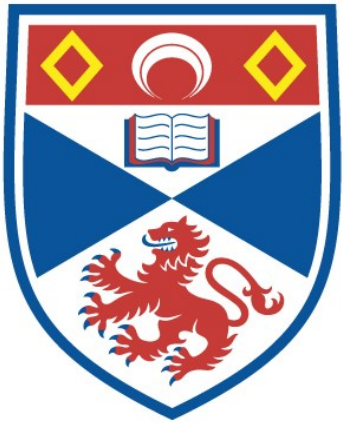
THE REACTIONS OF THIOPHENS AND FURANS WITH 2, 4-DINITROBENZENE DIAZONIUM COMPOUNDS

Suresh Trimbak Gore

A Thesis Submitted for the Degree of PhD
at the
University of St Andrews



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The Reactions of Thiophens and Furans

with 2,4--Dinitrobenzene Diazonium Compounds

being a Thesis

presented by

SURESH TRIMBAK GORE, B.Sc.

to the

UNIVERSITY OF ST. ANDREWS

in application for

THE DEGREE OF DOCTOR OF PHILOSOPHY

DECLARATION

I declare that this thesis is based on the results of experiments carried out by me, that it is my own composition and has not previously been presented for a higher degree.

The work was carried out in the Department of Chemistry of the University of St. Andrews, under the direction of Professor Lord Tedder, since March 1973.

CERTIFICATE

I hereby certify that Suresh Trimbak Gore, B.Sc. has spent eleven terms at research work under my supervision, has fulfilled the conditions of the Resolution of the University Court 1967, No. 1, and that he is qualified to submit the accompanying thesis in application for the degree of Doctor of Philosophy.

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to Professor Lord Tedder for his advice and encouragement over the past three years. I am also grateful to Dr. R. K. Mackie for his interest in this work.

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SUMMARY

The reaction of several thiophens and furans with 2,4-dinitrobenzene diazonium sulphate in glacial acetic acid/water mixture has been studied. Thiophen and its 2-and 3-monomethyl derivatives gave arylated products with the liberation of nitrogen. Although there is a strong indication that free radicals are involved, the reaction mechanism remains uncertain. Various likely paths are discussed.

2,4-Dimethyl, 2-t-butyl, and 2-phenyl thiophens yielded the azo compounds with the same diazonium salt. 2-Methylbenzo(b)thiophen, and 3-methylbenzo(b)thiophen also gave the azo coupled products.

2,5-Dimethylthiophen yielded an equal proportion of the 3-azo-compound and the 2,4-dinitrophenylhydrazone of 5-methylthiophen-2-aldehyde. Both the 2,3,5-trimethylthiophen and the tetramethylthiophen underwent side chain substitution in the 5-and 2-position respectively to give the corresponding 2,4-dinitrophenylhydrazones. Dinitrophenylhydrazones of various polyalkyl thiophen aldehydes were prepared and characterised.

^{1}H n.m.r. spectra of polyalkyl thiophens in deuteriotrifluoroacetic acid showed the proton exchange in methyl groups. However, acetylation of polymethyl thiophens and diazocoupling of polyalkyl benzenoid hydrocarbons failed to give any side chain substitution products.

The reaction of furan, 2-methylfuran and 3-methylfuran with the 2,4-dinitrobenzene diazonium solution in acetic acid yielded substituted N-(2,4 dinitroanilino)- 2-oxo-2,5-dihydropyrroles. Initial azo coupling with the furan followed by ring opening and subsequent rearrangement is though to be the likely path for this reaction. Benzo(b)furan gave arylated products under similar conditions while 2-methylbenzo(b)furan gave a small amount of the azo coupled product in addition to the arylated product.

Several primary aromatic amines including the weakly basic mono and dinitro anilines were diazotised in trifluoroacetic acid. Short reaction periods were required for the completion of the diazotisation and high yields of azo coupled products were obtained by subsequent coupling reactions. ^{1}H and ^{13}C n.m.r. data on these benzene diazonium ions in trifluoroacetic acid was also obtained.

CONTENTS

I N T R O D U C T I O N

Introduction

The reactions of arene diazonium compounds have been studied for more than a hundred years and this study has been associated with many important developments in organic chemistry. In addition to their academic interest arene diazonium salts have had a major industrial significance through their coupling reactions to yield the azo dyestuffs. The most important method of preparation of aromatic azo compound involves diazotisation of primary aromatic amines with aqueous nitrous acid, followed by the coupling of the resultant diazonium salt with an appropriate coupling component (e.g. phenol or a tertiary amine). One of the motives for the present study was a recent

Scheme 1

$$Ar\text{-}NH_2 \xrightarrow{\text{aq. } HNO_2} \underset{\text{diazonium salt}}{Ar\text{-}\overset{+}{N}\equiv N\ X^-} \xrightarrow{Ar^1} \underset{\text{Azo compound}}{Ar\text{-}N{=}N\text{-}Ar^1}$$

interest shown by the dyestuff manufacturers in thiophen azo compounds.

The free amino thiophens are very unstable compounds and are required to be stored either in an inert atmosphere or as a stannic chloride double salt. 2-Aminothiophen and 2-acetylaminothiophen readily undergo diazo coupling in the 5-position[1]. This tendency of the thiophen nucleus to undergo diazo coupling complicates the preparation of a diazonium salt from 2-aminothiophen. Steinkopf and Müller[2] isolated a small amount of 2-thienyl diazonium chloride, the major product being an azo dyestuff formed as a result of self coupling. More recently some Russian workers report[3] the preparation of 2-thienyl diazonium chloride, by treating the 2-aminothiophen double salt in 10% hydrochloric acid with sodium nitrite, and subsequent azo coupling

with 2-naphthol. Within the last few years there have been several reports in the patent literature of coupling reactions involving diazotised amino thiophen derivatives[4]. Even less is known about furan diazonium salts. 2-Methyl, and 2,5-dimethyl, 3-aminofuran have been diazotised and the resultant diazonium salts coupled with 2-naphthol but failed to couple with NN-dimethylaniline. These diazonium salts did not undergo the other characteristic reactions of arene diazonium salts[5].

Very few simple aminopyrroles are known, so that the number which have been diazotised is small[6]. The pyrrole diazonium salt is capable of conversion into diazopyrrole. A diazopyrrole will not undergo coupling but when heated with a phenol, proton transfer occurs and the resultant pyrrole diazonium salt will couple with the phenoxide anion.

The formation of aromatic diazonium salts in a single step reaction involving the reaction of excess of nitrous acid with a suitable aromatic compound has been developed by Tedder and his co-workers[7,8]. This reaction (Scheme 2) enables an aromatic compound to be converted to diazonium salt in a single experimental step, compared with the previosly employed three step process; nitration, reduction to the amine and diazotisation. This one step

Scheme 2

$$\text{Ar-H} \xrightarrow[\text{HX}]{\text{HNO}_2} \left[\text{Ar-NO}\right] \xrightarrow[\text{HX}]{\text{HNO}_2} \text{Ar-}\overset{+}{\text{N}}\equiv\text{N}\ \text{X}^-$$

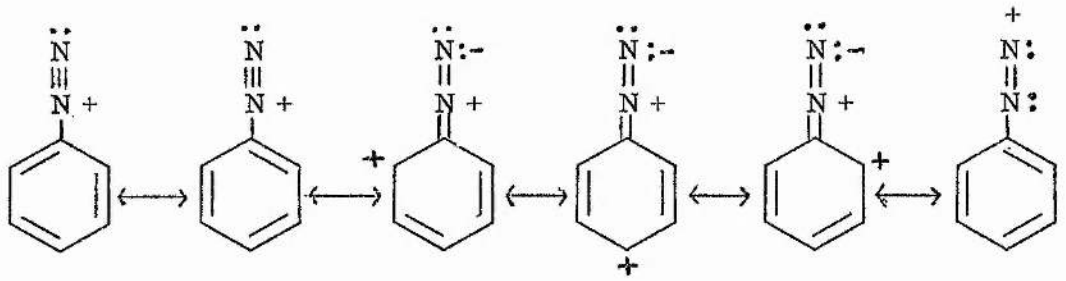
reaction has been successfully applied to yield diazonium salts from phenols, aromatic tertiary amines, phenol ethers and polyalkyl benzenes. In all cases

except phenols and tertiary amines, where the nitroso derivative was stabilised, the second step in scheme 2 was so rapid that no nitroso derivative was isolated. The mechanism for this reaction under a variety of conditions has been discussed[9].

In the present investigation this route appeared to provide an attractive alternative for the preparation of heteroaromatic diazonium salts and azo compounds from derivatives of thiophen and furan which could not be prepared by the conventional route. Several pyrroles have been converted to 2- and 3-diazopyrroles by this method and the azo compounds were isolated after coupling with 2-naphthol[10]. Attempts to apply the same method to thiophen or furan proved unsuccessful. Thiophen treated with nitrosyl sulphuric acid gave a dark brown solution similar to that encountered in the preparation of diazonium salt directly from anisole. These red brown colours had been ascribed to a π- complex between the nitrosonium ion and thiophen[11] or alternatively were previously ascribed to a complex ion formed between the nitrosonium ion and the aromatic nitroso compound[10]. Thiophen has a very similar range of reactivity to anisole, so that the failure to give diazonium salt under the same conditions was unexpected. Mesitylene, which is less reactive than thiophen, can be converted into a diazonium salt by the reaction with nitrosyl sulphuric acid.

The study of the coupling reaction of benzene diazonium ions with thiophen and furan was of interest for two reasons: firstly because this provided an alternative route to thiophen azo compounds and secondly because the reactivity of polynitrobenzene diazonium ions is similar to that of a nitrosonium ion which is believed to be an important intermediate in the direct

diazotisation process. The benzene diazonium ion, which can be considered as the resonance hybrid of the limiting structures (1a) to (1f) is a much weaker electrophile than nitronium ion, and couples only with phenols and tertiary amines. The reactivity of the benzene diazonium ion can be increased



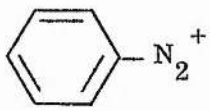
(1a) (1b) (1c) (1d) (1e) (1f)

by the introduction of electron withdrawing substituents like $-NO_2$, -F, or $-CF_3$ (see Table 1). In 1914 Meyer and his coworkers succeeded in forming azo compounds by the coupling of anisole and phenetole with 2,4-dinitrobenzene diazonium salts[12]. These workers also reported the coupling with butadiene derivatives[13] but recently these later products have been assigned different structures[14]. Even mesitylene coupled to give a crystalline azo compound with the reactive 2,4,6-trinitrobenzenediazonium ions[15].

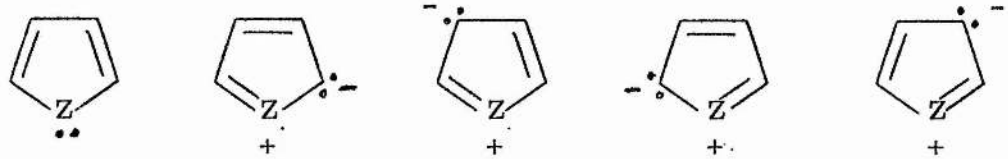
(Table 1 overleaf).

Table 1 [16]

Effect of substituents on coupling of benzene diazonium salts.

Substituents in 	Relative coupling rate with $C_6H_5O^-$	Couples with
No substituent	1	1,3,5 trimethoxybenzene
4-H_3C-O-	0.1	phenoxide anion
4-NO_2	1300	1,3 dimethoxy benzene
2,4-dinitro	Too fast for measurement	methoxybenzene
2,4,6-trinitro	" " " "	1,3,5 trimethylbenzene

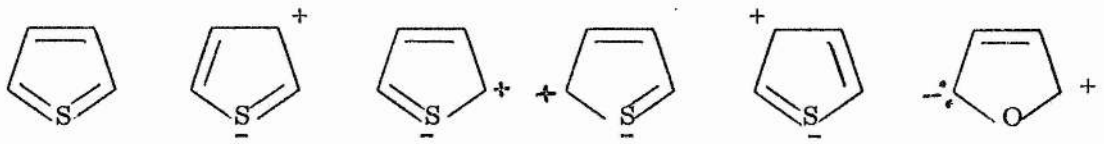
Thiophen, furan and pyrrole can all attain an "aromatic sextet" by the delocalisation of two electrons from the heteroatom in the π-orbitals of the ring. All three compounds show a high reactivity towards electrophilic aromatic substitution and they have sometimes been rather inappropriately described as "super aromatic". The delocalisation of the electron pair of the heteroatom can be depicted by considering these molecules as the resonance hybrids of the following contributing structures (2a) to (2e).



(2a) (2b) (2c) (2d) (2e)

Z = -N-, S, or O
|
H

In the case of thiophen, additional structures (3a) to (3e) are possible owing to the capacity of the sulphur atom to enlarge its valence shell. Finally structures such as (4) may be considered for furan in view of its "dienic" character.



(3a) (3b) (3c) (3d) (3e) (4)

The following table compares different criteria of "aromaticity" of benzene with corresponding values for thiophen, pyrrole and furan. Although values differ according to the procedure used for calculation, the following order of decreasing ground state aromaticity can be assigned. viz, benzene $\rangle$ thiophen $\rangle$ pyrrole $\rangle$ furan.

Table no. 2

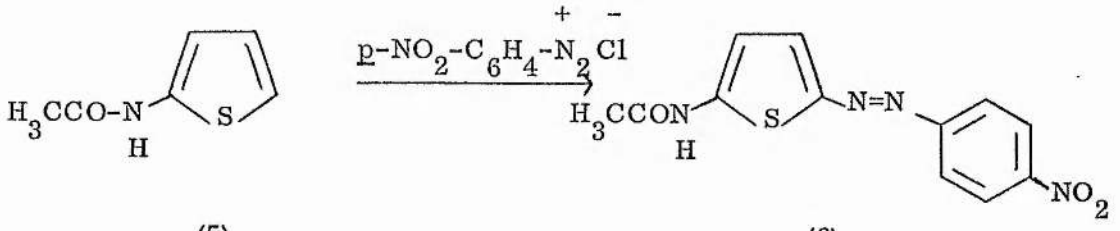
	Benzene	thiophen	pyrrole	furan	ref.
Resonance energy in K cal/mole.	36 36	28 31	24.5 31	22 23	17 18
Ratio of C(2)-C(3) to C(3)-C(4) bond length	1.	0.964	0.959	0.950	19
values based on induced ring current	100 100	75 90	59 67	46 52	20 21

The electron distribution in the ground state of these five membered heterocycles is affected by two opposing processes. The donation of an

electron pair from heteroatom to the π -orbital system of the ring is opposed by inductive withdrawal due to the greater electronegativity of the heteroatoms sulphur, oxygen, nitrogen. The electron distribution is often likened to that of anisole and aniline because of the similarity in chemical behaviour. Furan and thiophen derivatives are more susceptible to nucleophilic attack than corresponding benzene derivatives, and this makes the value of the above comparison questionable. In terms of resonance theory, the greater reactivity of these five membered heterocycles towards electrophiles can be attributed to the fact that the Wheland intermediate has the same number of covalent bonds as the starting molecule[22]. The reported examples of diazo coupling of these five membered heterocyclic compounds and their benzo analogues (viz. benzo (b)thiophen, benzo(b)furan, and indole) will now be considered. Pyrrole itself couples with diazonium cation in acid or neutral conditions to form a 2- azo derivative but in alkali the 2,5-bisazo derivative is obtained. Treibs and Fritz[23] have carried out an extensive survey of the coupling properties of substituted pyrroles using three diazonium salts of widely different reactivity. The most reactive pyrroles were those substituted with alkyl groups but with one α -position free. 2,5-Dimethyl-, 1-methyl-, and pyrrole itself formed a group of compounds of intermediate reactivity. A less reactive group of compounds included polyalkyl pyrrole 3-carboxylic acid esters. Pyrrole derivatives with 2 or more ethyl carboxylate groups failed to react even with para-nitrobenzene diazonium ions. These same workers extended their study to the replacement of groups other than hydrogen by incoming diazonium cations. Unfortunately the whole of this extensive study was of a qualitative

nature with the colours formed during the reaction frequently being regarded as evidence of diazo coupling.

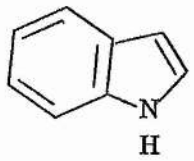
In the thiophen and furan series, examples of diazo coupling are far fewer in number. The only report of coupling with thiophen compounds involve activated molecules like 2-acetamidothiophen (5) which is reported to couple with 4-nitrobenzene diazonium chloride, to give 2-(4'- nitrobenzene azo)-5-acetamidothiophen (6)[1]. When 5-bromo-2-acetamidothiophen was treated with



(5) (6)

para-nitrobenzene diazonium chloride under the same conditions, the bromine atom was displaced to give the same azo compound. A thorough search of the literature yields only a few examples of furan azo compounds formed by coupling[24] and there are no examples of furan or simple substituted furans undergoing a diazo coupling reaction. It is therefore surprising to find the diazo coupling reaction quoted as a general reaction of furan in a well known organic text book[25].

In the condensed ring systems that is indole (7), benzo(b)thiophen (8) and benzo(b)furan (9), only indole and some of it s alkyl derivatives are reported to undergo diazo coupling. The coupling of benzenediazonium chloride[26], diazotised arsanilic acid[27], and diazotised sulphanilic acid[28] with indole are well known, with the last reaction being used as a colour test.



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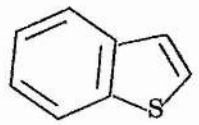

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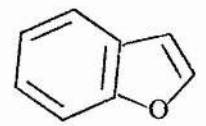


(9)

The coupling reaction of indole with para-nitrobenzene diazonium chloride has been investigated kinetically[29]. A nearly quantitative yield of 3- (4' -nitro-benzene azo)-indole was obtained. The reaction between pH 4 to 6 appears to represent a typical electrophilic substitution of an aromatic nucleus, and it is unnecessary to invoke addition to C(2) - C(3) double bond as is done in some other reactions of indoles.

3-Hydroxybenzo(b)thiophen [30,31] and 6-methyl, 3-hydroxybenzo(b) thiophen[32] were the only examples reported in the literature to undergo diazo-coupling in the benzo(b)thiophen series while there were none in the case of benzo(b)furans. Thus it seems that diazocoupling reactions of pyrroles and indoles are the only ones to have been studied in these series of compounds.

The present thesis reports the reactions of thiophen, benzo(b) thiophen, furan and benzo(b)furan and their various alkyl derivatives with the reactive 2,4-dinitrobenzene diazonium ion. The work in the thiophen series is discussed in three separate sections, because of the wide range of products formed. The first section deals with a group of compounds which undergo arylation, while the second section covers the reactions which give azo coupled products. The third section discusses the azo coupling reactions with the attack taking place on the alkyl side chain. The

investigation of other electrophilic substitution reactions like proton exchange, acetylation and nitration,which might proceed with side chain attack in the polyalkyl thiophens, , together with attampted diazo coupling reactions of polyalkyl benzenoid compounds,form the substance of the fourth section.

The reactions of furans and benzofurans together with the compounds synthesised for the structure determination of some of the products are discussed in the fifth section. Towards the end of this work, a method was developed to diazotise weakly basic aromatic amines, using trifluoroacetic acid as the reaction medium. Excellent yields were obtained. The added advantage is the possibility of running n.m.r spectra of the resulting solutions. The diazotisation of various aromatic amines and the n.m.r. data obtained from them form the last section of the thesis.

RESULTS & DISCUSSION

Section-1

Arylation reactions.

Thiophen undergoes various aromatic electrophilic substitution reactions very much more readily than benzene. Where comparative data is available, the similarity in the reactivity of anisole and thiophen is very striking, see table 3.

Table 3.

The partial rate factors for anisole (para-position) and thiophen (2-position) at 25°C.

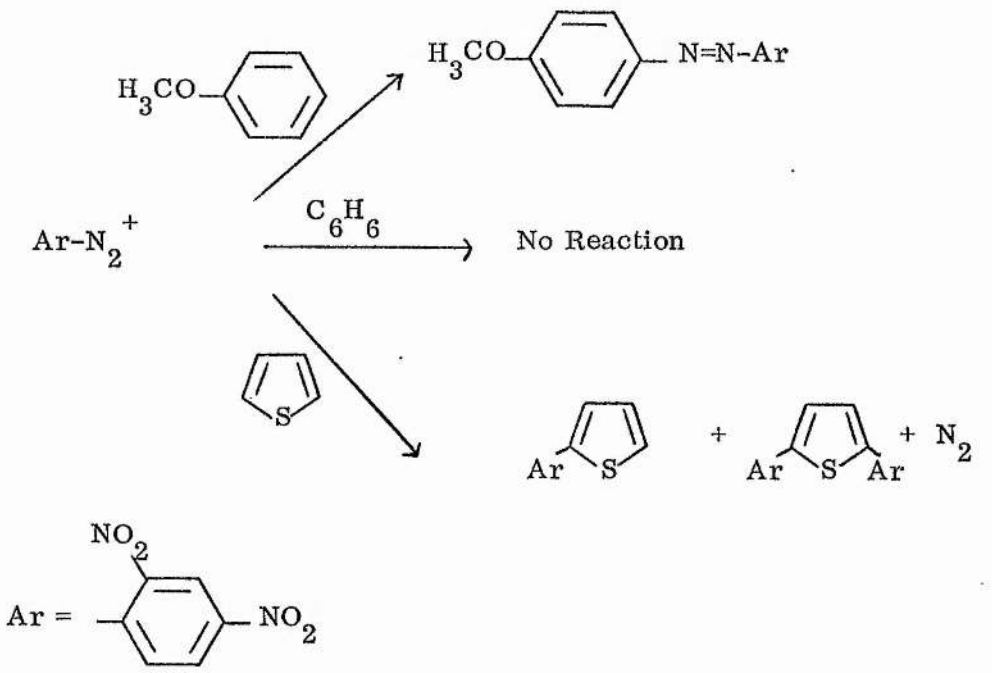
Reaction	Thiophen	Anisole	Reference
Bromination	1.7×10^{9}	1.1×10^{10}	33, 34
Chlorination	1.3×10^{7}	9.7×10^{6}	33, 35
Protodesilylation	5×10^{3}	1.01×10^{3}	36
Nitration	1.5×10^{2}	1.7×10^{2}	37

Anisole couples with 2, 4-dinitrobenzene diazonium ions,[12] but until the present work there has been no report of thiophen or any hydrocarbon thiophen derivatives coupling with a diazonium salt. The highly reactive 2, 4 dinitrobenzene diazonium sulphate solution was obtained by diazotising 2, 4 dinitroaniline in concentrated sulphuric acid[38]. This diazotisation can be carried out at room temperature and takes $1\frac{1}{2}$ to 2 hours.

A solution of thiophen in glacial acetic acid was added to an equimolar solution of 2, 4-dinitrobenzene diazonium sulphate and the reaction was stirred while maintaining the temperature at 0°C. Nitrogen was liberated from the reaction. The deep red coloured solution which formed after a

reaction period of 70 hours was poured onto crushed ice/water mixture, and extracted into chloroform. Crude product obtained after evaporation of the solvent from the dried extract. was chromatographed on an alumina column (protected from light) to give 2-(2'4'-dinitrophenyl) thiophen (17-20%). A small amount of 2, 5 bis-(2'4'-dinitrophenyl) thiophen (2. 5%) was also isolated. The monoarylated compound turned greenish on exposure to light, but could be purified again by chromatography.

Scheme 3.

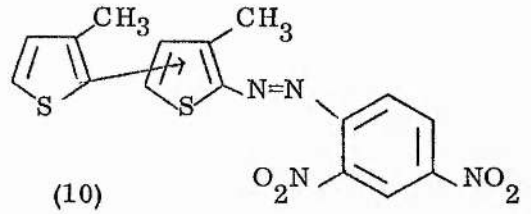


In parallel experiments when anisole and benzene were treated with 2, 4-dinitrobenzene diazonium sulphate in glacial acetic acid at $0^{o}C$ for 70 hours, <u>para</u>-(2, 4-dinitrobenzene azo)-methoxybenzene was isolated (in 36% yield) from the anisole experiment, whereas there was no reaction with benzene. The occurence of arylation from a cold acidic diazonium salt

solution, under conditions in which the diazonium salt is stable was most unexpected. The decomposition of the diazonium salt appeared to be induced by thiophen itself or else some product derived from it. This was confirmed when evolution of nitrogen was monitored[39] by connecting the reaction vessels of the thiophen and the benzene experiments to nitrometers. After 24 hours at room temperature, no nitrogen was evolved from the benzene solution, whereas the thiophen solution had evolved 75% of the theorectical maximum.

2-Methylthiophen, when treated with 2,4-dinitrobenzene diazonium sulphate in glacial acetic acid at 0^{o} for 68 hours, gave 2-methyl-5(2',4'-dinitrophenyl) thiophen as the main product (25%). Separation of a further fraction on a preparative TLC plate gave a trace of bis(2',4'-dinitrophenyl)-2-methylthiophen. That the mono aryl derivative had the 2',4'-dinitrophenyl-group in 5 position was as expected and further confirmed by observation of a coupling constant of 3.5 Hz between the thiophen protons. (The $\beta - \beta'$ coupling constant is 3.0-4.2 Hz[40]). The experiment was repeated at room temperature for 24 hours. Again the mono arylated products and a trace of biarylated products were isolated in similar yields. Reaction with 3-methylthiophen gave 3-methyl-2(2',4'-dinitrophenyl)-thiophen. (33.3%). A coupling constant of 5 Hz for the remaining two thiophen protons indicated that the aryl group was in 2 position. (^{1}H-^{1}H coupling constants for thiophen are $^{J}\alpha-\beta$ = 4.6-5.8 Hz and $^{J}\alpha-\beta'$ = 1.5-2.2 Hz[40]). The bis aryl derivative (M^{+} = m/e 430) was obtained in 1% yield. The mass spectrum and high resolution mass spectrum on a coloured compound, which was isolated in a small amount, suggested that it contained two 3-methyl

thiophenyl-groups and one 2'4'-dinitrophenyl azo group. A tentative structure (10) was assigned.



(10)

There is little precedent for aromatic compounds initiating the decomposition of aromatic diazonium salts in acidic media. Broadhead and Pauson report[41] that the addition of benzene diazonium sulphate to ferrocene in glacial acetic acid causes steady evolution of gas during several hours at $0^{o}C$, with concomitant phenylation of ferrocene. The reaction was successful with several diazonium salts. This reaction is undoubtedly induced by one electron transfer from the ferrocene. In the case of 2,4-dinitrobenzene diazonium sulphate, only a trace of arylated product was obtained. A considerable proportion of ferrocene was oxidised to ferricinium salts, while the diazonium salt was reduced to m-dinitrobenzene. Another reaction of interest is some very recent work[42] involving the interaction of aryl diazonium fluoroborate with 2,4,6-trisubstituted λ^3- phosphorin. Two arylation products are formed, viz. 1-aryl-1-methoxy-2,4,6-triphenyl-λ^5-phosphorin and the analogous compound with the phenyl group at C-4 arylated in the para position.

The arylation observed in the present studies, probably involves 2,4-dinitrophenyl radicals, since the corresponding carbonium ion would be unlikely to attack a thiophen nucleus which was already substituted by a 2,4-dinitrophenyl group, to yield a biaryl product. Furthermore a reaction

of thiophen was carried out under similar conditions, in presence of a large excess (nine times) of benzene, and the crude product was chromatograpted. The first fraction isolated was a mixture of 2,4-dinitrobiphenyl and 2-(2',4'-dinitrophenyl) thiophen. These compounds had almost identical Rf values and it was not possible to separate them. Comparison of the spectral data of this mixture with I.R., mass spectrum (M^+ = m/e 244) and ^{1}H n.m.r. of the authentic 2,4dinitrobiphenyl indicated positively the presence of 2,4-dinitrobiphenyl in the reaction product. In the arylation reactions so far, 1,3-dinitrobenzene was never present in appreciable yield, nor were significant amounts of 2,4, 2',4'-tetranitrobiphenyl isolated.

Many reactions of diazonium salts and other diazo compounds are known in which it is probable that a homolytic cleavage of the C_1-N_α bond occurs. The classical example is the Gomberg-Bachmann reaction. In aqueous solution at 0 to 5°, the diazotised aromatic amine is converted by the addition of alkali or sodium acetate to a covalent diazohydroxide or diazoacetate, and in the presence of a liquid aromatic compound the following overall reaction occurs.

Scheme 4.

$$Ar\text{-}N_2^+Cl^- + NaOH + Ar^1H \longrightarrow Ar\text{-}Ar^1 + N_2 + NaCl + H_2O$$

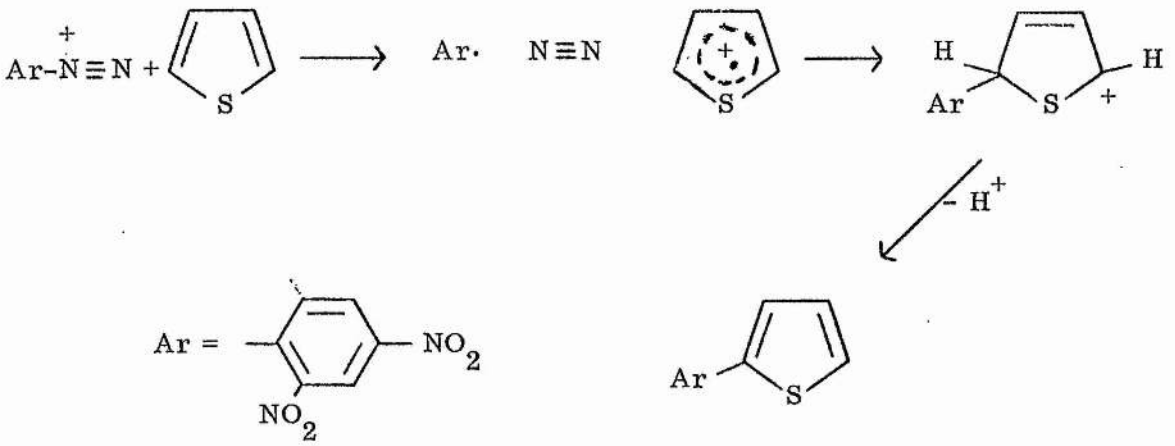
The reaction is heterogeneous and the biaryls formed are removed by steam distillation. In general, low yields (10-20%) of biaryls are obtained with a residue containing polymers of chains of the aryl components coupled together. Several biaryls including thiophen derivatives have been made by this method[43]. This reaction has also been applied to make heteroaryl thiophens[44]. The

homolytic arylation of thiophen has been studied systematically[45] including the Gomberg reaction, the thermal decomposition of N-nitroso acetanilides and diaroyl peroxides. 2- And 3- phenyl thiophens were obtained in the ratio of 90-95 : 10-5, from all the phenylating agents tested, except for the special case of phenyl azo triphenylmethane. Another method of forming aryl thiophens was developed by Mohlau and Berger[46], who added aluminium chloride to a suspension of dry diazonium chloride in thiophen, or other aromatic compounds to obtain biaryls in small yields.

The present understanding of the mechanism(s) of homolytic decomposition of diazonium ions and related compounds is far from complete. A probable exception is the decomposition of acyl aryl nitrosoamines, a multi pathway reaction, whose mechanism has been largely elucidated after an extensive study[47]. Related reactions also seem to follow multiple pathways. Small changes in reactant, solvent, additives etc. making drastic changes in rate, mechanism and products. Homolytic and heterolytic mechanisms often resemble each other more closely than was previously thought, e.g. a common intermediate, is proposed for the decomposition of arene diazonium ions in acidic methanol, when either homolytic and heterolytic decomposition of arene diazonium ions may occur[48].

The simplest mechanism for the arylation observed in the present reactions would be electron transfer followed by decomposition of the diazonium salt and the coupling of the aryl radical with the thiophen radical cation. Loss of a proton would then lead to the product.

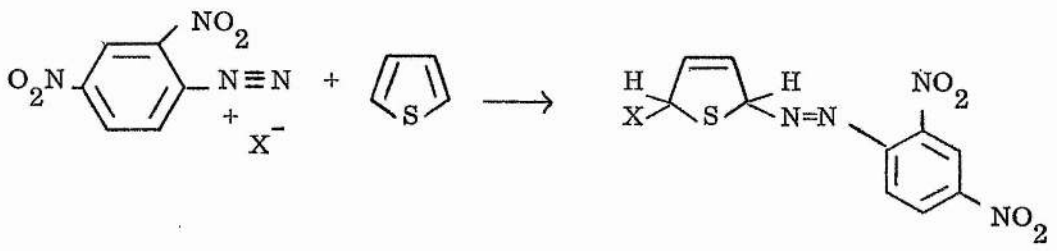
Scheme 5.



The objections to this simple mechanism are two fold. If electron transfer was the first step, then the polyalkyl thiophens should arylate too, (see section 2 and 3) since electron transfer can be expected to be faster than the coupling reaction. Furthermore when excess of thiophen was treated with the diazonium solution, yield of monoarylated thiophen is about 48% (based on the diazonium salt).

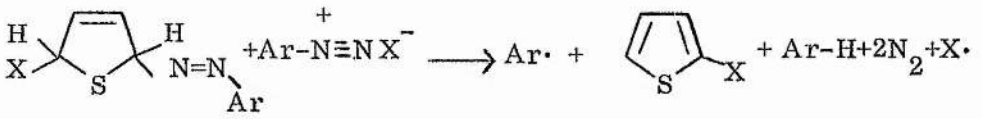
A mechanism which would be consistent with yield in presence of excess thiophen would involve coupling followed by addition of an anion (i.e. 2,5-electrophilic addition characteristic of furan).

Scheme 6.



The resulting adduct would be very susceptible to oxidation and 2,4-dinitrobenzene diazonium ions are powerful oxidising agents.

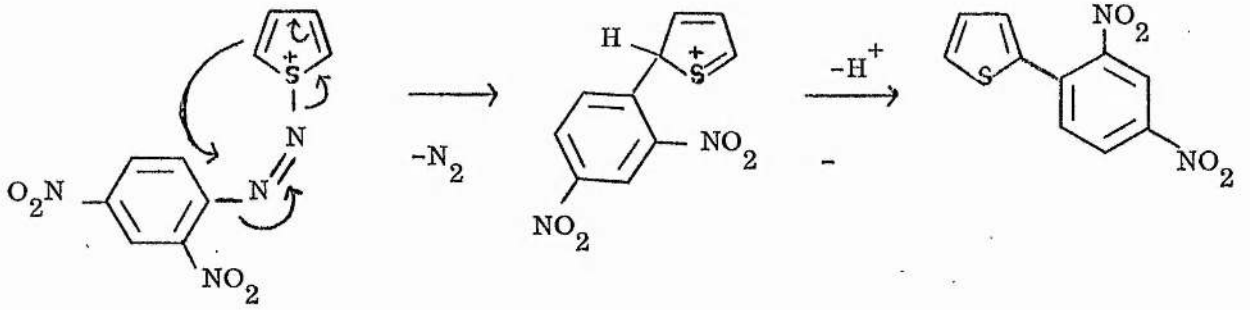
Scheme 6 contd.



This mechanism though consistent with the stoichiometry, can be ruled out because little 1,3-dinitrobenzene was found and no product corresponding to the thiophen product (X = HSO_4 or CH_3COO-) except with benzo(b)thiophen[39] when a trace of 3-hydroxy-2(2',4'-dinitrobenzene azo)-benzo(b)thiophen, was found which could be a by product from such a reaction.

A third alternative mechanism would involve initial coupling through the sulphur atom. The sulphur atom, by the use of its 3d orbitals can be shown to have a negative charge in some of the canonical forms of thiophen. Thus, possibility of an initial attack on the sulphur atom can not be excluded[49].

Scheme 7.



Reaction of thiophen in trifluoroacetic acid with diazotised 2,4-dinitroaniline provides further evidence that thiophen nucleus initiates the arylation. 2,4-Dinitroaniline was diazotised much more rapidly in pure trifluoroacetic acid, and the diazonium salt coupled with anisole, (see

section 6). Thus a coupling reaction could be carried out in simple solvent system. When thiophen was treated with the diazonium solution in trifluoroacetic acid, after a transient red colour, the solution developed a deep blue and a rapid evolution of nitrogen ensued almost immediately. Nitrogen evolution was rapid under these conditions and ^{1}H n.m.r. on an aliquot from the reaction after 1 hour showed signals due to 2-(2',4'-dinitrophenyl) thiophen, which was again the main product isolated. A low temperature (-15^{o}) proton n.m.r. on the reaction was done in an attempt to see any signals due to the transient red coloured reaction mixture. However, practical problems like transfer of cold reagents, (without condensation on the outside of n.m.r. tube) and inefficient mixing of the reactants made it difficult to obtain the spectrum of the reaction before the evolution of nitrogen has begun.

The fact that coupling occurs with polymethyl thiophens suggests that there is competition between arylation and coupling, and if the nucleus is sufficiently activated coupling is preferred. The observation that 2-t-butylthiophen and 2-phenylthiophen couple while 2-methylthiophen arylates suggests that steric hindrance may play a part in the reaction, and provides some support for the idea of coupling through the sulphur. The highly solvated 2,4-dinitrobenzene diazonium ion may have some difficulty in approaching the sulphur atoms in these compounds, although it should be noted that benzo(b)-thiophen also arylates.

One of the great difficulties in elucidating the mechanism has been the incomplete recovery of the starting materials. When the reaction mixture is

poured into water the insoluble products consisting mainly of arylated thiophens are easily extracted and purified by chromatography. However, other trace products remain on the column and in addition the water soluble products are almost impossible to isolate from the aqueous solution which contains excess sulphuric acid and acetic acid.

The mechanism of the arylation, an "acidic Gomberg" reaction (a multi pathway reaction) remains uncertain and it represents an aromatic substitution which has no exact parallel.

Section II

Azo Coupling.

Aromatic diazonium ions are only weakly electrophilic and the azo coupling reactions are essentially limited to those with phenols, amines and some reactive olefinic compounds. The diazonium ion usually attacks that atom of the nucleophilic component which exibits the greatest electron density. Thus in addition to carbon, which gives C-azo compounds, amino nitrogen and oxygen provide good sites giving N-azo, and O-azo compounds. The aromatic diazonium ion is also a reagent of high selectivity; e.g. the azo coupling reaction of phenoxide anions, gives mainly para-substituted azo compounds and a little ortho-substituted products. meta-Azo derivatives are not obtained even in traces.

The mechanism of diazo-coupling reaction is fairly well understood and is a typical electrophilic substitution i.e. an electrophilic addition with elimination reaction. A two step mechanism is proposed (scheme 8).

Scheme 8.

$$Ar\text{-}N{\equiv}N^{+} + Ar'H \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} Ar'(H)\text{-}N_2Ar^{+} \qquad (1)$$

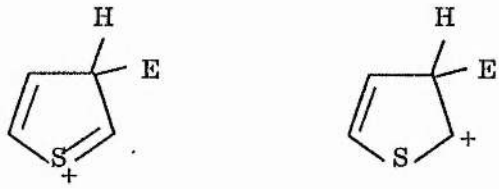
$$Ar'(H)\text{-}N_2Ar^{+} \xrightarrow[k_2]{+B} Ar\text{-}N{=}N\text{-}Ar' + BH^{+} \qquad (2)$$

Certain azo coupling reactions like that of p-chlorobenzene diazonium ion with 2-naphthol-6, 8-disulphonic acid, are base catalysed and a hydrogen istope effect is observed[51]. If the ratio of the rate constants k_2 and k_{-1} is large, the first step becomes rate determining and neither

base catalysis nor an isotope effect is observed.

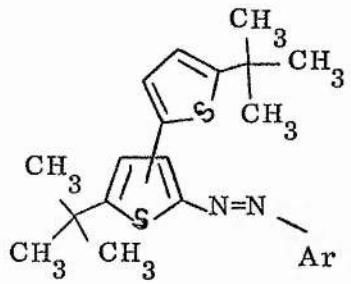
Electrophilic substitution reactions of thiophen give mainly α substituted products. This can be rationalised by taking the Wheland intermediates as models for the transition states. It is possible to see that for an α attack there are three limiting resonance structures (11a) to (11c) while only two such structures (12a) and (12b) are possible for the β attack. The isomer distribution of the products is dependent on the electrophile and the α/β ratio varies from 3400 for protodedeuteration[52] to 6.2 for the nitration reaction[53].

(11a) (11b) (11c) α attack



(12a) (12b) β attack

2-t-Butylthiophen in glacial acetic acid was reacted with the 2,4-dinitrobenzene diazonium solution, and the crude product obtained was separated on a silica column. The major product isolated was the azo compound, 2-t-butyl-5(2',4'-dinitrobenzene azo)-thiophen (16). A coupling of 4 Hz for the remaining two thiophen protons confirmed that substitution was in 5 - position. Apart from a small amount of unreacted t-butyl thiophen, a small amount of deep coloured solid (m.p. 220^{o}) was also isolated. This had M^{+} = m/e 472, and λ max 526 nm (ϵ 2.09×10^{5}) in the



(13)

u.v. spectrum. Although the high resolution mass spectrum did not agree very well ($\triangle$ m = 0.03), by analogy with the trace product from 3-methylthiophen, structure (13) is proposed for this compound.

5, Phenyl-2-(2', 4'-dinitrobenzene azo)-thiophen (17) was the main product from the azo coupling reaction of 2-phenylthiophen with the 2, 4-dinitrobenzene diazonium solution. Some unreacted starting material was also isolated. The reaction with 2, 4-dimethylthiophen was much faster and was stopped after stirring for five minutes, when a thick orange red precipitate was formed. A portion of the crude product obtained by filtration, was purified on a silica column to give 3, 5-dimethyl -2-(2', 4'-dinitrobenzene azo)-thiophen (18) in 62% yield. The high yield of the azo dye in this case can be rationalised as both the methyl groups, jointly activate the remaining free α position. The azo compound had no NH absorption in the I. R. spectrum. Comparison with the authentic sample of 4-methylthiophen -2-aldehyde-2', 4'-dinitrophenyl hydrazone showed that the diazonium ion had not attacked the side chain (see section 3) and the product was confirmed as the azo compound.

Until the present work there has been no report of thiophen or any hydrocarbon thiophen derivatives coupling with a diazonium salt, and it was thought that an activating substituent in the thiophen nucleus like acetamido[1] was essential. Comparison of the effect of substituent on the ability to couple shows that the reactivity of benzene and naphthalene derivatives decreases in

the order of

$$O^- > NR_2 > NHR > OR > OH.$$

The methyl group is an even weaker electron donor, yet benzene derivatives containing several favourably oriented methyl groups are able to couple. Mesitylene couples with 2, 4, 6-trinitrobenzene diazonium salt[15]. The same diazonium salt reacts with pentamethylbenzene and 1, 2, 3, 5-tetramethyl benzene, but it does not react with 1, 2, 4, 5- tetramethylbenzene[54]. Thus the inductive effect of only two ortho methyl groups in the latter compound is insufficient for the coupling. Under similar conditions an azo compound could not be isolated form t-butylbenzene[55]. Mesitylene has three methyl substituent in the nucleus, whereas t-butylbenzene has them in the side chain, hyperconjugation being unimportant in the latter case. Several polynuclear hydrocarbons such as benzo(a)pyrene yield crystalline azo derivatives even with moderately electrophilic 4-nitrobenzene diazonium compounds[56].

The relative reactivity of 2-methyl, 2-phenyl and 2-t-butyl thiophen in the electrophilic substitution in the five position can be judged from table 4.

Table 4.

Relative rates of a substitution (in 5 position) of 2-substituted thiophen

Substituent	Detritiation[a]	Acetylation[b]	trifluoro acetylation[c]
2-CH_3	2.1×10^2	33.7	3.8×10^2
2-t-C_4H_9	2.3×10^2	48.5	5.4×10^2
2-C_6H_5	15.5	-	1.1×10^2
H	1	1	1

contd. overleaf.

a) Reaction in CF_3COOH-CH_3COOH mixture at 24.8° ref. 57.

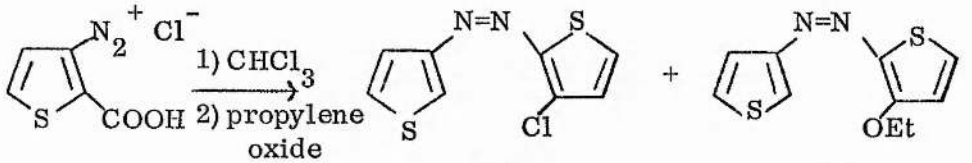
b) $SnCl_4$ catalysed acetylation by Ac_2O in dichloroethane at 25° ref. 58.

c) Reaction with $(CF_3CO)_2O$ in dichloroethane at 75° ref. 59.

Thus it seems that increased reactivity in the case of 2-t-butyl and 2-phenyl thiophen is hard to accept as the sole cause of the azo coupling reaction observed as opposed to the arylation reaction of thiophen itself.

Since the preliminary report of the present work[60], there has been a report[61] of the reaction of diazotised 3-aminothiophen-2-carboxylic acid with propylene oxide in chloroform. Two thiophen azo compounds (14), (15) were isolated. The ethoxy group in compound (15) was shown to originate from ethanol present in the commercial chloroform. Although the net result of the reaction is to join, via an azo linkage, two thiophen rings of which one may contain a deactivating group, the exact nature and sequence of the coupling and decarboxylation remains to be elucidated. The reaction conditions are also very different from the diazo coupling reactions in the present work.

Scheme 9.



(14) (15)

Although benzo(b)thiophen itself did not give an azo coupled product both the 2-methyl- and 3-methyl- benzo(b)thiophen coupled with 2,4-dinitrobenzene diazonium ion to give the corresponding azo dyes. 2-Methyl-3-(2',4'-dinitrobenzene azo)-benzo(b)thiophen (19) was obtained in 62%

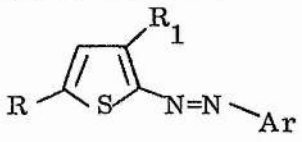
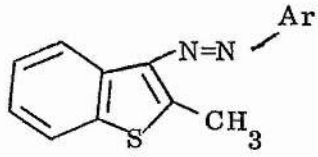
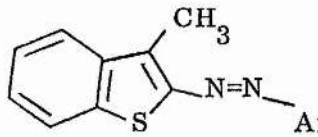
yield while 3-methyl-2-(2', 4'-dinitrobenzene azo)-benzo(b)thiophen (20) was obtained in 25% yield.

In benzo(b)thiophen, all the positions in the homocyclic part of the molecule are much less reactive than either of those in the heterocyclic part of the ring, and only small amounts, if any, of the isomers mono substituted in the benzene ring have been isolated from various other reactions of benzo (b) thiophen or its mono alkyl derivatives. In the present reactions, the azo dyes formed were very insoluble in all the solvents tried, and ^{1}H n.m.r. spectra could not be run. It is therefore assumed that substitution has taken place in the remaining free position in the heterocyclic part of the ring. In contrast with thiophen, benzo(b)thiophen is substituted preferentially at the β (or-3-) position in various electrophilic reactions, and the reactivity of these positions is much less compared to thiophen. The higher yield in the case of 2-methylbenzo(b)thiophen can thus be understood. Activation by the thiophen ring is not sufficient for coupling to occur in the homocyclic ring positions. Dibenzothiophen failed to couple with the 2,4-dinitrobenzene diazonium solution[62]. 2,3-Dimethylbenzo(b)thiophen, where both the reactive positions are blocked, did not undergo the diazo coupling reaction.

Both the 2-amino[63], and 3-amino[64] benzo(b)thiophens have been prepared. Benzo(b) thiophen-2-diazonium chloride, prepared by the method previously successful for 2-aminothiophen, failed to couple with 2-naphthol However other replacement reactions of the diazonium group could be carried out successfully. As seen before, benzo(b)thiophens with activating substituents were known to couple (page 9). The present work shows that

activation by the methyl group in the 2- or 3- position is sufficient to allow diazo coupling reaction with the 2,4-dinitrobenzene diazonium ion. Melting point and u.v. data of the thiophen and benzo(b)thiophen azo compounds (Ar = C_6H_3-2,4-$(NO_2)_2$), all of which are new, are collected in table 5.

Table 5.

Structure	no.	m.p.	λ_{max} nm(ϵ)
			
R = t-C_4H_9, R_1 = H	16	136°	412 (2.51×10^4)
R = C_6H_5 R_1 = H	17	183°	453 (2.48×10^4)
R = R_1 = CH_3	18	176°	418 (2.45×10^4)
	19	182°	408 (1.71×10^4)
	20	190°	406 (3.1×10^4)

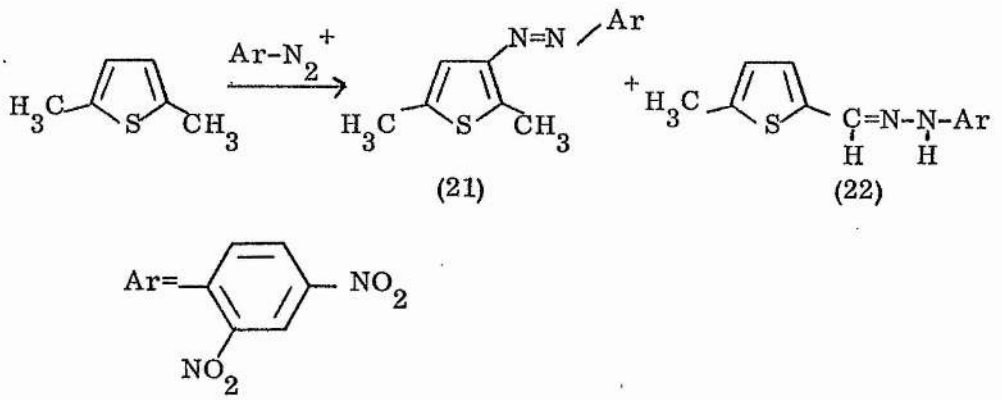
Section 3

Side chain attack : azo coupling.

The thiophen derivatives, studied in the previous section, reacted with the diazonium solution to give azo coupled products in the free α position. The diazo coupling reactions, when both the 2-and 5-position in the thiophen nucleus is substituted, are described below.

A solution of 2,5-dimethylthiophen in glacial acetic acid was added to the 2,4-dinitrobenzene diazonium solution, and the reaction mixture was stirred at 0^{o} for 68 hours. The crude product was chromatographed on silica with benzene as the eluent. Two coloured compounds were isolated. The more soluble yellow compound (m.p. 137^{o}), which was eluted first from the column, was found to be 3-(2',4'-dinitrobenzene azo)-2,5-dimethylthiophen (21). The second red product (m.p. 233^{o}) had the same elemental composition (analysis and high resolution mass spectrum) as the azo compound, but had an absorption at 3300 cm^{-1} in its infra red spectrum. This absorption was attributed to a N-H stretching vibration and the product was assigned the structure of 2,4-dinitrophenyl hydrazone of 5-methylthiophen-2-aldehyde. (22). This identification was confirmed by synthesis of the 2,4-dinitrophenyl

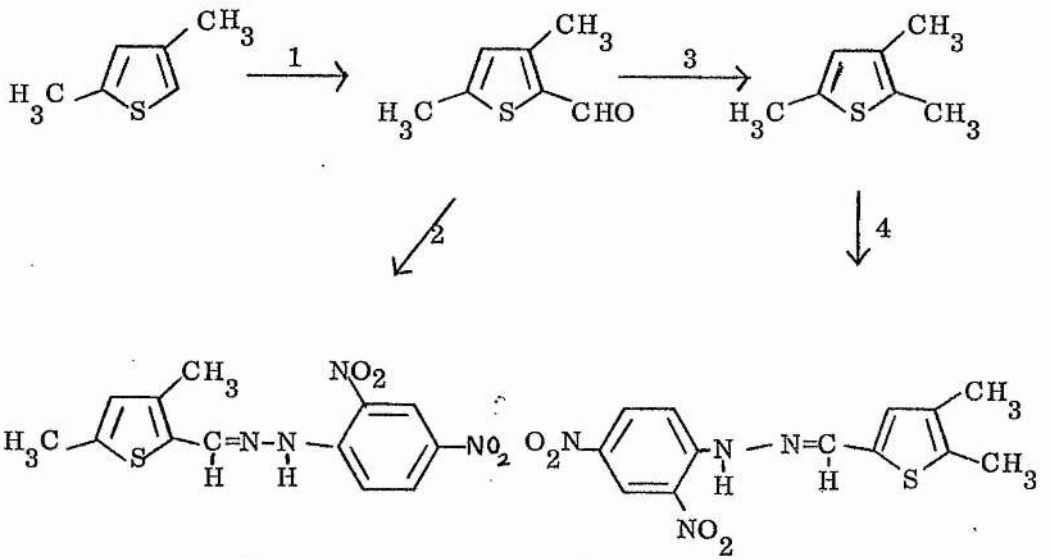
Scheme 10.



hydrazone of 5-methylthiophen-2-aldehyde, which proved to be identical with the above product (22) n.m.r., i.r., uv, m.p. and mixed m.p. A further fraction eluted by chloroform consisted of red resinous material difficult to separate and identification was not pursued further. The reaction of 2,5-dimethylthiophen with 2,4-dinitrobenzene diazonium ions is thus totally different from that of 2,4-dimethylthiophen: (section 2) where one of the α positions was free and azo coupling was the only product.

The coupling reaction of 2,3,5-trimethylthiophen (synthesised as in Scheme (11) occurred rapidly with the acidic 2,4-dinitrobenzene diazonium solution. The reaction was stopped after 15 minutes and the red product was filtered, dried and recrystalised (m.p. 252°). The ^{1}H n.m.r. spectrum (deuteriopyridine at 88°) had a signal at δ 8.36 (-C(H)=N-), and i.r. spectrum with an absorption at 3300 cm^{-1} (>NH) indicated that the product was also the result of coupling through the methyl group.

Scheme 11.



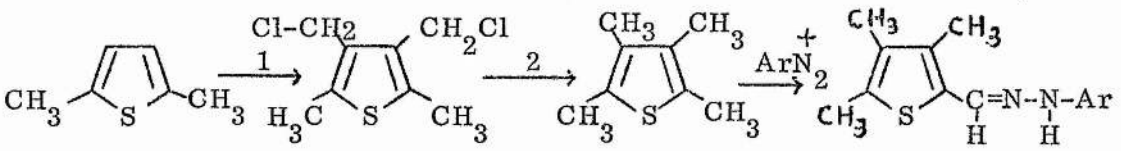
1) n-BuLi + $HCONMe_2$
2) $2,4\text{-}(NO_2)_2C_6H_3\text{-}NHNH_2$
3) NH_2NH_2 + KOH
4) $2,4\text{-}(NO_2)_2C_6H_3N\equiv N^+$

2,4-Dinitrophenyl hydrazones of 2,5-dimethylthiophen-3-aldehyde and 3,5-dimethylthiophen-2-aldehyde were synthesised. The product from the trimethylthiophen coupling reaction was found to be different from either of these (by comparing i.r., n.m.r. m.p. and mixed m.p.) and was assigned the structure of 2,4-dinitrophenyl hydrazone of 4,5-dimethylthiophen-2-aldehyde (23).

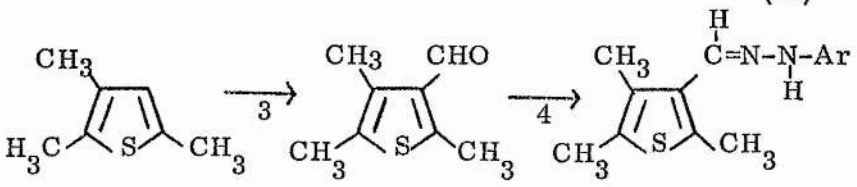
A solution of tetramethylthiophen, (synthesised as in scheme 12), in glacial acetic acid coupled extremely rapidly with the 2,4-dinitrobenzene diazonium solution. A thick red precipitate was formed almost instantaneously and the reaction was stopped after 5 minutes. The recrystallised product (m.p. 247-8°) had an NH absorption in the i.r. spectrum at 3290 cm^{-1}. The compound was insoluble in most of the common solvents and ^{1}H n.m.r. was run in deuteriopyridine at high temperature (88°C). The spectrum had a signal at δ 8.60, attributed to -HC=N-NH-. Thus the diazonium ion had again attacked the methyl group and the product was established as the 2,4-dinitrophenyl hydrazone of 3,4,5-trimethylthiophen-2-aldehyde (25), by comparison with the 2,4-dinitrophenyl hydrazone of 2,4,5-trimethylthiophen-3-aldehyde (26) which was synthesised by an unambiguous route (scheme 12) overleaf.

The azo coupling of reactive diazonium salts with acidic (electron deficient) methyl or methylene groups is well known . 2-Nitropropane may be considered as representative of this class of compounds. The C-H bond has an acidic character due to the neighbouring nitro group, and the anion formed by the removal of this proton can be attacked by the

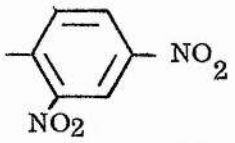
Scheme 12.



(25)



(26)

Ar= 

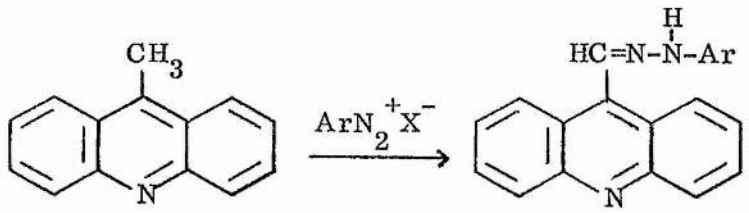
1) $(CH_2O)_3$+HCl 3) $C_6H_5NMeCHO+POCl_3$

2) $LiAlH_4$ 4) $Ar-NHNH_2$

electrophile viz the diazonium ion.

The azo coupling of heterocyclic compounds with methyl groups in ∝ or ɣ position from the heteroatom, such as 9 methylacridine (27) or 2 picoline, has been reported by Kharkharov and coworkers[65], the coupling reaction taking place at the methyl group. A series of diazonium salts were tested and the reaction products were identified by synthesising the corresponding phenyl hydrazones (28). The same authors also report[66] that the methyl

Scheme 13.



(27) (28)

group of 2,4,6-trinitrotoluene is able to react with diazo compounds because of the acidifying effect of the nitro groups. However this latter observation has been doubted[67].

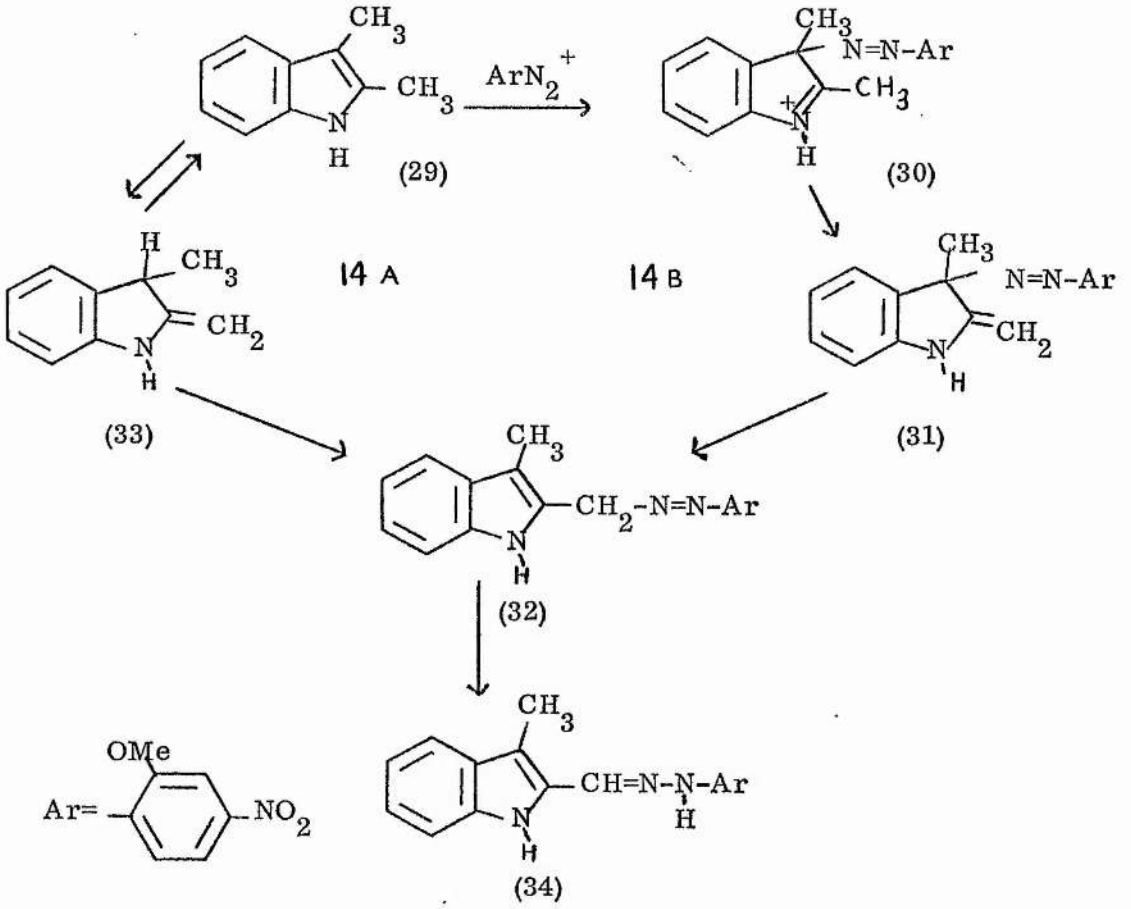
The coupling of diazonium salts with methyl groups in electron rich sites (as in the case of polymethyl thiophens) appeared to be without precedent. Since then a report, predating our preliminary communication[60], which describes the coupling of 2,3-dimethylindole (29) with 2-methoxy-4-nitrobenzene diazonium ion has appeared[68]. The coupling reaction occurred at either pH 3 or 6 to 7 to yield the corresponding phenyl hydrazone (34) in 83% and 48% yields respectively.

The product may arise either by the direct attack of the diazonium ion on (33) which is in equilibrium with the dimethylindole or by a 1,3 rearrangement of an initially formed 3-aryl azoindolenine (30) to the aryl azo methylindole (32) followed by isomerisation to give the phenylhydrazone (34), as shown in scheme 14. (overleaf).

The latter mechanism (14B) was preferred by the authors since it was consistent with the known reactivity of indole in the 3-position, and because it accounted for the formation of products under both acidic and neutral conditions. The authors doubt whether proton exchange in the methyl group (as required by the earlier path (14A) will occur at pH 6 to 7; although this has not been checked experimentally.

Examination of the ^{1}H n.m.r. spectrum of 2,5-dimethyl, 2,3,5-trimethyl, and 2,3,4,5-tetramethyl thiophen in deuteriotrifluoro-acetic acid shows that the ring protons (in case of 2,5-dimethyl and the trimethyl thiophen)

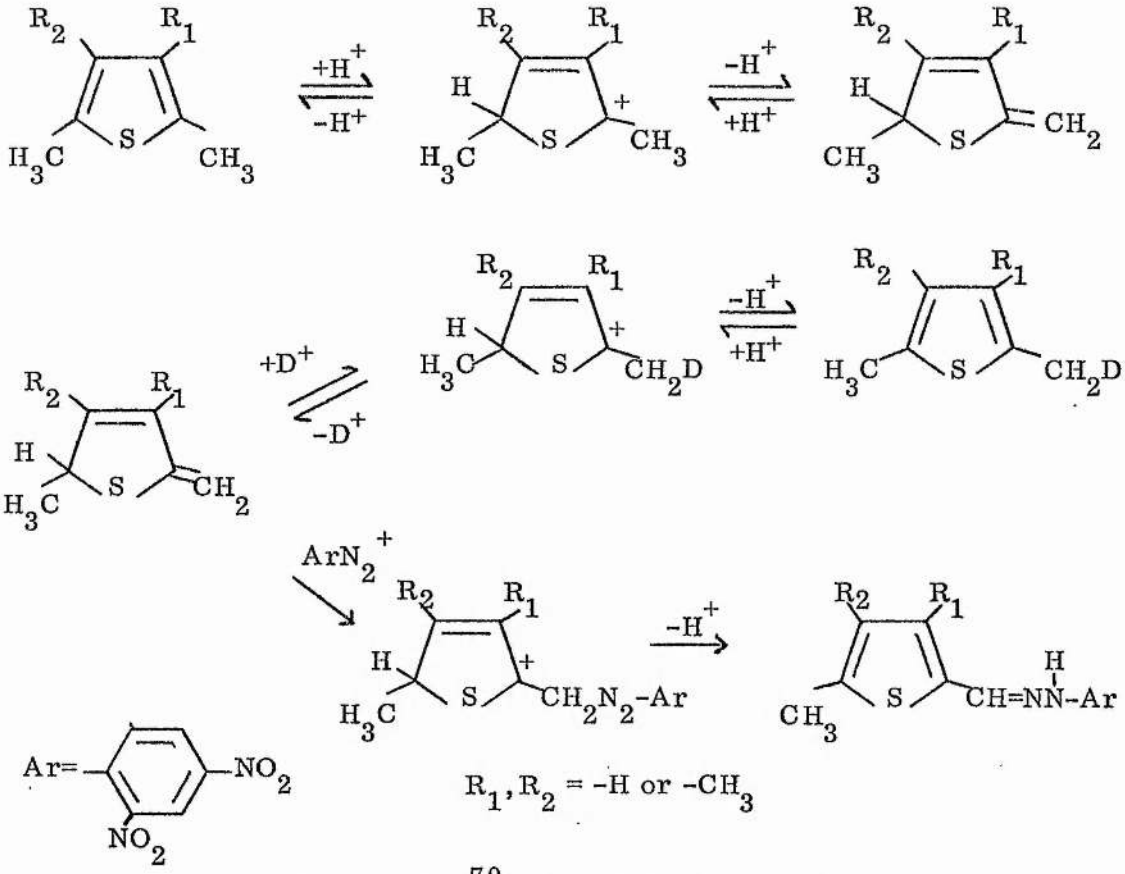
Scheme 14.



exchange extremely rapidly. The methyl protons exchange less rapidly but the exchange was sufficiently fast for this process to be associated with the coupling at the methyl group. Eaborn and Wright[69] have studied hydrogen exchange in 2-methyl, 3-methyl, and 2,3, dimethyl benzo(b)thiophens quantitatively. The rate of exchange of protons from the methyl group is about four orders of magnitude slower than the exchange of protons from the thiophen part of the ring. This is consistent with the qualitative observation with polymethyl thiophens (see section 4). For the reactions studied here, the exchange process and the coupling reactions almost certainly involve

similar mechanisms (Scheme 15).

Scheme 15.



Triebs and coworkers[70] report that 2,3,4,5-tetramethylpyrrole couples with diazotised aniline-p-sulphonic acid, with the ejection of the 2-methyl group. However, the only evidence given is that the reaction gives same olive green colour as that obtained from the reaction of 2,3,4-trimethylpyrrole. In general the requirement for the ready replacibility of a group (other than hydrogen) during the diazo coupling reaction is that the group should be electron attracting and be able to be eliminated as a stable entity, eg. a carboxyl or a sulphonic acid group.

Reaction of 2,3,4,5-tetramethylpyrrole was carried out with the 2,4-dinitrobenzene diazonium solution. The diazonium solution was found

very reactive and the blackish red coloured product was impossible to separate and identify. A similar reaction with 2,3-dimethylindole was also unsuccessful.

2,3-Dimethylbenzo(b)thiophen also failed to react with the diazonium solution. Proton exchange in the methyl group was not observed with the 2,3-dimethylbenzo(b)thiophen under the conditions when proton exchange was observed with tetramethyl thiophen

The interesting feature of these reactions is that electrophilic substitution at a methyl group takes place even when reactive "aromatic" sites are available (cf. 2,5-dimethyl and 2,3,5-trimethyl thiophen). Acylation reaction of 2,3,5-trimethylthiophen with acetic acid and trifluoroacetic anhydride however yielded 3-acetyl 2,4,5-trimethylthiophen, i.e. attack occurred at the "aromatic" 3-position. Thus the nature of the electrophile (and possibly solubility of the product formed) also has an important role, in addition to the acidity of the medium, in these azo coupling reactions to give the side chain substitution products.

Section 4

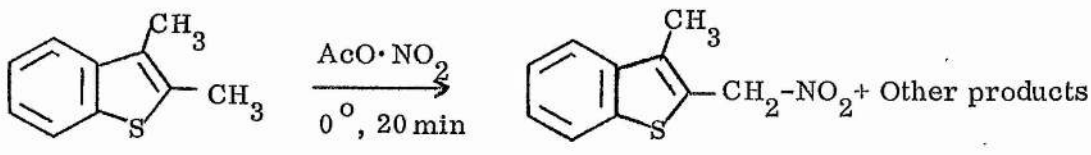
Further investigation in side chain attack.

This section deals with some electrophilic substitution reactions carried out to determine the scope of the side chain attack observed in the diazo coupling reactions of polymethyl thiophens. Both tetramethylthiophen and 2,3-dimethylbenzo(b)thiophen have all the positions in the thiophen ring occupied by methyl groups. Thus the observation, that tetramethyl-thiophen undergoes the diazo coupling reaction in high yields, whereas the latter compound does not react under similar conditions, requires explanation.

2,3-Dimethylbenzo(b)thiophen however does undergo side chain attack in the case of nitration and chlorination.

Bordwell and coworkers[71] added it to acetyl nitrate in acetic anhydride-acetic acid solution at 0^{o}. After a reaction period of 20 minutes, the main product isolated (33%) was 3-methyl-2-nitromethylbenzo(b)thiophen (36). Small amounts of 3-methylbenzo(b)thiophen-2-aldehyde, and 2,3-dimethyl-6-nitrobenzo(b)thiophen were also isolated. Inverse addition gave 18% of the aldehyde and very small amounts of the nitro compounds.

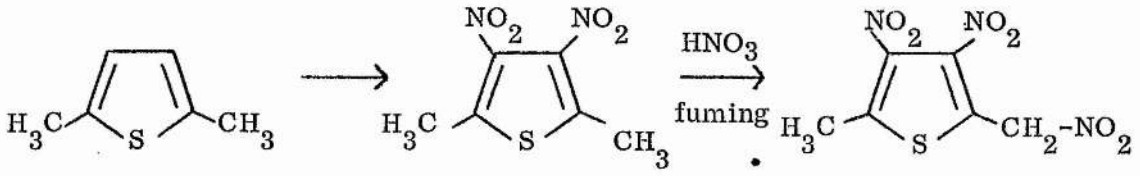
Scheme 16.



(35) (36)

The nitration of 2,5-dimethylthiophen with nitric acid liberated from potassium nitrate and sulphuric acid gives 3,4-dinitro, 2,5-dimethyl-thiophen[72]. Fuming nitric acid reacts further with the above dinitro compound to give a side chain nitration product (37).

Scheme 17.



(37)

In one experiment with tetramethylthiophen using acetyl nitrate, 3,4,5-trimethylthiophen-2-aldehyde was isolated in small yield. No nitro derivative was isolated and the reaction was not pursued. However, the conditions employed for the nitration are much more severe than those for the diazo coupling reaction.

2,3-Dimethylbenzo(b) thiophen with a mixture of chlorine in acetic acid in dark gave mainly 3-methyl-2-chloromethyl benzo(b)thiophen[73]. A stable 1:1 adduct between the benzo(b) thiophen and chlorine was postulated as an intermediate in this reaction. The side chain nitration was explained by Bordwell et. al. as a consequence of the tendency of the dimethyl-benzo(b) thiophen (35) to exist to some extent in a tautomeric form (35A), which should be much more nucleophilic than (35). The loss of aromaticity involved in the formation of (35A) could be offset to some degree by the relief of strain between the two methyl groups, and the peri hydrogen and the

(35) (35A)

3 methyl group. Later Eaborn and coworkers[69] studied detritiation in trifluoroacetic acid at 70° of 2-tritio, 3-tritio, 2-tritio methyl, 3-tritio methyl, and 3-methyl-2 tritiomethyl, benzo(b)thiophens. The loss of tritium showed first order kinetics. The detritiation in the methyl group is about 4000 times slower than that in the thiophen part of the ring. Detritiation of 3-methyl-2 tritiomethylbenzo(b)thiophen was the slowest among the compounds studied and at much the same rate as in ^{3}H benzene $k = 0.095 \times 10^{-7}$. After considering these observations, it was decided to see whether hydrogen exchange occured in the methyl groups of polymethyl thiophens.

The hydrogen exchange reaction studied in the present work was deuteriation or deuterio deprotonation . In a typical experiment ^{1}H n.m.r. were run on a 10%solution of the polymethyl thiophen in deuterio trifluoroacetic acid at 25°. A control experiment was done by running ^{1}H n.m.r. of the same compound as 10% solution in trifluoroacetic acid. The ^{1}H n.m.r. of the control, was the same before and after the experiment, and no decomposition of the thiophen had occured during the period. The reactions have been studied qualitatively. As expected, deuteriation in the thiophen ring was very fast and the signal for the ring protons was reduced considerably by the time the first reading was taken. However it never disappeared completely. The relative area under the methyl group signal also decreased

considerably. However, for all the compounds, after a few hours no further decrease in areas of methyl group signals was seen.

In one experiment with tetramethylthiophen, the spectrum of its 10% solution in deuteriotrifluoroacetic acid was run in a n.m.r. tube which had a concentric capillary tube filled with 1,2-dichloroethane. The amount of dichloroethane was constant and was used as the external standard. The areas under the signals due to α and β methyl groups (δ 2·32, and δ 2·18 respectively) were measured relative to the $-CH_2-$ signal of 1,2-dichloroethane The ratio of the relative areas due to the methyl group signal had attained a value of 0.50 after 22 hours and it did not decrease further.

Table 6

Time	15 min.	2hr. 30 mins.	4hr. 30 mins.	22 hrs.	46 hrs.
Ratio of relative areas due to the α and β methyl groups	0.83	0.63	0.61	0.50	0.50

2,3-Dimethylbenzothiophen did not undergo deuteriation in the methyl group at room temperature. It appears that the rate of exchange in the methyl group of tetramethylthiophen is of the same order of magnitude as the thiophen ring protons in benzo(b) thiophen (which are about 200 times less reactive than 2-position in thiophen[74]).

The replacement of hydrogen atom by deuterium in the methyl groups of mesitylene, hexamethylbenzene, and 9,10-dimethylanthracene has been observed in deuterio trifluoroacetic acid[75]. The number of deuterium atoms that had entered the molecule of the hydrocarbon were measured by low

voltage mass spectrometry. The reactivity of these hydrocarbons is much less than that of thiophen and temperature as high as 150° were needed for the proton exchange to occur. Indeed neither of these two compounds reacted with 2,4-dinitrobenzene diazonium sulphate in acetic acid, aq. sulphuric acid mixture at room temperature.

Acetylation of polymethyl thiophens.

Acylation is one of the extensively studied reaction in the thiophen series. Compared to benzene derivatives there are some differences in the experimental conditions employed. Aluminium chloride which often induces polymerisation has been successfully replaced by other milder catalysts such as zinc chloride, phosphoric acid and stannic chloride. The use of acid anhydride is generally preferred to that of acylchlorides, since a weaker acid is generated during the reaction, thus reducing the decomposition of acid sensitive starting materials. Another important difference is that less than stoichiometric quantities of Lewis acid catalysts can be used. This is probably due to the greater reactivity of thiophen nucleus or due to the lower ability of the acylated products formed to co-ordinate with the catalysts. Bourne and coworkers[76] found that mixtures of trifluoroacetic anhydride and carboxylic acids (acetic, benzoic and cinnamic acid) gave good yields of ketones from polyalkyl benzenes, phenyl ethers, furan and thiophen under mild conditions.

In general the aromatic compound (1 mol) was added to a solution of the acetic acid (1-1.5 mol) in trifluoroacetic anhydride (1.5 to 2 mols) and the reaction mixture was gently warmed (up to 60°) for few hours. Acetyl derivative was then isolated by suitable solvent extraction after the reaction

mixture was neutralised. Acetyl products were obtained exclusively. This acetylation reaction proceeds via acetyl trifluoroacetate, formed by the action of acetic acid on trifluoroacetic anhydride.

$$R.COOH + (CF_3CO)_2O \rightleftharpoons (R.CO).O.COCF_3 + CF_3COOH.$$

The unsymmetrical anhydride ionises to a limited extent into acetylium CH_3CO^+ and trifluoroacetate CF_3COO^- ions, the former ions or the solvated forms being the principal acetylating species. Using the same reagent, Marino et. al.[77] observed that mixtures of acetylated and trifluoroacetylated products are obtained, depending on substrate and the reaction conditions. In general, high temperature, solvent of high polarity and Lewis acids favour acetylation over trifluoroacetylation. In 1,2-dichloroethane at 75°, thiophen gave 100% acetylated product, while 2-methylthiophen gave 98.6% of the acetylated product[78].

The acetylations of various polymethyl thiophens were carried out on a small scale, and the yields of acetyl derivatives were calculated by converting the reaction products into oximes or semicarbazones. 2,5 And 2,4-dimethyl thiophen gave 3-acetyl-2,5-dimethylthiophen (55%) and 2-acetyl-3,5-dimethylthiophen (75%). The acetylation of 2,3,5-trimethylthiophen needed more acidic conditions and the same reagent was used in presence of excess of trifluoroacetic acid. 3-Acetyl-2,4,5-trimethylthiophen was the only product isolated, while tetramethylthiophen was recovered unreacted under similar conditions. ^1H n.m.r. on these acetylated products did not have a signal for $-CH_2-$ group, corresponding to side chain attack.

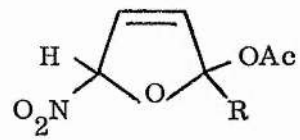
The conditions used for these reactions are very similar to those

where deuteriation is observed and it is significant that no side chain acetylation occurred. Attack at the ring position in the thiophen is much faster and once an acetylated derivative is formed, it is conceivable that it deactivates the thiophen nucleus for further electrophilic attack.

Section 5

The reaction of 2,4-dinitrobenzene diazonium ions with furans.

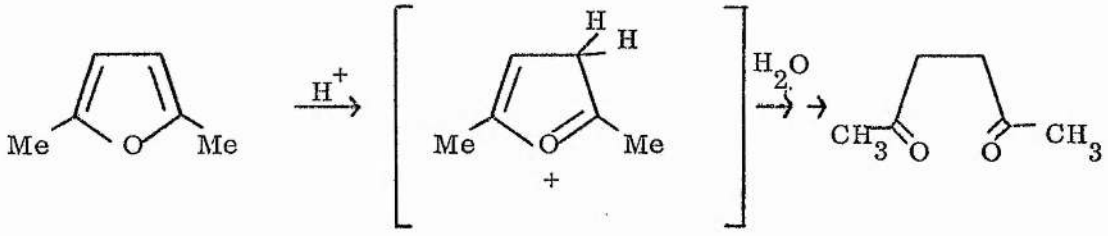
The chemistry of furan has been compared with that of thiophen and pyrrole in the introduction. Furan is less "aromatic" than these compounds and its chemical behaviour can be roughly compared to that of a diene ether which possesses unusually great resonance stabilisation. It however undergoes electrophilic substitution very readily, and the reactivity is often comparable to that of phenol. Substitution occurs preferentially in the 2-postion if free. Many of these 'substitutions' take place by 2,5-addition, followed by elimination. For example a crystalline intermediate (38) has been isolated[79] in the case of nitration of furan using acetic anhydride and nitric acid. Evidence for similar intermediates resulting from the 2,5-addition, has been obtained by ^{1}H n.m.r. in the bromination reaction[80]. Furan behaves as a typical diene in the Diels Alder reaction giving cycloaddition products with dienophiles.



(38)

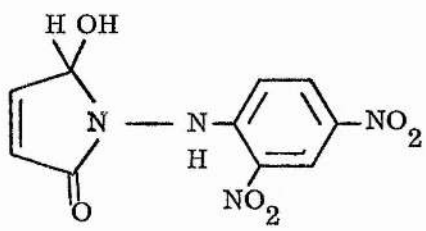
One important difference from thiophen, is that in the presence of dilute aqueous mineral acid, simple furans undergo hydrolytic ring opening, water or alcohol adding with the initially formed cation to give derivatives of 1,4-dicarbonyl compound. Furan itself gives mainly a polymeric material and a small amount of succindialdehyde, which is unstable under the reaction conditions. However, the ring opened compounds can be obtained in quantitative yields in the case of 2,5-disubstituted furans.

Scheme 18.

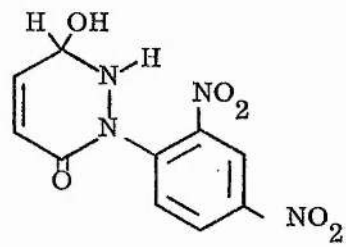


Although some ring opening was expected, the higher reactivity than that of thiophen towards electrophiles was one of the reasons to study these reactions of furans.

In the first reaction in the series, a solution of furan in glacial acetic acid was added to an equimolar solution of 2,4-dinitrobenzene diazonium sulphate. After a reaction period of 15 minutes the yellow product formed was isolated by filtration and then recrystallised (benzene/acetone) to yellow needles m.p. 193°. Mass spectrum (M^+ = m/e 280) and microanalyses suggested $C_{10}H_8N_4O_6$ to be the molecular formula. ^1H n.m.r. (DMSO-d_6) had two acidic protons (exchanged with D_2O) and i.r. spectrum indicated the presence of -NH,-OH, (3310 cm^{-1}) and a carbonyl group (1690 cm^{-1}). It seemed probable that the azo coupled furan which then ring opens or the product from the reaction of the diazonium salt with the already ring opened furan, rearranges to give this yellow product. Both the structure (39) and (40) could



(39)

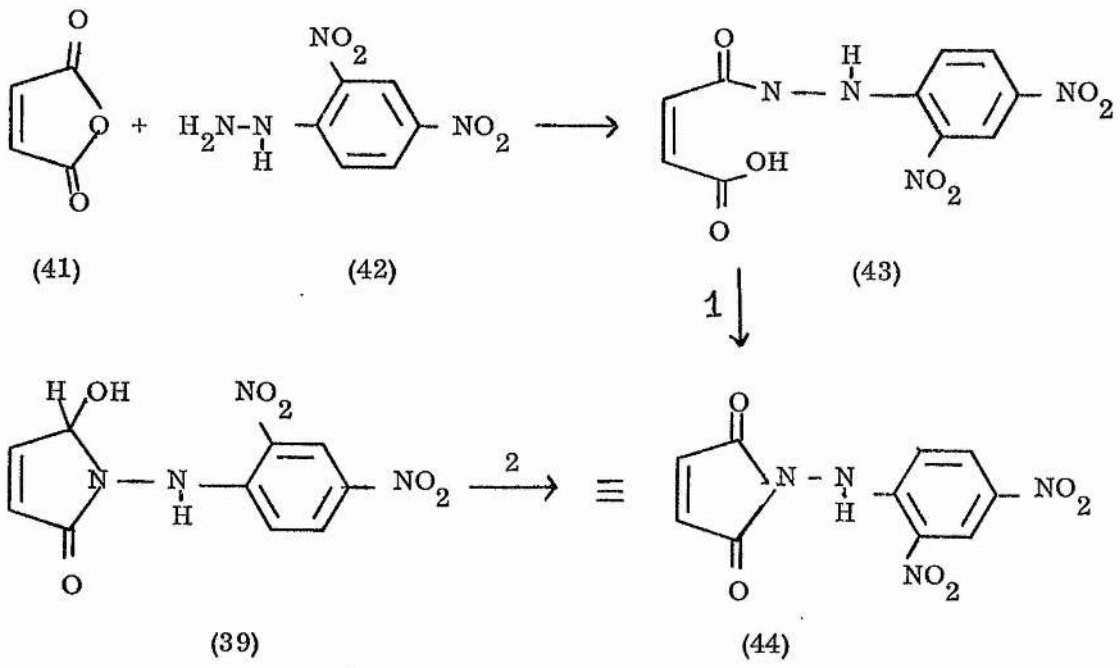


(40)

fit the spectral data.

This yellow product was assigned the structure (39) i.e. N-(2,4-dinitroanilino)-5 hydroxy - 2-oxo-2,5-dihydropyrrole, on the basis of following evidence. N-(2,4-dinitrophenylamino) maleimide was prepared by an unambiguous route[81] (scheme 19). 1-(2,4-Dinitrophenyl)-2-(3-carboxyacryloyl) hydrazine (43), prepared by the reaction of maleic anhydride (41) and 2,4-dinitrophenyl hydrazine (42), was cyclised in glacial acetic acid to give the substituted aminomaleimide (44). The above product from the furan reaction, (which is a secondary alcohol) was oxidised by dilute chromic acid, to a yellow solid, m.p. 233°, which was found to be identical in all respects with the N-(2,4-dinitrophenyl)aminomaleimide(44) prepared above. ^{1}H n.m.r. had a singlet (δ 7.24) for the olefinic protons and the ^{13}C n.m.r. had one

Scheme 19.



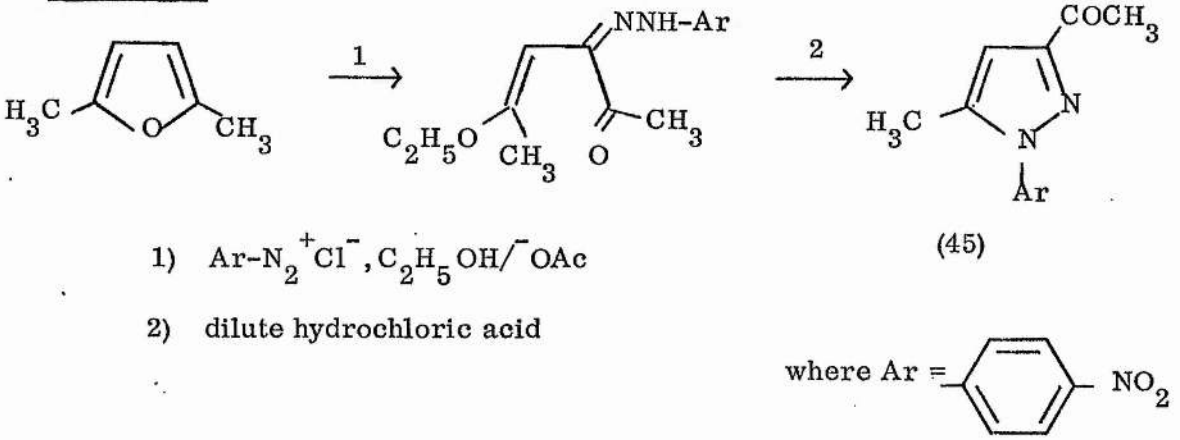
1) Glacial acetic acid.
2) Dilute chromic acid.

signal each for the carbonyl carbons (p.p.m. 168·02) and for the olefinic carbons (p.p.m. 134.24) thus indicating the symmetrical structure of the maleimide (as opposed to the six membered pyridazinedione which would have formed by the oxidation of (40)).

Previously reported reactions of furans with benzene diazonium compounds are mainly arylation reactions carried out either under Gomberg type reaction conditions to give 2-and 3-aryl furans[82] or reactions of 2-substituted furans carried out under Meerwein conditions to give arylation in the 5-position[83, 43b]. Reactive derivatives like 3-acetamidofuran can be coupled with the diazonium salts to give azo dyes[84].

Eastman and Detert[85] reacted 2, 5-dimethylfuran (see scheme 20) with p-nitrobenzene diazonium chloride in an ice cold aqueous alcoholic solution in the presence of excess of potassium acetate as buffer. The initial red coupling product could not be crystallised and was converted by heating in vacuo or by hydrolysing with dilute acid, to 1-p-nitrophenyl-3-acetyl-5-methylpyrazole (45).

Scheme 20.



1) $Ar\text{-}N_2^+Cl^-, C_2H_5OH/^-OAc$

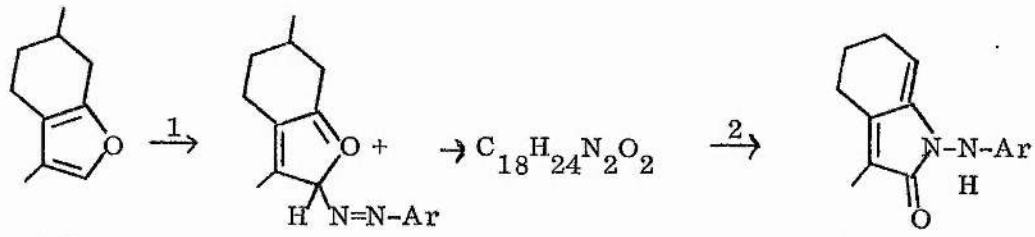
2) dilute hydrochloric acid

(45)

where Ar =

The coupling reaction of menthofuran (46), where an ∝ position in the furan ring is free, with p-methylbenzene diazonium sulphate under similar conditions has also been described by the same authors[86]. The initial unstable intermediate containing a molecule of methanol, was converted into a 2-pyrrolone derivative (47) by the action of aqueous acid (Scheme 21).

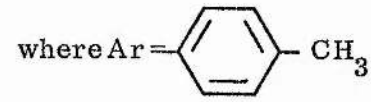
Scheme 21.



(46) (47)

1) ArN_2^+Cl, CH_3OH, ^-OAc

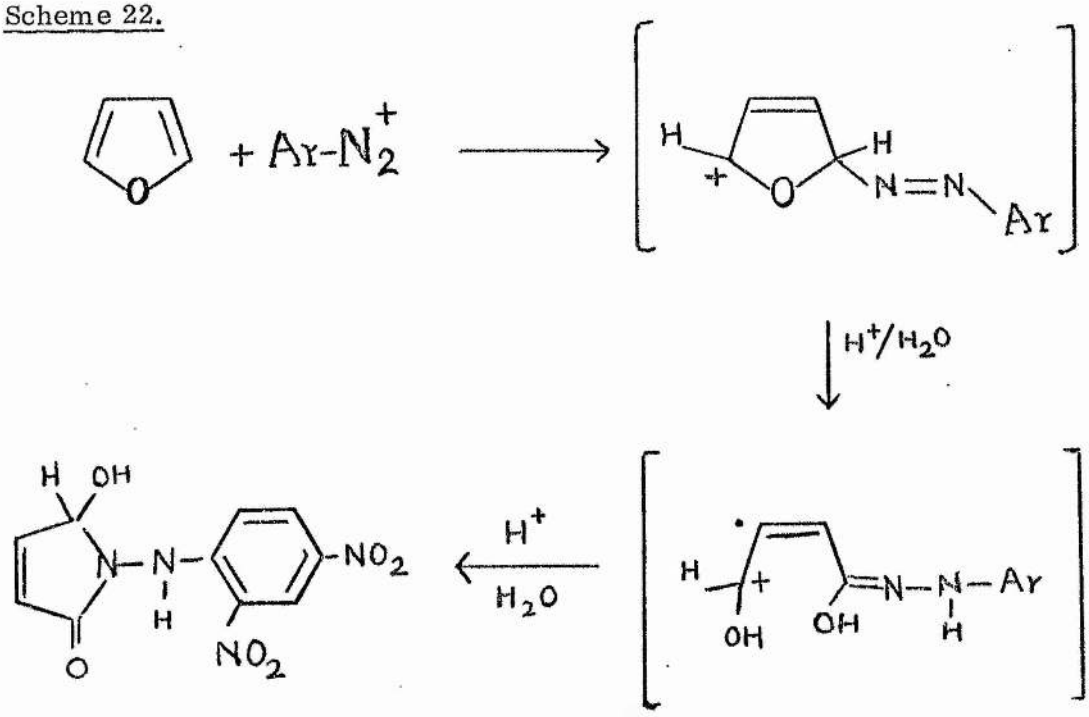
2) aqueous acid.



Although it remains to be proved, it seems unlikely that the compound formed after the ring opening of the furan, (viz. 1,4 dihydroxy 1,3 butadiene in equilibrium with succindialdehyde) will couple with the diazonium salt. Furan itself is very reactive towards electrophiles and initial azo coupling with the reactive 2,4-dinitrobenzene diazonium ion, followed by ring opening and subsequent rearrangement seems the likely path for this reaction (Scheme 22).

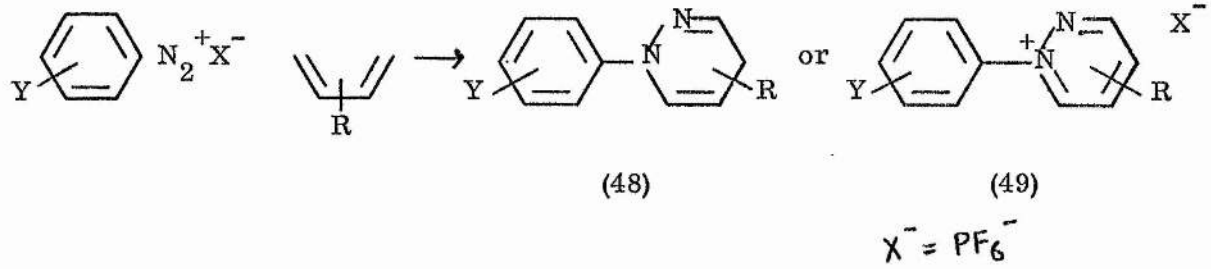
The final product (39) being similar to that obtained in the menthofuran reaction (47).

Scheme 22.



Recently it was reported[14] that aromatic diazonium salts undergo cycloaddition reaction with 1,3 dienes (Scheme 23), to produce N-substituted 1,6-dihydropyridazines (48) or pyridazinium salts (49), depending on the nature of the substitution in the aromatic ring.

Scheme 23.



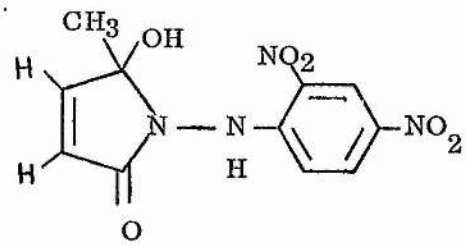
(48) (49)

$X^- = PF_6^-$

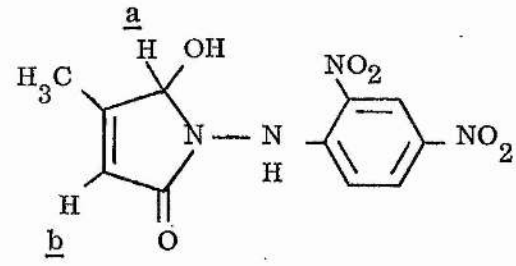
When electron withdrawing substitutents like para-nitro were present in the diazonium salt, in situ air oxidation to pyridazinium salt (with quaternary nitrogen) was inhibited and N-substituted 1, 6- dihydro pyridazine (48) was the main product.

Furan undergoes normal cycloaddition reactions with dienophiles. In the present reaction, with 2, 4-dinitrobenzene diazonium salt solution, the analogous product would have been the N-substituted -dihydropyridazine with an oxygen bridge across 2 and 5 carbon atoms, which would gave a six membered ring compound. However, considering the reaction conditions and the product for the furan reaction reported here, cycloaddition seems unlikely.

The coupling reaction with 2 methylfuran was carried out under similar conditions. The yellow product isolated from the reaction analysed correctly for $C_{11}H_{10}N_4O_6$, had two exchangeable protons in the ^1H n.m.r. spectrum and the i.r. spectrum had a carbonyl absorption at 1710 cm^{-1} and NH, OH absorption at 3200-3380 cm^{-1}. By analogy with the product from furan reaction this is assigned the structure of N-(2, 4-dinitroanilino) - 5-methyl 5-hydroxy -2-oxo-2, 5-dihydropyrrole (50).



(50)



(51)

A yellow product obtained from the reaction of 3-methylfuran with 2,4-dinitrobenzenediazonium solution was assigned the structure (51). That the methyl group was in 4 position in the 2-oxo-2,5-dihydropyrrole ring, (and not in 3 position) was confirmed by running ^{1}H n.m.r. in DMSO-D_6+ D_2O solvent. The protons a and b gave a singlet each at δ 5.52 and δ 6.95 respectively.

The reaction of 2,5-dimethylfuran. gave a resinous red solid which was extremely difficult to recrystallise (to assured state of purity). The mass spectrum on the compound had a peak at m/e 290 corresponding to the azo coupled product. (No NH absorption). However in another reaction of the dimethylfuran with the 2,4-dinitrobenzene diazonium fluoroborate in dioxan, a red compound with same molecular wt. (M^+ = m/e 290) was isolated. (11 % yield). This had an NH absorption in the I.R. spectrum 3280 cm^{-1} and thus appeared to be a product derived from a side chain attack. Large amounts of intractable resins were obtained in both cases and the reaction was not pursued.

In these reactions of the furan and the two mono alkyl furans, although azo coupled products were not isolated, it has been shown that these compounds are sufficiently reactive for an initial coupling reaction to take place with the 2,4-dinitrobenzene diazonium ions.

Benzo(b)furans are more stable towards ring opening in the acidic medium. The benzo(b)furan itself gave mono arylated and diarylated products.

No azo coupled products were isolated. The coupling reaction of 2-methyl benzo(b)furan however gave a small amount of azo coupled product in addition to the arylated product.

Section 6

"Diazotisation in trifluoroacetic acid. N. M. R. spectra of some benzene diazonium compounds".

Trifluoroacetic acid has been used as a medium for electrophilic aromatic substitution[88] and in particular as a nitrating medium with anhydrous nitric acid[89]. Spitzer and Stewart reported[90] almost quantitative conversion of benzene and toluene into their mono nitro derivatives using a mixture of sodium nitrate and trifluoroacetic acid. Cryoscopic measurement in trifluoroacetic acid by the same authors indicated that nitronium and nitrosonium ionscould be conveniently generated in this solvent using sodium nitrate and sodium nitrite respectively. Benzene and toluene, however, failed to give any nitroso compound even though 50% of the nitrite salt was converted to nitrosonium ions. Pettit and coworkers[91] isolated solid diazonium trifluoroacetates having the apparent formula $Ar\text{-}N_2^+ CF_3COO^-.CF_3COOH$, by diazotising aromatic amines with sodium nitrite in cold aqueous trifluoroacetic acid. Analogous double salts were obtained from other per halogeno carboxylic acids.

In the present work, diazotisation of several primary aromatic amines has been carried out with sodium nitrite and neat trifluoroacetic acid. In a typical experiment the aromatic amine (2 mMol) was dissolved or suspended in trifluoroacetic acid (5 ml) and equivalent amount of sodium nitrite was added in small portions. The reaction was stirred and maintained at room temperature. In 5 to 10 minutes a pale yellow coloured diazonium solution was obtained.

In addition to aniline, p-methylaniline, a series of weakly basic amines viz. mononitro anilines and 2,4-, 2,6-, 3,5- dinitroanilines were diazotised by the above method, and high yields of azo compound were obtained by subsequent coupling of the diazonium solutions. 2,4,6-Trinitroaniline however could not be diazotised under similar conditions.

Aromatic amines are usually diazotised by the action of sodium nitrite on a solution of the amine in aqueous mineral acid at temperatures of about 0^{o}. The overall picture of the process can be represented by the following scheme (24).

Scheme 24.

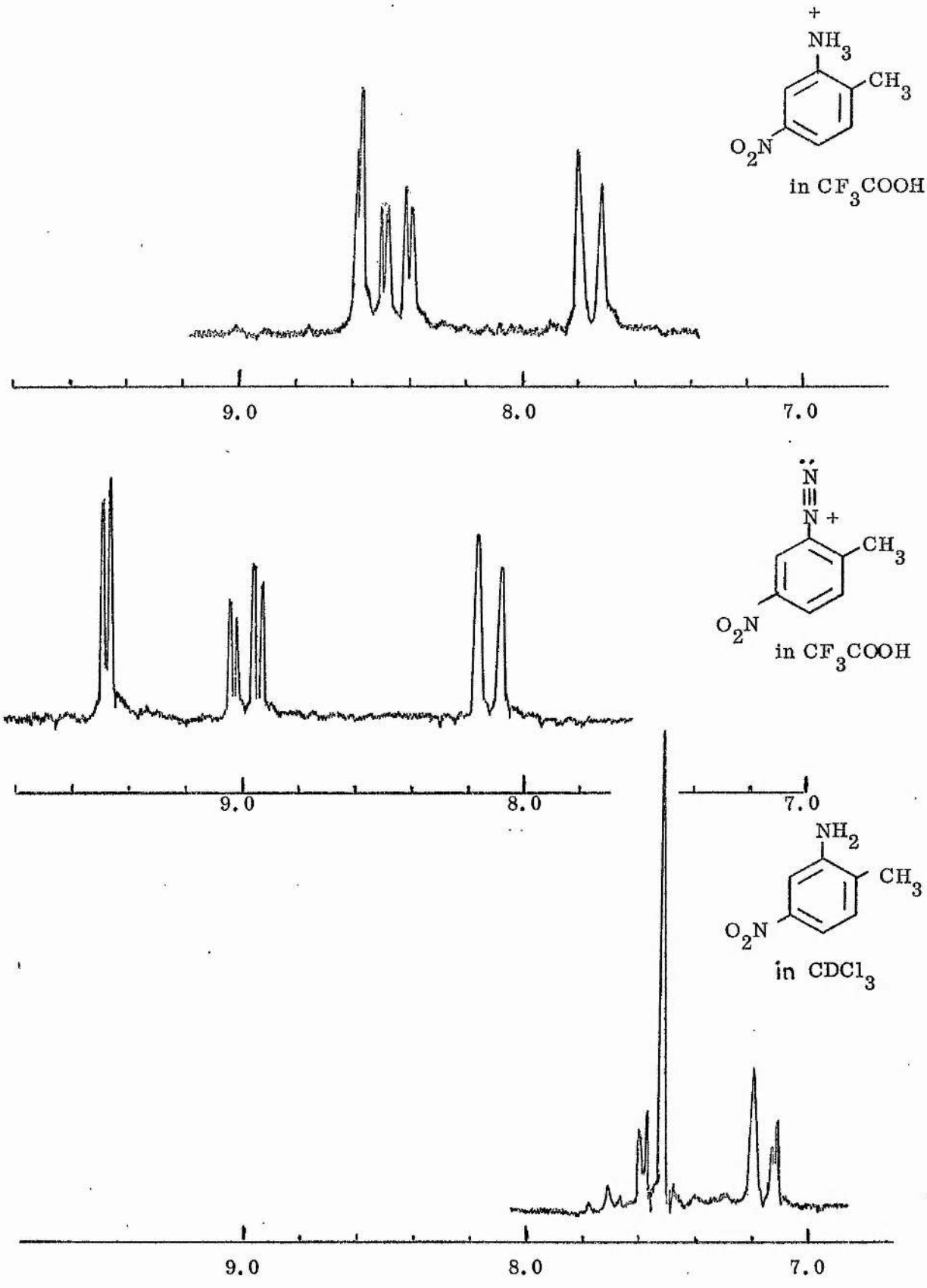
$$Ar\text{-}NH_2 \xrightarrow[\text{slow}]{NO\text{-}X} ArNH\text{-}NO \xrightarrow[\text{Fast}]{} Ar\text{-}N{=}N\text{-}OH \xrightarrow[\text{Fast}]{acid} Ar\text{-}N^{+}{\equiv}N$$

where X = Cl, Br, OH

The rate determining step being the N-nitrosation of the amine. As the amine becomes less basic the equilibrium between the amine and its ammonium salt increasingly favours the former which is generally less soluble in water and thus the normal method of diazotisation becomes increasingly difficult. Thus the optimum acidity for each diazotisation is when the equilibrium concentration corresponds to the saturated solution of the amine. However, the diazotisation of weakly basic polynitro anilines has been successfuly carried out by the nitrosyl sulphuric acid method. Solid sodium nitrite can be dissolved in 90 to 96% sulphuric acid without evolution of gas to give nitrosyl sulphuric acid. The amine may be added directly to this, and the reaction kept stirred at room temperature. On completion of the reaction, the mixture is diluted with ice. This process is

often very slow, (e.g. 2,4-dinitroaniline requires 1.5 to 2 hours for completion of the diazotisation[38]) because the concentration of the free amine is exceedingly small. This has been remedied by the use of phosphoric acid to dilute the reaction[92a] or by making use of solution of the amines in acetic acid[93,94], thus probably altering the ammonium, amine equilibrium in favour of the base.

In TFA, apart from the ease of diazotisation, and short reaction periods, one is dealing with a one solvent system and mineral acids are not present, which could be an important factor for further reactions with compounds sensitive to mineral acids. The most important advantage however is that n.m.r. spectra can be run by taking aliquots from the diazotisation reaction itself. The signal due to the trifluoroacetic acid proton, appearing at 10 to 10.5 δ does not mask rest of the spectrum. ^{1}H n.m.r. spectrum in the aromatic region of 2 methyl 5-nitroaniline in trifluoroacetic acid before and after the diazotisation are shown overleaf. A spectrum of the same compound in $CDCl_3$ (i.e. unprotonated form) is also shown for comparison.

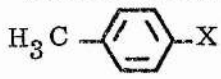

+
NH3
CH3
O2N
in CF3COOH
9.0
8.0
7.0
N
N +
CH3
O2N
in CF3COOH
9.0
8.0
7.0
NH2
CH3
O2N
in CDCl3
9.0
8.0
7.0

The spectrum of the diazonium solution does not have any peaks due to the base dissolved in trifluoroacetic acid i.e. the diazotisation is complete. A change of $\delta 0.9$ is observed in the shift of the 6 proton (ortho to the diazonium group) in going from the ammonium solution to the diazonium solution. A down field shift of approximately 1 ppm for the ortho and para protons and of approximately 0.5 ppm for the meta protons for the amine can be expected by the change of solvent from deuteriochloroform to trifluoroacetic acid. ^{1}H n.m.r. spectral data obtained from several other benzene diazonium solutions in trifluoroacetic acid are collected in the experimental section. Aromatic protons are strongly deshielded as expected due to the presence of the diazonium group, thus in the extreme case of 3,5 dinitrobenzene diazonium ion, where the combined effect of two nitro groups and the diazonium group is responsible for a low field signal at δ 9.92 for the 2 and 6 protons. Benzene itself gives a signal at $\delta 7.3$ in trifluoroacetic acid.

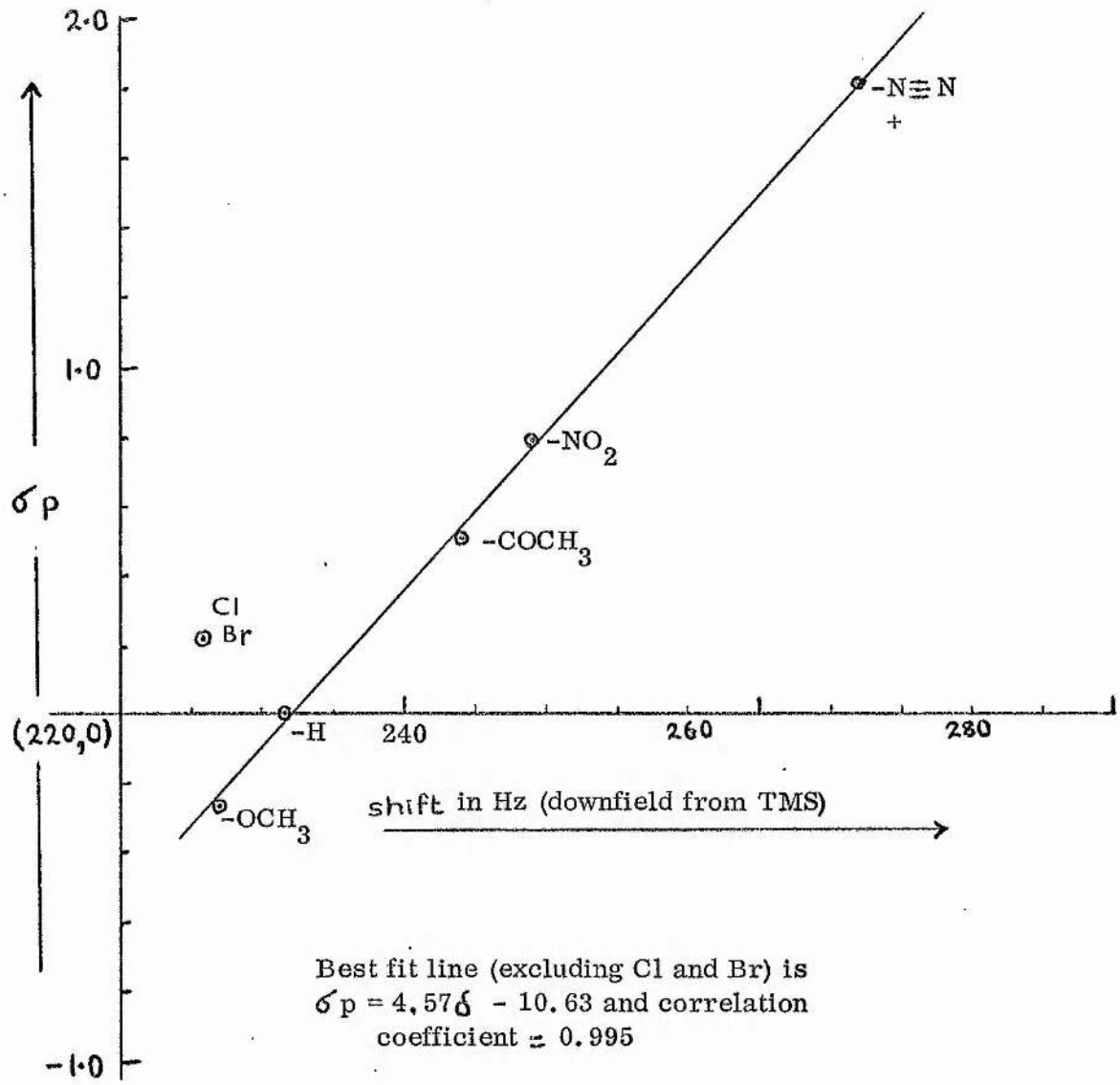
The proton chemical shift has often been correlated with parameters which reflect the effective electronegativity of the group to which the proton is attached. In general resonable correlation are reported for the para substituent. Less satisfactory correlation for meta substituents may be due to the effect of long range shielding contributions[95]. The chemical shift of the methyl group in p- substituted toluenes is reported by Jackman[96]. Shifts of α and β protons in p-substituted ethyl benzenes has been correlated with the Hammett substituent constant σ_p[97]. Except for chlorine and bromine substituents satisfactory correlation was obtained. In the present work, the chemical shift for the methyl group for a series of -p-substituted

toluenes was measured from their 10% solutions in trifluoroacetic acid. Excluding chlorine and bromine substituents a satisfactory correlation with the Hammett substituent constants σp^{98} was obtained.

The chemical shift data is collected in the following table 9

Substituent X in 	Shift in p.p.m. of $-CH_3$	σp^{98}
-O-Me	2.27	-0.268
-H	2.32	0.000
$-CO.CH_3$	2.44	0.502
$-NO_2$	2.49	0.778
-Cl	2.26	0.227
-Br	2.26	0.232
$-\overset{+}{N}\equiv N$	2.72	1.80[a]

a) value of σp calculated from the plot of σp ∇ Shift in Hz.



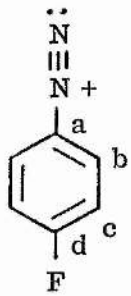
Best fit line (excluding Cl and Br) is $\sigma p = 4,57\delta - 10.63$ and correlation coefficient = 0.995

The diazonium group is known to be by far the strongest electron withdrawing substituent. It facilitates nucleophilic substitution even more than the nitro group[99]. Schoutissen observed[92b] that the first diazo component of p- benzene-bis diazonium salt couples in concentrated acids equally well as diazotised picramide thus the activating effect being roughly equivalent to that of the three nitro groups, (2,4,6- in picramide). Lewis and Johnson[100] obtained the values of 1.91, 2.18, and 1.32 respectively for the Hammett

substituent constant σ p of the diazonium group by measuring the ionisation constants of substituted benzoic acid, phenylacetic acid, and from the rates of coupling, the average value being 1.8 ± 0.5. Determination of substituent constant (σ p) from chemical shift correlations has been done in very few cases where conventional methods are difficult, e.g. ^{13}C chemical shift of the para carbon in organophosphorus compounds like $C_6H_5PZ_\eta$ was used to derive σ p for $-PZ_\eta$ groups[101]. The σ p value for the diazonium group of 1.80 obtained in the present work however agrees well with the average value derived by Lewis and Johnson.

^{13}C n.m.r. spectra of para-nitro and para-fluoro benzene diazonium ions in trifluoroacetic acid were studied on their 1M solutions. As temperatures of up to 35° were reached in the spectrometer probe, 1M solution (solute to solvent ratio $\sim$ 1 to 10) was found suitable, giving a spectrum in about an hour. Carbon - Fluorine coupling, which decreases with increasing number of bonds separating the carbon atom from the fluorine, was helpful in assigning the spectrum unambiguously.

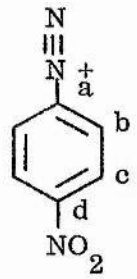
Table 7.



(53)

Peak ht.	ppm.	Coupling const.	Assignment and shift in ppm.
10 16	179.94 166.12	276.4 $^{1}J_{CF}$	d, 173.03
64 62	138.45 137.83	12.4 $^{3}J_{CCCF}$	b 138.12
60 58	123.08 121.81	25.4 $^{2}J_{CCF}$	c 122.45
17 17	110.21 110.05	3.0 $^{4}J_{CCCCF}$	a 110.13

Table 8.

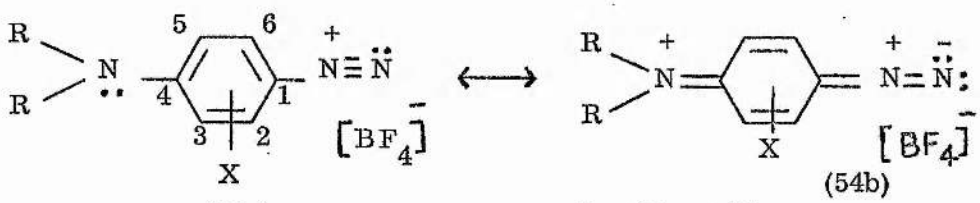


(52)

Peak height	ppm.	assignment
18	156.47	d
110	136.23	b
120	128.84	c
21	121.77	a

Allowing for the effects of para substituents, it can be seen that carbon of attachmentis strongly shielded by the diazonium group while the rest of aromatic carbons are increasingly deshielded in the order meta, ortho and para.

The only previous report on n.m.r. spectra of benzene diazonium compounds is the recent work by Radeglia and Jackowski[102], who studied the ^{1}H and ^{13}C n.m.r. spectrum of substituted para- dialkylaminobenzene diazonium fluoroborate. The delocalisation of the electron pair from the dialkyl amino nitrogen as depicted in (54a) and (54b) gives extra stability to this diazonium salt, which also explains the high field shift for the C-1.



(54a) (54b)

R = Me or Et

X = H, -2-OMe, or -3-OMe

(δ = 88 ppm) observed by these workers.

EXPERIMENTAL

General Experimental Procedures.

Melting points were determined in open capillaries and are uncorrected.

Infrared spectra were measured with a Perkin Elmer 257 spectrometer. Oils were recorded as liquid films while solids were recorded as nujol mulls.

Ultraviolet and visible spectra were obtained on a Unicam SP 800 instrument. Whenever possible analytical samples were used. All spectra were recorded as solutions in methanol.

^{1}H n.m.r. spectra were run on a Varian HA 100 spectrometer operating at 100 MHz. They were recorded as 10% (W/V) solutions with tetramethylsilane as the internal reference. For high temperature n.m.r. hexamethyl disilane was used as the internal reference.

^{13}C n.m.r. spectra were run on a Varian CFT 20 spectrometer operating at 20 MHz. They were proton decoupled. Tetramethylsilane was used as the internal reference and chemical shifts are recorded in parts per million downfield from the reference.

Mass spectra were recorded on AEI MS 902 instrument operating at 70 e.v.

Column chromatography was carried out either on activated alumina type H 100/200 mesh or on silica gel grade M 60.

Thin layer chromatography was done on silica (MN Kieselgel G) coated plates or alumina (MN Aluminium oxide G) coated glass plates, the

thickness of the adsorbent layer being 0.25 mm. Preparative plates had a thickness of 1 mm.

Abbreviations

s:	singlet
d:	doublet
dd:	double doublet
t:	triplet
m:	multiplet
br:	broad
d:	with decomposition (after melting point)
TFA:	trifluoroacetic acid
DMSO:	Dimethyl sulphoxide

Section 1

1) Diazotisation of 2,4-dinitroaniline[38]

Sodium nitrite (0.7g, 0.01M) was gradually added with stirring to concentrated sulphuric acid (11 ml) and the mixture was heated to 60° to complete dissolution. When the temperature had fallen to 35°, 2,4-dinitroaniline (1.83g, 0.01M) was added taking approximately twenty minutes. The resulting solution was stirred at room temperature for one and a half hours and then poured on to 20g of crushed ice. This solution, containing 0.01M of diazonium salt was filtered into a cooled measuring cylinder and the calculated portion used for each coupling reaction.

2) Coupling reaction of diazotised 2,4-dinitroaniline with anisole.

The 2,4-dinitrobenzene diazonium solution (0.01M) was added to anisole (1.08g, 0.01M) in glacial acetic acid (40 ml) and the resulting solution maintained at 0° for 68 hours, with continued stirring. The reaction was then poured into crushed ice water mixture and extracted in chloroform. The combined extracts were washed several times with water, aqueous sodium hydrogen carbonate and water before being dried (Na_2SO_4 anhyd.). Evaporation of the solvent gave a red oil which was chromatographed on alumina to give p-(2,4-dinitrobenzene azo)-methoxybenzene. Recrystallised from acetone/petrol (60:80) mixture to give orange needles m.p. 177-8° (lit[12] 177°). m/e 302 M^+ Total yield of the azo dye was (1.1g, 36%).

3) Coupling reaction with thiophen.

A freshly prepared 2,4-dinitrobenzene diazonium sulphate solution (0.01M) was added to a solution of thiophen (0.84g, 0.01M) in glacial acetic

acid (40 ml). The reaction became red coloured and a steady evolution of nitrogen gas was commenced. The reaction was maintained at 0^{o} for 70 hours with continued stirring. After the reaction period, the tarry mixture was diluted by pouring into crushed ice water mixture and extracted in chloroform. The chloroform extract was washed with water, aqueous sodium hydrogen carbonate solution, and again with water. After drying (Na_2SO_4 anhyd.) the extract, solvent was evaporated and the red oil obtained was chromatographed on an alumina column. The first yellow fraction eluted by benzene gave a light sensitive yellow coloured solid on evaporation of the solvent. This was purified on a small alumina column, protected from light, and then recrystallised from benzene/petrol to give yellow needles, m.p. 60^{o}, of 2-(2',4'-dinitrophenyl)-thiophen. Found C, 47.7; H, 2.7; N, 11.6%; $C_{10}H_6N_2O_4S$ requires C, 48.0; H, 2.4; N, 11.2%. $\underline{M}^+$ = m/e 250. γ max 1595; 1525(br) 1345(br) (NO_2), 915, 845, 750, 730 cm^{-1}. λ max = 335 nm ($\epsilon = 1.8 \times 10^4$) ^{1}H n.m.r. δ ($CDCl_3$) 7.17 (2H, m), 7.54 (1H, dd, J = 4 and 1 Hz), 7.76 (1H, d, J = 9 Hz), 8.38 (1H, dd, J = 9 and 2 Hz) 8.55 (1H, d, J = 2Hz). The yield of mono-arylated compound was (0.48g, 19%). Benzene eluted a second yellow fraction which on evaporation gave a yellow solid, recrystallised from benzene to give 2, 5-bis(2',4'-dinitrobiphenyl) thiophen, m.p. 172^{o}, (0.045g. 2.5%). Found C, 46.4; H, 1.9; N, 13.3%; $C_{16}H_8N_4O_8S$ requires C, 46.2; H, 1.9; 13.5%. $\underline{M}^+$ = m/e 416, λ max = 352 nm (1.3×10^4).

4) Reaction of 2,4-dinitrobenzene diazonium solution with benzene.

The diazonium solution (0.01M) was added to a solution of benzene (0.78g, .01M) in glacial acetic acid (40 ml) and the reaction was stirred for

70 hours at 0^{o}. There was no evolution of nitrogen gas and no significant amount of arylated or other products were isolated after the usual work up procedure. Most of the diazonium salt was unreacted as found by its subsequent coupling reaction.

5) Reaction with 2-Methylthiophen.

The diazonium salt solution (0.01M) was added to a solution of 2-methylthiophen (0.98g, 0.01M) in glacial acetic acid (40 ml), and the reaction was stirred for 24 hours at room temperature. At the end of the reaction period there was some tarry red ppt. formed. The reaction was poured into ice water and extracted in chloroform. The chloroform extract was then washed successively with water, sodium hydrogen carbonate solution (10%), and water, before being dried (Na_2SO_4 anhyd.). Evaporation of the solvent gave a black oil, which solidified on standing. This was chromatographed on an alumina column (2.5 cm x 63 cm). The major product eluted by benzene was 2-methyl-5-(2',4'-dinitrophenyl)thiophen (0.68g, 24.6%) m.p. 73.5-74°, Found C, 49.90; H, 3.05; N; 10.20%; $C_{11}H_8N_2O_4S$ requires C, 50.00; H, 3.03; N, 10.61%. Mass spectrum m/e 264 P^+, I.R. γ max 1595; 1525 and 1350 ($-NO_2$); 915, 820, 814 cm^{-1}. U.V. λ max 350 nm ($\epsilon = 8.94 \times 10^3$) 235 nm ($\epsilon = 1.46 \times 10^4$). ^1H n.m.r. δ ($CDCl_3$) 2.7 (3H, s), 6.75 (1H, m), 7.02 (1H, d, J = 3.5 Hz), 7.69 (1H, d, J = 8.5 Hz), 8.33 (1H, dd, J = 8.5 Hz, 2.4 Hz), 8.5 (1H, d, J = 2.4 Hz). After spin decoupling the signal at 2.7 δ, the multiplet at 6.75 δ was reduced to a doublet (J = 3.5 Hz). A further red fraction eluted by chloroform was found to contain several components, with close Rf values on a TLC. The second fraction from the preparative TLC

contained diarylated 2-methylthiophen (m/e 430 P^+). This was insufficient to purify further. However, there were no products corresponding to the azo coupled products.

The experiment was repeated, carrying out the reaction for 68 hours at 0^oC. 2-methyl-5-(2', 4' dinitrophenyl)thiophen was again the major product while the trace products appeared similar to those described above.

6) Reaction with 3-methylthiophen.

A solution of 3-methylthiophen (0.58g, 0.006 M) in glacial acetic acid (24 ml) was added to the diazonium solution (0.01 M) and the reaction stirred for 72 hours at 0^oC. The reaction mixture was then filtered and the precipitate taken up in chloroform. The extract was washed with water, 10% sodium hydrogen carbonate and water and then it was dried over anhydrous sodium sulphate. The black oil (1.85g) obtained after evaporation of the solvent was chromatographed on a silica column (3 cm x 60 cm). The first fraction eluted by benzene contained two compounds. It was boiled in petrol, and evaporation of the solvent from the filtrate gave a light sensitive yellow solid, which was then recrystallised from petrol. This is 3-methyl-2 (2', 4'-dinitrophenyl) thiophen, m.p. 92-3°. Found, C, 50.32; H, 2.92; N, 10.31%; $C_{11}H_8N_2O_4S$ requires C, 50.00; H, 3.03; N, 10.61%, (0.53g, 33%). Mass spectrum M^+ = m/e 264. I.R. ν max 1615; 1510 and 1320 cm^{-1} ($-NO_2$). U.V. λ max 335 nm (ϵ 4.8×10^3) 233 nm (ϵ 1.8×10^4). ^1H n.m.r. δ ($CDCl_3$) 2.8 (3H, s), 6.94 (1H, d, J = 5 Hz) 7.38 (1H, d, J = 5 Hz), 7.70 (1H, d, J = 9 Hz), 8.45 (1H, dd, J = 9 and 2.2 Hz) 8.73 (1H, d, J = 2.2 Hz). The compound insoluble in petrol was obtained in too small amounts to characterise fully. Mass

spectrum M^+ = m/e 388, and high resolution mass spectrum, Found m/e = 388.03051 ; $C_{16}H_{12}N_4O_4S$ requires m/e = 388.02990 , suggested that this compound contains two 3-methyl thiophenyl-groups, and one 2,4-dinitrophenyl azo group. A tentative structure (10) is proposed for this compound. A further fractions eluted by chloroform contained a small amount of diarylated compound, M^+ = m/e 430.

7) Reaction of 2,4-dinitrobenzene diazonium solution with excess thiophen.

A solution of thiophen (8.4g 0.1M) in glacial acetic acid (50 ml) was added to the diazonium solution (0.01 M). Further 50 ml of glacial acetic acid was added to make the reaction homogeneous. A steady evolution of gas commenced from the resulting red solution which was stirred for 40 hours at 0^o. The red oil, obtained after the work up as in previous reactions, was chromatographed on a silica column. Benzene eluted a greenish yellow solid which was purified on an alumina column (protected from light) to give the mono arylated compound 2-(2',4'-dinitrophenyl)-thiophen m.p. 60^o, i.r. n.m.r. etc. identical with the mono arylated compound obtained previously.

The total yield was (1.2g 48%). Only a trace of the 2,5-bis-arylated compound was obtained.

8) Coupling reaction of thiophen in presence of excess benzene.

Thiophen (0.84g 0.01 M) and benzene (7.02g, 0.09 M) were dissolved in glacial acetic acid and the solution was added to the freshly prepared diazonium solution. The reaction was stirred at 0^o for 40 hours before being diluted with ice/water and extracted in chloroform. The red oil obtained after

evaporation of the solvent from the dried (Na_2SO_4 anhyd.) extract was chromatographed on an alumina column to give a yellow solid (0.62g) m.p. 52°. γ max 3100, 1600, 1530(br), 1350, 920, 850, 835, 780, 760, 740, 720, 700 cm^{-1} and ^1H n.m.r. δ ($CDCl_3$) 7.1-7.3(m), 7.35-7,6(m), 7.68(d, 8.5 Hz), 7.79 (d, 9 Hz), 8.36 to 8.60(m), 8.69 (d, J = 2 Hz). Mass spectrum m/e = 250, 244 etc. That this yellow solid is a mixture of 2-(2',4'-dinitrophenyl)-thiophen and 2,4-dinitrobiphenyl was confirmed by comparing the spectral and other data obtained on a sample of 2,4-dinitrobiphenyl (prepared as in Ref. 103) m.p. 110° (lit[103] m.p. 110°), γ max, 3100, 1600;1520(br), 1350 (br) (-NO_2); 930, 920, 900, 855, 835, 780, 760, 740, 705, cm^{-1}. ^1H n.m.r. δ ($CDCl_3$) 7.3 to 7.6 (5H, m), 7.67 (1H, d, J = 9 Hz), 8.45 (1H, dd, J = 9 and 2 Hz), 8.69 (1H, d, J = 2 Hz). Mass spectrum M^+ = m/e 244. The 2,4-dinitrobiphenyl and the 2-(2',4'-dinitrophenyl)-thiophen had extremely similar Rf values and it was impossible to separate them.

q) Coupling reaction of thiophen with 2,4-dinitrobenzene diazonium solution in trifluoroacetic acid..

2,4-Dinitroaniline (0.005 M) was diazotised in trifluoroacetic acid as given in section 6. A solution of thiophen (0.42g, 0.005 M) in trifluoroacetic acid (5 ml) was added to the diazonium solution. After a transient red colouration, the reaction mixture became intensly blue coloured and a vigorous evolution of gas began. After stirring for 18 hours at room temperature, the reaction was diluted with ice cold water and extracted in chloroform. The crude product obtained after the evaporation of the solvent from the

dried extract was chromatographed on a silica column. The mono arylated product 2-(2',4'-dinitrophenyl)-thiophen, obtained in a higher yield, (0.49g, 39%) was again the main product isolated.

An attempt to run ^{1}H n.m.r. at cold temperature (-15^{o}) on the reaction mixture, before the evolution of gas has started, was unsuccessful. ^{1}H n.m.r. on the reaction after several hours at room temperature showed mainly the mono arylated compound.

10) Reaction with 2-(2',4'-dinitrophenyl)thiophen.

A solution of 2-(2',4'-dinitrophenyl)-thiophen (0.22g) in glacial acetic acid was added to a freshly prepared solution of 2,4-dinitrobenzene diazonium sulphate (0.001 M). The reaction was stirred at room temperature for 24 hours, before pouring into cold water. After extraction in chloroform and the usual work up procedure, the crude product was chromatographed. The starting material viz 2-(2',4'-dinitrophenyl)thiophen (0.170g, 77%) was the only product recovered.

Section 2

1) Reaction with 2-t-butylthiophen.

A solution of 2-t-butylthiophen[104] (0.280g, 0.002 M) in glacial acetic acid (16 ml) was added to the diazonium solution (0.0033 M) and the reaction was stirred at 0^{o} for 62 hours. The tarry red reaction mixture was then extracted in chloroform and the extract was washed successively with water, sodium hydrogen carbonate, and water, before being dried (Na_2SO_4 anhyd.). The black oil obtained after evaporation of the solvent was chromatographed on a silica column. The first fraction eluted by benzene was a small amount of unreacted 2-t-butyl thiophen. A purple oil obtained from the next fraction eluted by benzene yielded a deep red coloured solid on addition of petrol. This had m.p. 220^{o}C, λ max 526 nm ($\epsilon = 2.094 \times 10^{5}$), m/e 472 M^{+}. From high resolution mass spectrum, found 472.12448, $C_{22}H_{24}N_4O_4S_2$ requires 472.15468 a tentative structure was assigned (13). The yield was too small for doing further characterisation. The next fraction eluted by benzene yielded a red solid on addition of petrol. This was recrystallised from petrol, to give 2-t-butyl-5 (2',4'-dinitrobenzene azo)-thiophen, (0.14g, 20%), m.p. 136^{o}. Found C, 50.74; H, 4.15; N, 16.49%; $C_{14}H_{14}N_4O_4S$ requires C, 50.30; H, 4.19; N, 16.77%. I.R. γ max 1600; 1525, 1345 (NO_2); 1185; 1065 cm^{-1}. λ max 412 nm ($\epsilon = 2.505 \times 10^{4}$), 330 nm ($\epsilon = 7.5 \times 10^{3}$), 277 nm ($\epsilon = 6.2 \times 10^{3}$) δ (C_6D_6) 1.19 (9H, s), 6.60 (1H, d, J = 4 Hz), 7.19 (1H, d, J = 9 Hz) 7.55 (1H, d, J = 4 Hz) 7.65 (1H, dd, J = 9Hz and 2 Hz), 8.07 (1H, d, J = 2 Hz) $\underline{M}^{+}$ = m/e 334. High resolution mass spectrum, Found 334.07351; $C_{14}H_{14}N_4O_4S$ requires 334.07357.

2) Preparation of 2-phenylthiophen[105].

A mixture of chloranil (40g, 0.16 M), 2-(1-cyclohexenyl)-thiophen (14g, 0.085 M) and benzene (50 ml) was heated under reflux for 15 hours. The reaction mixture was then filtered and the filtrate extracted with several portions of 12% sodium hydroxide solution till the extracts were colourless. The benzene solution was washed with water (2 x 50 ml), before being dried (Na_2SO_4 anhydrous). Solvent was removed at low pressure and the residual oil (red) distilled to give 2-phenylthiophen. B.p. 84°C/0.5 mm. (9.5g, 70%). The product solidified on standing and was recrystallised from aqueous methanol. m.p. 37° lit.[105] 37-37.5°.

2-(1-Cyclohexenyl)-thiophen.

An ethereal sol. of 2-lithiothiophen was prepared[106] by adding thiophen (16.8g, 0.2 M) to a solution of n-butyllithium in ether. This was made by adding n-butyl bromide (54.8g, 0.4 M) to lithium (8.0g, 1.15 M) in dry ether (400 ml), and stirring the mixture for 15 minutes. A solution of freshly distilled cyclohexanone (19.6g, 0.2 M) in dry ether (30 ml) was then added rapidly to the stirred 2-lithiothiophen solution, kept cool in dry-ice acetone bath. After standing overnight at room temperature, the reaction mixture was again cooled and hydrolysed with cold dilute hydrochloric acid. The organic layer was washed with water and dried (Na_2SO_4 anhyd.). After evaporation of the unreacted thiophen, the residue was distilled to give (18g, 55%) of 2-(1-cyclohexenyl)-thiophen, b.p. 88°/0.5 mm. lit.[105] 117-20°/5 mm.

3) Reaction with 2-phenylthiophen.

A solution of 2-phenylthiophen (0.320g, 0.002 M) in glacial acetic acid (20 ml) was added to the 2,4-dinitrobenzene diazonium solution (0.002 M). The reaction mixture became red coloured on addition and was stirred for 40 hours at $0^{o}C$. At the end of the reaction period, the dark brown ppt. was filtered off, washed several times with water and dried (P_2O_5). This was chromatographed on a silica column using a mixture of benzene and carbon tetrachloride as an eluant. The first colourless fraction gave a small amount (0.020 mg) of unreacted 2-phenylthiophen. Next eluted was an orange coloured fraction which gave a brown solid after removal of the solvent. This was further purified on a small silica column, to give deep purple coloured solid, which was recrystallised from methanol to give 5-phenyl -2-(2',4'-dinitro-benzene azo)-thiophen (17). The yield was 14% 0.095g, m.p. 183^{o}, found C, 54.45; H, 2.71; N, 15.67%; $C_{16}H_{11}N_4O_4S$ requires C, 54.24; H, 2.83; N, 15.82%. Mass spectrum $\underline{M}^{+}$ m/e 354, λ max = 453 nm ($\epsilon = 2.48 \times 10^{4}$).

4) Reaction with 2,4-Dimethylthiophen.

2,4-Dimethylthiophen[107] (0.672g, 0.006 M) was dissolved in glacial acetic acid (24 ml) and the solution was added to the 2,4-dinitrobenzene diazonium solution (0.01 M) and the reaction kept stirred at room temperature. An orange red precipitate was obtained immediately. In five minutes the reaction mixture became thick and difficult to stir. The reaction was stopped and the product was filtered off, and was washed with water several times till the filtrate was found to be non acidic. After drying (P_2O_5), 1.54g of orange

red solid was obtained. A small portion (0.110g) was chromatographed on a silica column (2 cm x 40 cm) in benzene. The first orange red fraction gave a red solid which after recrystallisation (methanol) gave 0.08g of 3,5 dimethyl-2-(2', 4' dinitrobenzene azo)-thiophen, m.p. 176°. Found C,46.88; H,3.22; N,17.94%; $C_{12}H_{10}N_4O_4S$ requires C,47.67; H,3.27; N,18.30%. Mass spectrum M^+ = m/e 306. Found m/e = 306.04303 requires 306.04227. I.R. γ max 1610,1590; 1520,1340 cm^{-1} ($-NO_2$). No -NH absorption. U.V. λ max 418 nm (ϵ =2.5 x 10^4). Total yield of the azo compound was 72%.

5) Preparation of 2-methylbenzo(b)thiophen[108].

A solution of methyl p-toluene sulphonate (13g, 0.07 M) in anhydrous ether (35 ml) was added with stirring and cooling to an etheral solution of 2-lithiobenzo(b)thiophen. The mixture was stirred for an hour and then heated under reflux for $\frac{1}{2}$ hour before being poured into a mixture of crushed ice and water (150 ml). The ether layer was separated and the aq. layer was extracted with ether (3 x 25 ml) combined extracts were dried ($MgSO_4$) and the solvent removed at low pressure. The residue was recrystallised from petrol to give 2-methylbenzo(b)thiophen, 1.520g, m.p. 51° lit.[108] 51-52° M^+ = m/e 148.

2-Lithiobenzo(b)thiophen.

An ether solution of n-butyllithium was prepared by gradual addition, with stirring, of a solution of n-butyl bromide (29.5g 0.22 M) in dry ether (40 ml) to lithium film cut into small pieces (3.61g 0.52 M) and suspended in dry ether (70 ml). The reaction vessel was kept cool by ice-hydrochloric

acid bath. Stirring was continued for 1 hour. To the filtered solution of n-butyl lithium was then added a solution of benzo(b)thiophen (13.4g 0.1 M) in dry ether, and the reaction was stirred for a further 45 minutes while cooling it in an ice-hydrochloric acid bath. The solution of 2-lithiobenzo(b) thiophen thus obtained was used in the above reaction.

6) Preparation of 3-Methylbenzo(b)thiophen[109].

Phenylthiopropanone (10g 0.06 mole), polyphosphoric acid (80 g) and phosphorous pentoxide (4g) were stirred and heated at 120-5°C for 5.5 hours. When the reaction mixture had cooled to 85°C it was slowly added with stirring to 200 ml of water and the resulting solution was cooled in an ice bath. After standing overnight, the organic layer was separated and the aqueous layer was extracted in ether, after adding 2 x 10 ml portions of salt water. The combined extracts were dried with anhydrous sodium sulphate. After removal of the solvent, and distillation of the residue, 6g, 68% of 3-methylbenzo(b) thiophen was obtained as a pale yellow liquid b.p. 116-8°/18 mm. lit.[109] b.p. 80-1°/1 mm .

Phenylthiopropanone.

Thiophenol (11g, 0.1 M) was added to a solution of sodium hydroxide (5g) in 150 ml. water, kept stirred at room temperature. Freshly distilled chloroacetone (11.63g, 0.125 M) was then added and the mixture stirred for further 45 minutes and then extracted with 3 x 75 ml portions of ether. After drying the combined extracts over $MgSO_4$(anhyd.), the solvent was removed and the residue distilled to give phenylthiopropanone (11.5g, 70%) b.p. 144°/ 18 mm. lit.[109] b.p. 94-96°/0.5 mm.

7) Reaction with 2-Methylbenzo(b)thiophen.

To a solution of 2-methylbenzo(b)thiophen (0.296g, 0.002 M) in glacial acetic acid (8 ml) was added the 2,4-dinitrobenzene diazonium solution (0.0033 M) and the reaction was stirred for 68 hours at 0^{o}. At the end of the reaction, the red product was filtered off and taken up in chloroform. The extract was washed successively with water, sodium bicarbonate and water. Evaporation of the solvent from the dried extract gave a red solid. This was purified by chromatography on a silica column in benzene, and then recrystallised from benzene/ petrol mixture to give (0.425g, 62%) red needles of 2-methyl -3-(2',4'-dinitrobenzene azo)-benzo(b)thiophen (19) m.p. 182^{o}. Found : C, 52.56; H, 2.84; N, 16.70%; $C_{15}H_{10}N_4O_4S$ requires C, 52.63; H, 2.92; N, 16.37%. m/e 342 P^{+}. I.R. γ max 1600, 1520, 1340 ($-NO_2$) 1180, 1060, 750 cm^{-1} (no-NH-absorption) λ max 408 nm (ϵ 1.71×10^4) 288 nm (1.47×10^4) 222 nm (2.414×10^4). The compound was insoluble in most of the solvents available and n.m.r. spectrum was not obtained.

8) Reaction with 3-Methylbenzo(b)thiophen.

A solution of 3-methylbenzo(b)thiophen (0.296g; 0.002 M) in glacial acetic acid (8 ml) was added to the 2,4-dinitrobenzene diazonium solution (0.0033 M) and the reaction was stirred at 0^{o}C for 68 hours. At the end of the reaction, the red product formed was filtered and taken up in chloroform. The extract was washed with water, sodium hydrogen carbonate and water and then dried (Na_2SO_4 anhyd.). The red solid obtained by evaporation of the solvent was purified on a short silica column (1.5 cm x 25 cm). Benzene eluted an orange yellow fraction. The solid obtained by evaporation

of benzene was crystallised from benzene/petrol to give orange needles of 3-methyl-2-(2'4'-dinitrobenzene azo)-benzo(b)thiophen (20) (0.170g, 25%) m.p. 190°C. M^+ = m/e 342. Found C, 52.3; H, 2.9; N, 16.1%; $C_{15}H_{10}N_4O_4S$ requires, C, 52.6; H, 2.9; N, 16.4%. I.R. ν max 1520, 1340 cm^{-1} ($-NO_2$) u.v. λ max 406 nm. ($\epsilon = 3.1 \times 10^4$) 277 nm ($\epsilon = 1.0 \times 10^4$).

Section 3.

1) Reaction with 2,5-dimethylthiophen.

A solution of 2,5-dimethylthiophen (0.672g, 0.006 M) in glacial acetic acid (24 ml) was added to the diazonium solution (0.01 M) and the reaction mixture was stirred at 0^{o} for 68 hours. At the end of the reaction period, the red precipitate was filtered off, washed several times with water (till the filtrate was non-acidic) and dried (P_2O_5). The red solid was chromatographed on a silica column (3 cm x 90 cm). First eluted by benzene was a yellow fraction, which on evaporation of benzene gave a yellow solid. This was recrystallised from benzene petrol mixture to give 2,5-dimethyl-3-(2',4'-dinitrobenzene azo)-thiophen (0.250g, 13.5%). m.p. 137. Found, C,47.10; H,3.46; N,17.87%; $C_{12}H_{10}N_4O_4S$ requires C,47.67; H,3.27; N,18.30%. High resolution mass spectrum gave m/e M^+ = 306.04157 ; $C_{12}H_{10}N_4O_4S$ requires, 306.04227. Mass spectrum M^+ = m/e 306. I.R. γ max 1600; 1530 and 1350 (NO_2) cm^{-1}; 1190, 920, 850, 840, 750 cm^{-1}. U.V. λ max 378 nm (ϵ = 1.601 x 10^4). 218 nm (ϵ = 2.26 x 10^4). ^1H n.m.r. δ ($CDCl_3$) 2.4 (3H, s,), 2.78 (3H, S), 6.98 (1H, M), 7.8 (1H, d, J = 8.5 Hz), 8.43 (1H, dd, J = 8.5 and 2 Hz) 8.65 (1H, d, J = 2 Hz). A further orange yellow fraction eluted by benzene, gave a red solid on evaporation of the solvent. This was recrystallised from chloroform/ petrol mixture to give red needles (0.250 g, 13.5%) of 5-methylthiophen-2-carboxylaldehyde-2'4'-dinitrophenyl hydrazone (22) m.p. 233^{o}C. Found C,46.70; H,3.32; N,18.31%; $C_{12}H_{10}N_4O_4S$ requires C,47.67; H,3.27; N,18.30%. High resolution mass spectrum on M^+ = m/e 306, gave 306.042357; $C_{12}H_{10}N_4O_4S$

requires 306.042272. I.R. γ max 3295 (-NH) 1618, 1598, 1500, 1335, 1145, 830, 805 cm^{-1}. U.V. λ max 395 nm ($\epsilon = 2.72 \times 10^4$) 309 nm ($6.35 \times 10^3$), 223 nm ($1.54 \times 10^4$) mixed m.p. with authentic compound 233°.

A red glassy solid (0.675g) was obtained from the remaining fractions eluted by chloroform and chloroform methanol mixture. T.L.C. (silica, chloroform) showed it to contain various components. Mass spectrum gave no indication of high mol.wt. polymeric material and investigation was not pursued on this residual fraction.

2) Preparation of 2,3,5-trimethylthiophen[110].

3,5-Dimethylthiophen-2-aldehyde (17.5g, 0.125 M), hydrazine hydrate (25 ml) and ethylene glycol (100 ml) were placed in a 500 ml round bottom flask and heated at 130°-160°C for 45 minutes, when excess of hydrazine hydrate and water distilled over. The reaction was cooled below 60°C and potassium hydroxide pellets (25g, 0.45 M) were added. Mixture was heated under reflux and the hydrazone decomposed at 125°C with a vigorous evolution of nitrogen. After the evolution of nitrogen has subsided, the reaction was heated under reflux for further 15 minutes before being extracted in ether. The combined ether extracts were washed twice with water and hydrochloric acid (6N) and dried over $CaCl_2$. The solvent was removed at low pressure, and the residual oil distilled to give 2,3,5-trimethylthiophen (11g, 70%). b.p. 68°/20 mm (lit.[110] 162°/760 mm).

3) Reaction with 2,3,5-trimethylthiophen.

A solution of 2,3,5-trimethylthiophen (0.630g, 0.005 M) in glacial

acetic acid (40 ml) was added to the diazonium solution (0.0083 M) and the reaction was stirred at room temperature. A red precipitate was obtained immediately. After 15 minutes of stirring, the reaction mixture was poured on crushed ice/water and the red ppt. was filtered off. After washing several times with water (till the filtrate was non acidic) it was dried in vacuo (P_2O_5) and recrystallised from glacial acetic acid as red needles (1.49 g 93% yield). This is 4,5-dimethylthiophen-2-carboxylaldehyde-(2', 4'-dinitrophenyl)hydrazone (23) m.p. 252° M^+ = m/e 320. High resolution mass spectrum, Found 320.05886 requires 320.05792. Found C, 48.67; H, 3.99; N, 17.36%; $C_{13}H_{12}N_4O_4S$ requires C, 48.75; H, 3.75; N, 17.50%. I.R. γ max 3300 (NH) ; 1615, 1600 (>C=N-) ; 1500, 1335, (-NO_2) 1140, 845, 750 cm^{-1}. λ max 396 nm (ϵ 3.2×10^4). ^{1}H n.m.r. in C_5D_5N at 90°C, δ 1.88 (3H, s), 2.14 (3H, s), 6.96 (1H, s), 7.84 (1H, d, J = 9.5 Hz), 8.14 (1H, dd,) 8.36 (1H, s), 8.87 (1H, d, J = 2 Hz).

Mixed melting point of the above compound (23) with the 2,4-dinitrophenyl hydrazone derivatives obtained from 2,5-dimethylthiophen-3-aldehyde and from 3,5-dimethylthiophen-2-aldehyde showed depression of 20° and 30° respectively.

4) Preparation of tetramethylthiophen [111].

A) 2,5-Dimethyl 3,4-bischloromethylthiophen.

S-Trioxane (72g) was dissolved in concentrated hydrochloric acid (75 ml, 1.18g/cc) which had previously been saturated with hydrochloric acid gas (9.5g, over a period of three hours), at room temperature. 2,5-Dimethyl

thiophen (30g) was then added dropwise to the above solution. The pale green coloured reaction was stirred throughout the addition (30 min) and a further period of 45 minutes, while being kept cold in ice water bath. The reaction was then diluted with three volumes of water and extracted with ether and pet. ether. The combined extracts were washed successively with dilute hydrochloric acid, water, sodium bisulphite (5%), water, and dilute sodium hydroxide. The solid obtained by evaporation of the solvent from the dried (Na_2SO_4) extract, was recrystallised from hexane to give colourless needles (35.5g, 75%) of 2,5-dimethyl 3,4-bischloromethylthiophen. m.p. 67°C lit.[111] 67°.

B) Reduction of 2,5-Dimethyl 3,4-bischloromethylthiophen.

Tetrahydrofuran, was dried by keeping over sodium wire (one pellet/350 ml of solvent) overnight, and the distilled solvent was heated under reflux over lithium aluminium hydride (30 min) and then redistilled. (Both the distillations were stopped when only 10% of the solvent remained in the distillation flask). A suspension of lithium aluminium hydride (6.5g) in dry tetrahydrofuran (30 ml) was heated under reflux, and a solution of 3,4-bis-(chloromethyl)-2,5-dimethylthiophen (13g) in dry tetrahydrofuran (25 ml) was added dropwise so as to maintain the reflux. After the addition was complete the reaction was heated under reflux for further 1 hour, before being cooled to 10°C. A mixture of tetrahydrofuran and water (60 : 40) was then added slowly, keeping the temperature below 20°C, and the reaction mixture was then transferred to a big beaker containing conc. sulphuric acid,

ice, and water. The organic layer was then washed with water, dried, and distilled to give tetramethylthiophen as a colourless liquid, b.p. 77-79°/ 15 mm (5g, 58%). Lit.[111] 74-79°/15 mm.

5) Coupling reaction of tetramethylthiophen.

A solution of tetramethylthiophen (0.560g, 0.004 M) in glacial acetic acid (16 ml) was added to the diazonium solution, and the reaction was stirred at room temperature. A red precipitate was formed immediately after the addition, and the reaction was stopped after ten minutes, the mixture poured on to crushed ice and the precipitate was filtered off. This was washed several times with water, (till the filtrate was non acidic) and then dried (P_2O_5). Recrystallisation from aqueous dimethyl formamide gave red needles (1.25g, 93%) of 3,4,5-trimethylthiophen-2-aldehyde-(2,4-dinitrophenyl)-hydrazone (25). m.p. 247-8°. Mass spectrum M^+ = m/e 334. Found, C,49.94, H,4.37, N,16.53%; $C_{14}H_{14}N_4O_4S$ requires C,50.30; H,4.19; N,16.77%. ν max 3290 cm^{-1} (NH). λ max 406 nm ($\epsilon = 3.5 \times 10^4$). δ (C_5D_5N, 90°C) 1.76 (3H,s), 1.99 (3H,s), 2.14 (3H,s), 7.85 (1H, d, J = 10 Hz), 8.14 (1H, dd, J = 10 and 2 Hz), 8.60 (1H,s), 8.88 (1H, d, J = 2 Hz).

Mixed melting point with the dinitrophenyl hydrazone of 2,4,5-trimethyl thiophen-3-aldehyde (26), was 213°C.

6) Preparation of 2,3-Dimethylbenzo(b)thiophen[71]

3-phenylthio-2-butanone.

Thiophenol (7.3g) was dissolved in a solution of NaOH (2.66g) in water (20 ml). 3-Bromobutan-2-one (10g, 0.066 M) was then added dropwise

with stirring to the above solution over a period of 20 minutes with the temperature maintained at 25°. After stirring for 45 minutes at room temperature, the reaction was extracted in ether (3 x 40 ml) and the combined extracts were washed with water, and dried (Na_2SO_4). After removal of solvent, the residue was fractionally distilled (b.p. 136°/15 mm) to give (11g) 3-phenylthio-2-butanone.

Cyclisation of 3-phenylthio-2-butanone.

A mixture of 3-phenylthio-2-butanone (10g) polyphosphoric acid, (83.0g) and phosphorous pentoxide (4.2g) was heated at 120° for four hours. After the reaction has cooled to 90°, it was poured into ice water mixture (200g). After standing for few hours, the organic layer was separated and the rest extracted with ether (3 x 50 ml) and the combined organic phase washed with water and dried (Na_2SO_4). After removal of the solvent the residue was distilled to give (5.5g, 61%) 2,3,-dimethylbenzo(b)thiophen. b.p. 83.5-84.5°/0.4 mm. lit.[71] 96-98°/1.5 mm .

7) Coupling reaction of 2,3-dimethylbenzo(b)thiophen.

A solution of 2,3-dimethylbenzo(b)thiophen (0.65g, 0.004 M) in glacial acetic acid (25 ml) was added to a freshly prepared 2,4-dinitrobenzene diazonium sulphate solution (0.004 M). The reaction was stirred at room temperature for 24 hours. The reaction was then diluted with cold water and extracted in chloroform. Evaporation of the solvent from the washed and dried extract, gave a red coloured oil which was found to be unreacted 2,3-dimethylbenzo(b)thiophen.. No products corresponding to the side chain attack were isolated.

8) Preparation of alkyl substituted thiophen aldehydes.

4-Methylthiophen-2-aldehyde[110].

A solution of n-butyl lithium was prepared by gradual addition of 1 bromobutane (8.16g, 0.06 M) in dry ether (15 ml) to a suspension of lithium (small strips 0.840g, 0.12 M) in dry ether (20 ml). The reaction was stirred for 1 hour while maintaining temperature at -10^{o}C. When reaction had attained room temperature, the butyl lithium solution was filtered and 3-methylthiophen (2.9g, 0.03 M) was added. After stirring at room temperature for further 2 hours, the solution was added slowly to an ice cold solution of dimethyl formamide (4 ml) in dry ether (10 ml). The yellow suspension was stirred overnight and then poured onto ice. The organic layer was washed with water, dilute hydrochloric acid, aqueous sodium hydrogen carbonate, and again with water. The solvent was removed from the dried ($MgSO_4$) extract to give 4-methylthiophen-2-aldehyde.

3,5-Dimethylthiophen-2-aldehyde.

This was prepared from 2,4-dimethylthiophen by the procedure given above. The following quantitites were used. Lithium (5.8g, 0.84 M) in dry ether (150 ml), 1-bromobutane (45.7g, 0.33 M) and 2,4-dimethyl thiophen (28g, 0.25 M). After reacting the lithio derivative with dimethyl formamide (30 ml) and the work up the pale yellow coloured aldehyde was obtained. b.p. $125\text{-}6^{o}$/20 mm lit.[110] 101^{o}/8 mm . Total yield 21.7g, 62%.

2,5-Dimethylthiophen-3-aldehyde[112].

2,5-Dimethylthiophen (28g, 0.25 M), N-methyl formanilide (40.55g, 0.3 M) and phosphorous oxichloride (46g, 0.3 M) were placed in a round

bottom flask fitted with a reflux condenser, and the solution warmed on a steam bath until a vigorous evolution of hydrogen chloride gas commenced. Heating was removed until the reaction had subsided, and then it was heated for further 20 min on a steam bath. The solution was cooled and neutralised carefully with aq. sodium acetate. The mixture was steam distilled till no further oil came over. The distillate was extracted with ether; the ether extract washed with hydrochloric acid (6N), aq. sodium bicarbonate, and water. Ether was removed from the dried (Na_2SO_4 anhyd.) extract and the residue fractionated to give the aldehyde b.p. 70-3°/1 mm and unreacted 2,5-dimethylthiophen.

2,3,5-trimethylthiophen-4-aldehyde.

The experimental procedure was essentially the same as above. The following quantities of reagents were used. 2,3,5,-Trimethylthiophen (12.6g, 0.1 M), Phosphorus oxychloride (15.5g 0.2 M) and N-methyl formanilide (13.5g 0.1 M). The product obtained after steam distillation was fractionated to give 5g. of 2,3,5-trimethylthiophen-4-aldehyde b.p. 82°/1 mm lit.[112] b.p. 87°/3 mm .

9) 2,4-Dintrophenyl hydrazones of methyl and polymethyl thiophen carboxylaldehydes.

2,4-Dinitrophenylhydrazine reagent.

2,4-Dinitrophenylhydrazine (2g) was dissolved in methanol (30 ml) and water (10 ml). Concentrated sulphuric acid (4 ml) was added cautiously and the solution was filtered to give the reagent.

General method for preparing 2-4-Dinitrophenyl hydrazones.

The substituted thiophen carboxaldehydes were added dropwise to an excess of 2,4-dinitrophenylhydrazine. 2,4-Dinitrophenyl hydrazone which precipitated immediately, (orange to deep red colour) was filtered, washed with water, aq. methanol, and dried (P_2O_5). All the derivatives were high melting (above 220°) and extremely insoluble in common solvents for the purpose of obtaining ^1H n.m.r. spectra. Deuterio pyridine at 88-90° was used as a solvent for the spectra recorded below.

2,4-Dinitrophenylhydrazone of 5-methylthiophen-2-aldehyde (22).

Recrystallised from chloroform to give deep red coloured needles m.p. 233-4°, Found C,46.40, H,3.24, N,18.62%; $C_{12}H_{10}N_4O_4S$ requires C,47.67; H,3.27, N,18.30%. Mass spectrum M^+ = m/e 306. I.R. γ max, 3290 cm^{-1} (>NH). U.V. λ max 394 ($\epsilon = 2.77 \times 10^4$) 309 ($\epsilon = 6.44 \times 10^3$) 223 nm ($\epsilon = 1.48 \times 10^4$).

2,4-Dinitrophenylhydrazone of 4-methylthiophen-2-aldehyde.

Recrystallised from dimethyl formamide as red needles. m.p. 235-6°. Found, C,46.93; H,3.34; N,18.13%; $C_{12}H_{10}N_4O_4S$ requires, C,47.67; H,3.27; N,18.30%. Mass spectrum M^+ = m/e 306 I.R. γ max 3290 cm^{-1} (>NH). ^1H n.m.r. δ (C_5D_5N, 90°) 2.02(3H,s), 6.98-7.04 (2H,m), 7.83 (1H, d, J = 10 Hz), 8.11 (1H, dd, J = 10 and 2 Hz), 8.43 (1H,s), 8.86 (1H, d, J = 2 Hz) λ max 393 nm ($\epsilon = 2.47 \times 10^4$).

2,4-Dinitrophenylhydrazone of 2,5-dimethylthiophen-3-aldehyde.

Red needles (glacial acetic acid) m.p. 248-9°. Found, C,48.31;

H, 3.64; N, 17.32%; $C_{13}H_{12}N_4O_4S$ requires C, 48.75; H, 3.75; N, 17.50%. Mass spectrum M^+ = m/e 320 I.R. γ max 3290 cm^{-1}(NH). λ max 388 nm ($\epsilon = 1.9 \times 10^4$). ^1H n.m.r. δ (C_5D_5N, 88°) 2.21 (3H, s), 2.30 (3H, s), 7-7.08 (1H, m) 7.90 (1H, d, J = 10 Hz), 8.18 (1H, dd), 8.36 (1H, s), 8.90 (1H, d, J = 2 Hz) 3.6-4.0 (1H, br).

2,4-Dinitrophenylhydrazone of 2,4,5-trimethylthiophen-3-aldehyde. (26).

Recrystallised from formdimethylamide as bright red needles, m.p. 236°. Found C, 50.15; H, 4.25; N, 16.82%; $C_{14}H_{14}N_4O_4S$ requires C, 50.30; H, 4.19; N, 16.77%. Mass spectrum M^+ = m/e 334 I.R. γ max 3290 cm^{-1} (>NH) U.V. λ max 390 nm ($\epsilon = 2.15 \times 10^4$). ^1H n.m.r. δ (C_5D_5N, 88°) 2.08 (3H, s), 2.13 (3H, s), 2.38 (3H, s), 3.6-4.0 (1H, br), 7.75 (1H, d), 8.15 (1H, dd), 8.41 (1H, s), 8.90 (1H, d, J = 2 Hz).

2,4-Dinitrophenylhydrazone of 3,5-dimethylthiophen-2-aldehyde. (24).

Red needles (glacial acetic acid) m.p. 253-4°. Found, C, 48.32; H, 3.77; N, 17.48%; $C_{13}H_{12}N_4O_4S$ requires C, 48.75; H, 3.75; N, 17.50%. Mass spectrum M^+ = m/e 320. I.R. γ max 3280 cm^{-1} (NH) λ max 402 nm (2.7×10^4).

Section 4

1) Proton exchange reactions of polymethyl thiophens.

General procedure.

^{1}H n.m.r. spectra were run on the 10% solution of the polymethyl thiophen in deuteriotrifluoroacetic acid with tetramethyl silane as the internal standard. Similar spectra were run on a 10% solution in trifluoroacetic acid before and after the experiment. No decomposition of the thiophens was observed during the period in which the proton exchange reaction was studied.

Values of the relative area under various methyl group signals are collected in the following tables 10, 11 and 12.

Table 10. 2,5-Dimethylthiophen.

Time	Relative area of the methyl peak.
10 min.	1
50 min.	0.64
2.5 hrs.	0.64
5.25 hrs.	0.61
24 hrs.	0.61

Table 11. 2,4-Dimethylthiophen.

Time	Relative area	
	Peak 1	Peak 2
10 min.	0.82	1
2.25 hrs.	0.48	1
6.25 hrs.	0.36	1

Peak 1 δ 2.62 in TFA

Peak 2 δ 2.34 in TFA

Table 12.

2, 3, 5-trimethylthiophen.

Time	Relative area		
	Peak 1	Peak 2	Peak 3
10 min.	0.94	1	1
2 hrs.	0.86	1	1
18 hrs.	0.62	0.98	1
23.5 hrs.	0.56	0.95	1
42 hrs.	0.48	0.77	1

1 δ 2.32
2 δ 2.20
3 δ 2.02

2) Acetylation Experiments.

Acetylation of thiophen[76].

Thiophen (0.5 ml) was added to a solution of trifluoroacetic anhydride (1 ml) in acetic acid (0.5 ml). The mixture was warmed in a water bath for one hour while maintaining the temperature at 40-50°. The reaction was then carefully neutralised with $NaHCO_3$ solution and then extracted in chloroform. The solvent was evaporated from the dried (Na_2SO_4 anhyd.) extract to give 2 acetylthiophen (0.6g, 51%) δ ($CDCl_3$) 2.53 (3H, s), 7.66 (2H, m), 7.1 (1H, m). Semicarbazone m.p. 191-2° (lit.[76] 192°).

Acetylation of 2, 5-dimethylthiophen.

2, 5-Dimethylthiophen (0.560g, 0.005 M) was added to a solution of trifluoroacetic anhydride (2.1g, 0.01 M) in acetic acid (0.48g, 0.008 M). The resulting red coloured reaction mixture was maintained at 50° for one hour before being neutralised by aq. $NaHCO_3$ solution. This was extracted in chloroform and the solvent evaporated from the dried (Na_2SO_4 anhyd.) extract to give 3-acetyl-2, 5-dimethylthiophen δ ($CDCl_3$) 2.38 (3H, s), 2.41 (3H, s), 2.63 (3H, s), 6.96 (1H, s). The product was quantitatively converted

into its oxime derivative by reacting with (1.4g) hydroxylamine hydrochloride and a solution of sodium acetate (1.4g) in water (12 ml). The oxime melted at 82° (lit.[113] 83°). The yield of acetyl compound was 55%.

Acetylation of 2,3,5-trimethylthiophen.

2,3,5-Trimethylthiophen (0.378g, 0.003 M) was added to a mixture of acetic acid (0.3g), trifluoroacetic anhydride (1.5g) and trifluoroacetic acid (4 ml). The reaction became red coloured and was maintained at 40°C for 1 hour. After neutralisation with aq. $NaHCO_3$, the solution was extracted in chloroform. The solvent was evaporated from the dried (Na_2SO_4 anhyd.) extract to give a pale yellow coloured liquid. This is 3 acetyl, 2,4,5 trimethylthiophen, δ ($CDCl_3$) 2.16 (3H,s), 2.25 (3H,s), 2.44 (3H,s), 2.55 (3H,s),

The acetyl compound was converted into the semicarbazone derivative m.p. 157° (lit.[114] 157°). The yield of acetyl compound calculated from semicarbazone was 45%.

Acetylation of 2,4-dimethylthiophen.

2,4-Dimethylthiophen (0.56g, 0.005 M) was added to a mixture of trifluoroacetic anhydride (2.1g, 0.01 M), acetic acid (0.5g) and trifluoroacetic acid (5 ml). The reaction was maintained at 50° for 2 hours. After neutralisation with $NaHCO_3$ solution, the resulting solution was extracted in ether. The solvent was evaporated from the dried extract to give a brown oil. This was 3,5-dimethyl-2-acetylthiophen. δ ($CDCl_3$) 2.45 (3H,s), 2.48 (6H, br S), 6.64 (1H,s).

The oxime derivative melted at 69-70° (lit.[115] 70°). The yield of

the acetyl compound was 75%.

Attempted acetylation of tetramethylthiophen.

Tetramethylthiophen (0.42g, 0.003 M) was added to a mixture of trifluoroacetic anhydride (1.5g), acetic acid (0.3g) and trifluoroacetic acid (5 ml). The reaction was maintained at 50^{o} for one hour. After neutralisation with aqueous sodium hydrogen carbonate, the solution was extracted in chloroform. After evaporation of the solvent from the dried extract, a brown oil (0.38g) was obtained. ^{1}H n.m.r. in ($CDCl_3$) showed it to be unreacted tetramethyl thiophen. I.R. spectrum did not have any absorption for a carbonyl group.

3) Nitration of tetramethylthiophen.

A solution of tetramethylthiophen (0.420g, 0.003 M) in acetic anhydride (2 ml) was cooled to $5^{o}C$ and was added to a cold (-5^{o}) nitrating mixture of 5 M nitric acid (0.6 ml) and acetic anhydride (2 ml). The reaction was stirred for 10 minutes and then poured into ice water mixture. This was extracted in chloroform and the extract was washed with aqueous sodium bicarbonate solution till alkaline. After evaporation of the solvent from the dried extract, the crude product was chromatographed on a silica column. A colourless fraction eluted by benzene gave on evaporation a white solid which was recrystallised from ethanol water mixture to give white needles m.p. 46^{o} (0.08g, 17%). Found C, 62.04; H, 6.82%; $C_8H_{10}OS$ requires C, 62.34; and H, 6.49%. Mass spectrum had M^{+} = m/e 154, and ^{1}H n.m.r. δ ($CDCl_3$) 2.05 (s, 3H), 2.45 (6H, m), 9.94 (s, 1H). This is 3,4,5-trimethyl thiophen-2-aldehyde. lit.[116] 46^{o}. No nitro compounds were isolated from

further fractions.

4) Attempted coupling reactions of hexamethylbenzene and 9,10-dimethyl-anthracene.

9,10-Dimethylanthracene was prepared by bis chloromethylation of anthracene[117] followed by reduction with lithium aluminium hydride. A solution of 9,10-dimethylanthracene in glacial acetic acid was added to the 2,4-dinitrobenzene diazonium solution and the reaction was stirred for 40 hours at room temperature. After diluting the reaction mixture with cold water, the yellow precipitate was filtered off and dried. This was found to be unreacted 9,10-dimethylanthracene. From a similar experiment with hexamethylbenzene, again the starting material was recovered unreacted. I. R. spectrum showed absence of any NH absorption, thus side chain attack was not observed in these coupling reaction.

Section 5

1) Reaction of furan with 2,4-dinitrobenzene diazonium ion:-

A solution of furan (1.36g, 0.02 M) in glacial acetic acid (25 ml) was added to the 2,4-dinitrobenzene diazonium sulphate solution (0.02 M). The reaction mixture was stirred at room temperature for 15 minutes and the yellow ppt. formed was filtered, washed with water, once with aq. methanol and ether. The dried product was recrystallised from benzene/acetone m.p. 193-4°C Found C, 42.8; H, 2.9; N, 19.8%; $C_{10}H_8N_4O_6$ requires C, 42.9; H, 2.9; N, 20.0%. Mass spectrum M^+ = m/e 280, λ max, 332 nm (ϵ = 1.54 x 10^4) I.R. 3310, 1690, 1620, 1590, 1515, 1495, 1340, 1310, 1110, 925, 915, 870, 830, 800, 740, 700 cm^{-1}. ^1H n.m.r. δ (DMSO-D_6) 5.6(1H, d, 8 Hz) 6.34(1H, d, 6 Hz) 6.88(1H, d, 8 Hz) 7.28(1H, dd, 6 Hz, 1.5 Hz) 7.4(1H, d, 9 Hz), 8.34(1H, dd, 9 Hz, 2 Hz) 8.88(1H, d, 2 Hz) 10.16(1H, s). δ (DMSO-D_6+D_2O) 5.6(1H, s), 6.3(1H, d, 6 Hz) 7.26(1H, dd, 6 Hz, 1.5 Hz), 7.38(1H, d, 9 Hz), 8.32(1H, dd, 9 Hz, 2 Hz), 8.88(1H, d, 2 Hz). The yield of N-(2,4-dinitroanilino)-5-hydroxy-2-oxo-2,5-dihydropyrrole (39), was (4.03g, 72%).

Oxidation of the product from the furan reaction.

A chromic acid solution was made by dissolving sodium dichromate (0.600g) in concentrated H_2SO_4 (3 ml) and then adding dil. H_2SO_4 (5 M, 2 ml) to it. The solution was cooled (0 to 5°C) and added dropwise with stirring to an ice cold solution of compound (39), (0.560g, 0.002 M) in acetone A.R. (25 ml). The addition took place over two to three minutes and the green solution was stirred for further 5 minutes before being poured into water

(200 ml). The yellow ppt. formed was filtered, washed with water, a small amount of ice cold methanol (ppt. soluble) and ether. The dried product was purified by reprecipitation from a benzene solution (100 ml) by adding petrol (40:60) to give (0.340g, 61%) N-(2,4-dinitrophenylamino)maleimide (44)., m.p. 233°C (d) mixed m.p. with authentic sample 232-4°C (d) . M^+ = m/e 278 P^+. Found C, 43.5; H, 2.1; N, 19.9%; $C_{10}H_6N_4O_6$ requires C, 43.2; H, 2.2; N, 20.2%. I.R. and ^1H and ^{13}C n.m.r. spectra were identical with those of the N-(2,4-dinitrophenylamino) maleimide (44) made by an unambiguous route (as given in 2 and 3 below).

2) 1-(2,4,-Dinitrophenyl)-2-(3-carboxyacryloyl) hydrazine[118] (43).

2,4-Dinitrophenylhydrazine (20g) was added at room temperature to a solution of maleic anhydride (9.8g) in glacial acetic acid (200 ml). The reaction was stirred for 6 hours and then filtered to give a yellow solid (28g). This was dried over P_2O_5 and NaOH. to give 1-(2,4- dinitrophenyl)-2-(3-carboxyacryloyl) hydrazine m.p. 190-2°(d).

3) N-(2,4-dinitrophenylamino) maleimide[118,81].

1-(2,4-Dinitrophenyl)-2-(3-carboxyacryloyl) hydrazine (43), (1.5g) was heated under reflux in glacial acetic acid (50 ml) for 5 hours. A yellow product was obtained when the reaction was poured in water. The filtered solid was purified by dissolving in hot benzene and reprecipitating by petrol (40:60) to give N-(2,4- dinitrophenylamino) maleimide (44) m.p. 231-2°(d) lit. m.p. 232°C (d) , M^+ = m/e 278, δ (DMSO-D_6) 7.24(2H, s), 7.4(1H, d, 9 Hz), 8.4(1H, dd, J = 9 and 2 Hz), 8.92(1H, d, J = 2 Hz). I.R. 3380, 1740, 1620, 1595, 1520, 1500, 1340, 1320, 1060, 1050, 825, 740, 715 cm^{-1}. Found, C, 43.4;

H, 2.15; N, 20.0%; $C_{10}H_6N_4O_6$ requires C, 43.2; H, 2.2; N, 20.2%.

4) ^{13}C n.m.r. spectra of N-(2,4-dinitroanilino)5-hydroxy -2-oxo-2,5-dihydropyrrole (39), N-(2,4-dinitrophenyl amino) maleimide (44), and 2,4-dinitrophenylhydrazine (42) were obtained on their 1 M solution in DMSO + DMSO-D_6 (20%). The values are collected in the following table.

Table 13.

	(39)		(44)		(42)	
No.	P.H.	P.P.M.	P.H.	P.P.M.	P.H.	P.P.M.
1	14	168.50	45	168.01	22	149.25
2	19	149.31	24	147.45	14	134.37
3	24	148.96	14	138.21	61	129.39
4	11	137.19	76	134.16	12	127.57
5	30	129.86	12	130.89	57	123.29
6	24	125.63	31	130.27	54	115.48
7	22	122.80	25	122.91		
8	24	116.34	26	115.50		
9	21	84.58				

P.H. = Peak height P.P.M. parts per million downfield from Tetramethyl silane.

5) Reaction of 2-Methylfuran with 2,4-Dinitrobenzene diazonium ion in glacial acetic, aq. sulphuric acid:-

A solution of 2-methylfuran (0.82g, 0.01 M) in glacial acetic acid (30 ml) was added to the diazonium solution (0.01 M), and the reaction stirred at room temperature. A yellow ppt. was formed immediately and the reaction was stopped after 5 minutes, the solution was poured into cold water (200 ml) and

the ppt. was filtered off. It was washed with water (3 times) and dried (P_2O_5) in vacuum to give a yellow powder. After recrystallisation in aq. DMF and drying (P_2O_5), a yellow powder was obtained. This is N-(2,4-dinitroanilino)-5-methyl-5-hydroxy-2-oxo-2,5-dihydropyrrole (50). m.p. 205°C (d). (1.9g, 64%). M^+ = m/e 294. Found C, 44.7; H, 3.5; N, 18.9%; $C_{11}H_{10}N_4O_6$ requires C, 44.9; H, 3.4; N, 19.0%. I.R. γ max 3200-3380 (br, NH) 1710 (>C = 0), 1620, 1595, 1500(m), 1350 ($-NO_2$), 1315, 1270, 1230, 1155, 1140, 1120, 820, 740 cm^{-1}. U.V. λ max 328 nm (ϵ 1.431×10^4) 260 nm (7.62×10^3) N.M.R. (DMSO-D_6) δ 1.52(3H, s), 6.7(1H, d, 6Hz), 7.3-7.5 (2H, m), 8.3(1H, dd, 9Hz, 2Hz), 8.9(1H, d, 2Hz), 9.9(1H, br) δ (DMSO-D_6 + D_2O) 1.54(3H, s), 6.8(1H, d, 6Hz), 7.3-7.5(2H, m), 8.34(1H, dd, 9Hz, 2Hz), 8.92(1H, d, 2Hz).

6) Preparation of 3-methylfuran.

3-Methylbut-3-enal diethyl acetal[119].

A mixture of ethyl orthoformate (90 ml) and magnesium (35g) was stirred and heated at 60°. 2-Methyl allyl chloride (2 ml, freshly distilled) was added followed by a little methyl chloride. As the initial yellow colour faded, cooling was required to keep the temperature of the reaction below 70°. The remaining 2-methyl allyl chloride was added at a rate which maintained a temperature of 60° without external cooling. After standing overnight, the flask was cooled and saturated ammonium chloride solution (40 ml) was added until the reaction mixture set solid. The solid was collected on a filter and washed well with ether. The filtrate was then evaporated and the residue was

stirred with water (100 ml) for 9 hours. The lower layer was then saturated with salt and extracted with ether. Distillation of united upper layers gave 3-methylbut-3-enal diethyl acetal, 45g, boiling at 58^{o}-60^{o}/18-19 mm.

3,4-Epoxy-3 methylbutanal diethyl acetal[119].

A solution of monoperphthalic acid was prepared as follows[120]. A solution of sodium carbonate (0.6 mole) in water (250 ml) was cooled to 0^{o}, and treated with H_2O_2 (0.6 mole, 30%) keeping the temperature at -5^{o} to 0^{o}. 0.5 M of recrystallised phthalic anhydride was added to this and the reaction mixture was stirred for 30 minutes. The reaction was shaken with 350 ml of ether and carefully acidified with concentrated sulphuric acid (30 ml in 150 ml water). The per acid was extracted in ether and the extracts were washed with 40% ammonium sulphate solution and then dried over $MgSO_4$.

A solution of 3-methylbut-3-enal diethyl acetal (13.2g) in ether (20 ml) was treated with the etheral solution of monoperphthalic acid (0.085 M). The reaction was allowed to warm but kept below 30^{o} by occasional cooling. After standing overnight, the phthalic acid was removed by filtration and extraction of the filtrate with aq. $NaHCO_3$ solution. The dried ($MgSO_4$) filtrate was fractionated to give 3,4-epoxy-3-methylbutanal diethyl acetal (10.9g) b.p. 82-6^{o}/18 mm.

3-Methylfuran[121].

3,4-Epoxy-3-methylbutanal diethyl acetal (10g) and sulphuric acid (0.1 N, 1000 ml) were heated under a fractionating column for 3 hours. The methylfuran and ethanol being removed intermittently by distillation. The

distillate was washed with calcium chloride (20 ml, half saturated) and twice with ammonium chloride solution. It was then dried over sodium and re-distilled to give 1.2g of 3-methylfuran. b.p. 65°.

7) Reaction of 3-Methylfuran with 2,4-Dinitrobenzene diazonium ion in glacial acetic acid, aq. sulphuric acid:-

A solution of 3-methylfuran (0.125g, 1.5 mM) in glacial acetic acid (10 ml) was added to the diazonium solution (1.5 mM) kept stirred at room temperature. Further 10 ml glacial acetic acid was added and the red coloured reaction stirred for 16 hours (test for the presence of diazonium ions negative) before being poured in ice cold water (100 ml). The red ppt. formed was filtered, washed with water and dried in vacuum (P_2O_5). The red powder was purified by boiling in benzene and reprecipitating by petrol (40:60) to give a chrome yellow powder (0.140g, 32%). This is N-(2,4-dinitroanilino)-5 hydroxy-4-methyl - 2-oxo-2,5-dihydropyrrole (51). m.p. 193-4°C, Found : C, 44.6; H, 3.2; N, 18.9%; $C_{11}H_{10}N_4O_6$ requires C, 44.9; H, 3.4; N, 19.0%. M^+ = m/e 294. I.R. γ max 3220-3300 br(NH), 1685, 1615, 1585; 1500, 1340; 1085, 975, 870, 830, 740 cm^{-1}. U.V. λ max:- 330 nm (ϵ = 1.465 x 10^4), 255 nm (ϵ 1.020 x 10^4) N.M.R. in DMSO-D_6 δ 1.87(3H, S), 5.46(1H, d, J = 8 Hz), 6.6-7.0(2H, M) 7.4(1H, d, J = 9.5 Hz), 8.3(1H, dd, J = 10 Hz, 2Hz), 8.87 (1H, d, J = 2 Hz) 10.2(1H, br). δ (DMSO-D_6 + D_2O) 1.9(3H, s), 5.52(1H, s), 6.95(1H, s), 7.4(1H, d, J = 9.5 Hz), 8.3(1H, dd, J = 9.5 Hz, 2 Hz), 8.9(1H, d, 2 Hz).

8) Preparation of Benzo(b)furan[122].

A) o-Formylphenoxyacetic acid :- A solution of sodium hydroxide (80.0g, 2 M) pellets in distilled water (200 ml) was added to a mixture of

salicylaldehyde (100 ml) chloroacetic acid (94.5g, 1 M) and water (800 ml). The mixture was stirred slowly and heated to boiling when it turned red brown, and then under reflux for further three hours. After acidifying with conc. HCl (190 ml, sp.gr. 1.19) unchanged salicylaldehyde (40g) was removed. The residual acidic mixture was cooled to 20^{o}, and the precipitated solid filtered, washed with water, and dried to give (80g) of o-formylphenoxy acetic acid.

B) Benzo(b)furan :- A mixture of dry o-formylphenoxyacetic acid (80g, 0.45 M), sodium acetate (160g, anhydrous) acetic anhydride (400 ml) and glacial acetic acid (400 ml) was heated under gentle reflux with stirring for 8 hours. The hot solution was then poured into a mixture of crushed ice and water (2.2 l) and extracted with ether (500 ml). The ether extract was washed with water (500 ml) and then several times with 5% sodium hydroxide solution until the aq. layer was basic. After washing again with water, sat. sodium chloride, and drying (Na_2SO_4) the solvent was removed and residue distilled to give benzo(b)furan b.p. 62^{o}C/20 mm. Lit.[122] 166.5^{o}-168^{o} (735 mm) (32.8g, 62%).

9) Coupling reaction of benzo(b)furan.

A solution of benzo(b)furan (1.18g, 0.01 M) in glacial acetic acid (40 ml) was added to the freshly prepared solution of 2,4-dinitrobenzene diazonium sulphate (0.01 M). The reaction was stirred at room temperature for 24 hours, and the orange red precipitate was filtered off, washed with water and dried (P_2O_5). This was chromatographed on an alumina column.

The first fraction eluted by benzene gave a yellow solid an evaporation of the solvent, and this was recrystallised from benzene/petrol to give fine yellow needles of 2-(2',4'-dinitrophenyl) benzo(b)furan. (0.75g, 26%) m.p. 138°. M^+ = m/e 284. Found C, 59.2%; H, 2.7%; N, 9.7%; $C_{14}H_8N_2O_5$ requires C, 59.2%; H, 2.8%; 9.9%. I.R. spectrum showed absence of OH or C = O groups. U.V. λ max 366 nm ($\epsilon = 1.7 \times 10^4$).

A further red fraction eluted by chloroform gave an orange yellow solid. This was recrystallised from benzene/petrol to give the diarylated derivative. 2,3-bis-(2',4'-dinitrophenyl)benzo(b)furan. m.p. 100°. M^+ = m/e 450 i.r. spectrum showed absence of -OH or C = O groups. λ max 358 nm ($\epsilon = 1.6 \times 10^4$). Found C, 53.1%; H, 2.4%; N, 12.1%; $C_{20}H_{10}N_4O_9$ requires C, 53.3%, H, 2.2%, N, 12.5%.

10) Preparation of 2-Methylbenzo(b)furan[123].

A solution of n-butyllithium was prepared by the previous method using n-butylbromide (20.5g, 0.15 M), dry ether (20 ml) and lithium strips (2.1g, 0.3 M) in dry ether (25 ml). The solution was filtered into a three necked flask (dry, flushed with nitrogen) and then a solution of benzo(b)furan (10g) in dry ether (25 ml) was added to it dropwise with stirring. The temperature of the reaction was maintained at -5 to -10° throughout the addition. After two hours, freshly distilled dimethyl sulphate (10.5 ml) dissolved in dry ether (12 ml) was added dropwise and the reaction stirred for further three hours at room temperature before being poured into water. The ether layer was separated and aq. layer extracted with ether. (Aq. layer was kept alkaline to ensure that

dimethyl sulphate was completely decomposed). The combined ether extracts were dried (Na_2SO_4) and after removal of the solvent, the residue was distilled twice to give 2-methylbenzo(b)furan, b.p. 82-4°/18-20 mm Lit.[123] b.p. 189-191° (9.19g, 81%).

11) Coupling reaction of 2-methylbenzo(b)furan with 2,4-dinitrobenzene diazonium solution.

A solution of 2-methylbenzo(b)furan (1.32g, 0.01 M) in glacial acetic acid (30 ml) was added to a freshly prepared solution of 2,4-dinitrobenzene diazonium sulphate (0.01 M). Another 30 ml of glacial acetic acid was added to make the reaction homogeneous. After stirring at room temperature for 44 hours, the reaction was diluted with cold water and extracted in chloroform. The chloroform extract was washed successively with water, sodium bicarbonate solution, and water, before being dried (Na_2SO_4 anhyd.). The red oil obtained after evaporation of the solvent was chromatographed on an alumina column. The first colourless fraction eluted by benzene gave unreacted 2-methylbenzo (b)furan (0.270g). The next yellow fraction eluted by benzene gave a viscous oil, b.p. 260-5°/1 mm. This is 2-methyl-3-(2',4'-dinitrophenyl)benzo(b) furan. Found C, 60.2%; H, 3.4%; N, 9.2%; $C_{15}H_{10}N_2O_5$ requires C, 60.4%; H, 3.4%; N, 9.4%. I.R. spectrum:- 1600, 1520, 1335, 900, 830, 740 cm^{-1} ^1H n.m.r. δ ($CDCl_3$) 2.37(3H,), 7 to 7.7 and 7.9 to 9.0 (complex multiplets) M^+ = m/e 298. Total yield of the monoarylated compound was (0.55g, 23%). The next fraction eluted by benzene gave an orange yellow solid, m.p. 189°, M^+ = m/e 326. Found C, 55.0%; H, 3.0%;

N, 17.1%; $C_{15}H_{10}N_4O_5$ requires C, 55.2%; H, 3.1%; N, 17.2%. This is 2-methyl-3(2',4'-dinitrobenzene azo)-benzo (b)furan. I.R. spectrum had an absence of NH absorption. λ max 356 nm. The yield of the azo dye was (0.2g, 8%). The further fraction eluted by chloroform gave resinous red solid, which was difficult to separate.

12) Preparation of 2,5-dimethylfuran[111] and it's coupling reactions,

2,5-dimethylfuran.

Hexane-2,5-dione (97g) was added dropwise to a mixture of acetic anhydride (100g) and zinc chloride(1g)placed in a 3 necked flask. The reaction was stirred and temperature was maintained below 40^{o} by external cooling. After the exothermic reaction has subsided, the reaction was heated to reflux and kept under reflux for 4 hours. After cooling to room temperature, the reaction was made alkaline by adding 6N NaOH and then extracted in ether, (3 x 150 ml). The combined extract was washed with dil. NaOH, water, and the residue obtained by evaporation of the solvent from the dried extract was fractionated. 2,5-Dimethylfuran (40g, 49%) was obtained as a colourless liquid boiling at $92\text{-}5^{o}$/760 mm.

Coupling reaction of 2,5-dimethylfuran with 2,4-dinitrobenzene diazonium ions in glacial acetic/aqueous sulphuric acid.

A solution of 2,5-dimethylfuran (0.29g, 3 mM) in glacial acetic acid (15 ml) was added to the diazonium solution (3 mM) and the reaction was stirred at room temperature for 24 hours. The reaction was diluted with cold water and then the tarry red solution was extracted in chloroform. A red glassy solid, obtained on evaporation of the solvent from the dried extract, was put

on a silica column. A mixture of benzene and chloroform eluted a red solid, M^+ = m/e 290, m.p. 171-4° (d) High resolution mass spectrum, indicated $C_{12}H_{10}N_4O_5$ as the molecular formula. Found 290.065 requires 290.065 The compound, which appeared to be the azo dye 2, 5-dimethyl-3-(2',4'-dinitrobenzene azo)-furan, no NH in i.r. spectrum, was extremely difficult to purify A large amount of intractable resinous product was also obtained.

Reaction of 2, 5-dimethylfuran with 2, 4-dinitrobenzene diazonium fluoroborate in dioxan.

2, 4-Dinitrobenzene diazonium fluoroborate was added to a solution of 2, 5-dimethylfuran (0.29g, 3 mM) in dioxan (20 ml). The reaction was stirred at room temperature for 2 hours, when its colour changed from yellow to deep red. At the end of the reaction period it was poured in cold water, and the red ppt. was filtered off, washed several times with water and then dried (P_2O_5) to give 0.600g of a red powder. This was put on a short silica column. The orange red fraction eluted by a mixture of benzene and chloroform (3 : 1) gave a red solid. After recrystallisation from ethanol, deep red needles were obtained (0.1g, 11%). This had M^+ = m/e 290, and I.R. γ max at 3280 (NH); 1610;1510, 1330, 1130, 1020, 830, 795 cm^{-1}. Found C, 49.2%; H, 3.9%; N, 19.2%; $C_{12}H_{10}N_4O_5$ requires C, 49.7%; H, 3.5% N, 19.3%. m.p. 208°. This was assigned the structure of the 2, 4-dinitrophenyl hydrazone of 5-methylfuran-2-aldehyde. An authentic sample prepared from the 5-methylfuran-2-aldehyde had m.p. 210-1° Lit 87 212° γ max at 3280 (NH); 1600, 1510, 1330 (NO_2); 1130, 1020, 830, 795 cm^{-1}. Found, C, 49.8%; H, 3.4%; N, 19.1%; $C_{12}H_{10}N_4O_5$ requires C, 49.7%; H, 3.5%; N, 19.3%. Mixed m.p. with the above compound was 208°.

Further fractions eluted by chloroform gave a resinous solid which was extremely difficult to purify.

Section 6

1) General method of diazotisation.

The aromatic amine (0.005 M) was dissolved or suspended in trifluoroacetic acid (5 to 10 ml) and the mixture was stirred at room temperature. Sodium nitrite (0.005 M) was added gradually while the reaction was stirred and maintained at room temperature. The pale yellow to reddish yellow coloured diazonium solution was obtained after 5 to 10 minutes. These solutions coupled with the appropriate coupling component giving the azo dyes in high yields.

2) Diazotisation of p-nitroaniline and its coupling reaction with 1,3,5 trimethoxybenzene in trifluoroacetic acid.

para-Nitroaniline (0.690g, 0.005 M) was added to 8 ml of trifluoroacetic acid. Sodium nitrite (0.350g, 0.005 M) was then added in small portions over 5 minutes. The reaction was stirred for 5 minutes at room temperature. 1,3,5-trimethoxybenzene (0.420g, 0.0025 M) was dissolved in 2 ml of trifluoroacetic acid and the solution was added dropwise to half of the above diazonium solution. The deep red coloured reaction was stirred for 30 minutes at room temperature and then poured into 50 ml of water. The orange red precipitate formed was washed several times with water (total volume 200 ml) and dried over NaOH pellets in vacuo The red powder was recrystallised from ethanol as dark red needles (0.78g). This is p-(2,4,6-trimethoxybenzene azo)-nitrobenzene m.p. 149^{o}-150^{o} lit.[124] 150.5^{o}. M^{+} = m/e 317.

3) Coupling reaction of anisole with diazotised 2,4-dinitroaniline in trifluoroacetic acid.

2,4-dinitroaniline (0.915g, 0.005 M) was suspended in 12 ml of trifluoroacetic acid and sodium nitrite (0.350g, 0.005 M) was added in small portions. The reaction was stirred for 10 minutes at room temperature when a reddish yellow coloured diazonium solution was obtained. Anisole (0.510g, 5 mM) was dissolved in trifluoroacetic acid (5 ml) and the solution was added dropwise to the diazonium solution. The intense red coloured reaction was stirred for 17 hours at room temperature before being poured into 100 ml of cold water. The red precipitate formed was filtered and washed with water several times (till the filtrate was neutral). The red solid was then dried over P_2O_5 and then over sodium hydroxide. After recrystallisation from acetone/petrol red needles of p(2,4-dinitrobenzene azo)-methoxybenzene were obtained. Total yield (1.35g, 94%). m.p. 177^{o}, (lit.[12] $177-8^{o}$). M^{+} = m/e 302.

4) ^{1}H n.m.r. spectra of benzene diazonium ions in trifluoroacetic acid.

Several substituted anilines including the weakly basic mono and dinitroanilines were diazotised by above method. 0·5ml of the diazonium solution was used for obtaining the n.m.r. (after adding TMS as an internal reference (see table 14). In many cases spectrum of the amine dissolved in trifluoroacetic acid was also obtained (Table 15).

Table 14.

Substituent in the benzene diazonium ion	^{1}H spectrum in the aromatic region (multiplicity and coupling const., assignment)
1) None	Complex multiplets 7.8 to 8.7.
2) 3-nitro	9.56(t,2), 9.05(d, J=8 Hz, 4), 8.31(t, J=8 Hz, 5) 9.15(d, J=8 Hz, 6)
3) 4-(α,α,α -trifluoro)-methyl-	8.73(d, J=9 Hz, 2 and 6); 8.19(d, J=9 Hz, 3 and 5)
4) 4-nitro	9.0(d, J=10Hz, 2and 6), 8.82(d, J=10Hz, 3 and 5)
Substituents in the benzene diazonium ion	^{1}H n.m.r. for the aromatic protons (multiplicity and coupling const., assignment)
5) 2-methyl-4-nitro-	8.88(d, 9Hz, 6), 8.7 to 8.5(m, 3 and 5)
6) 2-methyl-5-nitro	8.12(d, 9 Hz, 3), 8.98(dd, 9 and 2 Hz, 4), 9.47(d, 2 Hz, 6).
7) 2,4-dinitro	9.52(d, 2 Hz, 3), 9.15(dd, 9 and 2 Hz, 5), 9.42(d, J=9 Hz, 6).
8) 3,5-dinitro	9.92(d, 2 Hz, 2 and 6), 9.81(t, 2 Hz, 4).
9) 2,6-dinitro	8.7 to 9.5 (complex multiplet for 3,4,5 protons).

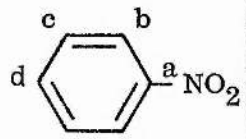
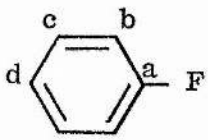
Table 15.

Substituent in the anilinium ion	^{1}H n.m.r. for the aromatic protons (multiplicity and coupling const., assignment)
4-(α,α,α -trifluoro)-methyl-	7.98(d, 9 Hz, 2 and 6), 7.64(d, 9 Hz, 3 and 5).
2-methyl-4-nitro	8.25 to 8.43 (m ,3and 5), 7.82(d, 8 Hz, 6).
2-methyl-5-nitro	7.74(d, 8.5 Hz, 3), 8.42(dd, 8.5 and 2 Hz, 4), 8.56 (d, 2 Hz, 6).
2,4-dinitro-	9.26(d, 2 Hz, 3), 8.32(dd, 9 and 2 Hz, 5), 7.08 (d, 9 Hz, 6).

5) ^{13}C n.m.r. spectra.

^{13}C n.m.r. spectra of p-fluoro and p-nitro-benzene diazonium ions in trifluoroacetic acid are reported in the discussion. All the spectra were run on ~ 1 M solution and a capillary tube filled with D_2O was used as the lock signal. Signals due to the trifluoroacetic acid itself were two quartets, viz. 1) 116.87 ppm. (J_{CF} = 284.8 Hz) and 2) 163.27 ppm. (J_{CCF} = 21.8 Hz) and these are omitted. Spectrum of fluorobenzene and nitrobenzene is reported in the following table.

Table 16.

ppm.	assignment	ppm.	assignment	Coupling const.
149.54	a	165.00	a	243 Hz J_{CF}
137.34	d	131.48	c	8 Hz J_{CCCF}
131.13	c	125.61	d	3 Hz J_{CCCCF}
125.25	b	116.62	b	21 Hz J_{CCF}
				

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