

Synthesis of Ylides Stabilised by the 3-Oxocyclohex-1-enyl Group

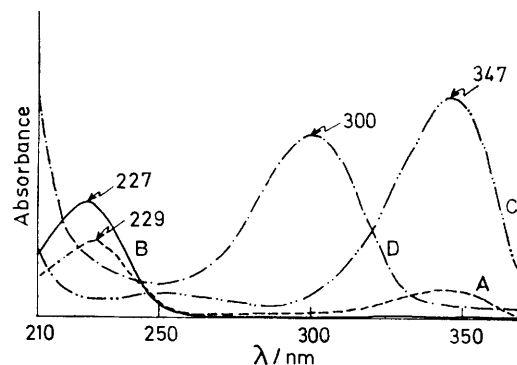
By Yasumitsu Tamura,* Tomohisa Miyamoto, Jiro Eiho, Hiroshi Taniguchi, Tadashi Nishimura, and Yasuyuki Kita, Faculty of Pharmaceutical Sciences, Osaka University, Toneyama, Toyonaka, Osaka, Japan

Methods are described for synthesising ylides of the C-P, C-S, C-N, NS-, N-SO, and N-P types, stabilised by the 3-oxocyclohex-1-enyl group. The stability and structures of the corresponding quaternary salts have also been investigated.

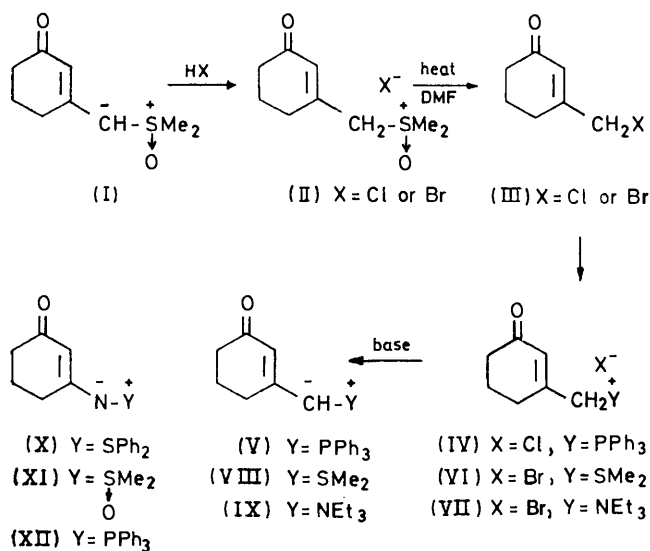
In recent years many ylides stabilised by a 3-oxoalk-1-enyl group have been reported,¹⁻⁷ and *N*-pyridinio-3-oxocyclohexenylaminides⁴ and dimethylsulphonio-(3-oxocyclohex-1-enyl)methanide (I)⁵⁻⁷ have been shown to have potential as synthetic intermediates. The present paper concerns the syntheses and properties of triphenylphosphonio- (V), dimethylsulphonio- (VIII), and triethylammonio-(3-oxocyclohex-1-enyl)methanides (IX), *N*-(3-oxocyclohex-1-enyl)-*SS*-diphenylsulphimide (X), *N*-(3-oxocyclohex-1-enyl)-*SS*-diphenylsulphoximide (XI), and *N*-triphenylphosphonio-(3-oxocyclohex-1-enyl)aminide (XII).

Heating dimethyl oxo-(3-oxocyclohex-1-enylmethyl)sulphonium chloride (II; X = Cl)⁵ or bromide (II; X = Br) in dimethylformamide (DMF) at 85° afforded 3-chloromethyl- (III; X = Cl) or 3-bromomethylcyclohex-2-enone (III; X = Br) in 69 or 78% yield, respectively. Refluxing a solution of (III; X = Cl)

10% sodium hydrogen carbonate to give a 96% yield of the phosphonium ylide (V). Treatment of (III; X = Br) with dimethylsulphide or triethylamine at room temperature gave the corresponding quaternary salt (VI) or



Treatment of quaternary salts (VI) and (VII) (in EtOH) with aqueous sodium hydroxide: A, the sulphonium bromide (VI); B, the ammonium bromide (VII); C, the sulphonium ylide (VIII); D, the ammonium ylide (IX)



SCHEME 1

and triphenylphosphine in tetrahydrofuran (THF) gave (3-oxocyclohex-1-enylmethyl)triphenylphosphonium chloride (IV) (48%), which was treated with aqueous

(VII) in 74 or 40% yield, respectively. The quaternary salts (VI) and (VII) show u.v. maxima at 229 and 227 nm, respectively in ethanolic solution, which undergo strong bathochromic shifts to 347 and 300 nm [assigned to the C-S (VIII) or C-N ylide (IX)] on addition of aqueous sodium hydroxide (see Figure). Attempts to isolate (VIII) and (IX), however, failed.

The sulphimide (X) and the sulphoximide (XI) were obtained by reactions of 3-chlorocyclohex-2-enone with *SS*-diphenylsulphimide⁸ at room temperature and with *SS*-dimethylsulphoximide at 85° (yields 82 and 60%). The phosphine imide (XII) was obtained in quantitative yield by reaction of triphenylphosphine with 3-azidocyclohex-2-enone⁹ in benzene at room temperature.

The structures of the *C*- and *N*-ylides (V) and (X)—(XII) were supported by their analytical data and i.r., n.m.r., and u.v. spectra (see Experimental section). Their olefinic protons were exchangeable with deuterium (D₂O) as in the case of the oxosulphonium ylide (I).^{5,7} The negative charges of the *C*-ylides (V), (VIII), and (IX) are shown to be largely delocalised⁷ over an enone

¹ T. Mukaiyama and M. Higo, *Tetrahedron Letters*, 1970, 5297; M. Higo, T. Sakashita, M. Toyoda, and T. Mukaiyama, *Bull. Chem. Soc. Japan*, 1972, **45**, 250.

² M. J. Berenguer, J. Castells, R. M. Galard, and Morenomanas, *Tetrahedron Letters*, 1971, 395.

³ A. G. Hortmann and R. L. Harris, *J. Amer. Chem. Soc.*, 1971, **93**, 2471.

⁴ Y. Tamura, N. Tsujimoto, and M. Ikeda, *Chem. Comm.*, 1971, 310; Y. Tamura, N. Tsujimoto, Y. Sumida, and M. Ikeda, *Tetrahedron*, 1972, **28**, 21.

⁵ Y. Tamura, T. Nishimura, J. Eiho, and T. Miyamoto, *Chem. and Ind.*, 1971, 1199.

⁶ Y. Tamura, T. Miyamoto, T. Nishimura, and Y. Kita, *Tetrahedron Letters*, 1973, 2351.

⁷ Y. Tamura, T. Miyamoto, T. Nishimura, J. Eiho, and Y. Kita, preceding paper.

⁸ Y. Tamura, K. Sumoto, J. Minamikawa, and M. Ikeda, *Tetrahedron Letters*, 1973, 4137.

⁹ Y. Tamura, Y. Yoshimura, and Y. Kita, *Chem. and Pharm. Bull. (Japan)*, 1972, **20**, 871.

system (i) from their u.v. and n.m.r. spectral data: the u.v. maxima are at longer wavelength and the chemical shifts of the vinyl protons are at higher field than those of the corresponding quaternary salts (Table). The u.v. maxima of the *N*-ylides (X)—(XII) are at nearly the same wavelength as those of the corresponding quaternary salts, which have already been shown to exist in the keto-form (iv) rather than the enol form (iii).¹⁰ The extent of delocalisation in these cases is therefore assumed to be relatively small.

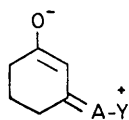
decomposed rapidly under the conditions, giving cyclohexane-1,3-dione and 3-aminocyclohex-2-enone, respectively.

EXPERIMENTAL

For instrumentation, see preceding paper.

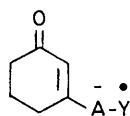
Dimethyloxo-(3-oxocyclohex-1-enylmethyl)sulphonium Bromide (II; X = Br).—Dimethyloxosulphonio-(3-oxocyclohex-1-enyl)methanide (I) (2.0 g) was dissolved in hot acetone (250 ml) and cooled in ice. Dry hydrogen bromide

Structures and u.v. and n.m.r. spectral data of the ylides (I), (V), and (VIII)—(XII) and the salts (II), (IV), (VI), and (VII)



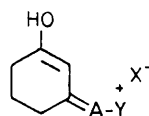
(i)

(I), (V), and (VIII)—(IX)



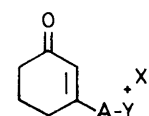
(ii)

(X)—(XII)



(iii)

(VI) and (VII)



(iv)

(II), (IV), (VI), (VII), and (X')—(XII')

Ylides					Salts					
No.	A	Y	λ_{\max}/nm (EtOH)	τ (Vinyl proton)	No.	A	Y	X	λ_{\max} . (EtOH)/nm enol (iii) keto (iv)	τ (Vinyl proton)
(I)	CH	SOMe ₂	354	4.35 ^b	(II)	CH	SOMe ₂	Cl	229	3.65 ^c
(V)	CH	PPh ₃	372	4.97 ^b	(IV)	CH	PPh ₃	Cl	226	4.26 ^d
(VIII)	CH	SMe ₂	(347) ^a		(VI)	CH	SMe ₂	Br	229	3.77 ^d
(IX)	CH	NEt ₃	(300) ^a		(CH)	SMe ₂	Cl	(290) ^a	(228) ^a	
(X)	N	SPh ₂	316	4.81 ^b	(VII)	CH	NEt ₃	Br	227	3.76 ^d
(XI)	N	SOMe ₂	288	4.33 ^b	(CH)	NEt ₃	Cl	(260) ^a	(228) ^a	
(XII)	N	PPh ₃	319	4.93 ^b	(X')	N	SPh ₂	Cl	(301) ^a	
					(XI')	N	SOMe ₂	Cl	(293) ^a	
					(XII')	N	PPh ₃	Cl	(306) ^a	

^a Observed only in solution, without isolation. ^b In CDCl₃. ^c In H₂O. ^d In D₂O.

Acidification of ethanolic solutions of the ylides (I), (V), and (VIII)—(XII) with hydrochloric acid gave the corresponding quaternary salts, whose stability and structures were examined by u.v. spectroscopy. The ammonium ylide (IX) gave an enol form (iii; A = CH, Y = NEt₃) of the ammonium salt (VII), which gradually isomerised to a more stable keto-form (iv; A = CH, Y = NEt₃). The initial u.v. maximum (λ_{\max} 300 nm) of the ammonium ylide (IX) underwent a hypsochromic shift to give maxima at 260 and 228 nm, assigned to the enol (iii) and the keto-form (iv), respectively. The peak at 260 nm gradually decreased and that at 228 nm gradually increased in intensity, reaching a maximum after several hours. The sulphonium ylide (VIII) (λ_{\max} 347 nm) also afforded a mixture of enol (iii; A = CH, Y = SMe₂) (λ_{\max} 290 nm) and keto-forms (iv; A = CH, Y = SMe₂) (λ_{\max} 228 nm), of which (iii) changed rapidly into (iv) at room temperature. In the cases of the oxosulphonium ylide (I) (λ_{\max} 354 nm), the phosphonium ylide (V) (372 nm), the sulphimide (X) (316 nm), the sulphoximide (XI) (288 nm), and the phosphine imide (XII) (319 nm), an absorption maximum due only to the keto-form¹⁰ (iv; A = CH, Y = SOMe₂, λ_{\max} 229 nm; A = CH, Y = PPh₃, 226; A = N, Y = SPh₂, 301; A = N, Y = SOMe₂, 293; A = N, Y = PPh₃, 306) was observed. The quaternary salts of (XI) and (XII) were

was bubbled through the solution and the resulting crystals were collected. More crystals were obtained by adding ether to the filtrate (total yield 2.70 g, 94%). Recrystallisation from methanol-ether gave *needles*, m.p. 106—107° (decomp.) (Found: C, 40.75; H, 5.65. C₉H₁₅BrO₂S requires C, 40.45; H, 5.65%); ν_{\max} (KCl) 1665 and 1630 cm⁻¹; τ (H₂O) 3.65br (1H, s, CH=), 4.98br (2H, s, CH₂S), 6.13 (6H, s, SMe₂), and 7.2—8.1 (6H, m, 3 × CH₂); τ (D₂O) 3.67 (1H, t, *J* 1.5 Hz, CH=, disappeared gradually), 6.15 (6H, s, SMe₂), and 7.2—8.1 (6H, m, 3 × CH₂).

3-Chloromethylcyclohex-2-enone (III; X = Cl).—A suspension of dimethyloxo-(3-oxocyclohex-1-enylmethyl)sulphonium chloride (II; X = Cl) (1.50 g) in dry DMF (2 ml) was heated at 85° for 1 h. Ice-water (30 ml) was added, the mixture was extracted with ether (2 × 40 ml), and the extract was washed with saturated aqueous sodium chloride and dried (MgSO₄). Removal of the solvent *in vacuo* followed by distillation at 85° (bath temp.) and 0.04 mmHg gave a pale yellow oil (III; X = Cl) (0.68 g, 69%), ν_{\max} (CHCl₃) 1670 cm⁻¹; τ (CDCl₃) 3.89br (1H, s, CH=), 5.84 (2H, s, CH₂Cl), and 7.3—8.2 (6H, m, 3 × CH₂). The *2,4-dinitrophenylhydrazone*, precipitated from ethanol, gave deep red crystals, m.p. 161—163° (from ethanol) (Found: C, 48.3; H, 3.95; Cl, 10.6; N, 17.15. C₁₃H₁₃ClN₄O₄ requires C, 48.1; H, 4.05; Cl, 10.9; N, 17.25%).

3-Bromomethylcyclohex-2-enone (III; X = Br).—A suspension of dimethyloxo-(3-oxocyclohex-1-enylmethyl)sulphonium bromide (II; X = Br) (1.0 g) in dry DMF (3 ml) was heated at 83° for 1 h and then evaporated *in vacuo*. Chromatography on silica gel with benzene followed by distillation at 65—75° (bath temp.) and 0.03 mmHg

¹⁰ C. A. Grob and H. J. Wilkens, *Helv. Chim. Acta*, 1967, **50**, 725.

gave a pale yellow oil (III; X = Br) (552 mg, 78%), ν_{\max} (CHCl₃) 1670 cm⁻¹; τ (CCl₄) 4.03br (1H, s, CH=), 6.02 (2H, s, CH₂Br), and 7.4—8.2 (6H, m, 3 × CH₂). The 2,4-dinitrophenylhydrazone, precipitated from ethanol and washed with ethanol, had m.p. 156.5—158° (Found: C, 42.5; H, 3.45; Br, 21.75; N, 15.4. C₁₃H₁₃BrN₄O₄ requires C, 42.3; H, 3.55; Br, 21.65; N, 15.2%).

(3-Oxocyclohex-1-enylmethyl)triphenylphosphonium Chloride (IV; X = Cl).—(a) A solution of 3-chloromethylcyclohex-2-enone (III) (4.57 g) and triphenylphosphine (8.29 g) in dry THF (30 ml) was refluxed with stirring for 8 h to give the phosphonium salt (IV). An additional crop was obtained by refluxing for another 42 h (combined yield 6.20 g, 48%). Recrystallisation from dichloromethane-ether afforded crystals, m.p. 267.5—270° (decomp.) (Found: C, 73.3; H, 6.15; Cl, 8.7; P, 7.5. C₂₅H₂₄ClOP requires C, 73.8; H, 5.95; Cl, 8.7; P, 7.6%); ν_{\max} (KCl) 1660 cm⁻¹; τ (CDCl₃) 1.8—2.6 (15H, m, aromatic), 4.26 (1H, d, J_{PH} 4.5 Hz, CH=, disappeared on addition of D₂O), 4.67 (2H, d, J_{PH} 16.8 Hz, CH₂P, disappeared on addition of D₂O), and 7.6—8.0 (6H, m, 3 × CH₂); λ_{\max} (EtOH) 226 (log ϵ 4.50), 261 (3.77), 268 (3.77), 276 (3.73), and 373 nm (4.26).

(b) A suspension of dimethyl(3-oxocyclohex-1-enylmethyl)sulphonium chloride (II) (5.70 g) and triphenylphosphine (6.81 g) in dry DMF (50 ml) was heated at 80—85° for 8 h. The hot mixture was diluted with benzene (500 ml) and cooled to room temperature; the resulting precipitate gave the phosphonium chloride (IV) (7.68 g, 73%).

(3-Oxocyclohex-1-enyl)triphenylphosphoniomethanide (V).—A suspension of (3-oxocyclohex-1-enylmethyl)triphenylphosphonium chloride (IV) (7.68 g) in water (60 ml) was cooled in an ice-bath. Aqueous 10% sodium carbonate (40 ml) was added in portions during 10 min with stirring. Stirring for a further 2 h gave the ylide (V) (6.76 g, 96%). Recrystallisation from acetone afforded yellow prisms, m.p. 220—222° (Found: C, 81.25; H, 6.4; P, 8.35. C₂₅H₂₃OP requires C, 81.05; H, 6.25; P, 8.35%); ν_{\max} (CHCl₃) 1545 and 1500 cm⁻¹; τ (CDCl₃) 2.2—2.7 (15H, m, aromatic), 4.9br (1H, s, CH=, disappeared on addition of D₂O), 6.90br (1H, d, J_{PH} 24 Hz, CHP, disappeared on addition of D₂O), and 7.3—8.4 (6H, m, 3 × CH₂); λ_{\max} (EtOH) 227 (log ϵ 4.46), 263 (3.64), 269 (3.68), 276 (3.67), and 372 nm (4.43); M^+ 370.

Dimethyl-(3-oxocyclohex-1-enylmethyl)sulphonium Bromide (VI).—To a solution of 3-bromomethylcyclohex-2-enone (III; X = Br) (150 mg) in acetone (5 ml) was added dimethyl sulphide (3 ml). The mixture was kept in the dark at room temperature for 20 h. Collection of the resulting solid followed by washing with acetone gave the sulphonium bromide (VI) (148 mg, 74%), m.p. 106—107° (decomp.) (Found: C, 42.85; H, 6.25; Br, 31.2; S, 12.5. C₉H₁₅BrOS requires C, 43.05; H, 6.0; Br, 31.8; S, 12.75%); ν_{\max} (KCl) 1665 cm⁻¹; τ (D₂O) 3.77br (1H, s, CH=, gradually disappeared), 5.72 (2H, s, CH₂S, disappeared rapidly), 7.07 (6H, s, SMe₂), and 7.4—8.2 (6H, m, 3 × CH₂); λ_{\max} (EtOH) 229 (log ϵ 3.93) and 348 nm (3.47).

Triethyl-(3-oxocyclohex-1-enylmethyl)ammonium Bromide

(VII).—A mixture of 3-bromomethylcyclohex-2-enone (III) (216 mg) and freshly distilled triethylamine (10 ml) was stirred at room temperature for 2 days. Collection of the resulting solid followed by washing with ether gave the hygroscopic ammonium bromide (VII) (133 mg, 40%). Recrystallisation from acetone-ether gave prisms, m.p. 159—160° (decomp.) (Found: C, 52.95; H, 8.45; N, 4.7. C₁₃H₂₄BrNO_{0.25}H₂O requires C, 52.95; H, 8.4; N, 4.75%); ν_{\max} (KCl) 1675 cm⁻¹; τ (D₂O) 3.8br (1H, s, CH=), 5.95 (2H, s, =C-CH₂-N), 6.68 (6H, q, J 7.5 Hz, 3 × CH₂-N), 7.2—8.2 (6H, m, 3 × CH₂), and 8.68 (9H, t, J 7.5 Hz, 3 × CH₃); λ_{\max} (EtOH) 227 nm (log ϵ 4.08).

N-(3-Oxocyclohex-1-enyl)-SS-diphenylsulphimide (X).—A mixture of 3-chlorocyclohex-2-enone (300 mg) and SS-diphenylsulphimide (1.00 g) was kept at room temperature overnight. Chromatography of the resulting yellow oil on silica gel with chloroform gave the sulphimide (X) (545 mg, 82%). Recrystallisation from ethyl acetate gave crystals, m.p. 152—153° (Found: C, 73.25; H, 5.8; N, 4.75. C₁₈H₁₇NOS requires C, 73.2; H, 5.8; N, 4.75%); ν_{\max} (CHCl₃) 1595 and 1515 cm⁻¹; τ (CDCl₃) 2.2—2.7 (10H, m, aromatic), 4.81 (1H, s, CH=, disappeared on addition of D₂O), and 7.3—8.3 (6H, m, 3 × CH₂); λ_{\max} (EtOH) 230sh (log ϵ 4.12), 267 (3.55), 274 (3.58), and 316 nm (4.17); M^+ 295.

SS-Dimethyl-N-(3-oxocyclohex-1-enyl)sulphoximide (XI).—A mixture of 3-chlorocyclohex-2-enone (1.31 g) and SS-dimethylsulphoximide (1.86 g) was heated at 85° for 5 h. After addition of aqueous sodium chloride (30 ml), the crude sulphoximide (XI) was liberated by treatment with concentrated aqueous sodium carbonate, and extracted with chloroform (5 × 30 ml). The extract was dried (MgSO₄) and evaporated *in vacuo*; washing the residue with ether gave yellow-brown crystals (1.19 g), which were purified by alumina column chromatography (with chloroform) (yield 1.13 g, 60%). Recrystallisation from benzene gave needles, m.p. 148—149.5° (Found: C, 51.75; H, 6.9; N, 7.25. C₉H₁₃NO₂S requires C, 51.35; H, 7.0; N, 7.5%); ν_{\max} (CHCl₃) 1630 and 1565 cm⁻¹; τ (CDCl₃) 4.33 (1H, s, CH=, disappeared on addition of D₂O), 6.78 (6H, s, SMe₂), and 7.5—8.2 (6H, m, 3 × CH₂); λ_{\max} (EtOH) 288 nm (log ϵ 4.38); M^+ 187.

N-Triphenylphosphonio-(3-oxocyclohex-1-enyl)aminide (XII).—To a stirred solution of triphenylphosphine (3.33 g) in benzene (30 ml) in a water-bath, 3-azidocyclohex-2-enone (1.74 g) in benzene (10 ml) was added in portions during 10 min. Stirring was continued for another 10 min and the mixture was then left at room temperature overnight. After addition of hexane (50 ml) the resulting phosphine imide (XII) (4.59 g, 97%) was collected. Recrystallisation from benzene gave crystals, m.p. 163—163.5° (Found: C, 77.85; H, 6.0; N, 3.7; P, 8.65. C₂₄H₂₂NOP requires C, 77.6; H, 5.95; N, 3.75; P, 8.35%); ν_{\max} (CHCl₃) 1590 and 1515 cm⁻¹; τ (CDCl₃) 2.0—2.65 (15H, m, aromatic), 4.93br (1H, s, CH=, disappeared on addition of D₂O), and 7.3—8.3 (6H, m, 3 × CH₂); λ_{\max} (EtOH) 227sh (log ϵ 4.34), 260sh, (3.78), 267sh (3.89), 275 (3.96), and 319 nm (4.43); M^+ 371.

[3/1676 Received, 7th August, 1973]