Diazo Ethers: Formation and Decomposition in the Course of Reactions Between Arenediazonium Ions and Different Alcohols

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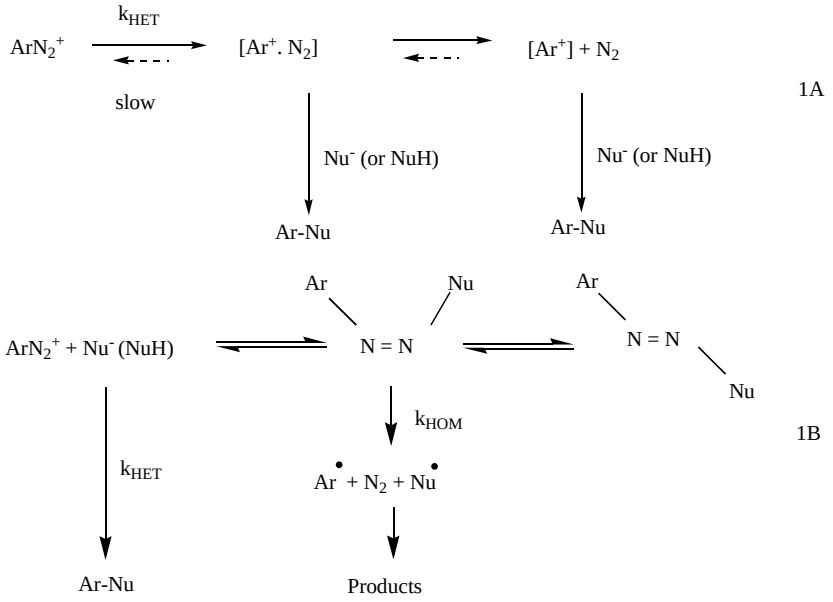
Abstract: The present review is aimed to summarize recent research on the O-coupling reactions of arenediazonium, ArN_2^+, ions with different alcohols under acidic conditions. Encapsulating in a nutshell their mechanisms, it appears that two possible products may be formed depending on experimental conditions, namely a highly unstable aryl cation, Ar^+, that yields substitution products and a reactive diazo ether, namely Ar-N=N-O-R, which initiates a radical mechanism through the formation of aryl radicals Ar• to yield reduction products.

INTRODUCTION

Arenediazonium, ArN_2^+, ions are important in preparative and synthetic chemistry [1-7] and became industrially significant after Griess [8] discovered the azo-coupling reaction, i.e. replacement of an electrofugic atom or group at a nucleophilic carbon atom by an arenediazonium ion. In addition to the well-known applications in synthetic and azo dye chemistry, new and interesting uses are emerging, e.g. ArN_2^+ ions are currently being used to modify carbon surfaces, [9] to probe interfacial compositions of colloidal aggregates, [10] and to assess the distribution of polar molecules in emulsions [11]. However, their use is not without potential hazard; under some conditions, some may be dangerously thermally unstable [2] and the role of some in carcinogenic and mutagenic processes is being explored [12].

Because of their well-recognized utility, the reactions of ArN_2^+ ions have stimulated mechanistic curiosity since the beginning of their extensive use. Their chemistry is very rich and complex, and in spite that thousands of publications about their reactions, scattered in many journals, reviews and books are available, some of their mechanisms are not completely understood and remain a matter of discussion nowadays [13-16].

It is currently accepted [1,2,5] that in aqueous acid, in the dark, ArN_2^+ ions spontaneously decompose via rate-determining loss of nitrogen to generate a highly reactive aryl cation that reacts with low selectivity with available nucleophiles, Scheme **1A** ($D_N + A_N$ mechanism). ArN_2^+ ions may also function either as 1-electron oxidants giving rise to different reduction products [17-23] and as



Scheme 1. Basic representation of the spontaneous $D_N + A_N$ dediazoniation mechanism (**1A**) showing the formation of a ion-molecule complex and a and a solvent separated ion-molecule pair leading to the formation of substitution Ar-Nu products and (**1B**) nucleophilic addition mechanism leading to the formation of Ar-N=N-Nu adducts in the (E)- and (Z)-configurations. Mechanism (**1B**) also shows the competitive spontaneous decomposition of ArN_2^+.

Lewis acids reacting with nucleophiles (Lewis bases, Nu^- or NuH followed by loss of a proton) to give covalently bonded adducts, ArN_2-Nu, at the β-nitrogen of the arenediazonium ion, which is the electrophilic reactive center, Scheme **1B** [1,5].

Examples of covalently bonded adducts are the azo dyes (C-coupling). Their formation has been extensively studied [4] and takes place when ArN_2^+ ions react with aromatic substrates containing strong electron donors such as hydroxy or amino groups, the reactivity order was found to be $-O^- > NR_2 > NHR > OR$ OH >> Me, [4]. C-coupling reactions are believed to proceed through the general electrophilic aromatic substitution, EAS, mechanism, Scheme **2**, involving the formation of a covalent complex (or σ

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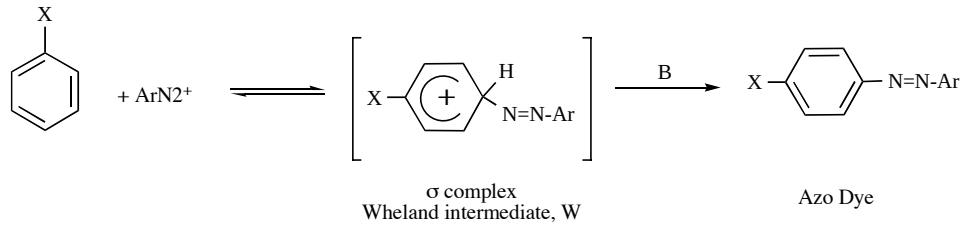
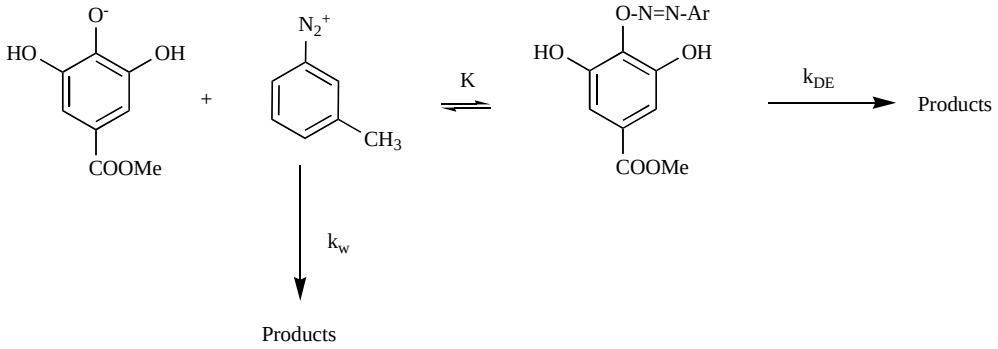


Scheme 2. Basic representation of a electrophilic aromatic substitution mechanism (C-coupling) leading to the formation of an azo dye.



Scheme 3. Proposed mechanism between 3MBD and the methyl gallate monoanion MG^- comprising the spontaneous $D_N + A_N$ pathway and a competitive reaction leading to the rapid formation of an transient intermediate DE that further decomposes [37].

complex, the Wheland intermediate, W), [4,5,24] followed by proton loss in a step which is usually considered, for the azo-coupling reaction, to be irreversible [25]. They are probably the EAS reactions characterized to the highest degree by its sensitivity to orientation and in practically all cases investigated, the reaction takes place exclusively at the o- and p-positions and, in fact, m-substitutions have never been observed [4,5,24].

However, atoms other than C may be involved [1,5] and ArN_2^+ ions may react with compounds bearing hydroxyl groups leading to the formation of diazo ethers of the Ar-N=N-O-R type, which are generally unstable and undergo further decomposition. Some representative examples that will be considered here are given in Schemes **3** and **4**.

In most instances analysed, the nucleophile must posses a negative charge, such as OH^-, CN^-, RO^-, and experimental conditions are chosen so that substantial concentrations of the anionic form of the nucleophile are present; [5,20,21,26] but formation of (Z)-diazoethers with neutral nucleophiles has also been reported [27-29]. For instance, the adducts formed by coupling ArN_2^+ ions with β-cyclodextrin were detected electrochemically [27,30] and this was exploited to get the first estimates of the association constants of aryl radicals to micellar and macromolecular systems [27,30,31].

Isolation and identification of the transient diazo ethers formed may be difficult because the stability of the adduct strongly depends on the leaving ability of the nucleophile, Scheme **1B**, so that if Nu^- is a good leaving group such as halide or acetate ions, the equilibrium lies largely on the side of the reactants and ArN_2^+ ions undergo spontaneous decomposition reactions which are believed to take place through a $D_N + A_N$ mechanism, Scheme **1A** [5,14,32]. On the other hand, if Nu- is a good nucleophile but a relatively poor leaving group (such as the ascorbate ion), stabilization may occur by conversion to a thermodynamically stable isomer (e.g., Z-E isomerization) [20,26]. In some circumstances, isomerization is not possible and the adduct splits homolitically to finally give reduction products [27-29].

Formation and Decomposition of Diazo Ethers with Anionic Nucleophiles

In this section we will focus on the formation and decomposition of diazo ethers in the course of dediazoniations with anionic O-nucleophiles. The reaction with OH^- will not be covered here and the interested reader is referred to more specialized reviews covering different aspects of the reaction [1,2,5,33-35]. It may be worth noting, however, that the reaction of ArN_2^+ with OH- ions is different with respect to other O-coupling reactions because deprotonation of the O-diazohydroxide adduct is possible leading to the formation of diazotates [5].

As noted before, ArN_2^+ ions may function readily as Lewis acids reacting with Lewis bases (nucleophiles), Nu^- or NuH (followed by loss of a proton) to give covalently bonded adducts, ArN_2-Nu, at the β-nitrogen of the arenediazonium ion. When ArN_2^+ ions react with aromatic substrates containing two ionizable groups (e.g. two hydroxy groups) at the nucleophilic arene nucleus, the reactivity of the substrate increases, but their effect has been proved not to be additive and strongly dependent on their relative positions in the benzene ring [1,2,5]. For instance, resorcinol (1,3 hydroxybenzene) has two ionized forms and has been shown as an example of a molecule having two nucleophilic centers able to couple, with the dianion coupling more than 10^4 times faster than the monoanion [5,36]. In contrast, the other two dihydric phenols, catechol (1,2-$C_6H_4(OH)_2$) and hydroquinone (1,4-$C_6H_4(OH)_2$) are oxidized in presence of diazonium ions and can undergo coupling reactions only under strictly defined conditions, for example, by first esterifying one of the hydroxyl groups and hydrolysing it later.

When the *o*- and *m*-positions of the hydroxy groups are blocked, diazo ethers may be readily formed and, in some instance, its formation and decomposition can be detected experimentally. For instance, Fig. (**1A**) shows typical absorbance-time profiles obtained upon reacting 3-methylbenzenediazonium, 3MBD, ions with methyl gallate, MG, where the absorbance increases rapidly at any [MG] up to a maximum after which a decrease is detected approaching a constant value that depends on the initial [MG] employed can be observed [37]. Similar biphasic profiles suggestive of

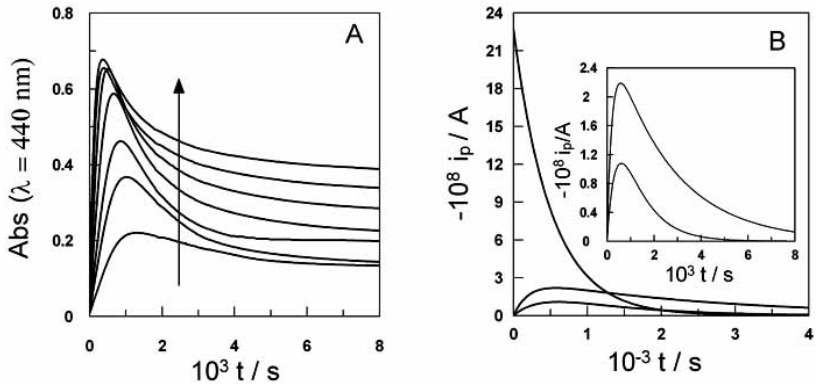


Fig. (1). A) Biphasic kinetic profile obtained monitoring product formation in the course of the reaction between 3-methylbenzenediazonium ions and methyl gallate. **B**) Variation in the peak current of the voltammetric reduction peaks detected in the course of the reaction. E_p = -0.05 V(β), E_p = -0.5 V (α) and E_p = -0.64 V (χ). The peak variation of the peak at E_p = -0.05 V (β) is associated to the loss of the arenediazonium ions. The inset is an amplification of the variation of the i_p of the reduction peaks associated with the formation and disappearance of the transient intermediate. The solid lines were drawn by fitting the experimental data to a first order equation (3MBD loss) and to an equation derived from a consecutive mechanism of the type A + B → I → Products. Adapted from S. Losada-Barreiro, V. Sánchez-Paz and C. Bravo-Díaz. *Helv. Chim. Acta*, **2007**, *90*, 1559-1573. Copyright Wiley-VCH Verlag GmbH & Co. KGaA. Reproduced with permission.

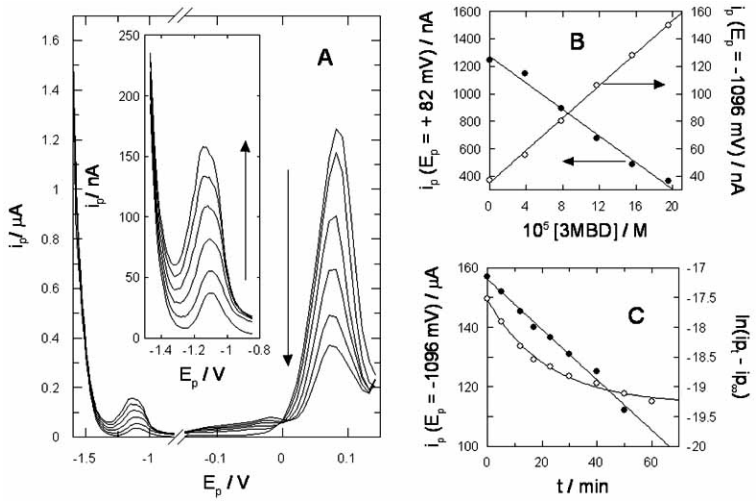


Fig. (2). A) Titration of 6-O-octanoyl-Ascorbic Acid (VC8) with aliquots of 3MBD at pH = 4 obtained at room temperature. The polarographic peaks of 3MBD are not observed (see text). **B**) Variation in the peak current of the polarographic peak detected at E_p = -1096 mV (○), which is attributed to the transient diazo ether formed between 3MBD and $VC8^-$, and the decrease in the peak current of the polarographic reduction peak of VC8 at E_p = +82 mV (●) upon titration. **C**) Variation in the peak current of the transient diazo ether with time at room temperature (○) and first-order plot (●). Reprinted with permission from U. Costas Costas, C. Bravo-Díaz and E. González-Romero. *Langmuir*, **2004**, *20*, 1631. Copyright 2004 American Chemical Society.

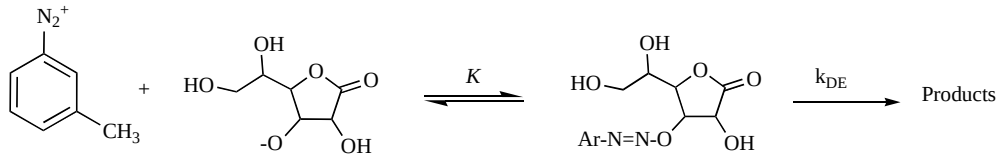
the formation of a intermediate were obtained on analyzing the effects of acidity at constant [MG] [37].

Moreover, the formation and decomposition of an intermediate was confirmed by employing electrochemical techniques, Fig. (**1B**), which also shows the variation of i_p with time of some reduction peaks detected in the course of the reaction. The saturation kinetics profiles obtained upon analyzing the effects of [MG] on k_{obs} at different pH substantiated the proposed mechanism shown in Scheme **3** [37].

The reactions of ArN_2^+ ions with ascorbic acid and some of its hydrophobic derivatives such as 6-O-octanoyl-ascorbic acid and 6-O-hexadecyl-ascorbic acid constitute another example of O-coupling reactions with anionic nucleophiles [20-23]. For these antioxidants, the formation of the adducts has been reported to be very fast and the intermediate could be evidenced by polarographic titration of the antioxidant with the arenediazonium ions, (Fig. (**2**)). Some stability has been assessed to the formed adduct and Doyle *et al.* were able to isolate and identify them [38]. Saturation kinetics were found on analyzing the effects of [antioxidant] on k_{obs}, leading to the proposal of the reaction mechanism shown in Scheme **4** [20,21].

Formation and Decomposition of Diazo Ethers with Neutral Nucleophiles: Alcoholyses of ArN_2^+ Ions Under Acidic Conditions

Much of the current knowledge on thermolysis of arenediazonium, ArN_2^+, ions in alcohols is based essentially on the work of Bunnett´s and Broxton´s groups in the 1960s-1980s; [1-3,5] for the most part carried out under alkaline conditions, that is, with solutions of metoxide ion in methanol. Under such conditions, both Z- and E-diazo ethers are formed in reversible reactions with half-lives of the order of a fraction of a second (Z) to a minute (E). The two diazo ethers are, however, unstable and decompose rapidly to the final dediazoniation products [5].



Scheme 4. Proposed mechanism for the reaction between 3-methylbenzenediazonium and ascorbate ions [20].

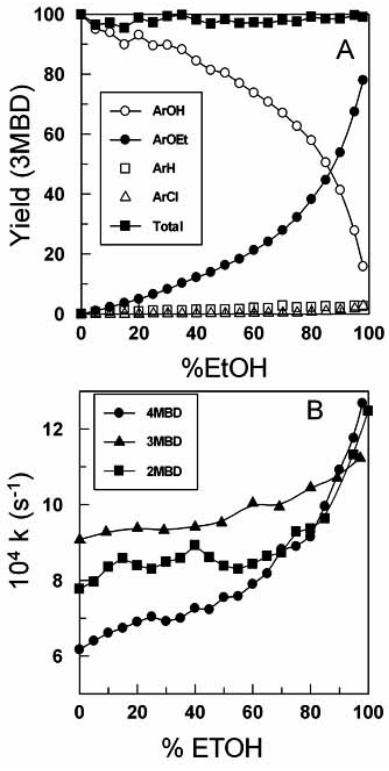


Fig. (3). A) Variation in k_{obs} for the solvolysis of toluenediazonium ions in EtOH under acidic conditions. **B**) Product distribution upon ethanolysis of 3-methylbenzenediazonium ions under acidic conditions. Adapted from R. Pazo-Llorente, C. Bravo-Díaz and E. González-Romero, Solvolysis of Some Arenediazonium Ions in Binary EtOH/H_2O Mixtures under Acidic Conditions. *Eur. J. Org. Chem.*, **2003**, 3421, Copyright Wiley-VCH Verlag GmbH & Co. KGaA. Reproduced with permission.

Much less work has been carried out under acidic conditions. In 1977, Bunnett and coworkers [39,40] published two papers on the thermolysis of arenediazonium, ArN_2^+, ions in acidic methanol seeking for evidence to probe, or discard, whether homolytic and heterolytic dediazoniations proceed via a common intermediate [41]. On the basis of kinetic and product distribution measurements, they concluded that in acidic methanol, dediazoniations take place through competing ionic and radical mechanisms, a conclusion substantiated in subsequent investigations by different researchers [14,15,32,42]. The proposed ionic mechanism is shown in Scheme **1B**, and they assumed that the radical pathway followed the propagation sequence postulated by DeTar and Turetzky [43], but could not find convincing evidence for the nature of the initiation step, hypothesizing a direct electron transfer from the methanol molecules to the ArN_2^+ ions. Based on the analyses of acidity on the ethanolyses of toluenediazonium ions, our laboratory recently proposed that the radical process was initiated by the homolytic splitting of transient diazo ethers which are formed by reaction of ArN_2^+ ions with the solvent.

The product distribution of the alcoholyses of toluenediazonium ions under acidic conditions was analyzed by HPLC over the whole composition range. Up to four dediazoniation products were detected in all runs, Fig. (**3A**), cresols (ArOH), methylphenetoles (ArOEt), toluene (ArH), and chlorotoluenes (ArCl; only obtained when HCl was employed as source of H^+ ions), with ArOH and ArOEt as the major ones. The sum of the yields of ArH plus ArCl is less than 5%. Fig. (**3B**) shows the kinetic results obtained for the ethanolyses at pH = 2 and, as observed, solvolytic rate constants increase modestly upon increasing the percentage of EtOH in the system. Changes in the electrolyte concentration (0 – 1 M) and acid concentration ([HCl = 10^2 – 1 M) did not result in significant changes in k_{obs} values [32,42,44] and chromatographic kinetic data [16,45,46] indicate that k_{obs} values for product (ArOH and ArOEt) formation are equal to each other and are the same as those obtained spectrophotometrically for ArN_2^+ loss, indicating that products are formed with the same half-life as that for ArN_2^+ loss.

The practical absence of reduction products indicates that, under acidic conditions, the reaction mainly proceeds through an ionic mechanism. In addition, a rate-limiting nucleophilic attack of a solvent molecule should produce a strong dependence of k_{obs} with the solvent composition, which is not observed, Fig. (**3A**), and therefore all evidence is consistent with the reaction mechanism shown in Scheme **1A**.

Consistent with this interpretation, the activation enthalpies found for the reactions, Table **1**, are relatively high, as in many unimolecular reactions, suggesting a transition state which has undergone bond breaking with little compensating bond making. The selectivity values of the presumed aryl cation, defined as in equation 1, are essentially constant with solvent composition, Table **1**, and are orders of magnitude lower than those reported for stabilized carbocations.

$$S_{Nu_2}^{Nu_1} = \frac{k_{Nu_1}}{k_{Nu_2}} = \frac{Yield_{Ar-Nu_1}[Nu_2]}{Yield_{Ar-Nu_2}[Nu_1]} \quad (1)$$

Surprisingly, the variation of k_{obs} with acidity follows a sigmoideal curve, Fig. (**4**), with k_{obs} being essentially constant up to pH =

Table 1. Determined Activation Energy and Activation Enthalpy for Ethanolysis of Toluenediazonium Ions Under Acidic Conditions and Selectivity of the Presumed Aryl Cation Towards Different Nucleophiles. 1) 0% EtOH. 2) 98%EtOH. Data from Pazo-Llorente *et al.* [32]

	E_a (1) kJ mol^{-1}	$\Delta H^{\#}$ (1) kJ mol^{-1}	E_a (2) kJ mol^{-1}	$\Delta H^{\#}$ (2) kJ mol^{-1}	S_W^{Cl-}	S_W^{MeOH}	S_W^{EtOH}
2MBD	108	106	106	103	2.7	0.4	0.5
3MBD	110	107	103	103	2.6	0.6	0.8
4MBD	112	110	116	114	1.7	0.7	0.7

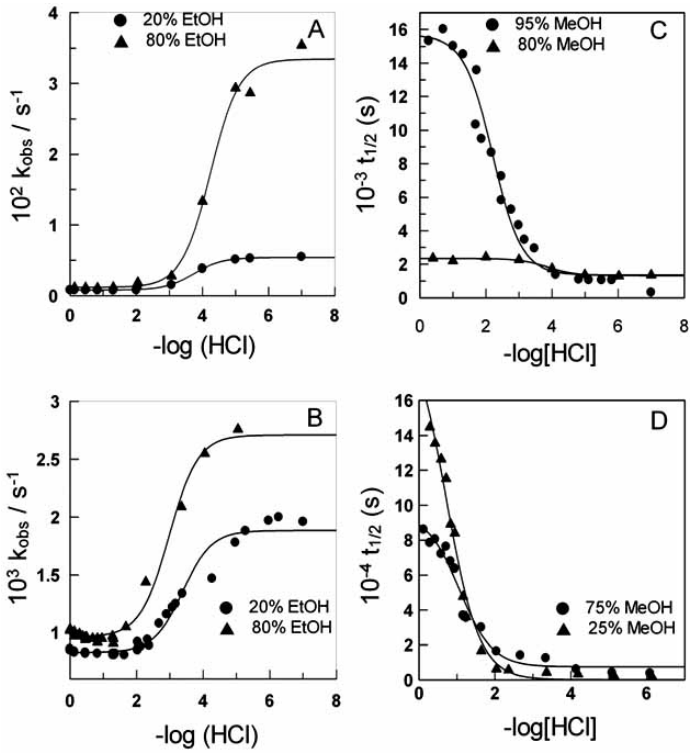


Fig. (4). Effects of acidity on k_{obs} for dediazoniation of 4MBD (**A**), T = 60 °C), 3MBD (**B**), T = 35 ºC), 4NBD (**C**), T = 50 ºC) and 4BrBD (**D**), T = 45 ºC). $[ArN_2^+] \sim 10^{-4}$ M.

Fig. (**A**) reproduced from *Eur. J. Org. Chem.*, **2004**, p. 3221-3226. Fig. (**B**) extracted from Pazo R, PhD Thesis, Universidad de Vigo, **2004**. Fig. (**C**) from *Eur. J. Org. Chem.*, **2006**, pp. 2201-2209 Copyright Wiley-VCH Verlag GmbH & Co. KGaA. Reproduced with permission. Fig. (**D**) from *Org. Biomol. Chem.*, (DOI 10.1039/b809521c). Reproduced by permission of the Royal Society of Chemistry.

3 followed by a sharp increase in k_{obs} upon decreasing the acidity. The extents of the increase in k_{obs} depend on the position of the substituent, for 4MBD is about 40 fold meanwhile that for 3MBD is about 3 times and 1.5 times for 2MBD, as well as on the percentage of MeOH in the system. Similar S-shaped variations were found when investigating the effects of acidity on the methanolysis of 4-nitrobenzenediazonium, 4NBD, and 4-bromobenzenediazonium, 4BrBD, ions, Fig. (**4C**) and (**4D**), respectively, but the rate increases are much larger. The kinetics are not, however, first order and for this reason in Figs. (**4C**) and (**4D**) half-life values are plotted instead of rate constants.

HPLC analyses of the reaction mixtures revealed that up to four main dediazoniation products can be detected – phenols, ArOH, phenetoles, ArOEt, or anisoles, ArOMe, chlorobenzenes, ArCl, and benzene derivatives, ArH, in addition to a number of minor ones depending on the substituents in the aromatic ring and on experimental conditions. Under acidic conditions, the major dediazoniation products are ArOH and ArOEt or ArOMe, but upon decreasing the acidity, the yields of the reduction product ArH becomes significative and quantitative conversion to this product can be achieved depending on experimental conditions. Fig. (**5**) is illustrative and shows the variation in the yields of the main dediazoniation products with the acidity under different experimental conditions for the ethanolysis of 4-methylbenzenediazonium ions.

Kinetic S-shaped plots such as those shown in Fig. (**4**) are usually observed in reactions of acid-base pairs where both forms are attainable and show different reactivity. Under the experimental conditions employed, only two species can undergo acid-base processes, the ArN_2^+ ions and ROH. Both have p*K*a values much higher than the working pH, [5] and so a hypothethical reaction of ArN_2^+ ions with hydroxide ions or alcoxide ions, as in alkaline media, appears unlikely. Changes in the nature of the acid (sulphuric instead of hydrochloric) did not result in significant changes in k_{obs} values, indicating that the observed S-shaped kinetic curves are not due to a change in the nature of the anions, which may act as nucleophiles.

Thus, both HPLC and kinetic results evidence a change in the mechanism of the reaction that is taking place under acidic conditions. Experimental data are consistent with a reaction mechanism such as that indicated in Scheme **1B**, from where equation 1 can be derived, and where k_{HET} and k_{HOM} stand for the rate constants for the spontaneous thermal heterolytic decomposition of ArN_2^+ and that for the decomposition of the diazo ether, respectively, and $K_1 = K$ [MeOH] with K standing for the equilibrium constant for diazo ether formation shown in Scheme **2**. Equation 1 is typical of processes where an S-shaped dependence of k_{obs} with -log[H^+] is observed.

$$k_{obs} = \frac{k_{HET}[H^+] + k_{HOM}K_1}{K_1 + [H^+]} \quad (2)$$

From equation 1, and by considering limits, we find that when $[H^+] >> K_1$, $k_{obs} \approx k_{HET}$, i.e., the reaction proceeds wholly through the $D_N + A_N$ mechanism and heterolytic products are obtained. On the other hand, when $[H^+] << K_1$, $k_{obs} \approx k_{HOM}$, i.e. the reaction proceeds wholly through the O-diazo ether and formation of reduction products is favoured. Solid lines in Figs. (**4**-**5**) were obtained by fitting the data to a titration curve of the Henderson-Hasselbach type, from where values of pK_1, k_{HET} and k_{HOM} can be obtained. Table **2** shows determined pK_1 values for different ArN_2^+ ions.

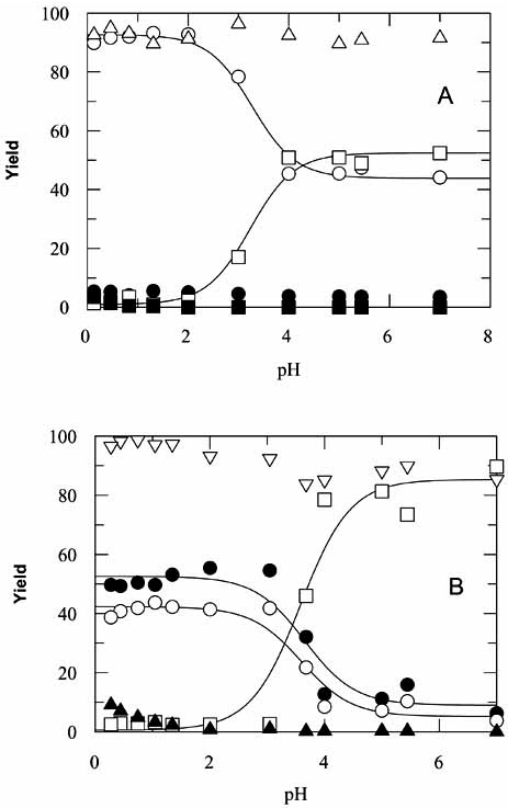


Fig. (5). pH-dependent product distribution for dediazoniation of 4MBD at 20% (**A**) and 80% (**B**) EtOH/H2O (v/v). ArOH (α), ArOEt (A), ArH (**A**), ArCl (χ), total (ArOH + Ar-OEt + ArH + ArCl) (X). Data from Pazo-Llorente, R.; Bravo-Díaz, C.; González-Romero, E. *Eur. J. Org. Chem.*, **2004**, pp. 3221-3226. Copyright Wiley-VCH Verlag GmbH & Co. KGaA. Reproduced with permission.

Table 2. Representative pK_1 Values the Diazo Ether Formation Obtained by Fitting the Experimental Kinetic or HPLC Data to Equation 1 [28,29]. Values for 4BrBD from Fernández-Alonso, A., Bravo, C. from *Org. Biomol. Chem.* (DOI 10.1039/b809521c). Reproduced by permission of the Royal Society of Chemistry. a) 20% EtOH, b) 80% EtOH, c) 95% MeOH, d) 90% MeOH, e) 25% MeOH, f) 75% MeOH

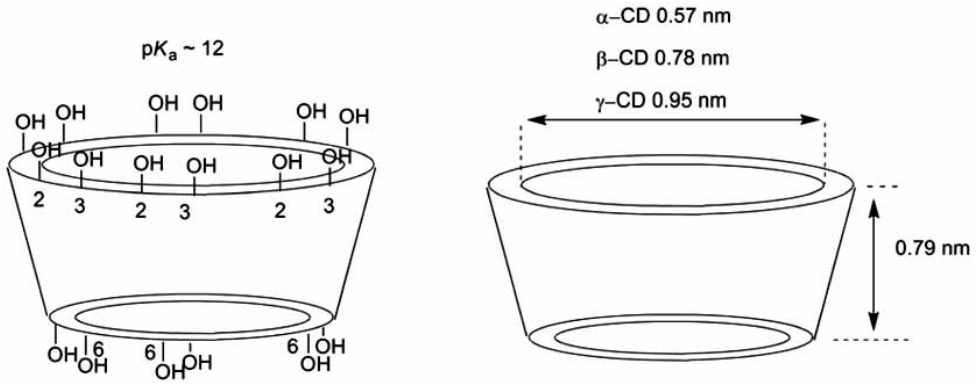
ArN_2^+	T (°C)	pK_1
2MBD	35	3.3[a] 3.6[b]
4MBD	60	3.4[a] 3.6[b]
4NBD	50	4.18[c] 2.20[d]
4BrBD	45	0.7[e] 1.2[f]

Reaction Between Arenediazonium Ions and Cyclodextrins: Formation of Diazo Ethers Under Restricted Geometry Conditions

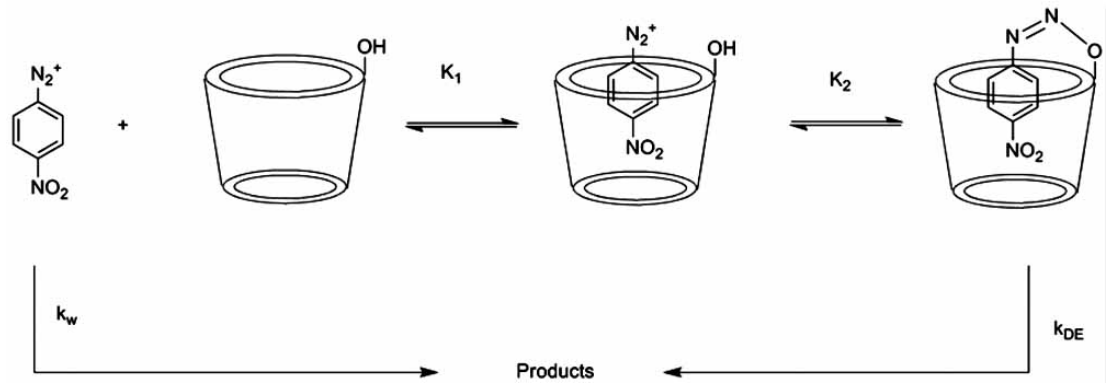
Cyclodextrins, CDs, are cyclic oligomers of a-D-glucose which are produced by enzymatic degradation of starch and are doughnut-shaped molecules formed by six, seven or eight glucose units, [47-50] Scheme **5**. The wider rim displays the C(2)- and C(3)-OH groups and the narrower rim displays the C(6)-OH ones on its flexible arm. These hydrophilic groups are on the outside of the molecular cavity whereas the inner surface is hydrophobic lined with the ether-like anomeric oxygen atoms and the C3-H and C5-H hydrogen atoms [49,51,52]. In aqueous solution, the hydrophobic cavity contains about 5 (α-CD), 7 (β-CD) or 17 (γ-CD) poorly held and easily displaceable water molecules showing a polarity lower than that of pure water, approximately equal to that of ethanol, where non-polar, suitably-sized, aliphatic and aromatic compounds can be hosted leading to the formation of inclusion complexes of different stoichiometry, typically 1:1, 2:1 and 1:2 CD to substrate ratios [51,52]. Such a property makes CDs to be widely used, for instance, to increase the water solubility of normally hydrophobic compounds.

The reactivity of some ArN_2^+ ions with CDs was investigated under acidic conditions [53]. Arenediazonium ions with electron-releasing substituents, such as $-CH_3$, do spontaneously decompose and no kinetic nor HPLC evidence of reaction with α-, β- or γ-CDs was found [53]. The results contrast with those observed when electron-withdrawing substituents are present in the aromatic ring, e.g. 4NBD [27,30]. In this case, the reaction is speeded by a factor of about 1700 on going from [β-CD] = 0 up to [β-CD] = 40 [4NBD]. This significant rate enhancement was rationalized in terms of the rapid inclusion of 4NBD, with the nitro group inserted into the CD cavity, Scheme **6**, followed by a pre-equilibrium step where the diazonium group reacts with the secondary hydroxy groups of the CD leading to the formation of a highly unstable diazo ether which further decomposes homolitically.

The formation of this diazo ether affects the product distribution. In the absence of CD, 4-nitrophenol is formed in quantitative yield [54]. However, the formation of the reduction product nitrobenzene is favoured upon increasing [β-CD] so that when [β-CD] > 20 quantitative conversion to nitrobenzene is achieved.



Scheme 5. Basic representation of natural cyclodextrins showing the hydroxyl groups and some relevant geometric parameters.



Scheme 6. Proposed mechanism for the reaction between 4NBD with β-CD in aqueous acid solution comprising the spontaneous decomposition of 4NBD, which leads to the formation of heterolytic products, and the formation of an inclusion complex followed by the formation of a unstable diazo ether that further decomposes homolitically leading to reduction products.

The possibility of 4NBD reacting with cyclodextrins without being incorporated into the CD cavity was discarded by blocking the CD upon addition of the ionic surfactant sodium dodecyl sulfate, SDS, to the system [55]. The SDS binding constant is very high, [55] K = 26800 M^{-1} and thus SDS is incorporated into the CD cavity leading to the formation of a nonreactive SDS/β-CD complex that releases 4NBD out of the CD cavity. As a consequence, addition of SDS to the 4NBD/β-CD system leads to a turnover of the homolytic mechanism to the heterolytic one and the formation of nitrobenzene is depressed with a concomitant increase in 4-nitrophenol formation, Fig. (**6**).

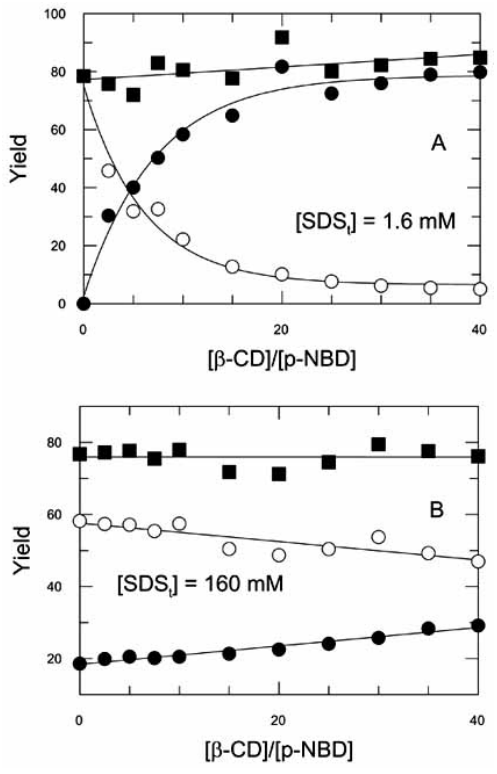


Fig. (6). Effects of [β-CD] on 4NBD dediazoniation product distribution in presence of a fixed [SDS_T]. α ArOH,)ArH, β Total (ArOH + ArH). **A**) [SDS_T] = 1.6x10^{-3} M. **B**) [SDS_T] = 0.16 M. [4NBD] ~ 2x10^{-4} M, [HCl] = 0.01 M, T = 60 ºC. Reprinted with permission from Bravo-Díaz, C.; González-Romero, E. *Langmuir*, **2005**, *21*, 4888. Copyright 2004 American Chemical Society.

CONCLUSIONS AND FUTURE PERSPECTIVES

The results shown here suggest that the formation of diazo ethers in O-coupling reactions under acidic conditions is much more common than it was believed. Until recently, most of the studies on their formation and decomposition were carried out under alkaline conditions, for instance the reaction of 4-nitro and 4-cianobenzenediazonium ions with MeO^- ions in methanol gives rise to the formation of 1:1 adduct in an equilibrium which lies strongly on the side of adduct (K > 10^7) [5].

Our data indicate that formation of diazo ethers under acidic conditions is not so favourable and that the formed diazo ethers are highly unstable species which undergo homolytic splitting leading to reduction products and special protocols and techniques must be employed to investigate them.

The results also suggest that both the formation and decomposition of diazo ethers depend on several factors such as the nature of the substituents in the aromatic ring and their position, the solvent, acidity of the medium, the presence of competing nucleophiles, temperature, etc. The role of these parameters has not been analyzed so far and further research addressing these points is needed.

Because diazo ethers split homolitically, reduction products are frequently observed in high yields, and thus the results obtained here indicate a simple, effective, and quick practical method for replacing an aromatic primary amino group by hydrogen via formation of ArN_2^+ ions, which can be prepared easily as tetrafluoroborates or acetates from readily available aromatic primary amines. These deamination processes involving reductive removal of the primary amine groups are particularly useful in synthetic aromatic chemistry because of the strong directing effects associated with amine substituents [56,57].

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