Dyes and Pigments, Vol. 27, No. 4, pp. 287–296, 1995

0143-7208/95 $9.50 + 0.00
0143-7208(94)00054-9

Nitration of Carbazole and *N*-Alkylcarbazoles

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(Received 15 August 1994; accepted 20 September 1994)

ABSTRACT

The nitration in 1,2-dichloroethane of carbazole and N-*alkylcarbazoles, which were synthesized using a phase-transfer reaction, was studied. The results show that 3-nitrocarbazoles and 3,6-dinitrocarbazoles are the main reaction products. Both the reaction conditions and the nature of the* N-*alkyl group influence the formation of, and the ratio of, the mononitrocarbazoles and dinitrocarbazoles.*

INTRODUCTION

Carbazole is a valuable component of coal tar and its use has been investigated in e.g. synthetic dyes,[1–3] agrochemicals,[4] pharmaceuticals,[5] sensitive materials,[6,7] surfactants[8,9] and polymers.[10] Aminocarbazoles and amino-*N*-alkylcarbazoles are the main intermediates used in these fields. The synthesized products are usually a mixture containing isomers, separation of which is difficult, resulting in a relatively high cost of the final products. Whilst the actual industrial use of carbazole is limited, much of it being used for conversion to carbon black, in view of the potential use of aminocarbazoles and amino-*N*-alkylcarbazoles as intermediates in the fine chemicals industry, we have attempted to obtain high yield and purity of nitrocarbazoles and *N*-alkyl-nitrocarbazoles; aminocarbazoles may be then obtained by reduction processes. We report here the synthesis of a series of nitrocarbazole derivatives and an evaluation of the influence of nitrating agents and reaction conditions on the ratio of the nitro isomers and their yield.

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EXPERIMENTAL

All melting points reported are uncorrected. TLC was used to identify the products of the nitration, and the amount of each constituent was determined using a dual wavelength TLC scanner (Shimadzu) CS-910. IR spectra were recorded on a Perkin–Elmer model 397 and ^{1}H NMR spectra on a Varian 90 MH EM360L, using TMS as internal standard; chemical shifts are given as δ (ppm).

N-alkylcarbazoles

Carbazole (0·06 mol) was added to a mixture of 50% aq. NaOH (35 ml), benzene (5 ml) and benzyltriethyl ammonium chlorate (BTEAC) (0·04 g) as phase-transfer catalyst. The mixture was stirred at 30°C, and methyl iodide (5·6 ml, 0·09 mol) slowly added; the reaction was continued for 2 h (monitoring by TLC), after which time no carbazole was present. The liquor was poured into hot water (60°C, 800 ml) and after standing overnight, filtered and the product washed several times with water, dried and recrystallized from ethanol (m.p. 88–89°C, yield 86%).

The synthesis of other *N*-*R*-carbazoles was similarly effected.

Mononitro-*N*-alkylcarbazoles

N-methylcarbazole (5·2 g, 0·028 mol) was dissolved in 1,2-dichloroethane (50 ml) and the solution cooled (ice-water bath) to 10°C. Concentrated nitric acid (65–68%, 3 g, 0·031 mol) was dropped in over 1 h with vigorous stirring. Stirring was continued for a further 1 h at 10°C, after which time the *N*-methylcarbazole had all reacted. The liquor was steam distilled to remove 1,2-dichloroethane; the mixture was cooled and filtered and the product washed several times with water, giving 6 g of product (yield 92·4%, purity 85·9%, m.p. 169–70°C after recrystallization from ethanol).

Other *N*-*R*-3-nitrocarbazoles were similarly prepared.

3,6-Dinitro-*N*-alkylcarbazoles

N-methylcarbazole (5·2 g, 0·028 mol) was dissolved in 1,2-dichloroethane (50 ml) and the solution cooled (ice-water bath) to 10°C. A mixture of fuming nitric acid (95–98%, 23 g) and an equal volume of 1,2-dichloroethane was added over 1 h with vigorous stirring and the mixture then heated to 40–50°C for 3·5 h. After cooling to room temperature, the product was filtered, washed several times with water and dried to give 7 g of a yellow powder (yield 90%, *N*-methyl-3,6-dinitrocarbazole content 83·3%).

The synthesis of other *N*-*R*-3,6-dinitrocarbazoles was carried out using a similar process.

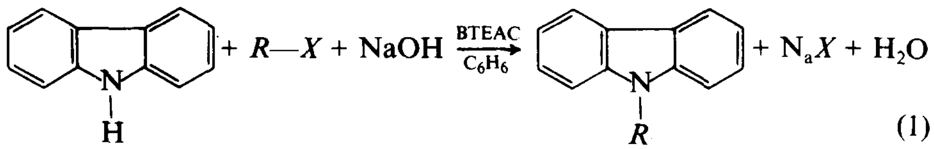
3,6-Dinitrocarbazole

A stirred slurry of carbazole (5 g) in 1,2-dichloroethane (100 ml) was cooled to 10°C and 95–98% nitric acid (7·3 ml) diluted with an equal volume of 1,2-dichloroethane was added dropwise; the system was then heated to 40–50°C and stirred for 3·5 h. After cooling to room temperature, the precipitate was collected and dried (yield 88·4%). The melting points of 3,6- and 1,6-dinitrocarbazole were 386°C and 346°C, respectively.

RESULTS AND DISCUSSION

Synthesis of *N*-alkylcarbazoles

The sodium salt of carbazole, produced from the carbazole and sodium hydroxide, reacted in the aqueous phase under the reaction conditions used with benzyltriethyl ammonium chlorate (BTEAC) as phase-transfer catalyst, giving the quaternary ammonium salt. The quaternary ammonium salt could then be transferred into the benzene phase to undergo nucleophilic reaction with alkylhalides. *N*-Alkylcarbazoles were thus obtained and the catalyst was recovered into the aqueous phase to continue the recycle. The products showed only one spot on TLC (silica gel; benzene : hexane : acetone 48 : 48 : 4 v/v) after recrystallization from ethanol.



(1)

Results and reaction conditions are shown in Table 1.

Mononitration

The main products of the mononitration were *N*-*R*-3-nitrocarbazoles when using 65–68% nitric acid as nitrating agent. The conversion of *N*-*R*-carbazoles was 100%, and the yields of the 3-nitro-*N*-*R*-carbazoles are shown in Table 2.

TABLE 1
Synthesis of *N*-*R*-Carbazoles

R	*R-X*	*R-X/carb. (mol)*	*T (°C)*	*t (h)*	*Yield (%)*	R_f	*M.p. (°C)*
CH_3	CH_3I	1·5	30	2·0	82·9	0·81	88–89
C_2H_5	C_2H_5Br	1·5	33–35	2·0	86·0	0·80	67–68
n-C_4H_9	n-C_4H_9Br	1·25	70–75	1·0	87·1	0·86	58–59
$CH_2C_6H_5$	$C_6H_5CH_2Cl$	1·25	70–75	1·0	91·0	0·84	118–119

The nitration of aromatic compounds using nitric acid in a neutral organic solvent involves the following:

$$2HNO_3 \rightleftharpoons NO_3^- + H_2NO_3^+ \tag{2}$$

$$H_2NO_3^+ \rightleftharpoons H_2O + NO_2^+ \tag{3}$$

$$ArH + NO_2^+ \rightleftharpoons ArHNO_2^+ \tag{4}$$

$$ArHNO_2^+ \rightarrow ArNO_2 + H^+ \tag{5}$$

A σ-complex intermediate is initially formed from the nitronium ion and carbazole during the nitration. The stability of this intermediate is the decisive factor influencing the position of the entering nitro group. The resonance structure for the *ortho*- or *para*-σ-complex in carbazole is stabilized by the effect of the unshared pair of electrons on the N atom; the *para*-σ-complex is much more stable than the *ortho*-analogue, due to the spatial effect of the substituent on the nitrogen atom and also the field effect, so that the 3- and 6-positions are the most reactive. The main product of mononitration is therefore the 3-nitro derivative; formation of the 1-nitro derivative and of dinitro compounds is minimal. On TLC (silica gel; benzene : chloroform 2 : 1), the R_f values of the 3-nitro-, 1-nitro-, and dinitro derivatives are 0·45–0·56, 0·70–0·75 and 0·22–0·30, respectively.

TABLE 2
Synthesis of *N*-*R*-3-Nitrocarbazoles

R	*T (°C)*	*t (h)*	*Yield (%)*	*Content (%)*			*M.p. (°C) of the 3-nitro derivatives*
				3-	*1-*	*di-*	
CH_3	10	1·0	92·4	85·9	5·1	9·0	167–70
C_2H_5	10	1·5	92·6	90·0	3·6	6·4	123–124
n-C_4H_9	10	2·0	96·7	94·4	3·1	2·5	97–98
$CH_2C_6H_5$	10	2·5	94·6	97·4	2·3	0·3	145–146

TABLE 3
Synthesis of *N*-*R*-Dinitrocarbazoles

R	*T (°C)*	*t (h)*	*Yield (%)*	*Content (%)*	
				3,6-	*1,6-*
H	40	3·0	85·8	70·2	29·8
CH_3	40	3·5	90·0	83·3	16·7
C_2H_5	40–50	3·5	98·0	86·4	13·6
n-C_4H_9	40–50	4·0	85·4	92·0	8·0
$CH_2C_6H_5$	40–50	5·0	92·6	100·0	0

Dinitration

Using 95–98% nitric acid in 1,2-dichloroethane, the products were dinitrocarbazoles and no mononitro derivatives, when the molar ratio of carbazole and nitric acid was 1 : 5·5 (Table 3). Only two spots were apparent on the TLC (silica gel; benzene : chloroform 2 : 1), at R_{f1} = 0·4–0·5 and R_{f2} = 0·54–0·74 for the 3,6-dinitro- and 1,6-dinitro derivatives, respectively. Elemental analysis confirmed that the products were dinitrocarbazoles (Table 4). The nitro group in the carbazole is characterized in the IR spectrum by strong asymmetrical and symmetrical stretching vibrations in the regions 1550–1510 cm^{-1} and 1365–1335 cm^{-1}, respectively. When 3,6-dinitrocarbazole was treated with Sn—HCl, the resultant product was 3,6-diaminocarbazole. The ^{1}H NMR spectrum of pure 3,6-diaminocarbazole (recrystallized from chloroform) showed peaks at δ 6·6–6·8 for the two protons at the 1- and 5- positions. A peak at 7·11 for the four protons at the 1-, 2-, 7- and 8- positions was also present, in accord with a 3,6-orientation of the amino groups. Therefore, the main component of the dinitration is 3,6-dinitrocarbazole.

TABLE 4
Elemental Analysis

Products	*C (%)*		*H (%)*		*N (%)*	
	Found	*Calculated*	*Found*	*Calculated*	*Found*	*Calculated*
3,6-Dinitro-	56·09	55·03	2·83	2·72	16·38	16·34
1,6-Dinitro-	55·98	55·03	2·78	2·72	16·32	16·34
N-Me-3,6-dinitro-	57·50	57·56	3·31	3·32	15·34	15·50
N-Et-3,6,-dinitro-	57·10	58·95	3·88	3·86	14·31	14·74
N-Bu-3,6-dinitro-	61·39	61·34	4·74	4·79	13·36	13·42
N-Bz-3,6-dinitro-	65·68	65·71	3·76	3·57	12·06	12·10

TABLE 5
Synthesis of *N*-*R*-3,6-dinitrocarbazoles under various conditions

Products	*Medium of nitration*	*Nitrating agents*	*N-R-carbazole: HNO_3 (mol)*	*T (°C)*	*t (h)*	*Yield (%)*
N-Methylcarbazole	$C_2H_4Cl_2$/AcOH	conc. HNO_3/AcOH	1 : 13	70–75	5·0	77·5
	$C_2H_4Cl_2$	fuming HNO_3/AcOH	1 : 3	70–75	5·0	76·7
	$C_2H_4Cl_2$	fuming HNO_3	1 : 5·5	40–42	3·5	90·0
N-Ethylcarbazole	$C_2H_4Cl_2$	fuming HNO_3/AcOH	1 : 3	70–75	5·0	77·5
	$C_2H_4Cl_2$	fuming HNO_3	1 : 5·5	40–50	3·5	98·0
N-Butylcarbazole	$C_2H_4Cl_2$	fuming HNO_3/AcOH	1 : 3	70–75	5·0	76·0
	$C_2H_4Cl_2$	fuming HNO_3	1 : 5·5	40–50	4·0	85·4
N-Benzylcarbazole	$C_2H_4Cl_2$	fuming HNO_3/AcOH	1 : 3	70–75	5·0	84·4
	$C_2H_4Cl_2$	fuming HNO_3	1 : 5·5	40–50	5·0	92·6

Conc. HNO_3 = 65–68%; fuming HNO_3 = 95–98%.

Influence of the reaction conditions on yield

The reaction conditions have a significant influence on the nitration; for example, the different yields of *N*-methyl-3,6-dinitrocarbazole obtained under various conditions are shown in Table 5. When 65–68% nitric acid diluted with acetic acid was used as nitrating agent, and the molar ratio of *N*-methylcarbazole to HNO_3 was as much as 1 : 13, the yield of 3,6-dinitrocarbazole was only 77·5% using 1,2-dichloroethane as reaction medium; mononitrocarbazoles were also present in the products. When the concentration of nitric acid was below 80%, nitric acid is not miscible with the medium. In order to obtain miscibility of the nitric acid with 1,2-dichloroethane, acetic acid was introduced so that the reacting phase became a homogeneous system. Even when 95–98% nitric acid was used as nitrating agent, with a molar ratio of *N*-methylcarbazole to HNO_3 of 1 : 3, and diluting the nitric acid with acetic acid, the dinitration yield was not increased, and mononitrocarbazoles were still present in the product. Fuming nitric acid is miscible in 1,2-dichloroethane, but the concentration of the nitric acid decreases as the reaction progresses. Theoretical computations indicate that the concentration of HNO_3 is only 57·8% at the end of the reaction, when the ratio of *N*-methylcarbazole and HNO_3 is 1 : 3. Nitric acid of concentration below 80% is immiscible with 1,2-dichloroethane, so the rate of the nitration is decreased. Since the reaction may not be completed, mononitro compounds are still present after 5 h, and the yield of dinitro compounds is lowered. When using a large excess of 95–98% nitric acid, the dinitration is complete, giving 3,6-dinitrocarbazole at low temperature in a short time.

Formation of the isomers of nitration and influencing factors

The mononitration and dinitration of carbazole are parallel reactions, as shown below. The main product of the mononitration of *N*-*R*-carbazoles in 1,2-dichloroethane is the 3-nitro derivative. For 1-nitrocarbazole, the product is 1,6-dinitrocarbazole, whilst for 3-nitrocarbazole the product could be either 3,6-dinitrocarbazole or 1,6-dinitrocarbazole. Mononitration or dinitration depends on the concentration of nitric acid, but the ratio of isomers is also influenced by the spatial effects of the substituent on the nitrogen atom, on the temperature of addition of acid, and on the reaction time.

Influence of the concentration of nitrating agent

Using 95–98% nitric acid in 4·5 fold excess, the products were dinitrocarbazoles, no mononitrocarbazoles being apparent, but when an equimolar ratio of fuming acid was used the 3-nitro compound was the main product (Table 6). When 65–68% nitric acid was used the formation of the dinitro compound was reduced, and the content of the mononitrocarbazoles increased; this indicates that the facility of the nitration decreases with decrease in the concentration of the nitric acid.

Thus, if the required final product is the 3,6-dinitro compound, it is more effective to use 95–98% nitric acid as nitrating agent, preferably in a 4·5 fold excess. If the 3-nitrocarbazole is the desired product, 65–68% nitric acid is the more effective reagent.

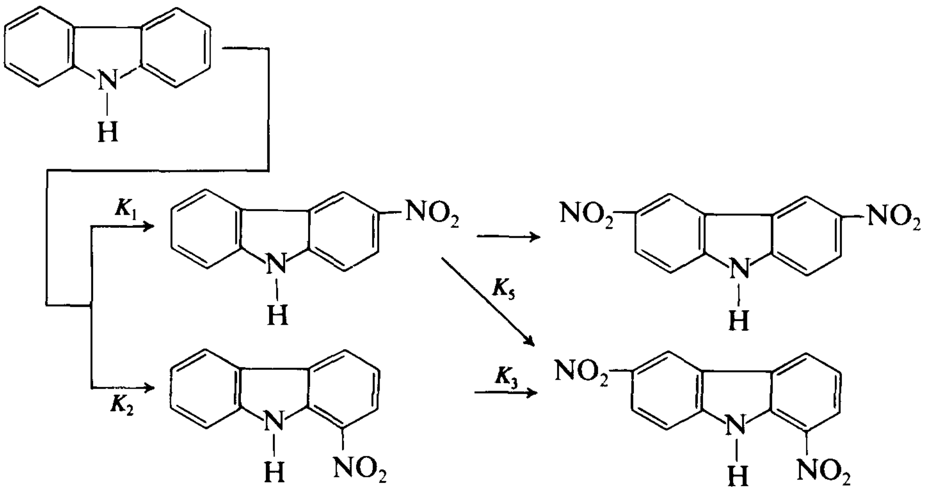


TABLE 6
Influence of Concentration of Nitrating Agent

Nitration of N-R-carbazole	*95–98% HNO_3*			*65–68% HNO_3*		
	3-(%)	*1-(%)*	*3,6-(%)*	*3-(%)*	*1-(%)*	*3,6-(%)*
R = Me	75·8	3·0	21·2	85·9	5·1	9·0
R = Et	73·7	2·0	24·3	90·1	3·6	6·4
R = Bu	74·6	1·6	23·8	90·1	3·1	2·5
R = Bz	—	—	—	97·4	3·3	0·3

Spatial effects of substituents on the nitrogen

The presence of different alkyl groups on the carbazole nitrogen atom results in a change in the ratio of the nitro isomers. As the size of the *N*-substituent increases, steric effects at the 1- and 8- positions become larger and thus limit the attack of NO_2^+ at these positions. Therefore, the content of 1,6-dinitrocarbazole is decreased in dinitrations. When the *N*-substituent was benzyl, no 1,6-dinitro derivative was produced (Table 3). The influence of these substituents on the mononitration reaction was the same (Table 2).

Influence of temperature

Optimum conditions for the mononitration are mild, and 3-nitrocarbazole was obtained at 10°C in 92·4% yield (85·9% products content) (Table 2). The amount of dinitrocarbazoles increased with increase in the reaction temperature.

The influence of the temperature on the isomers formed in dinitration depends on both the temperature during addition of acid and on the overall reaction temperature. After addition of acid is complete, the reaction then proceeds to completion. If the temperature when adding acid is kept at 10 ± 2°C, the isomer ratio of the dinitrocarbazoles at the end does not vary with increase in the overall reaction temperature, when using a large excess of 95–98% nitric acid; values obtained for the ratio of 3,6- to 1,6- isomers were 2·32, 2·30, 2·35, 2·32 and 2·36 for 20°C, 30°C, 40°C, 50°C and 60°C, respectively.

The temperature during addition of acid may be controlled by monitoring the rate at which the acid is added and by vigorous stirring, the reaction vessel being cooled in an ice-water bath. At a low temperature of addition of acid the ratio of 3,6-dinitro: 1,6-dinitro products is larger; the lower the temperature during acid addition, the larger this ratio (Table 7).

As the reaction time increases, the ratio increases (Table 7), until the reaction is complete and the ratio no longer changes. Specific ratios were 1·34, 1·56, 1·82, 1·88 and 1·95 for 1, 2, 3, 4 and 5 h respectively. The main

TABLE 7

Effects of Temperature During Addition of Acid on the Ratio of 3,6-: 1,6-Dinitrocarbazole

Reaction time (h)	*Temperature (°C)*		
	0–3	*14–16*	*70–72*
1·0	1·48	1·35	1·20
1·5	1·72	—	1·33
2·0	1·85	1·57	1·47

product during mononitration is the 3-mononitro derivative at low temperature when adding acid. This implies that $K_1 \gg K_2$; commonly, $K_3 \doteq K_4$ and $K_4 > K_5$. Because the nitro group attacks the ring which has not been substituted in the mononitration, the nitrated ring influences the value of K during dinitration. It is well known that $K_3 \doteq K_4 > K_5$. At the beginning of the second nitration, the first nitration has already been effected, and therefore:

$$[3\text{-NO}_2^-] > [1\text{-NO}_2^-]$$

$$V_{1\cdot 6} = K_3[1\text{-NO}_2]^m[\text{NO}_2^+]^n + K_5[3\text{-NO}_2]^{m'}[\text{NO}_2^+]^{n'}$$

$$V_{3\cdot 6} = K_4[3\text{-NO}_2]^{m'}[\text{NO}_2^+]^{n'}$$

$$\frac{V_{3\cdot 6}}{V_{1\cdot 6}} = \frac{K_4[3\text{-NO}_2]^{m'}[\text{NO}_2^+]^{n'}}{K_3[1\text{-NO}_2]^m[\text{NO}_2^+]^n + K_5[3\text{-NO}_2]^{m'}[\text{NO}_2^+]^{n'}}$$

where V is the velocity of the reaction. With prolongation of the reaction time, 1-nitrocarbazole decreases and eventually tends to disappear, so that $K_3[1\text{-NO}_2]^m[\text{NO}_2^+]^n$ tends to zero at this time:

$$\frac{V_{3\cdot 6}}{V_{1\cdot 6}} = \frac{K_4[3\text{-NO}_2]^{m'}[\text{NO}_2^+]^{n'}}{K_5[3\text{-NO}_2]^{m'}[\text{NO}_2^+]^{n'}} = \frac{K_4}{K_5}$$

Thus, we can obtain

$$V_{3\cdot 6}/V_{1\cdot 6} \text{ (prolonged reaction)} > V_{3\cdot 6}/V_{1\cdot 6} \text{ (beginning of reaction)}$$

Therefore, as the reaction time increases, the ratio of 3,6-: 1,6- tends to increase.

CONCLUSIONS

N-alkylcarbazoles are produced by *N*-alkylation of carbazole under phase-transfer catalytic conditions; the yields are high and the reaction time is short. For mononitration of *N*-alkylcarbazoles in 1,2-dichloroethane, the main product is the 3-nitro derivative. The use of 65–68% nitric acid is more beneficial than 95–98% acid for the formation of the 3-nitro monosubstituted derivatives. For the dinitration, the main products are the 3,6-dinitro derivatives. The yield increases with increase in the size of the *N*-substituent and as the temperature during addition of acid is decreased. 95–98% Nitric acid in a 4·5 fold excess is a more beneficial nitrating agent.

For further nitration of the mononitro derivative, when the nitrating agent is in large excess, the rate of dinitration is rapid when the temperature of the reaction is low.

REFERENCES

1. Murshtein, M. K, Pushkareva, Z. V. and Gryazev, V. F., *Tr. Komis. Po Spektroskopii, Akad. Nauk SSSR*, **3** (1964) 360; *Chem. Abstr.*, **64**: 17751h.
2. Allied Chem. & Dye Corp., *US Patent* 2 407 704 (1946); *Chem. Abstr.*, **41**: 1458e.
3. In, O. A., Novikova, G. M. and Niyazi, F. F., *Soversh. Protsessov Krasheniya Metodov Sint. Krasitelei*, (1983) 122; *Chem. Abstr.*, **102**: 8143u.
4. Pfaff, K., *Chem. Ber. PB 52021*, (1942) 1183; *Chem. Abstr.*, **42**: 9045a.
5. Searle, A. J. F., Gee, C. and Willson, R. L., In *Proceedings of the 3rd International Oxygen Radicals Chem. Biol. Conference*. Uxbridge, UK, 1984, pp. 377–9, *Chem. Abstr.*, **100**: 203140b.
6. Ricoh Co. Ltd. *Japanese Patent* 55 157 746 (1980); *Chem. Abstr.*, **95**: 106359a.
7. Ricoh Co. Ltd. *Japanese Patent* 55 69 148 (1980); *Chem. Abstr.*, **93**: 248206f.
8. Wyzsza Szkola Pedagogiczna, Opole Pol. PL 119 815 (1983); *Chem. Abstr.*, **99**: 89190b.
9. Sudol, M. & Nowakowska, M., *Przem. Chem.*, **62** (1983) 683.
10. Biswas, M. & Sukhendu Das, K., *Polymer*, **23** (1982) 1713.