EFFECT OF CONCEPT MAPPING STRATEGY ON ACHIEVEMENT IN ORGANIC CHEMISTRY OF CLASS XII SCIENCE STUDENTS

Kanak Sharma

Research Scholar
Faculty of Education
Kamachha, BHU, Varanasi 221010

Introduction

Chemistry is often full of abstract concepts resulting from its inherent complex nature. It may lead to extensive misconceptions among students (Gable, 1999). It is also a common problem in chemistry that even if students do well in examinations, they still may fail in solving basic textbook problems, which is a sign of rote learning (Pendley et al., 1994).

It is important to find various new as well as interesting ways that can lead towards meaningful chemistry learning. One way to accomplish this, is to apply Ausubel's theory of meaningful learning. Concept maps were devised as a device of meaningful learning which can be regarded as the counter and effective replacement of rote learning.

The use of concept map has been widely investigated in the field of chemistry. According to Francisco et al., (2002) and Nicoll et al., (2001), concept maps are a useful learning tool in chemistry. Concept maps can improve understanding of chemical concepts and help build connections among abstract concepts. Concept maps can also be used as a misconception correction tool. These concept maps bind concepts with linking words that help students see connections among them and organise their knowledge hierarchically, based on scientific knowledge. (Francisco et al., 2002; Nicoll et al., 2001)

Concept maps are spatial representations of concepts and their interrelationships that are intended to represent the knowledge structures that human stores in their minds (Jonassen, Beissne and Yacci, 1993). The use of concept maps as teaching strategy was first developed by Joseph D. Novak of Cornell University in the early 1980's. His Work was based on important idea in Ausubel's (1968) assimilation theory of cognitive learning which places central emphasis on the influence of students' prior knowledge on subsequent meaningful learning.

Concept maps are diagrammatic representations which show meaningful relationships between concepts in the form of propositions which are linked together by words, circles, and cross links. Concepts are arranged hierarchically with the super ordinate concepts at the top of the map, and subordinate at the bottom which are less inclusive than higher ones. "Cross links" are used to connect different segments of the concepts

hierarchy which indicate syntheses of related concepts, a new interpretation of old ideas, and some degree of creative thinking.

This research paper presents the outcome of an investigation to study the use of concept mapping as a teaching strategy to enhance meaningful learning and to improve achievement of students in Organic Chemistry.

Objectives of the Study

- To develop Concept maps of 2 concepts from selected one unit of Organic Chemistry syllabus prescribed by the C.B.S.E. Board for Class XII science students.
- To study the effectiveness of Concept Mapping Strategy in comparison to the Lecture Method in terms of achievement of Class XII science students in Organic Chemistry.
- To study the effectiveness of Concept Mapping Strategy in comparison to the Lecture method in terms of concept retention of Class XII science students in Organic Chemistry.

Design and Sample of the Study

The study was quasi-experimental in nature where Pre-test Post-test Non-equivalent Groups Design was used. The total 80 science students of two intact sections that is 'A' and 'B' of Class XII from Central Hindu Boys School of Varanasi city, were chosen as the sample of the study. Out of these two sections, section 'A' was randomly assigned as the experimental group (n_1=40) and other section 'B' as the control group (n_2=40) for the study (see Table 1).

Table 1 : The groups involved in the study and the number of students

Groups	Number of Students (N)
Experimental Group (Concept Mapping Strategy)	40
Control Group (Lecture Method)	40
Total	**80**

Tools Used in the Study

Twelve Concept maps of 2 concepts from selected one unit of Organic Chemistry syllabus prescribed by the C.B.S.E. Board.

Mixed Group Test of Intelligence (Hindi Version) by Dr P.N. Mehrotra, Verbal and Non-verbal Test was used for equating the both groups i.e. experimental and control groups on the basis of their intelligence scores.

An Achievement test consisting of 25 multiple-choice questions based on 2 concepts from selected one unit of Organic Chemistry syllabus prescribed by the C.B.S.E. Board for Class XII science students was developed by the investigator to measure the students' achievement and concept retention in Organic Chemistry. In this test each question carries one mark. The achievement test served as both pre-test and post-test (post-test I and post-test II).

Procedural Details of the Study

In the present study the investigator introduced 2 concepts of selected one unit namely; Phenol and Ether through 12 concept maps regarding various aspects such as preparation, properties, reactions and interconversions were developed by the investigator.

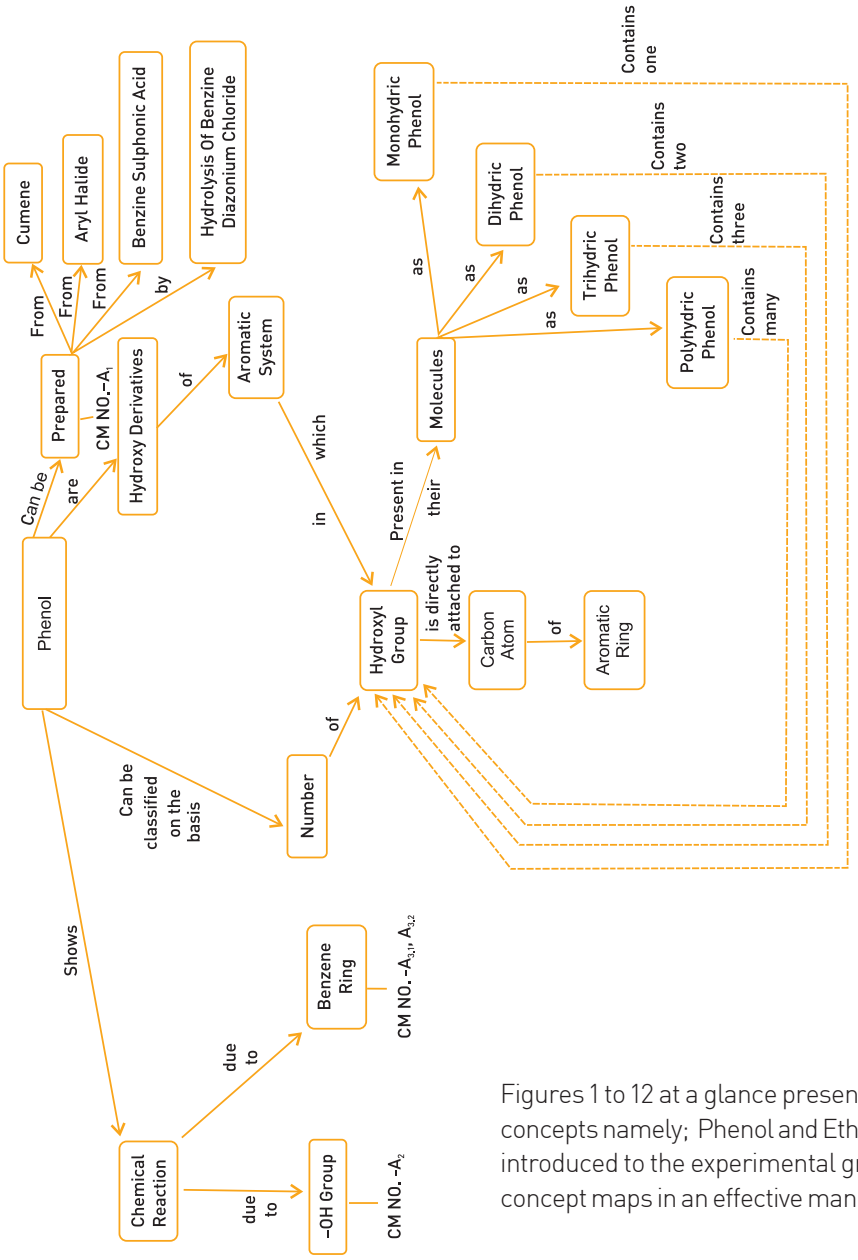

Fig. 1

Figures 1 to 12 at a glance present, how 2 concepts namely; Phenol and Ether were introduced to the experimental group through concept maps in an effective manner.

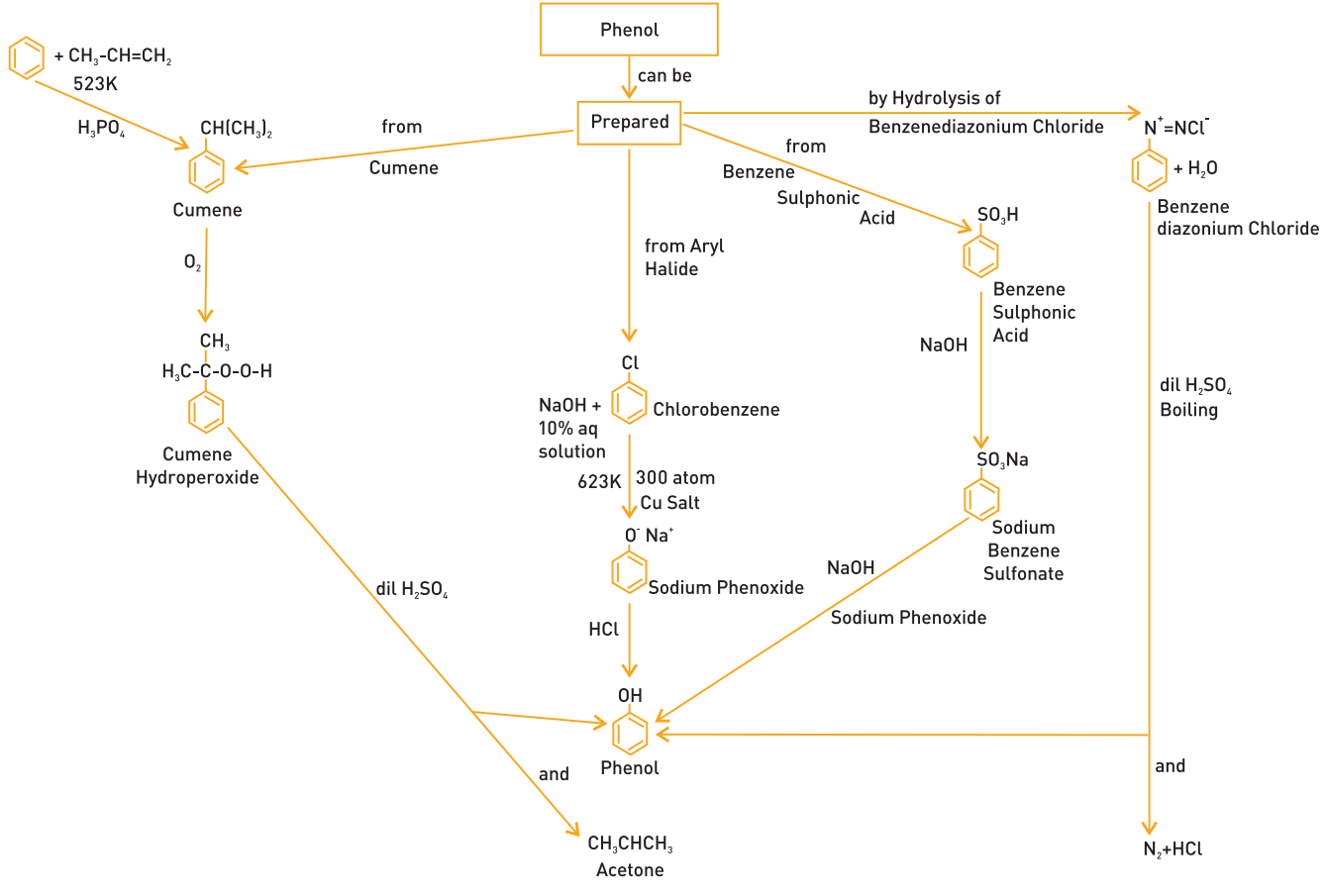
Phenol
can be
Prepared
from
Cumene
by Hydrolysis of
Benzenediazonium Chloride
from
Benzene
Sulphonic
Acid
from Aryl
Halide
+ CH_3-CH=CH_2
523K
H_3PO_4
$CH(CH_3)_2$
Cumene
O_2
CH_3
H_3C-C-O-O-H
Cumene
Hydroperoxide
dil H_2SO_4
Cl
Chlorobenzene
NaOH +
10% aq
solution
623K
300 atom
Cu Salt
O^- Na^+
Sodium Phenoxide
HCl
OH
Phenol
and
CH_3CHCH_3
Acetone
SO_3H
Benzene
Sulphonic
Acid
NaOH
SO_3Na
Sodium
Benzene
Sulfonate
NaOH
Sodium Phenoxide
N^+=NCl^-
+ H_2O
Benzene
diazonium Chloride
dil H_2SO_4
Boiling
and
N_2+HCl

Fig. 2

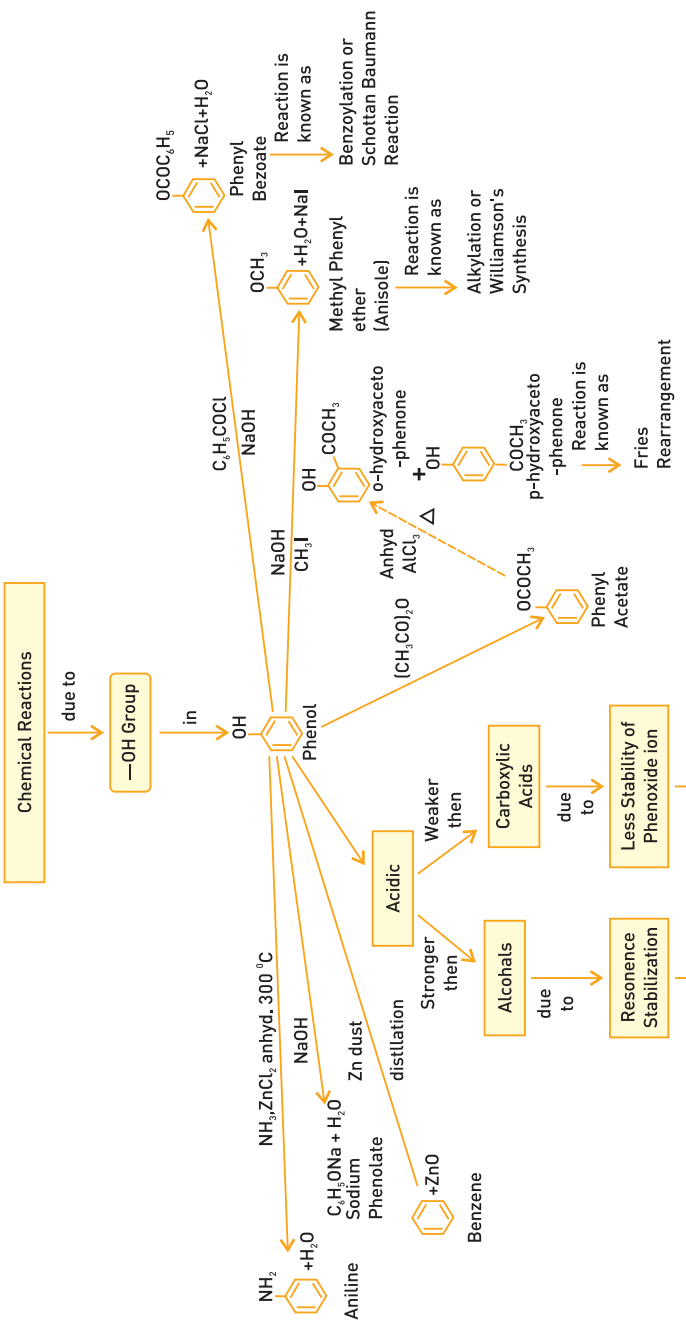
Chemical Reactions
due to
—OH Group
in
OH
Phenol
Acidic
Weaker then
Carboxylic Acids
due to
Less Stability of Phenoxide ion
than
Carboxylate ion
Stronger then
Alcohals
due to
Resonence Stabilization
of
Phenoxide ion
NaOH
CH3I
OCH3
+H2O+NaI
Methyl Phenyl ether (Anisole)
Reaction is known as
Alkylation or Williamson's Synthesis
C6H5COCl
NaOH
OCOC6H5
+NaCl+H2O
Phenyl Bezoate
Reaction is known as
Benzoylation or Schottan Baumann Reaction
(CH3CO)2O
OCOCH3
Phenyl Acetate
Anhyd AlCl3
Δ
OH
COCH3
o-hydroxyaceto -phenone
+
OH
COCH3
p-hydroxyaceto -phenone
Reaction is known as
Fries Rearrangement
NH3,ZnCl2 anhyd. 300 °C
NaOH
Zn dust
distllation
NH2
+H2O
Aniline
C6H5ONa + H2O
Sodium Phenolate
+ZnO
Benzene

Fig. 3

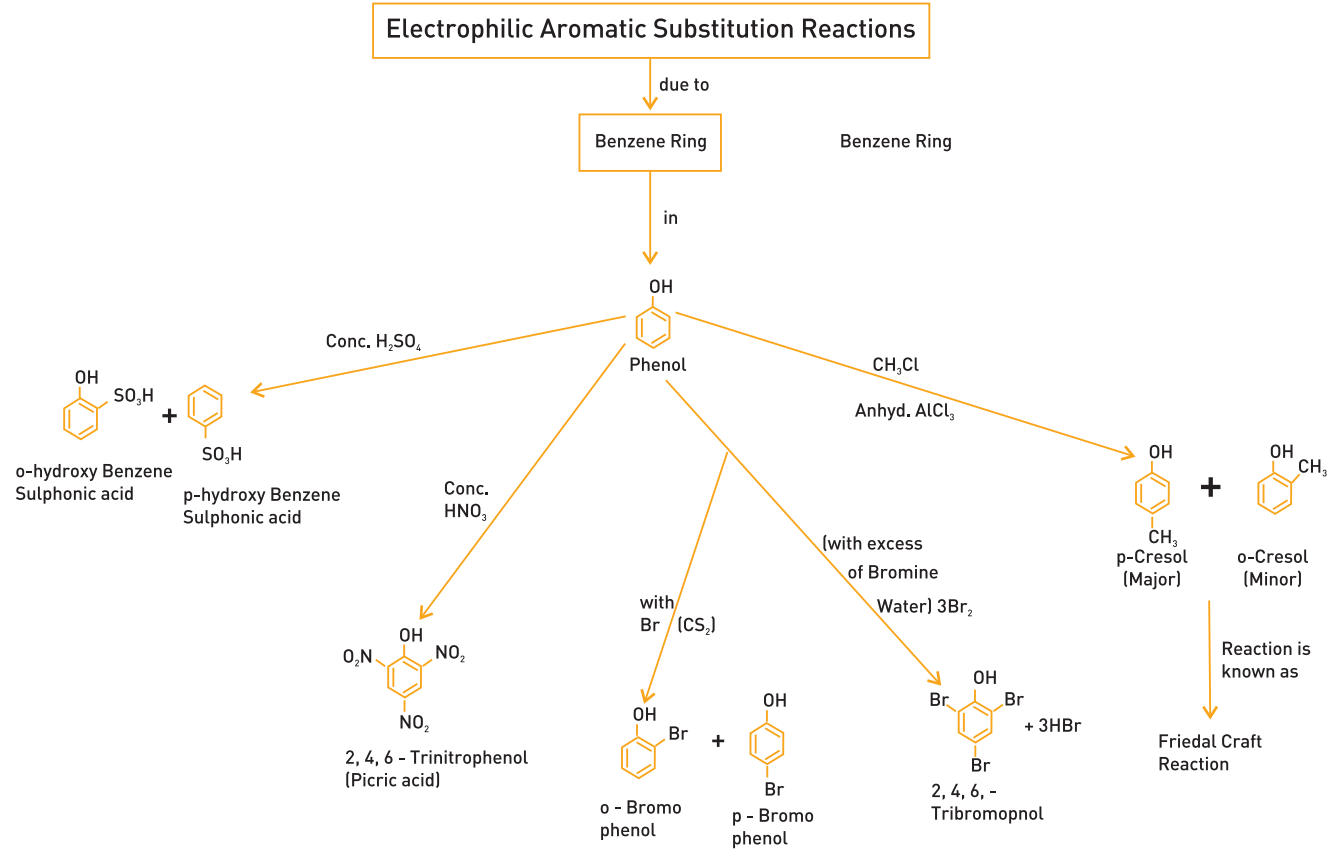
Electrophilic Aromatic Substitution Reactions
due to
Benzene Ring
Benzene Ring
in
OH
Phenol
Conc. H_2SO_4
SO_3H
SO_3H
o-hydroxy Benzene Sulphonic acid
p-hydroxy Benzene Sulphonic acid
Conc. HNO_3
O_2N
NO_2
NO_2
2, 4, 6 - Trinitrophenol (Picric acid)
with Br (CS_2)
Br
o - Bromo phenol
Br
p - Bromo phenol
(with excess of Bromine Water) $3Br_2$
Br
Br
Br
+ 3HBr
2, 4, 6, - Tribromopnol
CH_3Cl
Anhyd. $AlCl_3$
CH_3
p-Cresol (Major)
CH_3
o-Cresol (Minor)
Reaction is known as
Friedal Craft Reaction

Fig. 4

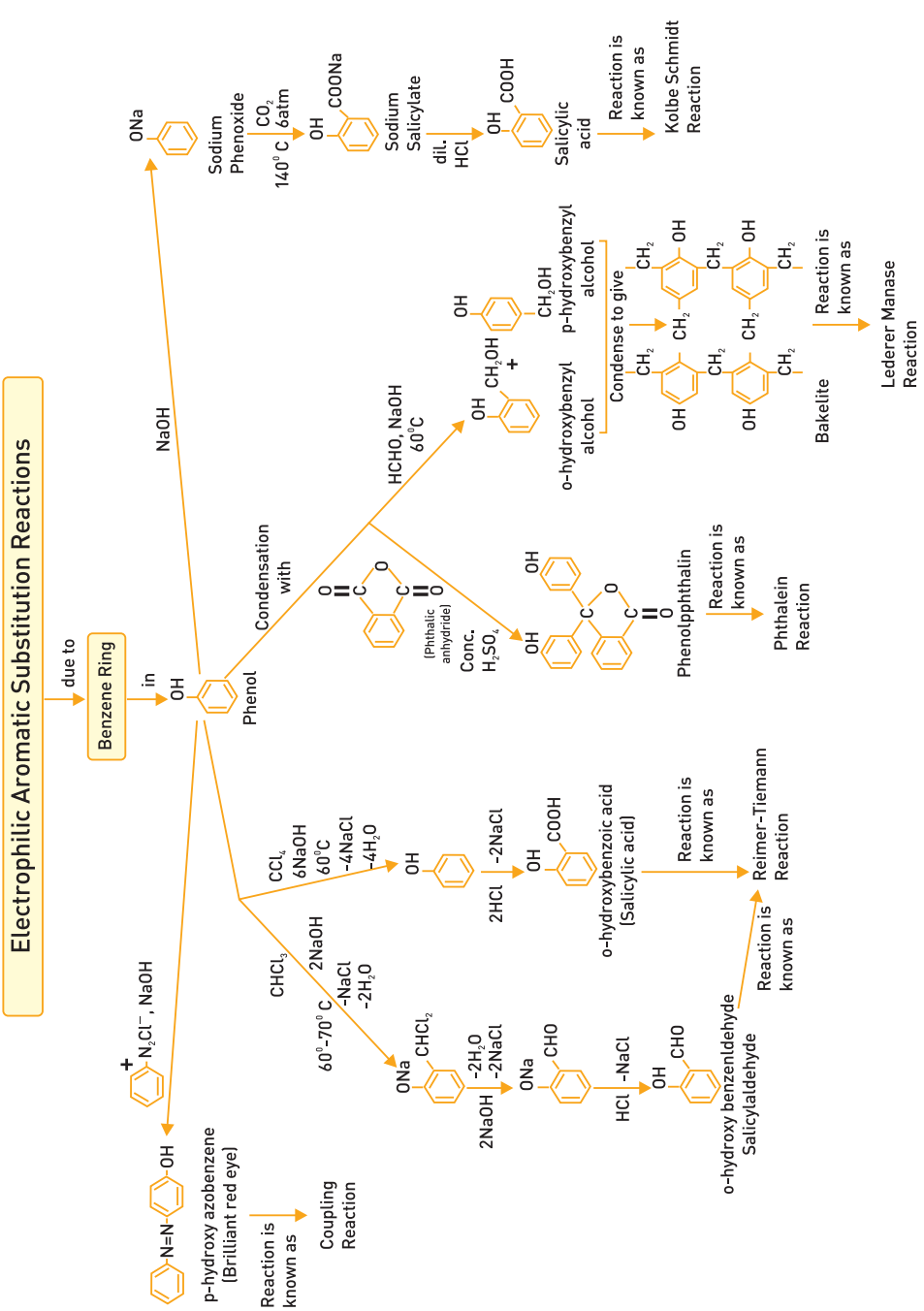
Electrophilic Aromatic Substitution Reactions
due to
Benzene Ring
in
Phenol
NaOH
Sodium Phenoxide
CO2, 6atm
140° C
Sodium Salicylate
dil. HCl
Salicylic acid
Reaction is known as
Kolbe Schmidt Reaction
Condensation with
HCHO, NaOH
60°C
o-hydroxybenzyl alcohol
p-hydroxybenzyl alcohol
Condense to give
Bakelite
Reaction is known as
Lederer Manase Reaction
(Phthalic anhydride)
Conc. H2SO4
Phenolpphthalin
Reaction is known as
Phthalein Reaction
CCl4 6NaOH 60°C -4NaCl -4H2O
2HCl -2NaCl
o-hydroxybenzoic acid (Salicylic acid)
Reaction is known as
Reimer-Tiemann Reaction
CHCl3 2NaOH
60°-70° C -NaCl -2H2O
-2H2O -2NaCl
2NaOH
HCl -NaCl
o-hydroxy benzenldehyde Salicylaldehyde
Reaction is known as
p-hydroxy azobenzene (Brilliant red eye)
Reaction is known as
Coupling Reaction

Fig. 5

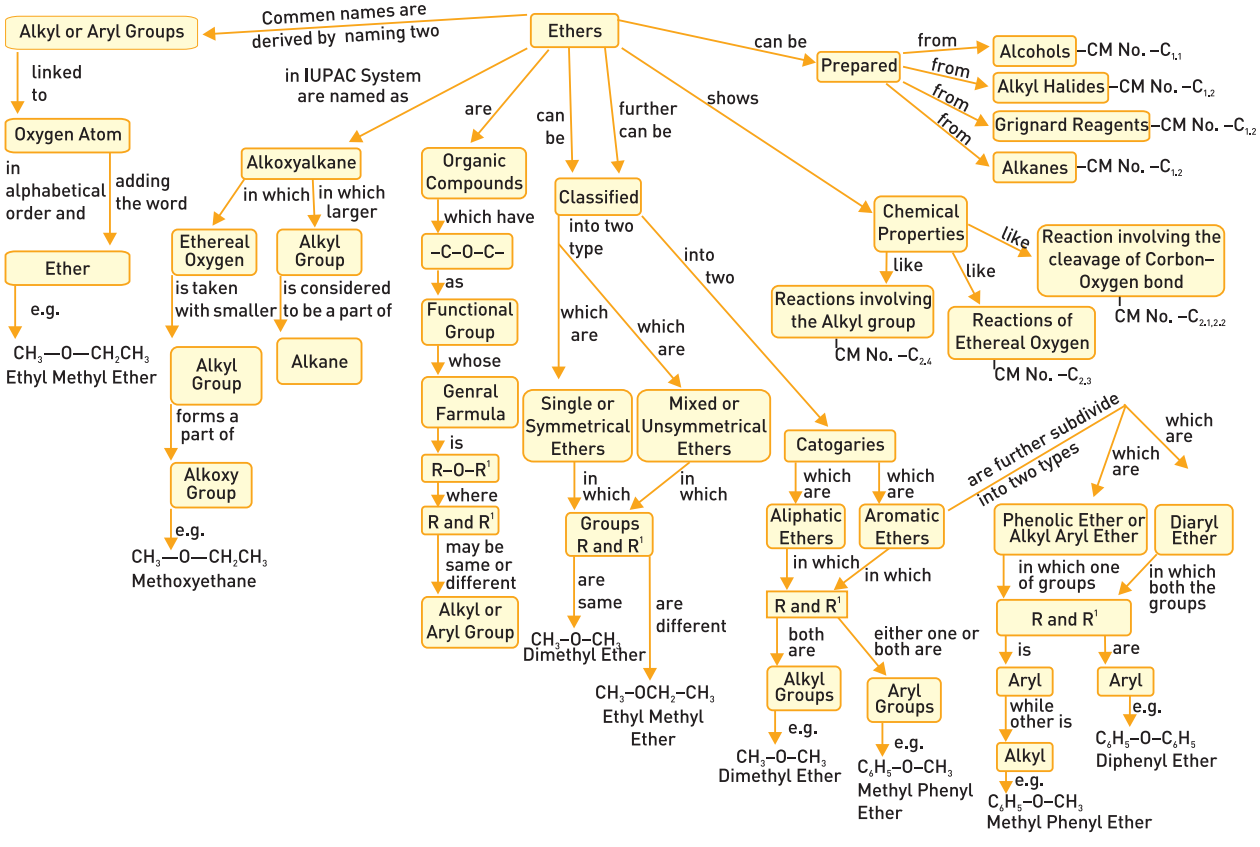
Ethers
Commen names are derived by naming two
Alkyl or Aryl Groups
linked to
Oxygen Atom
in alphabetical order and
adding the word
Ether
e.g.
$CH_3—O—CH_2CH_3$
Ethyl Methyl Ether
in IUPAC System are named as
Alkoxyalkane
in which
in which larger
Ethereal Oxygen
is taken with smaller
Alkyl Group
is considered to be a part of
Alkane
Alkyl Group
forms a part of
Alkoxy Group
e.g.
$CH_3—O—CH_2CH_3$
Methoxyethane
are
Organic Compounds
which have
–C–O–C–
as
Functional Group
whose
Genral Farmula
is
R–O–R¹
where
R and R¹
may be same or different
Alkyl or Aryl Group
can be
Classified
into two type
which are
which are
Single or Symmetrical Ethers
Mixed or Unsymmetrical Ethers
in which
in which
Groups R and R¹
are same
are different
$CH_3–O–CH_3$
Dimethyl Ether
$CH_3–OCH_2–CH_3$
Ethyl Methyl Ether
further can be
into two
Catogaries
which are
which are
Aliphatic Ethers
Aromatic Ethers
in which
in which
R and R¹
both are
either one or both are
Alkyl Groups
Aryl Groups
e.g.
$CH_3–O–CH_3$
Dimethyl Ether
e.g.
$C_6H_5–O–CH_3$
Methyl Phenyl Ether
shows
Chemical Properties
like
like
like
Reactions involving the Alkyl group
CM No. –$C_{2.4}$
Reactions of Ethereal Oxygen
CM No. –$C_{2.3}$
Reaction involving the cleavage of Corbon–Oxygen bond
CM No. –$C_{2.1,2.2}$
can be
Prepared
from
from
from
from
Alcohols –CM No. –$C_{1.1}$
Alkyl Halides –CM No. –$C_{1.2}$
Grignard Reagents –CM No. –$C_{1.2}$
Alkanes –CM No. –$C_{1.2}$
are further subdivide into two types
which are
which are
Phenolic Ether or Alkyl Aryl Ether
Diaryl Ether
in which one of groups
in which both the groups
R and R¹
is
are
Aryl
while other is
Alkyl
e.g.
$C_6H_5–O–CH_3$
Methyl Phenyl Ether
Aryl
e.g.
$C_6H_5–O–C_6H_5$
Diphenyl Ether

Fig. 6

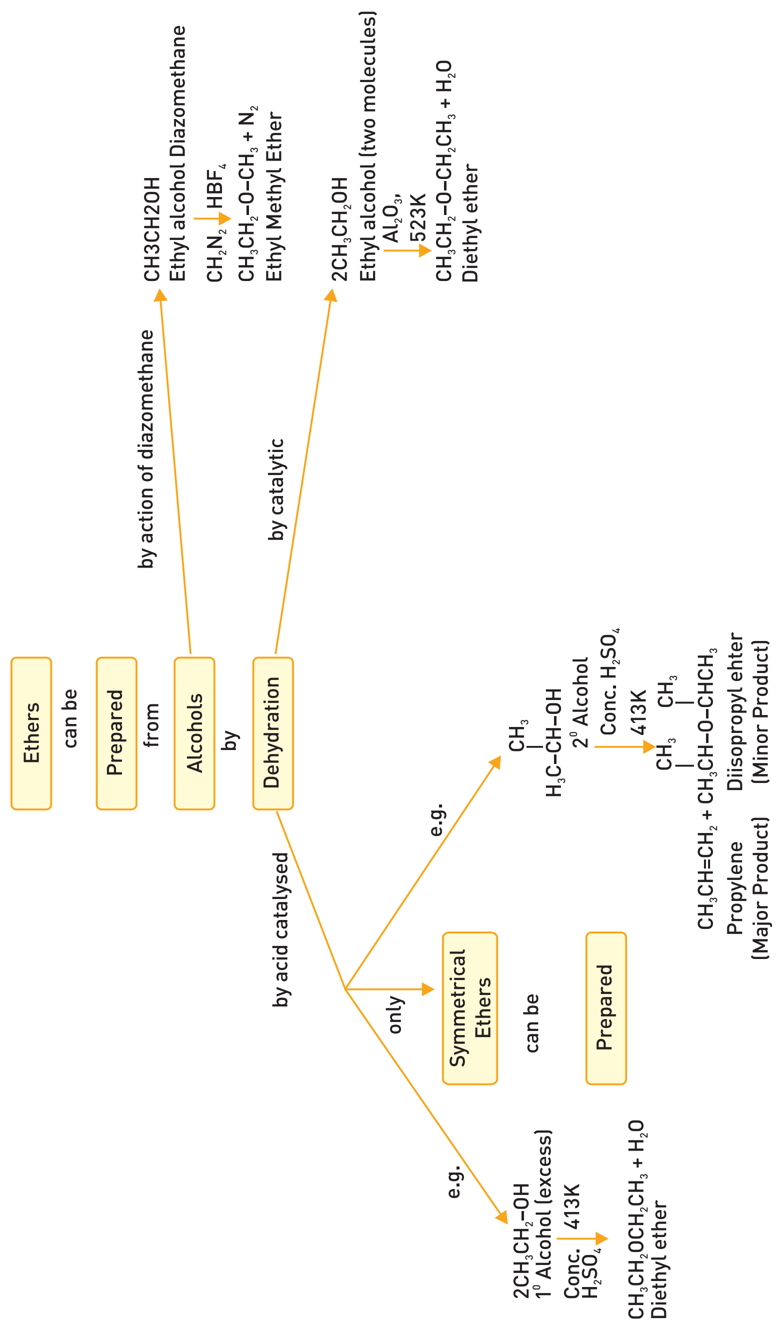
Ethers
can be
Prepared
from
Alcohols
by
Dehydration
by action of diazomethane
CH3CH2OH
Ethyl alcohol Diazomethane
CH2N2 HBF4
CH3CH2–O–CH3 + N2
Ethyl Methyl Ether
by catalytic
2CH3CH2OH
Ethyl alcohol (two molecules)
Al2O3,
523K
CH3CH2–O–CH2CH3 + H2O
Diethyl ether
by acid catalysed
only
Symmetrical Ethers
can be
Prepared
e.g.
H3C–CH–OH
CH3
2⁰ Alcohol
Conc. H2SO4
413K
CH3CH=CH2 + CH3CH–O–CHCH3
Propylene
(Major Product)
Diisopropyl ehter
(Minor Product)
e.g.
2CH3CH2–OH
1⁰ Alcohol (excess)
413K
Conc. H2SO4
CH3CH2OCH2CH3 + H2O
Diethyl ether

Fig. 7

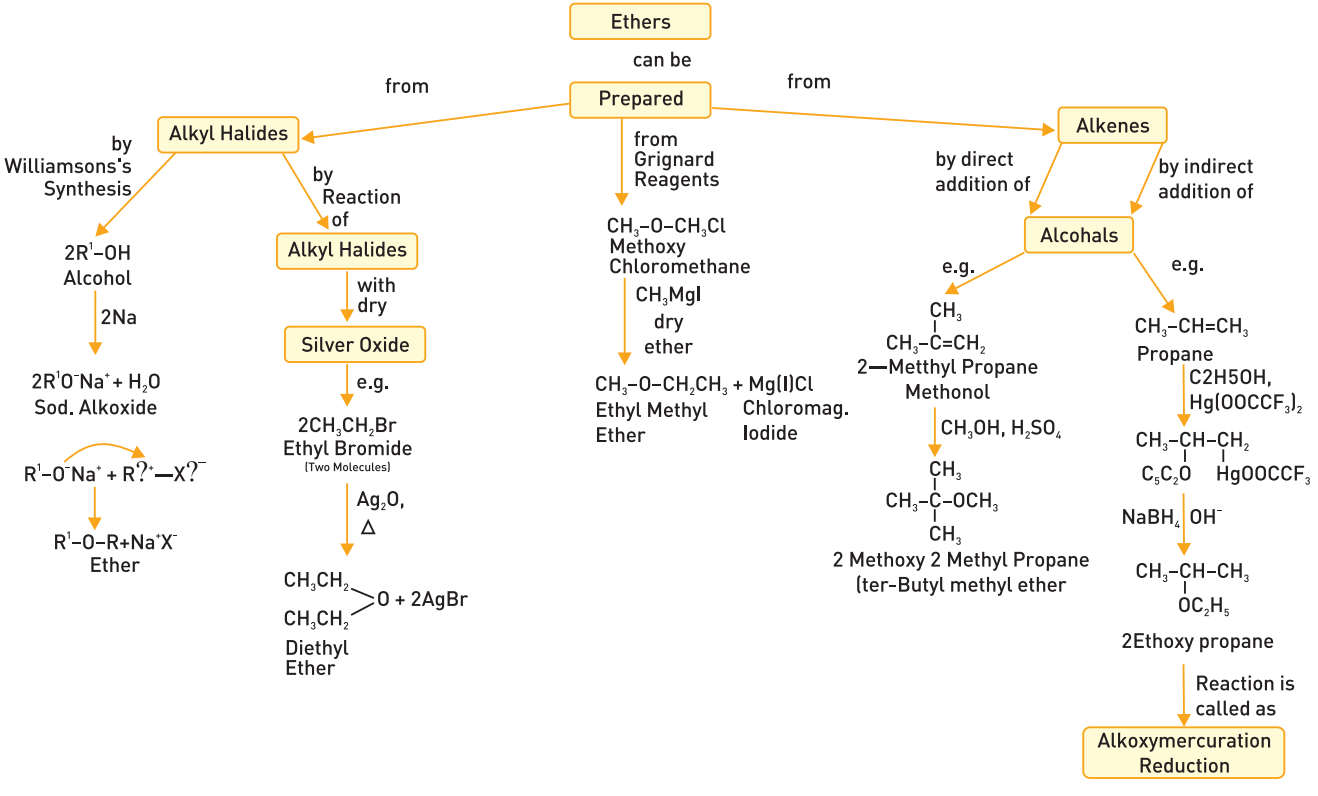
Ethers
can be
Prepared
from
Alkyl Halides
by
Williamsons's
Synthesis
2R¹–OH
Alcohol
2Na
2R¹O⁻Na⁺ + H₂O
Sod. Alkoxide
R¹–O⁻Na⁺ + R²–X
R¹–O–R+Na⁺X⁻
Ether
by
Reaction
of
Alkyl Halides
with
dry
Silver Oxide
e.g.
2CH₃CH₂Br
Ethyl Bromide
(Two Molecules)
Ag₂O,
Δ
CH₃CH₂
CH₃CH₂
O + 2AgBr
Diethyl
Ether
from
Grignard
Reagents
CH₃–O–CH₃Cl
Methoxy
Chloromethane
CH₃MgI
dry
ether
CH₃–O–CH₂CH₃ + Mg(I)Cl
Ethyl Methyl
Ether
Chloromag.
Iodide
from
Alkenes
by direct
addition of
by indirect
addition of
Alcohals
e.g.
CH₃
CH₃–C=CH₂
2—Metthyl Propane
Methonol
CH₃OH, H₂SO₄
CH₃
CH₃–C–OCH₃
CH₃
2 Methoxy 2 Methyl Propane
(ter-Butyl methyl ether
e.g.
CH₃–CH=CH₃
Propane
C2H5OH,
Hg(OOCCF₃)₂
CH₃–CH–CH₂
C₅C₂O
HgOOCCF₃
NaBH₄ OH⁻
CH₃–CH–CH₃
OC₂H₅
2Ethoxy propane
Reaction is
called as
Alkoxymercuration
Reduction

Fig. 8

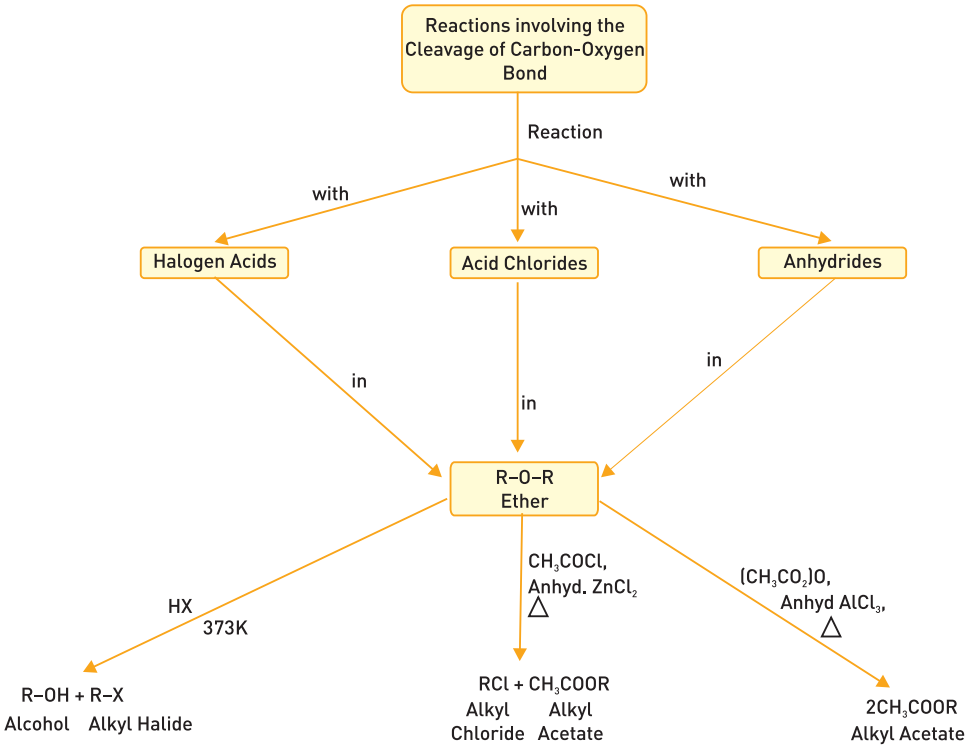
Reactions involving the Cleavage of Carbon-Oxygen Bond
Reaction
with
with
with
Halogen Acids
Acid Chlorides
Anhydrides
in
in
in
R–O–R
Ether
HX
373K
CH3COCl,
Anhyd. ZnCl2
(CH3CO2)O,
Anhyd AlCl3,
R–OH + R–X
Alcohol Alkyl Halide
RCl + CH3COOR
Alkyl Chloride Alkyl Acetate
2CH3COOR
Alkyl Acetate

Fig.9

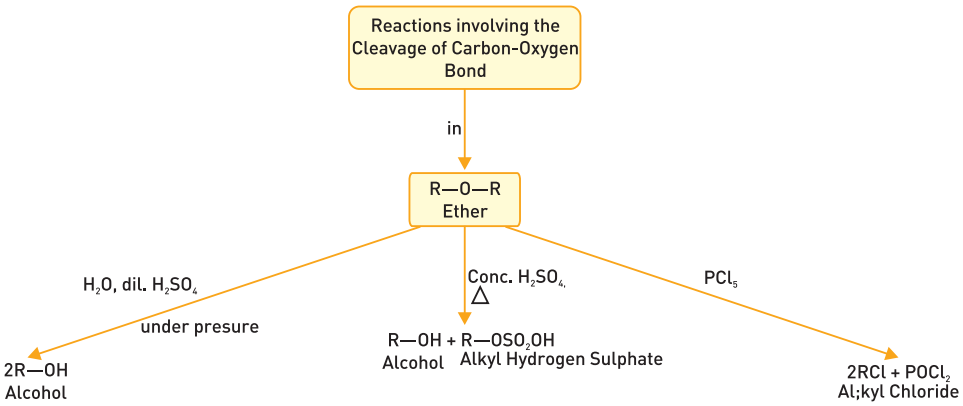
Reactions involving the Cleavage of Carbon-Oxygen Bond
in
R—O—R
Ether
H2O, dil. H2SO4
under presure
Conc. H2SO4,
PCl5
2R—OH
Alcohol
R—OH + R—OSO2OH
Alcohol Alkyl Hydrogen Sulphate
2RCl + POCl2
Al;kyl Chloride

Fig.10

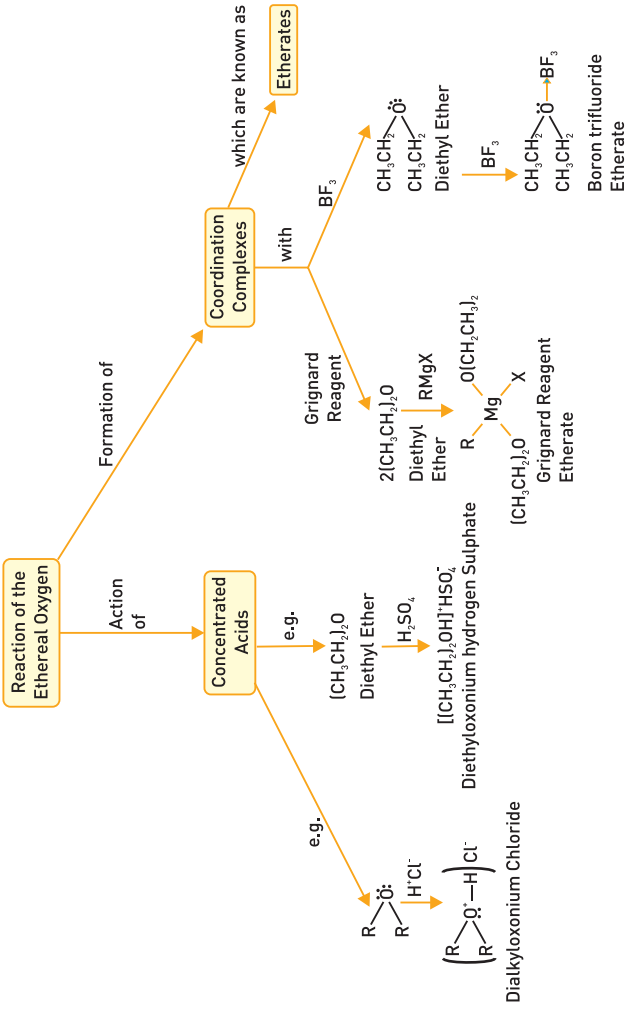
Reaction of the Ethereal Oxygen
Action of
Formation of
Concentrated Acids
Coordination Complexes
which are known as
Etherates
e.g.
with
$(CH_3CH_2)_2O$
Diethyl Ether
H_2SO_4
$[(CH_3CH_2)_2OH]^+HSO_4^-$
Diethyloxonium hydrogen Sulphate
e.g.
H^+Cl^-
Cl^-
Dialkyloxonium Chloride
BF_3
$CH_3CH_2\ddot{O}CH_2CH_3$
Diethyl Ether
BF_3
$CH_3CH_2\ddot{O}(BF_3)CH_2CH_3$
Boron trifluoride Etherate
Grignard Reagent
$2(CH_3CH_2)_2O$
Diethyl Ether
RMgX
$R-Mg-X$
$O(CH_2CH_3)_2$
$(CH_3CH_2)_2O$
Grignard Reagent Etherate

Fig. 11

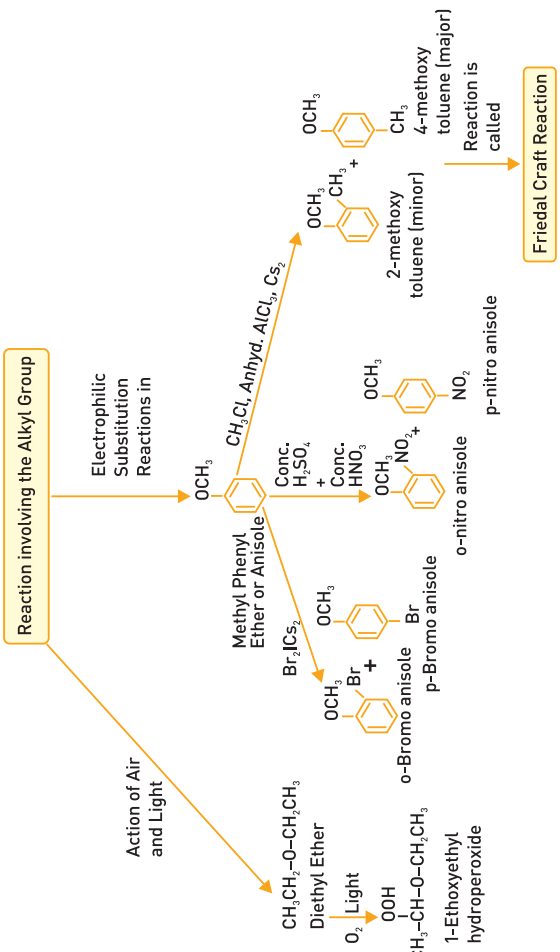
Reaction involving the Alkyl Group
Electrophilic Substitution Reactions in
Action of Air and Light
Methyl Phenyl Ether or Anisole
CH_3Cl, Anhyd. $AlCl_3$, CS_2
Conc. H_2SO_4 + Conc. HNO_3
Br_2/CS_2
2-methoxy toluene (minor)
4-methoxy toluene (major)
Reaction is called
Friedal Craft Reaction
o-nitro anisole
p-nitro anisole
o-Bromo anisole
p-Bromo anisole
$CH_3CH_2–O–CH_2CH_3$
Diethyl Ether
O_2 Light
1-Ethoxyethyl hydroperoxide

Fig. 12

The tool was tried out and item analysis was carried out in case of achievement test. The study's research pattern is given below in Table 2.

Table 2 : The Study's Research Pattern

Groups	Pre-Treatment	Treatment	Post-Treatment	Delayed Post-Treatment (After a gap of six weeks)
Experimental Group	I, T	Taught the selected concepts through Concept Mapping Strategy	T T	T T
Control Group	I, T	Taught the selected concepts through Lecture Method	T	T

The experimental group in Table 2 represents the group of students which was taught through Concept Mapping Strategy (CMS) and the control group represents the group which was taught through Lecture Method (LM). I shows the Intelligence Test, T shows the Organic Chemistry Achievement Test (Pre-test and Post-test (I and II)).

Before starting the experiment the investigator administered a Mixed Group Test of Intelligence on both experimental and control group. These two groups (experimental and control) are naturally assembled groups as intact classes, which may be similar. The subjects were not matched on the previous achievement in organic chemistry but were equated on the basis of their intelligence scores. "t" test was applied for matching the groups and results have been given below in Table 3.

Table 3 : Mean, S.D., and 't' values of Intelligence scores for Experimental group and Control group

Groups	N	Mean	S.D.	't'	p
Experimental Group	40	59.34	11.34	0.258	$\rightarrow$0.05
Control Group	40	60.02	12.22		

Table 3 reveals that "t" value of 0.258 for intelligence scores were not significant at 0.05 level. It meant that the both groups had almost the same intelligence level. After this the standardised achievement test was administered as pretest on both experimental and control group.

However, after the pretest the control group was taught through Lecture method and the experimental group was taught through Concept Mapping Strategy. In order to avoid the impact of teacher effectiveness both groups were taught by the same teacher (The investigator). After teaching all 12 concepts Post-test I was administered on both groups and after a gap of six weeks from the treatment each group was posttested again on Post-test II (delayed posttest) for measuring their concept retention. The data obtained was analysed descriptively and inferentially by calculating ANCOVA, $Mean_{Gain}$, S.D., & "t" values.

Result and Discussion

Effect of Concept Mapping Strategy on Achievement in Organic Chemistry

Ho1 : There is no significant difference between means of achievement scores of students taught through Concept Mapping Strategy and students taught through Lecture Method.

Table 4 : Summary Table of Analysis of Covariance (ANCOVA) showing Pre-test Post-test scores of Experimental and Control groups with respect to Achievement

Groups	Pre-test mean	Post-test Mean	Adjusted mean Difference	Source of Variation Squares	Sum of Squares	df	Mean Sum of	$F_{y.x}$	p
Experimental Group	6.22	13.63	0.1	Among Means	504.40	1	504.40	117.30	<0.01
Control Group	6.12	8.48		Within Groups	330.74	77	4.30		

A reference to Table 4 reveals that the obtained $F_{y.x}$ ratio after adjusting pretest differences into posttest was found to be 117.30 at dfs 1/77. which is significant at 0.01 level of confidence. It meant that experimental group differ from pretest to posttest on achievement test in Organic Chemistry. The above Table further shows that the mean post-test scores of experimental group was found to be higher than that of post test scores of control group. So, it can be concluded that the Concept Mapping Strategy is significantly more effective than the Lecture Method in the improvement of achievement in Organic Chemistry of Class XII science students. The findings of this study is on the same track as Kumuda (2000), Aparna (2002), Rao (2004), Candan, Turkman and Cardak (2006), Chiou and Chang (2008) and Demirdover et. al (2008). These researches have also studied the comparative effectiveness of Concept Mapping Strategy with respect to the traditional method in different subjects and at different levels.

Effect of Concept Mapping Strategy on Concept Retention in Organic Chemistry

Ho2 : There is no significant difference between the means of concept retention gain scores of students taught through Concept Mapping Strategy and students taught through Lecture Method.

Table 5 : $Mean_{Gain}$, S.D. and 't' values obtained on Pretest and Delayed Post-test (Post-test II) Achievement in Organic Chemistry by Experimental group and Control group

Groups	N	$Mean_{Gain}$ (Posttest II – Pretest)	S.D.	't'	p
Experimental Group	40	4.275	3.33	6.02	<0.01
Control Group	40	0.975	0.973		

A reference to the Table 5 reveals that there is a significant difference between the means of concept retention gain scores of students taught through Concept Mapping Strategy and students taught through Lecture Method. The above Table further shows that the mean concept retention gain score of experimental group is greater than the control group and the 't' value is significant at 0.01 level of confidence. On the basis of this result we can say that the Concept Mapping Strategy is significantly more effective than the Lecture Method for concept retention in Organic Chemistry.

To some extent, these results are supported by Gupta (1999), Ahuja (2006) and Parsa and Nikbakht (2004).

Gupta (1999) while specifically compared the relative effectiveness of the Concept Mapping Model, the Inductive Model and the Conventional Method to foster concept learning and concept retention in terms of comprehension and application of concepts in chemistry. She concluded that Concept Mapping Model and Inductive Model are significantly more effective than the Conventional Method to foster concept learning and concept retention in terms of comprehension and application of concepts in Chemistry.

Where as Heinze-Fry and Novak (1990) carried out a study on 40 students adopting Concept Mapping Strategy for one month covering three instructional units found that the mapping group achievement was high though not significant, in measure of initial learning, retention and learning efficiently.

Conclusion

Based on the result of this study, it can be concluded that the Concept Mapping Strategy is more effective for improving the achievement of students in Organic Chemistry and also more effective for concept retention in Organic Chemistry of Class XII science students when compared to the Lecture Method. Hence there is a need to include Concept Mapping Strategy with the constructivist basis as one of the major approaches to teach Organic Chemistry in schools at 10+2 level. Use of Concept Mapping Strategy as a main route of teaching or as a complementary strategy for traditional teaching method may improve the students' achievement in Organic Chemistry and knowledge retention capability.

In the teaching learning process of Organic Chemistry, the use of Concept Mapping Strategy will be beneficial for teachers and as well as for students too. Students can use concept maps in Organic Chemistry for learning concepts, which they think are not clear, at the grass-root level. They can also use concept maps for summarising materials when preparing for examinations, for revision of content, for highlighting key concepts and for understanding relationships among them, for helping them to identify gaps in their knowledge, if any, and hence convincing them about the continuity of subject matter.

In Organic Chemistry remedial teaching can also be done by the teachers with the help of concept maps for example, students can be assigned the task of preparing the concept map on the topic to be discussed in subsequent classes. From these students based concept maps, the teacher can get the idea of students' previous knowledge and the existing misconceptions in Organic Chemistry. Once misconceptions in students' cognitive structure are diagnosed, remedial teaching in this direction can be done.

References

Ahuja, Amit. 2006. Effectiveness of Concept Mapping in Learning of Science. Unpublished Doctoral Dissertation. University of Delhi, Delhi.

Aparna, C.F. 2002. The Effect of Concept Mapping as a Teaching Strategy and as an Evaluation Tool in Attainment of Science Concepts of Class V. Unpublished M.Ed. Dissertation, Regional Institute of Education., Mysore.

Aysel Candan, Lutfullah Turkmen and Osman Cardak. 2006. The Effects of Concept Mapping on Primary School Students' Understanding of the Concepts of Force and Motion. *Journal of Turkish Science Education.* 3(1). 66-75.

Demirdover C., M. Yilmaz, H. Vayvada , A. Atabey and D. Eylul. 2008. Comparison of Learning with Concept Maps and Classical Methods among Medical Students. *Proceedings of the Third Int. Conference on Concept Mapping*.

Francisco, J.S., M.B. Nakhleh, S.C. Nurrenbern, and M.L. Miller. 2002. Assessing Student Understanding of General Chemistry with Concept Mapping. *Journal of Chemical Education*, 79(2). 248-257.

Gabel, D. 1999. Improving Teaching and Learning through Chemistry Education Research : A Look to the Future. *Journal of Chemical Education*. 76(4). 548-553.

Garrett, Henry E and R.S. Woodworth. 1981. *Statistics in Psychology and Education.Vakils*. Feffer and Simons Ltd., Bombay .

Gupta, V. 1999. Effectiveness of Concept Mapping in Comparison to Inductive Model in Science Education. Unpublished Doctoral Dissertation, University of Delhi, Delhi.

Heinze-Fry, J.A. and J.D. Novak. 1990. Concept Mapping Brings Long Term Movement Towards Meaningful Learning. *Science Education,* 74(4). 461-472.

Jonassen, D.H., K. Beissner, and M. Yacci. 1993. *Structural knowledge -Techniques for representing, conveying and acquiring structural knowledge*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Kumuda, G. 2000. A Comparative Study of Two Strategies namely; Concept Mapping Method and Lecture Method, Retrived on 10-9-2011 from http://12freelance.com/articles/articles2622.html.

Nicoll, G., J.S. Francisco. and M. Nakhleh 2001. An Investigation of the Value of Using Concept Maps in General Chemistry. *Journal of Chemical Education.* 78(8), 1111-1117.

Novak, J.D. and D.B. Gowin. 1984. *Learning How to Learn*. Cambridge University Press, New York

Parsa, Yekta Z. and Nikbakht, A. Nasrabadi. 2004. Concept Mapping as an Educational Strategy to Promote Meaningful Learning. *Journal of Medical Education.* 5(2). 47-50.

Pendley, B.D., R.L. Bretz and Novak, J.D. 1994. Concept Map as a Tool to Assess Learning in Chemistry. *Journal of Chemical Education.* 71(1). 9-15.

Rao, Manjula P. 2004. Effect of Concept Mapping in Science on Science Achievement, Cognitive Skills and Attitude of Students. *Proceedings of the International Conference on Science, Technology and Mathematics Education* (epi STEME-HBCSE). 130-131.Goa. India.

Susan, Chiou and Chei, Chang. 2008. The Effect of Concept Mapping on Students' Learning Achievements and Interests. *Innovations in Education and Teaching International.* 45(4). 375-387.