Dehydration was effected by refluxing 3 g of the benzophenone adduct VI with 0.2 g of *p*-toluenesulfonic acid in 200 ml of dry benzene for 12 hr. The benzene solution was cooled, washed twice with aqueous sodium bicarbonate and twice with water, and dried over anhydrous magnesium sulfate. The solvent was removed. The residue was recrystallized from ethanol–acetonitrile to afford 2.10 g of N,N-dimethyl-*p*-(2,2-diphenylvinyl)-benzenesulfonamide (VII), mp 166–167.5°. A second crop (0.30 g) melted at 164–167.5°; the total yield was 84%. After four recrystallizations from acetonitrile, a sample melted at 166–168°.

Anal. Calcd for $C_{22}H_{21}NO_2S$: C, 72.70; H, 5.82; N, 3.85; S, 8.82. Found: C, 72.56; H, 5.83; N, 3.85; S, 8.77.

B. With Anisaldehyde to Form VIII.—This reaction was carried out essentially as described above for benzophenone. After 1.5 min, the clear dark gray reaction mixture was inversely neutralized. The ammonia was evaporated; then water and ether were added. Undissolved solid was collected by filtration and recrystallized from ethanol to give 4.74 g of white crystals, mp 141–145°. Evaporation of the ether layer of the filtrate and of ethereal extracts of the aqueous layer gave, on cooling, some solid, which was collected and recrystallized from ethanol to give 0.66 g of crystals, mp 139–148°. The two crops were combined and recrystallized from ethanol to afford 5.14 g (31%) of N,N-dimethyl-*p*-(2-hydroxy-2-*p*-methoxyphenylethyl)benzenesulfonamide (VIII), mp 143–148° and 147.5–150° after further recrystallization.

Anal. Calcd for $C_{17}H_{21}NO_4S$: C, 60.87; H, 6.31; N, 4.18; S, 9.56. Found: C, 60.73; H, 6.08; N, 3.90; S, 9.89.

Dehydration of 2 g of VIII was effected as described above for that of adduct VI to give 1.61 g (85%) of N,N-dimethyl-4′-methoxy-*trans*-4-stilbenesulfonamide (IX), mp 213.5–215.5°.

Anal. Calcd for $C_{17}H_{19}NO_3S$: C, 64.33; H, 6.03; N, 4.41; S, 10.10. Found: C, 64.29; H, 6.00; N, 4.46; S, 9.95.

Benzoylation of Sulfonamide I with Methyl Benzoate to Form X. A. By Sodium Amide.—To a stirred suspension of 0.105 mole (2.1 mole equiv) of sodium amide in 500 ml of liquid ammonia was added 9.97 g (0.05 mole) of N,N-dimethyl-*p*-toluenesulfonamide; the solid was rinsed in with a little ether. The resulting dark red mixture was stirred 30 min. Then 13.61 g (0.1 mole or 2 equiv) of methyl benzoate in ether was added. The color became pale green and a precipitate appeared. After 2 hr, 8 g of ammonium chloride was added, the ammonia evaporated, and the residue stirred with ether and water. Insoluble solid was collected by filtration. Ether extraction of the filtrate gave only an oil which did not crystallize. The filtered solid was recrystallized from acetonitrile to afford 5.79 g (38%) of N,N-dimethyl-*p*-phenacylbenzenesulfonamide (X), mp 191–195° and 192.5–195° after further recrystallization.

Anal. Calcd for $C_{16}H_{17}NO_3S$: C, 63.34; H, 5.65; N, 4.62; S, 10.57. Found: C, 63.11; H, 5.61; N, 4.80; S, 10.50.

B. By Sodium Hydride.—To a stirred slurry of 15 g (0.4 mole) of sodium hydride reagent[19] in 100 ml of refluxing 1,2-dimethoxyethane (monoglyme), under dry nitrogen, was added a mixture of 19.93 g (0.1 mole) of N,N-dimethyl-*p*-toluenesulfonamide (I) and 13.61 g (0.1 mole) of methyl benzoate in 100 ml of monoglyme. After 6 hr, most of the solvent was removed under reduced pressure and the residue worked up to give 0.70 g (2.3%) of X, melting point and mixture melting point with a sample prepared by the sodium amide method, 192.5–196°. The infrared spectra of the two samples were identical. Most (65%) of the starting sulfonamide I was recovered. Some (6%) benzoic acid was isolated.

Registry No.—I′, 13952-53-9; II, 10517-63-2; III, 13952-54-0; IV, 13952-55-1; V, 13952-56-2; VI, 13952-57-3; VII, 13952-58-4; VIII, 13952-59-5; IX, 13952-60-8; X, 13952-61-9; N,N-dimethyl-*p*-toluenesulfonamide, 599-69-9; sodium amide, 12125-45-0; ammonia, 7664-41-7.

(19) Obtained from Metal Hydrides, Inc., as an approximately 60% dispersion of sodium hydride in mineral oil.

Formation and Reactions of Trisodio-N-acetylsalicylamide[1]

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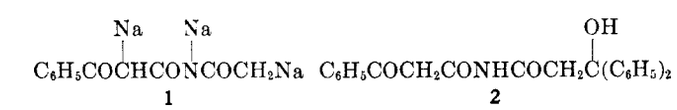
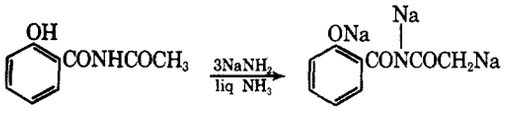
N-Acetylsalicylamide was converted, by means of sodium amide in liquid ammonia, into trisodio salt **3′**. This salt underwent alkylation with certain primary halides, carbonyl addition with various aromatic ketones and aldehydes, and aroylation with methyl benzoate exclusively at its terminal carbanion site. These reactions furnish a convenient new synthetic route to several known compounds as well as a method for the preparation of a number of new compounds.

Recently, several types of active hydrogen compounds have been converted into synthetically useful 1,3,5-trialkali salts by means of 3 molecular equiv of alkali amide in liquid ammonia.[2] For example, N-acetyl-α-benzoylacetamide was converted into trisodio salt **1** which underwent a carbonyl addition reaction with benzophenone to afford carbinol **2**.[2c]



In view of the structural similarity between N-acetyl-α-benzoylacetamide and N-acetylsalicylamide (**3**), where the phenolic OH may be regarded as a completely enolized carbonyl group, it seemed possible that **3** might likewise undergo threefold metalation to form the reactive trialkali salt **3′** (eq 1). This has been



(1)

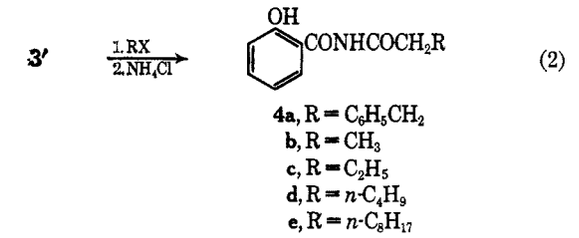
verified in the present study, as evidenced by condensations at the original terminal methyl position with electrophilic compounds.

Trisodio salt **3′** underwent alkylations with the appropriate halides to afford alkyl derivatives **4a–e** in yields of 31–74% (eq 2).[3] The results of these alkylations are summarized in Table I.

(1) (a) Acknowledgment is made to the donors of the Petroleum Research Fund administered by the American Chemical Society and to the Committee on Grants-in-Aid of Research of the Society of The Sigma Xi for partial support of this work; (b) abstracted from the Ph.D. dissertation of C.-L. Mao, Virginia Polytechic Institute, 1967.

(2) (a) K. G. Hampton, T. M. Harris, C. M. Harris, and C. R. Hauser, *J. Org. Chem.*, **30**, 4263 (1965); (b) J. F. Wolfe, C. L. Mao, D. R. Bryant, and C. R. Hauser, *ibid.*, **31**, 3725 (1966); (c) J. F. Wolfe and C. L. Mao, *ibid.*, **32**, 1977 (1967).

(3) Addition of benzyl chloride was not accompanied by stilbene formation which would have been expected if essentially all of the sodium amide had not been consumed in the threefold ionization of **3**. See S. Boatman, T. M. Harris, and C. R. Hauser, *ibid.*, **30**, 3593 (1965).



(2)

4a, R = $C_6H_5CH_2$
b, R = CH_3
c, R = C_2H_5
d, R = n-C_4H_9
e, R = n-C_8H_{17}

TABLE I

ALKYLATIONS OF TRISODIO SALT 3'

Alkyl halide	Alkylation product	Mp,[d] °C	Yield, %
$C_6H_5CH_2Cl$	N-Hydrocinnamoylsalicylamide[a] (**4a**)	146–147	52
CH_3I	N-Propionylsalicylamide (**4b**)	125–127[e]	50
C_2H_5Br	N-Butyrylsalicylamide (**4c**)	128–129[f]	74
n-C_4H_9Br	N-Caproylsalicylamide[b] (**4d**)	121–121.5	37
n-$C_8H_{17}Br$	N-Caprylsalicylamide[c] (**4e**)	116–117	31

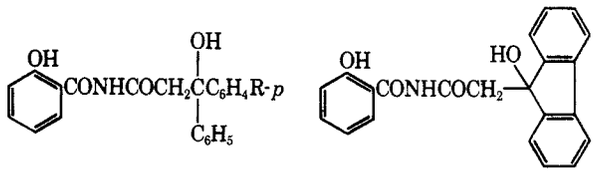
[a] *Anal.* Calcd for $C_{16}H_{15}NO_3$: C, 71.36; H, 5.61; N, 5.20. Found: C, 71.24; H, 5.47; N, 5.16. [b] *Anal.* Calcd for $C_{13}H_{17}NO_3$: C, 66.36; H, 7.28; N, 5.95. Found: C, 66.26; H, 7.23; N, 5.96. [c] *Anal.* Calcd for $C_{17}H_{25}NO_3$: C, 70.07; H, 8.65; N, 4.81. Found: C, 70.36; H, 8.45; N, 4.74. [d] All compounds were recrystallized from 95% ethanol. [e] Lit.[4] mp 126–127°. [f] Lit.[4] mp 128–129°.

Structural assignments **4a–e** were based on analyses (Table I), spectral studies, and chemical evidence. That **4a–e** were the products of C-alkylation, not the O- or N-alkyl derivatives, was verified by the absence of N-acetyl methyl resonance in their nmr spectra (see Experimental Section). The infrared spectra had strong absorption at 2.8–3.1 μ characteristic of both an NH and OH group. Structures **4a**, **4d**, and **4e** were further supported by acid-catalyzed hydrolysis to form, in addition to salicyclic acid, hydrocinnamic, caproic, and capric acid, respectively. Structural assignments **4b** and **4c** were verified by known independent syntheses from salicylamide and propionyl chloride and from salicylamide and n-butyryl chloride[4] (see Experimental Section).

Although alkylations of **3'** with unhindered primary alkyl halides would appear to be rather general, such was not the case when certain secondary halides were employed. Thus, attempted alkylation of **3'** with cyclohexyl bromide afforded none of the expected alkylation product, while attempted alkylation of **3'** with benzhydryl chloride produced tetraphenylethylene along with recovered **3**. In the latter case the strongly basic trisodio salt presumably effected dimerization of the halide.[2c,5]

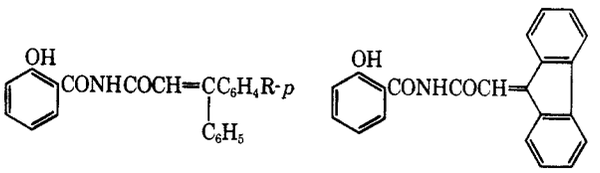
Trisodio salt **3'** underwent carbonyl addition reactions with benzophenone, p-chlorobenzophenone, and fluorenone to form hydroxy imides **5a**, **5b**, and **6** in yields of 72, 67, and 45%, respectively. Similarly, reaction of trisodio salt **3'** with p-methoxybenzophenone followed by treatment of the resulting crude product with p-toluenesulfonic acid in refluxing benzene afforded unsaturated imide **7b**[6] in 65% over-all yield.

Structural assignments for hydroxy imides **5a**, **5b**, and **6** were based on analyses (Table II) and nmr spectra, all of which had resonance for two methylene protons at 3.12–3.75 ppm in addition to the appropriate absorption for aromatic hydrogens (see Table III). Dehydration of **5a** and **6** to form unsaturated imides **7a** and **8** lent further support ot the proposed carbinol structures for these two compounds. Unsaturated imides **7a**, **7b**, and **8** were characterized by analyses (Table IV) and spectral data. In particular, the nmr spectra (Table III) has no absorption for methylene protons.



5a, R = H
b, R = Cl

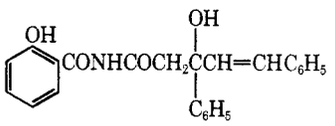
6



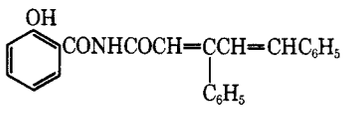
7a, R = H
b, R = OCH_3

8

Apparently trisodio salt **3'** underwent mainly 1,2 addition with chalcone since only carbinol **9**[6] and α,β-unsaturated imide **10** were isolated. That structural assignment **9** was correct was verified by analysis and by its dehydration to form **10**, the nmr spectrum of which was devoid of methylene proton resonance.

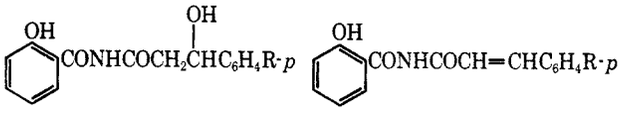


9



10

Trisodio salt **3'** also underwent carbonyl addition reactions with the appropriate aromatic aldehydes to form hydroxy imides **11a–c** in yields of 74, 20, and 16%, respectively. In a similar reaction with p-dimethylaminobenzaldehyde, unsaturated imide **12b**[6] was obtained directly in 73% yield.



11a, R = OCH_3
b, R = CH_3
c, R = Cl

12a, R = OCH_3
b, R = $N(CH_3)_2$

Analyses (Table II) and spectral data were consistent with structural assignments **11a–c**. The nmr spectra (Table III) had doublets at 2.9–3.1 ppm and triplets at 4.9–5.2 ppm ascribable to methylene and methinyl protons, respectively. The structure of **11a** was further supported by its facile dehydration to form unsaturated imide **12a**[6], the nmr spectrum of which lacked both

(4) T. Hanada, *Bull. Chem. Soc. Japan.*, **31**, 1024 (1959).
(5) R. B. Meyer and C. R. Hauser, *J. Org. Chem.*, **25**, 158 (1960).
(6) Although this compound appeared to be a single geometric isomer, its configuration was not determined.

TABLE II

CARBONYL ADDITION REACTIONS OF TRISODIO SALT 3′ WITH AROMATIC KETONES AND ALDEHYDES

Ketone or aldehyde	Product	Mp, °C	Yield, %	Empirical formula	Calcd, % C	Calcd, % H	Calcd, % N	Found, % C	Found, % H	Found, % N
Benzophenone	N-Salicyloyl-β-hydroxy-β-phenylhydrocinnamamide (**5a**)	183–184[a]	72	$C_{22}H_{19}NO_4$	73.11	5.30	3.88	73.02	5.42	3.90
p-Chlorobenzophenone	N-Salicyloyl-β-hydroxy-β-phenyl-*p*-chlorohydrocinnamamide (**5b**)	187–188[a]	67	$C_{22}H_{18}ClNO_4$[d]	66.75	4.58	3.54	67.09	4.74	3.49
Fluorenone	N-Salicyloyl-α-9-(9-hydroxyfluorenyl)acetamide (**6**)	145–148 dec[b]	45	$C_{22}H_{17}NO_4$	73.52	4.77	3.90	73.70	4.73	3.85
Chalcone	N-Salicyloyl-β-hydroxy-β-styrylhydrocinnamamide (**9**)	160–162 dec[c]	40	$C_{24}H_{21}NO_4$	74.40	5.46	3.62	74.10	5.50	3.77
Anisaldehyde	N-Salicyloyl-β-hydroxy-*p*-methoxyhydrocinnamamide (**11a**)	147–149 dec[a]	74	$C_{17}H_{17}NO_5$	64.75	5.43	4.44	64.90	5.59	4.44
p-Methylbenzaldehyde	N-Salicyloyl-β-hydroxy-*p*-methylhydrocinnamamide (**11b**)	129–131[a]	20	$C_{17}H_{17}NO_4$	68.21	5.73	4.68	68.41	5.81	4.74
p-Chlorobenzaldehyde	N-Salicyloyl-β-hydroxy-*p*-chlorohydrocinnamamide (**11c**)	144–146[a]	16	$C_{16}H_{14}ClNO_4$[e]	60.10	4.41	4.38	60.36	4.47	4.51

[a] Recrystallized from 95% ethanol. [b] Recrystallized from chloroform. [c] Recrystallized from acetic acid. [d] *Anal.* Calcd for Cl: 8.96. Found: Cl, 8.80. [e] *Anal.* Calcd for Cl: 11.09. Found: Cl, 11.01.

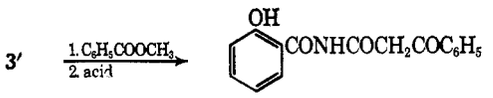
TABLE III

NMR DATA FOR PRODUCTS DERIVED FROM CARBONYL ADDITION REACTIONS[a,b]

Compd	Types of hydrogen and chemical shifts, δ, ppm — ArH	Methinyl	Methylene	Other
5a	7.25[c]	...	3.72	...
5b	7.43[c]	...	3.75[f]	...
6	7.38[c]	...	3.12[f]	...
7a	7.40[c,d]	...	...	...
7b	7.50[c,d]	...	...	3.91[f,h]
8	7.50[c,d]	...	...	...
10	7.80[c,d]	...	...	...
11a	7.25[c]	4.93[e]	2.92[g]	3.58[f,h]
11b	7.34[c]	5.10[e]	3.05[g]	2.17[f,i]
11c	7.35[c]	5.12[e]	3.08[g]	...
12a	7.50[c,d]	...	...	3.19[f,h]
12b	7.30[c,d]	...	...	2.95[f,j]

[a] Dimethyl sulfoxide-d_6 was used as the solvent for all of the above spectra. [b] Peak areas were consistent with the assignments given above. [c] Multiplet. [d] This multiplet was due to overlapping aromatic and vinyl peaks. [e] Triplet. [f] Singlet. [g] Doublet. [h] *p*-CH_3O. [i] *p*-CH_3. [j] *p*-$(CH_3)_2N$.

13 in 43% yield (eq 3). Structural assignment **13** was supported by analysis and by its nmr spectrum



(3)

13

which had a two-proton singlet at 4.58 ppm for the methylene hydrogens flanked by the two carbonyl groups. Further confirmation of structure **13** was obtained by its acid-catalyzed hydrolysis to form salicyclic acid and acetophenone.

Attempts to effect alkylation or carbonyl addition reactions at the methyl group of **3** by means of 1 or 2 mole equiv of sodium amide were unsuccessful and none of the possible O- or N-substituted derivatives were isolated from these reactions. Apparently the mono- and disodio salts of **3**, in which ionization of a methyl hydrogen is not realized, are relatively weak nucleophiles as compared to trisodio salt **3**′.

TABLE IV

UNSATURATED IMIDES DERIVED FROM CARBONYL ADDITION PRODUCTS

Addition product	Unsaturated imide	Mp, °C	Yield, %	Empirical formula	Calcd, % C	Calcd, % H	Calcd, % N	Found, % C	Found, % H	Found, % N
5a	N-Salicyloyl-β-phenylcinnamamide (**7a**)	191–192[a]	90	$C_{22}H_{17}NO_3$	76.95	4.70	3.84	76.86	4.93	4.04
...	N-Salicyloyl-β-phenyl-*p*-methoxycinnamamide (**7b**)	206–207[b]	65[f]	$C_{23}H_{19}NO_4$	73.98	5.13	3.75	74.28	5.13	3.89
6	N-Salicyloyl-α-fluorenylideneacetamide (**8**)	162–163[c]	53	$C_{22}H_{15}NO_3$	77.40	4.43	4.10	77.40	4.50	4.00
9	N-Salicyloyl-β-styrylcinnamamide (**10**)	215–216[d]	29[g]	$C_{24}H_{19}NO_3$	78.03	5.18	3.79	78.28	5.09	3.98
11a	N-Salicyloyl-*p*-methoxycinnamamide (**12a**)	181–182[e]	70	$C_{17}H_{15}NO_4$	68.67	5.09	4.71	68.46	5.10	4.67
...	N-Salicyloyl-*p*-dimethylaminocinnamamide (**12b**)	216–217[d]	73[f]	$C_{18}H_{18}N_2O_3$	69.66	5.85	9.03	69.69	6.03	8.85

[a] Recrystallized from isopropyl alcohol. [b] Recrystallized from acetone–ethanol. [c] Recrystallized from benzene. [d] Recrystallized from chloroform. [e] Recrystallized from 95% ethanol. [f] This yield was obtained by treating the crude condensation product with *p*-toluenesulfonic acid. [g] This yield was based on material isolated directly from the carbonyl addition reaction.

methinyl and methylene proton absorption as did the spectrum of unsaturated imide **12b** (see Table III).

All of the carbonyl additions described above were realized in highest yields when the reaction mixtures were neutralized after relatively short periods of time; lower yields were obtained after longer reaction times.[7]

In addition to alkylations and aldol-type condensations, trisodio salt **3**′ also underwent aroylation with methyl benzoate to form terminal benzoylation product

(7) See ref 2c and E. M. Kaiser and C. R. Hauser, *J. Org. Chem.*, **31**, 3317 (1966).

The synthetic utility of trisodio salt **3**′ is demonstrated by the fact that of the compounds prepared in the present study, only **4b** and **4c** appear to have been prepared by other methods. Both of these compounds were synthesized by a somewhat more circuitous route involving rearrangement of the appropriate O-acyl salicylamides.[4] Although a similar route could possibly be used for the synthesis of several other compounds reported in this study, the present method utilizing tri-

sodio salt **3′** seems to be more direct and convenient. Moreover, our method is applicable to the synthesis of a variety of N-acyl salicylamides which probably could not be prepared by rearrangement of O-acyl salicylamides.

Experimental Section[8]

Preparation of Trisodio Salt 3′.—To a stirred suspension of 0.06 mole of sodium amide, prepared from 0.06 g-atom of sodium in 300 ml of commercial anhydrous liquid ammonia[9] contained in a 500-ml three-necked flask equipped with an air condenser and a mechanical stirrer, was added 3.58 g (0.02 mole) of finely powdered N-acetylsalicylamide.[10] The resulting white suspension was stirred for 40 min before using as described below; this reagent was assumed to contain 0.02 mole of trisodio N-acetylsalicylamide (**3′**).

Alkylations of Trisodio Salt 3′.—To a stirred suspension of trisodio salt **3′** (0.02 mole) in 300 ml of liquid ammonia was added 0.02–0.022 mole of the appropriate alkyl halide in 20 ml of anhydrous ether. After 2–3 hr the reaction mixture was neutralized by addition of excess solid ammonum chloride and the ammonia was evaporated (steam bath) as an equal volume of ether was added. The suspended inorganic salts were dissolved by addition of 20 ml of 12 *N* hydrochloric acid and 150 g of crushed ice. The resulting two layers were separated and the aqueous layer was extracted with five 100-ml portions of ether–ethyl acetate (1:1). The original ethereal layer and the extracts were combined, washed with 5% sodium bicarbonate solution, dried ($MgSO_4$), and concentrated. Residues were washed with petroleum ether (bp 30–60°) and recrystallized from 95% ethanol. In the octylation of **3′**, the reaction mixture was stirred for 1 hr in liquid ammonia as the ammonia was gradually replaced by anhydrous ether. The resulting ethereal suspension was allowed to stir for 12 hr, neutralized with excess ammonium chloride, and processed in the manner described above. Yields and analytical data for alkylation products **4a–e** are given in Table I.

The nmr spectra of **4a**, **4d** and **4e** were consistent with the assigned structures. The spectrum of benzyl derivative **4a** had principal peaks ($CDCl_3$) at δ 7.10 (9 H multiplet, aromatic) and 2.77 ppm (4 H multiplet, CH_2CH_2Ph). The spectrum of butyl derivative **4d** had peaks ($CDCl_3$) at δ 7.29 (4 H multiplet, aromatic), 3.02 (2 H triplet with fine splitting, $COCH_2Bu$), 1.45 (6 H multiplet, $Me(CH_2)_3$), and 0.95 ppm (3 H triplet with fine splitting, CH_3). The spectrum of octyl derivative **4e** had peaks (DMSO-d_6) at δ 7.41 (4 H multiplet, aromatic), 2.74 (2 H triplet with shoulders, $COCH_2$), 1.20 (14 H broad singlet with shoulders, $Me(CH_2)_7$), and 0.90 ppm (3 H triplet with shoulders, CH_3). The infrared spectra of **4a–e** had principal bands at 2.8–3.1 (NH and OH) and 5.8–6.2 μ (C=O).

In an experiment similar to those described above, treatment of **3′** with cyclohexyl bromide afforded none of the expected cyclohexyl derivative; starting imide **3** and salicylamide were recovered.

In an attempt to effect benzhydrylation of **3′**, a suspension of 0.02 mole of **3′** in 300 ml of liquid ammonia was treated with 0.022 mole of benzhydryl chloride in 30 ml of dry ether. After 1 hr the reaction mixture was processed in the usual manner to afford 2.7 g (81%) of tetraphenylethylene, mp 222–224° (lit.[11] mp 222–224°), and 2.5 g (70%) of unchanged **3**.

Hydrolysis of Alkylation Products 4a, 4d, and 4e.—A 0.5–1.0 g sample of the appropriate alkylation product was refluxed with 50 ml of a 6 *N* hydrochloric acid for 2–12 hr. The hydrolysis mixture was cooled and the salicylic acid was collected by filtration and washed with petroleum ether. The aqueous acid solution and the petroleum ether washings were combined and extracted with three 50-ml portions of ether. The ethereal extracts were combined, dried ($MgSO_4$), and concentrated. The residues were recrystallized from appropriate solvents or distilled.

Hydrolysis of **4a** gave salicylic acid (90%), mp 156–158°, and hydrocinnamic acid (77%), mp 48–49° (lit.[12a] mp 49°). Likewise, **4d** was hydrolyzed to give salicylic acid (94%) and caproic acid (61%), bp 202–203° (lit.[12b] bp 205°). Hydrolysis of **4e** gave besides salicylic acid (84%), capric acid (82%), mp 29–31° (lit.[12b] mp 30°).

Independent Synthesis of 4b and 4c.—A 5.0-g (0.0366 mole) sample of salicylamide was dissolved in 10 ml of pyridine at −15° and 3.4 g (0.0366 mole) of propionyl chloride was added dropwise. The resulting solution was stirred at room temperature for 30 min and diluted with 50 ml of anhydrous ether. The ethereal solution was decanted and the remaining pasty mixture was stirred for 10 min with 100 ml of 1 *N* sulfuric acid. The resulting solid was collected by filtration, washed with water, and then refluxed for 30 min with 50 ml of water. The precipitate thus obtained was collected and recrystallized from benzene to give 2.10 g (30%) of **4b**, mp 126–127°. The infrared spectrum of this product was identical with that of **4b** prepared from trisodio salt **3′**. A mixture melting point showed no depression.

Similarly, a 5.0-g (0.0366 mole) sample of salicylamide was treated with 4.9 g (0.0366 mole) of *n*-butyryl chloride and the reaction mixture was processed as in the above experiment to afford 2.3 g (30%) of **4c**, mp 128–129.° A mixture melting point determination with a sample of **4c** prepared from trisodio salt **3′** showed no depression. The infrared spectra of the two samples were identical.

Condensations of Trisodio Salt 3′ with Aromatic Ketones.—To a stirred suspension of 0.02 mole of trisodio salt **3′** in 300 ml of liquid ammonia was added 0.02–0.022 mole of the appropriate ketone in 30 ml of dry ether. After 0.5–1.0 min,[13] the resulting dark grey solution was poured into a solution of excess ammonium chloride in 100 ml of liquid ammonia (inverse neutralization). The ammonia was evaporated (steam bath) as an equal volume of ether was added. The ethereal suspension was treated with a mixture of 20 ml of 12 *N* hydrochloric acid and 200 g of crushed ice. The two layers were separated and the aqueous layer was extracted with five 100-ml portions of ether–ethyl acetate (1:1). The original ethereal layer and the extracts were combined, washed with 5% sodium bicarbonate solution, dried ($MgSO_4$), and concentrated. The residues were washed with petroleum ether and recrystallized from appropriate solvents. Adducts **5a**, **5b**, and **6** had infrared absorption at 2.8–3.1 (NH and OH) and 5.8–6.2 μ (C=O).

In the condensation of **3′** with *p*-methoxybenzophenone, the crude product, which was isolated as described above, was refluxed with several crystals of *p*-toluenesulfonic acid in 50 ml of benzene for 3 hr to produce, on cooling the reaction mixture, unsaturated imide **7b**: infrared absorption at 2.8–3.1 (NH and OH) and 5.8–6.1 μ (C=O). In the condensation of **3′** with chalcone, the reaction mixture was allowed to stir for 5 min and neutralized by addition of excess ammonium chloride (direct neutralization).[14] The ammonia was replaced by ether and the ethereal suspension was treated with crushed ice and hydrochloric acid as described above. The solid material which separated between the layers was collected by filtration and recrystallized from acetic acid to afford 3.08 g (40%) of hydroxy imide **9**: infrared absorption at 2.8–3.1 (NH and OH) and 5.85–6.2 μ (C=O).[15] The aqueous layer was extracted with ether–ethyl acetate and these extracts were combined with the original ether layer. The combined organic extracts were washed with sodium bicarbonate solution, dried ($MgSO_4$), and concentrated to yield 2.13 g (29%) of unsaturated imide **10**: infrared absorption at 2.8–3.0 (NH and OH) and 5.8–6.2 μ (C=O).

Analytical data and yields for hydroxyimides **5a**, **5b**, **6**, and **9** are summarized in Table II. Similar data for unsaturated imides

(8) Melting points were taken on a Thomas–Hoover melting point apparatus in open capillary tubes and are corrected. Analyses were by Galbraith Laboratories, Knoxville, Tenn., and by G. B. Vaughan using an F & M Model 185 C, H, and N analyzer. Infrared spectra were taken on a Beckman IR-5A spectrophotometer using the potassium bromide pellet method. Nmr spectra were determined on a Varian Associates A-60 spectrometer using deuteriochloroform, with tetramethylsilane as internal standard, or dimethyl sulfoxide-d_6, with tetramethylsilane as external standard, as the solvent. Chemical shifts are measured to the center of a singlet or multiplet.

(9) See C. R. Hauser, F. W. Swamer, and J. T. Adams, *Org. Reactions*, **8**, 122 (1954).

(10) This compound was obtained from K & K Laboratories, Inc., and used without further purification.

(11) L. J. Durham and H. S. Mosher, *J. Am. Chem. Soc.*, **84**, 2811 (1962).

(12) (a) T. Mistui, H. Shiroyma, and S. Takei, *J. Agr. Chem. Soc. Japan*, **19**, 39 (1943); (b) R. L. Shriner, R. C. Fuson, and D. Y. Curtin, "The Systematic Identification of Organic Compounds," 4th ed, John Wiley and Sons, Inc., New York, N. Y., 1956, p 276.

(13) When the condensation of **3′** with benzophenone was allowed to proceed for 30 min before neutralization, only starting materials were recovered.

(14) Inverse neutralization of the reaction mixture produced only unsaturated imide **10**.

(15) The limited solubility of **9** in DMSO-d_6 at room temperature combined with its tendency to undergo dehydration to form **10** in this solvent at higher temperatures precluded satisfactory determination of its nmr spectrum.

7b and **10** appears in Table IV. Principal nmr absorptions for **5a**, **5b**, **6**, **7b**, and **10** are given in Table III.

Condensations of Trisodio Salt 3′ with Aromatic Aldehydes.—To a stirred suspension of 0.02 mole of trisodio salt **3′** in 300 ml of liquid ammonia was added 0.02–0.022 mole of the appropriate aldehyde in 30 ml of anhydrous ether. The reaction mixture was allowed to stir for 0.5–1.0 min, neutralized inversely with ammonium chloride, and processed as described for condensations of **3′** with aromatic ketones. In the condensation of **3′** with *p*-dimethylaminobenzaldehyde, the product isolated from the reaction mixture was found to be unsaturated imide **12b**, rather than the expected hydroxy imide.

The infrared spectra of **11a–c** and **12b** had absorption at 2.8–3.1 (NH and OH) and 5.8–6.2 μ (C=O). Analytical data and yields for hydroxy imides **11a–c** are presented in Table II. Similar data for unsaturated imide **12b** may be found in Table IV. Nmr data for these compounds appears in Table III.

Dehydration of Hydroxy Imides 5a, 6, and 11a to Form Unsaturated Imides 7a, 8, and 12a.—A 1.0–2.0-g sample of the appropriate hydroxy imide was refluxed with 25–40 ml of benzene containing a few crystals of *p*-toluenesulfonic acid for 1–12 hr. The resulting solution was cooled to precipitate the desired products which were recrystallized from appropriate solvents. The infrared spectra of these compounds had absorption at 2.8–3.1 (NH and OH) and 5.8–6.2 μ (C=O). Yields and analytical data for **7a**, **8**, and **12a** are given in Table IV. Important nmr peaks are presented in Table III.

Aroylation of Triosodio Salt 3′ with Methyl Benzoate.—To a suspension of 0.02 mole of trisodio salt **3′** in 300 ml of liquid ammonia was added 3.0 g (0.02 mole) of methyl benzoate in 20 ml of dry ether. The resulting mixture was stirred for 2 hr and the ammonia was evaporated (steam bath) as an equal volume of ether was added. The ethereal suspension was poured onto 300 g of crushed ice. The two layers were separated, the ethereal layer was discarded, and the aqueous layer was washed with 50 ml of ether which was also discarded. The aqueous layer was filtered and the dark residue was washed with water. The combined aqueous filtrate was cooled in an ice bath and acidified with 12 *N* hydrochloric acid to precipitate 2.42 g (43%) of N-salicyloyl-α-benzoylacetamide (**13**) as colorless needles, mp 167–168°, after two recrystallizations from 95% ethanol: nmr peaks (DMSO-d_6) at δ 7.42 (9 H multiplet, aromatic) and 4.58 ppm (2 H singlet, $-COCH_2CO$); infrared absorption at 2.9–3.1 (NH and OH) and 5.8–6.2 μ (C=O).

Anal. Calcd for $C_{16}H_{13}NO_4$: C, 67.84; H, 4.63; N, 4.95. Found: C, 68.05; H, 4.67; N, 5.04.

Hydrolysis of 13.—A 1.0-g sample of **13** was refluxed with 40 ml of 6 *N* hydrochloric acid for 5 hr. The resulting mixture was processed in the manner described for the acidic hydrolysis of alkylation products of **3′** to give 0.42 g (68%) of salicylic acid and 0.325 g (75%) of aceophenone, which was identified by comparison of its infrared spectrum with that of an authentic sample.

Registry No.—**3′**, 14001-88-8; **4a**, 13942-90-0; **4b**, 13942-91-1; **4c**, 13942-92-2; **4d**, 13942-93-3; **4e**, 13942-94-4; **5a**, 13942-95-5; **5b**, 13942-96-6; **6**, 14054-27-4; **7a**, 14001-89-9; **7b**, 13942-97-7; **8**, 14001-90-2; **9**, 13942-98-8; **10**, 14001-91-3; **11a**, 14001-92-4; **11b**, 14001-93-5; **11c**, 13942-99-9; **12a**, 13943-00-5; **12b**, 13943-01-6; **13**, 14001-94-6.

Selective Catalytic Dehydration. Thoria-Catalyzed Dehydration of Alcohols

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Thoria-catalyzed dehydration of secondary alcohols involves stereospecific *cis* elimination of water. Products from secondary 2-alkanols are largely (*ca.* 95%) 1-olefins. The major products from other secondary alkanols are the less substituted olefins. This is a general reaction of value in the preparation of alkenes of known structure. Thoria-catalyzed dehydration of tertiary alkanols is not selective.

Dehydration of alcohols over a metal oxide catalyst to form olefins has been extensively studied, particularly with low molecular weight alcohols and alumina catalysts. Recent reviews have summarized general dehydration literature[1] and progress in alumina-catalyzed dehydration of alcohols.[2] The extensive work of Pines and co-workers provides evidence that initial products of alumina-catalyzed dehydrations of primary and secondary alcohols arise from concerted *trans* elimination. Participation of two catalyst surfaces was proposed to achieve the required steric arrangement.[2,3] A parallel was noted between elimination reactions in solution and dehydration of alcohols catalyzed by alumina.

Differences in dehydration catalyzed by thoria and alumina have been discussed by Winfield.[1] Butadiene was the major product of thoria-catalyzed dehydration of 2,3-butanediol[4] but methyl ethyl ketone was the major product with alumina catalysis. Formation of 1-alkenes as major products from thoria-catalyzed dehydration of secondary 2-alkanols was recently shown to be a general reaction.[5] Alumina-catalyzed dehydration of 2-alkanols, however, results in formation of 2-alkenes as major products.[6] Alumina, but not thoria, catalyzes formation of diethyl ether from ethanol.[1]

Thoria-catalyzed dehydration of secondary 2-alkanols is an excellent synthetic method for preparing 1-alkenes of known structure. The present report describes this reaction in some detail and presents evidence that this dehydration involves stereospecific *cis* elimination of water.

Results

Dehydration of Secondary Alcohols.—Thoria and other oxides of actinide, lanthanide, and group IIIB elements catalyze the dehydration of secondary 2-alkanols to yield 1-alkenes as major products. Representative examples are summarized in Table I.

Dehydrations were conducted in a flow system with contact times of 0.1–0.5 sec, temperatures in the range of 330–420° and pressures of 10 mm to 1 atm.

The composition of olefins formed by thoria-catalyzed dehydration did not change significantly with temperature. The catalyst was remarkably stable and could be used to treat large quantities of alcohol, particularly when dehydrations were carried out at reduced pressure. Initially, about 5% of the product was ketone. This

(1) M. E. Winfield, *Catalysis*, **7**, 93.
(2) H. Pines and J. Manassen, *Advan. Catalysis*, **16**, 49 (1966).
(3) F. G. Schappell and H. Pines, *J. Org. Chem.*, **31**, 1735 (1966).
(4) M. E. Winfield, *J. Council Sci. Ind. Res.*, **18**, 412 (1945).
(5) A. J. Lundeen and R. Van Hoozer, *J. Am. Chem. Soc.*, **85**, 2180 (1963).
(6) H. Pines and W. O. Hoag, *ibid.*, **83**, 2847 (1961).