B.Sc. (Honours) Part-I

Paper-IC

Topic: Inductive Effect

UG

Subject-Chemistry

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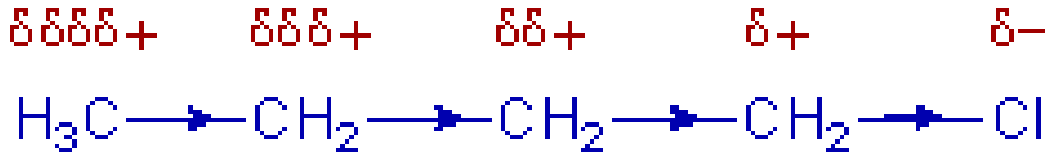
Inductive Effect

When an electron-donating or an electron-withdrawing group or species is introduced to a carbon chain of atoms their corresponding negative or positive charge is relayed through the carbon chain by the atoms belonging to it. This causes a permanent dipole to arise in the molecule it is called as the inductive effect.

Inductive Effect refers to the phenomenon wherein a permanent dipole arises in a given molecule due to the unequal sharing of the bonding electrons in the molecule. This effect can arise in sigma bonds.



In above example it is cleared that the inductive effect that arises in a chlorobutane molecule due to the more electronegative chlorine atom.

Salient features of inductive effect

- It is transmitted through the sigma bonds.
- It arises due to electronegativity difference between two atoms forming a sigma bond.
- The magnitude of inductive effect decreases while moving away from the groups causing it.

- It is a permanent effect.
- It influences the chemical and physical properties of compounds.

Inductive effect divided into two types:

1. Negative inductive effect (-I effect)

2. Positive inductive effect (+I effect)

1. Negative inductive effect (-I effect)

When an electronegative atom, such as a halogen, is introduced to a carbon chain of atoms resulting unequal sharing of electrons generates a positive charge which is transmitted through the chain. This causes a permanent dipole to arise in the molecule wherein the electronegative atom holds a negative charge and the corresponding effect is called the electron withdrawing inductive effect, or the -I effect.. Following are some examples of groups in decreasing order of their -I effect.

$NH_3^+ > NO_2 > CN > SO_3H > CHO > CO > COOH > COCl > CONH_2 > F > Cl > Br > I > OH > OR > NH_2 > C_6H_5 > H$

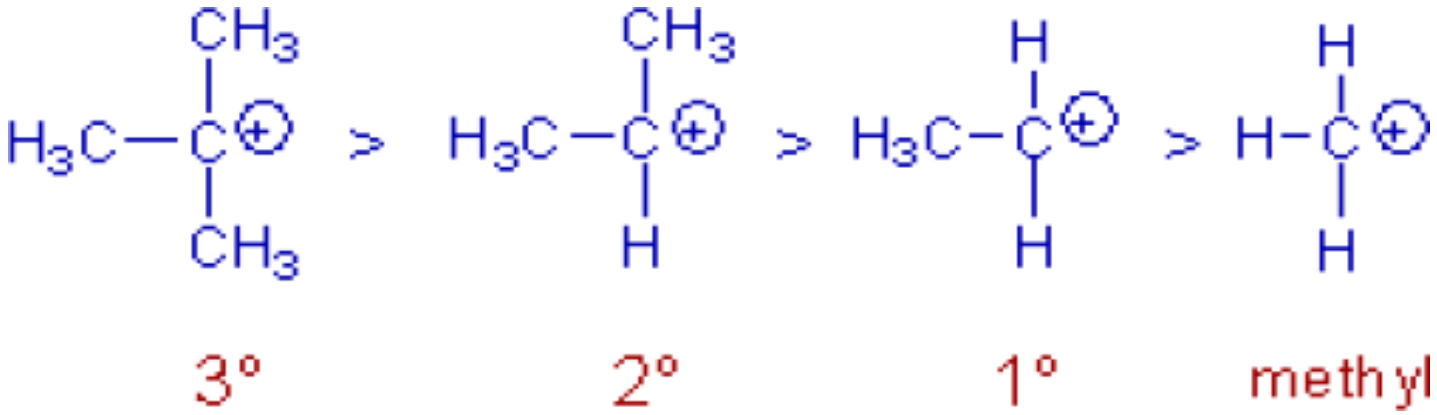
2. Positive inductive effect (+I effect)

- When a chemical species with the tendency to release or donate electrons, such as an alkyl group, is introduced to a carbon chain, the charge is relayed through the chain and this effect is called the Positive Inductive Effect or the +I Effect. Following are some examples of groups in decreasing order of their +I effect.

$$C(CH_3)_3 > CH(CH_3)_2 > CH_2CH_3 > CH_3 > H$$

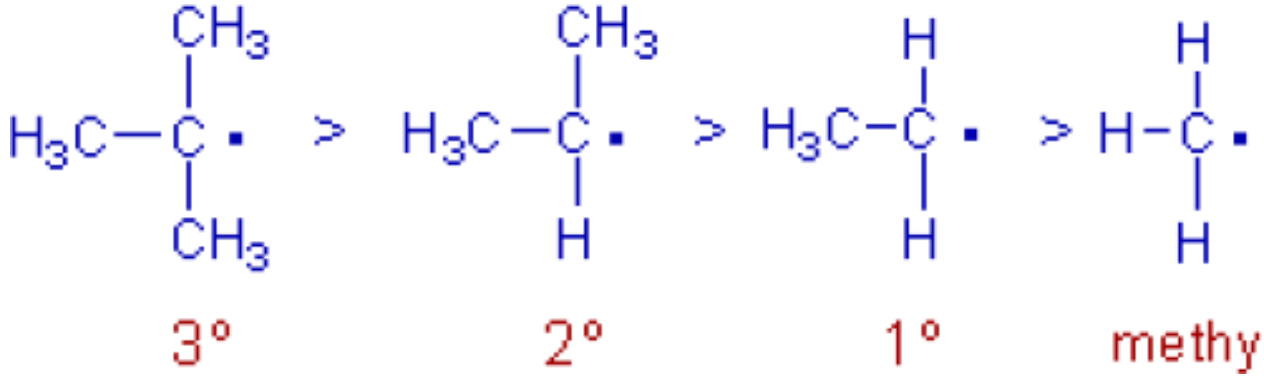
- **Applications of Inductive effects:**

1. The stability of carbocation increases with increase in number of alkyl groups due to their +I effect. The alkyl groups release electrons to carbon, bearing positive charge and thus stabilizes the ion.



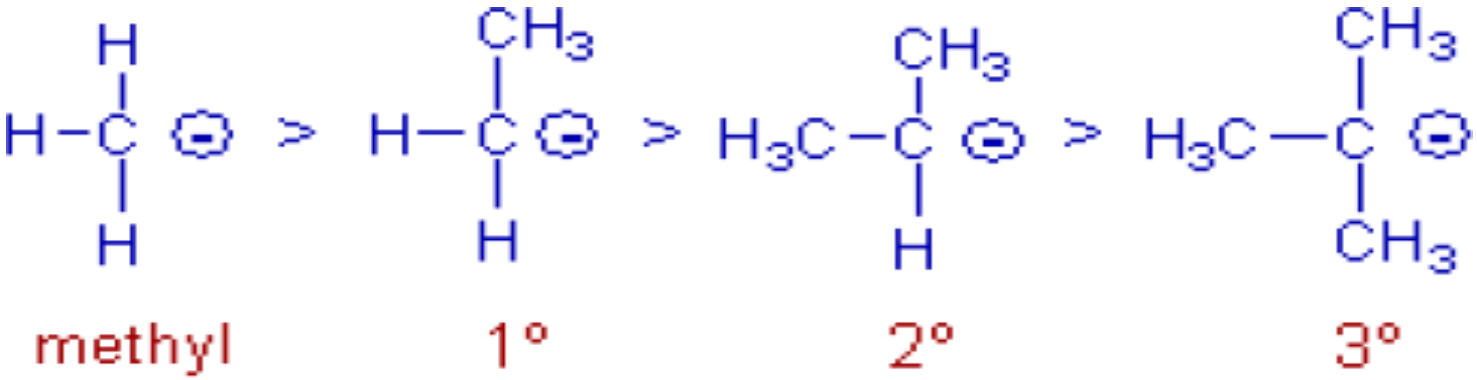
The order of stability of carbocation with decreasing order

2. In the same way the stability of free radicals increases with increase in the number of alkyl groups.



The order of stability of free radical with decreasing order

3. However the stability of carbanions decreases with increase in the number of alkyl groups since the electron donating alkyl groups destabilize the carbanions by increasing the electron density.



The order of stability of carbanion with decreasing order

4. Acidic strength of carboxylic acids and phenols:

The electron withdrawing groups (-I) decrease the negative charge on the carboxylate ion and thus by Stabilizes it. Hence the acidic strength increases when - I groups are present. However the +I groups decrease the acidic strength.

a) The acidic strength increases with increase in the number of electron withdrawing Fluorine atoms as shown below.

$CH_3COOH < CH_3COOH < CHF_2COOH < CF_3COOH$

b) Basic strength of amines:

The electron donating groups like alkyl groups increase the basic strength of amines whereas the electron withdrawing groups like aryl groups decrease the basic nature. Therefore akyl amies are stronger Lewis bases than ammonia, whereas aryl amines are weaker than ammonia.

Thus the order of basic strength of alky and aryl amines with respect to ammonia is as,

$$CH_3NH_2 > NH_3 > C_6H_5NH_2$$

c) Reactivity of carbonyl compounds:

The +I groups increase the electron density at carbonyl carbon. Hence their reactivity towards nucleophiles decreases. Thus formaldehyde is more reactive than acetaldehyde and acetone towards nudeophilic addition reactions.

Thus the order of reactivity follows: