heptafluoro-1,2-epoxyhexane[21] (10.8 g.), b.p. 62–63° (131 mm.), $n^{25}D$ 1.3150. An intermediate fraction, 13.9 g., b.p. 65–140.5° (131 mm.) was shown to contain 80% epoxide by gas chromatography. Unchanged ester (10.0 g.), b.p. 98–99° (20 mm.), $n^{25}D$ 1.4004, was also recovered. The yield of epoxide was 78% at 61% conversion.

Anal. Calcd. for $C_6F_7H_5O$: C, 31.9; H, 2.2; F, 58.8. Found: C, 32.5; H, 2.5; F, 58.8.

(21) After the completion of this work, the preparation of this compound was described by J. D. Park, F. E. Rogers, and J. R. Lacher, *J. Org. Chem.*, **26**, 2089 (1961).

Elimination Reactions of α-Halogenated Ketones. IX.[1a] A Comparison of the Reactions of 2-Bromo-2-(α-bromobenzyl)-1-indanone with Those of 2-Bromo-2-(α-bromobenzyl)-3,3-dimethyl-1-indanone

BARRY D. PEARSON, RANDALL P. AYER, AND NORMAN H. CROMWELL[1b]

Avery Laboratory, University of Nebraska, Lincoln, Nebraska

Received February 19, 1962

2-Bromo-2-(α-bromobenzyl)-1-indanone reacts with piperidine and morpholine to give 3-piperidino(and 3-morpholino)-2-benzal-1-indanone and not the β-amino-α,β-unsaturated ketones, 2-(α-piperidinobenzal)-and 2-(α-morpholinobenzal)-1-indanone, as was previously reported.[1c] Thermal elimination of hydrogen bromide from 2-bromo-2-(α-bromobenzyl)-1-indanone similarly gives 3-bromo-2-benzal-1-indanone and not as previously reported 2-(α-bromobenzal)-1-indanone. The mechanisms of these eliminations and rearrangements are discussed. When the 3-positions are blocked, as in 2-bromo-2-(α-bromobenzyl)-3,3-dimethyl-1-indanone, elimination with piperidine and morpholine does give the β-amino-α,β-unsaturated ketones and these compounds are readily hydrolyzed to 2-benzoyl-3,3-dimethyl-1-indanone. With cyclohexylamine the last mentioned dibromo compound gave 2-(α-bromobenzal)-3,3-dimethyl-1-indanone.

The elimination of hydrogen bromide from 2-bromo-2-benzyl-1-tetralones yields predominantly the endocyclic elimination product 2-benzyl-1-keto-1,4-dihydronaphthalenes.[2] The elimination of hydrogen bromide from the related 2-bromo-2-benzyl-1-indanones was expected to give mainly exocyclic elimination because of steric differences. This indeed is the case, but the reaction of 2-bromo-2-(α-bromobenzyl)-1-indanone (IV) with piperidine or morpholine does not give the β-amino-α,β-unsaturated ketones (Xa, Xb) as was previously reported.[1c] Instead the exocyclic ketones VIIa and VIIb are produced wherein rearrangement has taken place during the elimination-substitution. Also thermal elimination of hydrogen bromide from the same dibromo compound IV does not yield 2-(α-bromobenzal)-1-indanone (IX) as was previously reported but instead forms 2-benzal-3-bromo-1-indanone (II). The same bromo compound II can also be prepared in high yield by the bromination of 2-benzal-1-indanone (I) with *N*-bromosuccinimide.

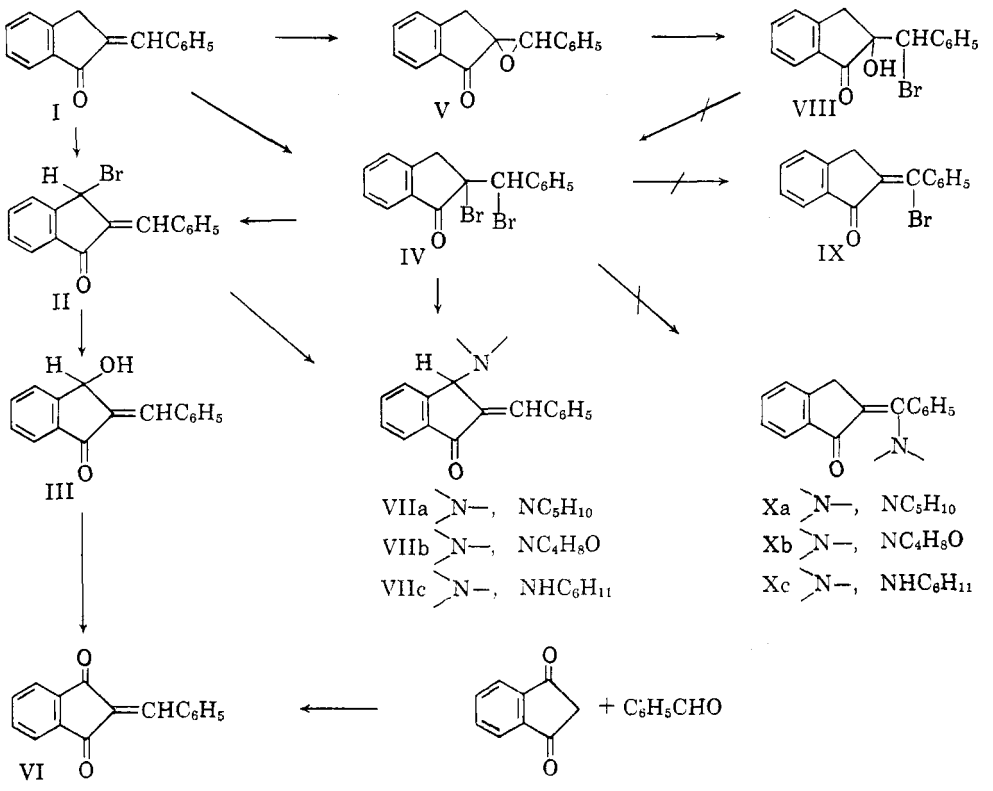
The β-amino-α,β-unsaturated ketone structures were considered to be correct for products from the reaction of the dibromo compound IV with amines because their ultraviolet and infrared spectra were somewhat different in an expected fashion from those of 2-benzal-1-indanone (I). However, it was observed[1c] that these amino products could not be hydrolyzed under the conditions normally successful with β-amino-α,β-unsaturated ketones.[3] Thus, as a final check on these amino products, it was considered desirable to carry out amine reactions with 2-bromo-2-(α-bromobenzyl)-3,3-dimethyl-1-indanone because only exocyclic elimination can occur from this compound.

3,3-Dimethyl-1-indanone was prepared in high yield, by the ring closure of β-phenylisovaleric acid with polyphosphoric acid, and condensed with benzaldehyde to give 2-benzal-3,3-dimethyl-1-indanone (XI). The latter with bromine in carbon tetrachloride solution readily formed 2-bromo-2-(α-bromobenzyl)-3,3-dimethyl-1-indanone (XV) in 72% yield. Piperidine and morpholine eliminated hydrogen bromide from this dibromo compound XV to give the β-amino-α,β-unsaturated ketones XVIIa and XVIIb, respectively. These strongly conjugated amino ketones had high melting points (180° and 214°, respectively) like amides and showed pronounced shifts of their carbonyl stretching frequencies (1640 and 1647 cm.$^{-1}$, respectively) when compared with the value for the parent 2-benzal-3,3-dimethyl-1-indanone (1705 cm.$^{-1}$). The strong conjugation between the electron donating amino group and the electron accepting carbonyl group results in the formation of an intense charge-transfer band in the visible spectrum of these compounds (406 and 401 mμ for XVIIa and XVIIb, respectively; $\epsilon \times 10^{-3}$, 19.6 and 21.0—ethanol solutions). This spectral data suggests that compounds XVIIa and XVIIb both have the same β-amino-α,β-unsaturated ketone structure, and to confirm this 2-(α-piperidinobenzal)-3,3-dimethyl-1-

(1) (a) For paper VIII, see G. Coppens, D. N. Kevill, and N. H. Cromwell, *J. Org. Chem.*, **27**, 3299 (1962). (b) To whom communications concerning this paper should be addressed. (c) N. H. Cromwell and R. P. Ayer, *J. Am. Chem. Soc.*, **82**, 133 (1960).

(2) A. Hassner and N. H. Cromwell, *J. Am. Chem. Soc.*, **80**, 893 and 901 (1958).

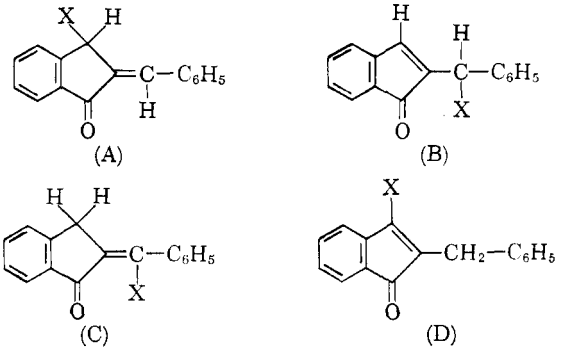
(3) N. H. Cromwell, *J. Am. Chem. Soc.*, **62**, 2897 (1940).



indanone (XVIIa) was hydrolyzed with aqueous sulfuric acid yielding the previously unknown 2-benzoyl-3,3-dimethyl-1-indanone (XVIII). The structure of this latter β-diketone was proven by its synthesis, using the general method of Stork,[4] from the reaction between benzoyl chloride and the pyrollidine enamine of 3,3-dimethyl-1-indanone. The infrared spectrum of the β-diketone XVIII shows two carbonyl stretching frequencies at 1726 cm.$^{-1}$ (indanone C=O) and 1679 cm.$^{-1}$ (C_6H_5CO) suggesting that this compound exists principally in the diketo form.

These results in the 3,3-dimethyl-1-indanone series, particularly the spectral data, indicated that the structures Xa and Xb, previously assigned[1c] to the compounds formed by the reaction of the appropriate amine with 2-bromo-2-(α-bromobenzyl)-1-indanone (IV), were incorrect. For further confirmation compound IV reacted with cyclohexylamine, but again the product Xc (isolated as the hydrochloride) did not have spectral characteristics consistent with a β-amino-α,β-unsaturated ketone structure. Considering their mode of formation and elemental analyses four general structures A, B, C, D seemed possible for the compounds previously assigned as IX, Xa, Xb, and Xc. The bromo compound assigned structure IX is included in this group because it reacts with piperidine and morpholine to yield the same amino ketones as are obtained when these amines react with the dibromo compound (IV).

(4) G. Stork, R. Terrell, and J. Szmuszkovicz, *J. Am. Chem. Soc.*, **76**, 2029 (1954).



X = Br, or >N— (where >N— is NC_5H_{10}, NC_4H_8O, or HNC_6H_{11})

To clarify the situation n.m.r. spectra were obtained of the bromo ketone and piperidino ketone (in deuterochloroform and carbon tetrachloride solutions, respectivey). The spectrum of the amino ketone indicated approximately ten aromatic protons near 2.5 p.p.m. (relative to tetramethylsilane = 10.0); six aliphatic protons at 8.6 p.p.m. and four aliphatic protons at 7.5 p.p.m., corresponding to the $-CH_2-CH_2-CH_2-$ and $-CH_2-\underset{|}{N}-CH_2$ features of the piperidino function, respectively, and approximately one proton at 5.1 p.p.m. A similar spectrum of the bromo ketone indicated ten aromatic protons at approximately 2.5 p.p.m. and a single proton at 3.6 p.p.m. These results eliminate structures C and D. The calculated shielding constants (assuming $CH_2\underset{|}{N}CH_2$ = 1.56,

TABLE I

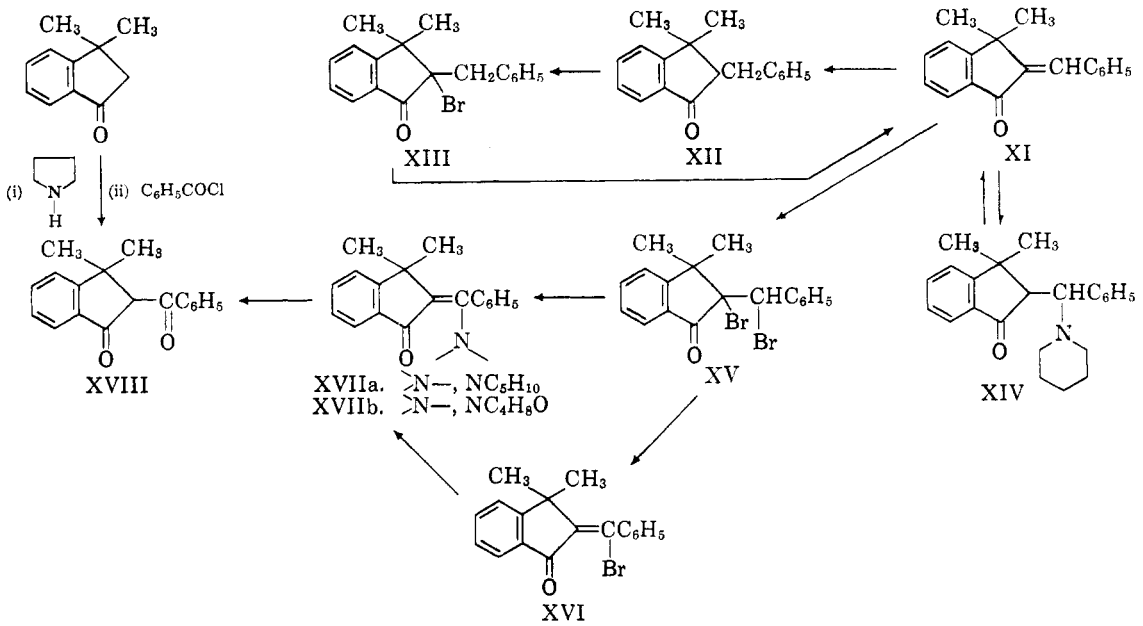
ANALYSES AND SPECTRA OF SUBSTITUTED 1-INDANONES

Compound	Ultraviolet Spectra: *n*-Hexane λ_{max}, mμ	$\epsilon \times 10^{-3}$	Ultraviolet Spectra: Methanol λ_{max}, mμ	$\epsilon \times 10^{-3}$	Infrared Spectra: CCl_4 Solutions, Cm.$^{-1}$	Calcd., %	Found, %
2-Benzal-1-indanone[a]	227	13.4					
	234	12.1			$\gamma_{C=O}$ 1706vs		
	241	8.2	227	10.0	$\gamma_{C=C}$ 1640s		
	300a	23.0	320	28.0			
	310	29.0			γ_{Ar} 1615m		
	323	25.1					
	337	11.6					
2-Benzal-3,3-dimethyl-1-indanone	227	10.7				$C_{18}H_{16}O$	
	242	8.3	224	7.8	$\gamma_{C=O}$ 1705vs		
	262	10.5	275a[b]	11.5	$\gamma_{C=C}$ 1627m	C 87.06	87.00
	310	18.2	310	17.5	γ_{Ar} 1612s	H 6.50	6.63
	322	17.6					
	335	10.7					
2-Bromo-2-(α-bromobenzyl)-1-indanone[c]	251	15.4	257	14.4	$\gamma_{C=O}$ 1735vs		
	294	2.9	295a	2.6	γ_{Ar} 1609m		
2-Bromo-2-(α-bromobenzyl)-3,3-dimethyl-1-indanone	253	11.6	257	11.3	$\gamma_{C=O}$ 1732vs	$C_{18}H_{16}OBr_2$	
	298	2.8	298a	3.5	γ_{Ar} 1610m	C 52.97	52.89
						H 3.95	4.13
						Br 39.16	39.35
2-Benzal-3-bromo-1-indanone[c]	229	16.2					
	234a	15.0	232	14.6	$\gamma_{C=O}$ 1710vs		
	254a	9.5	325	23.9	$\gamma_{C=C}$ 1630vs		
	319	23.5			γ_{Ar} 1603m		
	330	18.9					
2-(α-Bromobenzal)-3,3-dimethyl-1-indanone	262a	14.4				$C_{18}H_{15}OBr$	
	271	17.0			$\gamma_{C=O}$ 1708vs	C 66.07	66.19
	279	16.7	287	20.7	$\gamma_{C=C}$ 1623m	H 4.62	4.88
	290	17.2			γ_{Ar} 1613m	Br 24.42	24.40
	305a	8.6					
2-Benzal-3-piperidino-1-indanone[c]	229	13.7			$\gamma_{C=O}$ 1704vs		
	235	12.5	232	13.1	$\gamma_{C=C}$ 1633vs		
	314	23.0	324	24.0	γ_{Ar} 1608m		
	325a	19.2					
3,3-Dimethyl-2-(α-piperidinobenzal)-1-indanone	250	13.5				$C_{23}H_{25}NO$	
	288	3.8	260	11.7	$\gamma_{C=O}$ 1640vs	C 83.34	83.54
	297	3.8	406	19.6	γ_{Ar} 1605m	H 7.60	7.42
	365	13.5				N 4.23	4.10
	383	13.0					
2-Benzal-3-morpholino-1-indanone[c]	229	14.0			$\gamma_{C=O}$ 1705vs		
	235	13.1	231	12.4	$\gamma_{C=C}$ 1633vs		
	314	23.7	323	24.2	γ_{Ar} 1605m		
	325a	19.2					
3,3-Dimethyl-2-(α-morpholinobenzal)-1-indanone	249	12.9				$C_{22}H_{23}NO_2$	
	288	4.3	255	13.3	$\gamma_{C=O}$ 1647vs	C 79.25	79.27
	297	4.3	401	21.0	γ_{Ar} 1605m	H 6.95	6.68
	362	13.7				N 4.20	4.39
	380	12.2					
2-Benzyl-3,3-dimethyl-1-indanone	239	14.5				$C_{18}H_{18}O$	
	245a	11.8	244	12.6	$\gamma_{C=O}$ 1719vs	C 86.36	86.20
	282	2.2	270	1.7	γ_{Ar} 1607s	H 7.25	7.25
	291	2.2	288a	2.3			
2-Benzyl-2-bromo-3,3-dimethyl-1-indanone	246	10.2	253	10.8	$\gamma_{C=O}$ 1730vs	$C_{18}H_{17}OBr$	
	293	1.7	295a	2.5	γ_{Ar} 1603m	C 65.66	65.54
						H 5.21	5.22
						Br 24.27	24.65
3,3-Dimethyl-2-(α-piperidinobenzyl)-1-indanone			243	14.4	$\gamma_{C=O}$ 1720vs	$C_{23}H_{27}ON$	
			290a	4.7	γ_{Ar} 1610m	C 82.84	83.01
			312a	3.5		H 8.16	8.16
						N 4.20	4.36
2-Benzoyl-3,3-dimethyl-1-indanone	246	13.7	250	20.3	$\gamma_{C=O}$ 1726vs	$C_{18}H_{16}O_2$	
	292	4.0	297	4.6	(indanone)	C 81.79	81.93
	318	4.0	330	4.0	$\gamma_{C=O}$ 1679s	H 6.10	6.31
					(C_6H_5CO)		
					γ_{Ar} 1610m		
2-Benzal-3-hydroxy-1-indanone	230	8.8			γ_{OH} 3600w	$C_{16}H_{12}O_2$	
	303a	12.9	230	11.8	(free)	C 81.34	81.41
	314	18.9	323	22.3	$\gamma_{C=O}$ 1712s	H 5.12	5.21
	328	16.1			$\gamma_{C=C}$ 1635m		
					γ_{Ar} 1607m(d)		

TABLE I (*continued*)

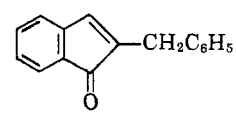
2-Benzal-1,3-indandione[7]	238	21.0	242	20.0	$\gamma_{C=O}$ 1735m			
	250	18.3	254	19.1	(S-*cis*-*cis*)			
	260	18.5	261	18.5	$\gamma_{C=O}$ 1695vs			
	340	35.7	341	31.0	(S-*cis*-*tans*)			
					$\gamma_{C=C}$ 1625m			
					γ_{Ar} 1590m(d)			
2-(α-Bromobenzyl)-2-hydroxy-1-indanone	245	15.0			γ_{OH} 3520m	$C_{16}H_{13}O_2Br$		
	252	13.2	251	16.7	(free)	C	60.57	60.89
	289	2.6	294	2.7	γ_{OH} 3420w	H	4.13	4.34
	299	2.6			(bonded)	Br	25.18	23.52c
					$\gamma_{C=O}$ 1725vs			
					γ_{Ar} 1615m			
2-Benzal-3-cyclohexylamino-1-indanone hydrochloride			230	11.9	$\gamma_{C=O}$ 1709s(b)	$C_{22}H_{24}OClN$		
			319	20.6	$\gamma_{C=C}$ 1648m(b)	C	74.66	74.57
					γ_{Ar} 1615m(b)	H	6.84	6.91
						N	3.96	4.01

[a] See ref. 2. [b] Symbols: a, shoulder; b, measured in Nujol; c, this compound loses bromine rapidly; d, measured in a KBr pellet. [c] See ref. 1c. [d] See ref. 7.



$C{=}C_{conj.}$ = 1.70, and C_6H_5 = 1.85 p.p.m.) are 4.7 and 3.9 p.p.m. for the piperidino ketone VIIa and the bromo ketone II, respectively. These calculated values are of the correct order and their difference (0.8 p.p.m.) is approximately the same (0.86 p.p.m.) as the difference between the corresponding values for benzylamine (6.44 p.p.m.) and benzyl bromide (5.58 p.p.m.).[5]

In an attempt to discover whether the dehydrobromination product II had structure A or B, a careful study of the ultraviolet and infrared spectra of many 1-indanone compounds previously prepared in this laboratory was undertaken (Table I). 2-Benzal-3,3-dimethyl-1-indanone (XI) can have only the structure indicated in view of the unambiguous mode of synthesis. It did seem possible, however, that 2-benzal-1-indanone (I) could have the alternative 2-benzylindone (XIX) structure. However, if this were the case, the indone (XIX), because of the conjugated system formed by its



(XIX)

five- and six-membered rings, would be expected to have a markedly different ultraviolet spectrum from that of the 1-indanone (I).[6] In fact the supposed 2-benzal-1-indanone (I) and the corresponding 3,3-dimethyl compound (XI) have almost identical ultraviolet and infrared spectra

(5) (a) L. M. Jackman, "Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry," Pergamon Press, New York, 1959, pp. 59. (b) Measurements and interpretation of the proton magnetic resonance spectra were done by Varian Associates, Palo Alto, California.

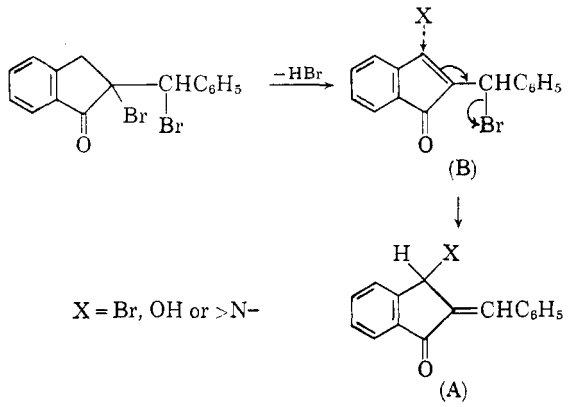
(6) In a private communication, Dr. House reports that 2-ethylindone(a) and 2-ethylidene-1-indanone(b) have the following spectral characteristics: (a) λ_{max} 242 ($\epsilon \times 10^{-3}$ 25.3—ethanol solutions) $\gamma_{C=O}$ 1712 cm.$^{-1}$, $\gamma_{Ar-C=C}$ 1610 cm.$^{-1}$ ($CHCl_3$ solution); (b) λ_{max} 266 ($\epsilon \times 10^{-3}$ 22.6), $\gamma_{C=O}$ 1708 cm.$^{-1}$, $\gamma_{C=C}$ 1658 cm.$^{-1}$, γ_{Ar} 1615 cm.$^{-1}$; see also H. O. House *et al.*, *J. Am. Chem. Soc.*, **79**, 6491 (1957), and *ibid.*, **82**, 1452 (1960).

apart from one additional band at 262 mμ (*n*-hexane solution) in the spectrum of the latter compound. This additional band is almost certainly due to steric hindrance between a hydrogen atom, attached to the aromatic nucleus of the 2-benzal substituent, and a 3-position methyl group. This steric hindrance is also reflected in the lowered intensity of the conjugation band at 310 mμ in the dimethylindanone XI when compared with the same band for 2-benzal-1-indanone ($\epsilon \times 10^{-3}$ 18.2 and 29.0, respectively). This data conclusively establishes that the product obtained from the condensation of benzaldehyde with 1-indanone is 2-benzal-1-indanone (I).

A similar comparison of the ultraviolet and infrared spectra of the bromo ketone, obtained from the thermal dehydrobromination of 2-bromo-2-(α-bromobenzyl)-1-indanone (IV), with those of 2-benzal-1-indanone (I) indicated that the bromoketone also had the benzal-1-indanone structure. Hydrolyzing the bromoketone (2-benzal-3-bromo-1-indanone (II)) in refluxing aqueous dioxane gave 2-benzal-3-hydroxy-1-indanone (III) in high yield. Oxidation of this latter compound with chromium trioxide in aqueous acetone gave 2-benzal-1,3-indandione (VI), a compound which can also be prepared from the condensation of benzaldehyde with 1,3-indandione.[7] The compounds previously obtained from the reaction of amines with compound (IV) and considered to be β-amino-α,β-unsaturated ketones are actually 3-amino-2-benzal-1-indanones (VIIa, VIIb, VIIc).

The mechanisms for the dehydrobromination-substitution rearrangements of 2-bromo-2-(α-bromo benzyl)-1-indanone (IV) upon heating and also upon reaction with amines to the 2-benzal-3-substituted-1-indanones are not at all clear. The structure of the dibromo compound (IV) has not been proved, but it is the expected product from the bromination of 2-benzal-1-indanone (I). In an attempt to prove the structure of the dibromo compound (IV) 2-benzal-1-indanone oxide[2] (V) was treated with hydrogen bromide in carbon tetrachloride to yield an unstable bromohydrin (VIII). The ultraviolet and infrared spectra of the latter compound suggest that it is 2-(α-bromobenzyl)-2-hydroxy-1-indanone. Attempts to react the bromohydrin (VIII) with hydrobromic acid in a sealed tube gave only tars. Halohydrins are, however, usually inert to this type of reaction.[8] The carbonyl stretching frequency of the dibromo compound (IV) is located at 1735 cm.$^{-1}$ which is higher than that of 2-benzyl-1-indanone at 1717 cm.$^{-1}$ and this is consistent for an α-halo ketone structure.[9] Kipping[10] further showed that this dibromo compound (IV) reacts with ethanolic solutions of sodium hydroxide, sodium acetate, or potassium iodide to give 2-benzal-1-indanone (I). With refluxing aqueous dioxane the dibromo compound (IV) also gives largely compound (I), but 8% of 2-benzal-3-hydroxy-1-indanone (III) was also isolated from the reaction mixture.

A probable mechanism for the formation of the 3-substituted 2-benzal-1-indanones (II, III and VII) from 2-bromo-2-(α-bromobenzyl)-1-indanone under various conditions is that elimination of hydrogen bromide initially forms 2-(α-bromobenzyl)-1-indone ([B], X = Br). This is entirely in keeping with the observed formation of endocyclic elimination products from 2-bromo-2-benzyl-1-tetralones.[2] The difference between 1-keto-1,4-dihydronaphthalene and indone, however, is that the ring system of the former is stable whilst that of the latter is highly strained and rapidly undergoes an anionotropic rearrangement[11] to form



the exocyclic 2-benzal-1-indanone structure. The driving force of this rearrangement is probably the changing of the hybridization state of the 3-position carbon atom in the indone ring from sp^2 to sp^3 in conjunction with the electron withdrawing forces of the carbonyl group. Thermal elimination-rearrangement from compound IV to form II probably involves the SN1′ mechanism while amine catalyzed elimination-substitution to give VII may involve the SN 2′ route. Both mechanisms can only lead to products of structure (A). Work is currently in progress to verify that the above mechanisms are indeed involved in these reactions.

An alternative mechanism for the formation of ketoamines (VII) seemed possible if previously formed N-bromoamine could react with 2-benzal-1-indanone (I) to form 2-benzal-3-bromo-1-indanone (II), which could then react with another molecule of the amine. To test this hypothesis N-bromomorpholine and N-bromopiperidine[12] reacted with the ketone (I) in benzene solutions. The corresponding ketoamines (VII) were isolated in

(7) D. Radulescu and V. Georgescu, *Bull. soc. chim. France*, [4], **37**, 1073 (1925).

(8) G. M. Bennett and F. M. Reynolds, *J. Chem. Soc.*, 131 (1935).

(9) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," John Wiley and Sons, N. Y., 1958, pp. 139.

(10) F. S. Kipping, *J. Chem. Soc.*, **65**, 499 (1894).

(11) C. K. Ingold, "Structure and Mechanism in Organic Chemistry," Cornell U.P., New York, 1953, pp. 590.

(12) P. L. Southwick and W. L. Walsh, *J. Am. Chem. Soc.*, **77**, 405 (1955).

approximately 1% yields. Hence this mechanism seems unlikely unless the formation and reaction of the N-bromoamines *in situ* with the dibromo compound (IV) is much more efficient than in the experiments mentioned above.

The formation of the β-amino-α,β-unsaturated ketones (XVII) from 2-bromo-2-(α-bromobenzyl)-3,3-dimethyl-1-indanone (XV) can take place by at least two mechanisms. Those most probable are (i) the elimination of hydrogen bromide under the influence of the amine followed by substitution of the intermediate 2-(α-bromobenzal)-3,3-dimethyl-1-indanone (XVI), and (ii) the substitution of the bromine atom *beta* to the carbonyl group by the amine followed by elimination of hydrogen bromide. When the dibromo compound (XV) reacted with cyclohexylamine in benzene solution only the unsaturated monobromo ketone XVI could be isolated from the reaction mixture. The monobromo ketone XVI reacted with piperidine to give the β-amino-α,β-unsaturated ketone XVIIa, but a preliminary study indicated that the rate of this reaction is slower than that of piperidine with the dibromo compound XV. It seems probable that cyclohexylamine is a sufficiently strong base to bring about elimination of hydrogen bromide from compound XV but not a sufficiently strong nucleophile to substitute the bromo compound XVI. The above evidence is insufficient to distinguish whether mechanism (i) or (ii) is the major pathway in this reaction.

2-Benzal-3,3-dimethyl-1-indanone (XI) is readily hydrogenated in the presence of palladium-on-charcoal to give 2-benzyl-3,3-dimethyl-1-indanone (XII) in 90% yield. With bromine in chloroform the latter forms 2-benzyl-2-bromo-3,3-dimethyl-1-indanone (XIII) and piperidine eliminates hydrogen bromide from this compound to reform the unsaturated compound (XI). The infrared spectrum of the α-halo ketone XIII has, as expected, a higher carbonyl stretching frequency than that of the benzyl-1-indanone (XII), (1730 and 1719 cm.$^{-1}$, respectively). When dissolved in piperidine 2-benzal-3,3-dimethyl-1-indanone (XI) forms an unstable addition product (XIV) which loses the amine again in storage. 2-Benzal-1-indanone (I) forms no such addition product with piperidine.

Experimental[13]

3,3-Dimethyl-1-indanone.—This ketone was conveniently prepared by the ring closure of β-phenylisovaleric acid (20.0 g.) with polyphosphoric acid (120 g.) at 90° for 15 min. After hydrolysis, accomplished by slowly pouring the acid solution into water, the ketone was extracted with ether and distilled, b.p. 101–103°/1.5 mm.; 14.7 g.; 82% (lit.[14] b.p. 110°/8 mm.).

2-Benzal-3,3-dimethyl-1-indanone (XI).—Freshly distilled benzaldehyde (29.0 g.; 0.268 mole) was rapidly added to a chilled solution prepared by the addition of potassium hydroxide (3.0 g.; 0.0530 mole) in ethanol (35 ml.) to 3,3-dimethyl-1-indanone (42.9 g.; 0.268 mole) in ethanol (75 ml.). The light green colored solution was stored in a refrigerator for 24 hr. and 2-benzal-3,3-dimethyl-1-indanone (51.3 g.; 77%) was collected and washed with 50% aqueous ethanol. Recrystallization from ethanol gave very pale yellow-green colored crystals, m.p. 80–82°.

2-Benzyl-3,3-dimethyl-1-indanone (XII).—2-Benzal-3,3-dimethyl-1-indanone (10.0 g.) was dissolved in methanol (170 ml.) and hydrogenated (1 atm.) in the presence of 10% palladium-on-charcoal (0.5 g.). After removal of the catalyst the solution was concentrated to incipient crystallization. 2-Benzyl-3,3-dimethyl-1-indanone (9.06 g.; 90%) was collected and recrystallized from aqueous methanol to give colorless crystals, m.p. 65°.

2-Bromo-2-(α-bromobenzyl)-3,3-dimethyl-1-indanone (XV).—Bromine (3.23 g.; 0.0201 mole), dissolved in carbon tetrachloride (8 ml.), was added during 1 hr. to a stirred solution of 2-benzal-3,3-dimethyl-1-indanone (5.0 g.) in carbon tetrachloride (50 ml.) at room temperature. After the solution had been stirred for a further 1.5 hr. in the dark the solvent was evaporated yielding the dibromo ketone (5.9 g.; 72%; m.p. 157–161°) as a colorless solid, m.p. 160°, after recrystallization from methanol and chloroform.

2-Benzyl-2-bromo-3,3-dimethyl-1-indanone (XIII).—Bromine (3.84 g.; 0.024 mole), dissolved in chloroform (9 ml.), was added during 1 hr. to a stirred solution of 2-benzyl-3,3-dimethyl-1-indanone (6.0 g.; 0.024 mole) in chloroform (45 ml.) at room temperature; however, warming was necessary for about 5 min. to initiate the reaction. The flask was cooled in ice water and the contents stirred for a further hour. The solvent was removed by flash evaporation leaving a yellow oil which solidified when stirred with petroleum ether (b.p. 60–70°) to yield the bromo ketone (6.85 g.; 87%), after recrystallization from ethanol, as a colorless solid, m.p. 67–68°.

2-(α-Piperidinobenzyl)-3,3-dimethyl-1-indanone (XIV).—2-Benzal-3,3-dimethyl-1-indanone (1.0 g., 0.00403 mole) was dissolved in piperidine (1.03 g.; 0.0121 mole) and the solution was stored at room temperature for 36 hr. The solution was then dissolved in isopropyl ether, washed with water, and extracted with 5% aqueous hydrochloric acid. When made basic with sodium carbonate solution the acid extract yielded 2-(α-piperidinobenzyl)-3,3-dimethyl-1-indanone as nearly colorless crystals (0.13 g.; 10%; m.p. 148–150°) after recrystallization from aqueous ethanol.

No corresponding reaction occurred when 2-benzal-1-indanone was dissolved in piperidine.

2-Benzoyl-3,3-dimethyl-1-indanone (XVIII).—3,3-Dimethyl-1-indanone (10.0 g.; 0.062 mole) was added to a previously dried (by azeotropic distillation) solution of pyrollidine (10.0 g.; 0.12 mole) and benzene (60 ml.). An immediate yellow coloration resulted and the solution was subjected to azeotropic distillation for 24 hr. to remove water (1.10 ml.). The solvent was removed by flash evaporation yielding a tar which was warmed in benzene (20 ml.) with benzoyl chloride (8.0 g.; 0.062 mole) for 15 min. prior to hydrolysis of the mixture with water (200 ml.). A solution of the resultant tar in ether (100 ml.) was stirred with a saturated solution of copper acetate (100 ml.) for 1 hr. yielding a buff colored copper complex (0.72 g.) which was collected and hydrolyzed by stirring with ether (100 ml.) and aqueous sulfuric acid (100 ml.; 7 *N*) for 0.5 hr. To the water washed and dried ether layer was added *n*-hexane; 2-benzoyl-3,3-dimethyl-1-indanone (0.42 g.; 3%) precipi-

(13) Melting points were read with a calibrated thermometer. Ultraviolet absorption spectra were determined with a Cary Model 11-MS recording spectrophotometer using reagent grade solvents. Infrared spectra were measured with a Perkin-Elmer Model 21 double beam recording instrument employing sodium chloride optics and matched sodium chloride cells with carbon tetrachloride solutions unless otherwise indicated.

(14) C. F. Koelsch and C. D. Le Claire, *J. Org. Chem.*, **6**, 516 (1941).

tated and after recrystallization from ethanol was obtained as colorless needles, m.p. 140–141°.

Attempts to prepare this diketone by a reaction between sodamide, 3,3-dimethyl-1-indanone, and phenyl benzoate were unsuccessful.

3,3-Dimethyl-2-(α-piperidinobenzal)-1-indanone (XVIIa).—A solution of 2-bromo-2-(α-bromobenzyl)-3,3-dimethyl-1-indanone (2.50 g.; 0.0061 mole), piperidine (5.20 g.; 0.062 mole), and benzene (50 ml.) was stored under nitrogen for 24 hr. at room temperature. A precipitate of piperidine hydrobromide (1.77 g.; 88%) was collected, the solution was reduced in volume to about 10 ml., and *n*-hexane was added to precipitate the β-amino-α,β-unsaturated ketone (1.62 g.; 78%) which was obtained as yellow crystals, m.p. 180°, after recrystallization from benzene–*n*-hexane. Attempts to prepare a stable hydrochloride of this amine were unsuccessful.

3,3-Dimethyl-2-(α-morpholinobenzal)-1-indanone (XVIIb).—A solution of 2-bromo-2-(α-bromobenzal)-3,3-dimethyl-1-indanone (2.5 g.; 0.0061 mole) and morpholine (5.3 g.; 0.061 mole) was stored under nitrogen for 24 hr. at room temperature. The solution was worked up as described in the previous experiment yielding morpholine hydrobromide (0.58 g.; 27%) and the β-amino unsaturated ketone (0.20 g.; 10%) as yellow crystals, m.p. 214–216° from benzene–*n*-hexane.

Hydrolysis of 3,3-Dimethyl-2-(α-piperidinobenzal)-1-indanone (XVIIa).—The β-amino-α,β-unsaturated ketone XVIIa (0.45 g.; 0.0011 mole) was gently refluxed with aqueous sulfuric acid (60 ml.; 7 *N*) for 9 hr. A colorless solid crystallized from the solution when cool and after recrystallization from ethanol it was shown to be 2-benzoyl-3,3-dimethyl-1-indanone (0.30 g.; 83%; m.p. 140–141°) identical in all respects with the material described above.

2-(α-Bromobenzal)-3,3-dimethyl-1-indanone (XVI).—A solution of cyclohexylamine (3.05 g.; 0.0308 mole) and 2-bromo-2-(α-bromobenzyl)-3,3-dimethyl-1-indanone (1.25 g.; 0.0038 mole) in benzene (25 ml.) was stored under nitrogen for 1 week at room temperature. Cyclohexylamine hydrobromide (1.04 g.; 95%) was collected. Removal of the solvent by flash evaporation left a black tar from which was crystallized, using benzene–*n*-hexane, 2-(α-bromobenzal)-3,3-dimethyl-1-indanone (0.09 g.; 9%) as yellow rhombs, m.p. 171–173° after recrystallization from the same solvent mixture.

Reaction between 2-(α-Bromobenzal)-3,3-dimethyl-1-indanone and Piperidine.—Piperidine (0.30 g.; 0.00357 mole) was added to a solution of the bromo compound XVI (0.12 g.; 0.000367 mole) in benzene (5 ml.) and the solution was stored under nitrogen for 18 hr. at room temperature. Piperidine hydrobromide (0.05 g.; 83%) was collected. The benzene solution was diluted with *n*-hexane and the β-amino-α,β-unsaturated ketone XVIIa (0.04 g.; 33%) was collected.

2-Benzal-3-bromo-1-indanone (II).—A solution of 2-benzal-1-indanone (1.0 g.; 0.00455 mole), *N*-bromosuccinimide (0.81 g.; 0.0455 mole), and benzoyl peroxide (0.05 g.) in carbon tetrachloride (15 ml.) was refluxed for 1 hr. over an infrared lamp. The succinimide was collected, the solvent removed, and the product crystallized from carbon tetrachloride. Further recrystallization from the same solvent gave 2-benzal-3-bromo-1-indanone (0.95 g.; 70%) as colorless needles, m.p. 119–120°, identical with the bromo compound obtained from the thermal dehydrobromination of 2-bromo-2-(α-bromobenzyl)-1-indanone.[16]

2-Benzal-3-hydroxy-1-indanone (III).—A solution of 2-benzal-3-bromo-1-indanone (1.0 g.; 0.00334 mole) in dioxane (30 ml.) and water (20 ml.) was refluxed for 15 hr. Then the solution was reduced in volume by flash evaporation until a solid precipitated. This was collected and recrystallized from ethanol to give 2-benzal-3-hydroxy-1-indanone (0.71 g.; 90%) as yellow colored crystals, m.p. 184–185°.

Oxidation of 2-Benzal-3-hydroxy-1-indanone (III).—A solution of chromium trioxide (0.57 g.) in sulfuric acid (0.5 ml.; *d* 1.84) and water (1.0 ml.) was added to a stirred solution of 2-benzal-3-hydroxy-1-indanone (0.18 g.) in acetone (5 ml.). After the addition was complete the green solution was stirred for 2 hr. Then the yellow precipitate which had formed was collected and recrystallized from ethanol to yield yellow colored leaflets of 2-benzal-1,3-indandione (0.16 g.; 89%), m.p. and mixed m.p. with an authentic sample 151–152° (lit.[7] 153°).

2-(α-Bromobenzyl)-2-hydroxy-1-indanone (VIII).—Hydrogen bromide was slowly bubbled into a gently refluxing solution of 2-benzal-1-indanone oxide (0.50 g.) in carbon tetrachloride (60 ml.) during 4 hr. When the solvent was reduced in volume to about 10 ml. the bromohydrin (0.42 g.; 63%) crystallized and after recrystallization from benzene–*n*-hexane was obtained as pink colored crystals, m.p. 104–107° with evolution of a gas.

2-Benzyl-3-cyclohexylamino-1-indanone Hydrochloride (Xc).—2-Benzal-3-bromo-1-indanone (0.50 g.; 0.00167 mole) was dissolved in freshly distilled cyclohexylamine (1.67 g.; 0.0167 mole) and the solution stored under nitrogen for 19 hr. at room temperature. Cyclohexylamine hydrobromide (0.29 g.; 97%) was then collected leaving an oil which could not be crystallized and so it was dissolved in ether and the amine hydrochloride (0.54 g.; 91%) was formed by passing hydrogen chloride into this solution. After recrystallization from absolute ethanol–ether the salt was obtained as colorless crystals, m.p. 198–201°.

Hydrolysis of 2-Bromo-2-(α-bromobenzyl)-1-indanone (IV).—A solution of 2-bromo-2-(α-bromobenzyl)-1-indanone (1.0 g.) in dioxane (60 ml.) and water (40 ml.) was refluxed for 28 hr., concentrated by flash evaporation, cooled and extracted with ether (2 × 70 ml.). Evaporation of the ether gave a tar which when stirred with benzene–*n*-hexane precipitated 2-benzal-3-hydroxy-1-indanone (50 mg.; 8%; m.p. and mixed m.p. with authentic material 184–185°). Concentration of the benzene–*n*-hexane solution gave 2-benzal-1-indanone (0.30 g.; 58%) identical with authentic material.

Reaction of N-Bromopiperidine with 2-Benzal-1-indanone.—A solution of bromine (0.73 g.; 0.00455 mole) and piperidine (1.16 g.; 0.0136 mole) in benzene (25 ml.) was added to a stirred solution of 2-benzal-1-indanone (1.0 g.; 0.00455 mole) in benzene (15 ml.). The solution was stored under nitrogen for 1 week at room temperature and piperidine hydrobromide (1.43 g.; 0.0087 mole) was then collected. The benzene solution was extracted with aqueous hydrochloric acid (2 × 50 ml.; 5*N*). The acid extract was heated with decolorizing charcoal, cooled, and made basic yielding a yellow precipitate which was collected, dried, dissolved in benzene, and filtered through neutral alumina to give 2-benzal-3-piperidino-1-indanone (15 mg.; 1%).

Acknowledgment.—This work was supported in part by Grant No. CY 2931, National Cancer Institute, U.S. Public Health Service.