Molecular Rearrangements. Part VI. Aryl(alkyl)amines (II) Thermal Rearrangement of *N*-Benzylaniline

M. Z. A. BADR[1] AND H. A. H. EL-SHERIEF
Chemistry Department, Faculty of Science, Assiut University, Assiut, Egypt, E.A.R.

Received February 19, 1974[2]

M. Z. A. BADR and H. A. H. EL-SHERIEF. Can. J. Chem. **53**, 3831 (1975).

Heating *N*-benzylaniline resulted in migration of the benzyl group to the *ortho*- and *para*-positions of the aniline nucleus. Ammonia, toluene, biphenyl, diphenylmethane, dibenzyl, *trans*-stilbene, aniline, together with 9-phenylacridine, and 2,3-diphenylindole, were also formed.

When phenol, quinoline, or isoquinoline were used as solvents, the normal rearrangement products were accompanied by 2- and 4-benzylphenols, 3-benzylquinoline, 2- and 4-(aminophenyl)quinoline, 4-benzylisoquinoline, and 1-(aminophenyl)isoquinolines.

It is concluded that the pyrolysis of the secondary amine depends on its homolytic fission to benzyl and phenylamine free radicals. Homolysis of some initially separated products was also observed.

M. Z. A. BADR et H. A. H. EL-SHERIEF. Can. J. Chem. **53**, 3831 (1975).

Par chauffage, le groupe benzyle de la *N*-benzylaniline se transpose aux positions *ortho* et *para* du noyau aniline. On obtient aussi de l'ammoniac, du toluène, du biphényle, du diphénylméthane, du dibenzyle, du *trans*-stilbène, de l'aniline ainsi que du phényle-9 acridine et du diphényl-2,3 indole.

Quand on utilise le phénol, la quinoléine ou l'isoquinoléine comme solvants, on obtient les produits de réarrangement normaux ainsi que les benzyl-2 et -4 phénols, du benzyl-3 quinoléine, les (aminophényl)-2 et -4 quinoléine, le benzyl-4 isoquinoléine et l'(aminophényl)-1 isoquinoléine.

La pyrolyse de l'amine secondaire dépend de sa rupture homolytique en radicaux libres benzyle et phénylamine. On observe aussi l'homolyse de quelques produits préalablement isolés.

[Traduit par le journal]

Can. J. Chem. Downloaded from www.nrcresearchpress.com by 64.107.14.30 on 11/10/14
For personal use only.

The present paper describes a novel rearrangement of *N*-monoalkylaniline involving an alkyl–N bond fission to ring alkylated anilines, when heated at elevated temperature in absence of any promoter, either alone or in the presence of aromatic solvents where their ring alkylation was also observed. Thus *N*-benzylaniline reacted on heating in a sealed tube in nitrogen atmosphere at about 315 °C. Ammonia was produced together with aniline, toluene, biphenyl, diphenylmethane, dibenzyl, *trans*-stilbene, *o*- and *p*-aminodiphenylmethanes, 9-phenylacridine, and 2,3-diphenylindole in relatively high yield, together with high boiling products not yet resolved. When heated at its boiling point under reflux for 100 h, the amine gave about the same products but in lower yields, with the difference that some benzaldehyde was isolated, with stilbene, diphenyl, and 9-phenylacridine not easily identified.

The products of this thermal rearrangement are quite different from those of the proton catalyzed rearrangement.

The presence of toluene, aniline, biphenyl, diphenylmethane, and dibenzyl in the products strongly suggests that the change depends on a free radical mechanism. This suggestion was further confirmed through the study of the rearrangement in high boiling solvents and scavengers under nitrogen atmosphere. In phenol, the normal products of rearrangement were obtained together with 2- and 4-benzylphenols. However, in anisole, the solvent molecules underwent molecular rearrangement to the expected products of the alkyl–aryl ether reaction, namely, *o*- and *p*-cresol together with phenol and its benzylated products. The products of anisole rearrangement were also isolated when it was heated alone under the conditions of the amine rearrangement.

The thermal rearrangement of *N*-benzylaniline in quinoline gave the normal rearrangement

---

[1] Author to whom correspondence should be addressed.

[2] Revision received May 15, 1975.

Can. J. Chem. Downloaded from www.nrcresearchpress.com by 64.107.14.30 on 11/10/14
For personal use only.

TABLE 1. Products of pyrolysis of *N*-benzylaniline

(*a*) Experimental conditions

Experiment number	Solvent: Type	Solvent: Amount (g)	Reaction temperature (°C)	Reaction time (days)	Amine used (g)
1	—	—	Reflux[b]	4.2	40
2[a]	—	—	315	12	40
3[a]	Phenol	12	315	12	40
4[a]	Anisole	11	315	12	40
5[a]	Quinoline	20	315	12	60
6[a]	Isoquinoline	—	315	12	60

(*b*) Experimental results

		Experiment number											
		1		2		3		3		5		6	
Product	Boiling point of fraction (°C/Torr)	Amount (g)	%	Amount (g)	%	Amount (g)	%	Amount (g)	%	Amount (g)	%	Amount (g)	%
Ammonia	—	'Evolved'	—	'Evolved'	—	'Evolved'	—	'Evolved'	—	'Evolved'	—	'Evolved'	—
Toluene	110/760	1	4	6	16.3	2.4	6	2.4	7.7	9.6	19.8	10.5	25
Dibenzyl[i]	125–135/10	0.55	2.4	0.7	1.9	0.4	1	0.5	1.6	0.57	1.2	0.6	1.4
Diphenylmethane[i]	125–135/10	0.95	4.1	1.2	3.2	6.2	15.6	0.95	2	0.44	0.9	0.4	1
Biphenyl	—	—	—	0.005	0.02	0.01	0.03	0.001	0.002	0.008	0.02	0.004	0.01
Stilbene	160–180/10	—	—	0.08	0.2	0.6	1.5	0.32	1	0.08	0.2	0.004	0.01
Aniline	184/160	5	21.7	11.5	31.8	10.1	25.4	8.5	27.2	12.3	25.4	12.5	29.8
o- and *p*-Aminodiphenyl methane[j]	165–170/4	6	26.1	6.5	17.8	13.5	34.2	11.7	37.5	20.0	41.2	13	31
9-Phenylacridine	220–240/2	—	—	3.5	9.5	3.0	7.3	2.8	9	—	—	—	—
2,3-Diphenylindole	220–240/5	—	—	3.5	9.5	4	10.1	4	12.8	5.5	11.3	5	12
Benzyl isomers of solvent used[g]	—	—	—	—	—	5.1[c]	—	—[d]	—	5[e]	—	5[f]	—
Non-volatile residue	Non-volatile	3.2	—	4.0	—	2.6	—	3.7[h]	—	4.2	—	6	—

[a] In nitrogen atmosphere.

[b] Benzaldehyde (1.8 g), n_D^{20} 1.5450, DNP derivative m.p. 236 °C.

[c] Fractions 70–120 °C/10 Torr contain benzylphenols in the ratio of 94.3% *o*- and 5.7% *p*-isomer identified by paper chromatography of their azodyes with diazotised sulfanilic acid, R_f (*o*-isomer) 0.61, R_f (*p*-isomer) 0.74, solvent butanol, water and ethyl alcohol in the ratio 5:5:1.7.

[d] It was separated into (2.2 g) of phenol (69%) and cresols (31%) in the ratio, *o*-isomer (95.5%), *p*-isomer (4.5%) benzylphenols (1.1 g) in the ratio *o*-isomer (97.3%) and *p*-isomer (2.7%) as found by g.l.c.

[e] The only isomer separated at 207–210 °C/7 Torr was 3-benzylquinoline (5 g) together with three different isomeric 2- and 4-(aminophenyl)quinolines (11 g) separated by trituration with petroleum ether (40–60) identified by i.r., mass spectra and u.v. (*cf.* Table 2).

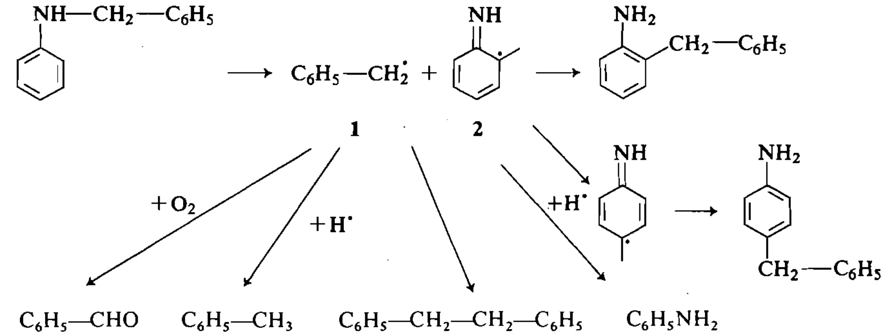
[f] The only isomer separated at 185–196 °C/8 Torr was 4-benzylisoquinoline together with isomeric 1-(2-aminophenyl)isoquinoline (5 g) and the 1-(4-) isomer (3.5 g) identified by i.r., mass spectra, u.v. (*cf.* Table 3) from fraction 215–218 °C/8 Torr.

[g] Neutral and amine products.

[h] Together with phenolic products.

[i] Identified by g.l.c.

[j] Separated by column chromatography on silica gel (100–150 mesh) using benzene as eluant.



SCHEME 1

products together with 3-benzylquinoline, 2-(4-aminophenyl)quinoline, 4-(4-aminophenyl)-quinoline and an isomeric product which was identified as 4-(2-aminophenyl)quinoline.

With isoquinoline, the normal rearrangement products were accompanied by 4-benzylisoquinoline, 1-(4-aminophenyl)isoquinoline and the isomeric 1-(2-aminophenyl)isoquinoline as summarized in Table 1.

The rearrangement mechanism may take place according to Scheme 1.

Diphenylmethane may be produced through deamination of both isomeric *o*- and *p*-aminodiphenylmethane (route *a*) according to Scheme 2, however, heating the two isomers alone in a sealed tube under the conditions of the amine rearrangement produced neither ammonia nor diphenylmethane. On the other hand, heating aniline alone in a sealed tube at about 315 °C for 10 days resulted in the formation of ammonia (route *b*), which was collected in a concentrated HCl trap and identified as the hydrochloride and other derivatives. Consequently, diphenylmethane was most favorably produced through coupling of one phenyl free radical, which resulted from homolysis of the aniline byproduct, with the benzyl free radical (route *c*).

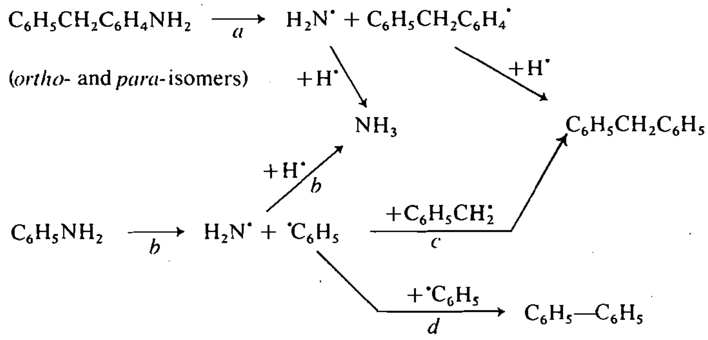
Combination of two phenyl radicals produced biphenyl (route *d*). The formation of biphenyl or diphenylmethane and ammonia may take place according to Scheme 2. The production of ammonia was assumed to partially proceed through intermediate formation of the amino free radical (route *b*). Such amino free radicals have been shown to exist (1).

9-Phenylacridine can reasonably be assumed to be formed from 2-aminodiphenylmethane as is shown in Scheme 3.

The formation of 2,3-diphenylindole can be explained according to Scheme 4.

Trans-stilbene could result from abstraction of the methylene hydrogens (β-scission) from dibenzyl under the influence of the free radicals present in the reaction medium in a procedure described previously (2).

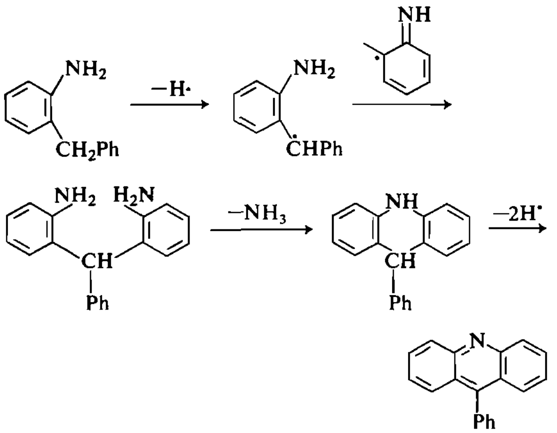
Substitution by the benzyl radical on phenol gave the expected products. Production of *o*- and *p*-benzylphenols instead of isomeric benzylanisoles during the amine rearrangement insures that anisole rearrangement under such condi-



SCHEME 2

Can. J. Chem. Downloaded from www.nrcresearchpress.com by 64.107.14.30 on 11/10/14
For personal use only.

Can. J. Chem. Downloaded from www.nrcresearchpress.com by 64.107.14.30 on 11/10/14
For personal use only.



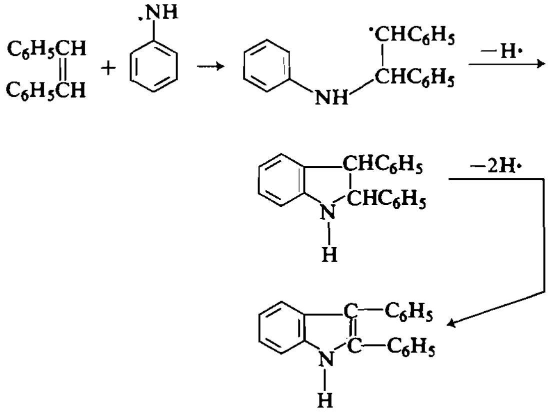
SCHEME 3

tions precedes the substitution step by benzyl radical, itself a product of the amine pyrolysis. However, absence of any other methyl derivatives among the products in an anisole solvent and the higher yield of *o*-cresol, strongly favor the assumption that the methyl group of anisole did not migrate as a separate free radical but possibly through an intramolecular route. However, the formation of *p*-cresol partially through an intermolecular migration of the methyl group within a solvent cage (3) was not excluded.

Thermal rearrangement of the amine in quinoline gave the expected products together with 3-benzylquinoline and three isomeric 2- and 4-(aminophenyl)quinolines. Free radical substitution at the 3-position of the quinoline nucleus was also observed by other workers (4, 5). Substitution by the benzyl radical at the 3-position of quinoline during the amine pyrolysis instead of at the 2- or 4-positions as observed in benzyl naphthyl ether pyrolysis in a quinoline solvent (6), could not be attributed to the difference in thermodynamic instability (7) of different isomeric benzylquinolines under such high thermal conditions. When both 2- and 4-benzylquinolines were heated under the conditions of the amine rearrangement, neither of the isomers were isomerized to their respective 3-benzylquinolines. On the other hand, the benzyl radical has less basic character (lower electron density) when compared with the aniline free radical (which has higher electron density). Since the increase of the nucleophilic character of a radical reflects an increase in its selectivity (8), consequently, in such radical competition the benzyl radical with its lower nucleophilic character will substitute selectively at the 3-position of quinoline which has a higher electron density than the 2- and 4-positions which will be attacked selectively and at a faster rate (9) by the anilino free radical with its higher nucleophilic character, producing the three isomeric 2- and 4-(aminophenyl)quinolines isolated.

Similarly, pyrolysis of the amine in isoquinoline gave the normal products together with 4-benzylisoquinoline and two isomeric 1-(2- and 4-aminophenyl)isoquinolines. On the same basis as above, during such radical competition, the less nucleophilic benzyl radical substitutes at the 4-position of isoquinoline with its higher electron density, while the anilino radical substitutes selectively and at a faster rate at the 1-position with its lower electron density.

The absence of biquinolyl or bi-isoquinolyl during such types of rearrangement strongly suggests that reactions with either quinoline or isoquinoline are based mainly on homolytic substitution steps rather than homolytic dehydrogenation processes yielding quinolyl or isoquinolyl radicals followed by coupling processes such as observed before (6).



SCHEME 4

Experimental

Analysis

Infrared spectroscopic analysis was carried out on a Pye-Unicam i.r. spectrophotometer, model SP 200G. The u.v. absorptions were carried out on a Pye-Unicam u.v. spectrophotometer, model SP8000. Gas-liquid chromatography analysis was carried out on a Pye-Unicam gas chromatograph, series 104, with a dual flame ionization detector, temperature programed, model 24. The column used was 20% SE30 on Chromosorb W (35–80) mesh. Thin layer chromatographic analysis was carried out on silica gel (25–40 mesh) using the solvents benzene–cyclo-

Can. J. Chem. Downloaded from www.nrcresearchpress.com by 64.107.14.30 on 11/10/14
For personal use only.

TABLE 2. Ultraviolet absorptions of isomeric aminophenyl quinolines

Isomer	λ_{max}(nm)	ε_{max}	λ_{max}(nm)	ε_{max}
4-(2-Aminophenyl)quinoline	230	18 555	285	8 555
4-(4-Aminophenyl)quinoline	230	12 220	285	4 888
2-(4-Aminophenyl)quinoline	255	32 999	285	7 940

TABLE 3. Ultraviolet absorption of isomeric aminophenyl isoquinolines

Isomer	λ_{max}(nm)	ε_{max}	λ_{max}(nm)	ε_{max}
1-(2-Aminophenyl)isoquinoline	235	14 200	285	3 100
1-(4-Aminophenyl)isoquinoline	235	8 500	285	2 000

hexane (3:1 by volume) and *n*-hexane – ethyl acetate (7:3 by volume); the spots were visualized by iodine vapor. Paper chromatographic analysis was carried out using C. Schleicher and Schull paper No. 2316. In phenol analysis, the paper was sprayed before use to the point of saturation with 4% aqueous Na_2CO_3 solution and dried in air at room temperature. Molecular ion determinations were recorded on a UNC-CH Hitachi mass spectrometer at 70 eV.

Pyrolysis of N-Benzylaniline

N-Benzylaniline was heated alone or with phenol, anisole, quinoline, or isoquinoline in a nitrogen atmosphere and the reaction products were distilled first under atmospheric pressure where ammonia was evolved and trapped as its hydrochloride, and toluene collected. The higher boiling products were separated into neutral and amine ones by treatment with concentrated HCl and extraction with ether.

Phenolic products are separated by means of Claisen's solution. The results are summarized in Table 1.

Thermal Rearrangement of Anisole

Redistilled anisole (6 g) was heated in a sealed tube at about 315 °C for 12 days. Fractionation of the products gave together with recovered anisole, rearranged phenolic products (0.4 g; 6.7%) which were found by g.l.c. to consist of phenol (67.8%) and cresols (32.2%), a mixture of *o*-cresol (70.2%) and *p*-cresol (29.8%).

Preparation of Reference Compounds

N-Benzylaniline (10): b.p. 148–149 °C/3 Torr; m.p. 36 °C; picrate m.p. 48 °C.

Diphenylmethane (11): b.p. 261–262 °C/760 Torr; m.p. 26 °C; n_D^{27} 1.5788.

o-Aminodiphenylmethane (12): crystallized from petroleum ether (40–60 °C), m.p. 52 °C; *N*-acetyl derivative, m.p. 135 °C; *N*-benzoyl derivative, m.p. 116 °C.

p-Aminodiphenylmethane (13): b.p. 165–167 °C/2 Torr; crystallized from petroleum ether (40–60 °C), m.p. 34–36 °C; picrate, m.p. 179 °C.

9-Phenylacridine (14): Yellow prisms, m.p. 182–183 °C.

o-Benzylphenol (15): b.p. 172–180 °C/15 Torr; phenyl urethane derivative, m.p. 117 °C.

p-Benzylphenol (16): b.p. 170–190 °C/14 Torr; crystallized from petroleum ether (60–80 °C) as hairy white needles, m.p. 84 °C; benzoate m.p. 87 °C.

o-Benzylanisole (17): Crystallized from ethanol as white crystals, m.p. 27–28 °C.

p-Benzylanisole (18): b.p. 152–155 °C/7 Torr; n_D^{20} 1.5781.

2-Benzylquinoline (19): crystallized from methanol as yellow orange needles, m.p. 156–157 °C.

3-Benzylquinoline (20): b.p. 170–190 °C; crystallized from petroleum ether (60–80 °C), m.p. 67–68 °C; picrate m.p. 180–182 °C.

4-Benzylquinoline (21): b.p. 230 °C/14 Torr; picrate m.p. 179 °C.

4-Benzylisoquinoline (22): crystallized from petroleum ether (60–80 °C) as colorless crystals, m.p. 119–120 °C; picrate m.p. 195–196 °C, methiodide m.p. 196–197 °C.

2-(4-Aminophenyl)quinoline (23): yellow crystals m.p. 134 °C; picrate, m.p. 194 °C.

1-(4-Aminophenyl)isoquinoline (24): b.p. 200–215 °C/0.1 Torr, crystallized from benzene, m.p. 190–191 °C.

2,3-Diphenylindole (25): crystallized from petroleum ether (60–80 °C), m.p. 123–124 °C.

We thank Dr. M. M. Bursey for his assistance with the mass spectral measurements.

1. N. J. FRISWELL and B. G. GOWENLOCK. *In* Advances in free radical chemistry, Vol. 11 *edited by* G. H. Williams. 1967. pp. 1–5.
2. C. HORREX and S. E. MILES. Discuss. Faraday Soc. **10**, 187 (1951).
3. Y. OGATA and K. TAKAGI. J. Org. Chem. **35**, 1944 (1970).
4. R. BRESLOW and L. N. LUKENS. J. Biol. Chem. **235**, 292 (1960); B. B. BRODIE, J. AXELROD, P. A. SHORE, and S. UNEFRIEND. J. Biol. Chem. **208**, 74 (1954); R. O. C. NORMAN and G. K. RADDA. Proc. Chem. Soc. London, 138 (1962).
5. H. F. JANSEN and J. P. WIBAUT. Recl. Trav. Chim. Pays-Bas, **56**, 699 (1939).
6. M. Z. A. BADR and M. M. ALY. Tetrahedron, **28**, 3401 (1972); M. Z. A. BADR and H. A. H. EL-SHERIEF. Can. J. Chem. **50**, 259 (1972).

7. J. W. ENGELSMA and E. C. KROOGMAN. Proc. Chem. Soc. London, 258 (1958).
8. M. SZWARC and J. H. BINKS. Theoretical organic chemistry. Special Publication 12, The Chemical Society. Butterworths, London. 1959. p. 262.
9. C. A. COULSON. J. Chem. Soc. London, 1435, (1955); C. W. WHELAND. J. Am. Chem. Soc. **64**, 900 (1942).
10. A. I. VOGEL. Practical organic chemistry. Longmans, 1956. p. 572.
11. A. I. VOGEL. Practical organic chemistry. Longmans, 1956. p. 315.
12. C. L. HEWETT, L. J. LERMIT, H. T. OPENSHAW, A. R. TODD, A. H. WILLIAMS, and F. N. WOODWARD. J. Chem. Soc. London, 292 (1948).
13. W. J. HICKINBOTTOM. J. Chem. Soc. London, 1119 (1937).
14. A. BERNTHESEN. Ann., **224**, 13 (1884).
15. F. M. ELKOBAISI and W. J. HICKINBOTTOM. J. Chem. Soc. London, 1873 (1959).
16. R. C. HUSTON. J. Am. Chem. Soc. **46**, 2775 (1924).
17. B. M. DUBININ. J. Gen. Chem. USSR **19**, 696 (1949); Chem. Abst. **44**, 1060 (1950).
18. L. N. PETROVA and O. V. SCHVARTS. J. Gen. Chem. USSR **20**, 1681 (1950).
19. H. DECKER and R. POSCHORR. Chem. Ber. **37**, 3400 (1904).
20. M. AVRAMOFF and Y. SPRINZAK, J. Am. Chem. Soc. **58**, 4090 (1936).
21. I. P. RABE and R. PASTERNACK. Chem. Ber. **46**, 1026 (1913).
22. L. RUGHEIMER and B. FRILING. Ann. **326**, 265 (1903).
23. H. JOHN and H. OTTAWA. J. Prakt. Chem. **133**, 13 (1932); H. GILMAN and G. C. GAINER. J. Am. Chem. Soc. **69**, 877 (1947).
24. H. GILMAN and G. C. GAINER. J. Am. Chem. Soc. **69**, 1946 (1947).
25. M. J. KAMLET and J. C. DACONS. J. Org. Chem. **26**, 220 (1961); C. F. H. ALLEN and J. A. VAN ALLEN. J. Am. Chem. Soc. **73**, 5850 (1951).

Can. J. Chem. Downloaded from www.nrcresearchpress.com by 64.107.14.30 on 11/10/14
For personal use only.