I.I. INTRODUCTION

Sulphur has a long history of application in medicine as a result of scabicated, insecticidal, fungicidal and purgative properties. Organosulphur chemistry has developed very rapidly during the last two decades previously a topic of interest only for specialists and now a day it may be considered as an integral and important part of general organic chemistry. The chemical versatility of organosulphur compounds has lead to its incorporation into a number of projects in several different areas of medicinal chemistry. The discovery of sulphonamide as antibacterial drug by a German scientist, Gerhard Domgak, marks an important milestone in the development of medicinal chemistry. This discovery leads to the synthesis of some 15,000 sulphonamides. A wide variety of organosulphur compounds show useful biological activity. They have become a regular armoury of pharmaceutical and crop protection chemistry.

Some of the OrganoSulphur compounds that have been isolated from natural sources include amino acids, vitamins, harmones and antibiotics, as well as numerous enzymes. Many of the natural products mentioned above enjoy extensive therapeutic usage. In addition, some of the most powerful synthetic drugs are also sulphur containing. Among the best known classes are sulfonamides (anti-infective agents) sunfonyl ureas (oral hypoglycemic agents), 2-thio uracils (anti-thyroid agents), phenothiazines (antihistamines, tranquilizers), thiobarbiturates (analgesics, anesthetics), aromatic surfones (antilepratic and antimalarials), 6-mercaptopurines (anti leukemic agents) etc.

The antibiotics like penicillin, ampicillin, and amoxycillin are organosulphur compounds. Anti-ulcer drugs ranitidine and cimitidine which are thioethers (organosulphide), and pentaprazole, omeprazole, lansoprazole and rabeprazole which are organosulphones are extremely effective and in many cases their use can avoid the need of surgery in the treatment of ulcer. Of the current agrochemicals some 30% contain sulphur in wide variety of oxidation states, because of their usefull biological activity. Some important examples of organosulphur compounds used as agrochemicals include thiophosphoryl insecticides like malathion, herbicides like chlorsulphuron, fungicides like dithiocarbamates and caplon and sulphone acaricides like tetradifon.
Organosulphur compounds are not only used as drugs but also as dyes and detergents\(^1\). Many dyes used in the textile industry contain sulphonic acid group which imparts water solubility and help to make the dye become fast to the fabric. Sulphur dyes, another class of vat dyes are obtained by heating various organic compounds with sodium polysulphides. Derivatives of 4,4'-diamino-2,2'-stilbenedisulphonic acid such as the phenylamido derivatives are fluorescent whitening agents used to enhance the appearance of white fabrics, e.g. cotton which otherwise tend to turn yellowish with repeated washing.

Application of organosulphur compounds is not confined to the fields mentioned above, but of late, it has also plunged into the field of electronics and superconductors\(^4a\). Representative examples of molecules are the tetrathiafulvalene derivatives\(^4b, 4c\), of which bis (ethylenedithio) tetrathiafulvalene, BEDT-TTF or ET, is the most notable. The derivative of ET with formula k-ET\(_2\)Cu (NCS)\(_2\) is a superconductor\(^4d\) and has a transition temperature of 10.4K, making it one of the highest-temperature organic superconductors.

Organosulphur compounds include organosulphides (thioethers), sulphoxides and sulphones etc. Of these, the synthesis and structural studies of simple sulphides, sulphones and sulphoxides are well known thing for a long time, but the studies on 1,1-bis (alkyl- or arylthio) ethylenes and their corresponding bis-sulphones and 1,2- bis (alkyl- or arylthio) ethylenes and their corresponding bis-sulphones are of recent origin.

The biological studies on sulphones revealed that they can be used in chemotherapy and agriculture. The sulphones of chlorothiazide and hydrochlorothiazide series are frequently used as diuretics. Sulphonal, (CH\(_3\))\(_2\)C (SO\(_2\)C\(_2\)H\(_5\))\(_2\), trional and tetrinal are used as sedatives and hypnotics. The discovery of dapsone\(^5\) as potential drug against leprosy has revolutionized its whole treatment. Dapsone is also proved to be a potent prophylactic agent. Bis (p-aminophenyl) sulphone was first synthesized by Fromm and Wittman\(^6\) and its chemotherapeutic activity was first evaluated by Buttle and his co-workers\(^7\) and later Rist\(^8\) demonstrated its high anti-bacterial activity. Buttle observed that it is hundred times as active as sulphonilamide. The N,N'-diacetyl and N,N'-digalactoside derivatives of bis (p-aminophenyl) sulphones have been found to be useful as therapeutic agents, similar to the sulphonamides. Sulphenone, 4-chlorodiphenylsulphone and tedion, 2,3,4,5-tetrachloro diphenylsulphone are used as acaricides. 3, 4-Dichlorotetrahydrothiophene-1,1-dioxide has been proposed as nematocide. Promine, [sodium bis (p-aminophenyl) sulphones- N', N'- bis
(glucosesulphonate)], diazone [disodium formaldehyde sulphonate bis (p-aminophenyl) sulphone] were found to be effective tuberculostatic agents, but found to be highly toxic. Streptococci and pneumococci infections can be effectively treated with diazzone.

Sulphones find application not only in the field of therapy and agriculture but also in the textile industry. Dimethylsulphone or methylsulphonylmethane (MSM) \( \text{CH}_3\text{SO}_2\text{CH}_3 \) is one of the best and safe drug for the relief of arthritis, inflammation, lupus and other debilitating and disabling pain conditions and also effective in ameliorating the symptoms of gastrointestinal upset. Dihydroxy- diethylsulphone, divinyl sulphones and hydroxy ethyl vinyl sulphones are used to give crease resistant finishes. Thiomorpholine-1,1-dioxide and 2-phenyl benzothiophene-3,5-dioxide are optical bleachers. There are many more applications of sulphones such as fuel additives, plasticisers and anti icing additives etc.

The recently originated unsaturated disulphones revealed from their biological studies that they can be used as effective fungicides. A few mercapto haloethylene sulphone derivatives, bis (organosulphonyl) ethylenes with the general formula \( \text{R}_1\text{SO}_2 (\text{R}_2) \text{C} = \text{C} (\text{R}_3) \text{SO}_2\text{R}_4 \), vinylene sulphonyl compounds and bis (arythio) ethylenes have been reported as effective fungicides to protect seed. They are also effective against mildew on cotton-cloth, paint and various plant foliage diseases. The activity of organosulphur compounds of biological importance has been found to vary depending upon the substituents present and also on the stereochemical configurations of the substances.

A brief account of the historical development of the chemistry of (organosulphonyl) ethylenes is presented here. It is reported in early 1947, by Schörnberg and Mustafa that benzoin (1) react with \( p \)-thiocresol (2) in the presence of anhydrous zinc chloride and HCl gas to form \( \alpha,\beta \)-bis (\( p \)-tolylmercapto) stilbene (3).

During the investigation of reactions of carbonyl compounds with mercaptans Romero and Romo reported the preparation of \( cis \)- and \( trans \)-\( \alpha,\alpha' \)-benzylthiostilbenes in poor yields. In 1958 the same disulphide was also reported by Bellido.
A convenient method for the preparation of 1,2-bis (alkyl- or arylthio) ethylenes is by the nucleophilic displacement of halogens with thiols from tetrachloroethylene, dichloroethylene, vinylidene halides and vinyl halides.

Tetrachloroethylene (4) on refluxion with sodium p-toluenethiolate gave trans-1,2-bis (p-tolylmercapto)-1,2-dichloroethylene (9). By isolating the intermediate product 1-(p-tolylmercapto)-1,2,3-trichloroethylene (7), the following mechanism was suggested. Under forcing condition tetra (p-tolylmercapto) ethylene (10) was also obtained.

The cis-1,2-bis(p-tolylmercapto)ethylene on chlorination gave cis isomer of 1,2-bis(p-tolylmercapto)-1,2-dichloroethylene. Both the cis and trans-1,2-bis (p-tolylmercapto)-1,2-dichloroethylenes on oxidation with peracetic acid yielded the corresponding cis-and trans-1,2-bis(p-tolylsulphonyl)-1,2-dichloroethylenes. Following a similar procedure for preparation, 1,2-bis(propylmercapto)-1,2-dichloroethylene\textsuperscript{22-25}, 1,2-bis(ethylthio)-1,2-dichloroethylene, 1,2-bis(dodecylthio)-1,2-dichloro ethylene and 1,2-bis(ethylthio)-1,2-difluoro
ethylene were reported\textsuperscript{26}. All these disulphides on oxidation yielded the corresponding disulphones which were claimed to be active seed protectants.

The preparation of trans-1,2-bis (isopropylthio)-1,2-dichloroethylene was reported in 1963, by Bluestone and Bimber\textsuperscript{15}. Six pairs of cis- and trans-1,2-bis (alkylsulphonyl) ethylenes suitable for use as seed fungicides were also prepared\textsuperscript{21} by treating 1,2-dichloroethylene with 2 moles of mercaptan and subsequently oxidising the product with peracetic acid. In this reaction, it is reported that cis-1,2-dichloroethylene (11) react readily with nucleophilic agents such as sodium benzenethiolate\textsuperscript{28a}, sodium $p$-toluenethiolate\textsuperscript{28b,29} and sodium $t$-butylmercaptide\textsuperscript{30}, while the trans-isomer, when treated likewise, recovered unchanged.

It has been explained that the first step in this reaction is elimination of HCl from cis-1,2-dichloroethylene (11) to give chloroacetylene (12), which by trans addition of thiol forms the cis-starting material (13). Compound (13) reacts further as shown above to give cis-1,2-bis (alkyl- or arylthio) ethylenes (15), trans-1,2-Dichloroethylene is inert because it does not eliminate HCl under the conditions of the reaction\textsuperscript{31}. The cis-bis-sulphides (15) obtained above isomerise into the corresponding trans-bis-sulphides. All these bis-sulphides on oxidation afforded the corresponding bis-sulphones.

![Chemical structure](image)

Where $R = C_6H_5$ and $(CH_3)_3C$
Benati et al.\textsuperscript{32} in 1963, reported the synthesis of \textit{cis}- and \textit{trans}-1,2-bis (\textit{p}-bromophenylsulphonyl) stilbenes. The addition of \textit{p}-bromothiophenol to tolan in presence of a base gave \textit{trans}-1-\textit{p}-bromophenylthiostilbene. This on bromination yielded \textit{cis}-and \textit{trans}-1-bromo-2-\textit{p}-bromophenylthiostilbenes. These bromophenylthiostilbenes on reaction with \textit{p}-bromobenzenethiol lead to the formation of \textit{cis}- and \textit{trans}-1,2-bis (\textit{p}-bromophenylthio) stilbenes, which on oxidation gave the corresponding bis-sulphones.

Naidu and Peeran reported the synthesis of (\textit{E})- and (\textit{Z})-1,2-bis(\textit{p}-toluenesulphonyl) stilbenes\textsuperscript{33}, and seven pairs of (\textit{E})- and (\textit{Z})-1-alkylsulphonyl-2-\textit{p}-toluenesulphonylstilbenes\textsuperscript{34}. They have established the geometrical configurations of these isomers through stereospecific synthesis and spectral studies. In 1982, the synthesis of (\textit{E})- and (\textit{Z})-1,2-bis (phenylsulphonyl) stilbenes was reported by Peeran et al.\textsuperscript{35}. Recently the synthesis of a number of \textit{cis}- and \textit{trans}-1,2-bis (alkylthio and arylthio) stilbenes and their corresponding bis-sulphones have been reported\textsuperscript{36-41}. It is reported\textsuperscript{42a} that \textit{trans}-1,2-dichloro-1,2-bis(4'-chlorophenyl)ethylene (16) reacts with potassium salts of various thiols (17) in dimethylformamide. The chlorine atoms at the double bonds are displaced by thiols giving bis-sulphides (18). All these bis-sulphides (18) on oxidation afforded the corresponding bis-sulphones (19).

Weis\textsuperscript{42a} has pointed out that the aliphatic thiols react with \textit{trans}-1,2-dichloro-1,2-bis(4'-chlorophenyl)ethylene (16) giving \textit{trans}-bis-sulphides (18) in good yields where as the aromatic thiols either react forming the product in low yields or do not react at all. He has also reported that \textit{cis}-1,2-dichloro-1,2-bis(4'-chlorophenyl)ethylene does not react with potassium salt of thiols even on long heating. Where R = \textit{p}-\textit{CH}_3\textit{C}_6\textit{H}_4 and (\textit{CH}_3)_3\textit{C}

Recently, Peeran et al.\textsuperscript{42b} have reported the preparation of some \textit{trans}-1,2-bis(alkylthio)-1,2- bis(4'-bromophenyl)ethylenes and their corresponding bis-sulphones.
Flynn and his co-workers\textsuperscript{30} reported that 1,1-dichloroethylene (20) when treated with thiols (21) under mild conditions, gave \textit{trans}-1-chloro-2-alkyl- or aryl-mercapto ethylenes (23). This is evidently not the product of elimination-addition which would be \textit{cis}-isomer of (23) (by \textit{trans} addition).

W. E. Truce et al.\textsuperscript{31} have suggested an addition-elimination mechanism by the isolation of the addition product (22). Under more vigorous conditions, both (22) and (23) are converted into \textit{cis}-1,2-bis (alkyl- or arylmercapto) ethylene (25) by an elimination-addition mechanism. Almost the exclusive formation of (23) rather than its \textit{cis}-isomer is as a result of the greater stability of the \textit{trans}-form and the transition state leading towards it\textsuperscript{43}. 

\textit{Where} R = p-\text{CH}_3\text{C}_6\text{H}_4 \text{ and (CH}_3)_3\text{C}
It is reported that, nucleophilic displacement of halogens with thiols, also takes place in the case of vinyl type of halides, to give cis-1,2-bis (arylmercapto) ethylenes. Truce et al.\textsuperscript{31} obtained cis-1,2-bis (p-tolylmercapto) ethylene (29) from both cis- and trans-1-chloro-2-p-tolylmercaptoethylenes (26, 27) and p-thiocresol. Similarly, both cis- and trans-1-chloro-2-phenylmercaptoethylenes with thiophenol gave only cis-1,2-bis (phenylmercapto) ethylene\textsuperscript{44} and cis- and trans-1-chloro-2-t-butylmercaptoethylenes with t-butylmercaptan gave cis-1,2-bis (t-butylmercapto) ethylene. The fact that, both starting materials which are geometrically isomeric gave one and the same product, suggest that they must be reacting via a common intermediate. An elimination-addition mechanism was proposed.
It is assumed that both cis- and trans-1-chloro-2-alkyl- or arylmercapto-ethylenes (26 and 27) gave alkyl or aryl mercaptoacetylene (28) by elimination of HCl, which by the trans addition of thiols gives rise to the desired product (29). In agreement with this assumption is the fact that alkyl or arylmercapto acetylenes themselves react with thiols to give cis-1,2-bis (alkyl- or aryl-mercapto) ethylene30,31.

In 1969, Calo et al.44 reported that unlike the 1-chloro-2-alkyl- or arylmercaptoethylenes (26 and 27), the β-halovinyl arylsulphones, ArSO₂CH=CHX (30 and 31) react with various thiols with total retention of configuration. This is exemplified by the preparation of cis-1-phenylthio-2-arylsulphonylethylenes45, (ArSO₂CH=CHSC₆H₅) (34) from cis-1-chloro-2-arylsulphonylethylene, (ArSO₂CH=CHCl) (30) and thiophenol and trans-1-phenylthio-2-arylsulphonylethylene, (ArSO₂CH=CHSC₆H₅) (37) from trans-1-chloro-2-arylsulphonylethylene, (ArSO₂CH=CHCl) (31) and thiophenol, where Ar = p-CH₃C₆H₄; p-ClC₆H₄ and p-O₂NC₆H₄. A possible path explaining retention is shown below. The group C₆H₅S thơ adds to the olefinic system and Cl thơ departs before the intermediate carbanions (32 and 35) have had time to rotate about the central bonds. The fact that the carbanions shown are probably tetrahedral is likely to be of little consequence, in as much as the two tetrahedral forms of the carbanion are rapidly interconverted by molecular rotation. The resultant sulphide-sulphone (34 and 37) on oxidation gave the corresponding disulphones.
Nucleophilic substitution in vinyl halides displacement mechanism.

It was observed that the addition of thiophenol to \( p \)-tolylsulphonylacetylene and \( p \)-nitrophenylsulphonylacetylene yielded \textit{cis}-1-phenylthio-2-\( p \)-tolylsulphonylethylene and \textit{cis}-1-phenylthio-2-\( p \)-nitrophenylsulphonylethylene\(^{49}\) respectively. It is also reported\(^ {48}\) that the nucleophilic addition of thiols to ethylsulphonylacetylene in presence of trion B yielded mainly \textit{cis}-1-ethylsulphonyl-2-alkylthieothlenes.

Peeran et al.\(^ {35}\) obtained \textit{trans}-1,2-bis (phenylthio) stilbene from benzoin and excess of thiophenol in the presence of pulverized zinc chloride and HCl gas. Following a similar procedure, Lakshmi Devi\(^ {51}\) prepared about six pairs of \textit{trans}-1,2-bis (alkylthio and arylthio) stilbenes and their corresponding disulphones.

Crombie\(^ {52}\), in his review on ‘geometrical isomerism about carbon-carbon double bonds’ has dealt extensively with the various methods of preparing geometrical isomers and their physical and chemical properties.
A number of physical methods have been used for the configurational studies of geometrical isomers. Usually, cis-isomers have lower melting point than the corresponding trans-isomers (Table I-1). This is generally attributed to the higher symmetry of trans compounds which results in better packing and greater forces in the crystal lattice.

Table I-1.
Melting points of some geometrical isomers

<table>
<thead>
<tr>
<th>Compound</th>
<th>M.P. °C</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cis</td>
<td>trans</td>
</tr>
<tr>
<td>CH$_3$CH=CHCOOH</td>
<td>50</td>
<td>72</td>
</tr>
<tr>
<td>HOOCCH=CHCOOH</td>
<td>130</td>
<td>286</td>
</tr>
<tr>
<td>C$_6$H$_5$CH=CHCOOH</td>
<td>68</td>
<td>133</td>
</tr>
<tr>
<td>CH$_3$CH=C(CH$_3$)COOH</td>
<td>45</td>
<td>64</td>
</tr>
<tr>
<td>C$_6$H$_5$CH=CHC$_6$H$_5$</td>
<td>60</td>
<td>124</td>
</tr>
<tr>
<td>C$_6$H$_5$CH=CHCOC$_6$H$_5$</td>
<td>46</td>
<td>58</td>
</tr>
<tr>
<td>$p$-CH$_3$C$_6$H$_4$SO$_2$CH=CHSC$_6$H$_5$</td>
<td>103-104</td>
<td>111-112</td>
</tr>
<tr>
<td>$p$-ClC$_6$H$_4$SO$_2$CH=CHSC$_6$H$_5$</td>
<td>69-70</td>
<td>89-90</td>
</tr>
<tr>
<td>$p$-NO$_2$C$_6$H$_4$SO$_2$CH=CHSC$_6$H$_5$</td>
<td>104-105</td>
<td>152-153</td>
</tr>
<tr>
<td>$p$-CH$_3$C$_6$H$_4$SO$_2$(Cl)C=C(Cl)SO$_2$C$_6$H$_4$CH$_3$-p</td>
<td>151-152</td>
<td>190-191</td>
</tr>
<tr>
<td>$p$-CH$_3$C$_6$H$_4$SO$_2$(C$_6$H$_5$)C=C(C$_6$H$_5$)SO$_2$C$_6$H$_4$CH$_3$-p</td>
<td>158-159</td>
<td>276-277</td>
</tr>
<tr>
<td>$p$-CH$_3$C$_6$H$_4$SO$_2$(C$_6$H$_5$)C=C(C$_6$H$_5$)SO$_2$CH$_2$CH$_3$</td>
<td>176-177</td>
<td>214-215</td>
</tr>
</tbody>
</table>
The cis compounds are also found to have higher boiling points (Table I-2).

Table I-2.

Boiling points of some geometrical isomers

<table>
<thead>
<tr>
<th>Compound</th>
<th>B.P. °C</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₃CCH=CHCH₃</td>
<td>3.73</td>
<td>0.96</td>
</tr>
<tr>
<td>CH₃CH₂CH=CHCH₃</td>
<td>37</td>
<td>35.85</td>
</tr>
<tr>
<td>ClCH=CHCl</td>
<td>60</td>
<td>48</td>
</tr>
<tr>
<td>BrCH=CHBr</td>
<td>112.5</td>
<td>108</td>
</tr>
</tbody>
</table>

Exceptions to this general behaviour where the cis isomers have higher melting points and lower boiling points, have also been reported (Table I-3).

Table I-3.

Some cis and trans isomers having complex physical constants

<table>
<thead>
<tr>
<th>Compound</th>
<th>M.P. °C</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₆H₅C(CN)=CHCN</td>
<td>89-90</td>
<td>42-43</td>
</tr>
<tr>
<td>C₆H₅COCH=CHCOC₆H₅</td>
<td>134</td>
<td>111</td>
</tr>
<tr>
<td>C₆H₅SO₂CH=CHCO C₆H₅</td>
<td>148-149</td>
<td>113-115</td>
</tr>
<tr>
<td>C₆H₅CH=CHSC₆H₄CH₃-p</td>
<td>63-64</td>
<td>42-43</td>
</tr>
<tr>
<td>p-NO₂C₆H₄CH=CHSC₆H₄CH₃-p</td>
<td>98-99</td>
<td>87-88</td>
</tr>
</tbody>
</table>
The *cis* compounds which have weaker forces in the crystal lattice possess greater solubility in inert solvents. The heats of combustion and heats of hydrogenation of *cis* isomers are also greater than those of *trans* isomers. The *cis-trans* isomerism has a significant effect on the strength of acids. The *cis* acids are usually (but not always) stronger than their *trans* isomers and this is illustrated in Table I-4.
Table I-4.

Strengths of some *cis* and *trans* isomeric acids\(^{57}\)

<table>
<thead>
<tr>
<th>Compound</th>
<th>(pK_a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>cis</em></td>
</tr>
<tr>
<td>ClCH=CHCOOH</td>
<td>3.32</td>
</tr>
<tr>
<td>CH(_2)CH=CHCOOH</td>
<td>4.44</td>
</tr>
<tr>
<td>C(_6)H(_5)CH=CHCOOH</td>
<td>3.88</td>
</tr>
<tr>
<td>CH(_2)CH=C(CH(_3))COOH</td>
<td>4.30</td>
</tr>
<tr>
<td>2,4,6-(CH(_3))(_3) C(_6)H(_2)CH=CHCOOH</td>
<td>6.12</td>
</tr>
</tbody>
</table>

In the case of symmetrically substituted olefines, dipole moments usually offer unambiguous configurational proof on the geometry of the molecules if the moment of these substituent groups is collinear with the bond joining them to the double bond\(^{64}\). However, if these substituent groups are angular and the possibility of their free rotation exists, dipole moment measurements may not always show a distinct difference between *cis* and *trans* isomers.

The dipole moments of symmetrically disubstituted olefines listed in the Table I-5 are in agreement with configurations assigned to them on the basis of other properties. While the *trans* isomers have zero dipole moments, the *cis* isomers have significant moments.
Table I-5.
Dipole moments of some cis and trans isomers

<table>
<thead>
<tr>
<th>Compound</th>
<th>$\mu$ (D)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2-Difluoroethylene</td>
<td>2.42</td>
<td>65</td>
</tr>
<tr>
<td>1,2-Dichloroethylene</td>
<td>1.74</td>
<td>66</td>
</tr>
<tr>
<td>1,2-Dibromoethylene</td>
<td>1.35</td>
<td>67</td>
</tr>
<tr>
<td>1,2-Diiodoethylene</td>
<td>0.75</td>
<td>68</td>
</tr>
<tr>
<td>1-Bromo-2-chloroethylene</td>
<td>1.56</td>
<td>67</td>
</tr>
<tr>
<td>2,3-Dichloro-2-butene</td>
<td>2.43</td>
<td>69</td>
</tr>
<tr>
<td>$\alpha,\beta$-Dichlorostilbene</td>
<td>2.69</td>
<td>70a</td>
</tr>
<tr>
<td>Azobenzene</td>
<td>3.00</td>
<td>70b</td>
</tr>
<tr>
<td>2,2-Azonaphthalene</td>
<td>3.00</td>
<td>70c</td>
</tr>
</tbody>
</table>

There are, however, many cis and trans isomers whose configurations cannot easily be decided from dipole moments. Some of these complex cases are listed in Table I-6.
### Table I-6.
Dipole moments of some complex cases

<table>
<thead>
<tr>
<th>S.No</th>
<th>Compound</th>
<th>B.P. (°C)</th>
<th>μ(D)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,2-Dichloropropene</td>
<td>76</td>
<td>0.84</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>93</td>
<td>2.20</td>
<td>71</td>
</tr>
<tr>
<td>2</td>
<td>1,3-Dichloropropene</td>
<td>104</td>
<td>1.92</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>112</td>
<td>1.73</td>
<td>71</td>
</tr>
<tr>
<td>3</td>
<td><em>cis</em>-1-Chloropropene</td>
<td>32-32.5</td>
<td>1.71</td>
<td>72</td>
</tr>
<tr>
<td>4</td>
<td><em>trans</em>-1-Chloropropene</td>
<td>37-38</td>
<td>1.97</td>
<td>72</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2-<em>p</em>-Chlorophenyl-2-phenylvinyl bromide</td>
<td>94-95</td>
<td>2.27</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43-44</td>
<td>1.28</td>
<td>73</td>
</tr>
<tr>
<td>6</td>
<td>2-<em>p</em>-Bromophenyl-2-phenylvinyl bromide</td>
<td>109</td>
<td>2.48</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>42-44</td>
<td>1.22</td>
<td>73</td>
</tr>
<tr>
<td>7</td>
<td>2-<em>p</em>-Chlorophenyl-1,2-diphenylvinyl bromide</td>
<td>160</td>
<td>2.61</td>
<td>70a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>119</td>
<td>1.57</td>
<td>70a</td>
</tr>
<tr>
<td>8</td>
<td>1,2-Bis(<em>p</em>-tolylmercapto)ethylene</td>
<td>91-92</td>
<td>2.61</td>
<td>74a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55.5-56.5</td>
<td>2.37</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1,2-Dichloro-1,2-bis(<em>p</em>-tolylmercapto)ethylene</td>
<td>101-102</td>
<td>2.39</td>
<td>74a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>81-82</td>
<td>2.60</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1,2-Dichloro-1,2-bis(<em>p</em>-tolylsulphonyl)ethylene</td>
<td>185-186</td>
<td>5.55</td>
<td>74a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>151-152</td>
<td>4.10</td>
<td></td>
</tr>
</tbody>
</table>

**M.P.(°C)**
Smith and King\textsuperscript{71} assigned trans configuration for the isomer boiling at 76 °C of 1,2-dichloropropene. In the case of 1,3-dichloropropene, the lower boiling isomer (104 °C) was assigned the trans configuration by Hatch and Roberts\textsuperscript{76}, but Smith and King\textsuperscript{71} fixed it as the cis isomer. The higher moment shown by trans-1-chloropropene than the corresponding cis isomer was explained by Hannay and Smyth\textsuperscript{72} on the basis of resonance. For the compounds (5),(6) and (7) Bergmann\textsuperscript{70a,73}, assigned cis configuration for the higher melting compounds and suggested that the lower melting compounds were a mixture of cis and trans isomers having moments about half those of the cis isomers. Later Curtin and Harris\textsuperscript{77} determined dipole moments for the isomers of 1-bromo-2-p-chlorophenyl-1,2-diphenylethylene (7) and claimed that the lower melting compound(119 °C) was essentially, a pure trans isomer. For the compounds (8), (9) and (10), Truce and Groten\textsuperscript{74a} assigned cis configuration for the higher melting compounds by the study of dipole moments, infrared and nuclear magnetic studies. But later, on the basis of crystallography and other physico-chemical studies they\textsuperscript{48} have reversed the configurations for the compounds (9) and (10).

Higher moment of the trans isomer is explained by the fact when the moment of one group acts towards the olefinic carbon and the moment of another acts away from the olefinic carbon as indicated in I.

\[
\begin{align*}
\text{C} = \text{C}
\end{align*}
\]
This is illustrated in the case of trans-p-amino- and trans-p-dimethylamino-cinnamonicnitriles which are having higher moments than the respective cis-compounds. Their values are shown in the Table I-7.

Table I-7.
Dipole moments of some cis- and trans- aminocinnamonicnitriles

<table>
<thead>
<tr>
<th></th>
<th>( \mu ) (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cis-p-Amino-cinnamonicnitrile</td>
<td>4.95</td>
</tr>
<tr>
<td>trans-p-Amino-cinnamonicnitrile</td>
<td>6.30</td>
</tr>
<tr>
<td>cis-p-Dimethylaminocinnamonicnitrile</td>
<td>5.68</td>
</tr>
<tr>
<td>trans-p-Dimethylaminocinnamonicnitrile</td>
<td>7.03</td>
</tr>
</tbody>
</table>

Geometrical isomers can be differentiated by UV absorption spectra. When bulky conjugating substituents are attached to the olefinic carbon atoms, the trans arrangement of the substituents allow coplanarity of the conjugating system facilitating the transition from the ground state to the first excited state. If the bulky substituents are cis to each other there will be steric inhibition of resonance due to deviation from coplanarity leading to a considerable decrease in the molecular extinction coefficient. In some cases, steric effect may also cause a hypsochromic shift of the absorption maximum of the cis isomer. These effects are illustrated by the data given in Table I-8.

Table I-8.
UV absorption spectra of some cis and trans isomers
(Wavelengths are in nm)

<table>
<thead>
<tr>
<th>Compound</th>
<th>cis</th>
<th>trans</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \lambda_{\text{max}} )</td>
<td>( \varepsilon_{\text{max}} )</td>
<td>( \lambda_{\text{max}} )</td>
</tr>
<tr>
<td>( \text{C}_6\text{H}_5\text{CH}=\text{CHC}_6\text{H}_5 )</td>
<td>280</td>
<td>13,500</td>
<td>295.4</td>
</tr>
<tr>
<td>( \text{C}_6\text{H}_5(\text{CH}_3)\text{C}=\text{CHC}_6\text{H}_5 )</td>
<td>260</td>
<td>11,900</td>
<td>270</td>
</tr>
</tbody>
</table>
Truce and Simms\textsuperscript{87} assigned geometrical configurations for the cis- and trans-styryl-p-tolylsulphones by ultraviolet spectral studies. They found that the trans isomer has higher absorption maximum and extinction coefficient than the corresponding cis isomer. Similar results have been reported for β-chlorovinylsulphones\textsuperscript{88,89} and α,β-unsaturated sulphones\textsuperscript{59}. For some geometrical isomers, in the spectral characteristics (Table I-9) deviate from the regularities mentioned in the above Table I-8. However, the absorption intensities of the long wavelength bands of the trans isomers are generally greater than those of the corresponding cis isomers.

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|c|c|}
\hline
S.No & Compound & \textit{cis} & \textit{trans} & \textit{Ref.} \\
\hline
1 & CH\textsubscript{3}CH=CH-CH=CH\textsubscript{2} & 223 & 22,600 & 223.5 & 23,000 & 90 \\
\hline
\end{tabular}
\caption{Some cis and trans isomers having complex spectral characteristics (Wavelengths are in nm)}
\end{table}
cis- and trans-Piperylenes (1) have maxima of identical intensity indicating no opposition to coplanarity. In the case of (2) also, the cis and trans isomer have maxima of identical intensity but the $\lambda_{\text{max}}$ of the cis isomer is at a higher wavelength. In compounds (3) to (7), the intensities are as expected, but the $\lambda_{\text{max}}$ of the cis isomers are at higher wavelengths. When deviation from the planar configuration becomes so large that the energy required for electronic excitation of the conjugated system is prohibitive, absorption reverts to that of the isolated chromophores $^{94}$.

Raman and IR spectra have also proved to be useful in differencing cis and trans isomers. Trans-1,2-Dichloroethylene shows no double bond stretching frequency in the infrared, although strong absorption band is found in the Raman spectrum at 1577 cm$^{-1}$. On the other hand, cis-1,2-dichloroethylene shows strong infrared absorption at 1590 cm$^{-1}$. Similar differences are shown between fumaric acid and maleic acid and trans and cis-3-hexenes. There is also a small but measurable shift in the position of the C=C stretching band between cis and trans isomers. This shift can be measured in the Raman spectrum where both isomers have strong double bond absorption $^{43}$. Thus cis olefines absorb at 1654-1657 cm$^{-1}$ whereas trans olefines absorb at 1668-1671 cm$^{-1}$. The relation of infrared absorption to geometrical configuration has been extremely well documented for many compounds $^{97-101}$.

Differences between the infrared spectra of geometrical isomers arise mainly due to symmetry differences. The bands most useful for distinguishing cis and trans isomers are those arising form
a) the C=C stretching frequency (1620-1680 cm$^{-1}$)\textsuperscript{101},
b) the –C-H in-plane and out-of-plane deformation frequencies (895-990 cm$^{-1}$)\textsuperscript{43} and
c) the =C-H in-plane deformation frequency (690 and 970 cm$^{-1}$)\textsuperscript{43} and out-of -plane
deformation frequency (1290-1310 cm$^{-1}$ and near 1405 cm$^{-1}$)\textsuperscript{102}. Some relevant data
are presented in Table I-10.

**Table I-10.**

Characteristic infrared frequency (in cm$^{-1}$) of ethylenes containing halogens
and other substituents or conjugated unsaturated groups.\textsuperscript{103}

<table>
<thead>
<tr>
<th>Compound</th>
<th>cis</th>
<th>trans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\nu$(C=C)</td>
<td>$\delta$(=C-H)</td>
</tr>
<tr>
<td>CH$_3$CH=CHCl</td>
<td>1640</td>
<td>675s</td>
</tr>
<tr>
<td>CH$_2$ClCH=CHCl</td>
<td>1625s</td>
<td>*</td>
</tr>
<tr>
<td>CHCl=CHCl</td>
<td>1950s</td>
<td>697</td>
</tr>
<tr>
<td>CH$_3$CH=CHBr</td>
<td>1614</td>
<td>685</td>
</tr>
<tr>
<td>CH$_2$BrCH=CHBr</td>
<td>1595</td>
<td>680</td>
</tr>
<tr>
<td>CH$_3$CH=CHC$_6$H$_5$</td>
<td>1653s</td>
<td>769s</td>
</tr>
<tr>
<td>CH$_3$CH(OH)CH=CHC$_6$H$_5$</td>
<td>1645w</td>
<td>*</td>
</tr>
<tr>
<td>$n$-C$_4$H$_9$CH=CHCOOH</td>
<td>1642</td>
<td>*</td>
</tr>
</tbody>
</table>

* Not recorded, identification uncertain.  s, strong; m, medium; w, weak

From theoretical consideration no $\nu_{C-C}$ should appear in the infrared spectra of
symmetrically substituted olefines since there is no appreciable change in dipole moment.
Thus ethylene and *trans*-1,2-dichloroethylene are both inactive in this region\textsuperscript{97}. On the other
hand, cis-1,2-dichloroethylene shows a strong infrared absorption at 1590 cm\(^{-1}\). Similarly in maleic acid \(\nu_{\text{C=C}}\) occur at 1635 cm\(^{-1}\), but fumaric acid shows no outstanding band in this region\(^{104a}\). Bernastein and Powling\(^{104b}\) studied the relative optical densities of C=C absorption in cis- and trans-1,2-dichloropropenes and their deuterio derivatives. It is observed that the trans isomers show high intensity C=C absorption compared to the respective cis isomers. The C=C stretching frequency is lowered from 1667 to 1653 cm\(^{-1}\) on passing from trans to cis methylstyrene\(^{105}\).

Allan et al.\(^{106}\) observed small but significant low frequency shifts of C=C on going from trans to cis isomers. Their values are listed in Table I-11.

Table I-11.

<table>
<thead>
<tr>
<th>Compound</th>
<th>(\nu_{\text{C=C}}) cm(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{CH}_3\text{C}≡\text{CCH=CHCOOCH}_3)</td>
<td>cis 1612 trans 1615</td>
</tr>
<tr>
<td>(\text{CH}_3\text{CH}=\text{CHCOOCH}_3)</td>
<td>cis 1644 trans 1659</td>
</tr>
<tr>
<td>(\text{CH}_3\text{CH}=\text{CHCOOH})</td>
<td>cis 1639 trans 1651</td>
</tr>
<tr>
<td>(\text{CH}_3\text{C}≡\text{CCH=CHCOOCH}_3)</td>
<td>cis 1612 trans 1615</td>
</tr>
<tr>
<td>(\text{CH}_3\text{CH}=\text{CH-C}≡\text{CCOOCH}_3)</td>
<td>cis 1615 trans 1626</td>
</tr>
<tr>
<td>(\text{CH}_3\text{C}≡\text{CCH=CHCOOH})</td>
<td>cis 1609 trans 1619</td>
</tr>
</tbody>
</table>

Harwell and Hatch\(^{107}\) after scrutinizing the spectra of halosubstituted propenes, attributed the strong and sharp =C-H in-plane bending bands in the region 1290 and 1235 cm\(^{-1}\) to the cis and trans compounds respectively. Their values are cited in Table I-12.
Table I-12.

=C−H in-plane bending bands of some cis- and trans- compounds

<table>
<thead>
<tr>
<th>Compound</th>
<th>cm⁻¹</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cis</td>
<td>trans</td>
</tr>
<tr>
<td>CH₃CH=CHBr</td>
<td>1285</td>
<td>1202</td>
</tr>
<tr>
<td>BrCH₂CH=CHBr</td>
<td>1292</td>
<td>1242</td>
</tr>
<tr>
<td>HOCH₂CH=CHBr</td>
<td>1287</td>
<td>1235</td>
</tr>
<tr>
<td>ClCH₂CH=CHBr</td>
<td>1287</td>
<td>1235</td>
</tr>
<tr>
<td>CH₃CH=CClBr</td>
<td>1307</td>
<td>1230</td>
</tr>
</tbody>
</table>

Kilpatrick and Pitzer¹⁰⁸ showed that the medium to strong bands at 990-965 cm⁻¹ found in trans ethylenic compounds are due to =C−H out-of-plane deformation. Rasmussen and Brattain⁹⁹ have shown that this absorption bands appear only with trans double bonds. Typical cases of absorption within the 980-965 cm⁻¹ range⁹⁸, ¹⁰¹,¹⁰⁷,¹⁰⁹a are recorded in almost all cases and the frequency lies close to 965 cm⁻¹. But if the double bond is α, β to the carbonyl group, a small displacement to higher frequency occurs. Crotanic, cinnamic and acrylic acids¹⁰⁴a absorb in the range 982-974 cm⁻¹. The halogens attached to the double bond have a more pronounced effect.

Haszeldine¹⁰⁹b quoted values of 935 cm⁻¹ for the =C−H deformation of −CH=CHBr and −CH=CHCl and Kitson¹⁰⁹c has confirmed this. Conjugation with aromatic rings as in stilbenes¹¹⁰-¹¹² does not influence the position of the 965 cm⁻¹ band, but it is displaced to slightly lower frequency when conjugated with acetylenic links.¹⁰⁶

Sheppard and Simpson⁹⁸ reported a range of 728-625 cm⁻¹ for the =C−H out-of-plane deformation in cis disubstituted ethylenes. It is much more sensitive to the environment than the corresponding 965 cm⁻¹ trans band. Halogen atoms on one or both alkyl substituents or at the olefinic carbon atom cause a marked shift to higher frequency¹⁰⁹c, conjugation with carbonyl group has also a marked effect⁹⁶. Thus the group −CH=CHCOOH (cis) absorbs near
820 cm\(^{-1}\). This absorption is usually much weaker in intensity than that of the \(\text{trans}\) compounds.

Boonstra and Rinzema\(^{112}\) studied \(1\)-alkylthio-2-alkenes, RSCH=CHR and found an absorption band near 1600 cm\(^{-1}\), a strong band at 1350-1330 cm\(^{-1}\) and another strong band at 935 cm\(^{-1}\). They have also studied \(\text{cis}\)- and \(\text{trans}\)-1,2-bis (alkythio) ethenes, RSCH=CHSR, and assigned bands arising in the region 1545 - 1535 cm\(^{-1}\) for the C=C stretching vibrations of the \(\text{cis}\) isomers. This band was absent in all the corresponding \(\text{trans}\) isomers. The assignment of the former band (1545 – 1535 cm\(^{-1}\)) towards the C=C stretching vibrations in the \(\text{cis}\) isomers was contradicted by Truce and Groten\(^{23}\).

The nuclear magnetic resonance spectral studies provide information on the number of olefinic protons, the type of double bond, and in many case of geometrical configuration of the groups about the double bond. In the case of the disubstituted olefines the measurements of the coupling constants between protons on opposite end of the double bond allows a distinction to be made between \(\text{cis}\) and \(\text{trans}\) isomers. Coupling is not observed in the case of symmetrical substitution, since protons are not chemically shifted relative to each other. It has been observed constantly in a number of investigations that \(J_{\text{trans}} > J_{\text{cis}}\).

The spin-spin coupling constants of ethylenic hydrogens in 1,2-disubstituted ethenes, (J values) vary from 6-14 cps in the \(\text{cis}\) compounds and from 11-18 cps in the \(\text{trans}\) compounds\(^{113}\).

The coupling constants for the homologous \(\text{cis}\) and \(\text{trans}\)-1-phenyl-2-(phenylsulphonyl) ethenes were found\(^{114}\) to be 12.4 and 15.7 c.p.s. The values are in agreement with the observation that \(\text{trans}\) ethenes of this type invariably have higher coupling constants that the corresponding \(\text{cis}\) isomers. The spin-spin coupling constants for some unsaturated sulphides and sulphones are presented in Table I-13.
Table I-13.

Vicinal coupling constants for some

cis and trans unsaturated sulphides and sulphones

<table>
<thead>
<tr>
<th>Compound</th>
<th>( J_{HH} ) cps</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cis</td>
<td>trans</td>
</tr>
<tr>
<td>( p-\text{CH}_3\text{C}_6\text{H}_4\text{SCH=CHCOOH} )</td>
<td>9.7</td>
<td>15.4</td>
</tr>
<tr>
<td>( p-\text{CH}_3\text{C}_6\text{H}_4\text{SCH=CHCOOC}_2\text{H}_5 )</td>
<td>10.4</td>
<td>14.9</td>
</tr>
<tr>
<td>( \text{CH}_3\text{CH}_2\text{SO}_2\text{CH=CHCH}_5 )</td>
<td>-</td>
<td>15.5</td>
</tr>
<tr>
<td>( \text{CH}_3\text{CH}_2\text{SO}_2\text{CH=CHCH}<em>3\text{Cl}</em>{2-3,4} )</td>
<td>-</td>
<td>15.5</td>
</tr>
<tr>
<td>( \text{CH}_3\text{CH}_2\text{SO}_2\text{CH=CH-pyridyl-3} )</td>
<td>-</td>
<td>15.5</td>
</tr>
<tr>
<td>( \text{CH}_3\text{SO}_2\text{CH=CHCH}_5 )</td>
<td>-</td>
<td>16.0</td>
</tr>
<tr>
<td>( \text{CH}_3\text{SO}_2\text{CH=CH(CH}_2)_6\text{CH}_3 )</td>
<td>-</td>
<td>15.0</td>
</tr>
<tr>
<td>( p-\text{ClC}_6\text{H}_4\text{SO}_2\text{CH=CHCH}_5 )</td>
<td>-</td>
<td>16.2</td>
</tr>
</tbody>
</table>

The \( \alpha,\beta \)-ethylenic sulphones which were prepared by different routes have been confirmed\(^{115,116}\) as trans isomers by n.m.r spectral studies since the spin-spin coupling constants were found to be in the range of \( J_{HH} = 14-16 \) cps. In trisubstituted ethylenes of the type \( \text{CH}_3\text{aC=CHb} \) differences in chemical shifts rather than coupling constants have been used\(^{117,118}\) to differentiate the cis and trans isomers.

Geometrical isomers can also be differentiated by mass spectra. In general the relative abundance of the molecular ion of cis-isomer is lower than that of the trans-isomer. This distinction has, however, been found to be absent in many substituted ethylenes. For example both the isomers of 2-butene, 2-pentene, 4-methyl-2-pentene and 3-hexene gave molecular ion of same stability. The cis-trans isomers of hex-2-ene-1-ol have been distinguished by mass spectrometry. As expected both the isomers gave similar spectra but the molecular ion
peak from the trans isomer is more intense than the cis isomer. The dehydration fragment for the cis isomer is much stronger. In order to study the effect of geometry of the double bond upon the fragmentation pathways Hill and his co-workers$^{119}$, have determined the mass spectra of cis- and trans-1-p-tolyl sulphenyl-2-p-tolylsulphonylstilbenes and cis- and trans-1,2-bis (p-tolylsulphonyl) stilbenes. The mass of cis- and trans- sulphenylsulphones were found to be identical so also the mass spectra of cis- and trans-1,2-bis (p-tolylsulphonyl) stilbenes. The mass spectra of cis-and trans –isomers of these compounds was found to be identical.

The element selenium is exceedingly effective in the prevention of necrotic liver degeneration. The element has been shown to be constantly present in tissues of higher animals$^{120}$. A comparison of tissue distribution of selenium with that of other trace elements in organs from Glasgow residents has led Liebscher and Smith$^{121}$ to conclude that selenium, like copper and zinc but unlike arsenic, antimony and mercury, must be an essential element for human being.

A strange rationale does exist, however for the incorporation of selenium into potential medicinal agents; this is predicted on the close resemblance of selenium to the biologically important element sulphur.

Minor chemical variations in the structure of active drugs have been known to result in remarkable modifications in their biological properties, hence the substitution of selenium for sulphur could in theory, lead to a more effective agent. Sulphur and Selenium belonging to same group, same size can be considered to be isosteric. The medicinal implications of the concept of isosterism have been reviewed by Schatz$^{122}$. In general compounds in which the selenium atom is part of an actual or potential functional group capable of reacting with sulphydryl groups tend to be considerably more toxic than their sulphur isosters. High toxicity does not rule out a compound for drug use, but it prevents frequently the administration of an effective dose that is also safe.

On the other hand when Se atom is not readily accessible as in a stable ring system such as selenophene, the toxicities of sulphur and selenium analogues do not differ widely. In some instances, cyclic selenium compounds have been reported to be even less toxic than the comparable sulphur compounds. Selenium compounds can act as anti bacterial agents and are sometimes more active than their sulphur analogues. Bis (p-amino phenyl) diselenide$^{123}$ is
found to be thousand fold more effective as an antibacterial agent than bis (p-amino phenyl) disulphide. Selenium compounds that have been tested for their bactericidal properties have frequently been screened simultaneously as potential fungicides. In comparing anti fungal activities of some selenium compounds had 10-1000 times greater effectiveness on a molar basis than sulphur compounds. Selenium compounds can also act as antiparasitic agents\textsuperscript{124}, analgesics\textsuperscript{125}, local anaesthetics\textsuperscript{126a}, antiinflammatory compounds\textsuperscript{126b}, antihistamines\textsuperscript{126c} and anti cancer agents\textsuperscript{127}.

Selenium compounds also play an important role in the metabolism of plants, animals and micro organisms. Selenocysteine itself is labile under the concentrated acid condition often used for the hydrolysis of proteins\textsuperscript{128}. At the biochemical level, several enzymes handle selenomethionine as if it was the normal substrate. The two amino acids differ, however in several properties. Selenomethionine proved highly effective in protecting amino acids from radiation damage. Selenomethionine also protected several enzymes from radiation damage more completely than did methionine\textsuperscript{129}.

Powerful cancer chemo preventive effects are seen for selenoamino acids, and various synthetic organoselenium compounds\textsuperscript{130}. A series of novel organo- selenium compounds \(p\)-Methoxybenzeneselenol (MBS), benzylselenocyanate (BSC) and \(1,4\)-phenylenebis-(methylene) selenocyanate (\(p\)-XBC) are synthesized for chemoprevention and are of lower toxic activity\textsuperscript{131a-c,132}. Effects of those compounds on carcinogenesis have been examined in several organs and found chemo preventive effects in animal models.

The compounds \(p\)-Methoxybenzeneselenol (MBS), benzylselenocyanate (BSC) and \(1,4\)-phenylene bis-(methylene)selenocyanate (\(p\)-XBC) inhibit carcinogenesis in some organs using animal models and are effective in both the initiation and post-initiation phase. These organo seleniums are less toxic and more chemopreventive than inorganoseleniums and natural organoseleniums. These organoseleniums can be candidates of chemo preventive agents for human cancers\textsuperscript{133}.

Selenium and vitamin E have attracted great attention after the decision of the National Institutes of Health to sponsor the selenium and vitamin E chemoprevention trail (SELECT) for the prevention of prostate cancer\textsuperscript{134}. There has been a growing interest in the synthesis of organoselenium compounds with respect to enzymology and bioorganic chemistry because these compounds are much less toxic compared to inorganic selenium
species. Several of these organoselenium compounds, including selenomethionine and aromatic selenium molecules, have been found to inhibit both tumorigenesis in a variety of the animal models\textsuperscript{135-138} and human tumor cell growth in vitro\textsuperscript{139}. Cancer cell death mechanisms have been associated with structural characteristics of organoselenium molecules\textsuperscript{140}.

\(\alpha\)-, \(\gamma\)-Tocopheryl and \(\gamma\)-tocotrienyl phenylselenyl succinate as well as their succinate analogues were synthesized and their pro-apoptotic properties on prostate cancer cell were evaluated. The new strategy of using conjugates of succinylated tocopherol and tocotrienols with selenium to probe the biological responses and mechanism of cell death induced by the structural and chemical modifications of the functional domain has been proven to be successful\textsuperscript{141}.

The literature reviewed so far indicates that only a very few number of (\(E\))- and (\(Z\))-sulphides, sulphones, sulphide-sulphones and bisulphones are known. The physico-chemical data available on these compounds is also scanty and the collection of more data would be a valuable addition to our present knowledge of these compounds. With these considerations, the author undertook the synthesis, physico-chemical study and biological evaluation of a few new (\(E\)) - and (\(Z\)) - sulphides, sulphones, sulphide-sulphones, disulphones and some related selenium compounds.
1.2. REFERENCES:


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