apparently is the result of a cage reaction. Garst and Cole[15] have shown that 3% of the phenyl radicals from PAT are not scavengeable and, therefore, disappear in either a cage or a molecular process. At higher concentrations of PAT, *more* benzene is formed, but the sum of the yields of benzene and chlorobenzene *decreases*. An attractive hypotheses which explains these facts is that *free* phenyl radicals react with PAT in two ways: one produces benzene and the other traps phenyl radicals. The interesting thing is how efficient PAT is as a radical scavenger: 0.2 *M* PAT traps about 30% of the phenyl radicals in pure CCl_4. It is clear, therefore, why Eliel, *et al.*,[16] found that the yield of biphenyl decreases as the PAT concentration is increased in homolytic substitution in benzene. This results from the fact that PAT is a radical scavenger, rather than from the fact that biphenyl is produced in a geminate process.[17] The addition of phenyl radicals to PAT might be expected to be fast since it produces a stabilized radical with structure reminiscent of that of diphenylpicrylhydrazyl.

Acknowledgment.—Discussion with Prof. J. E. Leffler is appreciated.

(15) J. F. Garst and R. S. Cole, *Tetrahedron Letters*, 679 (1963).

(16) E. L. Eliel, M. Eberhardt, O. Simamura, and M. Meyerson, *ibid.*, 749 (1962).

(17) Also see D. H. Hey, M. J. Perkins, and G. H. Williams, *ibid.*, 445 (1963).

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE JOHNS HOPKINS UNIVERSITY, BALTIMORE, MD.]

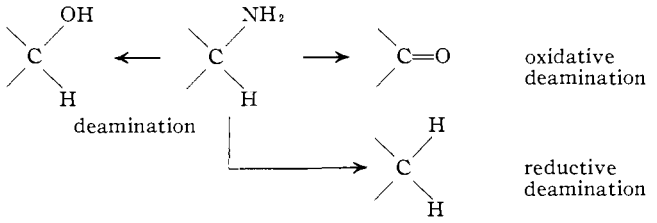
A Direct Method for Reductive Deamination of Aliphatic Amines[1]

BY ALEX NICKON[2] AND ADA S. HILL

RECEIVED OCTOBER 19, 1963

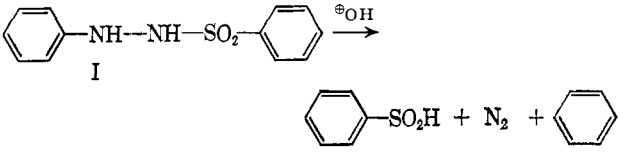
Treatment of a primary amine sulfonamide with hydroxylamine-O-sulfonic acid in alkaline solution provides a direct method for reductive deamination (R-NH_2 → R-H) in the aliphatic series. Amino groups on primary, secondary, and tertiary aliphatic carbons can be replaced and these include benzylic, as well as ring and bridgehead carbons. The yields vary widely, but are usually high when corrected for unchanged sulfonamide. The conversion of β-naphthylamine to naphthalene indicates the method is also applicable to aromatic amines. Oxidative deamination to form a ketone (or an aldehyde) is a minor side reaction when the amino carbon carries one (or two) hydrogens. Side reactions predominated in the case of 9-aminofluorene *p*-toluenesulfonamide. Under typical experimental conditions in alkaline aqueous ethanol, the benzenesulfonamide of optically active 2-phenyl-2-butylamine gave 2-phenylbutane, with partial retention of configuration. A mechanism for the reductive deamination is proposed that involves N-amination of the sulfonamide and loss of a sulfinic acid to give a monosubstituted diimide (RN=NH), which loses nitrogen. Under the experimental conditions hydroxylamine-O-sulfonic acid converted benzenesulfinic acid to benzenesulfonamide, which was identified as a product in one of the runs with benzylamine benzenesulfonamide.

The removal or replacement of a primary amino group attached to carbon can be accomplished many ways. Such processes are usually referred to as "deaminations" even though they can lead to a variety of products and can be brought about directly or indirectly by numerous reagents. For clarity in discussion we shall restrict the term *deamination* to an amine transformation that gives a product of the same oxidation level.[3] *Oxidative deamination* and *reductive deamination* can then refer to transformations of an amine to products of higher and lower oxidation levels, respectively. Deamination is exemplified by the nitrous acid treatment of a primary amine to produce



(among other things) an alcohol. The mechanism of this well known reaction continues to attract much research attention.[4] Oxidative deamination is illustrated by the conversion of an amine to a carbonyl compound. This over-all change can sometimes be brought about in the laboratory directly by the use of oxidizing agents[5] and is of biological importance in connection with oxidations and transaminations of amino acids.[6] Reductive deamination involves net replacement of an amino group by hydrogen. Procedures that accomplish this change for aromatic primary amines are well known,[7] but in the aliphatic series no direct method has been available. In a preliminary note we recently described such a method,[8] and the present paper reports the details of that study.[9]

Our approach originated from a report by Escales that alkaline treatment of benzenesulfonphenylhydrazide (I) yielded benzenesulfinic acid, nitrogen, and benzene.[10] Later, McFayden and Stevens treated a series of benzenesulfonaroylhydrazides II (Ph = phenyl, Ar = aryl) with sodium carbonate and obtained



the corresponding aromatic aldehydes along with nitrogen and benzenesulfinic acid.[11] To account for

(1) Abstracted from the Ph.D. Dissertation of Ada Sinz Hill (nee Ada Sinz), The Johns Hopkins University, 1960.

(2) Alfred P. Sloan Foundation Fellow.

(3) Oxidation levels are used in the sense suggested by R. Robinson, "The Structural Relations of Natural Products," Oxford University Press, London, 1955, p. 4.

(4) J. H. Ridd, *Quart. Rev.* (London), **15**, 418 (1961).

(5) L. Hellerman and A. G. Sanders, *J. Am. Chem. Soc.*, **49**, 1742 (1927).

(6) J. S. Fruton and S. Simmonds, "General Biochemistry," 2nd Ed., John Wiley and Sons, Inc., New York, N. Y., 1958, pp. 750–766.

(7) N. Kornblum, "Organic Reactions," Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1944, p. 262.

(8) A. Nickon and A. Sinz, *J. Am. Chem. Soc.*, **82**, 753 (1960).

(9) Another direct method has since been reported and involves treatment with difluoramine [C. L. Bumgardner, K. J. Martin, and J. P. Freeman, *ibid.*, **85**, 97 (1963)].

(10) R. Escales, *Chem. Ber.*, **18**, 893 (1885).

(11) J. S. McFayden and T. S. Stevens, *J. Chem. Soc.*, 584 (1936). Their reaction has proved useful for the synthesis of aromatic aldehydes, and an important modification has been described by M. S. Newman and E. G. Caflish, Jr. [*J. Am. Chem. Soc.*, **80**, 862 (1958)]. These last workers found that solid surfaces such as powdered soft glass catalyze the reaction markedly and can lead to successful conversions where others have reported failures [C. Niemann and J. T. Hays, *ibid.*, **65**, 482 (1943)].

TABLE I

Amine[a]	Sulfonamide deriv.[b]	Solvent for recrystn.[c]	M.p., °C. Found	M.p., °C. Reported	Formula	Calcd. C	Calcd. H	Found C	Found H	Ref.
Benzylamine	Bs	EtOH	86–87.5	88	...	...	...	...	...	37a
Benzylamine	Ts	EtOH	114–115	116	...	...	...	...	...	37a
Benzylamine	Ms	EtOH–H_2O	64.5–65	65	$C_8H_{11}NO_2S$	51.87	5.99	52.03	5.95	38
α-Phenylethylamine	Bs	EtOH	101.5	102	$C_{14}H_{15}NO_2S$	64.34	5.79	64.38	5.80	39
α-Phenylethylamine	Ms	...	Liquid[d]	...	$C_9H_{13}NO_2S$	54.25	6.58	54.26	6.51	
2-Phenyl-2-butylamine	Bs	EtOH	126.5–127	126–127	$C_{16}H_{19}NO_2S$	66.40	6.62	66.58	6.63	40a
(−)-2-Phenyl-2-butylamine	Bs	EtOH	107.5–108.5[e]	108.8–109.6	$C_{16}H_{19}NO_2S$	66.40	6.62	66.53	6.58	40b
1-Hexylamine	Ts	EtOH	63–64	62	...	...	...	...	...	41
1-Octylamine	Ts	EtOH	55.5–56	56	$C_{15}H_{25}NO_2S$	63.56	8.89	63.70	8.95	42
2-Octylamine	Ts	...	Liquid[f]	...	$C_{15}H_{25}NO_2S$	63.56	8.89	63.62	8.93	
2,4,4-Trimethyl-2-pentylamine[g]	Ts	EtOH	133–135	134.5–135.5	...	...	...	...	...	43
Cyclohexylamine	Bs	EtOH	89–91	89	...	...	...	...	...	37a
p-Menthanediamine[h]	di-Ts	Pyr–MeOH	234–234.5	...	$C_{24}H_{34}N_2O_4S_2$	60.22	7.16	60.50	7.17	
Benzhydrylamine	Bs	EtOH	184–186	182	...	...	...	...	...	44a
9-Aminofluorene	Ts	EtOH	204–204.5[i]	...	$C_{20}H_{17}NO_2S$	71.62	5.11	71.81	5.05	
9-Amino-9,10-dihydro-9,10-ethanoanthracene	Ms	Acetone	233–233.5	...	$C_{17}H_{17}NO_2S$	68.20	5.72	68.33	5.90	
β-Naphthylamine	Bs	EtOH–H_2O	97–98	98[j]	...	...	...	...	...	45
β-Naphthylamine	Ts	EtOH	132–133	133	...	...	...	...	...	37b
β-Naphthylamine	Ms	EtOH–H_2O	157.5–158.5	153.5	...	...	...	...	...	46
3β-Amino-5α-cholestane	Ts	EtOH–Bz	223–223.5[k]	...	$C_{34}H_{55}NO_2S$	75.36	10.23	75.38	10.05	
3β-Amino-5α-cholestane	Bs	EtOH	180.5–181	...	$C_{33}H_{53}NO_2S$[l]	75.09	10.12	75.26	10.09	
3β-Amino-5α-cholestane	Ms	EtOH	183	...	$C_{28}H_{51}NO_2S$[l]	72.21	11.04	72.19	10.98	

[a] All amines are commercial samples with the exception of racemic and (−)-2-phenyl-2-aminobutane, 9-amino-9,10-dihydro-9,10-ethanoanthracene, and 3β-aminocholestane (see Experimental). [b] Bs = benzenesulfonamide, Ts = toluenesulfonamide, Ms = methanesulfonamide. [c] Pyr = pyridine, Bz = benzene. [d] Purified by distillation; b.p. 165° (*ca.* 10 mm.), $n^{26.5}D$ 1.5314. [e] α −38° ($CHCl_3$, *c* 1.0). [f] Purified by chromatography on alumina and distillation; b.p. 200° (*ca.* 10 mm.), $n^{27}D$ 1.5071. [g] Commercial *tert*-octylamine from Matheson Coleman and Bell. [h] Commercial *p*-menthanediamine from Rohm and Haas Co. [i] Slight decomposition; sample introduced at 180°. [j] Also reported[37b] m.p. 102°. [k] α +7° ($CHCl_3$, *c* 1.0). [l] We thank Mr. F. Edamura for the preparation of these analytical specimens.

$$\underset{\text{II}}{PhSO_2NH\text{–}NHC(=O)Ar} \longrightarrow PhSO_2H + N_2 + Ar\text{–}C(=O)\text{–}H$$

these products they suggested that the reaction initially produces an unstable intermediate III, which readily evolves nitrogen. They noted that Escales' reaction was of similar nature and suggested it proceeded *via* the unstable intermediate IV. We felt that a sulfonylhydrazide of type V (R = aliphatic) could generate a similar intermediate in alkali, and this view led us to develop the following two-step process for reductive deamination.

$$\underset{\text{III}}{Ar\text{–}C(=O)\text{–}N{=}NH} \qquad \underset{\text{IV}}{Ph\text{–}N{=}NH} \qquad \underset{\text{V}}{R\text{–}N(NH_2)\text{–}SO_2Ar}$$

In the first step (eq. 1) an aliphatic primary amine is converted to a sulfonamide derivative by treatment with an aromatic (or aliphatic) sulfonyl chloride. In the second step (eq. 2) the sulfonamide is treated in hot alkaline solution with an aminating agent such as hydroxylamine-O-sulfonic acid (hereafter abbreviated HOS) or chloramine.[12,13] The method appears general and has been applied to a variety of aliphatic primary amines and to one aromatic amine.

$$R\text{–}NH_2 \xrightarrow{ArSO_2Cl} R\text{–}NHSO_2Ar \qquad (1)$$

$$RNHSO_2Ar \xrightarrow[NH_2X]{\ominus OH} ArSO_2H + N_2 + RH \qquad (2)$$

X = OSO_3H or Cl

Results

The amines used in this study (Table I) are known compounds and were readily converted to one or more of the corresponding N-substituted sulfonamides by treatment in pyridine with benzenesulfonyl chloride, *p*-toluenesulfonyl chloride, or methanesulfonyl chloride. Many of these derivatives have not been previously characterized and Table I lists their relevant physical constants and analytical data.

In the reductive deamination procedure the sulfonamide was added to hot aqueous sodium hydroxide containing (if necessary) enough ethanol to give a homogeneous solution. Solid HOS[14] (or in some cases aqueous chloramine[15]) was added and the reaction mixture was distilled. In most cases the product (hydrocarbon) was separated from the aqueous distillate by extraction with carbon tetrachloride and was identified and assayed by infrared spectroscopic comparison with standard carbon tetrachloride solutions of the authentic hydrocarbon. Any unchanged sulfonamide was readily recovered from the distillation flask by acidification and extraction. Hydroxylamine-O-sulfonic acid[14,16] (and chloramine[15]) are known to decompose in aqueous alkali to several products, among which are hydrazine, hydroxylamine, ammonia, and nitrogen. Consequently, a large excess of the reagent was used and we varied the mole ratio of HOS to the sulfonamide as well as the concentrations of sodium hydroxide and ethanol to learn how these factors affected the yields.

The results, summarized in Table II, show that the reaction is fairly general.[17] Amino groups on primary,

(12) Chloramine was tried in some of our initial experiments with β-naphthylamine but proved less reliable than HOS, which was adopted for all subsequent work.

(13) Other N-aminations by these reagents are known. (a) E. Abel, *Monatsh.*, **87**, 164 (1956); (b) R. Gösl and A. Meuwsen, *Chem. Ber.*, **92**, 2521 (1959); (c) H. H. Sisler, R. A. Bafford, G. M. Omietanski, B. Rudner, and R. J. Drago, *J. Org. Chem.*, **24**, 859 (1959).

(14) F. Sommer, O. F. Schulz, and M. Nassau, *Z. anorg. allgem. Chem.*, **147**, 142 (1925).

(15) L. F. Audrieth and R. A. Rowe, *J. Am. Chem. Soc.*, **77**, 4726 (1955).

(16) R. Nast, K. Nyul, and E. Grziwok, *Z. anorg. allgem. Chem.*, **267**, 304 (1952).

(17) (a) Some olefinic and acetylenic linkages can be reduced by strongly alkaline solutions of HOS, presumably through the intermediate genera-

TABLE II

Run	Amine	Sulfonamide	Molar ratio[a]	Experimental conditions[i]	Product	Yield,[b] % Actual	Yield,[b] % Corrected
A1	Benzyl-	Bs	9	c,p	Toluene	30–60(5)	65–>90(2)
A2	Benzyl-	Bs	22	d,m,p	Toluene	60(2)	>90(2)
A3	Benzyl-	Ts	12	g,p	Toluene	50(1)	>90(1)
A4	Benzyl-	Ts	12	h,l,r	Toluene	45(1)	>90(1)
A5	Benzyl-	Ts	12	o,q	Toluene	20–25(2)	>90(2)
A6	Benzyl-	Ms	8	d,p	Toluene	60(2)	80(2)
B1	α-Phenylethyl-	Bs	9–12	d,p	Ethylbenzene	20–30(3)	85(1)
B2	α-Phenylethyl-	Bs	58	d,p	Ethylbenzene	40(1)	[u]
B3	α-Phenylethyl-	Ms	18	c,q	Ethylbenzene	40(1)	60(1)
B4	α-Phenylethyl-	Ms	4.5	c,q	Ethylbenzene	20(1)	40(1)
B5	α-Phenylethyl-	Ms	88	e,p	Ethylbenzene	60(1)	75(1)
B6	α-Phenylethyl-	Ms	44	e,p	Ethylbenzene	60(1)	80(1)
B7	α-Phenylethyl-	Ms	44	g,p,v	Ethylbenzene	80(1)	85(1)
C	2-Phenyl-2-butyl-	Bs	19–26	c,h,l,p	2-Phenylbutane	10(3)	>90(3)
D1	(−)-2-Phenyl-2-butyl-	Bs	80	h,l,p	(−)-2-Phenylbutane[w]	25(1)	>90(1)
D2	(−)-2-Phenyl-2-butyl-	Bs	58	h,l,p	(−)-2-Phenylbutane[w]	30(1)	>90(1)
E	Benzhydryl-	Bs	29	h,k,p	Diphenylmethane	5(3)	80–>90(3)
F	9-Aminofluorene	Ts	30	x	Fluorene	*ca.* 2(1)	[u]
G1	9-Amino-9,10-dihydro-9,10-ethanoanthracene	Ms	33	x	9,10-Dihydro-9,10-ethanoanthracene	3(1)	61(1)
G2	9-Amino-9,10-dihydro-9,10-ethanoanthracene	Ms	13	x	9,10-Dihydro-9,10-ethanoanthracene	6(1)	81(1)
H	1-Hexyl-	Ts	23	h,j,p	*n*-Hexane	35–40(3)	>90(3)
I1	Cyclohexyl-	Bs	21	h,k,p	Cyclohexane[v]	15–20(2)	70(2)
I2	Cyclohexyl-	Bs	11–21	f,p	Cyclohexane[v]	10(3)	40–45(3)
J	1-Octyl-	Ts	25	h,j,p	*n*-Octane	25–30(3)	>90(3)
K	2-Octyl-	Ts	17–25	h,k,p	*n*-Octane	10–15(3)	>90(3)
L	2,4,4-Trimethyl-2-pentyl-	Ts	25	h,l,p	2,4,4-Trimethylpentane	5–10(3)	>90(2)
M	*p*-Menthanedi-	di-Ts	21	e,n,p	[x]	<2(2)	[u]
N1	β-Naphthyl-	Bs	[u]	s,o	Naphthalene	5(1)	[u]
N2	β-Naphthyl-	Bs	[u]	x	Naphthalene	5(1)	[u]
N3	β-Naphthyl-	Ts	[u]	s,t	Naphthalene	0–15(10)	[u]
N4	β-Naphthyl-	Ts	[u]	x	Naphthalene	2–19(7)	[u]
N5	β-Naphthyl-	Ms	[u]	s,t	Naphthalene	2–5(2)	[u]

[a] Molar ratio of HOS (or chloramine) to amine sulfonamide. The chloramine cases are indicated by footnotes *s* or *t*. [b] Yields from infrared assay are rounded off to the closest lower multiple of 5% (*e.g.*, 63% is rounded to 60%). "Actual" yields based on total sulfonamide added; "corrected" yields account for recovery of starting material and are based on sulfonamide consumed. Parenthesized figures indicate the number of runs on which the yields are based. [c] The concentration of sodium hydroxide in the final solution was 5–7%, [d] 8%, [e] 10%, [f] 10–15%, [g] 12%, [h] 15%. [i] The percentage by volume of ethanol in the final solution: [j] 20%, [k] 20–30%, [l] 30%, [m] 30–60%, [n] 50%. [o] This run was conducted in a solution containing 5 g. of sodium dissolved in *ca.* 80 ml. of ethanol. [p] The temperature of the solution when HOS was added was 80–95°, [q] 40–60°, [r] 25°. [s] Aqueous chloramine added to the alkaline solution, which was at 80–95°, [t] 25°. [u] Not determined. [v] HOS added in 5 equal portions and the product was removed by five successive distillations each conducted after 20% of the reagent had been added. The individual yield from each stage was 35, 16, 16, 8, and 6%. [w] Product from runs D1 and D2 were combined before determination of optical rotation. [x] See Experimental. [y] Also identified by gas chromatography.

secondary, and tertiary aliphatic carbons can be replaced and these include primary, secondary, and tertiary benzylic carbons as well as those on rings and bridgeheads. The conversion of β-naphthylamine to naphthalene (runs N) suggests applicability of the reaction to aromatic amines but nothing can be said at present about its generality in the aromatic series.[18] The yields in reductive deaminations varied widely and were often low. In most cases the amine sulfonamide does not enter any principal side reactions because the yields were generally high when corrected for recovered starting material. Higher conversions are attainable by recycling, as in run B7 where a final yield of 80% of ethylbenzene was realized. In that run the methanesulfonamide of α-phenylethylamine in aqueous alkali was treated successively with five batches of HOS and in each case the ethylbenzene was removed by distillation before addition of the next batch of HOS. The hydrocarbon yields do not seem to depend much on the nature of the sulfonamide group (benzenesulfonyl, *p*-toluenesulfonyl, or methanesulfonyl) or on the amount of ethanol in the alkaline solution. Large excesses of HOS usually improve the yields, but only up to a limit. For example, a 44:1 molar ratio of HOS (run B6) gave the same yield (60%) of ethylbenzene as did an 88:1 molar ratio (run B5) under similar conditions. Runs D1 and D2 bear out this same point. Attempts to effect reductive deamination in the 3β-amino-5α-cholestane series were unsuccessful. Starting material was recovered almost quantitatively when 3β-amino-5α-cholestane *p*-toluenesulfonamide was treated with HOS under a variety of alkaline conditions.

The relationship between yield and amine structure is of special interest. For a related series the yields decreased as the number of alkyl groups on the amine carbon increased. This trend is evident in the octyl series (runs J, K, L), and also in the benzylic series benzylamine (runs A), α-phenylethylamine (runs B), and 2-phenyl-2-butylamines (runs C and D). Furthermore, each of the benzylic amines (runs A, B, C, and

tion of diimide (HN=NH) [E. Schmitz and R. Ohme, *Angew. Chem.*, **73**, 807 (1961); R. Appel and W. Büchner, *Ann.*, **654**, 1 (1962)]; (b) Bumgardner, *et al.*, applied our reductive deamination to the *p*-toluenesulfonamide of cyclopropylcarbinylamine and obtained butene-1.[9]

(18) The experiments with β-naphthylamine were among the first in our exploratory work with chloramine and HOS, and the reaction conditions were less well regulated. Consequently the low yields may not necessarily reflect what is to be expected for aromatic systems.

D) gave higher yields than corresponding nonbenzylic ones of similar substitution (runs J, K, and L). The way in which alkyl and phenyl groups affect the ease of reaction at the amine nitrogen is presently not certain; steric and electronic effects may both be involved.

In some runs we looked for by-products and found small amounts (0.1–2%, corrected) of aldehydes and ketones in those cases where the amino group was attached to primary or secondary carbons. These carbonyl compounds were usually not detectable by infrared but were isolated as their 2,4-dinitrophenylhydrazones, which were identified through physical constants and, in some cases, by direct comparison with authentic samples. Compounds thus identified were benzaldehyde (from runs A1, A3, A5), acetophenone (runs B1, B2, B3), hexanal-1 (run H), cyclohexanone (runs I1 and I2), and octanal-1 (run J).

In the case of 9-aminofluorene *p*-toluenesulfonamide (run F) the expected hydrocarbon, fluorene, was obtained in very low yield (*ca.* 2%). Interestingly, fluorenone azine was isolated as a by-product, and we had spectroscopic indication that considerable fluorenone was formed (strong carbonyl band at 1722 cm.$^{-1}$). No azines were encountered with the other amines.

The only aromatic amine studied was β-naphthylamine, which was also the only case where chloramine was tried as the N-aminating agent as well as HOS. With HOS under a variety of conditions the yields of naphthalene were 2–19%.[19] Chloramine gave up to 15% yield, but we found aqueous chloramine solution difficult to assay and less convenient to handle than was crystalline HOS. In one run with HOS an unidentified oil was obtained along with the naphthalene. This oil showed a strong, sharp band at 2115 cm.$^{-1}$ along with absorption at 1282 cm.$^{-1}$. The crude naphthalene from the chloramine runs may have contained this same material because the infrared spectra showed weak peaks at 2115 and 1282 cm.$^{-1}$. Bands at those positions are characteristic of azides,[20] which may be by-products in our reactions. No azide peaks were observed in the reductive deamination of the aliphatic amines.

Discussion

The pathway we proposed[8] for the reductive deamination reaction is illustrated with an amine benzenesulfonamide in eq. 3–5; steps involving proton transfers are omitted. Under alkaline influence the sulfonamide first undergoes N-amination by HOS (eq. 3).[21] Other aminations by this reagent (and by chloramine) have been reported.[13] This step must compete with several others involving HOS, which is unstable in alkali.[14,16,17] The N-aminosulfonamide VI then loses the elements of benzenesulfinic acid to form a monosubstituted diimide VII (eq. 4), which readily converts to hydrocarbon by loss of nitrogen (eq. 5). We made no attempt to identify nitrogen because it is also produced in the decomposition of HOS. Substituted diimides of the type VII have also been postulated as intermediates in the McFayden–Stevens reaction,[11] in Wolff–Kishner reductions,[22] and in various oxidations of monosubstituted hydrazines.[23]

$$RNHSO_2Ph + NH_2OSO_3^{\ominus} \xrightarrow{\overset{\ominus}{O}H} R-\underset{\text{VI}}{\overset{NH_2}{\overset{|}{N}}}-SO_2Ph \quad (3)$$

$$R-\underset{\text{VI}}{\overset{SO_2Ph}{\overset{|}{N}}}-NH_2 \xrightarrow{\overset{\ominus}{O}H} \underset{\text{VII}}{R-N=NH} + PhSO_2^{\ominus} \quad (4)$$

$$\underset{\text{VII}}{R-N=NH} \longrightarrow RH + N_2 \quad (5)$$

Although the benzenesulfinate ion is predicted as a product (eq. 4), it would not be expected to survive in the presence of HOS. In separate experiments we treated sodium benzensulfinate with 1.4 equivalents of HOS under alkaline conditions and obtained benzenesulfonamide in 62% yield (eq. 6). In contrast, sodium benzenesulfonate did not undergo this reaction.[24] Consequently, if benzenesulfinate is formed in the reductive deamination reaction, some of it should be converted *in situ* to benzenesulfonamide. We confirmed this expectation in the case of benzylamine benzenesulfonamide by isolating benzenesulfonamide in 21% yield (corrected). This yield is too high for the compound to be derived from any side reaction.

$$PhSO_2^{\ominus} + NH_2OSO_3^{\ominus} \longrightarrow PhSO_2NH_2 + SO_4^{-2} \quad (6)$$

The precise mechanism of the N-amination step (eq. 3) is not clear. Various workers have suggested that HOS (or chloramine) in alkaline media can generate the electron-deficient species NH (nitrene) as the active agent in N-amination of amines.[17,25] Others have proposed that HOS combines with amines by direct displacement.[26] Extension of these views to our sulfonamides leads to two distinct pathways for the formation of the N–N bond (eq. 3). In one, the HOS is first transformed to the nitrene (eq. 7a), which subsequently combines with the anionic (or neutral) form of the sulfonamide (eq. 7b). In the other pathway (eq. 8) the N–N bond is created in a direct displacement by the sulfonamide nitrogen, probably in anionic form. Various modifications of these pathways can also be envisaged. In any event the N-amination step (eq. 3) is probably yield-determining because subsequent steps (eq. 4 and 5 or their equivalents) are expected to be relatively rapid and evidently do not involve any significant side reactions.

$$\text{(a)}\quad NH_2OSO_3^{\ominus} \xrightarrow{\overset{\ominus}{O}H} NH$$

$$\text{(b)}\quad R-\underset{\ominus}{N}-SO_2Ph + NH \longrightarrow \underset{\ominus NH \quad \text{IX}}{R-\overset{|}{N}-SO_2Ph} \quad (7)$$

$$R-\overset{\curvearrowright}{N}\overset{\ominus}{\overset{\curvearrowright}{N}}H_2-OSO_3^{\ominus} \longrightarrow \underset{SO_2Ph}{\overset{|}{R-N}}-NH_2 + SO^{-2} \quad (8)$$

That we did not isolate any N-aminosulfonamide VI in our reactions indicates a short survival time for this intermediate in the strong alkaline media. Alternatively, if the N–N bond is created through a nitrene pathway (eq. 7b) the newly derived anion IX could produce the monosubstituted diimide VII directly by ejection of benzenesulfinate ion before combination

(19) In two runs we observed 29 and 51% yields, but were unable to duplicate these results.

(20) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," 2nd Ed., John Wiley and Sons, Inc., New York, N. Y., 1958, p. 273.

(21) Presumably HOS exists as the zwitterion $^{+}NH_3OSO_3^{-}$ in the solid state and in neutral or weakly acidic media, as the cation $^{+}NH_3OSO_3H$ in strongly acidic solutions, and as the anion $NH_2OSO_3^{-}$ in alkaline solutions. The stability of the dry solid is probably due to the zwitterionic form.

(22) (a) W. Seibert, *Chem. Ber.*, **80**, 494 (1947); **81**, 266 (1948); (b) G. Lardelli and O. Jeger, *Helv. Chim. Acta*, **32**, 1817 (1949); (c) H. H. Szmant, H. F. Harnsberger, T. J. Butler, and W. P. Barie, *J. Am. Chem. Soc.*, **74**, 2724 (1952); (d) R. B. Turner, R. Anliker, R. Helbling, J. Meier, and H. Heusser, *Helv. Chim. Acta*, **38**, 411 (1955); (e) N. J. Leonard and S. Gelfand, *J. Am. Chem. Soc.*, **77**, 3272 (1955).

(23) (a) D. J. Cram, J. S. Bradshaw, W. Lwowski, and G. R. Knox, *ibid.*, **84**, 2832 (1962); (b) D. J. Cram and J. S. Bradshaw, *ibid.*, **85**, 1108 (1963).

(24) This alkaline conversion of a sulfinic, but not a sulfonic, acid to a sulfonamide may be generally useful for detection and characterization of sulfinic acids.

(25) (a) U. Wannagat and H. Kohnen, *Angew. Chem.*, **69**, 783 (1957); (b) P. A. S. Smith and J. H. Hall, *J. Am. Chem. Soc.*, **84**, 480 (1962), footnote 3; (c) L. F. Audrieth and L. H. Diamond, *ibid.*, **76**, 4869 (1954).

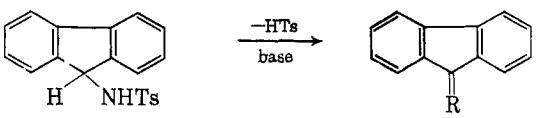
(26) J. W. Cahn and R. E. Powell, *ibid.*, **76**, 2565 (1954); G. M. Omietanski, A. D. Kelmers, R. W. Shellman, and H. H. Sisler, *ibid.*, **78**, 3874 (1956); R. Gösl and A. Meuwsen, *Chem. Ber.*, **92**, 2521 (1959).

with a proton. Stable monosubstituted diimides have not been reported, and the collapse of VII to the hydrocarbon is expected.[27]

The effects of aryl and alkyl substitution on the yields in the reductive deaminations are of mechanistic significance. However, until more knowledge becomes available on the properties and behavior of nitrenes,[28] we feel that neither our results nor information currently available in the literature permits an unequivocal decision about the N-amination mechanism. The two pathways eq. 7 and 8 may in fact be competitive, and the outcome could depend on the individual case.

In the over-all pathway for reductive deamination the question of stereochemistry arises in the collapse of the monosubstituted diimide VII (eq. 5). We therefore examined an optically active amine, (−)-2-phenyl-2-butylamine.[29] Reductive deamination of its benzenesulfonamide (runs D) in aqueous sodium hydroxide (15%) containing 30% ethanol produced (−)-2-phenylbutane whose specific rotation indicated an optical purity of 20 ± 10%.[30] Recovered starting material had not lost any of its optical activity, and the product is known not to racemize under the reaction conditions.[23,31] Since (−)-2-phenyl-2-butylamine and (−)-2-phenylbutane are configurationally related,[29] we conclude that the reaction proceeded with about 20% net retention of configuration. Recently Cram, Bradshaw, Lwowski, and Knox used our reductive deamination in connection with their studies of carbanions generated by fission of C–N bonds.[23] They treated the benzenesulfonamide of (−)-2-phenyl-2-butylamine in water–ethanol–sodium hydroxide with HOS and observed 32% net retention of configuration in the derived (−)-2-phenylbutane. Their experimental conditions were similar to ours, though not identical, and the stereochemical results agree satisfactorily. A full discussion of the stereochemistry and mechanism of this C–N bond fission and its relation to other electrophilic substitutions has been given by Cram and Bradshaw.[23b]

Oxidative deamination to form carbonyl compounds was a minor side reaction in those cases where the nitrogen was attached to a carbon bearing a hydrogen. When this C–H is acidic enough the carbonyl compound might arise from the starting sulfonamide by a base-induced elimination of a sulfinic acid, followed by hydrolysis. This pathway has analogy[32] and is illustrated with 9-aminofluorene *p*-toluenesulfonamide(X), which would proceed to fluorenone XII *via* the intermediate imine XI. We obtained some direct support for this pathway by showing that X was transformed to XII



X XI, R = NH
XII, R = O

(isolated as the phenylhydrazone) on treatment with alkali in the absence of HOS. This pathway may not be general because we did not isolate any benzaldehyde when benzylamine benzenesulfonamide was treated with aqueous alkali in the absence of HOS. Interestingly, however, some benzaldehyde was formed when hydrazine was added to the alkaline solution. The requirement for HOS or hydrazine in benzaldehyde formation suggests these reagents might function as oxidizing agents.

The reaction of 9-aminofluorene *p*-toluenesulfonamide is of interest because it produced fluorenone azine (as well as fluorenone) and was the only case where these side reactions predominated. Formation of the azine can be rationalized in several ways,[32a] most of which depend on the presence of the relatively acidic hydrogen at C-9. Evidently the reductive deamination reaction has less chance of success when the amino-carbon carries a hydrogen of appreciable acidity.

Experimental[33]

9-Amino-9,10-dihydro-9,10-ethanoanthracene.—The crude amine was prepared by the method of Wilhelm and Curtin[34] and was purified by sublimation or, better, by treatment in ether–ethanol with Norit A, evaporation to dryness, and crystallization from ethanol; m.p. 129–130°.

3β-Amino-5α-cholestane.—Reduction of 5α-cholestan-3-one oxime (30 g., m.p. 202° dec., α + 50°)[35] with sodium (125 g.) in ethanol (1250 ml.) or in isoamyl alcohol by the method of Dodgson and Haworth[35a] yielded mainly 3β-amino-5-α-cholestane (21 g.), m.p. 75–91°. Its identity was confirmed by acetylation (75% yield) with acetic anhydride in ether to 3β-acetamido-5α-cholestane, m.p. 245–247°, α +12°.[35b]

Amine sulfonamides were prepared by reaction of the amine (*ca.* 10 g., commercial sample when available) with the appropriate sulfonyl chloride[36] (*ca.* 10 g.) in dry pyridine (*ca.* 50 ml.). The reaction mixture was heated on a steam bath (or left at room temperature when methanesulfonyl chloride was used) for 30 min., was cooled, and was acidified with hydrochloric acid. Ether-soluble products were recovered by extraction with ether. Ether-insoluble products were also water insoluble and were recovered by filtration. Yields were usually higher than 70%. Crystallization solvents, physical constants, analytical data, and relevant literature references[37−46] are summarized in Table I.

(27) Conceivably, a monosubstituted diimide could convert to a corresponding azamine under some conditions prior to loss of nitrogen.

$$R{-}N{=}NH \longrightarrow R{-}\overset{\oplus}{N}H{=}\overset{\ominus}{N} \longleftrightarrow R{-}\ddot{N}H{-}\ddot{N}:$$

Disubstituted azamines (R_2N–N) have been postulated in reactions of 1,1-disubstituted hydrazines [J. Kenner and E. C. Knight, *Ber.*, **69**, 341 (1936); J. A. Carpino, *J. Am. Chem. Soc.*, **79**, 4427 (1957); D. M. Lemal, T. W. Rave, and S. D. McGregor, *ibid.*, **85**, 1944 (1963), and references cited there].

(28) G. Smolinsky, E. Wasserman, and W. A. Yager, *ibid.*, **84**, 3220 (1962), and references cited there.

(29) We are grateful to Drs. E. H. White and R. R. Johnson, who supplied us in 1959 with racemic and optically active 2-phenyl-2-butylamine. They obtained the optically active (−)-form by resolution through the tartrate and established its configurational relationship to (+)-2-methyl-2-phenylbutyric acid by a Curtius rearrangement [E. H. White and J. Stuber, *ibid.*, **85**, 2168 (1963)]. This last acid is known to be related configurationally to (−)-2-phenylbutane [D. J. Cram and J. Allinger, *ibid.*, **76**, 4516 (1954)]. More recently, Cram and Bradshaw related the (+)-acid to the (−)-amine by a similar sequence of reactions.[23]

(30) The possible experimental error is high because the concentration of (−)-2-phenylbutane in the solutions used for optical rotations was determined by infrared spectroscopy.

(31) D. J. Cram, C. A. Kingsbury, and B. Rickborn, *J. Am. Chem. Soc.*, **83**, 3688 (1961).

(32) E. L. Holmes and C. K. Ingold, *J. Chem. Soc.*, 1305 (1926).

(32a) NOTE ADDED IN PROOF.—For analogies to pathways that involve diazoalkanes as intermediates, see C. G. Overberger and J-P. Anselme, *Tetrahedron Letters*, **No. 21**, 1405 (1963), and references cited therein.

(33) Unless stated otherwise, the following information applies. Melting points are corrected and boiling points are uncorrected. Infrared spectra were recorded in carbon tetrachloride with a Perkin–Elmer Model 21 spectrophotometer equipped with sodium chloride optics. Elemental analyses were performed by Mr. J. Walter at The Johns Hopkins University. Optical rotations were taken at room temperature in chloroform with a sodium lamp light source.

(34) M. Wilhelm and D. Y. Curtin, *Helv. Chim. Acta*, **40**, 2129 (1957). We wish to thank Drs. J. B. DiGiorgio, W. Mendelson, B. E. Weller, and Mr. M. Bursey for preparation of this amine.

(35) (a) D. P. Dodgson and R. D. Haworth, *J. Chem. Soc.*, 67 (1952); (b) C. W. Shoppee, D. E. Evans, H. C. Richards, and G. H. R. Summers, *ibid.*, 1649 (1956).

(36) Benzenesulfonyl chloride had b.p. 115–118° (10 mm.), *p*-toluenesulfonyl chloride had m.p. 67–68.5°, and methanesulfonyl chloride was Eastman reagent grade. Twice as much reagent was used in the case of *p*-menthanediamine.

(37) R. L. Shriner, R. C. Fuson, and D. Y. Curtin, "The Systematic Identification of Organic Compounds, A Laboratory Manual," 4th Ed., John Wiley and Sons, Inc., New York, N. Y., 1956: (a) p. 288; (b) p. 294; (c) p. 111; (d) p. 327.

(38) Also recently prepared by T. P. Johnston, C. L. Kussner, and L. B. Holum, *J. Org. Chem.*, **25**, 399 (1960).

(39) This compound has been reported without analysis by H. Mauser, *Chem. Ber.*, **90**, 307 (1957).

(40) (a) D. J. Cram, C. A. Kingsbury, and A. Langemann, *J. Am. Chem. Soc.*, **81**, 5785 (1959); (b) also recently prepared by Cram and Bradshaw,[23] who reported α_{546} −44.6° (in benzene).

Preparation of Aqueous Chloramine.[15]—Aqueous sodium hypochlorite[47] (1 volume, *ca.* 1 *M*), cooled to its freezing point, was added slowly to aqueous ammonia (1 volume, *ca.* 1.7 *M*), which was *ca.* 75% frozen, and was kept in an ice bath during reaction. A minimum of stirring and of gas evolution assured a solution that contained chloramine.[48]

Hydroxylamine-O-sulfonic Acid (HOS).—Except for a few modifications, the method of Sommer, Schulz, and Nassau[14] was used. Chlorosulfonic acid[49] (300 ml.) was added, cautiously at first, to hydroxylamine sulfate (190 g.). The flask was fitted with a drying tube and was heated on a steam bath until the mixture was a smooth paste (8–12 hr.). The product was isolated as a white powder as described in the literature[14] and was dried at room temperature under vacuum. The dried solid (254 g.) kept very well when stored under vacuum, which was preferable to storage over phosphorus pentoxide.[14,50] The compound is now commercially available (Eastman).

Reaction of HOS with Sulfonamides of Primary Aliphatic Amines. (a) General Procedure.—A three-neck, round-bottom flask equipped with a magnetic stirrer, a heating mantle, reflux condenser, and take-off condenser was used. Carbon tetrachloride (10 ml.) was placed in the distillation receiver, which was cooled in an ice bath[51] during reaction. The stopcocks of all separatory funnels were lubricated with carbon tetrachloride before use.

The sulfonamide (*ca.* 1 g.) was dissolved in hot aqueous sodium hydroxide (*ca.* 100 ml.). If solution did not take place, ethanol (10–30 ml.) was added until the system was homogeneous; HOS (10 g.) was added in small portions through the reflux condenser, which was kept stoppered except during addition of HOS. The reaction mixture was distilled for *ca.* 1 hr. The content of the receiver was transferred quantitatively to a separatory funnel and was acidified with dilute hydrochloric acid (100 ml., *ca.* 5%). The carbon tetrachloride layer was washed with two fresh portions of water (100 ml. each; W-1 and W-2, respectively) and was then filtered through a short column of sodium sulfate (1–2 g.) into a 25-ml. volumetric flask. Fresh carbon tetrachloride (*ca.* 8 ml.) was shaken in the same sequence with the three water layers (acidified distillate, W-1, and W-2) and was filtered through the sodium sulfate into the volumetric flask. This last procedure was repeated with a third portion of carbon tetrachloride (*ca.* 8 ml.). The combined filtrates were diluted to 25 ml. with fresh carbon tetrachloride that had been filtered through the sodium sulfate column. The amount of hydrocarbon in the carbon tetrachloride was determined from its infrared spectrum by an empirical method described below.[52] The identity of the product was established by comparison of the infrared spectrum with that of the authentic hydrocarbon in carbon tetrachloride, and in some cases was established by other methods as well.

(b) Isolation of Carbonyl Compounds.—In most cases carbonyl peaks due to by-products were undetectable by infrared. After infrared assay, the carbon tetrachloride solution of the product was treated with glacial acetic acid (*ca.* 2 ml.) and 2,4-dinitrophenylhydrazine (*ca.* 0.01 g.). The mixture was heated cautiously for 1–2 min., water was added and the carbon tetrachloride was evaporated. If a 2,4-dinitrophenylhydrazone separated from the aqueous layer, it was identified by its melting point, which corresponded satisfactorily with the reported value in each case. In addition, authentic 2,4-dinitrophenylhydrazones were prepared[37c] from benzaldehyde, acetophenone, and cyclohexanone for mixture m.p.'s which were in each case undepressed. The 2,4-dinitrophenylhydrazones isolated were those of benzaldehyde from benzylamine benzenesulfonamide (runs A1, A3, A5); acetophenone from α-phenylethylamine benzenesulfonamide (runs B1, B2), and methanesulfonamide (run B3); hexanal-1[53a] from 1-hexylamine *p*-toluenesulfonamide (run H); cyclohexanone from cyclohexylamine benzenesulfonamide (runs I1, I2); octanal-1[53b] from 1-octylamine *p*-toluenesulfonamide (run J). The corrected yields ranged from 0.1 to 2%.

(c) Isolation of Unchanged Sulfonamides.—The reaction mixture remaining from distillation was acidified with concentrated hydrochloric acid and extracted twice with ether. The combined ether layers were washed twice with water and once with saturated sodium chloride solution, were filtered through anhydrous sodium sulfate, and were evaporated to dryness. The solid residue was weighed and was identified, without purification, as unchanged amine sulfonamide by melting point determinations or by infrared comparisons.

The distillation residue also contained ammonia (identified by a positive test with Nessler reagent[54]), hydrazine (isolated as benzalazine by treatment with benzaldehyde, m.p. 90–92° and undepressed by authentic benzalazine), and sulfate ion, which was indicated by formation of a copious white precipitate when an aqueous barium chloride solution was added. These are among the products expected from decomposition of HOS in an aqueous alkaline medium.[14,16]

(d) Empirical Infrared Assay Method.—For each hydrocarbon a series of solutions of known concentrations was prepared in carbon tetrachloride (25 ml.). The hydrocarbons used were the purest grades available commercially. The infrared spectra of these solutions were recorded under standardized instrumental conditions with no cell in the compensating beam. Spectral characteristics of the sodium chloride cells used (0.1- and 0.5-mm. path lengths) did not vary appreciably through the course of this work. Several prominent absorption bands were selected and the values of percentage transmission were plotted against the corresponding concentrations. Smooth curves were drawn, one for each spectral band. In several cases a second set of curves was prepared from spectra of a second set of standard solutions and in every case the two graphs were superimposable to within ±1%.

The carbon tetrachloride solution of the hydrocarbon from reductive deamination was examined by infrared in the same cell and under the same conditions used to prepare the calibration graphs. The concentrations determined from the percentage transmission of the prominent bands were averaged, and this average value, expressed as percentage yield and rounded to the closest lower multiple of 5%, was taken as the experimental yield (Table II).

Reductive Deamination Details Not Included in Table II. HOS with (−)-2-Phenyl-2-butylamine Benzenesulfonamide.—The conversion of (−)-2-phenyl-2-butylamine (b.p. 60° at 0.5 mm., $n^{25}D$ 1.5160, α −17° neat)[29] to the benzenesulfonamide and the reductive deamination were carried out as usual. The recovered starting sulfonamide had m.p. 103.5–108° and after one crystallization from ethanol it had m.p. 106–108.5°, α −41° ($CHCl_3$). After infrared assay of the product, the bulk of carbon tetrachloride was removed by distillation. The optical rotation of the distillation residue was measured and the concentration of the (−)-2-phenylbutane was determined twice by dilution of two portions of the distillation residue with carbon tetrachloride and subsequent assay by infrared spectroscopy as described previously. The distillate, residue, and dilutions from this procedure were combined and a second distillation was carried out, this time with a spinning band fractionation column. The optical rotation and concentration of this second distillation residue were determined as before. The average of these three determinations of specific rotation (−4.6, −6.7, −4.0°) was −5.1°. Optically pure (−)-2-phenylbutane is reported to have α_D −27.3° (neat)[55a] and α_D −24.3° (neat).[55b] Therefore, the net retention of configuration was *ca.* 20 ± 10%. The estimated accuracy makes allowance for errors in the infrared assay of concentration, etc.

HOS with 9-Amino-9,10-dihydro-9,10-ethanoanthracene Methanesufonamide (Run G1).—The sulfonamide (2.43 g.) in solution with aqueous sodium hydroxide (20%, 80 ml.) and ethanol (20 ml.) was treated with HOS (10 g.). The product was obtained in the usual manner in carbon tetrachloride and the infrared spectrum was as expected. Evaporation left a solid (0.020 g.), m.p.

(41) L. Demény, *Rec. trav. chim.*, **50**, 51 (1931).

(42) R. Sasin, F. R. Longo, F. A. Carey, C. M. Paulson, Jr., and G. S. Sasin, *J. Am. Oil Chemists' Soc.*, **37**, 152 (1960) [*Chem. Abstr.*, **54**, 10673*i* (1960)].

(43) W. D. Emmons and J. P. Freeman, *J. Am. Chem. Soc.*, **77**, 6061 (1955).

(44) Beilstein "Handbuch der Organischen Chemie," vierte Auflage, Verlag von Julius Springer, Berlin; (a) Vol. XII, 1929, p. 1326; (b) Vol. XV, 1932, p. 150.

(45) The staff of the Research Laboratory of Hopkin and Williams, Ltd., "Organic Reagents for Organic Analysis," 4th Ed., Hopkin and Williams, Ltd., London, 1944, p. 132.

(46) C. S Marvel, M. D. Helfrick, and J. P. Belsley, *J. Am. Chem. Soc.*, **51**, 1272 (1929).

(47) H. S. Booth, Ed., "Inorganic Syntheses," Vol. I, McGraw-Hill Book Co., Inc., New York, N. Y., 1939, p. 90.

(48) A. T. Palin, *Analyst*, **70**, 203 (1945).

(49) Care was taken to use only the clear supernatant of the practical grade (Eastman). Alternatively the iron-free, 99 + % grade (Matheson, Coleman, and Bell) was used.

(50) P. Kovacic and R. P. Bennett, *J. Am. Chem. Soc.*, **83**, 221 (1961).

(51) For reductive deamination of cyclohexylamine benzenesulfonamide one reaction mixture was distilled into a Dry Ice–acetone cooled receiver, which was also equipped with an auxiliary trap that contained an additional 10 ml. of carbon tetrachloride. Spectroscopic examination (infrared, 5.0-mm. cell) showed that some cyclohexane was present in the trap. The yield of cyclohexane in the reciver (10%) was not appreciably different from those obtained from reactions with ice-cooled receivers (10–20%).

(52) When a carbon tetrachloride solution that contained *ca.* 50% ethanol was carried through the washing procedure just described, no ethanol bands were evident in the infrared spectrum (5.0 mm. cell) of the washed solution.

(53) Beilstein, "Handbuch der Organischen Chemie," vierte Auflage, drittes Erganzungwerk, Springer Verlag, Berlin, 1959, Vol. I; (a) p. 2825; (b) p. 2871.

(54) G. L. Clark, L. K. Nash, and R. B. Fischer, "Quantitative Chemical Analysis," W. B. Saunders and Co., Philadelphia, Pa., 1950, p. 382.

(55) (a) P. W. B. Harrison, J. Kenyon, and J. R. Shepherd, *J. Chem. Soc.*, 658 (1926); (b) D. J. Cram, *J. Am. Chem. Soc.*, **74**, 2149 (1952). The reported values are actually for the (+)-enantiomer.

141.5–142.5° (reported[56] for 9,10-dihydro-9,10-ethanoanthracene, m.p. 142–143°). Aqueous sodium hydroxide and ethanol (in the same quantities as before) were added to the original reaction mixture, which was treated with more HOS (10 g.). The distillate yielded 0.018 g. of hydrocarbon, m.p. 139–142°. A repetition of the whole process gave 0.012 g., m.p. 133–139°. The combined yield from the three cycles was 0.050 g. (3%). The recovered starting material weighed 2.31 g., m.p. 226–230.5°.

In a second run (G2) the methanesulfonamide (2.0 g.) in aqueous sodium hydroxide (15%; 115 ml.) and ethanol (10 ml.) was treated with HOS (10 g.). The crude hydrocarbon was isolated from the distillate in 6% yield (0.082 g.), and 1.86 g. of starting material was recovered.

HOS with 9-Aminofluorene *p*-Toluenesulfonamide.—The sulfonamide (1.0 g.) in aqueous sodium hydroxide (20%, 80 ml.) and ethanol (30 ml.) was treated with HOS (10 g.). The hot solution turned yellow even before addition of HOS, and the color deepened as the reaction progressed. After distillation, the residual solution contained a bright red solid, m.p. 271–272°, unchanged after one crystallization from benzene and undepressed on mixture with fluorenone azine[57] of m.p. 271.5–272°; infrared spectra (KBr) of the two were identical.

The carbon tetrachloride solution of the distillate showed a strong carbonyl band at the same position (1722 cm.$^{-1}$) as fluorenone does. The solution of the product was filtered through alumina (20 g.) and was eluted with more carbon tetrachloride. An infrared spectrum of the first 50 ml. of eluate showed no carbonyl peak and indicated a 2.5% yield of fluorene. The 50 ml. of eluate was evaporated to dryness and, after one crystallization from ethanol, the residue (0.019 g., 3.8%) had m.p. 45–77° undepressed on mixture with fluorene.

HOS with 3β-Amino-5α-cholestane *p*-Toluenesulfonamide.—Numerous unsuccessful attempts were made to effect reductive deamination. The alkaline solutions tried included aqueous sodium hydroxide, potassium hydroxide in aqueous dioxane, pyridine in water, dry pyridine, sodium ethoxide in ethanol, and sodium methoxide in benzene. Variations in temperature and in proportions of HOS were also tried. After each run the reaction mixture was acidified with hydrochloric acid and extracted with ether, which was evaporated. The residue was chromatographed on alumina. Initial fractions eluted with benzene contained oily residues derived from the solvents whose infrared spectra (CS_2) were not identifiable as cholestane, which was available for direct comparison. Elution with benzene–ether gave the starting sulfonamide (m.p. 220–222°) in yields over 95% except for a run carried out in dry pyridine where the recovery was 41%.

HOS with β-Naphthylamine Sulfonamides.—The apparatus used was a 1-neck round-bottom flask equipped with a reflux condenser, a heating mantle and, when necessary, a dropping funnel; HOS (1.5–10 g.), either in water solution or as a solid, was added to a mixture of the sulfonamide (0.5 or 5.0 g.) and aqueous sodium hydroxide (*ca.* 250 ml. of 2.4% or of 1.5%). The reaction mixture was stirred at room temperature (0–20 hr.) then heated but not refluxed (3–19 hr.). The product that collected on the reflux condenser was flushed out with water and was collected by filtration with suction and weighed. Naphthalene, identified by m.p. and infrared, was produced in yields of 2–19%. (In two runs, 29 and 51% yields were obtained, but we were unable to reproduce these higher yields.).

In one reaction where β-naphthylamine *p*-toluenesulfonamide (0.5 g.) in aqueous sodium hydroxide (230 ml., 1.5%) was treated with HOS (10 g.) at room temperature and heated immediately (3 hr.), a colorless oil was observed in the filtrate after naphthalene (2% yield) was collected. This oil was extracted from the filtrate with ether and was recovered by evaporation of the ether in a stream of air at room temperature. The residue (0.008 g.) was red by the time the ether had evaporated. An infrared spectrum of this oil showed a strong, sharp band at 2115 cm.$^{-1}$. No further study of this oil was made.

Chloramine with β-Naphthylamine Sulfonamides.—A procedure similar to that with HOS was often used, but highest yields were obtained as follows. A 1-neck flask was equipped with a heating mantle, a magnetic stirrer, and a take-off condenser. Aqueous chloramine (60 ml.) diluted to 110 ml. was added to a hot solution of the sulfonamide (1.0 g.) and sodium hydroxide (0.1–0.2 g.) in water (*ca.* 100 ml.). The reaction mixture was distilled for 1–2 hr., during which time the solution darkened. The naphthalene in the distillate was collected and weighed. The naphthalene was usually pink and was identified by m.p. (usually *ca.* 75–80°), by mixture m.p., and by its infrared spectrum, which was identical with that of naphthalene (Baker Analyzed) except for one sharp band at 2115 cm.$^{-1}$ and one very weak, diffuse band at 1282 cm.$^{-1}$. These same bands appeared in the spectrum of the oil isolated from reaction of β-naphthylamine *p*-toluenesulfonamide with HOS.

When reactants were mixed at room temperature, left overnight at *ca.* 0°, and then steam distilled, no naphthalene was produced. Substitution of the sodium salt of β-naphthylamine *p*-toluenesulfonamide[58] for the free sulfonamide in one run gave a 5% yield of naphthalene. To see if solid surfaces were beneficial,[11] one run with β-naphthylamine *p*-toluenesulfonamide was conducted as usual, but with glass wool added. Naphthalene was obtained in 5% yield. Addition of a second portion of aqueous chloramine (110 ml.) gave an additional 5% yield.

Isolation of Benzenesulfonamide.—Benzylamine benzenesulfonamide (14.0 g.) in aqueous sodium hydroxide (15%, 400 ml.) was treated with HOS (30 g.). After distillation, the original reaction mixture was acidified with concentrated hydrochloric acid and was extracted twice with ether. The combined ether layers were washed once with water (which was discarded) and then twice with aqueous sodium carbonate (*ca.* 10%). The ether layer on work-up afforded benzylamine benzenesulfonamide (7.9 g.), m.p. 80–85°. The combined sodium carbonate layers were acidified with concentrated hydrochloric acid and were extracted with ether. Evaporation of the ether extracts gave benzenesulfonamide, m.p. 150–154° (0.8 g., 21% corrected), identified by mixture m.p. and infrared comparisons with authentic material (m.p. 150–153°).[37d]

Reaction of Sodium Benzenesulfinate with HOS.—HOS (10 g.) was added in small portions to a hot solution of sodium benzenesulfinate (10 g.) in aqueous sodium hydroxide (110 ml., 15%). The reaction mixture was refluxed for 2 hr. and left to cool overnight, was acidified with hydrochloric acid, and was extracted with ether. Evaporation of the ether left benzenesulfonamide (6 g., 62%), m.p. 149–152°, mixture m.p. with authentic benzenesulfonamide 150–152°. The infrared spectra (KBr) of these two compounds were identical. No benzenesulfonamide was formed when sodium benzenesulfonate was treated with HOS in a similar manner.

Control Reactions. (a) **With Benzylamine Benzenesulfonamide.**—This sulfonamide (2.0 g.) in aqueous sodium hydroxide (100 ml., 12%) was distilled slowly for 4.5 hr. The distillate was extracted with carbon tetrachloride and each extract was treated with 2,4-dinitrophenylhydrazine in the same manner as in the reductive deamination procedure. No benzaldehyde 2,4-dinitrophenylhydrazone was produced. Hydrazine hydrate (3 ml. of 85% in water) was added to the original reaction flask and a second distillation was conducted for 3 hr. This distillate gave a negative test for ammonia with Nessler reagent[54] and had pH 9–10. Extraction with carbon tetrachloride and treatment in the usual way gave some benzaldehyde 2,4-dinitrophenylhydrazone, m.p. 237.5–239°, undepressed by authentic material. To test the effect of sulfate ion benzylamine benzenesulfonamide was treated as above with sodium hydroxide and then distilled during 1.5 hr. (distillate A). The initial solution was partly neutralized with concentrated sulfuric acid (leaving the solution still distinctly alkaline) and distilled for 1.5 hr. (distillate B). Hydrazine hydrate (3 ml.) was added and distillation continued another 1.5 hr. (distillate C). Distillates A and B were neutral to pH paper and gave no derivative with 2,4-dinitrophenylhydrazine. Distillate C had pH 9–10 and yielded benzaldehyde 2,4-dinitrophenylhydrazone, as confirmed by m.p. and mixture m.p.

(b) **With 9-Aminofluorene *p*-Toluenesulfonamide.**—When this sulfonamide was refluxed several hours in aqueous sodium hydroxide and ethanol under typical conditions the solution turned yellow, and eventually a red oil separated. The oil was separated and the alkaline solution was acidified with hydrochloric acid and extracted with ether. Evaporation of the ether left a residue, which was treated with phenylhydrazine and acetic acid in ethanol. Fluorenone phenylhydrazone crystallized as an orange solid, m.p. 146–149° (reported[44b] 151°).

Acknowledgment.—This work was supported by a Frederick Gardner Cottrell Grant from the Research Corporation, by the Alfred P. Sloan Foundation, and by a grant-in-aid from the Hynson, Westcott and Dunning Fund of The Johns Hopkins University, to all of whom we express our appreciation. We are also grateful to Drs. E. H. White and J. H. M. Hill for helpful discussions.

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