

CHAPTER 7

Aliphatic Electrophilic Substitution

❖ Bimolecular Mechanisms – SE_2 and SE_i

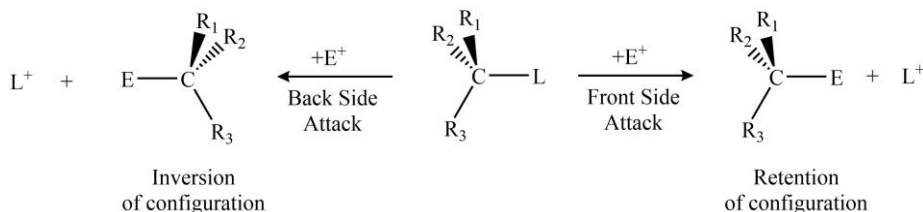
The electrophilic substitution in the aliphatic compounds is just similar to the aliphatic nucleophilic substitution, except for the fact that here an electrophile displaces a functional group rather than an electrophile. In this section, we will discuss the two major types of electrophilic substitutions; SE_2 (substitution electrophilic bimolecular) and SE_i (substitution electrophilic internal) mechanisms.

➤ SE_2 (Substitution Electrophilic Bimolecular) Mechanism

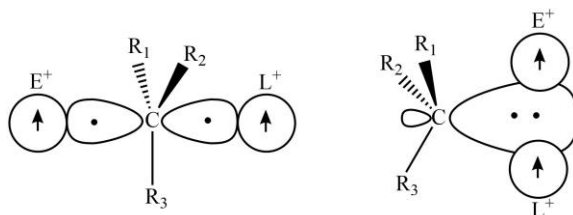
The bimolecular electrophilic substitution (SE_2) reactions may simply be defined as the chemical changes where a stronger electrophile displaces a weaker one in an aliphatic substrate.

This mechanism is quite analogous with the SN_2 route excepting the mode of attack. In the SN_2 mechanism, a stronger nucleophile replaces a weaker one via the backside attack due to its inter-cloud repulsion with the leaving group; however, in the SE_2 route, the attacking electrophile may come from the front, as well as from the backside because it is only using its vacant orbital towards substrates causing little to no repulsion. So, the SE_2 mechanism can be divided into SE_2 -front and SE_2 -back based upon the front and back attacks, respectively.

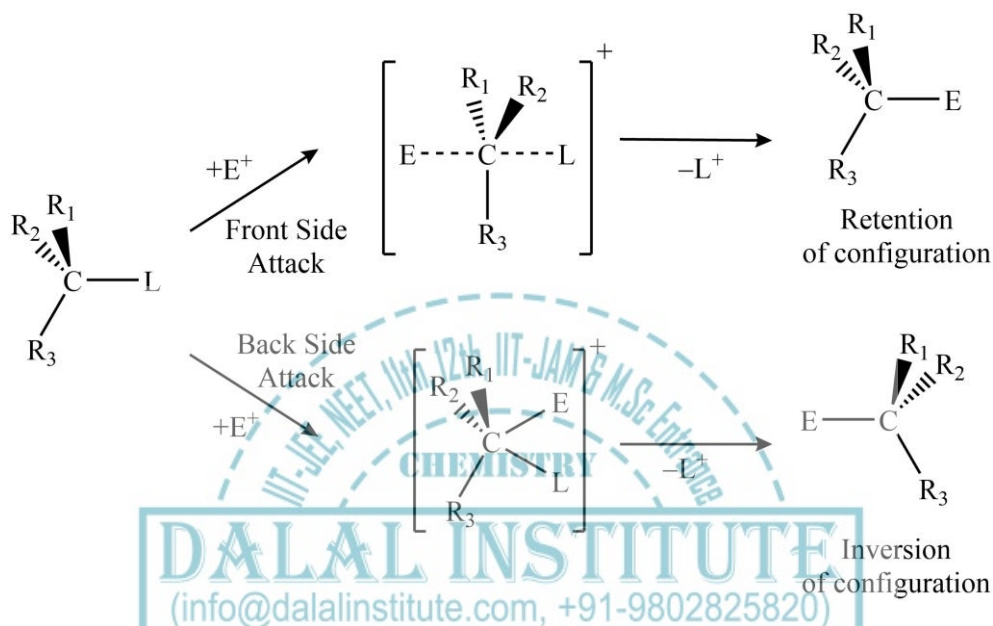
Illustrative reaction: The general reaction showing both types of electrophilic attacks (with their corresponding products), is shown below.



Mechanism involved: The proposed mechanism for the reaction given above says that the two electrons of the carbon-electrophile bond reside in the central orbital. Ingold proposed that the electronic distribution responsible for different stereochemistry of products is a function of bond-extension's magnitude and the extent of bond ionicity of the transition state.



It is obvious that the transition state needs to have high ionicity and good bond extension potential for SE_2 -back reactions so that the carbon's orbital is sufficiently spread on both ends, resulting in the inverted configuration in the case of a chiral substrate. On the other hand, if there is a very little bond extension and low ionicity in the transition state, the electron-pair of the original bond pretty much retains its position and gives rise to the retention of the configuration, and we get SE_2 -front case.



Where E^+ is the attacking electrophile whereas L^+ is the leaving group. Furthermore, it is also worthy to note that organometallic compounds have exceptional susceptibility towards electrophilic substitution.

Salient Features: The main features of the mechanism involved in electrophilic substitution bimolecular or SE_2 type reactions are given below.

i) SE_2 reactions follow second-order kinetics with the rate law

$$\text{Rate} = k[RX][E]$$

Where k is the rate constant. The symbol $[RX]$ and $[E]$ represent the molar concentration of the substrate and attacking electrophile, respectively.

ii) If the substrate is chiral, then the SE_2 mechanism can lead to the inversion, as well as, retention of the configuration; depending upon the mode of attack (front or back).

iii) The rate of the substitution becomes independent of the concentration of the attacking electrophile if its concentration is extremely high in comparison to the substrate.

iv) Stereochemical studies can be employed to differentiate between SE_2 -front and SE_2 -back.

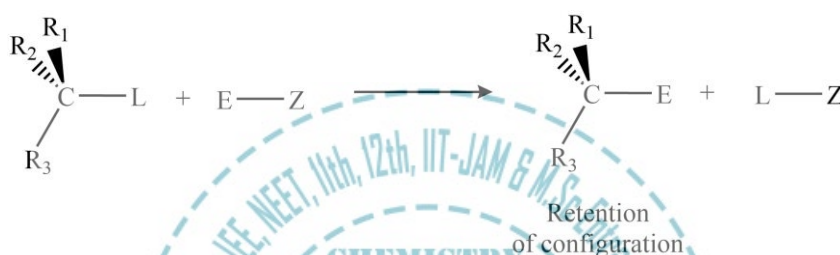
v) The SE_2 reactions are favored by the more polar $C-L$ bond.

➤ **SE_i (Substitution Electrophilic Internal) Mechanism**

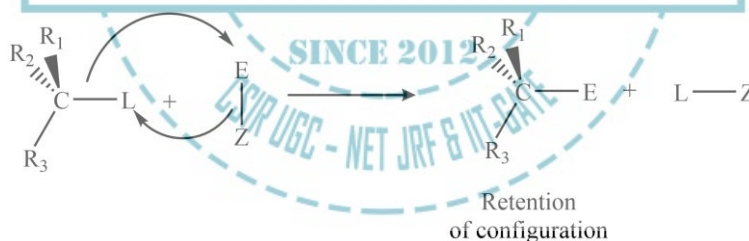
The internal electrophilic substitution (SE_i) reactions may simply be defined as the chemical changes where a stronger electrophile displaces a weaker one in an aliphatic substrate by assisting its departure.

This mechanism is also very analogous with the SN₂ route excepting the mode of attack. In the SN₂ mechanism, a stronger nucleophile replaces a weaker one via the backside attack due to its inter-cloud repulsion with the leaving group; however, in the SE_i route, the attacking electrophile comes from the front and assists the departure of leaving group by forming a bond with it.

Illustrative reaction: The general reaction showing this type of electrophilic attack (with the corresponding product) is shown below.



Mechanism involved: The proposed mechanism for the reaction given above says that the two electrons of the carbon-electrophile bond reside in the central orbital. It is observed that if there is a very little bond extension and low ionicity in the transition state, the electron-pair of the original bond pretty much retains its position and gives rise to the retention of the configuration, and we get SE_i case (like SE₂-front).



Salient Features: The main features of the mechanism involved in electrophilic substitution internal or SE_i type reactions are given below.

i) SE_i reactions follow second-order kinetics with the rate law

$$\text{Rate} = k[\text{RX}][\text{EZ}]$$

Where k is the rate constant. The symbol $[\text{RX}]$ and $[\text{EZ}]$ represent the molar concentration of the substrate and attacking electrophile, respectively.

ii) Like SE₂-front, SE_i reactions result in the retention of the configuration.

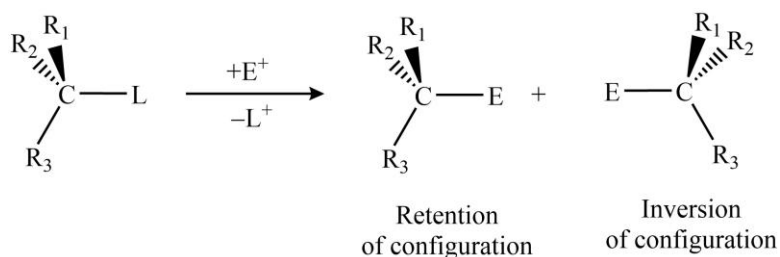
iii) The SE₂ reactions are favored by the more polar C-L bond.

❖ The SE_1 Mechanism

The unimolecular electrophilic substitution (SE_1) reactions may simply be defined as the chemical change in which a stronger electrophile displaces a weaker one in an aliphatic substrate via the formation of a carbanion.

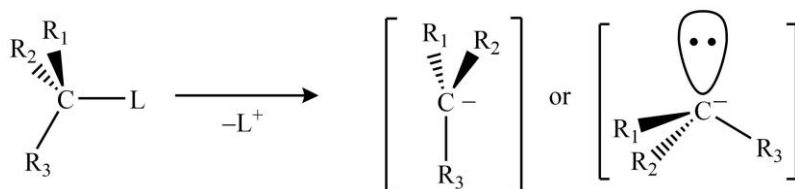
This mechanism is quite analogous with the SN_1 route excepting the nature of intermediate. In the SN_1 mechanism, a stronger nucleophile replaces a weaker one via the formation of a carbocation intermediate; however, in the SE_1 route, before the attacking electrophile attack, the intermediate formed after the dissociation of electrofuge is a carbanion.

Illustrative reaction: The general reaction showing this type of electrophilic attack (with its corresponding product) is shown below.

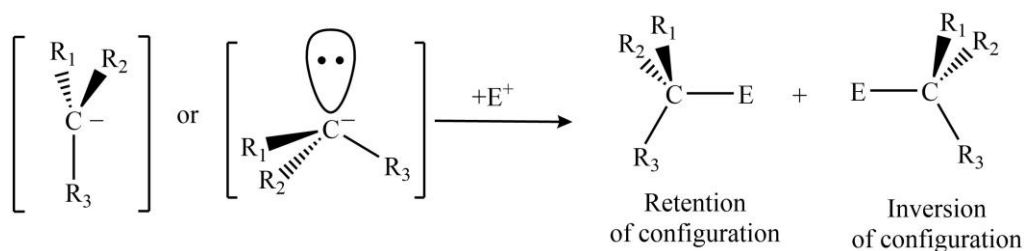


Mechanism involved: The proposed mechanism for the reaction given above involves a three-step route which must be discussed before we give the salient features of the same.

i) *Heterolysis in substrate:* This is the slowest, and therefore, is the rate-determining step that gives rise to a carbanion.



ii) *Electrophilic attack:* This is a very fast step and involves the combination of attacking electrophile with the carbanion produced in the previous step.



The stereochemistry of SE_1 reactions is quite complicated to rationalize because of the configuration of intermediary carbanions obtained via the first step of heterolysis. Generally, we consider carbanions planar (sp^2 hybridization) or pyramidal (sp^3 hybridization), or an in-between configuration. As far as the energy is concerned, pyramidal geometry is more advantageous because lone pair will stay in sp^3 hybridized orbital. Furthermore, a pyramidal carbanion can retain its structure in the course of substitution to result in the retention of the final configuration. However, it does not always go this way because a pyramidal carbanion has been shown to result in racemization due to ‘pyramidal inversion’; amines and R_3C^- carbanions are typical examples.



Figure 1. The pyramidal inversion of carbanion.

On the other hand, if the carbanion is of trigonal planar geometry, the electrophile can attack from both sides to give rise to racemized yield. So, we can conclude that racemization is the characteristic feature of the SE_1 route. However, it is quite tedious to determine how the racemization actually occurred; via pyramidal inversion or planar carbanions.

Salient Features: The main features of the mechanism involved in electrophilic substitution unimolecular or SE_1 type reactions are given below.

i) SE_2 reactions follow first-order kinetics with the rate law

$$Rate = k[RX]$$

Where k is the rate constant. The symbol $[RX]$ represents the molar concentration of the substrate.

ii) If the substrate is chiral, then this always leads to the racemization of the final product.

iii) Unlike SN_1 -type, SE_1 reaction can also occur at bridgehead carbon because the intermediate (carbanion in this case) need not to be planar.

iv) The rate of the substitution increases as the steric bulk around the carbon center decreases.

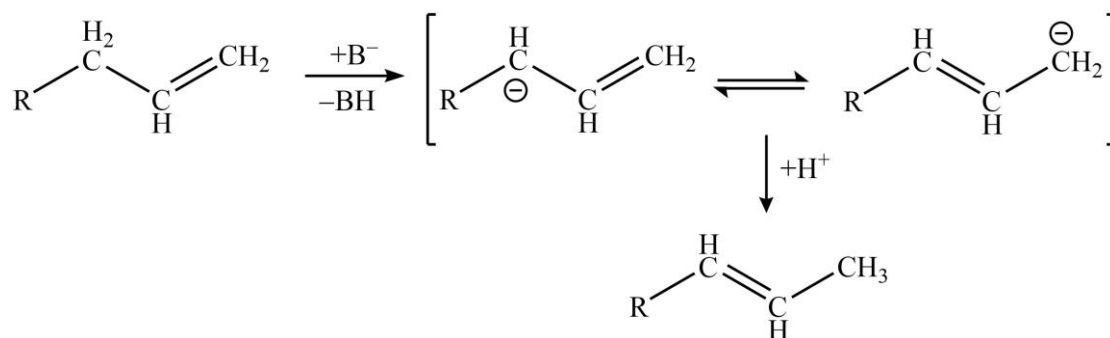
v) The SE_2 reactions are favored by the more polar C–L bond.

❖ Electrophilic Substitution Accompanied by Double Bond Shifts

If the substrate in electrophilic substitution is allylic in nature, the final product may undergo rearrangement, which is quite similar to the allylic rearrangements in nucleophilic substitutions. There are two main routes for this behavior to occur; one is analogous to the SE_1 pathway (leaving group is detached first) giving a resonance-stabilized allylic carbanion which attacks the electrophile E, the second one involves the initial attack on E by the π -bond to yield a carbocation which then which loses X forming new alkene unit.

➤ *Base-catalyzed Double Bond Migration*

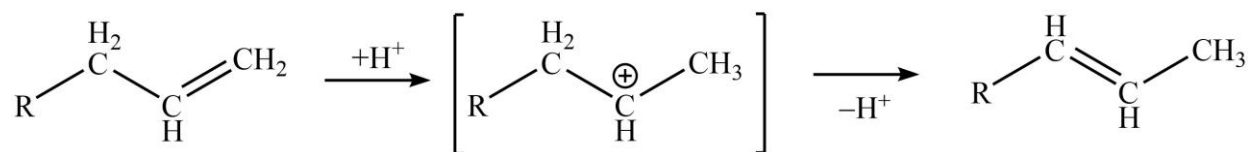
The first pathway is the base-catalyzed double bond migration, where an equilibrium mixture of isomers is obtained with stable configuration as the major product. The reaction occurs in two steps, in which the step is the abstraction of a proton by the base to yield a resonance stabilized carbanion, which in turn, is attacked by electrophile (proton in this case) to give rise to a more stable species. The typical reaction portraying mechanism is given below.



It is also worthy to note that terminal and non-conjugated alkenes can easily be converted into internal and conjugated olefins using this route, proving its significance in synthetic organic chemistry.

➤ *Acid-catalyzed Double Bond Migration*

The second pathway is the acid-catalyzed double bond migration, where an equilibrium mixture of isomers is obtained with a stable configuration as the major product. The reaction initiates with the attack of E on the π -bond to yield a carbocation which then loses L forming a new alkene unit. The typical reaction portraying mechanism is given below.



Just like base-catalyzed double bond migration, this route can also be used to convert terminal and non-conjugated alkenes into internal and conjugated olefins.

➤ *Effect of Solvent Polarity*

Just like the case of aliphatic nucleophilic substitution reactions, the raise in solvent polarity boosts the chances of the SE_1 pathway by supporting the ionization because of the better solvation of carbanions. However, if SE_2 and SE_1 reactions are competing with each other in parallel propagation, then less polar solvents favor the SE_2 pathway and polar solvents favor the SE_1 mechanism. Finally, If the nucleophilic character of the solvent is very small, the electrophile with properly placed assisting functionality might support the reaction; and therefore, motivating the reaction towards the SE_i pathway; otherwise, solvent polarity has little to no effect upon SN_i reactions.



❖ Problems

- Q 1. Define electrophilic substitution reactions.
- Q 2. What is the fundamental difference between SE_2 and SE_i mechanisms?
- Q 3. Discuss the step-to-step mechanism of SE_1 reactions.
- Q 4. How can electrophilic substitution occur via double bond shift?
- Q 5. Discuss the effect of substrate structure and leaving group on the reactivity of electrophilic substitution in aliphatic compounds.
- Q 6. How does the nature of nucleophiles affect the rate of aliphatic electrophilic substitution?
- Q 7. Write down a short note on the solvent polarity's effect on electrophilic substitution reactions in aliphatic systems.

❖ Bibliography

1. M. B. Smith, *March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure*, John Wiley & Sons, Inc., New Jersey, USA, 2013.
2. D. Klein, *Organic Chemistry*, John Wiley & Sons, Inc., New Jersey, USA, 2015.
3. C. A. Coulson, B. O'Leary, R. B. Mallion, *Hückel Theory for Organic Chemists*, Academic Press, Massachusetts, USA, 1978.
4. M.S. Singh, *Reactive Intermediates in Organic Chemistry*, John Wiley & Sons, Inc., New Jersey, USA, 2014.
5. H. Zimmerman, *Quantum Mechanics for Organic Chemists*, Academic Press, New York, USA, 1975.
6. J. Clayden, N. Greeves, S. Warren, *Organic Chemistry*, Oxford University Press, Oxford, UK, 2012.
7. R. L. Madan, *Organic Chemistry*, Tata McGraw Hill, New Delhi India, 2013.

LEGAL NOTICE

This document is an excerpt from the book entitled “A Textbook of Organic Chemistry – Volume 1 by Mandeep Dalal”, and is the intellectual property of the Author/Publisher. The content of this document is protected by international copyright law and is valid only for the personal preview of the user who has originally downloaded it from the publisher’s website (www.dalalinstitute.com). Any act of copying (including plagiarizing its language) or sharing this document will result in severe civil and criminal prosecution to the maximum extent possible under law.



This is a low resolution version only for preview purpose. If you want to read the full book, please consider buying.

Buy the complete book with TOC navigation, high resolution images and no watermark.

Home

CLASSES

CSIR UGC – NET JRF, IIT-GATE, M.Sc Entrance, IIT-JAM, IIT-JEE, NEET, 11th and 12th

Want to study chemistry for CSIR UGC – NET JRF + IIT-GATE; IIT-JAM + M.Sc Entrance; IIT-JEE + NEET + 11th +12th; and all other postgraduate, undergraduate & senior-secondary level examinations where chemistry is a paper?
[READ MORE](#)

BOOKS

Publications

Are you interested in books (Print and Ebook) published by Dalal Institute?
[READ MORE](#)

VIDEOS

Video Lectures

Want video lectures in chemistry for CSIR UGC – NET JRF + IIT-GATE; IIT-JAM + M.Sc Entrance; IIT-JEE + NEET + 11th +12th; and all other postgraduate, undergraduate & senior-secondary level examinations where chemistry is a paper?
[READ MORE](#)

Postgraduate Level

Senior-Secondary Level

Undergraduate Level

CSIR UGC – NET JRF & IIT-GATE

First Chemistry Batch
(1st January – 31st May)

Second Chemistry Batch
(1st July – 30th November)

11TH, 12TH, NEET & IIT-JEE

First Chemistry Batch
(1st April – 31st August)

Second Chemistry Batch
(1st October – 28th February)

M.SC ENTRANCE & IIT-JAM

First Chemistry Batch
(1st February – 30th June)

Second Chemistry Batch
(1st August – 31st December)

Regular Program

Online Course

Result

Regular Program

Online Course

Result

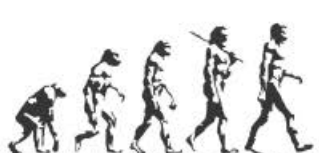
Regular Program

Online Course

Result

Join the revolution by becoming a part of our community and get all of the member benefits like downloading any PDF document for your personal preview.

[Sign Up](#)



JOIN THE REVOLUTION FROM BEAST TO

BUDDHA

D DALAL INSTITUTE

.....Chemical Science Demystified.....

Main Market, Sector 14, Rohtak, Haryana 124001, India
(+91-9802825820, info@dalalinstitute.com)
www.dalalinstitute.com

..... India's Best Coaching Center for Academic and Competitive Chemistry Exams
(CSIR UGC – NET JRF + IIT-GATE; IIT-JAM + M.Sc Entrance; IIT-JEE + NEET + 11th +12th; and all other postgraduate, undergraduate & senior-secondary level examinations where chemistry is a paper)

International
Edition



A TEXTBOOK OF ORGANIC CHEMISTRY

Volume I

MANDEEP DALAL



First Edition

DALAL INSTITUTE

Table of Contents

CHAPTER 1	11
Nature of Bonding in Organic Molecules	11
❖ Delocalized Chemical Bonding	11
❖ Conjugation	14
❖ Cross Conjugation	16
❖ Resonance	18
❖ Hyperconjugation	27
❖ Tautomerism	31
❖ Aromaticity in Benzenoid and Nonbenzenoid Compounds	33
❖ Alternant and Non-Alternant Hydrocarbons	35
❖ Huckel's Rule: Energy Level of π -Molecular Orbitals	37
❖ Annulenes	44
❖ Antiaromaticity	46
❖ Homoaromaticity	48
❖ PMO Approach	50
❖ Bonds Weaker Than Covalent	58
❖ Addition Compounds: Crown Ether Complexes and Cryptands, Inclusion Compounds, Cyclodextrins	65
❖ Catenanes and Rotaxanes	75
❖ Problems	79
❖ Bibliography	80
CHAPTER 2	81
Stereochemistry	81
❖ Chirality	81
❖ Elements of Symmetry	86
❖ Molecules with More Than One Chiral Centre: Diastereomerism	90
❖ Determination of Relative and Absolute Configuration (Octant Rule Excluded) with Special Reference to Lactic Acid, Alanine & Mandelic Acid	92
❖ Methods of Resolution	102
❖ Optical Purity	104
❖ Prochirality	105
❖ Enantiotopic and Diastereotopic Atoms, Groups and Faces	107
❖ Asymmetric Synthesis: Cram's Rule and Its Modifications, Prelog's Rule	113
❖ Conformational Analysis of Cycloalkanes (Upto Six Membered Rings)	116
❖ Decalins	122
❖ Conformations of Sugars	126
❖ Optical Activity in Absence of Chiral Carbon (Biphenyls, Allenes and Spiranes)	132
❖ Chirality Due to Helical Shape	137
❖ Geometrical Isomerism in Alkenes and Oximes	140
❖ Methods of Determining the Configuration	146

❖ Problems.....	151
❖ Bibliography.....	152
CHAPTER 3.....	153
Reaction Mechanism: Structure and Reactivity	153
❖ Types of Mechanisms.....	153
❖ Types of Reactions	156
❖ Thermodynamic and Kinetic Requirements.....	159
❖ Kinetic and Thermodynamic Control	161
❖ Hammond's Postulate.....	163
❖ Curtin-Hammett Principle	164
❖ Potential Energy Diagrams: Transition States and Intermediates	166
❖ Methods of Determining Mechanisms.....	168
❖ Isotope Effects	172
❖ Hard and Soft Acids and Bases.....	174
❖ Generation, Structure, Stability and Reactivity of Carbocations, Carbanions, Free Radicals, Carbenes and Nitrenes.....	176
❖ Effect of Structure on Reactivity	200
❖ The Hammett Equation and Linear Free Energy Relationship.....	203
❖ Substituent and Reaction Constants.....	209
❖ Taft Equation.....	215
❖ Problems.....	219
❖ Bibliography.....	220
CHAPTER 4.....	221
Carbohydrates	221
❖ Types of Naturally Occurring Sugars	221
❖ Deoxy Sugars	227
❖ Amino Sugars.....	229
❖ Branch Chain Sugars	230
❖ General Methods of Determination of Structure and Ring Size of Sugars with Particular Reference to Maltose, Lactose, Sucrose, Starch and Cellulose.....	231
❖ Problems.....	239
❖ Bibliography.....	240
CHAPTER 5.....	241
Natural and Synthetic Dyes	241
❖ Various Classes of Synthetic Dyes Including Heterocyclic Dyes	241
❖ Interaction Between Dyes and Fibers	245
❖ Structure Elucidation of Indigo and Alizarin	247
❖ Problems.....	252
❖ Bibliography.....	253
CHAPTER 6.....	254
Aliphatic Nucleophilic Substitution	254
❖ The S_N2 , S_N1 , Mixed S_N1 and S_N2 , S_Ni , S_N1' , S_N2' , S_Ni' and SET Mechanisms.....	254

❖ The Neighbouring Group Mechanisms.....	263
❖ Neighbouring Group Participation by π and σ Bonds	265
❖ Anchimeric Assistance	269
❖ Classical and Nonclassical Carbocations	272
❖ Phenonium Ions.....	283
❖ Common Carbocation Rearrangements.....	284
❖ Applications of NMR Spectroscopy in the Detection of Carbocations	286
❖ Reactivity – Effects of Substrate Structure, Attacking Nucleophile, Leaving Group and Reaction Medium	288
❖ Ambident Nucleophiles and Regioselectivity	294
❖ Phase Transfer Catalysis.....	297
❖ Problems.....	300
❖ Bibliography	301
CHAPTER 7	302
Aliphatic Electrophilic Substitution	302
❖ Bimolecular Mechanisms – SE_2 and SE_i	302
❖ The SE_1 Mechanism	305
❖ Electrophilic Substitution Accompanied by Double Bond Shifts	307
❖ Effect of Substrates, Leaving Group and the Solvent Polarity on the Reactivity	308
❖ Problems.....	310
❖ Bibliography	311
CHAPTER 8	312
Aromatic Electrophilic Substitution	312
❖ The Arenium Ion Mechanism.....	312
❖ Orientation and Reactivity	314
❖ Energy Profile Diagrams	316
❖ The Ortho/Para Ratio.....	317
❖ <i>ipso</i> -Attack	319
❖ Orientation in Other Ring Systems	320
❖ Quantitative Treatment of Reactivity in Substrates and Electrophiles	321
❖ Diazonium Coupling.....	325
❖ Vilsmeier Reaction	326
❖ Gattermann-Koch Reaction	327
❖ Problems.....	329
❖ Bibliography	330
CHAPTER 9	331
Aromatic Nucleophilic Substitution	331
❖ The $ArSN_1$, $ArSN_2$, Benzyne and S_RN_1 Mechanisms.....	331
❖ Reactivity – Effect of Substrate Structure, Leaving Group and Attacking Nucleophile.....	336
❖ The von Richter, Sommelet-Hauser, and Smiles Rearrangements	339
❖ Problems.....	343
❖ Bibliography	344

CHAPTER 10	345
Elimination Reactions	345
❖ The E ₂ , E ₁ and E ₁ CB Mechanisms	345
❖ Orientation of the Double Bond.....	348
❖ Reactivity – Effects of Substrate Structures, Attacking Base, the Leaving Group and The Medium	352
❖ Mechanism and Orientation in Pyrolytic Elimination.....	355
❖ Problems.....	358
❖ Bibliography.....	359
CHAPTER 11	360
Addition to Carbon-Carbon Multiple Bonds	360
❖ Mechanistic and Stereochemical Aspects of Addition Reactions Involving Electrophiles, Nucleophiles and Free Radicals.....	360
❖ Regio- and Chemoselectivity: Orientation and Reactivity	370
❖ Addition to Cyclopropane Ring	374
❖ Hydrogenation of Double and Triple Bonds	375
❖ Hydrogenation of Aromatic Rings.....	377
❖ Hydroboration	378
❖ Michael Reaction.....	379
❖ Sharpless Asymmetric Epoxidation	380
❖ Problems.....	382
❖ Bibliography	383
CHAPTER 12	384
Addition to Carbon-Hetero Multiple Bonds.....	384
❖ Mechanism of Metal Hydride Reduction of Saturated and Unsaturated Carbonyl Compounds, Acids, Esters and Nitriles	384
❖ Addition of Grignard Reagents, Organozinc and Organolithium Reagents to Carbonyl and Unsaturated Carbonyl Compounds.....	400
❖ Wittig Reaction.....	406
❖ Mechanism of Condensation Reactions Involving Enolates: Aldol, Knoevenagel, Claisen, Mannich, Benzoin, Perkin and Stobbe Reactions	411
❖ Hydrolysis of Esters and Amides.....	433
❖ Ammonolysis of Esters.....	437
❖ Problems.....	439
❖ Bibliography.....	440
INDEX.....	441



Mandeep Dalal

(M.Sc, Ph.D, CSIR UGC – NET JRF, IIT-GATE)

Founder & Educator, Dalal Institute

E-Mail: dr.mandeep.dalal@gmail.com

www.mandeepdalal.com

Mandeep Dalal is an Indian research scholar who is primarily working in the field of Science and Philosophy. He received his Ph.D in Chemistry from Maharshi Dayanand University, Rohtak, in 2018. He is also the Founder of "Dalal Institute" (India's best coaching centre for academic and competitive chemistry exams), the organization that is committed to revolutionize the field of school-level and higher education in Chemistry across the globe. He has published more than 40 research papers in various international scientific journals, including mostly from Elsevier (USA), IOP (UK), and Springer (Netherlands).

Other Books by the Author

A TEXTBOOK OF INORGANIC CHEMISTRY – VOLUME I, II, III, IV

A TEXTBOOK OF PHYSICAL CHEMISTRY – VOLUME I, II, III, IV

A TEXTBOOK OF ORGANIC CHEMISTRY – VOLUME I, II, III, IV

ISBN: 978-81-952427-3-3



9 788195 242733 >

MRP: Rs 800.00

**D DALAL
INSTITUTE**

..... Chemical Science Demystified

Main Market, Sector 14, Rohtak, Haryana 124001, India

(info@dalalinstitute.com, +91-9802825820)

www.dalalinstitute.com