **ether** is an organic compound containing an oxygen bonded to two carbon atoms.

Table 4 Ethers

| General Formula                                                                                                                                                                                                    | Methanol and Methyl ether                                                                                                             |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| $R-O-R$ <u>ROR</u><br>where <u>R</u> and <u>R'</u> represent carbon chains or rings bonded to functional groups                                                                                                    | <br>Methanol bp = 65°C      Methyl ether bp = -25°C |
| Examples of Ethers                                                                                                                                                                                                 |                                                                                                                                       |
| <br>Cyclohexyl ether<br><br>Butyl ethyl ether | $R-O-R'$<br>$CH_3CH_2CH_2-O-CH_2CH_2CH_2CH_3$<br>Propyl ether<br>$CH_3CH_2-O-CH_3$<br>Ethyl methyl ether                              |

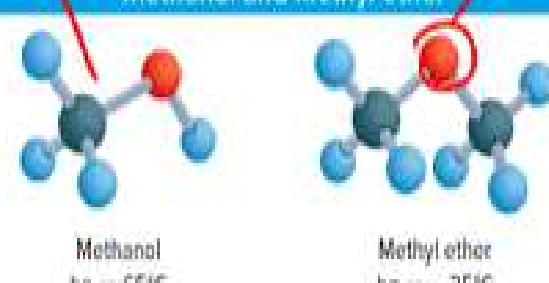


## Ethers



- Ethers have no hydrogen atoms bonded to their oxygen atoms, so they cannot form hydrogen bonds with each other. *the result??*
- Because of that, Ethers are volatile and have low boiling points compared to alcohols.

Table 4 Ethers

| General Formula                                                                      | Methanol and Methyl ether                                                                                                               |
|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| $ROR$<br>where R and R' represent carbon chains or rings bonded to functional groups | <br>Methanol bp = 65°C      Methyl ether bp = -25°C |

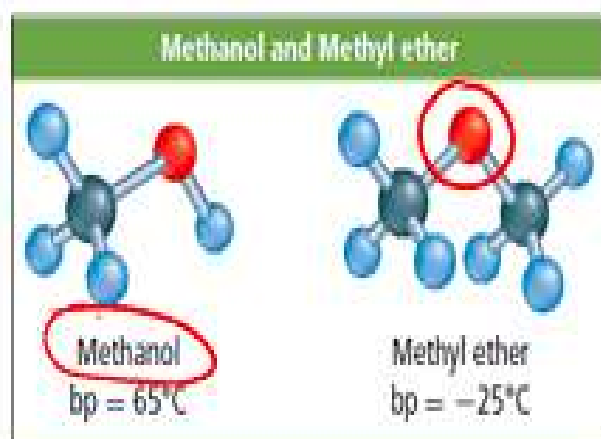
O-H hydrogen bond

O only

No hydrogen bond

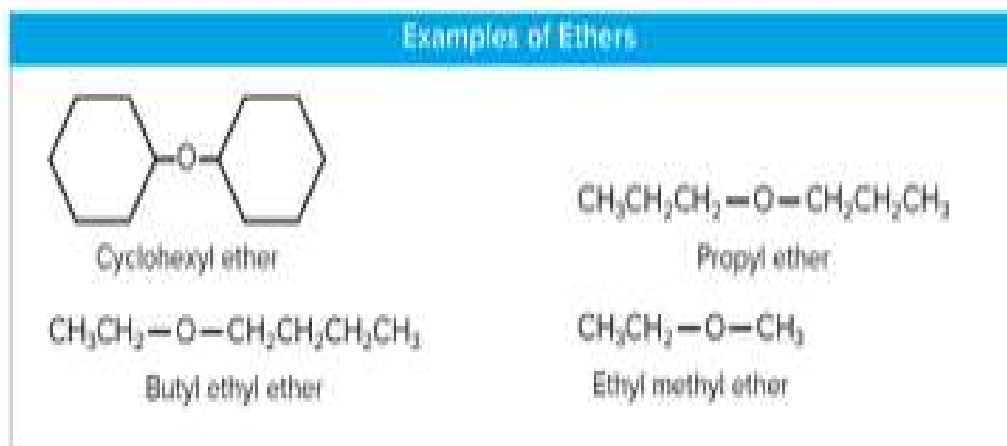
## Methanol and Methyl ether

- Because ethers have no hydrogen atoms bonded to the oxygen atom, their molecules **cannot form hydrogen bonds with each other**.
- Therefore, ethers are generally more volatile and have much lower boiling points than alcohols of similar size and mass.
- Ethers are much less soluble in water than alcohols because they have no hydrogen to donate to a hydrogen bond.
- However, the oxygen atom can act as a receptor for the hydrogen atoms of water molecules.



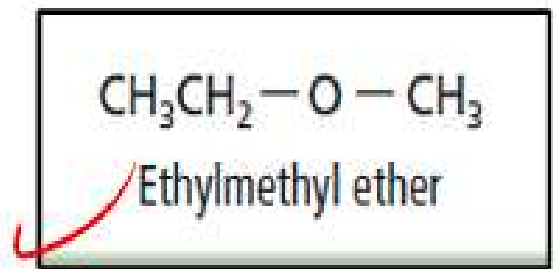
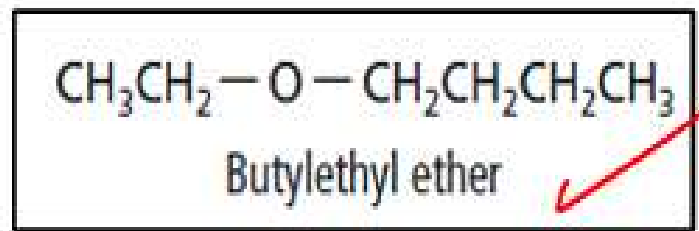
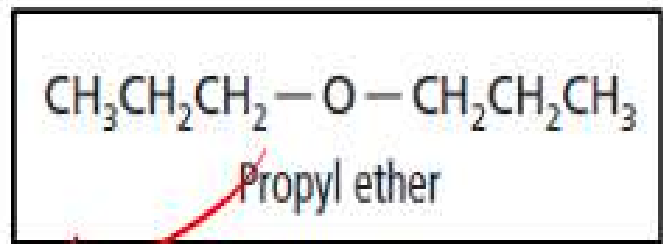
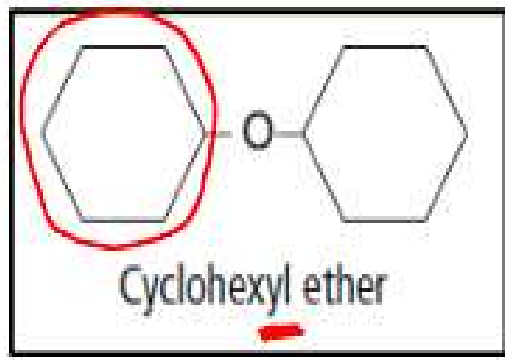
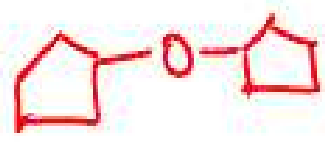
## Ethers

- Ethers with identical chains are named by the chain followed by the word *ether*.
- Ethers with different chains are named in alphabetical order followed by *ether*.



# Examples of Ethers

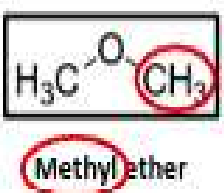
alkyl  
 cyclopropyl ether



## Naming Ethers

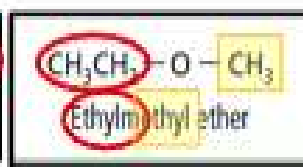
Symmetrical  
identical alkyl chains

- first name the alkyl group
- then add the word *ether*



Asymmetrical  
different alkyl chains

- the groups are listed in alphabetical order
- then followed by the word *ether*



## Quiz

2. The formula at right is for what kind of compound?



- ☐ A alcohol
- ☐ B ether
- ☐ C amine
- ☐ D alkyl halide

## Quiz

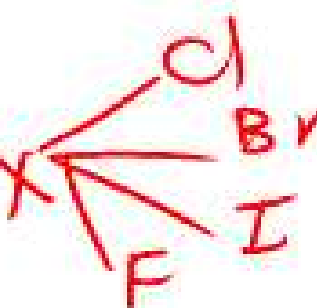
2. The formula at right is for what kind of compound?



☒ A alcohol  $\text{CH}_3-\text{OH}$

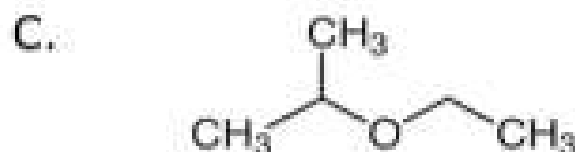
☐ B ether **CORRECT**

☒ C amine  $\text{R}-\text{NH}_2$

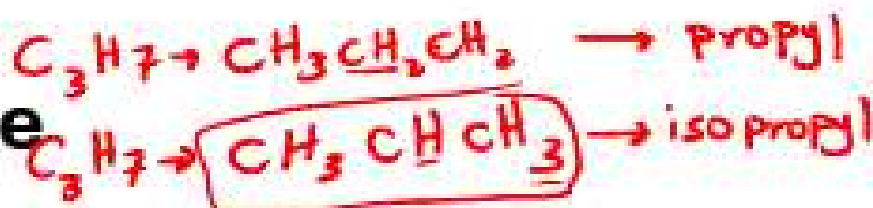
☒ D alkyl halide  $\rightarrow \text{R}-\text{X}$  

## Practice

- Name the ether represented by each structure.



## Practice



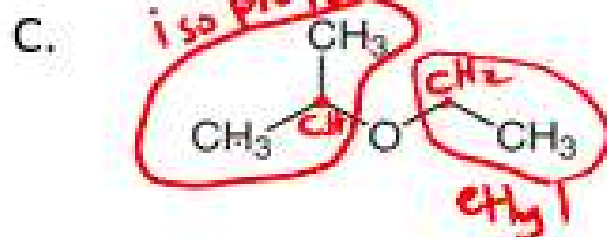
- Name the ether represented by each structure.



**Butylethyl ether**



**Cyclohexyl ether**



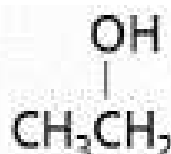
**Ethylisopropyl ether**

## Practice

- Based on the molecular structures below, which compound would you expect to be more soluble in water? Explain your reasoning.



Methyl Ether



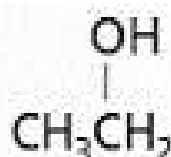
Ethanol

## Practice

- Based on the molecular structures below, which compound would you expect to be more soluble in water? Explain your reasoning.



Methyl Ether

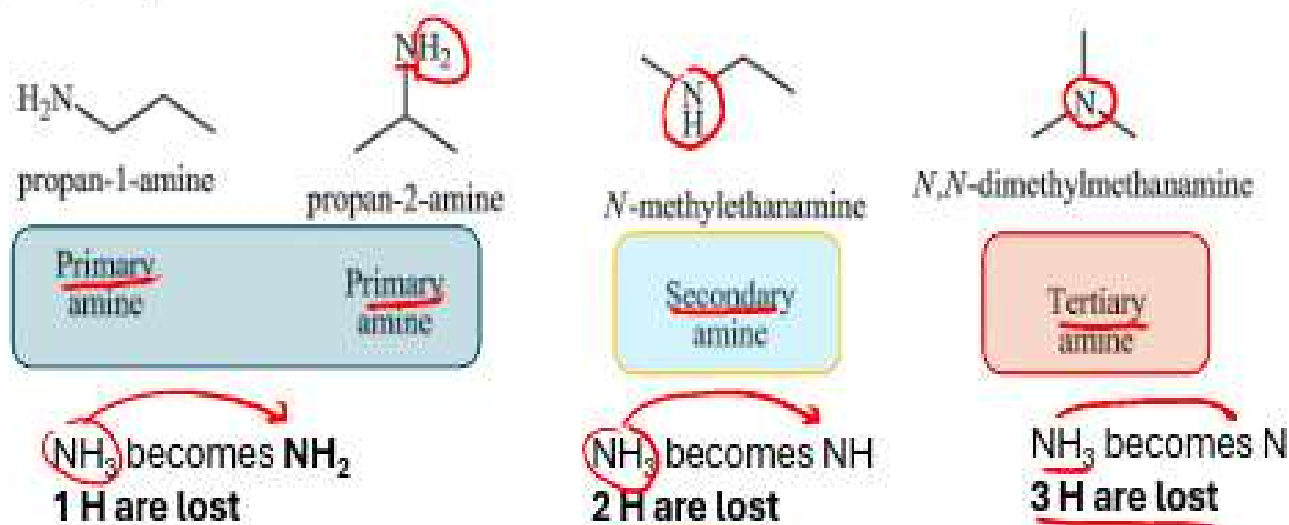


Ethanol

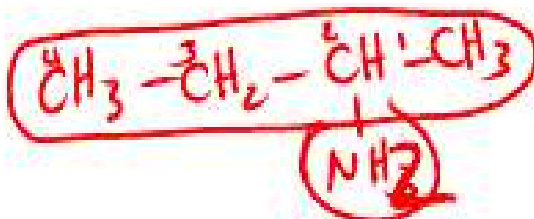
Ethanol has a hydrogen atom bonded to Oxygen, so it can make a hydrogen bond. Ethanol will be more soluble in water because of that.

## Amines

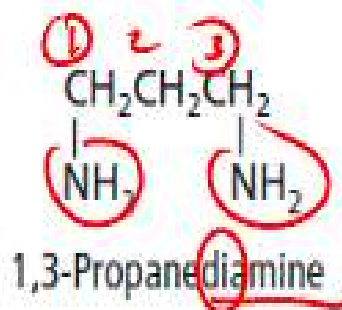
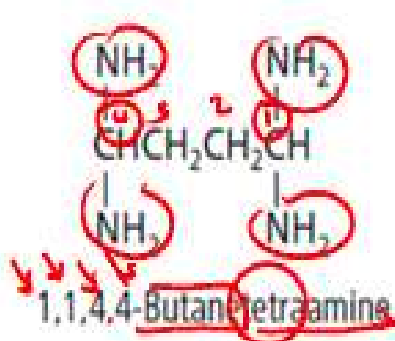
- Amines contain **nitrogen atoms bonded to carbon atoms** in aliphatic aromatic rings and have the general formula  $RNH_2$  *weak base*
- Chemists consider amines derivatives of ammonia ( $NH_3$ ).
- Amines are considered primary, secondary, or tertiary amines depending on whether one, two, or three of the hydrogens in ammonia ( $NH_3$ ) have been replaced by organic groups.



## Naming Amines



- the  $-NH_2$  (amino) group is indicated by the suffix -amine (the last part of the name is **amine**).
- When necessary, the position of the amino group is designated by a number.
- If more than one amino group is present, the prefixes *di-*, *tri-*, *tetra-*, and so on are used to indicate the number of groups.



## Quiz

3. What kind of organic compound would most likely be derived from ammonia,  $\text{NH}_3$ ?

 alcohol

 ether

 amine

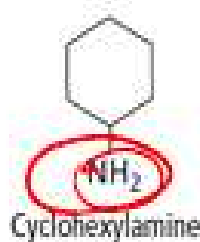
 alkyl halide

CORRECT

## Examples of amines Table 5



secondary amine  
tertiary amine



Primary

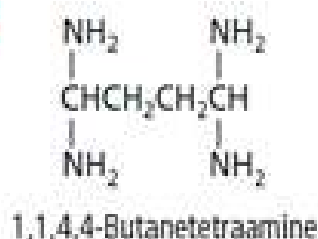
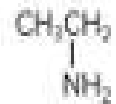
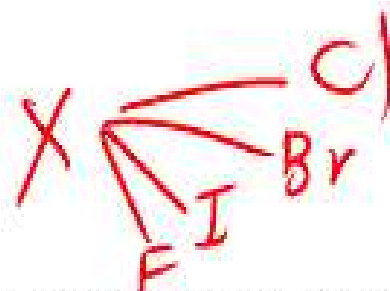


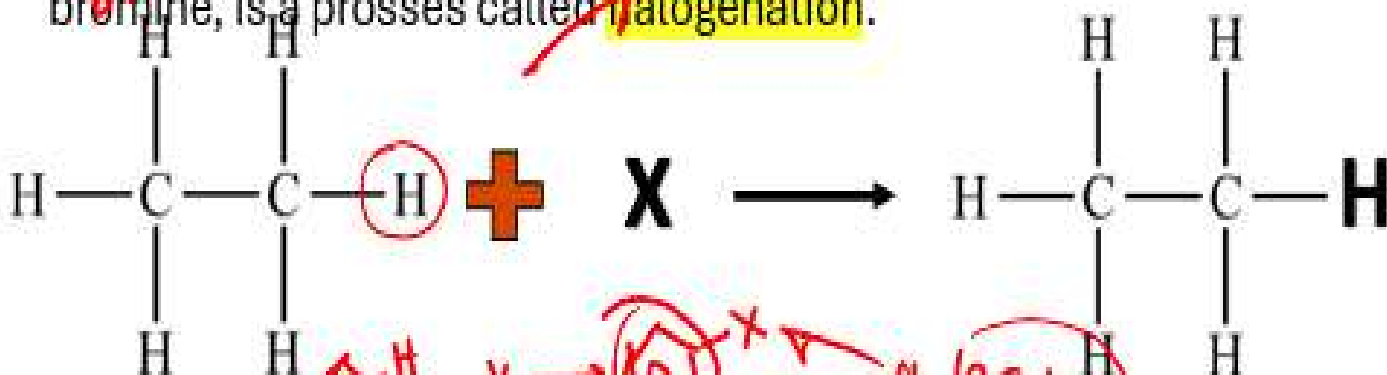
Table 5 Amines

| General Formula                                                                                      |                                                                                                 |                                                                                              |                                                                                                               |                                                                                                          |
|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| $RNH_2$<br>where R represents a carbon chain or ring bonded to the functional group                  |                                                                                                 |                                                                                              |                                                                                                               |                                                                                                          |
| Examples of Amines                                                                                   |                                                                                                 |                                                                                              |                                                                                                               |                                                                                                          |
| <br>Cyclohexylamine | <br>Ethylamine | <br>Aniline | <br>1,1,4,4-Butanetetraamine | <br>1,3-Propanediamine |

## تفاعلات الاستبدال Substitution Reactions



- A **substitution reaction** is one in which one atom or a group of atoms in a molecule is replaced by another atom or group of atoms.
- Replacing hydrogen atom with a halogen, typically chlorine or bromine, is a process called **halogenation**.



X is Cl or Br but not I, Iodine does not react with alkanes.

alkyl halide



Table 3.3

Substitution Reactions

Generic Substitution Reaction

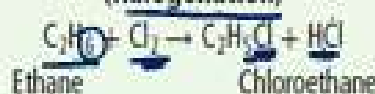


where X is fluorine, chlorine, or bromine

Halogenation

Example of General Substitution Reaction

(Halogenation)



Ethane

Chloroethane

Alkyl Alcohol

General Alkyl Halide-Alcohol Reaction



Alkyl halide

Alcohol

Example of an Alkyl Halide-Alcohol Reaction



Chloroethane

Ethanol

General Alkyl Halide-Ammonia Reaction



Alkyl halide

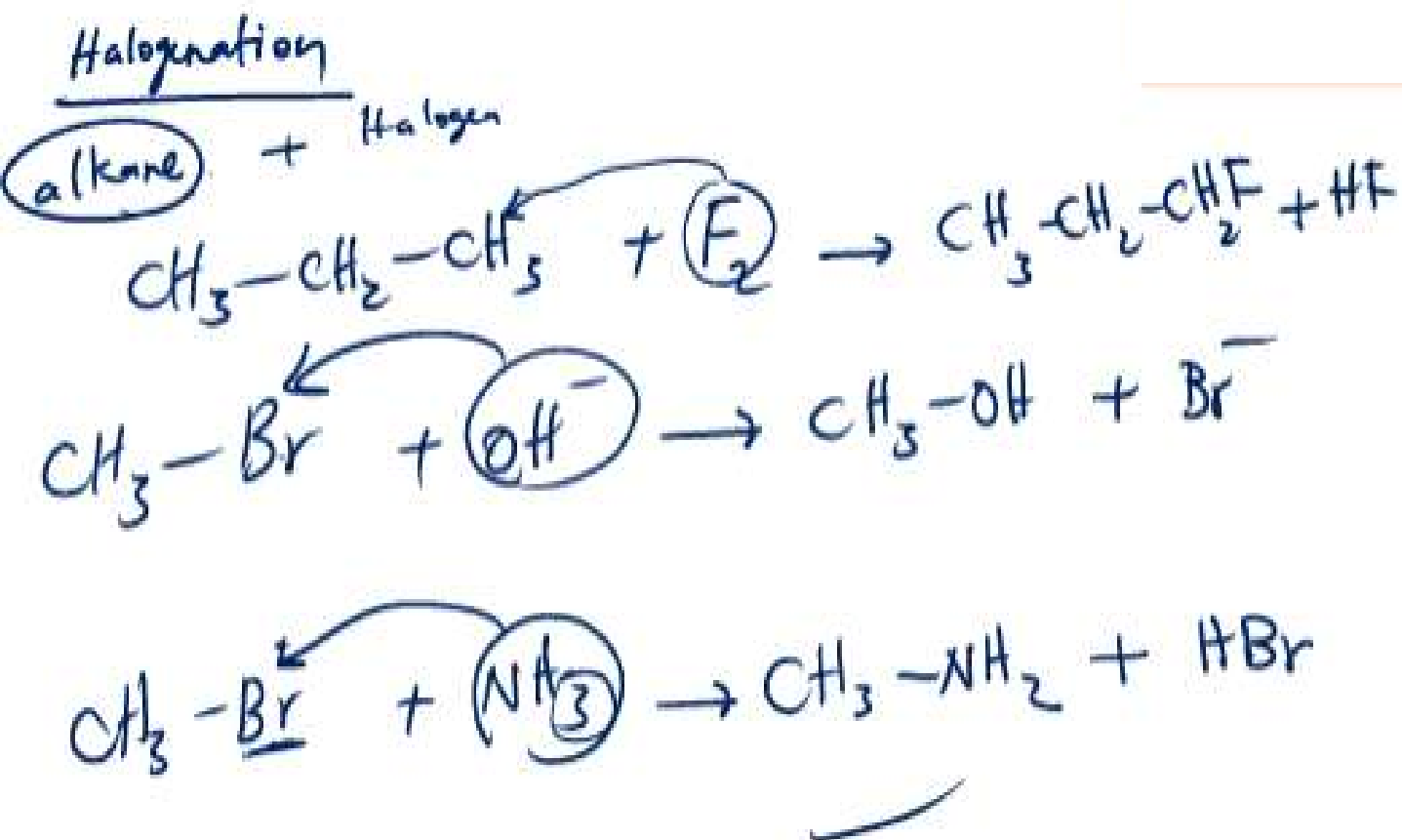
Amine

Example of an Alkyl Halide-Ammonia Reaction



1-Bromooctane

Octaneamine



## Further substitution

- Once an alkane has been halogenated, the resulting alkyl halide can undergo other types of substitution reactions in which the halogen atom is replaced by another atom or group of atoms.
- For example, reacting an alkyl halide with a basic solution results in the **replacement** of the halogen atom by an **-OH** group, forming an **alcohol**.

### General Alkyl Halide-Alcohol Reaction



Alkyl halide

Alcohol

### Example of an Alkyl Halide-Alcohol Reaction



Chloroethane

Ethanol

## Further substitution

- Reacting an alkyl halide with ammonia ( $NH_3$ ) **replaces the halogen atom with an amino group** ( $-NH_2$ ), forming an alkyl amine.
- The alkyl amine is one of the products produced in this reaction. Some of the newly formed amines continue to react, resulting in a mixture of amines.

### General Alkyl Halide-Ammonia Reaction



Alkyl halide

Amine

### Example of an Alkyl Halide-Ammonia Reaction



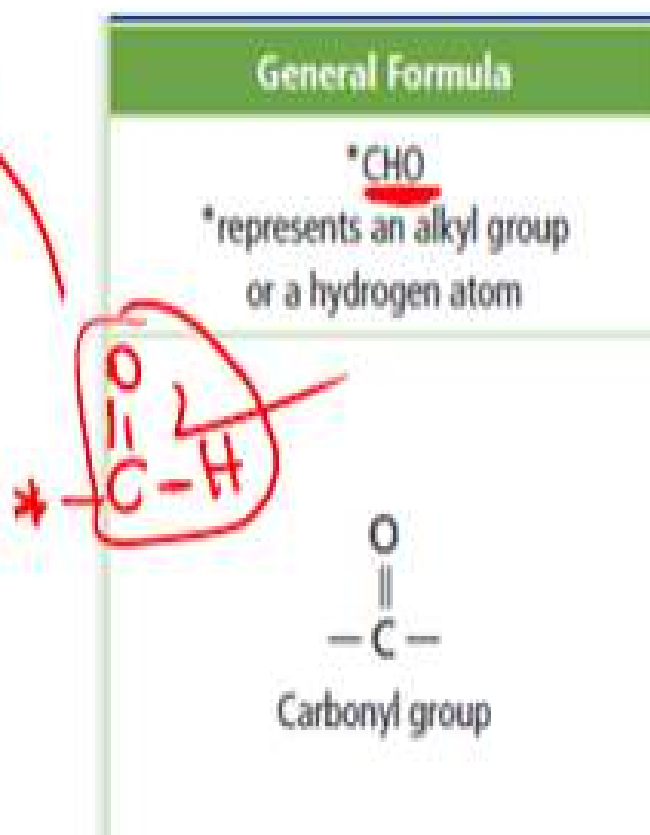
1-Bromooctane

Octaneamine

|    |                                                                                                            |
|----|------------------------------------------------------------------------------------------------------------|
| 28 | CHM.5.6.01.016.06 Explain the physical properties of aldehydes and ketones.                                |
| 29 | CHM.5.6.01.003.23 Define carboxylic acid while explaining, using equation, why it is classified as an acid |
| 30 | CHM.5.6.01.013.27 Draw the structure of an ester given its formula                                         |

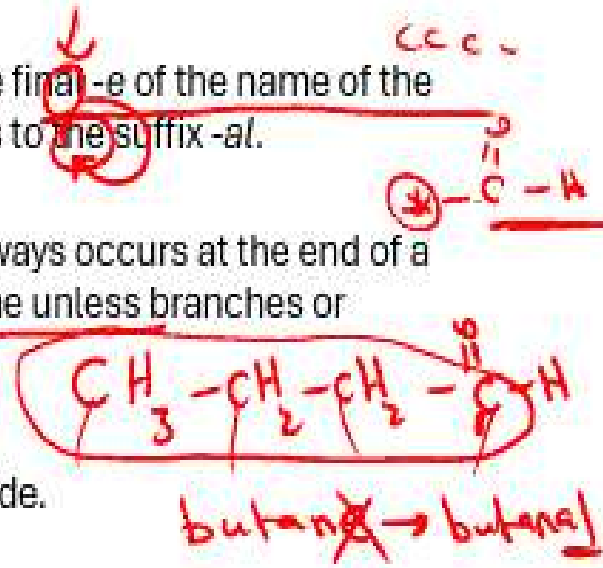
## Aldehydes

- An **aldehyde** is an organic compound in which a carbonyl group located **at the end** of a carbon chain is ~~bonded~~ to a carbon atom on one side and a hydrogen atom on the other.
- Aldehydes have the general formula  $*CHO$ , where  $*$  represents an alkyl ~~group~~ or a hydrogen atom, as shown in table.



# Naming Aldehydes

- Aldehydes are formally named by changing the final -e of the name of the alkane with the same number of carbon atoms to the suffix -al.
- Because the carbonyl group in an aldehyde always occurs at the end of a carbon chain, no numbers are used in the name unless branches or additional functional groups are present.
- Methanal is also commonly called formaldehyde.
- Ethanal has the common name *acetaldehyde*.



# Examples of Aldehydes

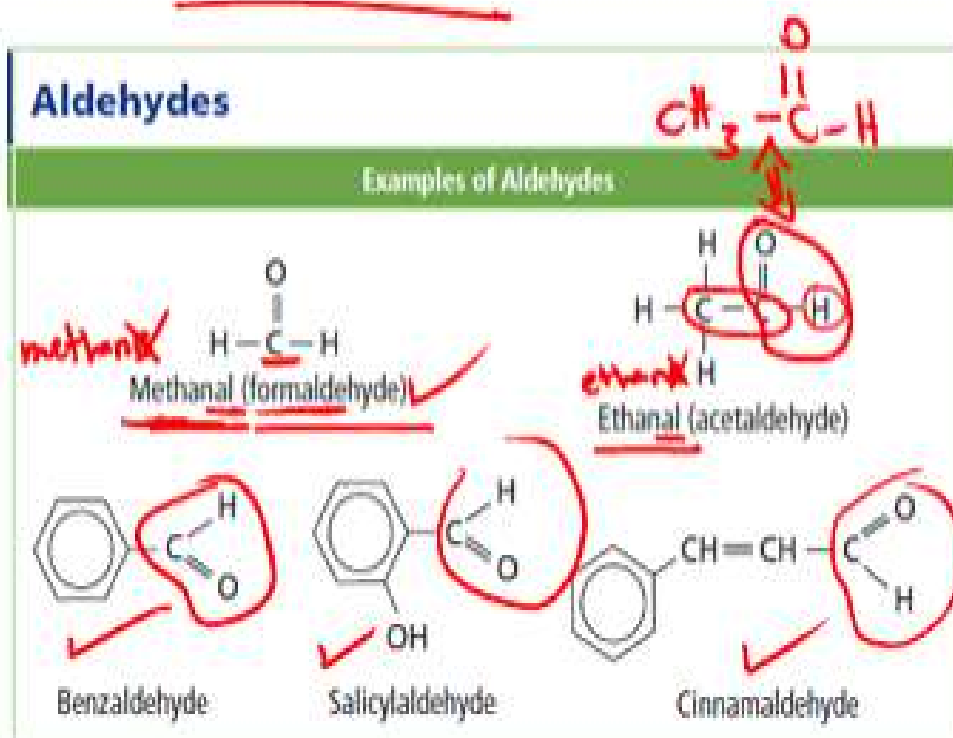


Table 7 Aldehydes

| General Formula                                                               | Examples of Aldehydes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $\text{*CHO}$<br>*represents an alkyl group or a hydrogen atom                | <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <math>\begin{array}{c} \text{O} \\    \\ \text{H}-\text{C}-\text{H} \end{array}</math><br/>                         Methanal<br/>(formaldehyde)                     </div> <div style="text-align: center;"> <math>\begin{array}{c} \text{H} \quad \text{O} \\   \quad    \\ \text{H}-\text{C}-\text{C}-\text{H} \\   \\ \text{H} \end{array}</math><br/>                         Ethanal (acetaldehyde)                     </div> </div>                                                                                                                                                                                                                                              |
| $\begin{array}{c} \text{O} \\    \\ -\text{C}- \end{array}$<br>Carbonyl group | <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <math>\begin{array}{c} \text{H} \\   \\ \text{C}_6\text{H}_5-\text{C}=\text{O} \end{array}</math><br/>                         Benzaldehyde                     </div> <div style="text-align: center;"> <math>\begin{array}{c} \text{H} \\   \\ \text{C}_6\text{H}_4-\text{C}=\text{O} \\   \\ \text{OH} \end{array}</math><br/>                         Salicylaldehyde                     </div> <div style="text-align: center;"> <math>\begin{array}{c} \text{H} \quad \text{H} \quad \text{O} \\   \quad   \quad    \\ \text{C}_6\text{H}_5-\text{C}=\text{C}-\text{C}-\text{H} \end{array}</math><br/>                         Cinnamaldehyde                     </div> </div> |

### Quiz

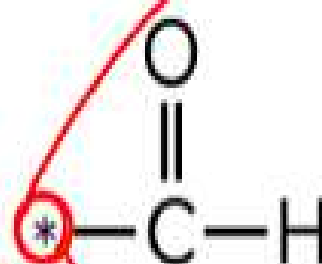
2. What has the general formula shown at right?

☒ a carbonyl group

☒ an aldehyde **CORRECT**

☒ a ketone

☒ an ester



aldehydic

## Properties of Aldehydes

- An aldehyde molecule contains a polar, reactive structure.



- However, like ethers, aldehyde molecules cannot form hydrogen bonds among themselves because the molecules have no hydrogen atoms bonded to an oxygen atom.

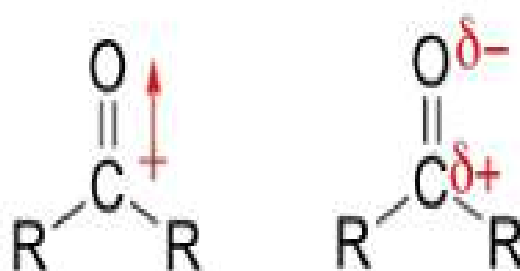
*Because of that*

*-OH can form hydrogen bonds*

- Therefore, aldehydes have lower boiling points than alcohols with the same number of carbon atoms.

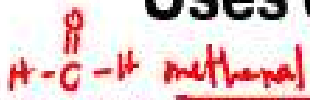
- Water molecules can form hydrogen bonds with the oxygen atom of aldehydes, so aldehydes are more soluble in water than alkanes but not as soluble as alcohols or amines.

## Properties of Aldehydes

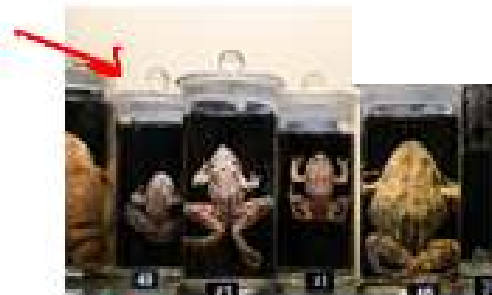


An aldehyde molecule contains a polar, reactive structure.  
But aldehyde molecules cannot form hydrogen bonds

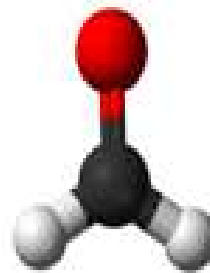
## Uses of Aldehydes



- **Formaldehyde** has been used for preservation (حفظ العينات) for many years.

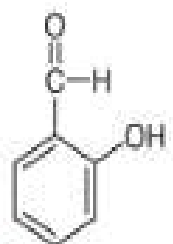
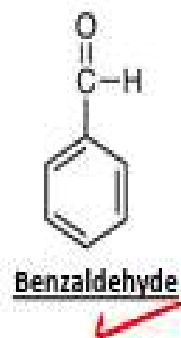


- Industrially, large quantities of **formaldehyde** are reacted with urea to manufacture a type of **grease-resistant, hard plastic** used to make **buttons, appliance and automotive parts**, and **electrical outlets**, as well as the **glue** that holds the layers of plywood together.



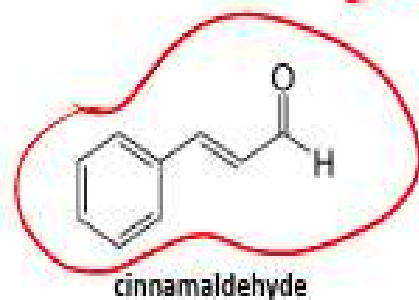
## Uses of Aldehydes

- **Benzaldehyde** and **salicylaldehyde**, are two components that **give almonds (اللوز) their natural flavor**.

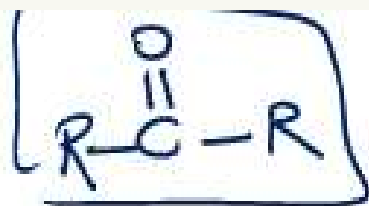


salicylaldehyde

- The **aroma and flavor of cinnamon**, a spice that comes from the bark of a tropical tree, are produced largely by **cinnamaldehyde**.

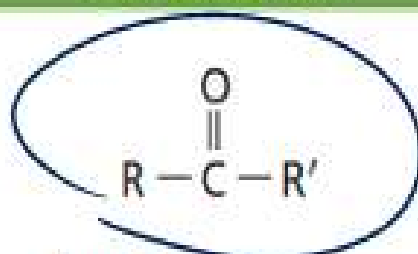


## 2 **Ketones**



- A carbonyl group can also be located within a carbon chain rather than at the end.
- **A ketone** is an organic compound in which the **carbon of the carbonyl group** is bonded to **two other carbon atoms**. Ketones have the general formula shown in the picture.

### General Formula

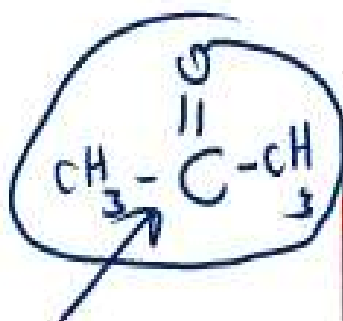
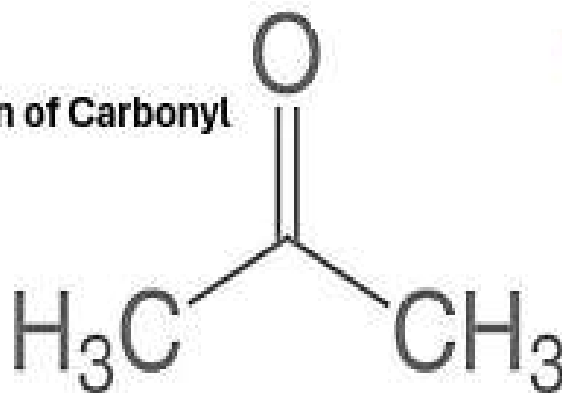


where R and R' represent carbon chains or rings bonded to functional groups

## **Ketones**

- The carbon atoms on either side of the carbonyl group are bonded to other atoms.
- The **simplest** ketone, commonly known as **acetone**, has only hydrogen atoms bonded to the side carbons.  
*commercial*

The carbon of Carbonyl



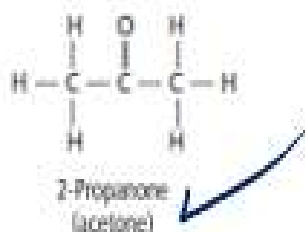
# $R-\overset{\overset{O}{\parallel}}{C}$ ~~Naming Ketones~~ Aldehyde Alkanal $\rightarrow$ al

alkanone

- Ketones are formally named by changing the -e at the end of the **alkane** name to -one.
- and including a **number** before the name to indicate the position of the **ketone group**.



2-propanone

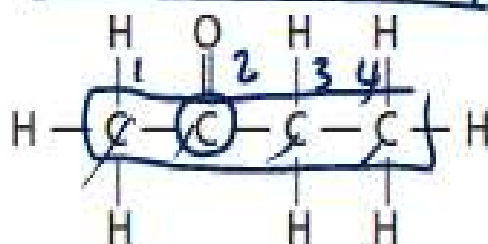


~~Acetone~~ In the previous example, the alkane name **propane** is changed to **propanone**. The carbonyl group can be located **only** in the center, but the prefix **2-** is usually added to the name for clarity.

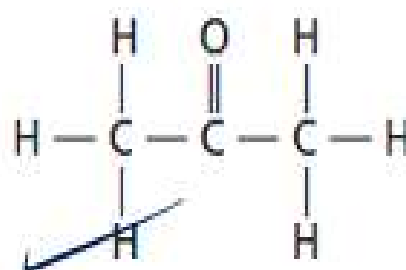
## Naming Ketones

- Examples

2-butanone



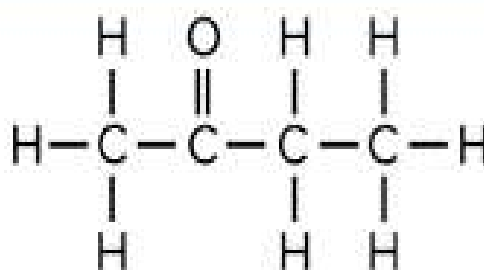
2-Butanone  
 (methyl ethyl ketone)



2-Propanone  
 (acetone)

## Quiz

3. What is the name of the compound with the formula shown at right?



 2-butanal

 **2-butanone**

CORRECT

 ethyl methyl ether

 methyl ethanoate

## Properties and Uses of Ketones

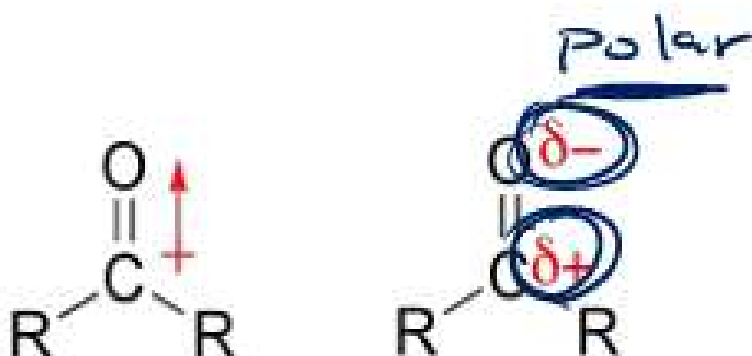
   
Ketones and aldehydes share many chemical and physical properties because their structures are similar.

 Ketones are polar molecules and are less reactive than aldehydes. For this reason, ketones are popular solvents for other moderately polar substances, including waxes, plastics, paints, lacquers, varnishes, and glues.  The O is not bonded to

Like aldehydes, ketone molecules cannot form hydrogen bonds with each other but can form hydrogen bonds with water molecules. Therefore, ketones are somewhat soluble in water.

Acetone is completely miscible with water.

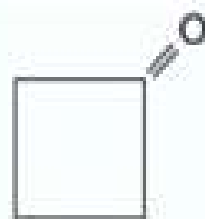
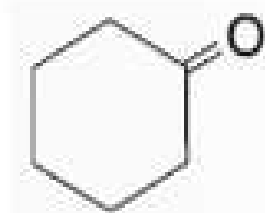
# Properties of Ketones



A Ketone molecule contains a polar, less reactive than aldehydes.  
But ketone molecules cannot form hydrogen bonds

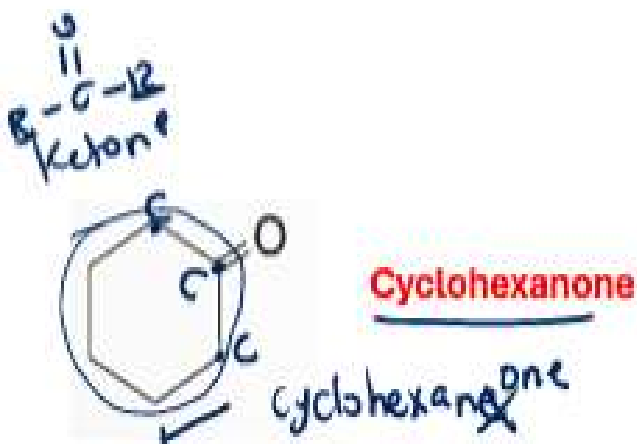
## Plenary

- Name the following compound



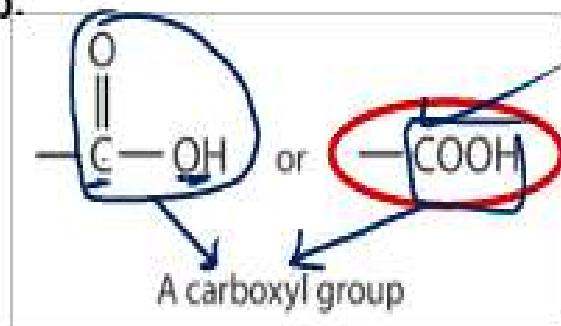
## Plenary

- Name the following compound



## Carboxylic Acids

- A **carboxylic acid** is an organic compound that has a carboxyl group.
- Carboxyl group** consists of a **carbonyl group** bonded to a **hydroxyl group**.



A carboxyl group is usually represented in condensed form by writing  $\text{COOH}$ .  
 For example, acetic acid, the acid found in vinegar, can be written as  $\text{CH}_3\text{COOH}$

# Carboxylic Acids (General Formula)

## General Formula

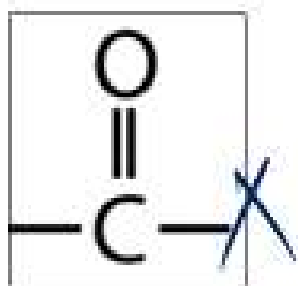


where R represents carbon chains or rings bonded to functional groups

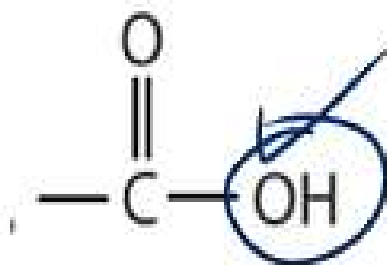
## Activity

- What is the difference between carbonyl and carboxyl group?

(Hint: draw them both and compare)



carbonyl



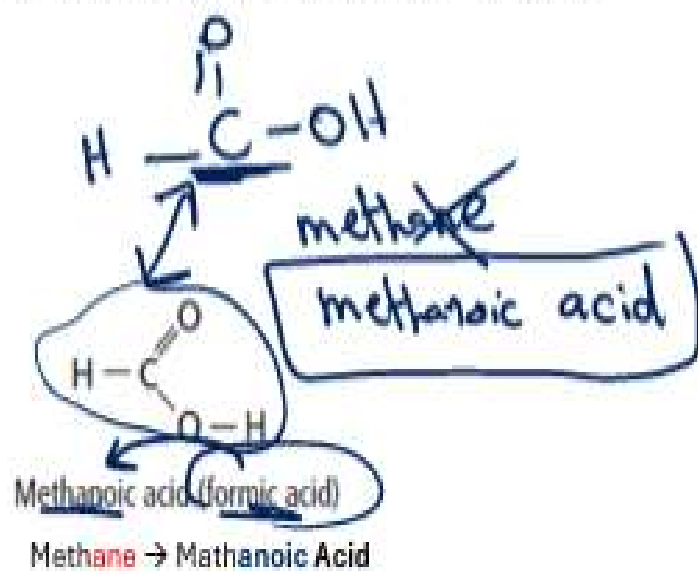
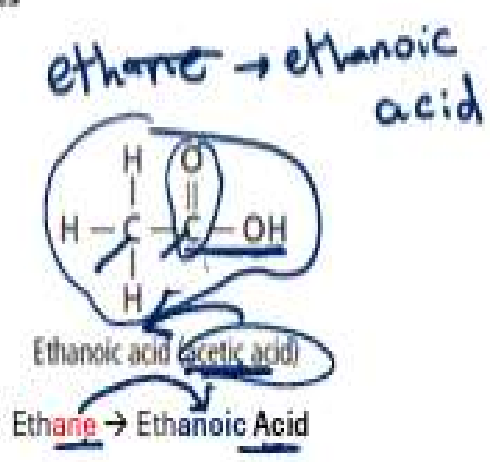
carboxyl

# Naming Carboxylic Acids ~~Alkane~~

acid

- The formal name is formed by **changing the ~~ane~~** of the parent alkane to **-anoic acid**. Thus, the formal name of acetic acid is **ethanoic acid**.

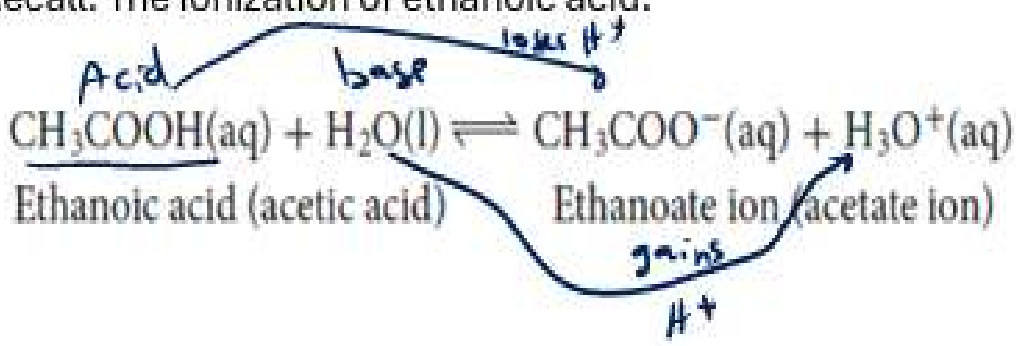
Examples



## Properties of Carboxylic acid

- Carboxylic acids are polar and reactive.  
 $\text{Acids} \xrightarrow{\text{(lose } H^+)} \text{lost as } H^+$
- Those that dissolve in water ionize weakly to produce hydronium ions, the anion of the acid in equilibrium with water, and the unionized acid.

- Recall: The ionization of ethanoic acid.



# Properties of Carboxylic acid

- Carboxylic acids can ionize in water solution because the **two oxygen atoms** are **highly electronegative** and **attract electrons** away from the hydrogen atom in the **-OH group**.
- As a result, the **hydrogen proton** can transfer to another atom that has a pair of electrons not involved in bonding, such as the oxygen atom of a water molecule. Because they ionize in water, soluble carboxylic acids turn **blue litmus paper red** and have a **sour taste**.



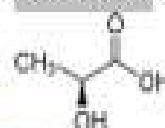
ethanoic acid  
 $\text{CH}_3\text{COOH}$

## Two Dicarboxylic Acid

- An acid with two carboxyl groups is called a **dicarboxylic acid**.
- Some important carboxylic acids, such as **oxalic acid** and **adipic acid**, have two or more carboxyl groups.



- Others have additional functional groups such as hydroxyl groups, as in the **lactic acid** found in yogurt.



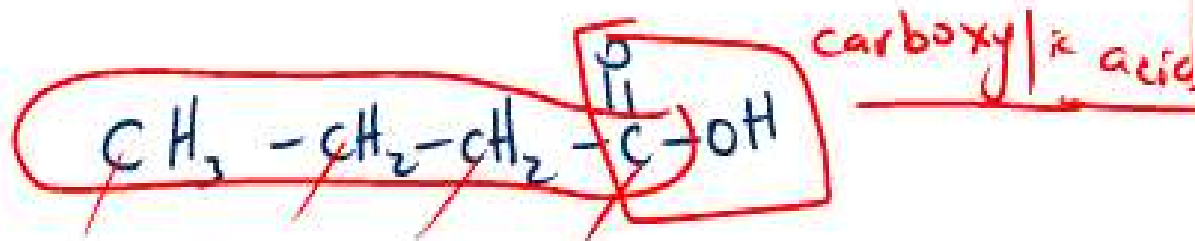
- Typically, these acids are **more soluble in water** and often **more acidic** than acids with only a carboxyl group.

**More carboxyl groups = more soluble and reactive**

## Carboxylic Acids

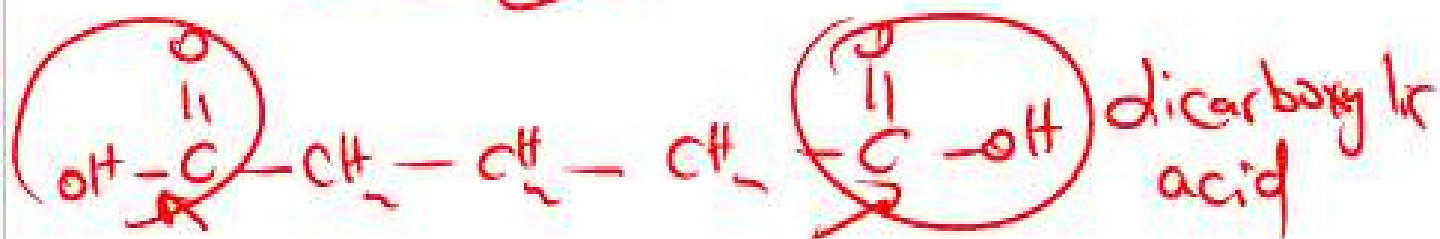
Table 9 Carboxylic Acids

| General Formula                                                                                              | Examples of Carboxylic Acids                                                                                                                                                                                                                                                                                                                                                      |
|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $^*-C(=O)OH$ <p>where * represents a hydrogen atom, carbon chain, or ring bonded to the functional group</p> | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <math display="block">\begin{array}{c} H \\   \\ H-C-C(=O)OH \\   \\ H \end{array}</math> <p>Ethanoic acid (acetic acid)</p> </div> <div style="text-align: center;"> <math display="block">H-C(=O)OH</math> <p>Methanoic acid (formic acid)</p> </div> </div> |



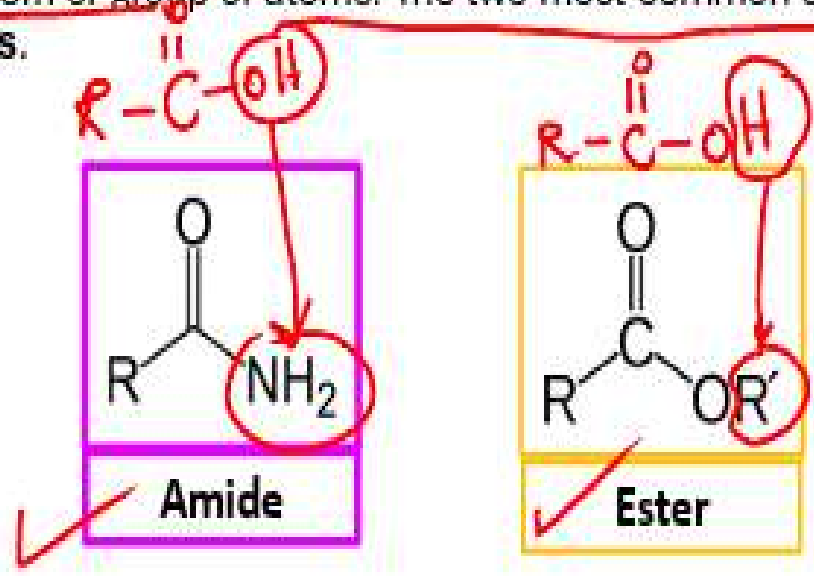
~~butanoic acid~~

butanoic acid

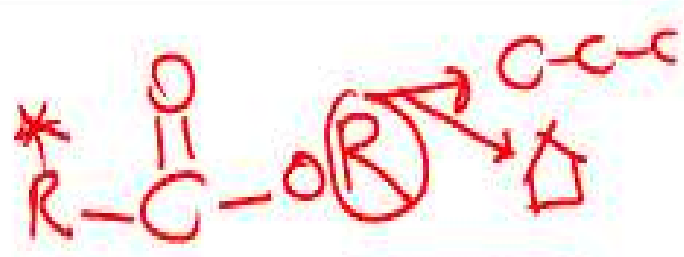


# Organic Compounds Derived from (Aldehydes, Ketones, Carboxylic Acids) Acids

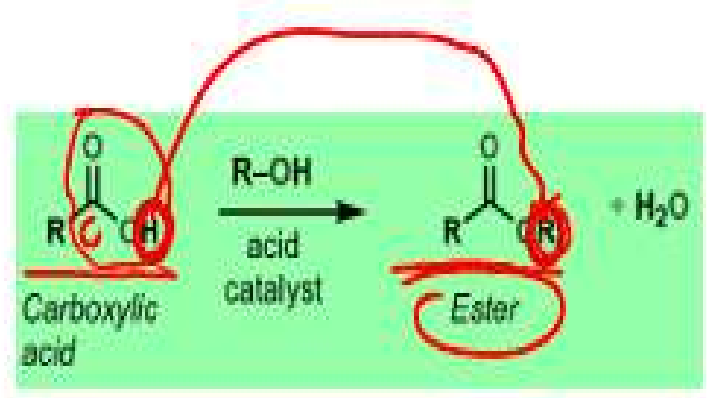
- The hydrogen or the hydroxyl group of a carboxylic acid is replaced by a different atom or group of atoms. The two most common classes are **esters** and **amides**.



## Esters



- An **ester** is any organic compound with a carboxyl group in which the hydrogen of the hydroxyl group has been replaced by an alkyl group



# Naming esters *comes from the*

- Write the **name** of the **alkyl group** followed by the **name of the acid** with the **-ic acid** ending replaced by **-ate**.
- Note how the name *propyl* results from the structural formula.
- The name shown in parentheses is based on the name *acetic acid*, the common name for ethanoic acid.

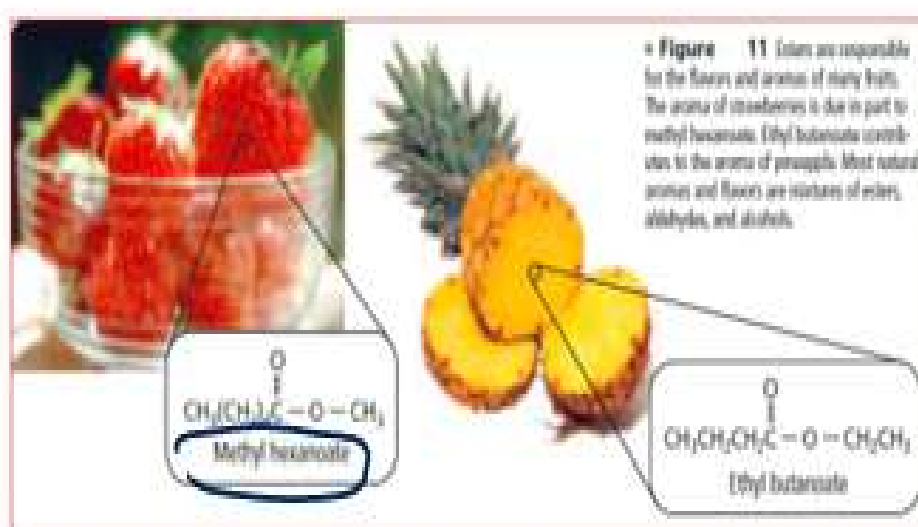
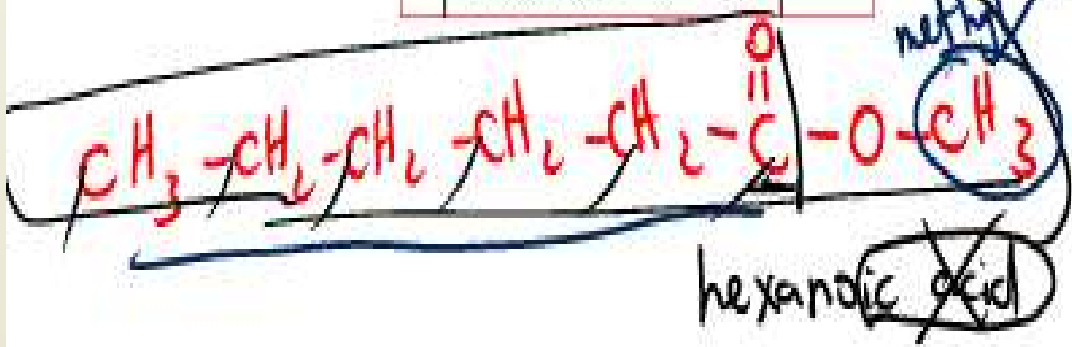
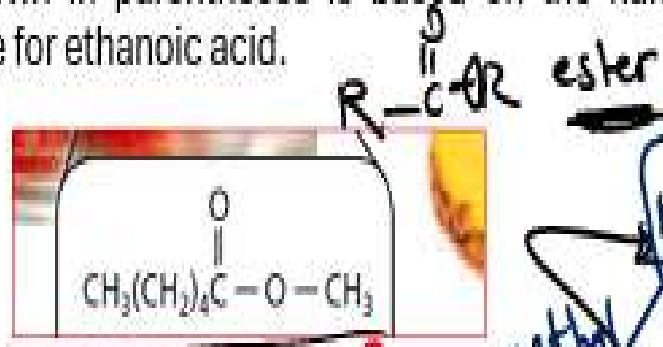


Table 10 Esters

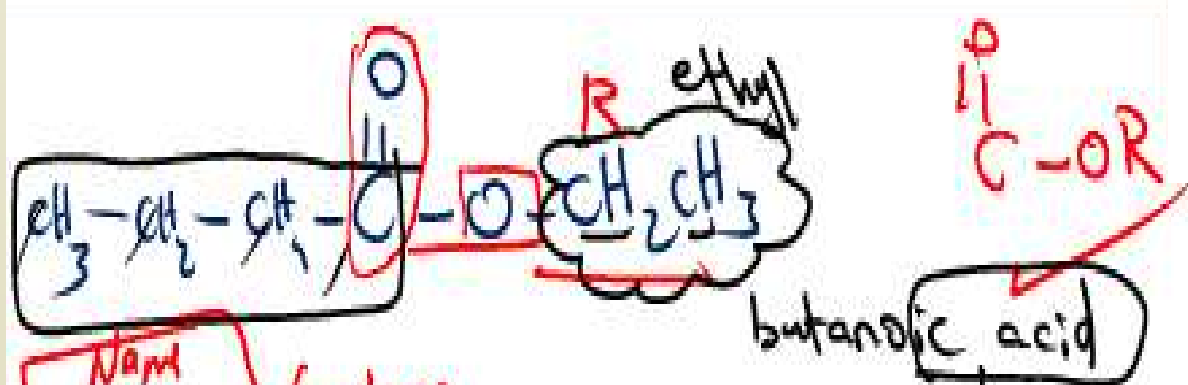
| General Formula                                                                                | Examples of an Ester                                                                                                                                                                                                                                                                                                                                                                                                                               |
|------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $\begin{array}{c} \text{O} \\ \parallel \\ \text{---C---O---R} \end{array}$ <p>Ester group</p> | <div style="display: flex; justify-content: space-around;"> <div> <p>Ethanoate group</p> <math display="block">\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{---C---} \end{array}</math> </div> <div> <p>Propyl group</p> <math display="block">\text{---O---CH}_2\text{CH}_2\text{CH}_3</math> </div> </div> <p style="text-align: center;">Ester group</p> <p style="text-align: center;">Propyl ethanoate<br/>(propyl acetate)</p> |

# Naming esters

- Write the **name** of the **alkyl group** followed by the **name of the acid** with the -ic acid ending replaced by -ate.
- Note how the name *propyl* results from the structural formula.
- The name shown in parentheses is based on the name *acetic acid*, the common name for ethanoic acid.



methyl hexanoate



Name  
 this  
 compound

family??

ethyl butanoate