
UNIT 8 OXIDATION AND REDUCTION

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8.1 INTRODUCTION

You are familiar with reactions involving loss or gain of electrons which are known as oxidation or reduction reactions respectively. Such oxidation and reduction reactions play an important role in organic syntheses and biochemical transformations. It is, therefore, very useful to know the methods and reagents used for oxidising and reducing various types of organic compounds. In this unit you will learn some of these methods.

Objectives

After studying this unit, you should be able to:

- define the terms oxidation and reduction,
- calculate the oxidation number of an element in a molecule,
- describe various methods for the oxidation of alkenes, alkyne, alcohols, aldehydes and ketones,
- explain selective oxidation,
- describe various methods for the reduction of the alkenes, alkynes, aldehydes, ketones, and some nitrogen functional groups.

8.2 WHAT IS OXIDATION AND REDUCTION

First we must know what oxidation and reduction mean. Oxidation and reduction can be defined in two ways: loss of electrons or increase in the oxidation state, is defined as oxidation and gain of electron or decrease in the oxidation state as reduction. In organic reactions it is not easy to determine whether a carbon atom loses or gains electrons. However, it is easy to calculate the change in oxidation state of the carbon atoms and hence, classify a particular reaction as oxidation or reduction. Thus, conversion of a functional group in a molecule, from a lower oxidation state to a higher one will be termed as oxidation, while the opposite of it would be reduction. It is obvious that to fully comprehend oxidation and reduction, one must know what oxidation state stands for.

Oxidation State

A comparison of the oxidation states of atoms in reactants and products enables us to keep an account of the transfer of electrons in a chemical reaction. Oxidation state is equal to the charge an atom would have if all the electrons in a covalent bond were

assigned to the more electronegative atom. You will understand the significance of this definition as you go through the examples given in this section.

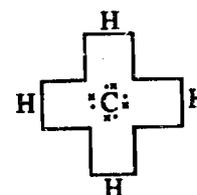
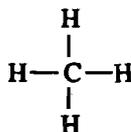
If you know how to calculate the oxidation states of different atoms present in the reactants and the products, you can find out what is oxidised and what is reduced. The importance of oxidation state for the oxidation-reduction reactions is similar to the importance of currency in a business transaction.

To calculate oxidation states one must know how to write the Lewis structure of molecules and ions. The method of writing Lewis structure has been discussed in detail in Unit 3 of "Atoms and Molecules" course.

You can calculate the oxidation state of a particular atom in a compound or ion using the following formula:

$$\text{Oxidation state} = \text{No. of valence electron(s)} - \frac{\text{No. of electrons assigned to the atom after adjustment as per electronegativity}}{2}$$

Suppose we want to calculate the oxidation state of carbon and hydrogen atoms in methane molecule. Let us first write the Lewis structure of methane:



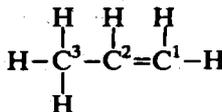
Methane

Note that the bonding electrons which are assigned to carbon atom are shown by means of enclosing lines. Since carbon is more electronegative than hydrogen, all the eight electrons have been assigned to the carbon atom. Hence as per relative electronegativity values, electrons assigned to carbon atom = 8 and electrons assigned to each hydrogen atom = 0.

We know that carbon atom has four valence electrons and hydrogen atom has one. Since carbon is more electronegative than hydrogen, eight bonding electrons of the four C-H bonds have to be assigned to the carbon atom while calculating the oxidation state of this carbon atom. Using the equation stated above:

$$\begin{aligned} \text{Oxidation state of carbon} &= 4 - 8 = -4 \\ \text{Oxidation state of hydrogen atom} &= 1 - 0 = +1 \end{aligned}$$

Similarly you can calculate the oxidation states of various carbon atoms in a propene molecule. Since in propene all the three carbon atoms have different electron environment, all the three carbon atoms will have different oxidation state. We will first write the Lewis structure of propene.



$$\begin{aligned} \text{No. of valence electrons of all the three carbon} &= 4 \\ \text{No. of electrons assigned to } C_1 &= 6 \\ \text{No. of electrons assigned to } C_2 &= 5 \\ \text{No. of electrons assigned to } C_3 &= 7 \end{aligned}$$

Thus,

$$\begin{aligned} \text{Oxidation state of } C_1 &= 4 - 6 = -2 \\ \text{Oxidation state of } C_2 &= 4 - 5 = -1 \\ \text{Oxidation state of } C_3 &= 4 - 7 = -3 \end{aligned}$$

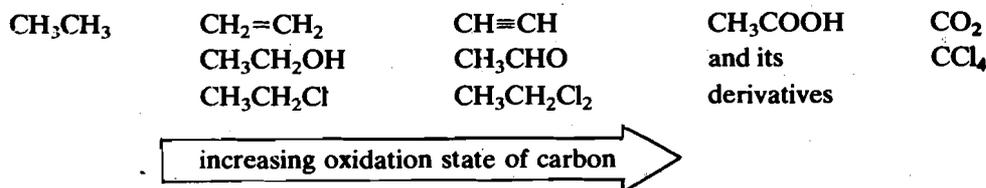
Note that the oxidation state of an element in a compound is the average value for the element, if more than one atom of the same element is present in one molecule of the compound. Thus the average oxidation state of carbon in propene is:

$$\frac{(-2) + (-1) + (-3)}{3} = \frac{-6}{3} = -2$$

While assigning the bonding electrons, care must be taken in case of bonds linking atoms of the same element, (e.g., C-C, C=C and N=N). In such cases, the bonding electrons must be distributed equally to each of the two atoms linked.

For example, the four electrons constituting the double bond between two carbon atoms must be distributed equally to each of these two carbon atoms.

We can list a series of compounds according to the increasing oxidation state of carbon:



SAQ 1

Calculate the oxidation state of the carbon atom(s) in the following molecules.

- a) CH₂=CH₂
- b) CH₃CHO

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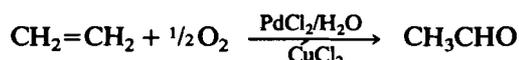
8.3 OXIDATION REACTIONS

Some important oxidation reactions are discussed below:

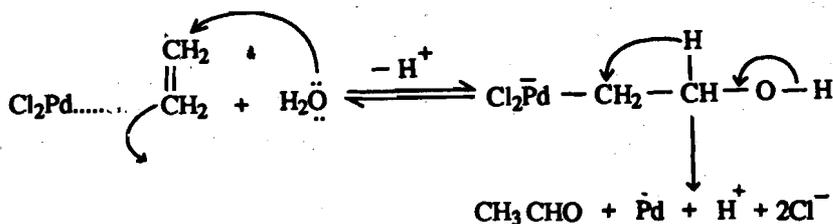
8.3.1 Oxidation of Alkenes and Alkynes

Some oxidation reactions of alkenes and alkynes have been discussed in Unit 5 of this course. In this unit we shall study the oxidation of alkenes using transition metal complexes.

Many organic reactions can be brought about by transition metal complexes. This is a rapidly growing area of organic chemistry with extensive applications in industries. Transition metals possess unfilled orbitals capable of accepting electrons. Simple alkenes can provide a pair of electrons by coordination through the π bond. Such complexes can rearrange to form intermediates, with a carbon metal bond, which undergo further transformation. An example is palladium catalysed oxidation of ethene, known as Wacker process, which is used for commercial preparation of ethanal.



The reaction is believed to proceed through a palladium complex with the alkene. Water adds to this complex with the formation of a metal carbon σ bond and loss of a proton. In the final step, hydride ion migration occurs as shown.



Cupric chloride reoxidises the palladium formed, regenerating PdCl₂ for the continuation of the catalytic cycle.

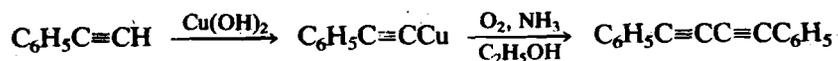


The resultant cuprous chloride can be again oxidized to cupric chloride as shown below:



Later in this unit, we will see how transition metal complexes can also bring about reduction of alkenes and alkynes.

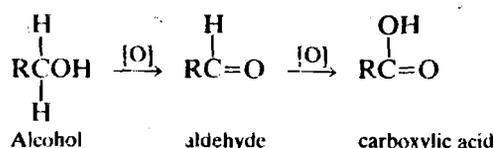
Ferrialkynes undergo oxidative coupling. For example



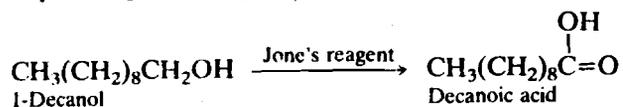
This reaction has been used to prepare monocyclic, unsaturated large ring compounds (annulenes)

8.3.2 Oxidation of Alcohols

An important reaction of alcohols is their oxidation to yield carbonyl compounds. Alcohols with α -hydrogen atom(s) undergo oxidation readily. Oxidation of an alcohol involves the loss of one or more α -hydrogens. The nature of the product formed depends upon the number of α -hydrogens present in the alcohol, that is, whether the alcohol is primary, secondary or tertiary. Primary alcohols first give aldehydes by losing two hydrogens. The aldehyde formed tends to undergo further oxidation to give a carboxylic acid. In aqueous solution, aldehydes are more easily oxidised than alcohols. Therefore, oxidation usually continues until the carboxylic acid is formed.



Oxidising agents commonly used for the oxidation of primary alcohols to carboxylic acids are, chromium trioxide (CrO_3) in aqueous sulphuric acid (Jones' reagent), potassium permanganate or potassium dichromate. For example,



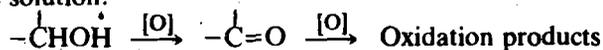
If the reaction mixture is kept in between the boiling points of the aldehyde and the alcohol, the aldehyde distils off as soon as it is formed and further oxidation is avoided. Yield of aldehydes by this method is usually low. Therefore, this technique is of limited synthetic value.

You will recollect that due to hydrogen bonding alcohols are higher boiling than the corresponding aldehydes.

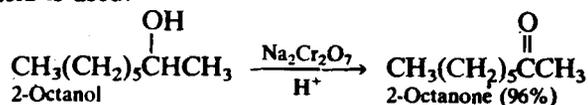
Pyridinium chlorochromate or chromium-pyridine complex is a more selective reagent. These reagent are soluble in non-aqueous solvents, such as CH_2Cl_2 and oxidation stops at the aldehyde stage.



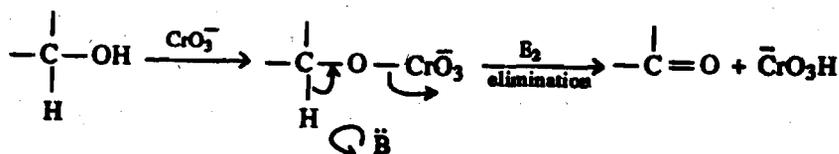
Secondary alcohols on oxidation give excellent yields of ketones which are stable. Acidic conditions are usually maintained because, ketones get oxidised further in alkaline solution.



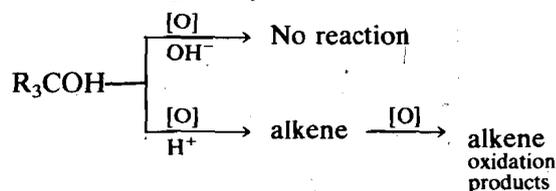
For large-scale oxidations, an inexpensive reagent, sodium dichromate in aqueous acetic acid is used.



Oxidation of primary and secondary alcohols follows E2 reaction pathway which you have studied in Unit 7. The first step involves the reaction between alcohol and the chromium (VI) reagent to form the chromate intermediate. In the next step, bimolecular elimination takes place to give carbonyl compound.

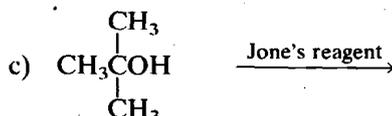
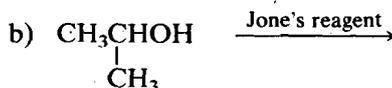


Tertiary alcohols do not get oxidised under alkaline conditions. Under acidic conditions, tertiary alcohols undergo dehydration and the resultant alkene may get oxidised.



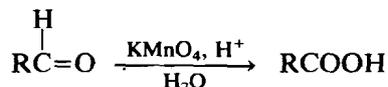
SAQ 2

Predict the product(s) of the following reactions



8.3.3 Oxidation of Aldehydes and Ketones

As mentioned above, aldehydes are very readily oxidised to acid. Aldehydes can be oxidised by the same reagents that oxidise alcohols. Permanganate or dichromate salts are the most common oxidising agents.



Aldehydes are so easy to oxidise that even a mild reagent like silver diammonia complex (Tollens, reagent) can be used for oxidation. For example:

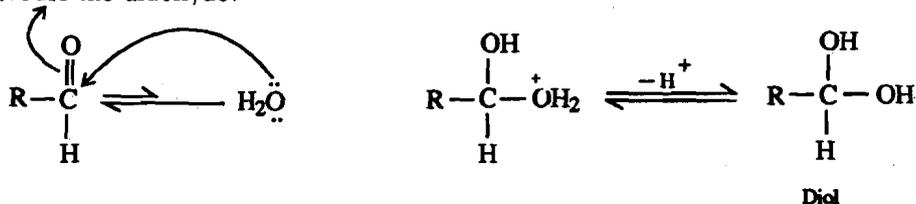


Tollens' reagent oxidises aldehydes in high yield without attacking carbon-carbon double bond or other functional groups.

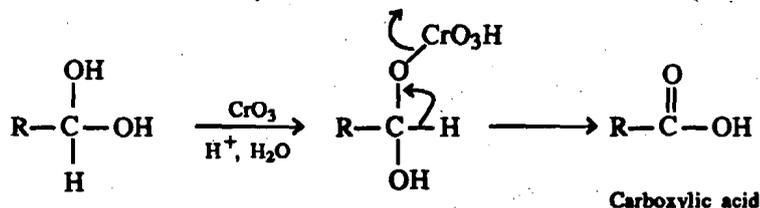


In this reaction, a shining coat of silver metal gets deposited on the glass surface of the reaction vessel. So it can be used as a test to detect the presence of aldehydes. Mirrors are also prepared commercially in this way.

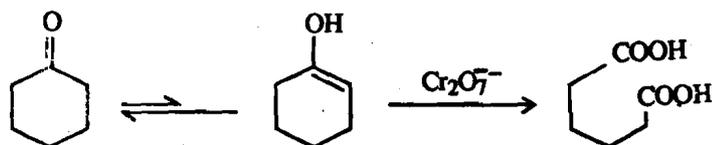
Mechanism: In the first step, H_2O as nucleophile adds to the carbonyl carbon to give a 1,1-diol or a hydrate. Diol formation is a reversible step and the equilibrium usually favours the aldehyde.



In the second step the diol reacts like any normal primary or secondary alcohol and is oxidised to a carboxylic acid as discussed in the case of oxidation of alcohol.



Ketones are not easily oxidised. Oxidation of ketones occurs only when forced by the use of strong oxidising agents and perhaps involves the cleavage of the molecule through the corresponding enol to produce an acid.

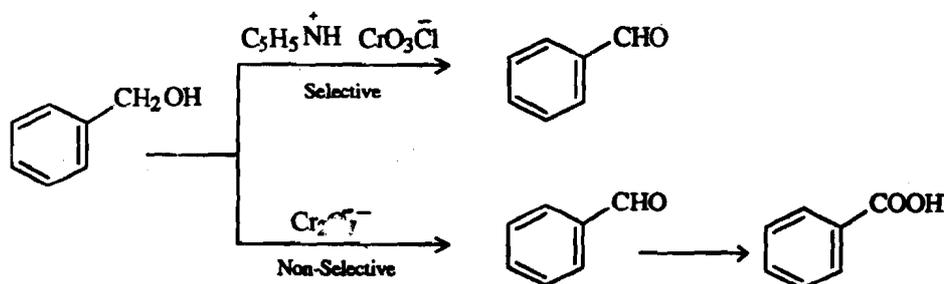


The arrows of unequal length indicate that the equilibrium lies in favour of the ketone. However, as the enol is oxidised more of it gets formed and the reaction can go to completion. The reaction is only useful for symmetrical ketones such as cyclohexanone, as a mixture of products is formed from unsymmetrical ketones.

Oxidation is the reaction in which aldehydes differ from ketones. It is because an aldehydic group contains one hydrogen atom at the carbonyl carbon. While a ketonic group has no such hydrogen atom. This hydrogen is abstracted in oxidation. The analogous reaction for a ketone requires abstraction of an alkyl or aryl group which does not take place.

8.3.4 Selectivity in Oxidation

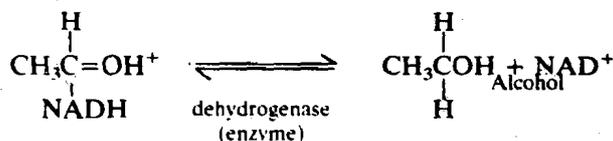
A molecule may contain a functional group which can be oxidised to a product which is susceptible to further oxidation. To stop at the intermediate stage we must use a selective oxidising agent.



In the above example, the dichromate is non-selective between primary alcohol and aldehyde groups while pyridinium chlorochromate oxidises only the alcohol but not the aldehyde. Similarly, for oxidation of a molecule containing more than one oxidisable group, a selective reagent will be needed if oxidation at only one centre is desired.

8.3.5 Biological Oxidation

Oxidation and reduction are very important reactions in living organisms. These reactions are usually very complex. We may, at this stage, talk about the technical reduction of ethanal to ethyl alcohol in a simplified manner because it also proceeds through a hydride transfer reaction. The hydride source is the reduced form of the coenzyme nicotinamide adenine dinucleotide. It is a complex molecule but for our purpose we can look at it as NADH which can transfer a hydride ion (like lithium aluminium hydride) and get converted into its oxidised form NAD⁺. In biological systems an enzyme catalyst brings together the molecule to be reduced i.e., acetaldehyde and the reducing agent, i.e. NADH. The situation may be considered somewhat similar to a metal bringing together hydrogen and an alkene in catalytic hydrogenation.



Ethanal gains a hydride ion from NADH and a proton from the solvent.

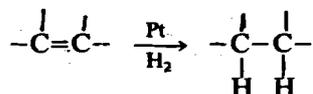
The reaction is reversible and the same enzyme can catalyse the oxidation of alcohol to ethanal.

8.4 REDUCTION REACTIONS

In this section we shall study the reduction of different classes of compounds, like alkenes, alkynes, aldehydes, ketones and some nitrogen functional groups.

8.4.1 Reduction of Alkenes and Alkynes

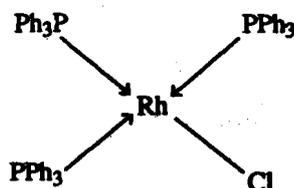
Addition of hydrogen to carbon-carbon multiple bonds (hydrogenation) can be carried out with the help of transition metal catalysts such as platinum, palladium or nickel. The finely divided catalyst is shaken as a suspension with a solution of the alkene in an organic solvent in the presence of hydrogen gas (heterogeneous hydrogenation). You may remember that the manufacture of vegetable fats involves hydrogenation of double bonds present in vegetable oils.



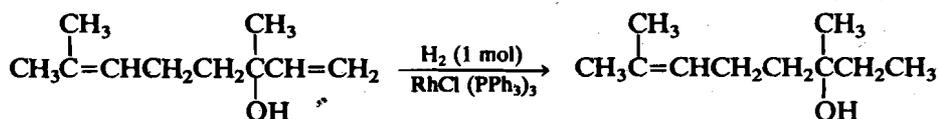
Hydrogen and the alkene first become associated with the metal surface. Hydrogen is then transferred to the unsaturated carbons of the organic molecule. The two hydrogens are added on the same side (*syn*-addition) of the alkene.

Some transition metals can be rendered soluble in organic solvents by complexation with ligands, like triphenylphosphine. These complexes can be used for homogeneous hydrogenation e.g. tris(triphenylphosphine) chlororhodium called Wilkinson catalyst is soluble in benzene. These complexes can be used for homogeneous hydrogenation.

Wilkinson and Fischer were given Nobel Prize in 1973 for their work in transition metal chemistry

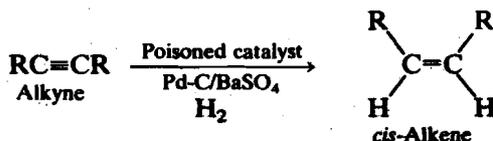


Rhodium catalyst is more selective and can be used to reduce less substituted double bonds in the presence of more substituted double bonds.



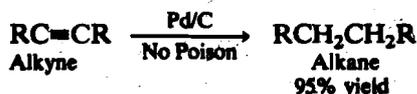
A catalyst mixed with a selective inhibiting agent is called a poisoned catalyst.

Like alkenes, alkynes also undergo catalytic hydrogenation. Addition of hydrogen to an alkyne takes place in two steps. The first addition results in the formation of an alkene; since an alkene can also undergo catalytic hydrogenation, the second addition gives an alkane. By using a calculated amount of hydrogen and a poisoned catalyst, hydrogenation can be stopped at the alkene stage. The catalytic poisons selectively block hydrogenation of alkenes.



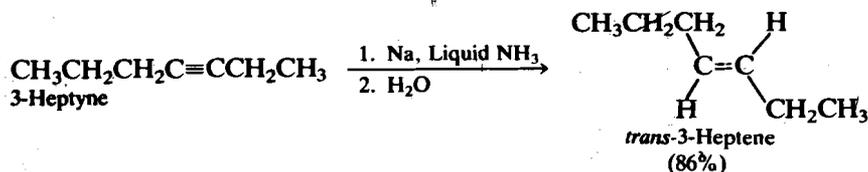
Stereoselective reaction is a reaction which yields predominantly one isomer.

This is a stereoselective addition reaction giving predominantly *cis* alkenes. In the absence of a poison, catalytic hydrogenation of an alkyne gives the alkane.



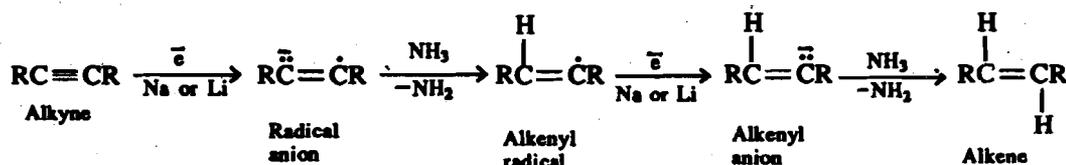
Can we modify the reduction of alkynes so as to get only *trans* alkenes? The answer is yes; we can get only *trans* products, but with a different reducing agent and through a different mechanism.

If we carry out the reduction of an alkyne with sodium metal or lithium metal in liquid ammonia, *trans* alkene is almost the exclusive product. For example, 3-heptyne is reduced to *trans*-3-heptene in this way:

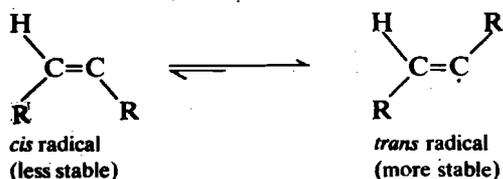


A radical anion has one centre with a negative charge and another, with an unpaired electron.

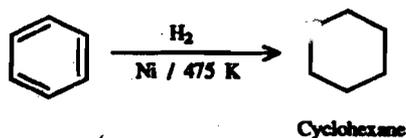
In the first step of this mechanism, the alkyne accepts one electron to give a radical anion. The radical anion is protonated by the ammonia solvent to give an alkenyl radical; which gets further reduced by accepting another electron to give an alkenyl anion. This species is again protonated to give the alkene.



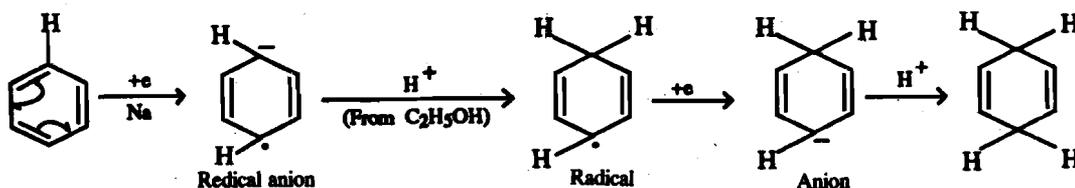
Formation of the *trans* alkene is due to the rapid equilibration of the intermediate alkenyl radical between the *cis*- and *trans*-forms. The equilibrium lies on the side of the more stable *trans* species.



Aromatic rings are resistant to catalytic hydrogenation and hence forcing conditions of high temperature and pressure are required for their hydrogenation.



When aromatic rings are reduced by sodium, potassium or lithium in liquid ammonia, usually in the presence of an alcohol, they yield 1,4-dihydrobenzene (cyclohexa-1,4-diene). This reaction is called Birch reduction. This reaction proceeds through a radical anion intermediate.



The function of sodium is to supply electrons while the function of alcohol is to supply protons.

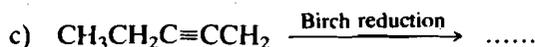
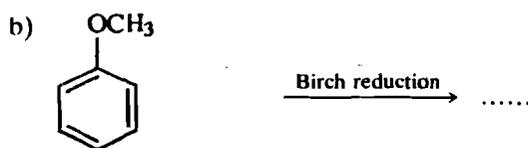
Groups attached to the aromatic ring effect the rate of Birch reduction. Electron donating groups decrease the rate of the reaction and are generally found on the nonreduced position of the product. On the other hand, electron withdrawing groups increase the rate of the reaction and are found on the reduced positions of the product.

Ordinary alkenes do not undergo Birch reduction. However, phenylated alkenes, internal alkynes and conjugated alkenes do undergo Birch reduction.

Alkenes and alkynes can also be reduced by hydroboration which you have studied in Unit-5.

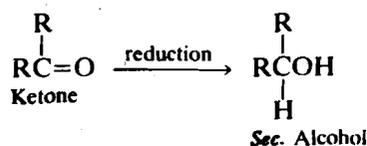
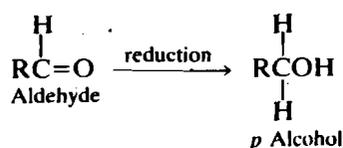
SAQ 3

Give the products in the following Birch reduction.



8.4.2 Reduction of Aldehydes and Ketones

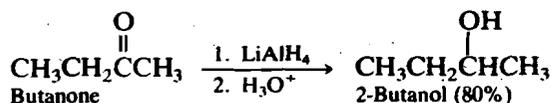
Both aldehydes and ketones undergo reduction, the nature of the product depending on the reagent used for the purpose. Catalytic hydrogenation or reduction with dissolving metals (e.g., sodium and alcohol) or metallic hydrides (lithium aluminium hydride or sodium borohydride) give alcohols. Reduction of aldehydes gives primary alcohols and that of ketones gives secondary alcohols.



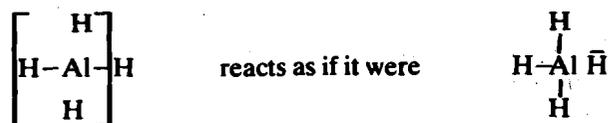
Reduction of aldehydes or ketones can be carried out by a number of reagents. Let us discuss them separately.

Reduction with Metal Hydrides

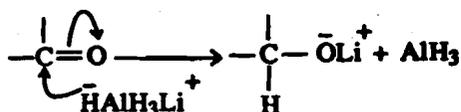
Complex metal hydrides (lithium aluminium hydride or sodium borohydride) are versatile reducing agents. Lithium aluminium hydride (LiAlH_4) readily reduces aldehydes, ketones, carboxylic acids, amides and esters. It can be used in solvents like ether or tetrahydrofuran (THF), for example,



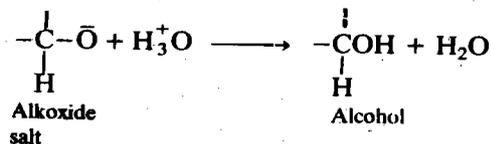
Mechanism: To understand the mechanism of reduction with LiAlH_4 , let us first study some important characteristics of LiAlH_4 . This reagent is a good source of H^- , the hydride ion. This is because hydrogen is more electronegative than aluminium. Thus, the $\text{Al}-\text{H}$ bonds of the AlH_4 ion carry a substantial fraction of the negative charge. In other words,



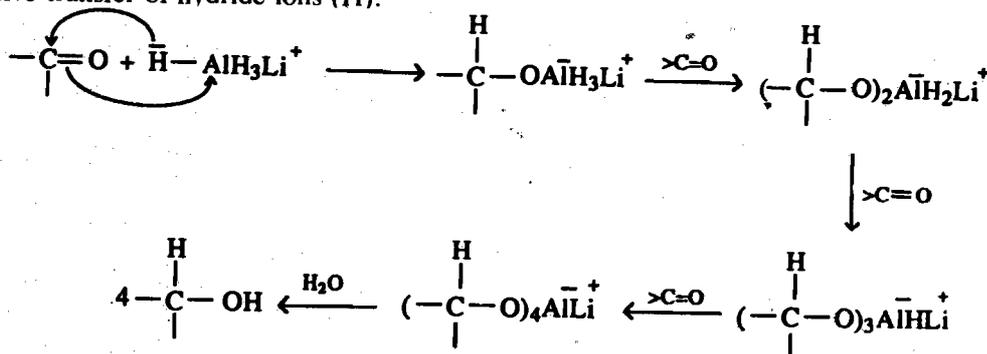
In the reaction of LiAlH_4 with an aldehyde or a ketone, the hydride ion (obtained from AlH_4) attacks the carbonyl carbon and the lithium ion, coordinated to the carbonyl oxygen, acts as a Lewis-acid catalyst.



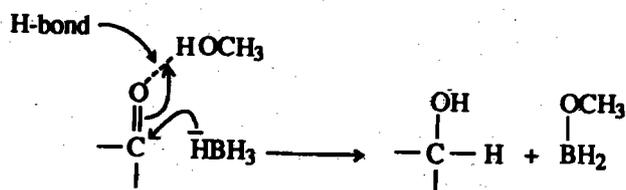
In the second step, proton from hydronium ion is added to the alkoxide salt to give the alcohol.



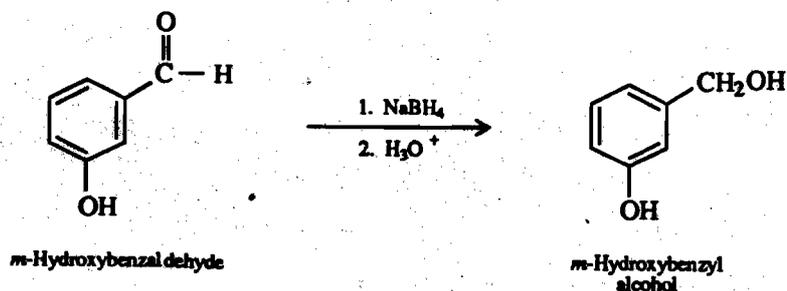
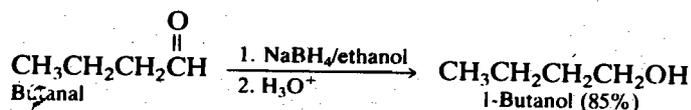
All the four hydrogen atoms in LiAlH_4 may be used in reduction which involves successive transfer of hydride ions (H^-).



Sodium borohydride (NaBH_4) is another important reducing agent. It also reduces aldehydes and ketones to alcohols. The reduction of aldehydes and ketones with NaBH_4 is conceptually similar to that of LiAlH_4 . But unlike lithium ion, sodium ion does not coordinate to the carbonyl oxygen. For this reason NaBH_4 reduction can be carried out in protic solvents, like water or alcohol. Hydrogen bonding between the solvent (alcohol) and the carbonyl group serves as a weak acid catalyst that activates the carbonyl group.

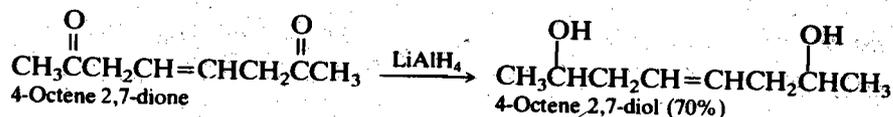


High yields are usually obtained by such reduction, as the following examples indicate.

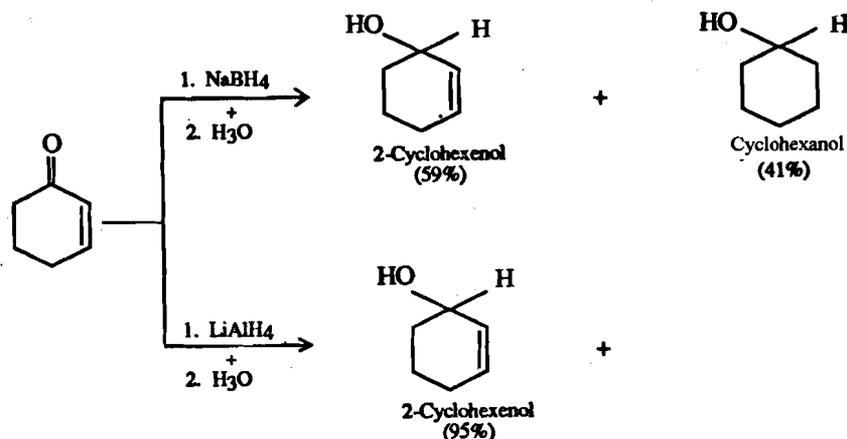


Both LiAlH_4 and NaBH_4 are highly useful reducing agents. However, LiAlH_4 is much more reactive than NaBH_4 . There are a number of functional groups that react with LiAlH_4 but not with NaBH_4 .

Neither NaBH_4 nor LiAlH_4 reduces isolated double bonds, consequently, a molecule that contains both a double bond and a carbonyl group can often be reduced selectively at the carbonyl position, e.g.

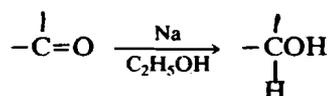


However, a carbon-carbon double bond in conjugation with a carbonyl group is sometimes attacked. LiAlH_4 is particularly useful for reducing α, β -unsaturated ketones which often undergo overreduction with NaBH_4 to give a mixture of both unsaturated and saturated alcohols. With LiAlH_4 , however, a clean reduction to the allylic alcohol occurs. For example, 2-cyclohexenone on reduction with NaBH_4 gives 59% 2-cyclohexenol and 41% cyclohexanol, whereas 95% 2-cyclohexenol is obtained when LiAlH_4 is used as a reducing agent.

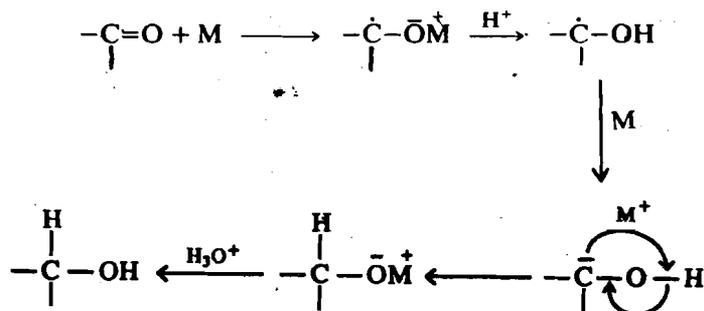


Reduction with Metals

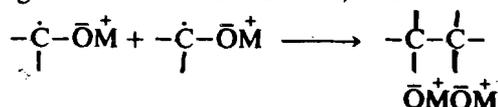
Aldehydes and ketones can also be reduced by treatment with metals e.g., sodium in ethanol.



In connection with the reduction of aromatic compounds, you have learnt that a metal transfers an electron to the aromatic ring and the radical anion formed takes up a proton to give a neutral radical which is then reduced further. A similar mechanism operates here.



If a proton source is not available, dimerisation of the first formed radical anion may occur to give the dialkoxide of the 1, 2-diol.



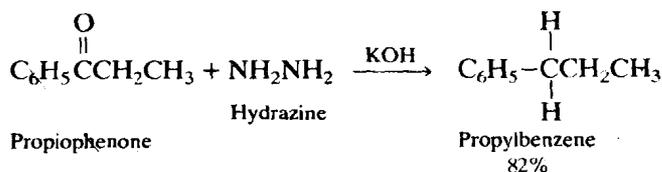
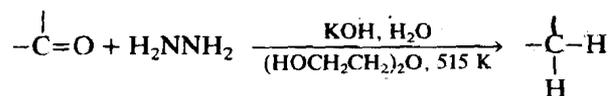
Reduction of Aldehydes or Ketones to Hydrocarbons

Aldehydes and ketones can be reduced to hydrocarbons by the action of (i) hydrazine and a strong base like potassium hydroxide (Wolff-Kishner reduction) or (ii) amalgamated zinc and concentrated hydrochloric acid (Clemmensen reduction) or (iii) aldehydes or ketone and phosphonium ylides (Wittig reaction). Wittig reaction you have studied in Unit 6. Here we shall discuss only Wolff-Kishner reduction and Clemmensen reduction.

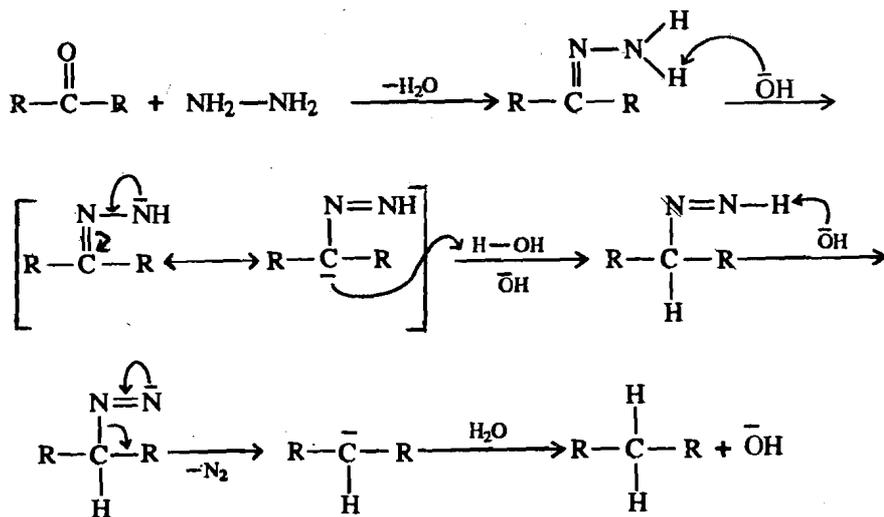
In 1911 Ludwig Wolff in Germany and N.M. Kishner in Russia discovered this reaction independently.

i) Wolff-Kishner Reduction

Aldehydes and ketones can be reduced to alkanes by treating them with hydrazine, $\text{H}_2\text{N}-\text{NH}_2$, at a high temperature, in alkaline medium. This reaction is known as Wolff-Kishner reduction. It is a useful synthetic method for converting an aldehyde or a ketone to an alkane. For example,



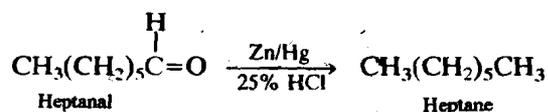
This reaction is an extension of imine formation, discussed in Unit 6. The aldehyde or ketone is first converted to a hydrazone, the imine of hydrazine, by reaction with hydrazine. The hydrazone is then treated with a base, which leads to the expulsion of nitrogen and formation of a carbanion which is instantaneously protonated by water to give an alkane.



Wolff-Kishner reduction can be carried out at room temperature if a strong base like potassium 2-methyl-2-propoxide is used in a polar solvent like dimethyl sulphoxide.

ii) Clemmensen Reduction

Aldehydes and ketones can be converted into the corresponding alkanes under acidic conditions by Clemmensen reduction. In this reaction, zinc amalgam (an alloy of zinc and mercury) and concentrated HCl are used to reduce an aldehyde or ketone.

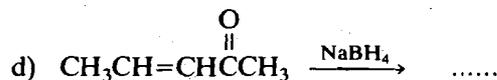
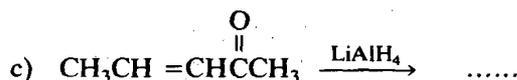
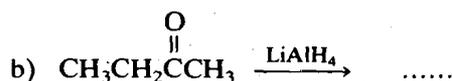
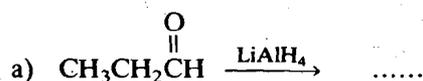


There is considerable uncertainty about the mechanism of this reaction.

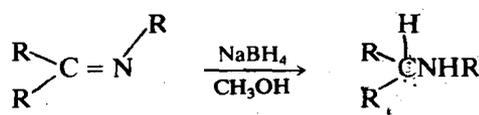
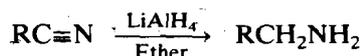
Wolff-Kishner or Clemmensen reduction are particularly useful for the introduction of alkyl groups into benzene ring. You may recall that Friedel-Crafts alkylation can also be used for this purpose. But the problem with Friedel-Crafts alkylation is that rearrangement of the alkyl groups is usually observed.

SAQ 4

Give the products of the following reactions

**8.4.2 Reduction of Some Nitrogen Functional Groups**

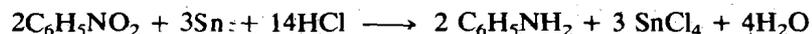
Carbon-nitrogen double bond can be easily reduced by reagents used for carbon oxygen double bond.

Nitriles containing a carbon nitrogen triple bond can be reduced to primary amines with LiAlH_4 

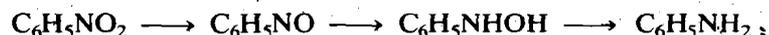
Primary amines can also be obtained by reduction of nitro compounds



Aromatic nitro compounds are often reduced using a metal, tin or iron, with hydrochloric acid. The amine is obtained as salt from which it can be liberated with aqueous sodium hydroxide. Tin(0) is oxidised to Tin(IV) in the process.



The reduction is believed to proceed through the following stages:

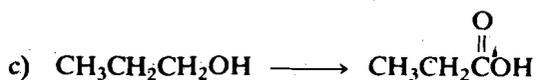
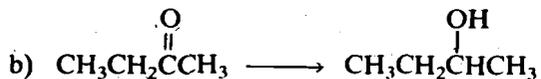
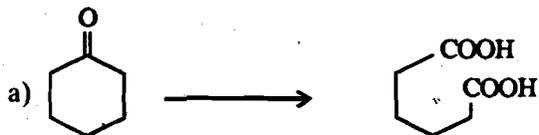
By varying the reaction conditions, specially the pH of the solution, some of these intermediates can be isolated. For example, with Zn dust and ammonium chloride solution, the main product is $\text{C}_6\text{H}_5\text{NOH}$ (phenyl hydroxylamine).**8.5 SUMMARY**

- Conversion of a functional group in a molecule from a lower oxidation state to a higher oxidation state is known as oxidation, reduction is just the reverse of oxidation.
- Alkenes can be oxidised to aldehydes using transition metal complexes.
- Alcohols with α hydrogen undergo oxidation with a number of oxidising agents. Primary alcohols first give aldehydes which tend to get oxidised further to give carboxylic acids. Secondary alcohols on oxidation give ketones and tertiary alcohols do not get oxidised easily.
- Unsaturated aliphatic hydrocarbons can be reduced with the help of transition metal catalyst. Aromatic ring can be reduced by sodium or potassium in liquid ammonia to give 1,4-dihydrobenzene.
- Aldehydes are easily oxidised to acids while ketones are fairly resistant to oxidation.

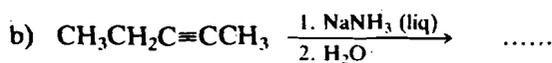
- Both aldehydes and ketones undergo reduction with metals or metallic hydrides (LiAlH_4 or NaBH_4) to give alcohols.
- Aldehydes and ketones can be reduced to hydrocarbons by (a) Clemmensen reduction (b) Wolff Kishner reduction and (c) Wittig reaction.

8.6 TERMINAL QUESTIONS

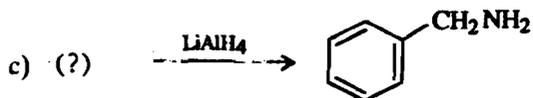
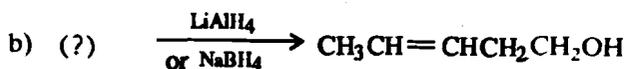
1) What reagents can be used to bring about the following transformation.



2) Complete the following equations



3) Give starting compounds for the following



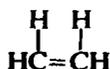
4) Write one example for the following reactions

- Wolff-Kishner reaction
- Clemmensen reaction

8.7 ANSWERS

Self Assessment Questions

1) a) Lewis structure of ethene:

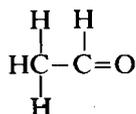


No. of valence electrons of carbon = 4

No. of electron assigned to carbon = 6

Oxidation state = $4 - 6 = -2$

b) Lewis structure of ethanal

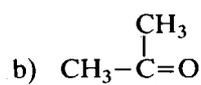
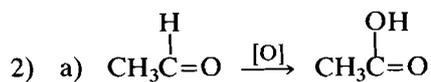


No. of valence electrons of carbon = 4

No. of electrons assigned to alkyl carbon = 7

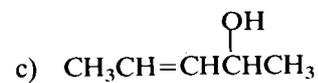
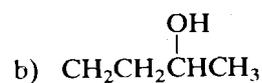
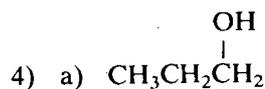
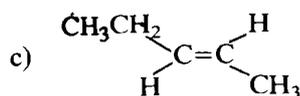
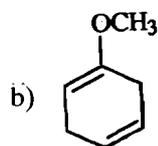
No. of electrons assigned to carbonyl = 3

Therefore,

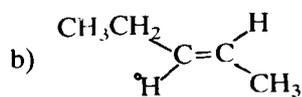
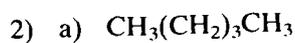
Oxidation state of alkyl carbon = $4 - 7 = -3$ Oxidation state of carbonyl carbon = $4 - 3 = +1$ Average oxidation state = $(-3) + (+1)/2 = -1$ 

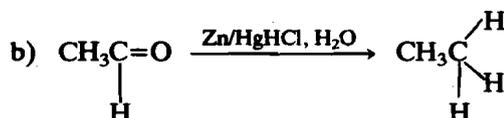
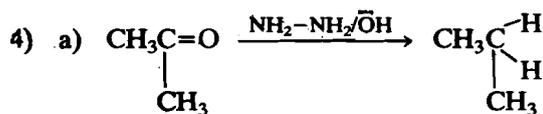
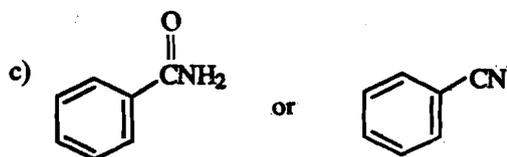
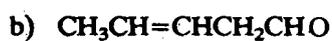
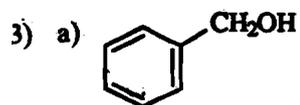
c) No reaction

3) a) No reaction

**Terminal Questions**

- 1) a) KMnO_4 , OH
 b) LiAlH_4 or NaBH_4
 c) Jone's reagent





Further Reading

- 1) Organic Chemistry, 5th edition; by R.T. Morrison and R.N. Boyd; Prentice-Hall of India Pvt. Ltd.
- 2) A Text Book of Organic Chemistry; by B.S. Bhal and Arun bahal; R. Chand & Company Ltd.
- 3) Organic Chemistry, Vol. I and II; by S.M. Mukherji, S.P. Singh and R.P. Kapoor; Wiley Eastern Ltd.
- 4) Text Book of Organic Chemistry, 24th edition; by P.L. Soni and H.M. Chawla; Sultan Chand & Sons.
- 5) Text Book of Organic Chemistry, 2nd edition; by Llyod N. Ferguson; Affiliated East-West Press Pvt. Ltd.
- 6) Reaction Mechanism and Reagent in Organic Chemistry, 2nd edition; by Gurdeep R. Chatwal; Himalava Publishing House.