Thermal Decomposition of 2-(Cyanoethylthio)benzenediazonium Tetrafluoroborate in Acetonitrile Solution[1]

D. C. Lankin,[2] R. C. Petterson,* and R. A. Velazquez

Department of Chemistry, Loyola University (New Orleans), New Orleans, Louisiana 70118

Received May 3, 1974

The thermal decomposition of ortho-substituted arenediazonium tetrafluoroborate salts[3] in the presence of aliphatic or aromatic nitriles has been shown to result in the formation of the corresponding nitrilium tetrafluoroborate salts,[4] some of which have been isolated.[4a] If these nitrilium salts, formed *in situ*, are allowed to react with a substituent, either an aromatic ring[1c,5a] or a heteroatom,[5a-d] positioned ortho to it, a facile entry into a number of novel heterocyclic ring systems results. For example, the syntheses of substituted phenanthridines,[1b,5a] morphananthridines,[5a] dibenzo[*b,f*][1,4]oxazepines,[5a] dibenzo[*b,f*][1,4]thiazepines,[5a] 4*H*-[3,1]benzoxazines,[5a,b,d] and benzoxazoles[5c] have been described.

In a few examples cited where the nitrilium ion attacks a heteroatom,[5a-e] the heteroatom is usually unsubstituted.[6] It was of interest to us to investigate the decomposition of a diazonium salt in which the heteroatom is blocked by an alkyl group. We describe here a study of the decomposition of diazonium salt **2** in acetonitrile solution in which a cyclization reaction is observed, albeit accompanied by fragmentation.

The diazonium tetrafluoroborate salt **2**, readily obtained from the amine **1**,[7] was decomposed in refluxing acetonitrile solution. After aqueous bicarbonate work-up three products were obtained and identified as 3-(2-acetamidophenylthio)propionitrile (**3**), 2-methylbenzothiazole (**4**), and 3-(2-fluorophenylthio)propionitrile (**5**) (Scheme I).

Table I
Results of the Thermal Decomposition of 2 in Refluxing Acetonitrile[a]

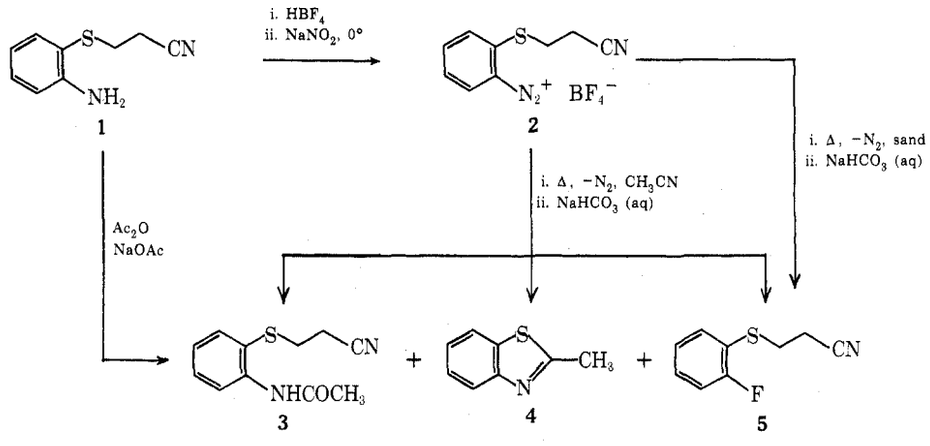
Concn of **2**, mol/l.	% yield[b] **3**	**4**	**5**
1.17	13	39	48
0.19	29	41	29
0.05	100		
0.02	100[c]		

[a] In each case, the reaction time was 20 hr. [b] Determined by nmr. [c] Analysis (tlc) of the crude reaction mixture, after hydrolysis and work-up, indicates the presence of a single component; recrystallization from toluene affords the amide **3**, mp 89–90°.

counts for the formation of the products **3–5**. In the first step the diazonium salt **2** undergoes decomposition in the acetonitrile solution with the evolution of nitrogen gas to form the nitrilium tetrafluoroborate salt **6**. This salt may cyclize in a reaction which is probably reversible to give **7**, and then fragment, with the loss of the cyanoethyl moiety, to give 2-methylbenzothiazole (**4**). The formation of the amide **3** undoubtedly arises from hydrolysis, during the work-up, of uncyclized nitrilium salt **6**, a reaction for which there is ample precedent.[4b] The fluoronitrile **5** most probably arises from the reaction of tetrafluoroborate ion with **2** (Baltz–Schiemann reaction),[11] although the formation of **5** from **6** cannot be ruled out.

As noted earlier, the product composition in the decomposition of **2** in acetonitrile solution varies with concentration (Table I). The variation of the amount of **3** and **5** appears to be consistent with two competitive divergent reaction pathways (Scheme II). In concentrated solution tetrafluoroborate ion competes favorably with acetonitrile in the reaction with **2**, and, as a result, the amount of fluoronitrile **5** which is formed, relative to the total amount of products (**3** + **4**) derived from the nitrilium ion **6**, is appre-

Scheme I

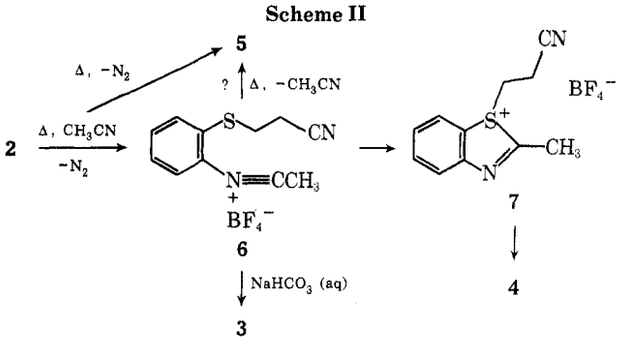


The ratio of these products was found to vary dramatically with concentration as may be seen by the product ratios summarized in Table I.

The structure of amide **3** was confirmed by independent synthesis from the amine **1**. The benzothiazole **4** was identified by comparison of its infrared and pmr[8] spectra and glc retention times with those of **4** obtained commercially. The structure of the fluoronitrile **5** follows from its elemental analysis, infrared and pmr[9] spectra, mass spectral fragmentation pattern,[10] and independent synthesis from **2**.[11,12]

In Scheme II we outline a possible mechanism which ac-

Scheme II



ciable. In contrast, in dilute solution the reaction of acetonitrile with **2** is dominant and in very dilute solution no product derived from reaction of tetrafluoroborate ion with **2** could be detected and only the amide **3** was obtained.

One puzzling aspect of the decomposition of **2** in acetonitrile is the way in which the yield of benzothiazole **4** varies with concentration. The fact that **4** is only obtained from the decompositions of **2** in relatively concentrated solutions and that **4** is totally absent from the products of decomposition of **2** in dilute solutions argues against a unimolecular decomposition of the presumed intermediate cyclic sulfonium salt **7**. It would appear that one or more of the starting materials or products is involved in the decyanoethylation of **7** to give **4**.[13] Solvation effects on intermediates **6** or **7** might also play a role in the variation in the amounts of **4** as well as **3** and **5** which are formed. The reaction sequence to give **4**, as we have formulated it, is undoubtedly an incomplete oversimplification of the actual events and, in reality, may be considerably more complicated. Further studies, involving the synthesis of heterocyclic ring systems using diazonium salts, are continuing.

Experimental Section

General Procedures. Spectra were determined as follows: ir, Vaseline mull, Perkin-Elmer 337; nmr, $CDCl_3$ solution, Varian A-60A; mass spectra, Hitashi Perkin-Elmer RMU-6A operating at 70 eV. Elemental analyses were performed by Chemalytics, Inc., Tempe, Ariz. Melting points were measured in a Thomas-Hoover apparatus and are uncorrected. Analysis by thin layer chromatography (tlc) involved the use of Eastman Kodak precoated silica gel sheets, with fluorescent indicator, as the adsorbent, elution with chloroform, and visualization with iodine vapor and/or with ultraviolet light. Analysis by glc was performed using a 210 × 0.6 cm i.d. Pyrex column packed with 25% DC Hyvac silicone grease on 60–80 mesh Chromosorb P at 190°. Preparative separations were performed using an annular column 160 cm long made of a 3.2-cm o.d. Pyrex tube surrounding an inner 1-cm o.d. sealed Pyrex tube the annular space of which was packed with 20% silicone grease on 60–80 mesh Chromosorb P at 140°.

Preparation of 3-(2-Aminophenylthio)propionitrile (1). A solution of freshly distilled *o*-aminothiophenol (50.1 g, 0.40 mol) in acrylonitrile (42.6 g, 0.77 mol) was stirred for 0.5 hr at room temperature and then allowed to stand overnight. The crude product was distilled at 1 atm and two fractions, bp 62 (*ca.* 5 ml) and 76° (*ca.* 35 ml), were discarded. The remainder was distilled at reduced pressure, providing the aminonitrile **1**, 53.5 g (74%), bp 128–134° (0.12 Torr), which solidified, giving almost colorless crystals, mp 44–46°. Recrystallization from benzene raised the melting point to 45.5°.

Anal. Calcd for $C_9H_{10}N_2S$: C, 60.64; H, 5.61. Found: C, 60.43; H, 5.61.

Ir (Vaseline) 3490 m, 3390 (NH_2), 2260 w–m (CN), 750 cm^{-1} s (aromatic ring, 1,2 disubstituted[14]); nmr ($CDCl_3$) δ 2.47 (2 H, m, $-CH_2CN$), 2.98 (2 H, m, $-CH_2S-$), 4.21 (2 H, br s, $-NH_2$), 7.37–6.40 (4 H, m, aromatic).

An alternate method of preparing **1** was also evaluated. A solution of 2-aminothiophenol (125 g, *ca.* 1.0 mol) in acrylonitrile (200 ml) was stirred for a total of 48 hr. The excess acrylonitrile was removed by distillation at 1 atm and the residual material was recrystallized three times from toluene to give 49.8 g (28%) of **1**, mp 41–42.5°. The yield of **1**, prepared in this way, was not optimized, and a work-up of the mother liquors would probably have raised the yield significantly.

Synthesis of 2-(Cyanoethylthio)benzenediazonium Tetrafluoroborate (2). To a cooled (−5°), vigorously stirred solution of **1** (10.1 g, 0.057 mol) in 48–50% fluoroboric acid (50 ml) was added dropwise during 25 min a solution of sodium nitrite (12.0 g, 0.174 mol) in 10 ml of water. The temperature was maintained between −5 and 0°. After addition was complete, the green slurry was stirred for an additional 10 min and then filtered. The crystals were washed with cold ether and dried at 25° under vacuum, affording 14.3 g (90.5%) of **2**, mp 82–83° dec, which was stored at 0° in an aluminum foil-wrapped bottle. Recrystallization of **2** from methanol–ether raised the melting point to 86.5° dec.

Anal. Calcd for $C_9H_8BF_4N_3S$: C, 39.01; H, 2.89. Found: C, 39.28; H, 2.71.

Ir (Vaseline) 2230–2250 m (CN, N_2^+), 1460 s, 1370 m, 1040 m, v broad, 760 cm^{-1} s (aromatic ring, 1,2-disubstituted[14]).

The tetrafluoroborate salt **2** is a yellow, crystalline solid which is stable indefinitely when kept at 0° and protected from moisture and light. The salt **2** appears to decompose slowly if kept at room temperature. The decomposition is indicated by a darkening of the yellow color of the crystals.

Thermal Decomposition of 2 in Acetonitrile Solution. General Procedure. An acetonitrile solution of **2** in a round-bottomed flask equipped with a reflux condenser, magnetic stirrer, and gas bubbler was plunged into a preheated (95–100°) oil bath. After a few minutes gas evolution began and the solution started to reflux. Gas evolution ceased after 20–30 min and boiling was continued for a total of 20 hr. The reaction mixture was cooled, the acetonitrile was removed under vacuum, and the residue was dissolved in $CHCl_3$ (50–100 ml). The $CHCl_3$ solution was then washed with saturated aqueous $NaHCO_3$ solution (3 × 75 ml) and dried (anhydrous Na_2SO_4) and the $CHCl_3$ was evaporated. Table I summarizes the detailed results of these decompositions.

Thermal Decomposition of 2 in Sand. The diazonium fluoroborate **2** (5.0 g, 0.18 mol) was combined with 50 g of sand and placed in a flask that was heated to 80–85°. Gas evolution had ceased and the color of the diazonium salt had disappeared after 15–20 min, but heating was continued for a total of 1 hr. After cooling the sand was leached overnight with methylene chloride, which was washed with saturated sodium bicarbonate solution, dried (anhydrous sodium sulfate), and evaporated, giving 2.6 g (80%) of an oil which was shown to be **3-(2-fluorophenylthio)propionitrile (5)**. An analytically pure sample of **5** was obtained by preparative glc.

Anal. Calcd for C_9H_8FNS: C, 59.64; H, 4.45. Found: C, 59.81; H, 4.54.

Ir (film) 3050 w, 2925 w, 2240 m (CN), 1260 m, 1220 m, 1120 m, 1070 m, 955 w, 815 m, 750 cm^{-1} s (aromatic ring, 1,2-disubstituted[14]); nmr ($CDCl_3$) δ 2.50 (2 H, m, $-CH_2CN$), 3.08 (2 H, m, $-CH_2S-$), 7.55–6.66 (4 H, m, aromatic); mass spectrum *m/e* (rel intensity) 181, M^+ (53), 141 (100), 127 (13), 83 (33).

Acetylation of 3-(2-Aminophenylthio)propionitrile (1). A solution of **1** (1.07 g, 0.59 mol) in acetic anhydride (25 ml) with a catalytic amount of sodium acetate was heated at 90° for 3 hr. The solution was cooled and poured over ice with stirring. The resulting solid was collected, washed with water, and dried, providing 1.24 g (95%) of crude product. Recrystallization from toluene gave analytically pure **3-(2-acetamidophenylthio)propionitrile (3)**, mp 89.5–90°.

Anal. Calcd for $C_{11}H_{12}N_2OS$: C, 59.97; H, 5.49. Found: C, 59.82; H, 5.55.

Ir (Vaseline) 3040 m (NH), 2230 m (CN), 1660 (amide I, C=O), 1525 m, 1565 m (amide II), 1010 m, 750–760 cm^{-1} s (aromatic ring, 1,2-disubstituted[14]); nmr (DMSO-d_6) δ 2.68 (2 H, m, $-CH_2CN$), 3.09 (2 H, m, $-CH_2S-$), 2.08 (3 H, s, $COCH_3$), 7.66–7.00 (4 H, m, aromatic), 9.11 (1 H, br s, NH).

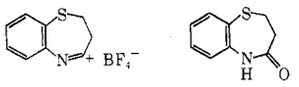
Acknowledgments. We are grateful to the Edward G. Schlieder Educational Foundation and to the National Science Foundation (GP-11004) for support of this study. We thank Professor Gary W. Griffin and the University of New Orleans for making available to us the nmr spectrometer which was employed in this work. R. A. V. wishes to thank the Office of Education for a NDEA Fellowship.

Registry No.—**1**, 4327-52-0; **2**, 51932-75-3; **3**, 37587-95-4; **4**, 120-75-2; **5**, 51932-76-4; *o*-aminothiophenol, 137-07-5; acrylonitrile, 107-13-1.

References and Notes

(1) (a) Presented at the Louisiana Section of the American Chemical Society 11th Annual Meeting-in-Miniature, April 26, 1974. (b) Arenediazonium Ion Reactions. III. (c) For the previous paper in this series, see R. C. Petterson, J. T. Bennett, D. C. Lankin, G. W. Lin, J. P. Mykytka, and T. G. Troendle, *J. Org. Chem.*, **39**, 1841 (1974).
(2) Postdoctoral Research Fellow, Loyola University, 1973.
(3) For a general discussion of arenediazonium salt decompositions, see H. Zollinger, *Accounts Chem. Res.*, **6**, 335 (1973), and references cited therein.
(4) (a) In the case of the decomposition of simple arenediazonium tetrafluoroborates in nitrile solution, the resulting nitrilium tetrafluoroborates may, in some instances, be isolated; see F. Klages and W. Grill, *Justus Liebigs Ann. Chem.*, **394**, 21 (1955); H. Meerwein, P. Laach, R. Mersch, and J. Spille, *Chem. Ber.*, **89**, 209 (1956). (b) These salts are further hy-

drolyzed by the addition of water to the corresponding amides; see L. G. Makarova and A. N. Nesmeyanov, *Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 887 (1954); *Chem. Abstr.*, **50**, 5548 (1956).
(5) (a) R. R. Schmidt, W. Schneider, J. Kang, and O. Burkert, *Chem. Ber.*, **103**, 1634 (1972); (b) R. R. Schmidt and W. Schneider, *Tetrahedron Lett.*, 5095 (1970); (c) J. M. Birchall, R. N. Haszeldine, J. N. Kokavouras, and E. S. Wilks, *J. Chem. Soc. C*, 562 (1971); (d) R. C. Petterson, unpublished observations.
(6) (a) The diazotizations of *o*-phenylenediamine to give benzotriazole[6b] and *o*-aminothiophenol to give benzothiadiazole,[6c] respectively, could be considered examples which fit this type of reaction. In these cases, the nitrogen of the diazo group is not lost but instead cyclizes onto the adjacent amino and thiol group, respectively. (b) P. Ladenburg, *Ber.*, **9**, 219 (1876); A. O. Fitton and R. K. Smalley, "Practical Heterocyclic Chemistry," Academic Press, New York, N. Y., 1968, p 47 ff. (c) P. Jacobson, *Ber.*, **21**, 3104 (1888); P. Jacobson and H. Janssen, *Justus Liebigs Ann. Chem.*, **277**, 218 (1893).
(7) N. M. Bikales, U. S. Patent 3,211,718 (1965); *Chem. Abstr.*, **64**, P845*f* (1966).
(8) N. S. Bhacca, L. F. Johnson, and J. N. Shoolery, "High Resolution NMR Spectra Catalog," Vol. I, Varian Associates, Palo Alto, Calif., 1962, Spectrum No. 191.
(9) (a) For a detailed discussion and interpretation of the pmr spectra of related 1,2-disubstituted ethane derivatives, see R. C. Hirst and D. M. Grant, *J. Chem. Phys.*, **40**, 1909 (1964); (b) E. O. Bishop in "Nuclear Magnetic Resonance for Organic Chemists," D. W. Mathieson, Ed., Academic Press, New York, N. Y., 1967, Chapter 7, pp 103–127.
(10) For examples of fragmentation patterns of arylthio ethers, see H. Budzikiewicz, C. Djerassi, and D. H. Williams, "Mass Spectrometry of Organic Compounds," Holden-Day, San Francisco, Calif., 1967, p 286 ff.
(11) Summaries of the Baltz–Schiemann reaction have appeared: (a) A. E. Pavlath and A. J. Leffler, "Aromatic Fluorine Compounds," Reinhold, New York, N. Y., 1962; (b) H. Suschitzky, *Advan. Fluorine Chem.*, **4**, 1 (1965); (c) P. Roe, *Org. React.*, **5**, 193 (1949).
(12) (a) It should be noted that no products, which could be derived from the imino carbocation (i), arising from intramolecular cyclization of the cyanoethyl moiety, were obtained. For example, aqueous hydrolysis of i would undoubtedly lead to ii. Thin layer chromatographic analysis of the



i ii

reaction mixture and of a pure sample of ii[12b] proved that none of ii was present among the reaction products.[12c] (b) W. H. Mills and J. B. Whitworth, *J. Chem. Soc.*, 2738 (1927). (c) We have decomposed **2** in a variety of other organic solvents, in hopes that the intramolecular cyclization might be observed. Thus far, only complex mixtures of products, largely derived from reactions of the solvents with **2**, have been obtained.
(13) The fate of the cyanoethyl moiety in the conversion **7** → **4** is not known with certainty. Decyanoethylation of **7**, for example, may conceivably occur by (a) elimination as acrylonitrile, (b) elimination as β-fluoropropionitrile from attack of BF_4^- at the carbon which is β to the cyano group in **7**, or (c) β-hydroxypropionitrile formed during the hydrolytic work-up. In a single experiment, we have identified (glc) acrylonitrile (route a) in the reaction mixture, prior to hydrolysis. However, it is not known whether pathways b or c are also involved or at what stage (before hydrolysis or during hydrolysis) decyanoethylation actually occurs.
(14) K. Nakanishi, "Infrared Absorption Spectroscopy," Holden-Day, San Francisco, Calif., 1964, p 27.

Preparation of Some Bicyclo[3.3.1]nonane Derivatives from Adamantanone

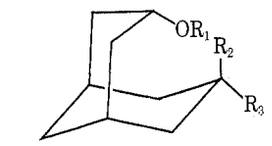
David P. G. Hamon* and Garry F. Taylor

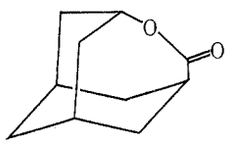
Department of Organic Chemistry, University of Adelaide, Adelaide, South Australia, Australia, 5000

Received March 12, 1974

In connection with syntheses in these laboratories, the compound **1** was desired. In an attempt to prepare it the following approach was adopted; however, this gave the epimeric compound **6.**

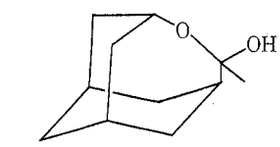
Addition of slightly more than 1 equiv of methylmagnesium iodide to the lactone **2**,[1] obtained by Baeyer–Villiger oxidation of adamantanone, gave a monoadduct in 80% yield. The infrared spectrum showed absorptions at 3370 and 1720 cm^{-1} consistent with the structural formula **3.** The nmr spectrum was more consistent with a mixture of **3** and the cyclic hemiacetal **4** (in the ratio 1:4). Attempts to

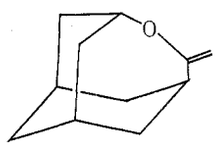




1, $R_1 = R_3 = H$; $R_2 = CH_3C{=}CH_2$ **2**

3, $R_1 = R_3 = H$; $R_2 = COCH_3$
6, $R_1 = R_2 = H$; $R_3 = CH_3C{=}CH_2$
7, $R_1 = R_2 = H$; $R_3 = COCH_3$
8, $R_1 = R_3 = COCH_3$; $R_2 = H$
9, $R_1 = COCH_3$, $R_2 = H$; $R_3 = CH_3C{=}CH_2$





4 **5**

acetylate or benzoylate this product in pyridine gave a mixture of unchanged starting material and a liquid product in both cases. The spectral properties of the new product were consistent with the structure **5:** ν_{max} 1650 cm^{-1} (enol ether); nmr (CCl_4) δ 4.62 (methylene group).

A Wittig reaction[2] on the ketol **3** using methylenetriphenylphosphorane in ether was incomplete even after 48 hr. However, a compound having spectral properties consistent with the structure **1** could be isolated in 60% yield: ν_{max} 3350, 3080, 1640, and 885 cm^{-1}; nmr (CCl_4) δ 4.66 (methylene protons), 3.95 (proton next to oxygen), 3.14 (hydroxylic proton), and 1.68 (vinylic methyl group).

Because of the sluggishness of the Wittig reaction, epimerization at the center C_7 in the ketol **3** may have occurred prior to reaction. Therefore doubt existed as to whether the compound formed had structure **1** or structure **6.** The configuration of the isopropenyl side chain was established in the following manner.

Equilibration[3] of the ketol **3** with sodium methoxide in methanol gave a mixture of epimers in approximately a 1:1 ratio which could be separated by preparative tlc. The compound of lower R_f was the new epimer **7** which was readily converted to the acetate **8.** Moreover, the Wittig reaction on the ketol **7** was complete in less than 15 hr and gave a compound identical in all respects with that prepared from the ketol **3.** Furthermore, this compound from the Wittig reactions was converted to its acetate **9** and the double bond in the molecule was cleaved by ozonolysis to give a compound which was identical by melting point and mixture melting point to the compound **8** prepared above. This establishes that the product of each Wittig reaction is the compound **6,** the C_7 epimer of compound **1.**

Experimental Section

General Melting points were recorded on a Kofler hot stage and are uncorrected. Infrared spectra were recorded on a Perkin-Elmer 337 spectrophotometer. Nmr spectra were recorded on a Varian T-60 spectrometer using TMS as an internal standard. Mass spectra were recorded on a Hitachi Perkin-Elmer RMU-6D spectrometer. Elemental analyses were performed by the Australian Microanalytical Service, Melbourne. All preparative tlc plates were prepared from 50% Kieselgel G and 50% HF 254 applied to the glass plates as a suspension in water, and activated at 120°.

endo-**7-Acetyl-***endo*-**3-hydroxybicyclo[3.3.1]nonane (3).** Methylmagnesium iodide (6 ml, 2.33 *M*, 0.013 mol) was added slowly under nitrogen to a stirred solution of the lactone **2** (1.8 g, 0.01 mol) in ether (20 ml) and after the addition stirring was continued for a further 2 hr at 20°. The mixture was cooled, treated with saturated ammonium chloride solution (10 ml), and extracted