INTRODUCTION

CHEMISTRY OF ORGANIC AZIDES

The chemistry of azides has been the subject of intensive investigation in the last years because of their importance in preparative heterocyclic chemistry. Indeed, many nitrogen containing heterocycles such as carbazoles(1-4), furoxans(5-7), oxazoles(8,9), Δ^2-triazolines(10-12), triazoles(13-15), tetrazoles(16), aziridines(17,18), oxadiazines(19), benzimidazolones(20,21) and others have been obtained in good yield by decomposition or addition reactions of these substances. This review includes alkyl and aryl azides, carboxazides, sulphonyl azides, alkylidene and arylidene hippuric azides.

PREPARATION OF AZIDES

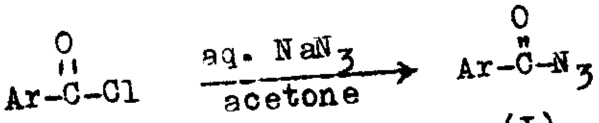
A. (ACID AZIDES)

Two general methods have been employed for the preparation of acid azides.

I From Reaction of Acid Chlorides with Sodium Azides:

1) Aroyl azides.

Aroyl chlorides in dry acetone with aqueous sodium azide give the corresponding aroyl azides(22)



$$\mathrm{Ar{-}\overset{O}{\overset{\|}{C}}{-}Cl} \xrightarrow[\text{acetone}]{\text{aq. NaN}_3} \mathrm{Ar{-}\overset{O}{\overset{\|}{C}}{-}N_3}$$

(I)

2) Saturated monocarboxylic acid azides

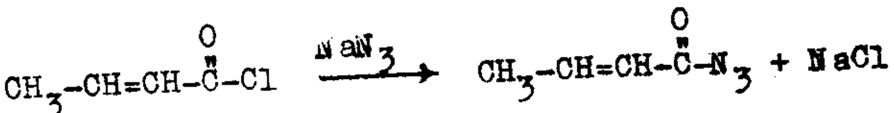
These are obtained from the reaction of the acid chlorides with sodium azides. This method is preferred in the case of low molecular weight acids, whose hydrazides and azides are difficult to extract from water.

By this method acetyl chloride is converted to methyl isocyanate (III) through the azide(23,24) (II)

$$\underset{}{CH_3COCl} \xrightarrow{NaN_3} \underset{(II)}{CH_3CON_3} \xrightarrow{\sim} \underset{(III)}{CH_3N{=}C{=}O} + N_2$$

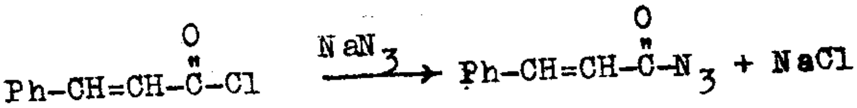
3) α,β-Unsaturated acid azides:

The formation of olefinic acid azides by sodium azide procedure appears to be limited only by the availability of the acid chloride. Examples, of α,β-olefinic acid azides prepared by this method are crotonyl(25) (IV), and cinnamoyl azides(25,26) (V).



$$CH_3{-}CH{=}CH{-}\overset{O}{\overset{\|}{C}}{-}Cl \xrightarrow{NaN_3} CH_3{-}CH{=}CH{-}\overset{O}{\overset{\|}{C}}{-}N_3 + NaCl$$

(IV)



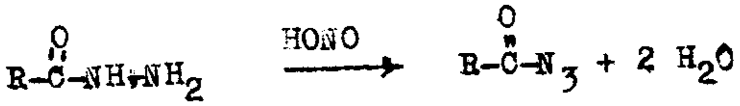
$$Ph{-}CH{=}CH{-}\overset{O}{\overset{\|}{C}}{-}Cl \xrightarrow{NaN_3} Ph{-}CH{=}CH{-}\overset{O}{\overset{\|}{C}}{-}N_3 + NaCl$$

(V)

II. From Diazotization of Acid Hydrazides :

1. Saturated aliphatic monocarboxylic acid azides.

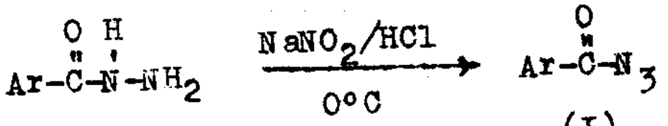
Acyl azides are commonly prepared by treating acid hydrazides in cold aqueous solution, with nitrous acid, the required hydrazides can be prepared from esters by the reaction with hydrazine(27).



$$R-\overset{O}{\overset{\|}{C}}-NH-NH_2 \xrightarrow{HONO} R-\overset{O}{\overset{\|}{C}}-N_3 + 2\,H_2O$$

2- Aroyl azides.

Aroyl azides (I) are prepared by treating aroyl hydrazides in ice-cold hydrochloric acid with ice-cold sodium nitrite(28).



$$Ar-\overset{O}{\overset{\|}{C}}-\overset{H}{\overset{|}{N}}-NH_2 \xrightarrow[0°C]{NaNO_2/HCl} Ar-\overset{O}{\overset{\|}{C}}-N_3$$

(I)

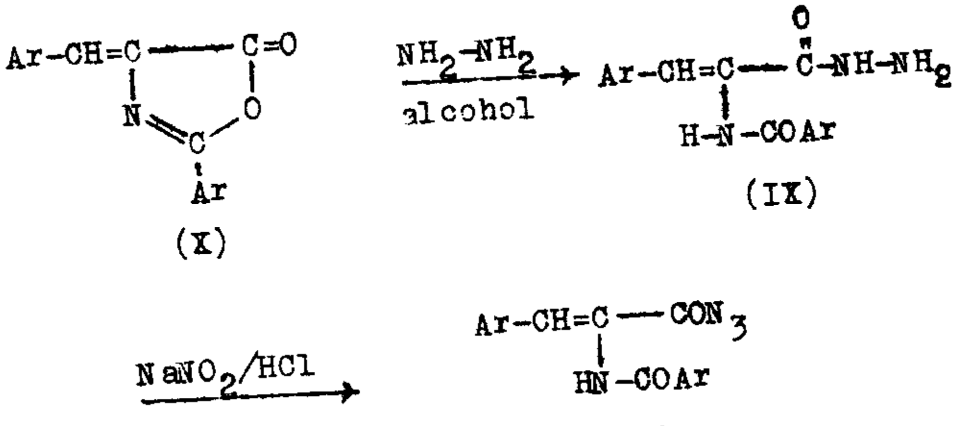
3- α,β-Unsaturated acid azides.

Formation of olefinic acid azides via the hydrazide is sometimes complicated due to side reactions. The hydrazides of α,β-olefinic acids are difficult to convert to azides owing to the possible cyclisation upon the treatment with nitrous acid. Cinnamoyl hydrazides (VI) react with nitrous acid to yield 1-nitroso-5-phenyl-2-pyrazolidone(26) (VII).

(VI) (VII)

4- Arylidene and alkylidene hippuric azides.

Arylidene hippuric azides (VIII) are obtained from the corresponding hydrazides (IX) in ice-cold hydrochloric acid solution, by treating with ice cold sodium nitrite(29). Arylidene hydrazides are obtained from the corresponding 4-arylidene azlactones (X) by treating with hydrazine hydrate in alcohol:



(X) (IX) (VIII)

B. (CARBAMOYL AZIDES)

Three general methods have been employed for the preparation of carbamoly azides :

1- Via the reaction of isocyanates with hydrazoic acid.

Carbamoyl azide (XI) was obtained from isocyanic acid and HN_3(30)

$$HNCO + HN_3 \longrightarrow \underset{(XI)}{H_2NCON_3}$$

A number of N-monosubstituted carbamoyl azides (XII) have been prepared by the interaction of isocyanate with HN_3 at low temperature in non aqueous solvent such as ether[31-33].

$$\underset{(R=H,\ alkyl\ or\ aryl)}{RNCO + HN_3} \longrightarrow \underset{(XII)}{RNHCON_3}$$

The reaction of ketenes with HN_3 has been employed for preparation of methyl carbamoyl azide (XIII) and diphenylmethyl carbamoyl azide(34) (XIV).

$$CH_2{=}C{=}O + 2HN_3 \longrightarrow \underset{(XIII)}{CH_3{-}NH.CO.N_3} + N_2$$

$$(C_6H_5)_2C{=}C{=}O + 2HN_3 \longrightarrow \underset{(XIV)}{(C_6H_5)_2{-}CHNHCON_3} + N_2$$

2- Via diazotization of semicarbazides:

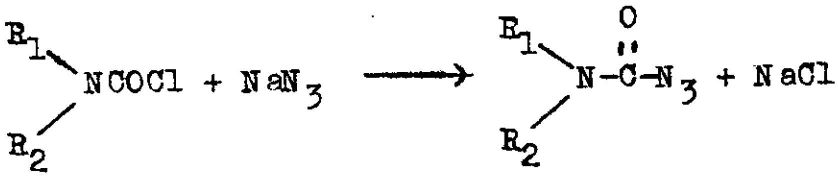
Carbamoyl azides (XV) have been prepared from the reaction of nitrous acid with semicarbazides(35) (XVI).

$$\underset{\text{(XVI)}}{RNHCONHNH_2} + HNO_2 \longrightarrow \underset{\text{(XV)}}{RNHCON_3} + 2H_2O$$

(R=H, alkyl or aryl)

3- Via the reaction of carbamoyl chlorides with NaN_3:

Several N,N-disubstituted carbamoyl azides (XVII) have been prepared by the reaction of carbamoyl chlorides (XVIII) with NaN_3(36-39).

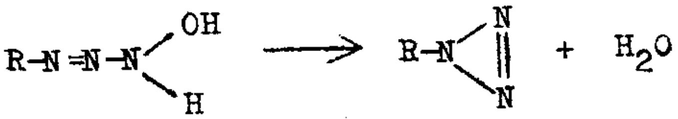


(XVIII) (XVII)

	R_1	R_2
a,	CH_3	CH_3
b,	$i\text{-}C_4H_9$	C_4H_9
c.	$i\text{-}C_5H_{11}$	C_5H_{11}
d,	CH_3	C_6H_5

C- (ARYL AZIDES)

Aryl azides have been prepared in a good yield by the action of ammonia on aryl diazonium perbromides(40), and also by the reaction of aryl diazonium salts with hydroxylamine(41,42). Both processes involves an alkaline medium, for when the solution of the diazonium salt is added to the alkaline hydroxylamine, high yields of the parent amine can be recovered, whereas, if the diazonium solution is first mixed with hydroxylamine salt and then rendered alkaline, the aryl azide becomes the chief product. The mechanism of reaction would appear to be a type of Lossen reaction in which the stages are: the initial formation of the diazo-amino compound (XIX) then loss of water, with rearrangement to the azide(43) (XX)



(XIX) (XX)

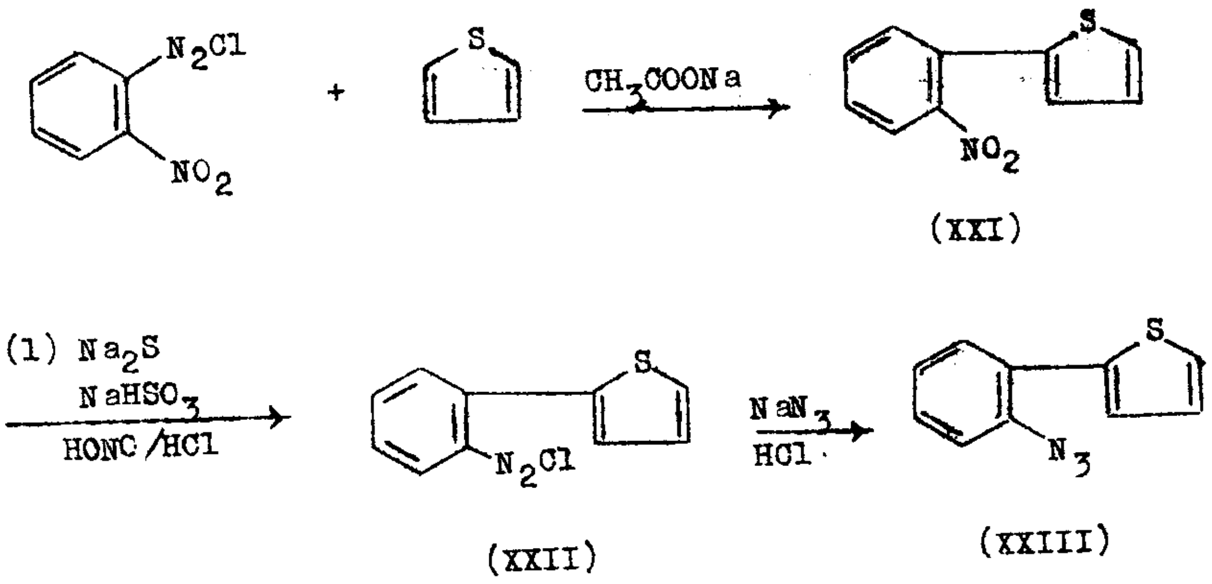
D- (HETEROCYCLIC AZIDES)

It has been reported(44) that o-(α-thienyl)-phenyl azide could be readily obtained by three step process ;

(i) The reaction between diazotized o-nitroaniline and thiophene yields α-(o-nitrophenyl)thiophene (XXI).

(ii) Reduction of nitro group to amino group followed by diazotization gives (XXII).

(iii) The diazonium salt was treated with sodium azide and hydrochloric acid to give the azide (XXIII)



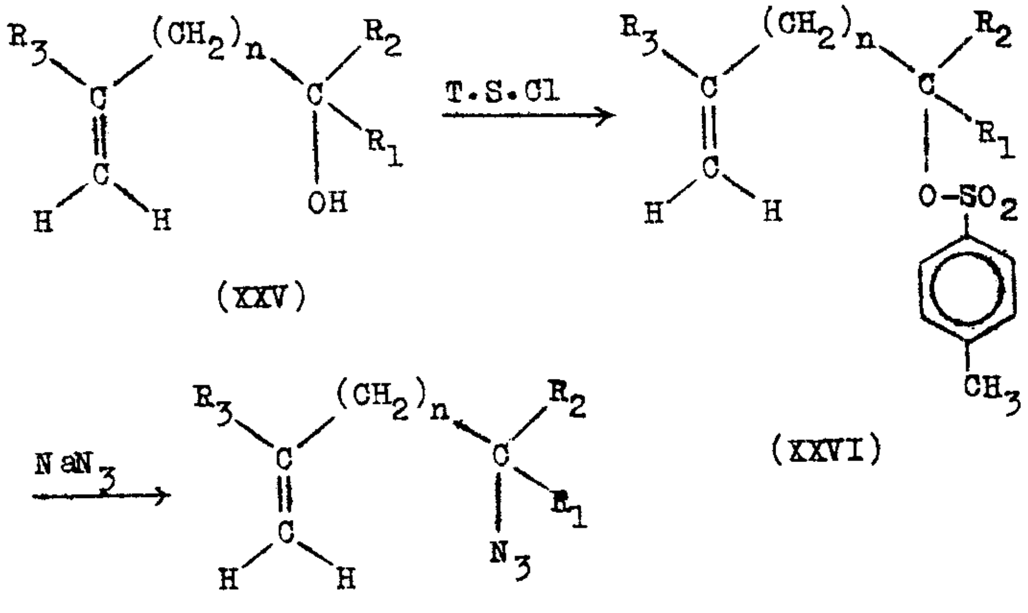
(XXI)

(XXII)

(XXIII)

E- Olefinic Azides

It has been reported(45) that olefinic azides (XXIV) can obtained from alcohols (XXV) by their convertion to the p-toluene sulphonate esters (XXVI), and treating the crude esters with sodium azide in aqueous ethanol or pyridine at room temperature.



(XXV) (XXVI) (XXIV)

F- (ARYL SULPHONYL AZIDES)

Aryl sulphonyl azides (XXVII) may be prepared by treating aryl sulphonyl chlorides (XXVIII) with sodium azide in water under reflux for 24 hours(46,47).

$$Ar{-}SO_2{-}Cl \xrightarrow{aq.\ NaN_3} Ar{-}SO_2{-}N_3$$

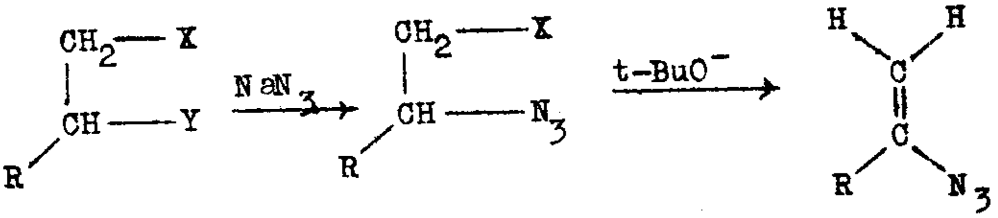
(XXVIII) (XXVII)

Ar

a, C_6H_5
b, $C_6H_4{-}CH_3(p{-})$
c, $C_6H_4{-}NO_2(o{-})$
d, $C_6H_4{-}NO_2(p{-})$

G- (VINYL AZIDES)

It has been reported(48) that, vinyl azides (XXIX) were prepared as follows :



(X=Y=Br) (XXIX)

CHEMICAL REACTIONS OF ORGANIC AZIDES

I- Decomposition Reactions

Mechanism of Thermal and Photochemical Decomposition:

(i) Thermal decomposition (thermolysis):

The strong variation of the enthalpy and entropy of activation with the para substituents in the thermal decomposition, cannot be explained in terms of an induction effect, but is in agreement with a concerted mechanism involving an electron deficient α-nitrogen atom in the transition state(49).

Indeed a para-electron repelling substituents will then stabilize the transition state and a para-electron withdrawing substituents will have then the reverse influence. Consistent with a synchronous mechanism for the thermal decomposition is also the fact that electron repelling substituents facilitate migration, and electron withdrawing substituents hinder migration.

(ii) The photochemical decomposition (photolysis)

Photolysis, involves discrete nitrene intermediate(50-52). This is concluded from the observation that the migration aptitude is practically one for all para-substituted triphenyl methyl azides as well in the direct photolysis as in the photosensitized rearrangement(49-52).

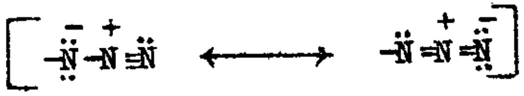
The photolysis of nine sec- and tert-alkyl azides have been studied in detail(53). The products consist of imines derived from 1,2 shifts of groups on the alkyl carbon atom α- to the azido nitrogen atom, no evidence of typical nitrene processes(53) (aromatic substitution, aliphatic C-H insertion) was found.

(A) Decomposition Via a Concerted Mechanism

Decomposition of acid azides must be regarded as proceeding by a synchronous mechanism.

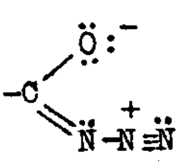
(i) Decomposition of acyl, and sulphonyl azides :

According to the octet resonance contributions of azido group (A and B), the order of the $N-N_2$ bond which breaks is 1.5. This double bond character is decreased by introducing an acyl, or sulphonyl group in conjugation with the triazo group (C and D) respectively.

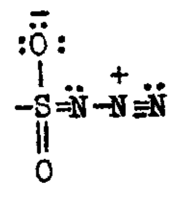


$$\left[-\ddot{\overset{-}{N}}-\overset{+}{N}\equiv N \longleftrightarrow -\ddot{N}=\overset{+}{N}=\overset{-}{N}\right]$$

(A) (B)



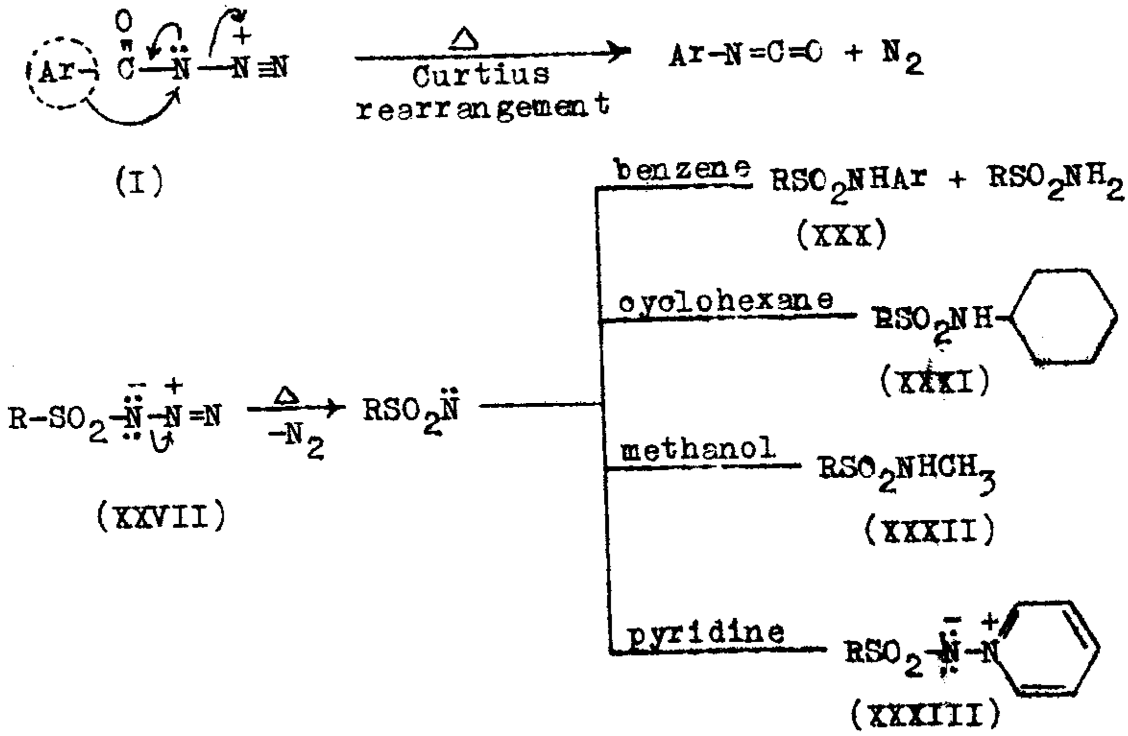
(C)



$$-S(=O)(-\overset{-}{O}:)=\ddot{N}-\overset{+}{N}\equiv N$$

(D)

Therefore, acyl azides, and sulphonyl azides are less stable than alkyl and aryl azides. There still remains a great difference in reactivity between acyl azides and sulphonyl azides which cannot be explained on the basis of the resonance forms, the only explanation, therefore, is that the former decomposes by a synchronous mechanism and latter does not.



(I)

(XXVII)

(XXX)

(XXXI)

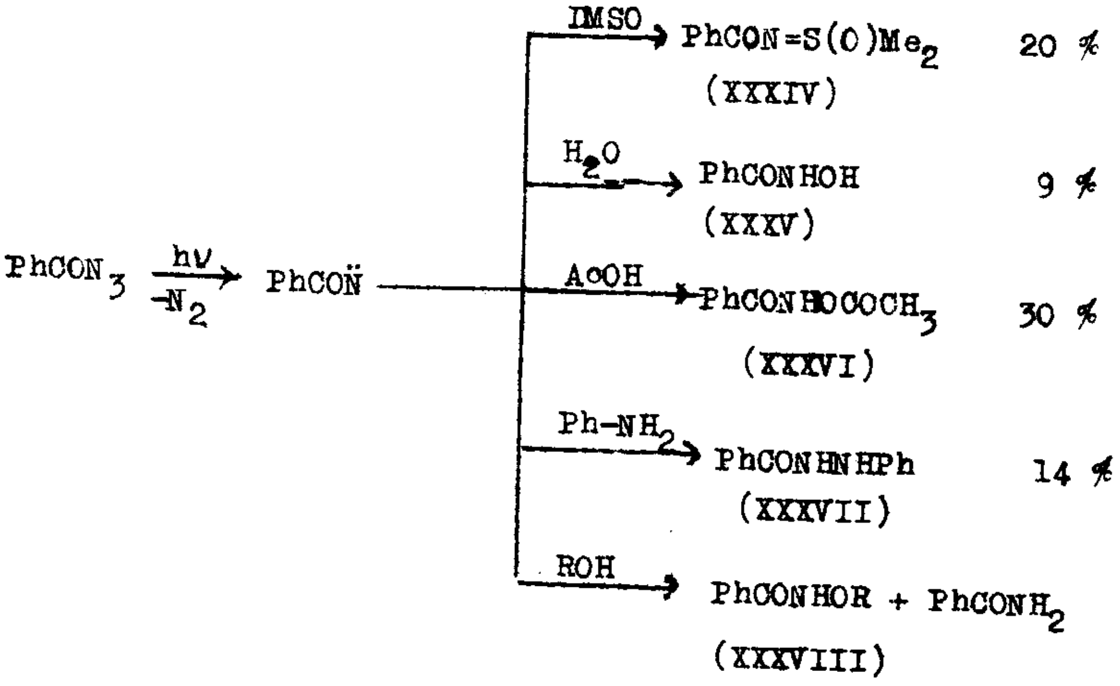
(XXXII)

(XXXIII)

This conclusion is supported by the fact that neither insertion or addition products, nor amides are isolated in the thermal Curtius rearrangement(54-56).

These reaction products would result from an intermediate nitrene. If nevertheless, in these cases the loss of nitrogen would preceed the rearrangement the life time of the intermediate nitrene should be so short that it would not have time to react with solvent. The photochemical decomposition of acyl azides, on the other hand, proceeds by an intermediate nitrene which, in many cases leads to typical nitrene reaction products(57-59).

This is not unreasonable, since a photochemical reaction provides enough energy to break the $N-N_2$ bond without alkyl or aryl participation. Horner(60) for example has proved the existance of benzoyl nitrene as the primary cleavage product of the photolysis of benzoyl azide in the presence of trapping reagents.



B- Decomposition of Alkyl, Aryl Azides

Nitrene intermediates are formed with thermal decomposition reactions of most alkyl, aryl, sulphonyl azides, the loss of nitrogen from organic azides results in unchanged monovalent nitrogen intermediates[61-63] (XXXIX). Variously called nitrenes, imidogens, imine radical, azens, azylenes, and azacarbenes

$$R{-}N_3 \xrightarrow{\Delta \text{ or } h\nu} N_2 + R{-}N$$

(XXXIX)

Important characteristics of nitrenes will be briefly summarized here.

1) Nitrenes have a short life time (only several micro-seconds(37,64) and undergo stabilization by the following reactions :

   (i) Isomerization to imines, (ii) Dimerization to azo compounds, (iii) Hydrogen abstraction followed by ring closure to heterocyclic compounds; (iv) Bimolecular insertion into C-H bonds to secondary amines; (v) Addition to solvent yielding yields and (vi) Addition to unsaturated systems yielding heterocyclic compounds(65-71).

2) At room or higher temperature they can behave as

diradicals (triplet) as well as electrophilic (singlet) species, depending on the nature of the nitrene and on the reaction condition(72-87).

3) Relative reactivity: Studies of relative reactivity with primary, secondary and tertiary C-H bonds have revealed the following order of selectivity; phenylnitrene > carbethoxynitrene > sulphonylnitrene > carbene(88-92).

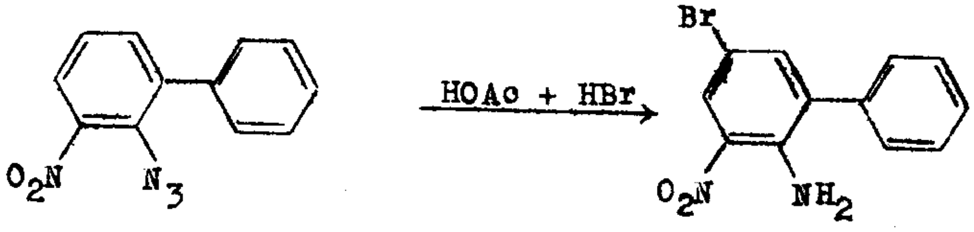
4) Nitrenes have triplet ground state consistent with Hund's rule, as shown by electron spin resonance studies at very low temperatures(93-97).

TYPES OF DECOMPOSITION REACTIONS

1. Acid-Catalyzed Decomposition :

i) Acid-catalyzed decomposition of alkyl and aryl azides :

The acid-catalyzed decomposition of alkyl and aryl azides has been studied fairly extensively(98,99) in solutions of hydrogen bromide in acetic acid, many o-azidobiphenyls decompose vigorously at (50-60°C)(100). The hydrogen bromide catalyzed decomposition gives rise to amines. Thus 2-azido-3-nitro-biphenyl (XL) is coverted into 2-amino-5-bromo-3-nitrobiphenyl (XLI)



(XL) (XLI)

The mechanism proposed by Smith et al(100), is represented as follows :

$$\mathrm{ArN_3 + H^+ \longrightarrow ArNH\text{-}\overset{+}{N}{\equiv}N \xrightarrow[-N_2]{Br} ArNHBr \xrightarrow{H^+}}$$

slow

$$\mathrm{Ar\overset{+}{N}H_2Br \xrightarrow{Br^-} ArNH_2 + Br_2}$$

$$\mathrm{ArNH_2 + HBr \rightleftharpoons Ar\overset{+}{N}H_3\overset{-}{Br}}$$

$$\mathrm{ArNH_2 + Br_2 \longrightarrow BrArNH_2HBr}$$

ii) Acid-catalyzed Curtius rearrangement of Acid Azides:

Yukawa et al(101) have studied the decomposition of substituted benzoyl azides in various solvents. The decomposition of para-substituted benzoyl azide in toluene or in acetic acid solution failed to give a linear Hammett plot. In acetic acid containing (20 %) sulphuric acid, however, a linear Hammett correlation was observed. This result was similar to that of the Schmidt reaction of carboxylic acids(102).

This shows that the acid-catalyzed Curtius rearrangement, and the rearrangement of carboxylic acids have the same rate-determining step, namely the decomposition of the conjugate acid of the acyl azide(101,103-105).

$$\mathrm{RCON_3 + H^+ \rightleftharpoons RCO\ddot{N}H\text{-}\overset{+}{N}_2 \xrightarrow[slow]{} R\overset{+}{N}H{=}C{=}O + N_2}$$

Coleman et al(106), have kinetically investigated the decomposition of benzoyl azide in benzene and nitrobenzene solution with different halides as Lewis acids. They grouped the halides into three classes based on the kinetic equation involved.

Class 1: $GaCl_3 > AlBr_3 > AlCl_3 > FeCl_3$

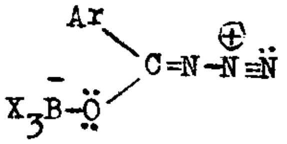
Class 2: $SbCl_5 > TiCl_4 > SnCl_4 > TeCl_4$

Class 3: $SbCl_3 > SbBr_3$

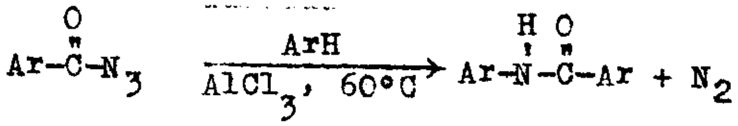
In each class the halides are listed in the order of their relative acid strengths.

$$PhCON_3 + AlBr_3 \xrightarrow{fast} PhCON_3 \cdot AlBr_3 \xrightarrow{slow} PhN{=}C{=}O + N_2 + AlBr_3$$

Trifluoride or trichloride in toluene solution at 60°C gives an adduct which decomposes between -20° and 0°. The adducts could be isolated as crystalline substance from the reaction mixture. Their infrared spectra in dichloromethane indicated that the BX_3 molecules, add onto the carbonyl group and not onto the azide group. Very probably the same phenomenon occurs in reactions studied by Newmann et al(107).



Recently, Fahmy et al.(108) showed that the decomposition of aroyl azides with $AlCl_3$, in different aromatic hydrocarbon substrates give N-aryl-amides (XLII), and azide acts as aryl carbamoylating agent for aromatic hydrocarbons.



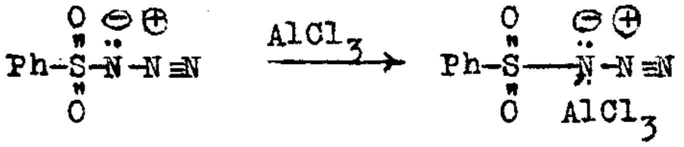
$$Ar-\overset{O}{\overset{\|}{C}}-N_3 \xrightarrow[AlCl_3,\ 60°C]{ArH} Ar-\overset{H}{\overset{|}{N}}-\overset{O}{\overset{\|}{C}}-Ar + N_2$$

(XLII)

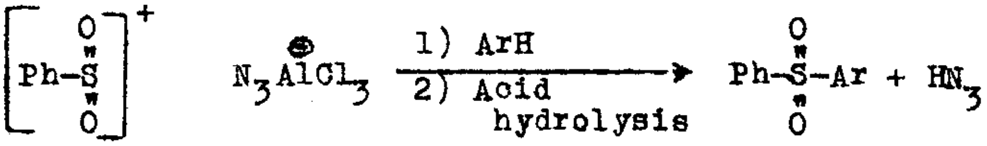
iii) Lewis acid-catalyzed decomposition of aryl sulphonyl azides :

It has been reported that benzene sulphonyl azide (XXVII) undergoes acid-catalyzed decomposition in different aromatic substrates under the condition of Friedel-Crafts reactions, and aryl sulphatation takes place to yield diaryl sulphones(108).

The reaction possibly takes place according to the following scheme :



(XXVII)

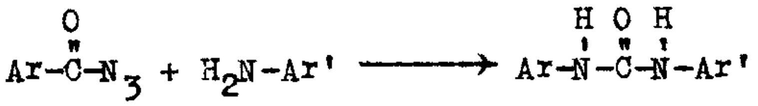


(XLIII)

2- BASE-CATALYZED DECOMPOSITION OF ACID AZIDES

A) With Amines and Amino Acids :

Aroyl azides (I) react with aromatic amines (aniline, p-anisidine, o-chloroaniline, p-chloroaniline) to give the corresponding diaryl ureas (XLIV)(109) via Curtius rearrangement.

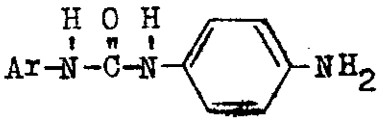


$$Ar-\overset{O}{\overset{\|}{C}}-N_3 + H_2N-Ar' \longrightarrow Ar-\overset{H}{N}-\overset{O}{\overset{\|}{C}}-\overset{H}{N}-Ar'$$

(XLIV)

Ar	Ar'
a, C_6H_5	a, C_6H_5
b, $C_6H_4OCH_3$(p-)	b, $C_6H_4OCH_3$(p-)
c, C_6H_4Cl(o-)	c, C_6H_4Cl(o-)
d, C_6H_4Cl(p-)	d, C_6H_4Cl(p-)

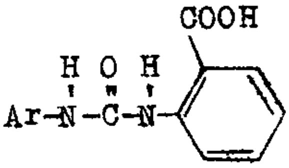
Similarly, p-phenylene diamine reacts with (one mole) of aroyl azides (I) to give the corresponding sym-N-aryl-N'-4-aminophenyl-ureas (XLV)(109)



(XLV)

Ar
a, C_6H_5
b, $C_6H_4OCH_3$(p-)
c, C_6H_4Cl(p-)

In case of amino acids, aroyl azides (I) react with anthranilic acid in refluxing benzene to give the corresponding, sym-N-aryl-N'-[2'-carboxyphenyl] ureas(109) (XLVI)

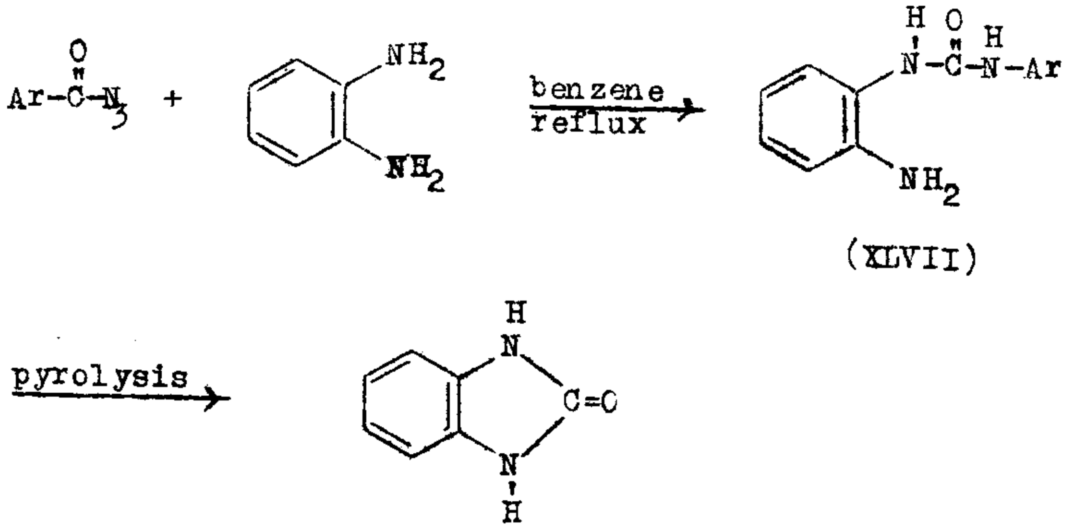


(XLVI)

Ar

a, C_6H_5
b, $C_6H_4OCH_3$(p-)
c, C_6H_4Cl(p-)

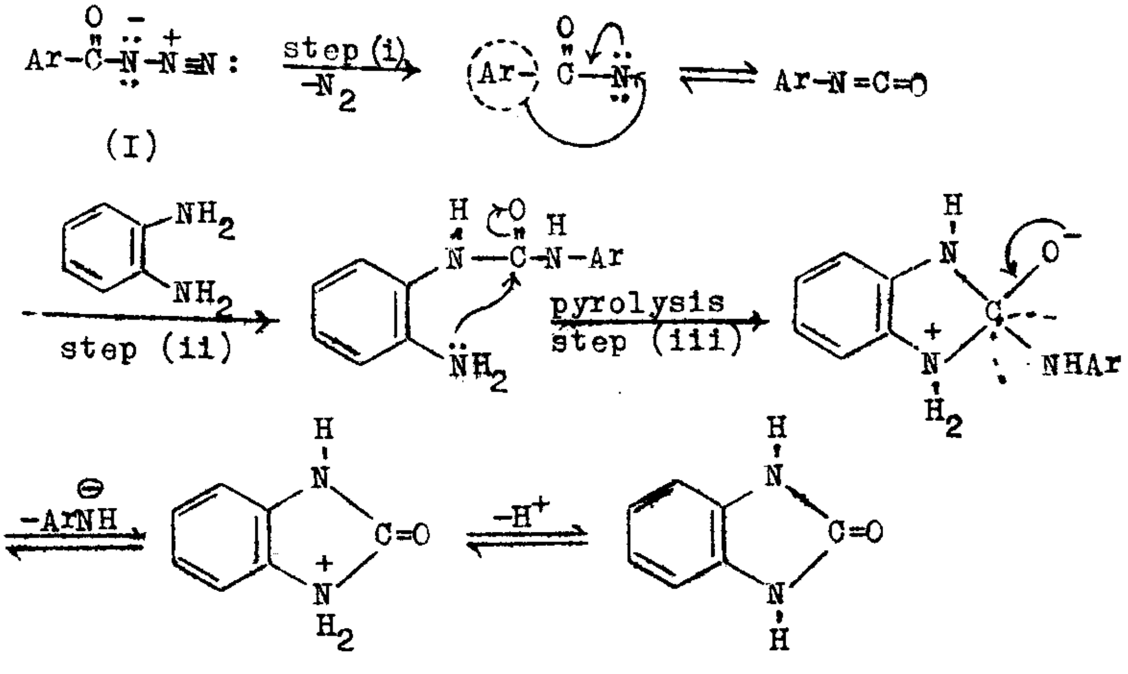
Aroyl azides react with o-phenylene diamine to give, sym-N'-[2'-aminophenyl]-N-aryl-ureas(XLVII) which upon pyrolysis give benzimidazolone (XLVIII)(110)



(XLVII)

(XLVIII)

The reaction probably takes place according to the following mechanism :

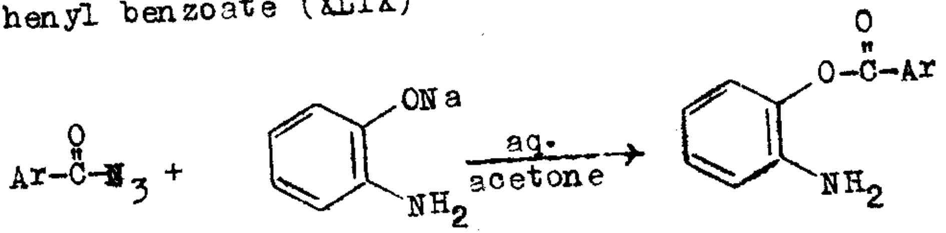


(I)

(XLVIII)

B) With o-Amino-Sodium Phenate :

When o-amino-sodium phenate was used as a substrate with two basic centres (⌬-O$^{\ominus}$ and NH_2 groups), it gives with aroyl azides (I) in acetone the corresponding o-aminophenyl benzoate (XLIX)$^{(110)}$

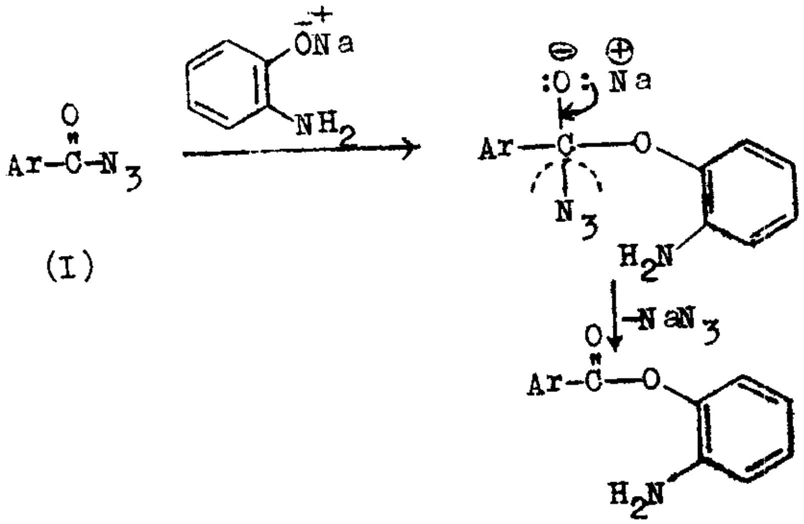


(I)

(XLIX)

a, $Ar=C_6H_5$; b, $Ar=C_6H_4OCH_3(p-)$; c, $Ar=C_6H_4Cl(p-)$;
d, $Ar=C_6H_4NO_2(p-)$

The reaction possibly takes place according to the following mechanism :



(I)

(XLIX)

c) With hydrazines:

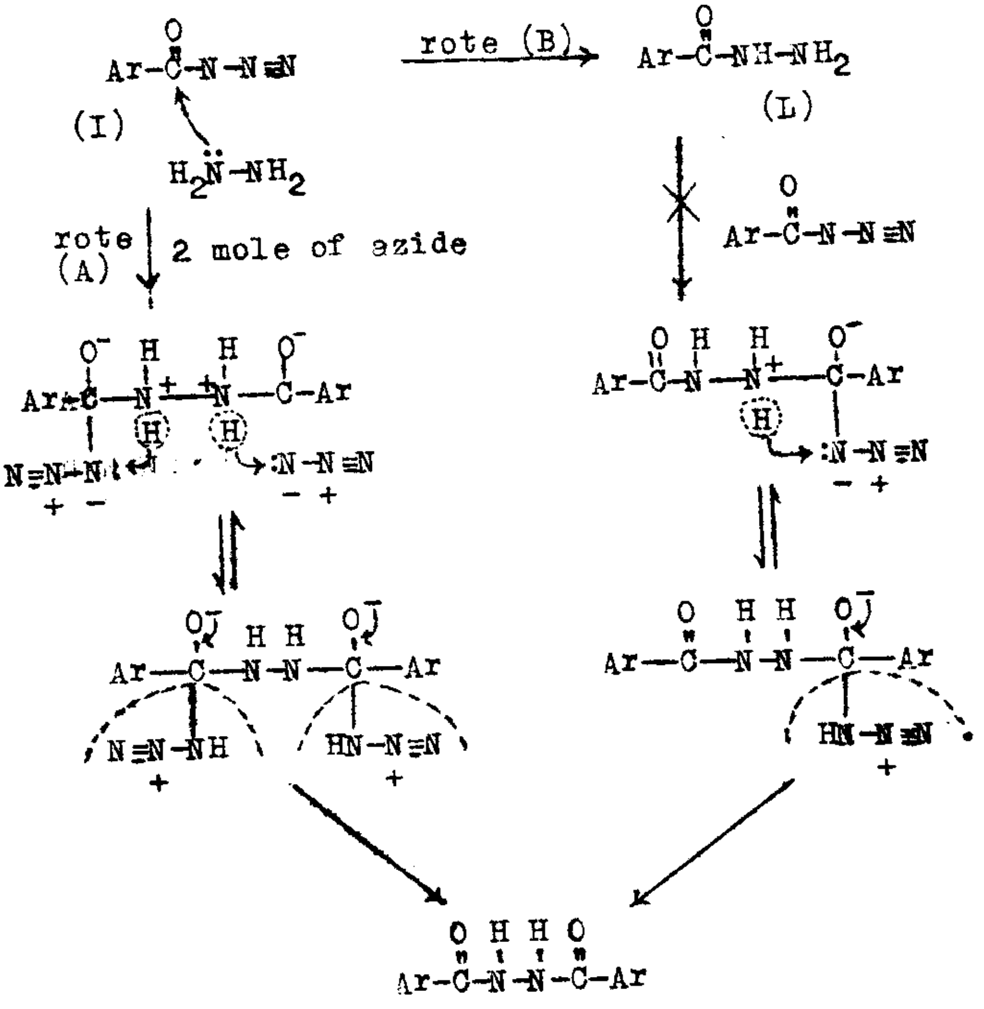
Aroyl azides (I) undergo hydrazinolysis with excess hydrazine hydrate to give the corresponding aroyl hydrazides (L)(111)

$$\mathrm{Ar{-}\overset{O}{\overset{\|}{C}}{-}N_3 + H_2N{-}NH_2 \longrightarrow Ar{-}\overset{O}{\overset{\|}{C}}{-}NH{-}NH_2 + HN_3}$$

(I) (L)

a, Ar=C_6H_5; b, Ar=$C_6H_4OCH_3$(p-); c, Ar=$C_6H_4NO_2$(o-);
d, Ar=$C_6H_4NO_2$(m-); e, Ar=$C_6H_4NO_2$(p-); f, Ar=C_6H_4Cl(o-);
g, Ar=C_6H_4Cl(m-); h, Ar=C_6H_4Cl(p-); i, Ar=C_6H_4Br(o-);
j, Ar=C_6H_5-CH=CH-

When decomosition of aroyl azides was carried out with (0;5 mole) of hydrazine in benzene the corresponding N,N'-diaroyl hydrazines(111) (LI) were obtained via the following scheme

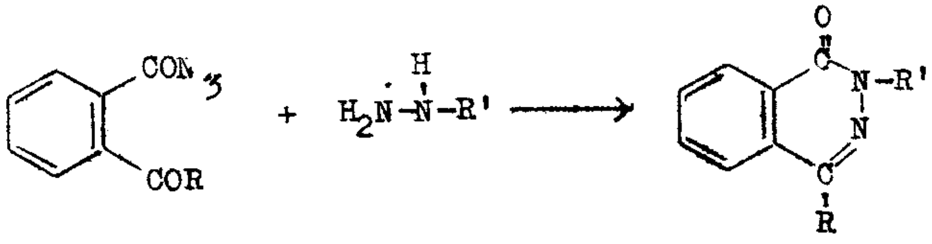


(LI)

a, Ar=C_6H_5; b; Ar=$C_6H_4OCH_3$(p-); c: Ar=$C_6H_4NO_2$(m-);
d, Ar=$C_6H_4NO_2$ (p-); e, Ar=C_6H_4Cl(m-); f, Ar=C_6H_4Cl(p-);
g, Ar=C_6H_4Br(o-); h; Ar=C_6H_5-CH=CH-

O-Aroyl benzazides (LII) react with hydrazine hydrate to give the corresponding 1-aryl phthalaz-4-ones(108) (LIIIa-d), and similarly react with phenyl hydrazine and p-nitrophenyl hydrazine to give 1,3-di-aryl-phthalaz-

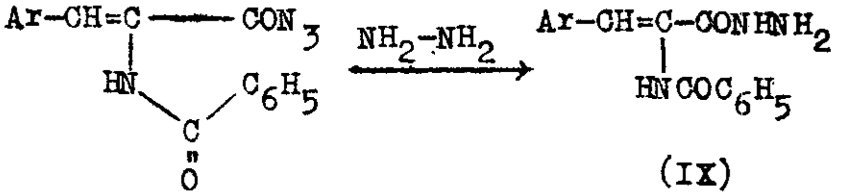
4-ones(110) (LIII)



(LII) (LIII)

R	R'
a; C_6H_5	a; H
b; $C_6H_4CH_3$(p-)	b; C_6H_5
c; $C_6H_4OCH_3$(p-)	c; $C_6H_4NO_2$(p-)

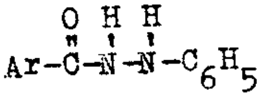
Arylidene hippuric azides (VIII) react with excess hydrazine hydrate to give arylidene hippuric hydrazides(109) (IX)



(IX)

a; Ar=C_6H_5 ; b; Ar=$C_6H_4OCH_3$(p-) ; c; Ar = 

Similary , phenylhydrazine, reacts with aroyl azides (Ia-e) in benzene to give, the corresponding β-aryl-α-phenylhydrazines (LIV)(111) via the same mechanism.

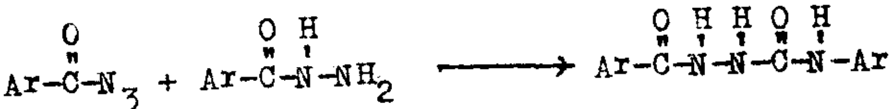


$$\mathrm{Ar{-}\overset{O}{C}{-}\overset{H}{N}{-}\overset{H}{N}{-}C_6H_5}$$

(LIV)

a; Ar=C_6H_5; **b**; Ar=$C_6H_4OCH_3$(p-); **c**; Ar=$C_6H_4NO_2$(p-);
d; Ar=C_6H_4Br(o-); **e**; Ar=C_6H_5-CH=CH

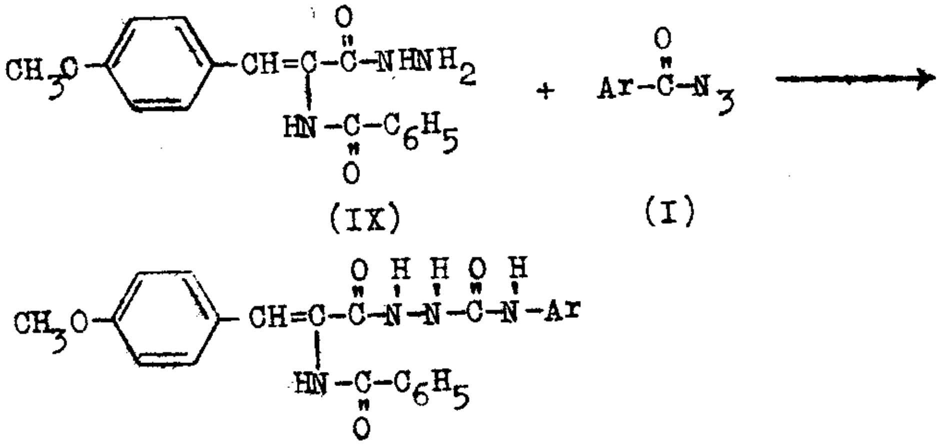
Benzoyl azide (I) reacts with acid hydrazides (L) to give the corresponding sym.-N-aroyl-N'-aryl-semicarbazides (LV)



$$\mathrm{Ar{-}\overset{O}{C}{-}N_3 + Ar{-}\overset{O}{C}{-}\overset{H}{N}{-}NH_2 \longrightarrow Ar{-}\overset{O}{C}{-}\overset{H}{N}{-}\overset{H}{N}{-}\overset{O}{C}{-}\overset{H}{N}{-}Ar}$$

(I) (L) (LV)

Similarly, anisylidene hippuric hydrazides (IX) react with aroyl azides (I) to give sym-N-[α-benzamido-4-methoxycinnamoyl]-N'-aryl-simicarbazides (LVI)[109] via the same mechanism.



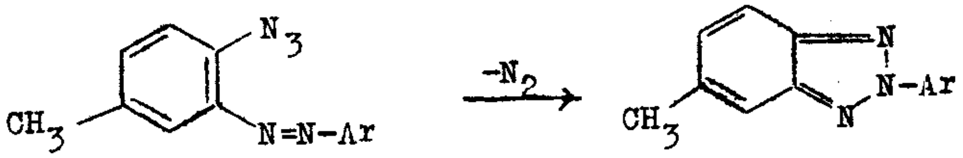
(IX) (I)

(LVI)

3- Thermal Cyclization of Azides:

Aryl and heterocyclic azides decompose thermally with cyclization by various routes depending on environment and structure(112). Such decompositions can be used as preparative methods for various heterocyclic compounds by making use of azides with suitable ortho-substituents.

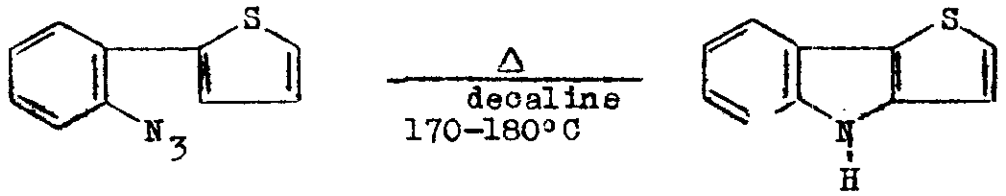
i) Cyclization to benztriazoles : Pyrolysis of o-azido aromatic azo compounds (LVII) results in the formation of the corresponding substituted 2-aryl benztriazoles(13-15) (LVIII).



(LVII)　　　(LVIII)

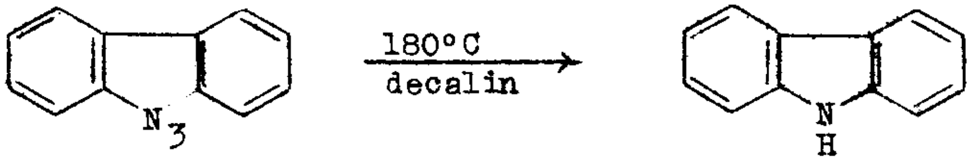
ii) Cyclization to 4-thieno (3,2-b) indole :

o-(α-Thienyl)phenyl azide (XXIV) undergoes thermal decomposition in decalin or (kerosene) at (170-180°C). The loss of nitrogen was accompanied by ring closure to the carbazole analaguse, 4-thieno-(3,2-b)indole(113) (LIX)



(XXIV)　　　(LIX)

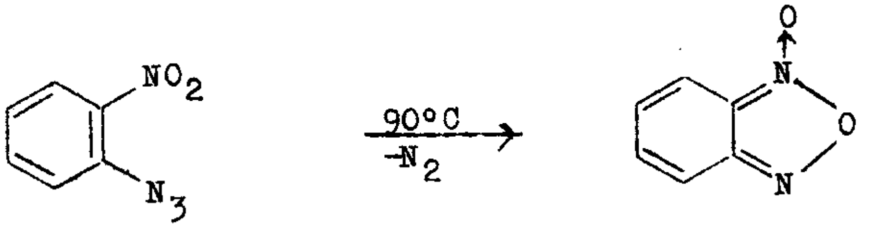
iii) Cyclization to carbazole: Thermal decomposition of o-azidobiphenyl (LX) results in the formation of carbazole(1-4) (LXI)



(LX) (LXI)

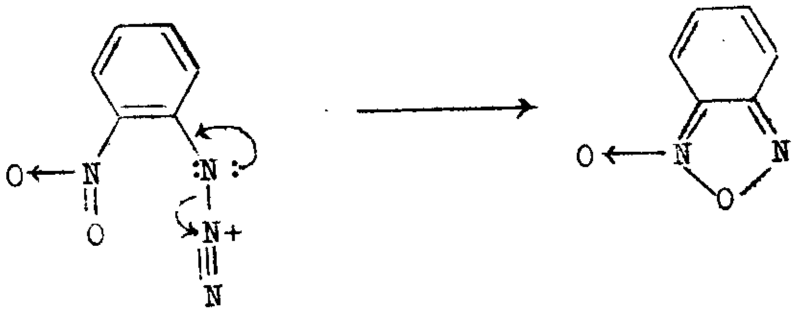
iv) Cyclization to benzofuroxane :

Thermal decomposition of o-nitrophenyl azide (LXII) at 85-90°C gives benzofuroxane (LXIII) with loss of nitrogen(5-7).



(LXII) (LXIII)

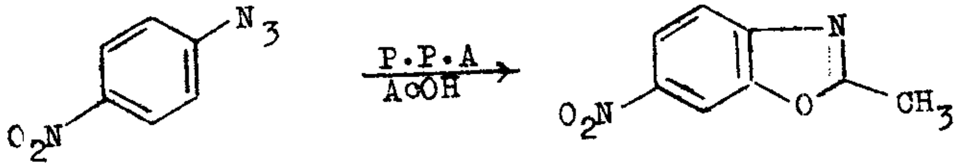
The reaction takes place via a concerted mechanism, involving rupture of the $(N-N_2)$ bond of the azide group with concomitant cyclization.



(LXII) (LXIII)

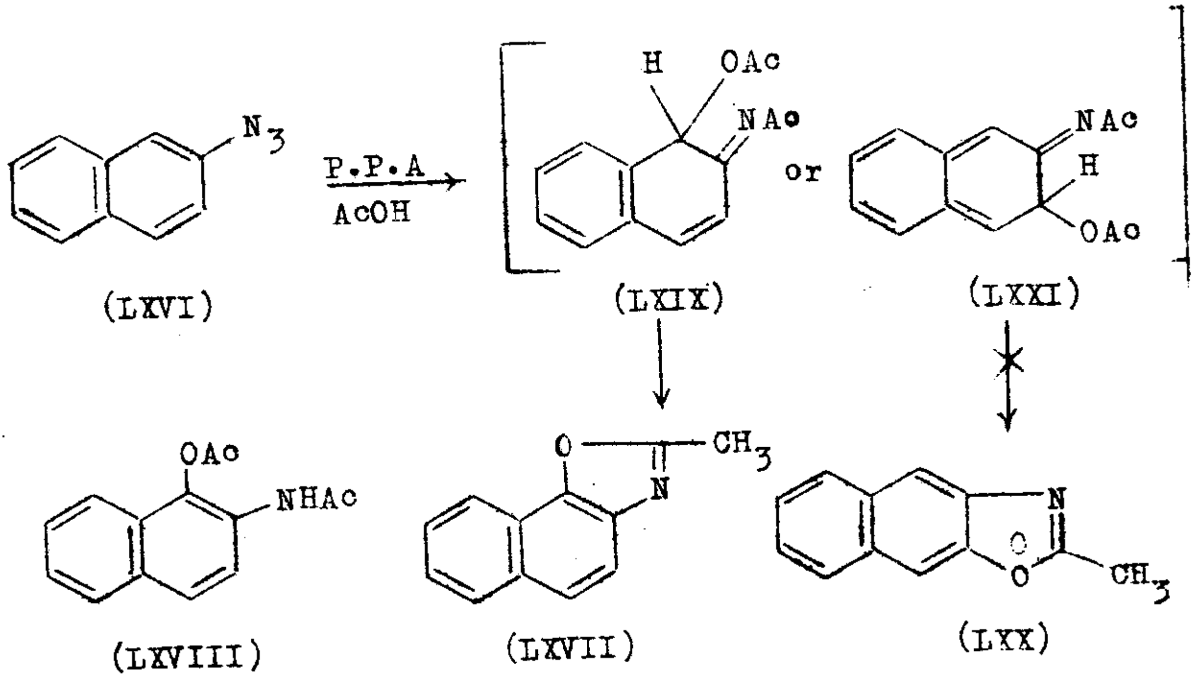
v) Cyclization to benzoxazole:

Thermal decomposition of aryl azides in a hot mixture of carboxylic acid and polyphosphoric acid (1:1) gives benzoxazole derivatives. p-Nitro-phenyl azide (LXIV) gives a high yield of 2-methyl-6-nitro-benzoxazole(8,9) (LXV)

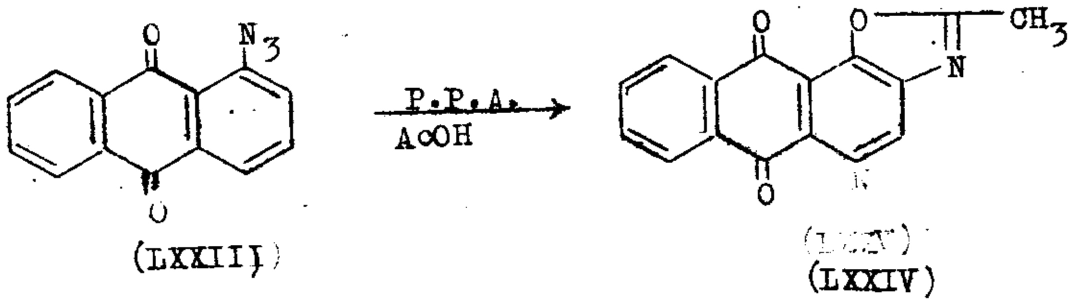


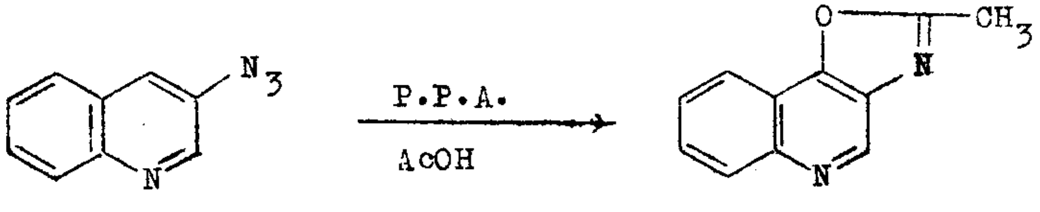
(LXIV) (LXV)

2-Azidonaphthalene (LXVI) gives under the same condition the angular naphthoxazole (LXVII), and the N,o-diacetyl naphthalene (LXVIII) via the intermediate (LXIX) rather than the linear isomer (LXX). This is due to the greater stability of the intermediate(114) (LXIX) than (LXXI).



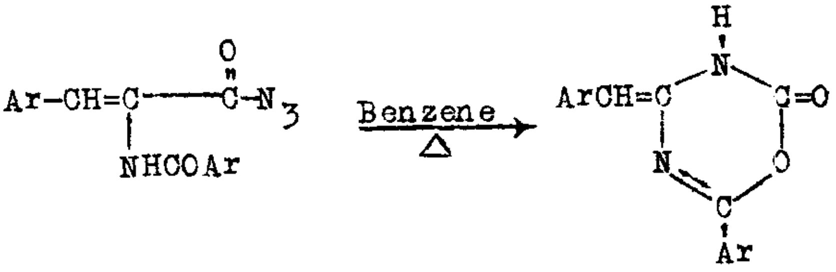
In a similar manner the thermal decomposition of 2-azido-anthraquinone(114) (LXXII) and 3-azidoquinoline(9) (LXXIII) in a mixture of acetic acid/polyphosphoric acid, furnished the corresponding oxazoles (LXXIV) and (LXXV), respectively.





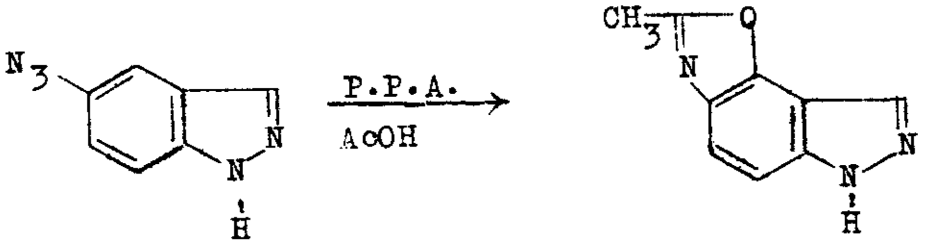
(LXXIII) (LXXV)

vi) Cyclization to 1,3,5-oxadiazines(19): Arylidene hippuric azides (VIII) undergo thermal decomposition in benzene to give 4-arylidene-6-aryl-2-oxo-1,3,5-oxadiazines (LXXVI)



(VIII) (LXXVI)

vii) Cyclization to oxazoles(114): 5-Azidoindole (LXXVII) undergoes thermal decomposition in a mixture of P.P.A., AcOH (1:1) to give oxazolo-(4,5) indazole (LXXVIII)

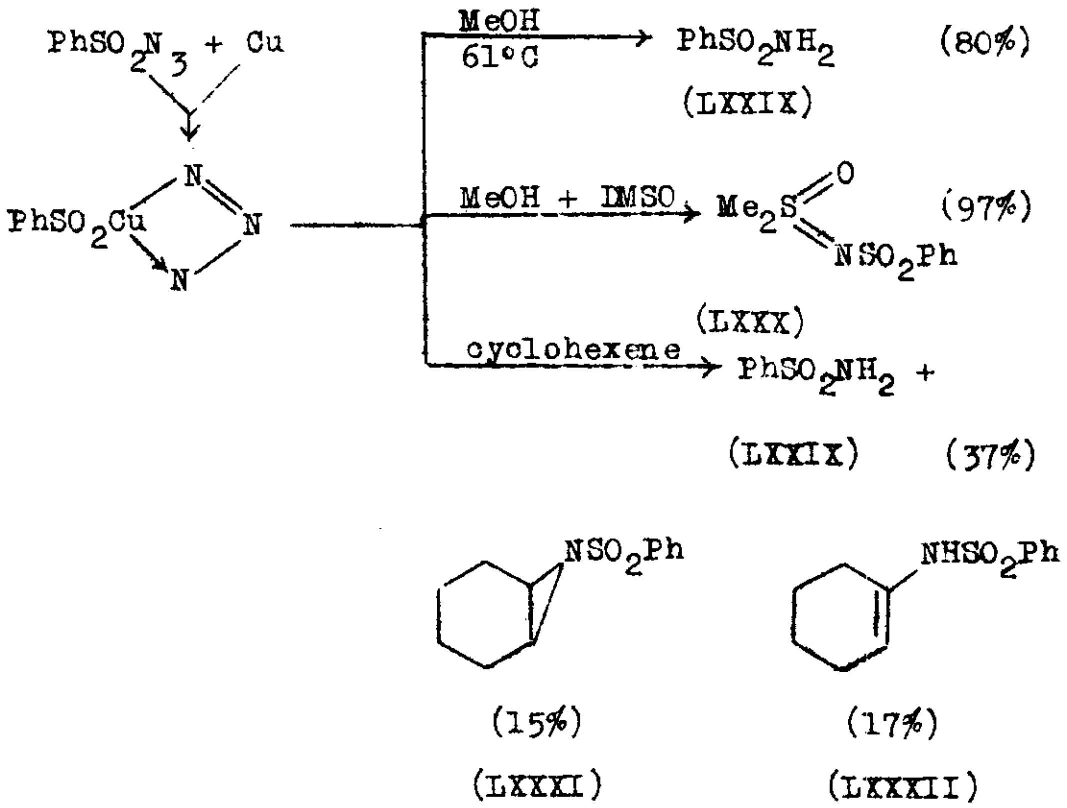


(LXXVII) (LXXVIII)

4- Decomposition of Sulphonyl Azides via Copper Complexes:

Kwart et al.(115,116) have found that benzenesulphonyl azide forms a complex with freshly reduced copper powder. This copper azide complex decomposes at a lower temperature than the pure sulphonyl azide. In refluxing methanol, benzene sulphonamide (LXXIX) is isolated as the major product. In the presence of dimethyl sulphoxide, N-benzene-sulphonyl dimethyl-sulphoximine (LXXX) was obtained in almost quantitative yield. In cyclohexane solution benzene sulphonamide (LXXIX), N-benzene sulphonyl-7-azabicyclo (4.1.0) heptane (LXXXI) and 1-cyclohexenenyl benzene sulphonamide (LXXXII) are isolated as the main reaction products.

In pure alcohol, the decomposition should occure by two competitive reactions producing benzenesulphonamide together with a ketone and oxidized copper. In the presence of DMSO, it seems that a copper nitrene intermediate is formed which is trapped by DMSO. In cyclohexene solution, the authors have observed that the aziridine disappears from the products when DMSO is added. The yield of enamine, however, is practically uneffected by DMSO



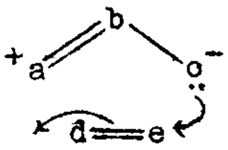
II- ADDITION REACTIONS

The addition reactions of organic azides to unsaturated systems can occur by two mechanisms(117). If the reaction temperature is lower than the decomposition temperature of the azide, a 1,3-dipolar addition is observed. When, however, the reaction is carried out at the wavelength or at the decomposition temperature of the azide, the addition proceeds through an intermediate nitrene, and can be used as a synthetic route for some heterocycles.

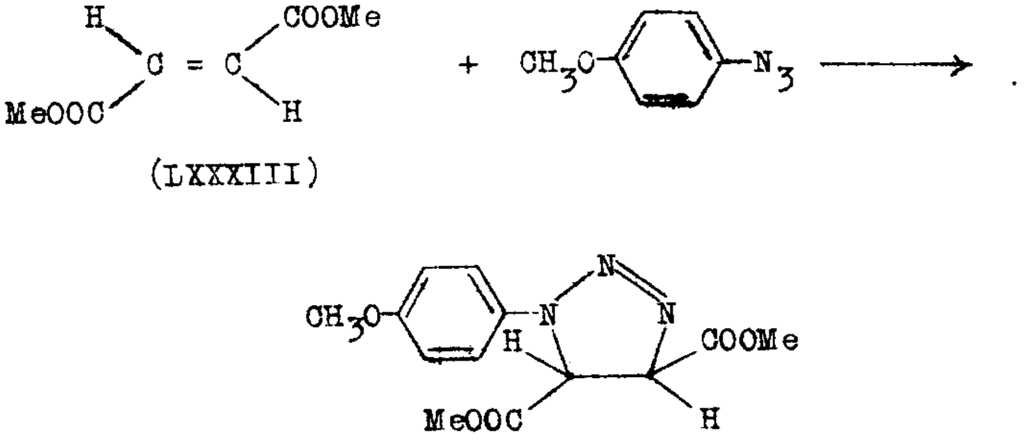
1,3-DIPOLAR CYCLOADDITIONS

General Principles:

The characteristics of the 1,3-dipolar cycloaddition mechanism of azides have been described in details by Huisgen(118-119). According to the author, the addition of a 1,3-dipole (abc) to a dipolarophile (de) occurs by concerted mechanism in which the two new σ bonds are formed simultaneously although not necessarily at equal rates.



As a consequence stereoselective cis addition is observed. Thus the addition of p-methoxyphenyl azide to dimethyl fumarate (LXXXIII) yields 1-(p-methoxyphenyl)-4-5-trans-dicarbomethoxy-Δ^2-triazoline (LXXXIV)[120]:



(LXXXIII)

(LXXXIV)

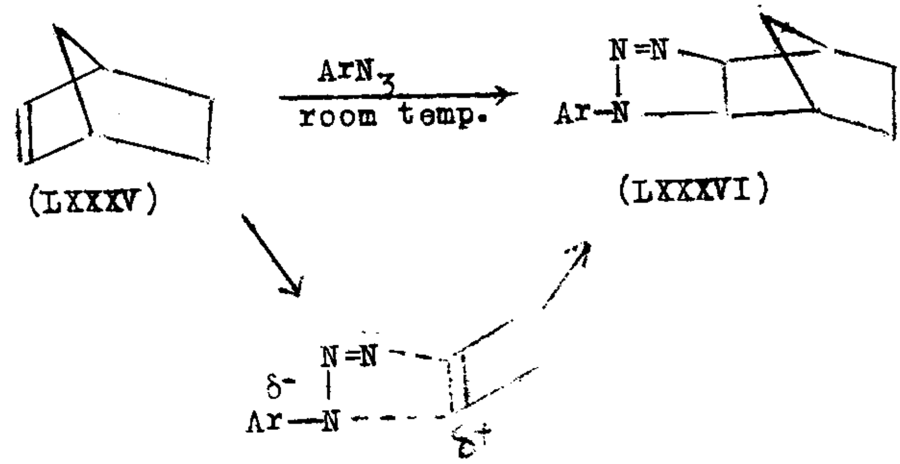
A) Addition of Azides to Double Bonds .

1) Addition to olefinic double bonds :

(i) Aryl azides:

Aryl azides react with olefins to give 1,2,3-Δ^2-tri-azolines(10-12) whereas unactivated olefins are sluggish toward aryl azides, strained bicyclic systems, on the contrary, are particularly reactive(121-125).

Bicyclo (2.2.1) heptenes, such as norbornene (LXXXV) react readily at room temperature, and the addition occurs at the hindered exoside to give (LXXXVI)(126-129)

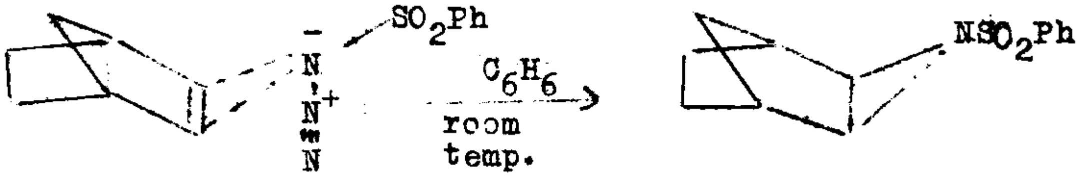


(LXXXV)

(LXXXVI)

ii) Benzene sulphonyl azides :

By treating norbornene (LXXXV) with benzenesulphonyl azide (XXVII) in benzene at room temperature, a crystalline product possessing aziridine structure (LXXXVII) is obtained in quantitative yield(130,131).

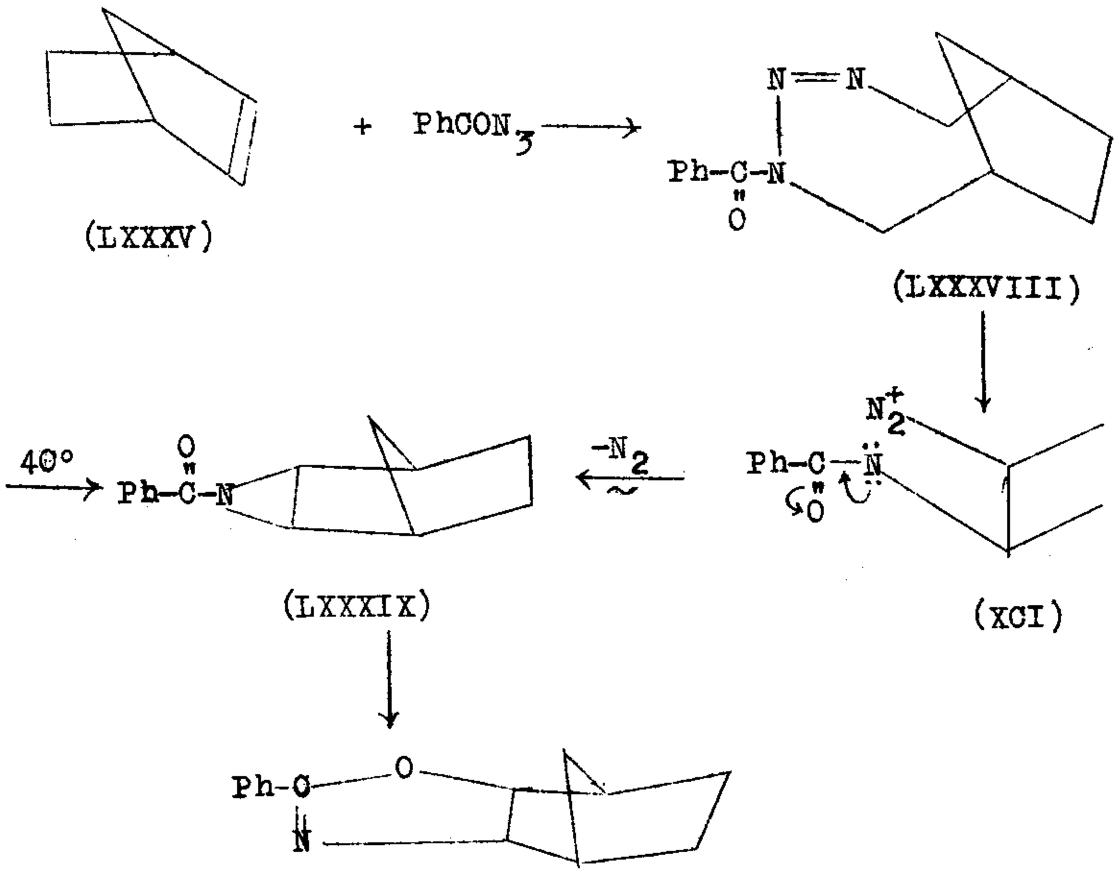


(LXXXV)

(LXXXVII)

iii) Benzoyl azide :

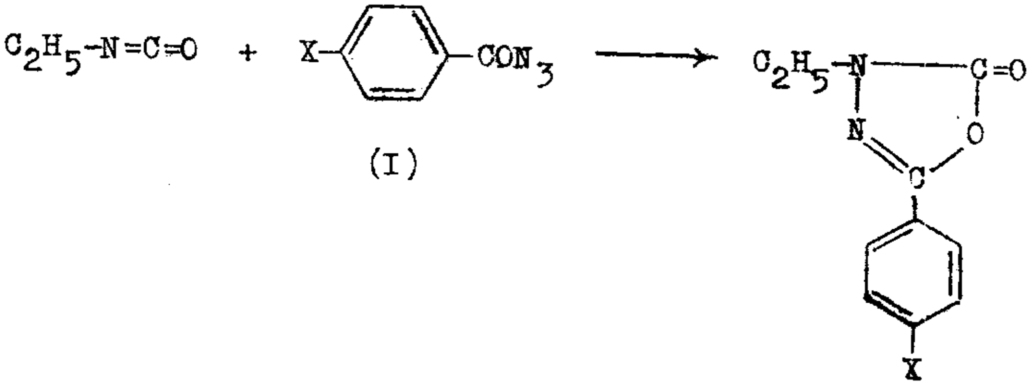
Triazoline (LXXXVIII) formed from the reaction of benzoyl azide (I) with norbornene (LXXXV) was alreadly decomposed into N-benzoyl-aziridine (LXXXIX)(127). This compound was isomerizes quantitatively by distillation under normal pressure(128,129) to an exooxazoline derivative (XC)



(XC)

2- Addition to double bonds in isocyanates:

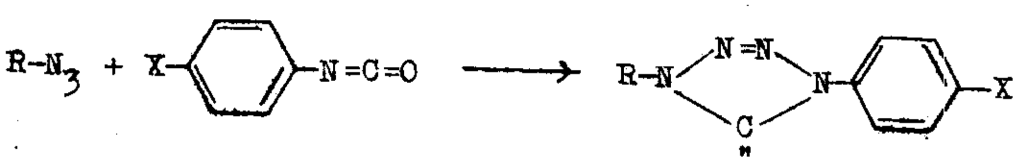
Aroyl azides (I) were shown to react with ethyl isocyanate to give 2-aryl-4-ethyl-1,3,4-oxadiazolin-5-ones(132) (XCII)



(I)

(XCII)

Aryl isocyanates add butyl, and cyclohexyl azides (XCIII) to give the corresponding cycloadducts (XCIV)(133).



(XCIII)

(XCIV)

a; R=C_4H_9 ; b; R=

Sulphonyl isocyanates were found to react readily with alkyl, and aryl azides to give 1-alkyl-, or aryl-4-sulphonyl-Δ^2-tetrazolin-5-ones (XCV)(134).

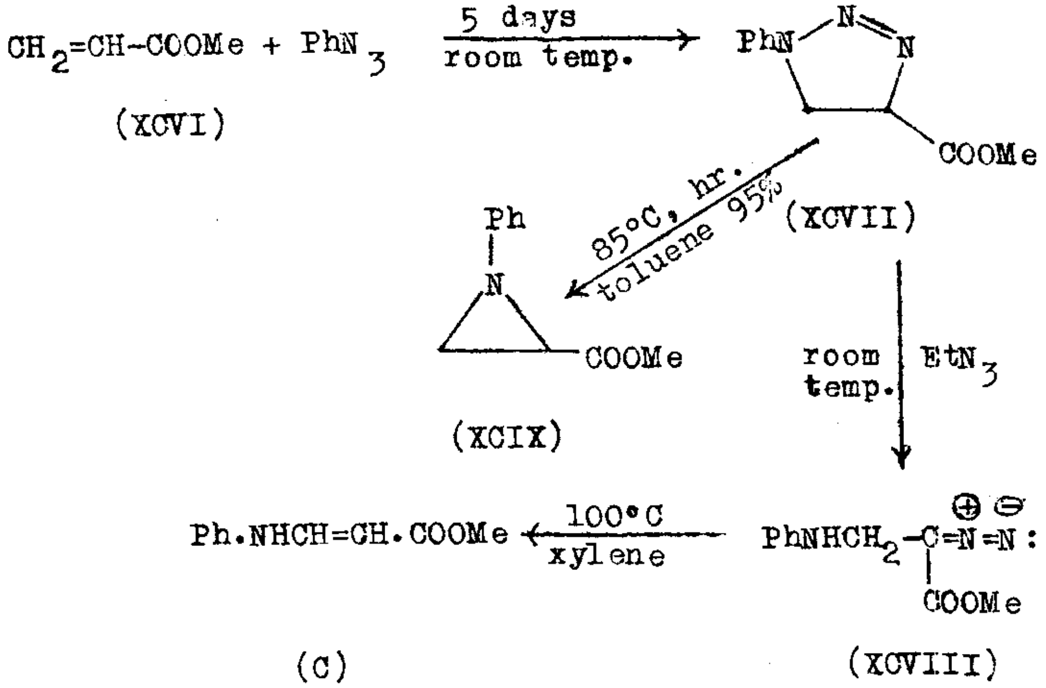
(XCV)

3- <u>Addition to conjugated double bonds</u> :

(i) <u>In α, β-unsaturated esters</u> :

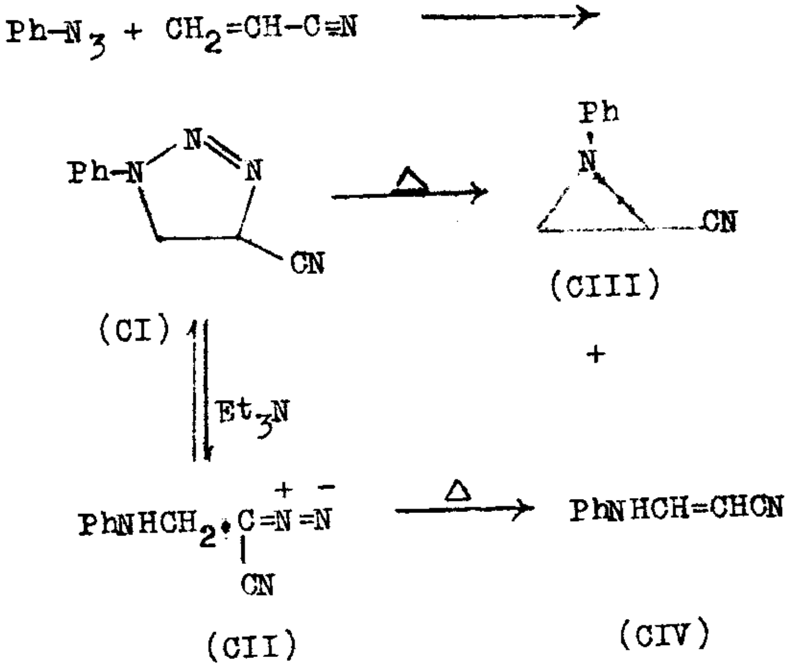
Huisgen et al$^{(120)}$ have studied the addition reactions of aryl azides to α, β-unsaturated esters. Methyl acrylate (XCVI) reacts with aryl azides to form 1-aryl-4-carbmethoxyl-Δ^2-triazolines (XCVII), the orientation addition is in agreement with the rule based on electronic factors. These Δ^2-triazolines are completely converted by base catalysis into the ring-open chains (XCVIII).

Thermal decomposition of (XCVII) gives 1-phenyl-2-carbmethoxy aziridine (XCIX) whereas (XCVIII) gives β-anilinomethyl acrylate (C).



(ii) In α,β-unsaturated nitriles :

Phenyl azide reacts with acrylonitrile to give 1-phenyl-4-cyano-Δ^2-triazoline (CI) which is in equilibrium with 3-anilino-2-diazopropionitrile (CII) in the presence of triethylamine, both isomers decompose thermally to give 1-phenyl-2-cyanoaziridine (CIII), and 3-anilinoacrylonitrile (CIV)(135)

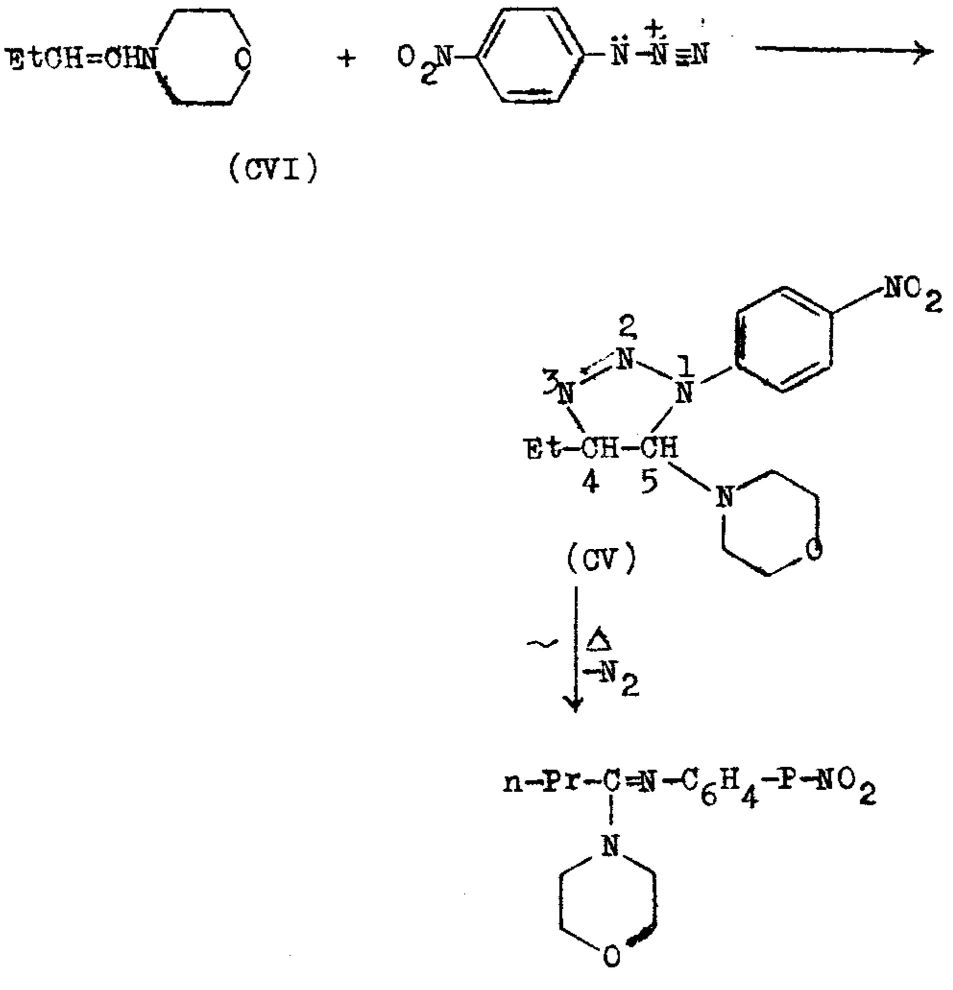


4- Addition to double bonds in enamines.

(i) Aryl azides:

Enamines contain electronic rich double bonds are thus react readily with azides. Only one addition product is formed, namely a 5-amino-Δ^2-triazoline, as a result of electronic control(136,137).

Thus 1-(p-nitrophenyl)-4-ethyl-5-morpholino-Δ^2-triazoline (CV) arises from the addition of p-nitrophenyl azide to 1-morpholino-1-butene (CVI). The addition products rearrange by heating into amidines (CVII).



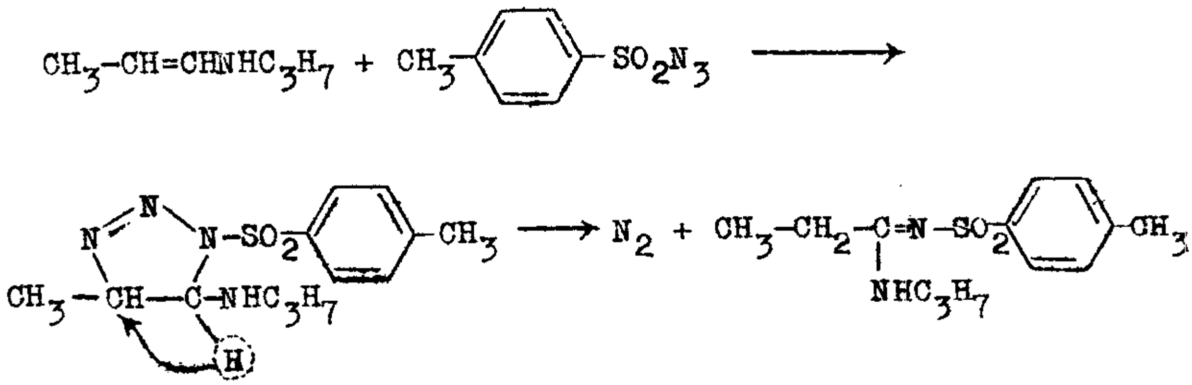
(CVI)

(CV)

(CVII)

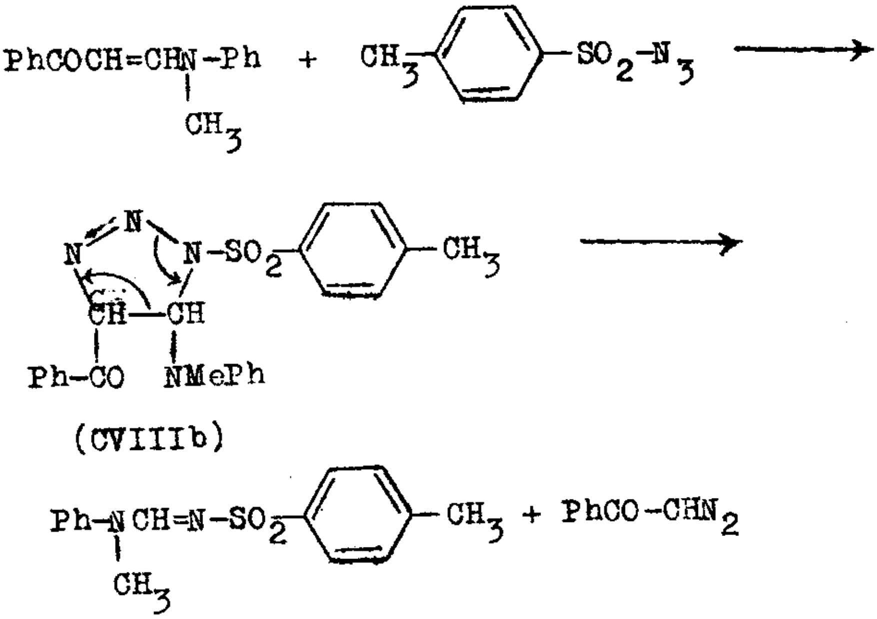
ii) Sulphonyl azides :

Sulphonyl azides react rapidly (at room temperature) with enamines and gave no triazolines. The reaction products nevertheless can be easily explained when an intermediate triazoline (CVIII) is postulated. The hypothetical triazoline can then decompose in three different ways leading either to amidines (CIX) and nitrogen, or to amidines (CX) and diazoketones (CXI), or to triazoles (CXII) and sulphonamines (CXIII)(138-142).



(CVIIIa)

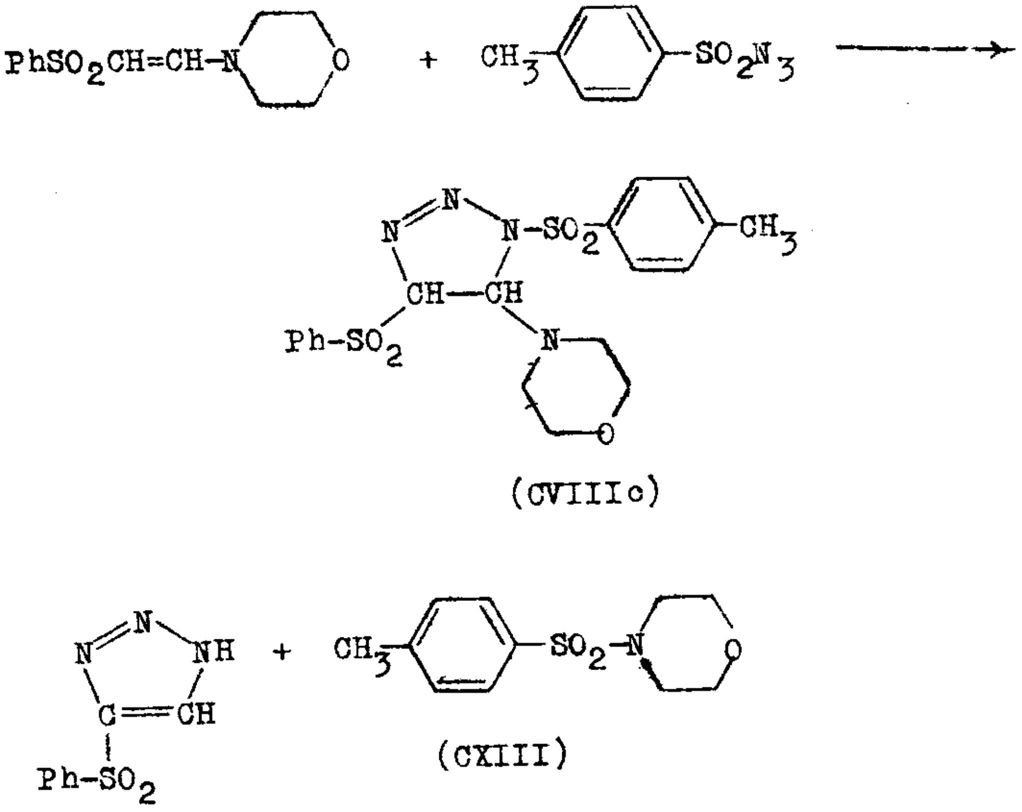
(CIX)



(CVIIIb)

(CX)

(CXI)



(CVIIIc)

(CXIII)

(CXII)

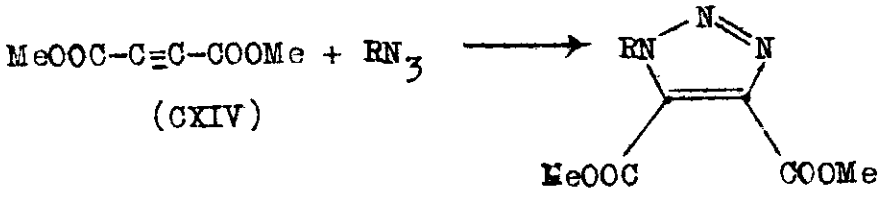
B- Addition of Azides to Triple Bonds

Azides have been found to add to acetylenic compounds to give 1,2,3-triazoles$^{(143-149)}$. Huisgen reported that the dipolarophilic activity of alkynes is similar in magnitude to those of alkenes including :

(1) Addition to acetylenic esters :

Acetylenic esters react with alkylazides, aryl azides, carboalkoxy azides, and tosyl azides yielding triazoles$^{(150-154)}$.

When dimethyl acetylene-dicarboxylate (CXIV) is the starting material, the 1-substituted 4,5-dicarbomethoxy-1,2,3-triazoles (CXV), are obtained.

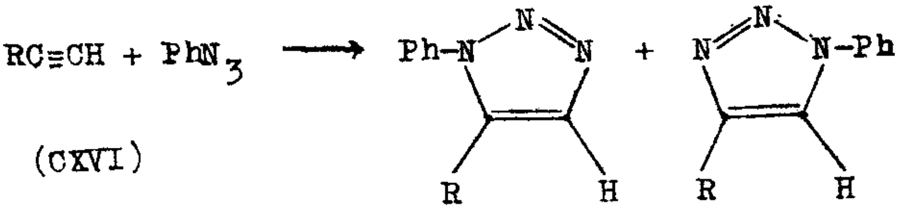


(CXIV)

(R = alkyl, aryl, or tosyl)   (CXV)

(2) Addition to monosubstituted acetylenes :

With monosubstituted acetylenes such as phenylacetylene (CXVIa), and propiolaldehyde diethyl acetal (CXVIb) the orientation of phenyl azide is determined both by electronic and steric effects(155,156), and a mixture of two triazoles are formed (CXVII) and (CXVIII).



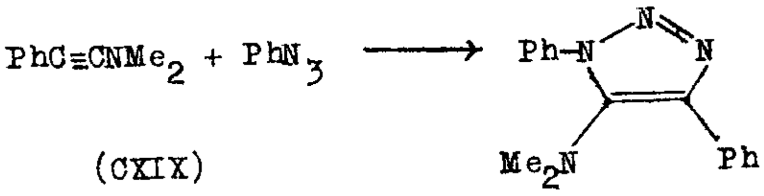
(CXVI)

(CXVII)   (CXVIII)

a; $R=C_6H_5$; $R = CH(OEt)_2$

(3) Addition to Ynamines :

Ynamines (CXIX) react with phenyl azide in the same way as enamines and result in formation of amino-substituted triazoles (CXX)(157).



(CXIX)

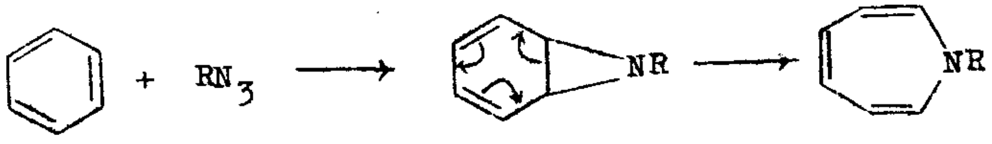
(CXX)

ADDITION OF AZIDES VIA NITRENE INTERMEDIATES

1- Addition to carbon-carbon double bonds :

(i) Addition to benzene

When ethyl azido formate, cyanogen azide or acyl azide are decomposed in benzene solution no aziridines were isolated but eliminated azepines (CXXI) were obtained(158,159). The 7-azanor-caradienes (CXXII) were most probably formed as unstable intermediates but rearrange immediately into the more stable azepines.



(CXXI) (CXXII)

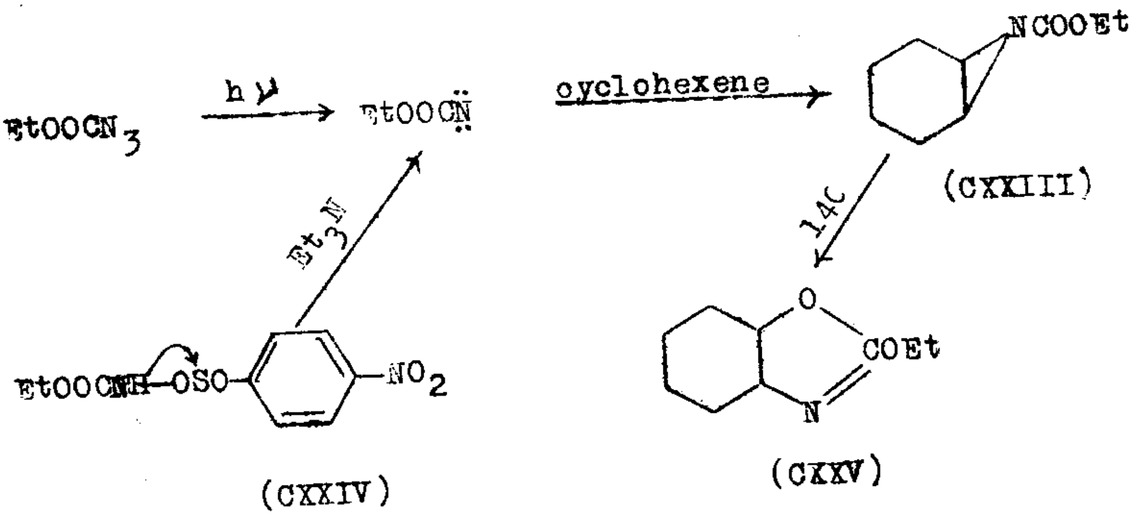
a; R = $COOC_2H_5$; b; R = CN ; c; R = CON_3

ii) Addition to cyclohexene

Photochemical decomposition of ethyl azidoformate in cyclohexene gives 7-carbethoxy-7-azabicyclo (4.1.0) heptane (CXXIII) as main product together with the three isomeric cyclohexenylmethanes(160-162).

A nitrene mechanism for the reaction is supported by the fact that the same products in almost the same ratio are obtained in the base induced cleavage of

N-p-nitrobenzene sulphonoxyurethan (CXXIV). All evidences indicates that the second reaction yields the carbethoxynitrene by an α-elimination mechanism. The cycloaziridine isomerizes at 140°C into 2-ethoxy-4,5-cyclohexano-Δ^2-oxazoline (CXXV)

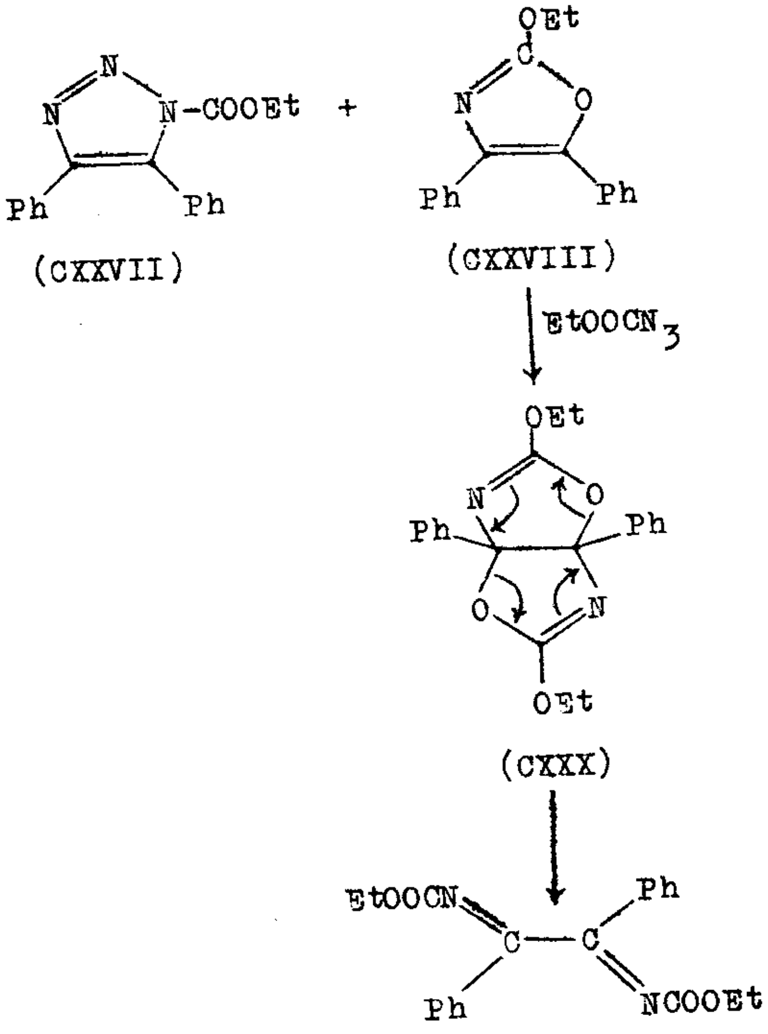


2- Addition to carbon-carbon triple bonds :

When ethyl azido-formate is warmed with diphenyl acetylene (CXXVI) carbethoxy-1,2,3-triazoles (CXXVII) and 2-ethoxyoxazoles (CXXVIII) can be obtained(163). These products result from 1,3-dipolar addition of the azide and the nitrene to the triple bond, respectively. The triazoles cannot be intermediates in the formation of oxazoles because they are stable under the reaction conditions (130°C).

The oxazoles (CXXVIII) are capable of adding a second molecule of nitrene to give a bisethoxycarbonyliminoethane (CXXIX) via (CXXX)

$$\underset{\text{(CXXVI)}}{Ph\text{-}C{\equiv}C\text{-}Ph} + EtOOCN_3 \xrightarrow{130^\circ C}$$



(CXXVII) (CXXVIII) (CXXX) (CXXIX)

SPECTROSCOPIC STUDY ON ORGANIC AZIDES

I) Ultraviolet spectra :

Rao et al(164) determined the u.v. spectra, in ethyl alcohol, for several aliphatic and aromatic azides e.g., ethyl azide absorb at (λ_{max} 287 nm , ϵ_{max} 0.020 x 10^{-3}) phenyl azide absorb at (λ_{max} 283, ϵ_{max} 1.550 x 10^{-3}), (λ_{max} 277 nm , ϵ_{max} 2.270 x 10^{-3}) and (λ_{max} 248 nm, ϵ_{max} 9.940 x 10^{-3}).

Sheniker et al(165) reported that the typical aliphatic azide such as ($Et-N_3$, N_3CH_2COOH) shows a characteristic absorption band at 2850 Å. The 2850 Å band disappears when conjugated with C=O. In aromatic azides, the intensity of 2850 Å band increases considerably, in $Ph-N_3$ by a factor 5 in $C_{10}H_7-N_3$ by a factor of B-10 as compared with $Et-N_3$ or N_3CH_2COOH.

2) Infrared spectra :

Rao et al(166) showed that the azide asymmetric vibration lies in the region of (2114 - 2083 cm^{-1}), and that it is partically independent of the environmental structure.

Varsanyi et al(167) investigated that the I.R. spectra in the range (2.8 - 15 μ) for phenyl azide, benzyl azide, 2,4,6-tribromophenyl azide, as liquids and they found that, in general the I.R. frequencies of three azides were similar to some lower values for benzyl, and 2,4,6-tribromophenyl azide because of their larger mass. Bands for the azido group for three azides, respectively at 2115, 2115 and 2108 for the asym-valence-vibration, 1294, 1256 and 1250, for the sym-valence vibration, 879, 875 and 857 for the RN_2-N deformation vibration and 670, 677, and 682 cm^{-1} possible azide vibration.

Sheniker et al$^{(168)}$ showed that the position of the azide band in the absence of conjugation is at (2110 - 2100 cm^{-1}), conjugation or presence of an electron acceptor group at α-C shifted this to (2166 - 2185 cm^{-1}), electron donor groups raised in intensity while electron acceptor group lowered it.

Sheniker et al$^{(169)}$ showed that the band position and integral intensities of ν(as)N_3 band occupy the (2170 - 2100 cm^{-1}) region rather than the narrower (2160-2120 cm^{-1}) region given previously in the literature in the aliphatic azides, the bands are found at 2110-2100 cm^{-1} conjugation with C=C, C=O, N=C, or SO_2 groups increases the wave number to (2150 - 2130 cm^{-1}). Conjugation with P=O, P=S or the presence of the electron acceptor at the α-C-atom increases the frequencies to (2163-6 cm^{-1}).

AIM OF THE PRESENT INVESTIGATION

It was stated previously that acetic acid azide(23,24) was easily decomposed to give methyl isocyanate.

In the present investigation we introduce phthalimido moiety in acetic acid molecule to see its effect on the stability of the azides obtained, and on the mode of acid-, and base-catalyzed decomposition.

Also, phthalimido moiety was introduced in benzoic acid molecule to see its effect on the stability of the azides obtained, and on the mode of acid-, and base-catalyzed decomposition.

The present investigation was also planed to synthesis N-aryl-N'-phthalimido methyl ureas, N,N'-di-[phthalimido] methyl ureas, and N-aroyl-phthalimido methyl amines via decomposition reactions of phthalimido acetic acid azides in different media.

It was also planed to synthesis sym.N,N'-di-[phthalimido]-phenyl-ureas, phthalimido-benzanilides, phthalimido benzoic acid hydrazides and N-aroyl-phthalimides via decomposition reactions of phthalimido benzoic acid azides in different media.