

REACTIONS OF 2-ACYL-1,3-INDANDIONES WITH NITROGEN NUCLEOPHILES

Pavel HRNCIAR and Eva SVANYGOVA

Department of Organic Chemistry,

Comenius University, 842 15 Bratislava, The Slovak Republic

Received September 12, 1994

Accepted October 11, 1994

Dedicated to Professor Milan Kratochvil on the occasion of his 70th birthday.

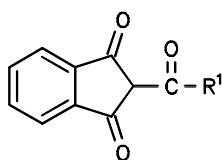
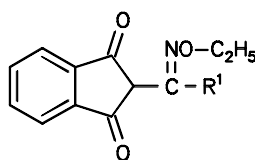
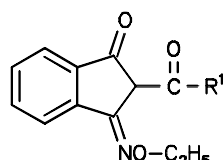
It is known that 2-acyl-1,3-hexanediones react with nitrogen nucleophiles selectively at carbonyl carbon of acyl group. Many derivatives prepared in this manner showed significant herbicide efficiency¹⁻⁴.

Reactions of 2-acyl-1,3-indandiones with nitrogen nucleophiles were studied rarely. The question, if they react with carbonyl carbon of acyl group or indandione skeleton, has not been answered unambiguously. Vanag et al.⁵ stated that 2-diphenylacetyl-1,3-indandione reacted with ammonia at carbonyl carbon of acetyl group. On the contrary, Braun and Mosher⁶ pointed out that the same reaction yielded the product of reaction at carbonyl carbon of indandione skeleton. Similar discrepancy occurred at the course of reaction with hydrazine^{5,6}. Later, Mosher has changed his opinion by publishing the conclusion that nitrogen nucleophiles react with carbonyl carbon of acyl group⁷⁻¹⁰.

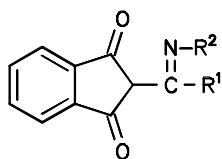
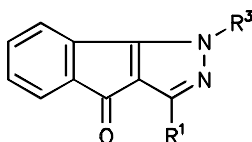
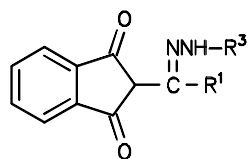
To make clear the question which carbonyl carbon of 2-acyl-1,3-indandiones enters the reaction with nitrogen nucleophiles we carried out the reactions with 2-acetyl- (*Ia*), 2-propionyl- (*Ib*), 2-pivaloyl- (*Ic*), and 2-benzoyl-1,3-indandione (*Id*). We used different 2-acyl-1,3-indandiones with the aim to find out if the character of acyl group affects the course of reaction. We used ethoxyamine, primary amines, phenylhydrazine, hydrazine and methylhydrazine as nucleophile reactants. The reactions were carried out in methanol at reflux at 10% excess of nitrogen base. The reactions with phenylhydrazine, hydrazine and methylhydrazine were performed with twofold excess of nitrogen base. The separation of reaction products was carried out by chromatography on silica gel.

We found that 2-acyl-1,3-indandiones *I* react with ethoxyamine both at the acyl-carbonyl carbon to produce 2-(1-ethoxyiminoalkyl)-1,3-indandiones *II* and the carbonyl carbon of indandione skeleton to give rise 3-(ethoxyimino)-2-acyl-1-indanones *III*. In all cases, the carbonyl carbon of acyl group was preferred (the observed ratio of products *II* to *III* was 6 – 8 : 1). From the reaction of 2-acyl-1,3-indandiones with primary amines only the products *IV* of reaction with the acylcarbonyl carbon were isolated.

The hydrazines used reacted with 2-acyl-1,3-indandiones also at carbonyl carbon of acyl group in the first step to produce hydrazones. However, the products isolated in most cases were formed by the attack of hydrazone nitrogen at carbonyl carbon of indandione skeleton giving rise to derivatives of indeno[2,3-*d*]pyrazole-4-one V. It is interesting that 2-acetyl-1,3-indandione and 2-propionyl-1,3-indandione, reacting with phenylhydrazine and hydrazine, yielded only corresponding hydrazones VI.

*I**II**III*

In formulae *I*, *II*, *III* : *a*, $R^1 = \text{CH}_3$; *b*, $R^1 = \text{C}_2\text{H}_5$; *c*, $R^1 = t\text{-C}_4\text{H}_9$; *d*, $R^1 = \text{C}_6\text{H}_5$

*IV**V**VI*

	<i>IV</i>		<i>V</i>		<i>VI</i>	
	R^1	R^2	R^1	R^3	R^1	R^3
<i>a</i>	CH ₃	C ₃ H ₇	CH ₃	CH ₃	CH ₃	H
<i>b</i>	CH ₃	<i>i</i> -C ₃ H ₇	C ₂ H ₅	CH ₃	CH ₃	C ₆ H ₅
<i>c</i>	CH ₃	C ₄ H ₉	<i>t</i> -C ₄ H ₉	H	C ₂ H ₅	H
<i>d</i>	C ₂ H ₅	C ₃ H ₇	<i>t</i> -C ₄ H ₉	CH ₃	C ₂ H ₅	C ₆ H ₅
<i>e</i>	C ₂ H ₅	<i>i</i> -C ₃ H ₇	<i>t</i> -C ₄ H ₉	C ₆ H ₅		
<i>f</i>	C ₂ H ₅	C ₆ H ₅	C ₆ H ₅	H		
<i>g</i>	<i>t</i> -C ₄ H ₉	C ₃ H ₇	C ₆ H ₅	CH ₃		
<i>h</i>	C ₆ H ₅	<i>i</i> -C ₃ H ₇	C ₆ H ₅	C ₆ H ₅		

An attempt to convert the hydrazones *VI* to the indeno[2,3-*d*]pyrazole-4-ones *V* by refluxing in methanol for 12 h failed.

The structure of isolated products was assigned on the basis of elemental analysis, ^1H NMR and IR spectra. The structure assignment was supported by comparison of chemical shift and multiplet shape of starting 2-acyl-1,3-indandione skeleton at enol acyl group¹¹. Similar arrangement of chemical shifts of aromatic hydrogens have also products *II* and *IV*. This fact sustains our assignment of the structure of these compounds which means that the reactions of 2-acyl-1,3-indandiones with nucleophiles took place at the acylcarbonyl carbon.

TABLE I
Yields, analytical and spectral data of compounds *II* and *III*

Compound	M.p., °C Yield, %	Formula (M.w.)	Calculated/Found			^1H NMR spectrum
			% C	% H	% N	
<i>Ila</i>	132 – 134	$\text{C}_{13}\text{H}_{13}\text{NO}_3$	67.53	5.67	6.06	1.33 t, 3 H, $J = 6.5$ (CH_3); 2.60 s,
	62	(231.2)	67.46	5.44	6.21	3 H (CH_3); 4.03, 2 H, $J = 7$ (CH_2); 7.45 – 7.68 m, 4 H (aryl)
<i>Ilb</i>	109 – 111	$\text{C}_{14}\text{H}_{15}\text{NO}_3$	68.63	6.12	5.71	1.20 – 4.96 m, 6 H ($2 \times \text{CH}_3$); 3.15 q,
	52	(245.2)	68.69	6.10	5.93	2 H (CH_2); 2.08 q, 2 H (CH_2); 7.45 – 7.71 m, 4 H (aryl)
<i>Ilc</i>	87 – 89	$\text{C}_{16}\text{H}_{17}\text{NO}_3$	70.33	6.96	5.12	0.55 t, 3 H (CH_3); 1.27 s, 9 H (CH_3);
	38	(273.3)	70.25	7.12	5.00	3.71 q, 2 H, $J = 7$ (CH_2); 7.72 – 8.4 m, 4 H (aryl)
<i>Ild</i>	126 – 128	$\text{C}_{18}\text{H}_{15}\text{NO}_3$	73.72	5.12	4.80	0.75 t, 3 H, (CH_3); 4.17 q, 2 H, $J = 7$
	52	(293.3)	73.85	4.90	4.90	(CH_2); 7.26 – 7.95 m, 9 H (aryl)
<i>IIIa</i>	97 – 102	$\text{C}_{13}\text{H}_{13}\text{NO}_3$	67.53	5.62	6.06	1.31 t, 3 H, $J = 6.5$ (CH_3); 1.43 s, 3 H
	16	(231.2)	67.28	5.90	6.32	(CH_3); 4.31 2 H, $J = 7$ (CH_2); 7.25 – 7.83 m, 4 H (aryl)
<i>IIIb</i>	65 – 68	$\text{C}_{14}\text{H}_{15}\text{NO}_3$	68.63	6.12	5.71	1.41 – 1.52 m, 6 H ($2 \times \text{CH}_3$); 2.92 q,
	12	(245.2)	68.36	6.43	5.72	2 H (CH_2); 4.31 q, 2 H (CH_2); 7.52 – 8.24 m, 4 H (aryl)
<i>IIIc</i>	19 – 26	$\text{C}_{16}\text{H}_{17}\text{NO}_3$	70.33	6.96	5.12	0.48 t, 3 H (CH_3); 1.41 s, 9 H
	traces	(273.3)	78.51	6.68	4.68	($2 \times \text{CH}_3$); 3.71 q, 2 H, $J = 7$ (CH_2); 7.72 – 8.4 m, 4 H (aryl)
<i>IIId</i>	87 – 93	$\text{C}_{18}\text{H}_{15}\text{NO}_3$	73.72	5.12	4.80	1.14 t, 3 H (CH_3); 3.5 q, 2 H, $J = 6.2$
	12	(293.3)	73.56	4.73	4.60	(CH_2); 7.49 – 8.28 m, 9 H (aryl)

The multiplet of aromatic hydrogens has the symmetrical arrangement similarly to starting 2-acyl-1,3-indandiones. It means that the symmetrical substitution of aromatic part of indane skeleton remained preserved. On the other hand, the symmetry of substitution on the aromatic part of indane skeleton was affected by reaction of nitrogen nucleophile with carbonyl carbon of indandione skeleton. The arrangement of multiplets of aromatic indane protons of pyrazoles *V* was also changed.

TABLE II
Yields, analytical and spectral data of compounds *IV*

Compound	M.p., °C Yield, %	Formula (M.w.)	Calculated/Found			¹ H NMR spectrum
			% C	% H	% N	
<i>IVa</i>	149 – 150	C ₁₄ H ₁₅ NO ₂	73.36	6.55	6.11	1.32 t, 3 H (CH ₃); 2.82 s, 3 H (CH ₃);
	71	(229.2)	73.12	6.45	6.43	3.62 q, 2 H, <i>J</i> = 6.5 (CH ₂); 7.41 – 7.73 m, 4 H (aryl)
<i>IVb</i>	157 – 159	C ₁₄ H ₁₅ NO ₂	73.36	6.55	6.11	0.81 t, 3 H (CH ₃); 1.21 q, 6 H, <i>J</i> = 3.5
	63	(229.2)	73.71	6.50	6.00	(2 × CH ₃); 2.91 s, 3 H (CH ₃); 3.51 q, <i>J</i> = 6.8 (CH ₂); 7.43 – 7.71 m, 4 H (aryl)
<i>IVc</i>	169 – 171	C ₁₅ H ₁₇ NO ₂	74.01	6.99	5.76	0.79 t, 3 H (CH ₃); 1.46 – 1.91 m, 4 H
	68	(243.2)	73.92	7.12	5.63	(CH ₂); 3.46 q, 2 H, <i>J</i> = 7 (CH ₂); 7.48 – 7.81 m, 4 H (aryl)
<i>IVd</i>	74 – 75	C ₁₅ H ₁₇ NO ₂	74.07	6.99	5.76	0.79 – 1.24 m, 6 H (2 × CH ₃);
	62	(243.2)	74.14	6.83	5.93	1.34 – 1.86 m (aryl); 2 H (CH ₂); 3.05 q, 2 H, <i>J</i> = 7 (CH ₂); 3.4 q, 2 H, <i>J</i> = 7 (CH ₂); 7.51 – 7.90 m (aryl)
<i>IVe</i>	63 – 65	C ₁₅ H ₁₇ NO ₂	74.07	6.99	5.76	0.81 t, 3 H, 1.80, 3 H (2 × CH ₃); 1.23, 3 H
	60	(243.2)	74.10	6.81	5.93	(CH ₃); 2.77 q, 2 H, <i>J</i> = 7 (CH ₂); 3.29 – 3.47 m, 1 H (CH); 7.37 – 7.51 m, 4 H (aryl); 8.1 s, 1 H (OH)
<i>IVf</i>	137 – 139	C ₁₈ H ₁₅ NO ₂	77.98	5.42	5.13	0.92 t, 3 H (CH ₃); 3.62 q, 2 H, <i>J</i> = 7
	71	(277.3)	77.90	5.63	5.25	(CH ₂); 7.43 – 7.95 m, 9 H (aryl)
<i>IVg</i>	174 – 175	C ₁₇ H ₂₁ NO ₂	75.30	7.83	5.21	0.9 t, 3 H (CH ₃); 1.49 m, 9 H (CH ₃);
	63	(271.3)	75.40	7.61	4.92	1.68 – 1.86 m, 3 H (CH ₃); 3.41 q, 2 H, <i>J</i> = 7 (CH ₂); 7.45 – 7.72 m, 4 H (aryl)
<i>IVh</i>	170 – 172	C ₁₉ H ₁₇ NO ₂	78.31	5.81	4.81	1.28 s, 3 H, 1.31 s, 3 H (CH ₃); 3.22 – 3.47 m,
		(291.4)	78.49	5.78	4.93	1 H (CH); 7.32 – 7.64 m, 9 H (aryl)

The structure of products of nucleophilic substitution of 2-acyl-1,3-indandiones was further confirmed by IR study of their spectra in the range of symmetrical and asymmetrical vibration of β -dicarbonyl part of indandione skeleton. Within the range of valence C=O vibrations, the compounds prepared have absorption bands. On the basis of our previous experience¹²⁻¹⁴, we are able to find out if these compounds have the coupled indandione cyclic β -dicarbonyl skeleton (the validity of equation $\nu_s(\text{CO}) = 0.78 \nu_{\text{as}}(\text{CO}) + 412.8$ needed). Such a relationship between ν_s and ν_{as} was found only for compounds *II* and *IV* and not for the compounds *III* and *V*.

TABLE III

Yields, analytical and spectral data of compounds V

Compound	M.p., °C Yield, %	Formula (M.w.)	Calculated/Found			¹ H NMR spectrum
			% C	% H	% N	
<i>Va</i>	139 – 142	C ₁₂ H ₁₀ N ₂ O	72.73	5.05	14.14	2.33 s, 3 H (CH ₃); 3.95 s, 3 H (CH ₃);
	43	(198.1)	72.76	5.01	13.90	7.18 – 7.59 m, 4 H (aryl)
<i>Vb</i>	81 – 82	C ₁₃ H ₁₂ N ₂ O	73.58	5.66	13.20	1.35 t, 3 H (CH); 2.68 q, 2 H (CH);
	51	(212.2)	73.57	5.68	13.21	3.93 s, 3 H (CH ₃); 7.2 – 7.4 m, 4 H (aryl)
<i>Vc</i>	195 – 198	C ₁₄ H ₁₄ N ₂ O	74.34	6.19	12.39	1.39 s, 9 H (CH ₃); 7.23 – 7.69 m,
	46	(226.2)	74.16	6.31	12.13	4 H (aryl)
<i>Vd</i>	147 – 148	C ₁₅ H ₁₆ N ₂ O	75.00	6.67	11.67	1.37 s, 9 H (3 × CH ₃); 3.95 s, 3 H
	32	(240.2)	75.11	6.66	11.64	(CH ₃); 7.32 – 7.71 m, 4 H (aryl)
<i>Ve</i>	145 – 148	C ₂₀ H ₁₈ N ₂ O	79.47	5.96	9.27	1.44 s, 9 H (3 × CH ₃); 7.11 – 7.71 m,
	43	(302.3)	79.51	5.85	9.25	9 H (aryl)
<i>Vf</i>	265 – 267	C ₁₆ H ₁₀ N ₂ O	78.04	4.05	11.38	7.48 – 8.3 m, 9 H (aryl)
	43	(246.3)	77.76	3.96	11.35	
<i>Vg</i>	195 – 198	C ₁₇ H ₁₂ N ₂ O	78.46	4.62	10.77	4.04 s, 3 H (CH ₃); 7.23 – 7.32 m,
	42	(260.3)	78.58	4.68	10.74	9 H (aryl)
<i>Vh</i>	206 – 208	C ₂₂ H ₁₄ N ₂ O	81.99	3.73	8.69	7.43 – 8.40 m, 14 H (aryl)
	43	(322.4)	82.10	3.71	8.58	

EXPERIMENTAL

The ^1H NMR spectra of CDCl_3 solutions (δ , ppm; J , Hz) were measured at 80 MHz TESLA E S 587 instrument, the IR spectra of chloroform solutions were recorded with Spectra 75 JR (Zeiss, Jena) apparatus. Starting materials (2-acyl-1,3-indandiones *Ia* – *Id*) were prepared according to the described procedure¹⁵.

2-(1-Ethoxyiminoalkyl)-1,3-indandiones *Ila* – *Ild* and 3-Ethoxyimino-2-acyl-1-indanones *IIla* – *IIId*

2-Acyl-1,3-indandione (0.01 mol) and ethoxyamine (0.012 mol) were heated in methanol (100 ml) at 30 °C (at reflux in the case of 2-pivaloyl-1,3-indandione) for 5 h. The solvent was evaporated, the residue dissolved in a small volume of chloroform and the reaction mixture was separated chromatographically on silica gel (elution with heptane–chloroform 10 : 1), the compounds *Ila* – *Ild* were eluted as first. The analytical data of prepared compounds are summarized in Table I.

2-(1-*N*-R²-Iminoalkyl)-1,3-indandiones *IV*

2-Acyl-1,3-indandione (0.01 mol) and primary amine (0.012 mol) were heated in methanol at reflux for 3 h. Methanol was evaporated and the crude product dissolved in a small volume of chloroform and purified by chromatography on silica gel (elution with heptan–chloroform 5 : 1). The analytical data of compounds *IV* are summarized in Table II.

1-R³-3-R¹-Indano[2,3-*d*]pyrazol-4-ones *V*

2-Acyl-1,3-indandione (0.01 mol) and the corresponding hydrazine (0.012 mol) was stirred in 100 ml of methanol at 30 °C for 4 h. The solvent was evaporated and the crude product was purified by

TABLE IV

Yields, analytical and spectral data of compounds *VI*

Compound	M.p., °C Yield, %	Formula (M.w.)	Calculated/Found			^1H NMR spectrum
			% C	% H	% N	
<i>Vla</i>	237 – 239	$\text{C}_{11}\text{H}_{10}\text{N}_2\text{O}_2$	65.35	4.95	13.86	1.33 t, 3 H (CH_3); 4.12 s, 2 H (NH);
	65	(202.3)	65.32	5.05	13.79	7.41 – 7.62 m, 4 H (aryl)
<i>Vlb</i>	186 – 189	$\text{C}_{17}\text{H}_{14}\text{N}_2\text{O}_2$	73.38	5.04	10.07	1.39 t, 3 H (CH_3); 4.36 s, 1 H (NH);
	61	(278.4)	73.43	5.12	9.93	6.52 – 7.69 m, 9 H (aryl)
<i>Vlc</i>	210 – 212	$\text{C}_{12}\text{H}_{12}\text{N}_2\text{O}_2$	66.67	5.55	12.96	1.12 t, 3 H (CH_3); 3.72 q, 2 H (CH_2);
	53	(216.3)	66.58	5.41	13.10	4.81 s, 1 H (NH); 7.42 – 7.62 m, 4 H (aryl)
<i>Vld</i>	159 – 162	$\text{C}_{18}\text{H}_{16}\text{N}_2\text{O}_2$	73.97	5.48	9.59	1.21 t, 3 H (CH_3); 3.83 q, 2 H (CH_2);
	51	(292.4)	74.13	5.36	9.48	6.58 – 7.65 m, 9 H (aryl)

chromatography on silica gel (elution with heptane–chloroform 8 : 1). The analytical data of compounds *V* are summarized in Table III.

The reaction conditions used for the reaction of 2-acetyl- and 2-propionyl-1,3-indandiones with hydrazine and/or phenylhydrazine yielded the corresponding hydrazones *VI*. Their analytical data are summarized in Table IV.

REFERENCES

1. Nippon Soda Ltd.: Japan. Kokai *81*, 68, 660; Chem. Abstr. *95*, 168641 (1981).
2. Formigoni A.: *Phytopathology* *9*, 1028 (1979).
3. Nippon Soda Ltd.: Japan. Kokai *80*, 115, 802; Chem. Abstr. *93*, 162729 (1980).
4. Burtch L. M., Fischer D. B.: *J. Am. Soc. Sugar Beet Technol.* *21*, 112 (1981); Chem. Abstr. *96*, 15989 (1982).
5. Zelman V. H., Vanag G. Ya.: *Izv. Akad. Nauk Latv. SSR* *1959*, 69.
6. Braun R. A., Mosher W. A.: *J. Am. Chem. Soc.* *80*, 3048 (1958).
7. Mosher W. A., Presch S.: *J. Org. Chem.* *35*, 1026 (1970).
8. Mosher W. A., Presch S.: *J. Org. Chem.* *35*, 2109 (1970).
9. Mosher W. A., Presch S.: *J. Chem. Eng. Data* *17*, 258 (1972).
10. Mosher W. A., Sweder R. N.: *J. Heterocycl. Chem.* *8*, 855 (1972).
11. Bohac A., Hrnciar P., Sraga J.: *Chem. Papers* *46*, 31 (1992).
12. Perjessy A., Hrnciar P.: *Tetrahedron* *27*, 6159 (1921).
13. Perjessy A., Hrnciar P.: *Spectrochim. Acta, A* *38*, 499 (1982).
14. Bohac A., Perjessy A., Loss D., Hrnciar P.: *Monatsh. Chem.* *122*, 943 (1991).
15. Kilgare L. B., Ford J. M., Wolfe W. C.: *Ind. Eng. Chem.* *34*, 494 (1942).