of needles: mp 77–77.5°; pmr ($CDCl_3$) δ 2.17 (s, 3, SCH_3), 4.08 (s, 1, CHOH), 5.13 (s, 1, CHOH, D_2O exchanged), 7.16–7.48 (m, 5, C_6H_5).

Ethyl Mandelate.—Methyl orthotrithiomandelate (4.3 g, 16.5 mmol) was dissolved in 50 ml of 90% ethanol. To this solution was added 2.8 g of sodium bicarbonate and 16.5 mmol of iodine which was added slowly in small portions. After 1 hr at 25° the reaction product was concentrated under vacuum, diluted with 100 ml of water, and extracted twice with 100 ml of ether. The ether solution was dried ($MgSO_4$) and distilled to yield 1.74 g of ethyl mandelate (59%): bp 79–81° (0.25 Torr); pmr ($CDCl_3$) δ 1.13 and 4.24 (t, 3 and q, 2, J = 7.3 Hz, CH_3CH_2), 3.90 (s, 1, CHOH), 5.12 (s, 1, CHOH, D_2O exchanged), 7.17–7.55 (m, 5, C_6H_5).

Reduction of Keto Mercaptals and Acetals.—Reduction of 2-benzoyl-1,3-dithiolane with sodium borohydride in 95% ethanol at 25° yielded 1.83 g (86%) of **2-(α-hydroxybenzyl)-1,3-dithiolane** as an oil.

Anal. Calcd for $C_{10}H_{12}O_2S_2$: C, 56.60; H, 5.70; S, 30.16. Found: C, 56.76; H, 5.82; S, 30.11.

In a similar fashion 2-benzoyl-*m*-dithiane was reduced to **2-(α-hydroxybenzyl)-*m*-dithiane**, mp 70–72°, lit.[25] 70.5–71.6°. Reduction of the methyl acetal of phenylglyoxal by sodium borohydride in water yielded **1-phenyl-2,2-dimethoxyethanol**: bp 75–78° (0.25 Torr); pmr ($CDCl_3$) δ 3.20 (s, 6, OCH_3), 4.24–4.59 (m, 3, D_2O simplifies the spectrum to a q, 2, CH(OH)CH, J = 6.7 Hz), 7.15–7.47 (m, 5, C_6H_5).

Anal. Calcd for $C_{10}H_{14}O_3$: C, 65.91; H, 7.74. Found: C, 65.87; H, 7.58.

Registry No.—γ-Hydroxy-γ-phenylpropyl methyl sulfoxide, 21504-02-9; γ-hydroxy-γ-phenylpropyl methyl sulfone, 21504-03-0; ethanedithiol dimercaptal of phenylglyoxal, 21504-27-8; ethylene glycol diacetal of phenylglyoxal, 21504-04-1; ω-chloro-ω-(methylmercapto)acetophenone, 14755-55-6; methyl mercapto of phenylglyoxal, 17565-23-0; methyl acetal of phenylglyoxal, 6956-56-5; 2-benzoyl-*m*-dithiane, 21504-07-4; 2-benzoyl-1,3-dithiolane, 21504-08-5; 1-phenyl-2,2-di(methylmercapto)ethanol, 21504-10-9; 1,1-di(methylmercapto)-2-phenyl-2-propanol, 21504-09-6; 1,1-di(methylmercapto)-2-phenyl-2-butanol, 21504-11-0; 1,1-diphenyl-2,2-di(methylmercapto)ethanol, 21504-12-1; β,β-di(methylmercapto)-α-methoxystyrene, 21504-14-3; β,β-di(methylmercapto)-α-benzoyloxystyrene,2 1504-15-4; β,β-di(methylmercapto)-α-acetoxystyrene, 21504-16-5; ω,ω-di(methylmercapto)-ω-succiniminoacetophenone, 21504-17-6; ω,ω,ω-tri(methylmercapto)acetophenone, 21504-18-7; S-methyl phenylthioglyoxylate, 13603-60-6; ethyl phenylglyoxylate, 1603-79-8; 1,2-di(methylmercapto)-1,2-dibenzoylethylene (*cis*), 21537-94-0; 1,2-di(methylmercapto)-1,2-dibenzoylethylene (*cis*) (pyridazine derivative), 21504-21-2; 1,2-di(methylmercapto)-1,2-dibenzoylethylene (*trans*), 21517-43-1; methyl orthotrithiomandilate, 21504-22-3; S-methyl thiomandelate, 21504-28-9; ethyl mandelate, 774-40-3; 1-phenyl-2,2-dimethoxyethanol, 21504-23-4; ω-(methylsulfinyl)acetophenone, 2813-22-1.

(25) E. J. Corey and D. Seeback, *Angew. Chem.*, **77**, 1134 (1966).

Notes

β-Keto Sulfoxides. VII. Conversion into γ- and δ-Keto Esters[1]

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Received March 11, 1969

A recent report by Nozaki, Mori, and Kawanisi on chain extensions by the use of β-keto sulfoxides[2] prompts us to report some similar observations. The reactions described by Nozaki, Mori, and Kawanisi and extended herein provide convenient three and four carbon chain extensions of aliphatic or aromatic esters (Scheme I).

ω-(Methylsulfinyl)acetophenone readily reacts in basic solution with ethyl bromoacetate and ethyl acrylate to yield γ- and δ-keto esters **2** and **3**. All attempts to carboxylate the enolate anion to form the β-keto ester **1** (*e.g.*, with carbon dioxide, ethyl chloroformate, methylmagnesium carbonate[3]) failed. Ethyl chloroformate gave reaction at the oxygen atom to yield **4**.

$C_6H_5COCH(SOCH_3)(CH_2)_xCO_2C_2H_5$

1, x = 0
2, x = 1
3, x = 2

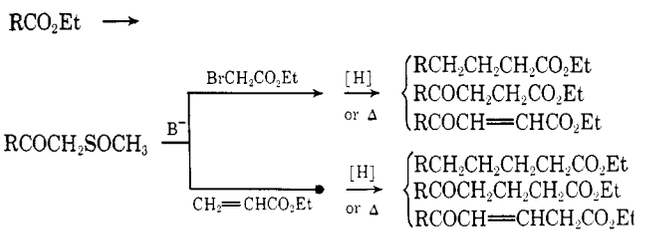
$C_6H_5C(OCO_2C_2H_5)=CHSOCH_3$

4

Compound **2** is easily reduced to yield ethyl ω-benzoylpropionate. The sulfoxide is easily pyrolyzed to ethyl *trans*-3-benzoylacrylic acid. Compound **3** undergoes similar reactions. Under more vigorous conditions, **3** can be reduced directly to ethyl ω-phenylvalerate.

When an excess of ethyl acylate is employed in the condensation reaction, a further reaction product (**5**) between **3** and ethyl acrylate is observed in 59% yield.

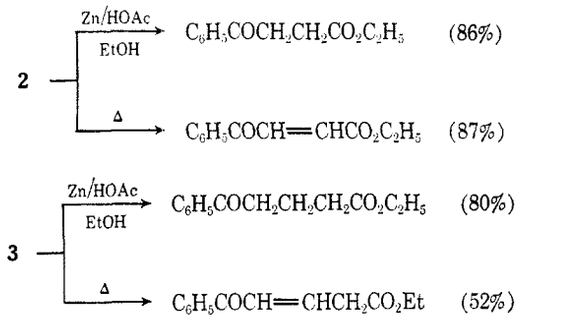
SCHEME I



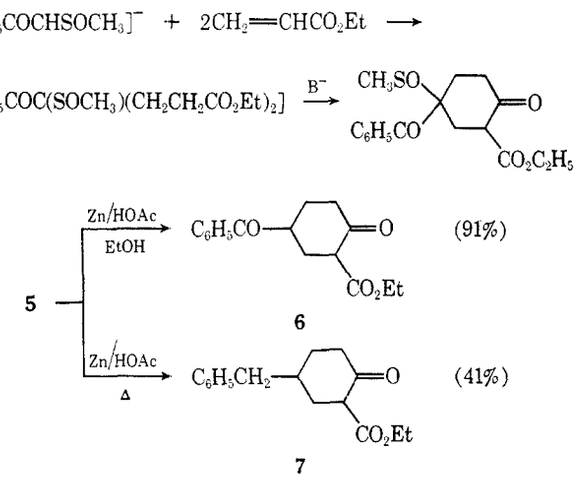
(1) For part VI, see G. A. Russell and L. A. Ochrymowycz, *J. Org. Chem.*, **34**, 3618 (1969). This work was supported by a grant from the Army Office of Research (Durham).

(2) H. Nozaki, T. Mori, and M. Kawanisi, *Can. J. Chem.*, **46**, 3767 (1968).

(3) M. Stiles, *J. Amer. Chem. Soc.*, **81**, 2598 (1959); E. Szarvary, *Ber.*, **30**, 1836 (1897).



Compound **5** can be reduced to either the diketo ester **6** or the keto ester **7**.



Experimental Section

β-(Methylsulfinyl)-α-(oxycarboethoxy)styrene (4).—ω-(Methylsulfinyl)acetophenone (4.55 g, 25 mmol) was converted to its sodium salt by the reaction of 1 equiv of sodium hydride in 60 ml of THF. The heterogenous mixture was diluted to 250 ml with hexane at 0°, and 2.7 ml of ethyl chloroformate in 50 ml of hexane was added dropwise. After 3 hr at 25°, the reaction mixture was filtered, concentrated *in vacuo*, and chromatographed on a 2.5 × 28 cm silica gel column with ethyl acetate (50%)–hexane (50%) as the solvent. After elution of 1.1 g of phenylglyoxal, there was recovered 4.2 g of the styrene (66%) that showed only one component by tlc. The viscous oil was evacuated at 0.1 Torr for 8 hr to give the following analysis: nmr ($CDCl_3$) δ 1.30, 4.25 (t, 3; q, 2; J = 7.6 Hz, CH_3CH_2), 2.84 (s, 3, $SOCH_3$), 6.85 (s, 1, $CH(SOCH_3)$), and 7.20–7.68 (m, 5, C_6H_5).

Anal. Calcd for $C_{12}H_{14}O_4S$: C, 56.69; H, 5.55; S, 12.55. Found: C, 56.75; H, 5.40; S, 12.68.

Ethyl β-(Methylsulfinyl)-β-benzoylpropionate (2a).—The sodium salt of ω-(methylsulfinyl)acetophenone (25 mmol) was prepared as described previously in 150 ml of THF. At 5°, a solution of 4.2 ml of ethyl bromoacetate in 10 ml of THF was added dropwise. The solution was stirred for 2 hr at 25°, filtered, concentrated *in vacuo*, and diluted with 200 ml of water, and the pH was adjusted to 5 with hydrochloric acid. Extraction with three 100-ml portions of chloroform yielded a yellow oil after drying ($MgSO_4$) and solvent removal. The oil was chromatographed on a silica gel column. Nonpolar impurities were eluted with hexane (95%)–ethyl acetate (5%). The propionate ester was eluted away from unreacted β-keto sulfoxide by chloroform to yield 4.08 g (61%) of a viscous oil whose nmr spectrum ($CDCl_3$) was consistent with a mixture of diastereomers; mass spectrum (70 eV) *m/e* (rel intensity) 268 (8), 275 (10), 223 (10), 204 (40), 131 (35), 105 (100).

Reduction with zinc and acetic acid[4] of ethyl β-(methylsulfinyl)-β-benzoylpropionate for 10 hr yielded 4.65 g (86%) of **ethyl β-benzoylpropionate** from 7 g of the sulfoxide. The β-benzoylpropionate was isolated by extraction with ethyl acetate followed by chromatography on a silica gel column with hexane (90%)–ethyl acetate (10%) as the eluent. The product had bp 118–120° (2 Torr) [lit.[5] bp 123° (2 Torr)].

(4) G. A. Russell and G. J. Mikol, *J. Amer. Chem. Soc.*, **88**, 5498 (1966).
(5) J. F. Eijkman, *Chem. Zentr.*, **75**, 1259 (1904).

Pyrolysis of ethyl β-(methylsulfinyl)-β-benzoylpropionate at 120° at 2 Torr yielded **ethyl β-benzoylacrylate.** The sulfoxide (1.40 g) was heated in a 25-ml flask with a reflux condenser. After 2 hr, the products were chromatographed on silica gel with hexane (95%)–ethyl acetate (5%) as the eluent to yield 0.93 g (87%) of β-benzoylacrylate, bp 119–120° (2 Torr) [lit.[6] bp 192° (32 Torr)]. The nmr spectrum was consistent with the *trans* isomer; nmr ($CDCl_3$) δ 1.30 and 4.27 (t, 3; q, 2; J = 7.5 Hz, CH_3CH_2), 7.35 (q, 2, J_{AB} = 19.2 Hz, *trans* CH=CH), 7.25–7.65 and 7.80–8.10 (m, 3 and 2, C_6H_5).

Ethyl γ-(Methylsulfinyl)-γ-benzoylbutyrate (3).—The sodium salt of ω-(methylsulfinyl)acetophenone (25 mmol) was prepared as described previously in 200 ml of THF. To this solution was added 2.6 g of ethyl acrylate. The solution was stirred for 6 hr at 25° and quenched with 10 ml of water. The solution was concentrated *in vacuo* and diluted with 300 ml of saturated aqueous ammonium chloride. Extraction with three 100-ml portions of chloroform, followed by drying ($MgSO_4$) and vacuum evaporation, yielded a yellow oil that was chromatographed on a silica gel column. Nonpolar impurities were removed with hexane (80%)–ethyl acetate (20%). Hexane (50%)–ethyl acetate (50%) yielded 0.4 g of **5**. The major product (**3**) was eluted with ethyl acetate to yield 5.3 g (75%) of a colorless oil whose nmr ($CDCl_3$) was consistent with a mixture of diastereomers; mass spectrum (70 eV) *m/e* (rel intensity) 282 (5), 264 (15), 237 (10), 204 (40), 131 (35), 105 (100).

Reduction of ethyl γ-(methylsulfinyl)-γ-benzylbutyrate by the technique employed for the reduction of **2** yielded 3.44 g (80%) of **ethyl γ-benzoylbutyrate** from 5.50 g of the sulfoxide, bp 157–158° (10 Torr) [lit.[7] bp 315° (750 Torr)].

Pyrolysis of ethyl γ-(methylsulfinyl)-γ-benzoylbutyrate at 140° (2 Torr) yielded **ethyl 4-benzoyl-3-butenate.** Heating of 1.1 g of the sulfoxide for 2 hr yielded 0.44 g (51.5%) of the unsaturated ester isolated by chromatography, bp 152–156° (4 Torr).

Anal. Calcd for $C_{13}H_{14}O_3$: C, 71.54; H, 6.47. Found: C, 71.80; H, 6.53.

Ethyl γ-(methylsulfinyl)-γ-benzoylbutyrate could be reduced to **ethyl δ-phenylvalerate** under vigorous conditions. The sulfoxide (2.85 g) was dissolved in 30 ml of ethanol to which 6.5 g of zinc and 35 ml of acetic acid were added slowly so that the temperature did not exceed 30°. The reaction was stirred for 6 hr at 25° and then refluxed for 4 hr. The cooled reaction mixture was filtered and the filtrate was concentrated *in vacuo*. The residue was dissolved in 100 ml of chloroform, washed with two 100-ml portions of diluted aqueous sodium bicarbonate, dried ($MgSO_4$), and concentrated *in vacuo*. Chromatography on silica gel yielded 1.1 g (54%) of an oil eluted by hexane (95%)–ethyl acetate (5%), bp 143–147° (10 Torr) [lit.[8] bp 150° (11 Torr)], whose nmr spectrum was consistent with ethyl δ-phenylvalerate.

2-Carboethoxy-4-(methylsulfinyl)-4-benzoylcyclohexanone (5.)—To 25 mmol of the anion of ω-(methylsulfinyl)acetophenone in 200 ml of THF was added 20 ml of ethyl acrylate. The reaction mixture was stirred for 6 hr at 25°, quenched by the addition of 15 g of ammonium chloride, stirred for an additional hour, and poured into 300 ml of water. Extraction with three 100-ml portions of chloroform gave a product that was washed and dried ($MgSO_4$) and chromatographed on silica gel as described previously to yield 5.03 g (60%) of the substituted cyclohexanone and 1.74 g of **3**. The nmr spectrum of **5** was very complex because of the presence of three asymmetric centers and the possibility of keto–enol equilibria; mass spectrum (70 eV) *m/e* (rel intensity) 336 (3), 320 (8), 318 (5), 272 (55), 226 (50), 110 (100), 105 (70). Reduction by zinc and acetic acid as described previously yielded 2.96 g (91%) of **2-carboethoxy-4-benzoylcyclohexanone (6)** from 4 g of the sulfoxide. The 2-carboethoxy-4-benzoylcyclohexanone isolated by column chromatography was crystallized from pentane (90%)–ethyl acetate (10%) to give a product with mp 49–51° whose nmr spectrum was consistent with a mixture of keto and enol forms.

Anal. Calcd for $C_{16}H_{18}O_4$: C, 70.05; H, 6.61. Found: C, 70.26; H, 6.44.

Using the modified reduction procedure that converted **3** into the valeric acid derivative, **5** was reduced to **2-carboethoxy-4-benzoylcyclohexanone (7)** in 41% yield. Compound **7** was isolated as an oil by column chromatography.

(6) G. P. Rice, *J. Amer. Chem. Soc.*, **45**, 233 (1923).
(7) C. K. Kuhn, *Ann.*, **302**, 220 (1898).
(8) J. N. Braun and H. Deutsch, *Chem. Ber.*, **45**, 2178 (1912).

Anal. Calcd for $C_{15}H_{20}O_3$: C, 73.82; H, 7.74. Found: C, 73.60; H, 7.51.

Registry No.—ω-(Methylsulfinyl)acetophenone, 2813-22-1; **2**, 20708-04-7; **3**, 20708-05-8; **4**, 20708-06-9; **5**, 20708-07-0; **6**, 20708-08-1; **7**, 20708-09-2; ethyl 4-benzoyl-3-butenate, 20708-10-5.

Reaction of Sodium Dicyanocuprate with Vinyl and Aryl Halides[1a]

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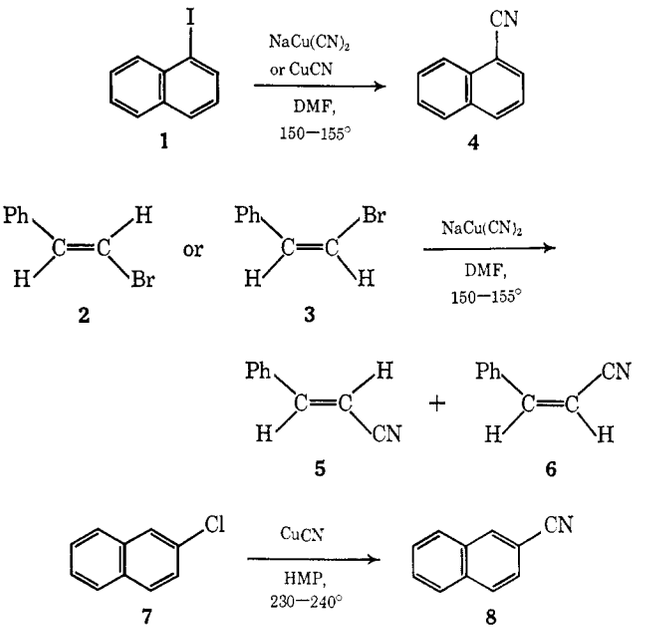
Received February 24, 1969

The advantageous use of lithium dialkyl- or diarylcuprates [*e.g.*, $LiCu(CH_3)_2$] as reagents for conjugate addition to unsaturated carbonyl compounds[2] and for coupling reactions with alkyl and aryl halides[3] raised the question whether analogous di- or polycyanocuprate species might offer advantages in the conversion of aryl and vinyl halides to the corresponding cyano compounds. The conversion of aryl or vinyl halides into the corresponding cyanides has usually been effected by heating the halide with copper(I) cyanide[4] to 150–220° in solvents (or diluents) such as pyridine, quinoline, dimethylformamide, N-methylpyrrolidone, or dimethyl sulfoxide.

The reactions of alkali metal cyanides, MCN, with copper(I) cyanide to form a series of cyano cuprate species, $M_nCu(CN)_{n+1}$ where n = 1, 2, or 3, have been described.[5] From formation of the complexes $M^+Cu(CN)_2^-$ where M = Li, Na, or K by reaction of CuCN with M^+CN^- in dimethylformamide (DMF) solution, we conclude that the sodium derivative was most satisfactory for preparative use; at 80°, a 1 *M* solution of $NaCu(CN)_2$ in dimethylformamide (DMF) was readily obtained whereas the K and Li salts were less soluble. Reaction of this solution with the aryl iodide **1** or the vinyl bromides **2** or **3** at 150–155° for periods of 4 to 10 hr yielded the corresponding nitriles **4**–**6** (Scheme I). For comparison the reaction **1** → **4** was complete in 2–4 hr with CuCN in DMF and the reaction **2** → **5** was complete in 2 hr with CuCN in refluxing N-methylpyrrolidone.[4e] The aryl chloride **7** failed to react under these circumstances but was converted into the nitrile **8** in good yield by heating to 230–240° for 3 hr with CuCN in hexamethylphosphoramide (HMP). Although the conversion **1** → **4** proceeded approximately four times as fast when the cyanide reagent was CuCN rather than $NaCu(CN)_2$, the reaction in dimethylformamide solution was more convenient with the complex $NaCu(CN)_2$ because a homogeneous reaction mixture was maintained throughout the reaction period.

SCHEME I



From the data obtained (Table I) in conversions of the vinyl bromides **2** and **3** into the unsaturated nitriles, we are led to suggest that the initial conversion of bromide to the cyanide proceeds with retention of configuration (*e.g.*, **3** → **6**). However, the products are not configurationally stable to the reaction conditions so that mixtures of the isomeric nitriles **5** and **6** are formed from either vinyl bromide.

TABLE I

REACTION OF SODIUM DICYANOCUPRATE WITH *cis*- AND *trans*-β-BROMOSTYRENES

		Yield, %			
Starting halide	Reaction time, hr	*cis*-β-Bromostyrene 3	*trans*-β-Bromostyrene 2	*cis*-Cinnamonitrile 6	*trans*-Cinnamonitrile 5
trans isomer **2**	6		13	9	78
	10		3	14	74
	24			14	58
cis isomer **3**	2	30	1.5	56	9
	4	3.5	0.5	50	43
	6			35	51
	11			19	57

From these studies, we conclude that the cyanocuprate species, $M_nCu(CN)_{n+1}$, are somewhat less reactive than CuCN in reactions with aryl and vinyl halides.

(1) (a) This research has been supported by Research Grant No. AFOSR-68-1518 from the Directorate of Chemical Science, Air Force Office of Scientific Research; (b) National Institutes of Health Predoctoral Fellow, 1966–1969.

(2) (a) H. O. House, W. L. Respess, and G. M. Whitesides, *J. Org. Chem.*, **31**, 3128 (1966); (b) H. O. House and W. F. Fischer, Jr., *ibid.*, **33**, 949 (1968).

(3) (a) E. J. Corey and G. H. Posner, *J. Amer. Chem. Soc.*, **89**, 3911 (1967); **90**, 5615 (1968); (b) G. M. Whitesides, W. F. Fischer, Jr., J. San Filippo, Jr., R. W. Bashe, and H. O. House, *ibid.*, **91**, 4871 (1969).

(4) (a) R. G. R. Bacon and H. A. O. Hill, *Quart. Rev.*, **19**, 121 (1965); (b) D. T. Mowry, *Chem. Rev.*, **42**, 189 (1948); (c) R. G. R. Bacon and H. A. O. Hill, *J. Chem. Soc.*, 1097 (1964); (d) M. S. Newman and D. K. Phillips, *J. Amer. Chem. Soc.*, **81**, 3667 (1959); (e) M. S. Newman and H. Boden, *J. Org. Chem.*, **26**, 2525 (1961); (f) L. Friedman and H. Shechter, *ibid.*, **26**, 2522 (1961); (g) E. J. Corey and L. S. Hegedus [*J. Amer. Chem. Soc.*, **91**, 1233 (1969)] have recently described the conversion of the vinyl bromide **2** to the nitrile **5** with $K_4Ni_2(CN)_6$.

(5) (a) M. H. Ford-Smite, "The Chemistry of Complex Cyanides," Her Majesty's Stationery Office, London, 1964, p 34; (b) M. Sneed, J. Maynard, and R. Bronsted, "Comprehensive Inorganic Chemistry," Vol. 2, D. Van Nostrand Co., Inc., New York, N. Y., 1954, pp 81, 91; (c) W. P. Griffith, *Quart. Rev.*, **16**, 188 (1962); (d) R. M. Izatt, H. D. Johnson, G. D. Watt, and J. J. Christensen, *Inorg. Chem.*, **6**, 132 (1967); (e) R. E. Dodd and R. P. H. Gasser, *Proc. Chem. Soc.*, 415 (1964); (f) G. Guiseppetti and C. Tadim, *Periodica Mineral.*, **35**, 431 (1966); (g) D. T. Cromer, *J. Phys. Chem.*, **61**, 1388 (1957); (h) S. K. Tobia and M. F. El-Shahat, *J. Chem. Soc., A*, 2444 (1968).