in the mixture of the epimeric 5α-cholestane-3α,8-diol-7-one 3β-acetates[11] (0.564 μCi of ^{14}C/mmole) resulting from the mixture of the epimeric *cis*-5α-cholestane-3β,7,8-triol 3β-acetates.[6]

In order to establish if the missing tritium was originally from the 15 position, the remaining 5α-cholest-7-en-3β-ol acetate (0.565 μCi of ^{14}C/mmole) was oxidized with selenium dioxide[12] to 5α-cholest-8(14)-en-3β,7α-diol diacetate[11] which, adsorbed on silver nitrate–kieselgel G–Celite, gave rise to 5α-cholesta-7,14-dien-3β-ol acetate: mp 67–69°; uv max (C_2H_5OH) 242 mμ (ε 9700).[13] This diene was oxidized with chromium trioxide in acetic acid to yield 5α-cholest-8(14)-en-3β-ol-7,15-dione acetate; mp 153–155°; uv max (C_2H_5OH) 260 mμ (ε 6200); $[\alpha]^{25}D$ 65 (*c* 1, $CHCl_3$)[13] (0.567 μCi of ^{14}C/mmole). This compound showed a $^{3}H:^{14}C$ ratio identical with that of 5α-cholest-7-en-3β-ol acetate. The formation of a keto group in position 15, unaccompanied by a decrease of the $^{3}H:^{14}C$ ratio, shows that the 15β hydrogen of **3** is not radioactive.

In order to establish the stereospecificity of the exchange of hydrogens in position 15, a biosynthetic experiment has been performed starting from 3(±)-(2*R*)-[2-^{14}C-2-^{3}H]mevalonic acid lactone (10 μCi of ^{14}C, $^{3}H:^{14}C$ 9.20). Incubation and isolation procedures were the same as described above. Radioactive cholesta-5,7-dien-3β-ol acetate[11] was transformed and purified as in the previous experiment, and the 5α-cholest-7-en-3β-ol acetate[11] obtained (0.581 μCi of ^{14}C/mmole) showed a $^{3}H:^{14}C$ ratio 8.97 corresponding to 4.90 labeled hydrogens out of 5 radioactive carbon atoms. This result shows that the exchange of the 15β hydrogen is stereospecific.

The loss of hydrogen from the 15β position has been followed in cholesterol biosynthesis after the cyclization of squalene to lanosterol. Accumulation of labeled lanosterol (**2**) has been obtained by incubating rat liver homogenates with 3(±)-(2*S*)-[2-^{14}C-2-^{3}H]mevalonic acid lactone (10 μCi of ^{14}C, $^{3}H:^{14}C$ 10.16) in presence of 10^{-3} *M* sodium arsenite.[14] The unsaponifiable residue was acetylated, carrier lanosterol acetate (lanosta-8,24-dien-3β-ol acetate) was added, and the mixture was separated by tlc[15] on kieselgel G impregnated with silver nitrate. The isolated lanosterol acetate[11] showed a $^{3}H:^{14}C$ ratio corresponding to 5.74 labeled hydrogens out of 6 radioactive carbon atoms. This rather low ratio could have been caused by contamination of small amounts of demethyl analogs of lanosterol which are difficult to separate. Chromic acid oxidation[16] of radioactive lanosterol acetate gave rise to methyl 25,26,27-trisnor-3β-acetoxylanost-8-en-7,11-dione-24-oate[11] with a $^{3}H:^{14}C$ ratio corresponding to 3.95 labeled hydrogens out of 5 radioactive carbon atoms. This result proves that the lanosterol retains the radioactive 15β hydrogen.

It seems unlikely that the expulsion of the 4,4-dimethyl groups occurs with involvement of the 15β hydrogen. However the isomerization of 5α-cholest-8-en-3β-ol into 5α-cholest-7-en-3β-ol is proved to proceed through incorporation of only one hydrogen atom from the medium[17] and it is not intramolecular in nature.[6] Therefore it seems probable that the elimination of the 15β hydrogen accompanies the expulsion of the 14α-methyl group.

Further aspects of this elimination are under investigation.

Table I

Compound	$^{3}H:^{14}C$, μCi:μCi	Atom equiv Found	Atom equiv Calcd
3(±)-(2*S*)-[2-^{14}C-2-^{3}H]Mevalonic acid lactone	10.00		
5α-Cholest-7-en-3β-ol acetate	6.07	3.02/5	3/5
cis-5α-Cholestane-3β,7,8-triol 3β-acetate mixture	6.07	3.02/5	3/5
5α-Cholestane-3β,8-diol-7-one 3β-acetate	6.05	3.01/5	3/5
5α-Cholest-8(14)-en-3β-ol-7,15-dione acetate	5.90	2.94/5	3/5
3(±)-(2*S*)-[2-^{14}C-2-^{3}H]Mevalonic acid lactone	10.16		
Lanosta-8,24-dien-3β-ol acetate	9.70	5.74/6	6/6
25,26,27-Trisnor-3β-acetoxylanost-8-en-7,11-dion-24-oate	6.68	3.95/5	4/5
3(±)-(2*R*)-[2-^{14}C-2-^{3}H]Mevalonic acid lactone	9.20		
5α-Cholest-7-en-3β-ol acetate	8.97	4.90/5	5/5

Acknowledgments. This research was supported by Grant NB 04202-04 from the National Institutes of Health, Bethesda, Md., to the Institute of Pharmacology and by a grant of the National Research Council of Italy to the Institute of Organic Chemistry.

(12) L. F. Fieser and G. Ourisson, *J. Am. Chem. Soc.*, 75, 4404 (1953).
(13) All melting points are uncorrected. Satisfactory elementary analyses were obtained for all new compounds.
(14) M. L. Moller and T. T. Tchen, *J. Lipid Res.*, 2, 342 (1961).
(15) F. C. den Boer, *Z. Anal. Chem.*, 205, 308 (1964).
(16) J. F. Cavalla, J. F. Mc Ghie, E. C. Pickering, and R. A. Rees, *J. Chem. Soc.*, 2474 (1951).
(17) G. J. Schroepfer, Jr., W. Lee, R. Kammereck, and J. McCoskey, Abstracts, 154th National Meeting of the American Chemical Society, Chicago, Ill., Sept 1967, No. C-140.
(18) Post-doctoral fellow of the Commission for Scientific Research of Italian Switzerland.

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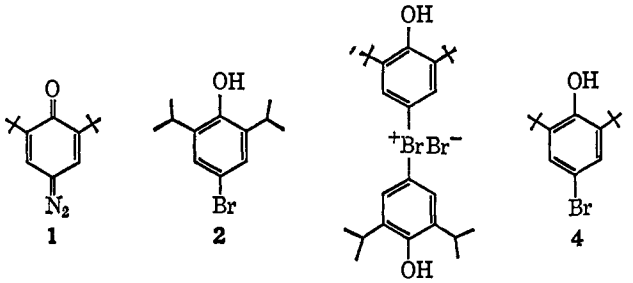
Halonium Ylides. I

Sir:

We wish to advocate the existence of bromonium ylides as reaction intermediates and to present preliminary findings concerning the chemistry of such ylides. Irradiation (>4800 Å, ~5–15°) of a degassed hexafluorobenzene solution 0.19 *M* in 3,5-di-*t*-butylbenzene 1,4-diazooxide[1] (**1**) and 0.94 *M* in 2,6-diisopropyl-4-bromophenol (**2**) leads to the precipitation of diarylbromonium bromide **3** as a reddish syrup isolable in *ca.* 15% yield after crystallization from hexafluorobenzene, *n*-hexane, and methylene chloride mixtures. The colorless salt has an elemental composition (*Anal.*

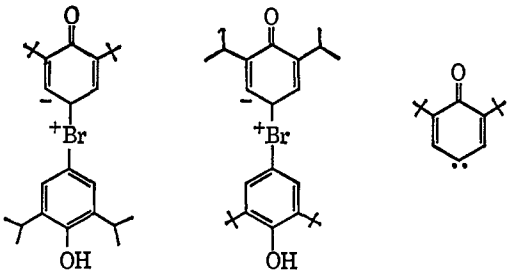
(1) G. F. Koser and W. H. Pirkle, *J. Org. Chem.*, 32, 1992 (1967).

Calcd for $C_{26}H_{38}Br_2O_2$: C, 57.57; H, 7.06; Br (total), 29.47; Br (ionic), 14.74. Found: C, 57.52; H, 7.05; Br (total), 28.92[2]) and spectra [nmr (trifluoroacetic acid, TMS), *t*-butyl δ 1.52 (s), isopropyl 1.34 (d, J = 6.8 Hz), aromatics 7.76 (s) and 7.64 (s), and isopropyl methine 3.43 (m, J = 6.8 Hz); infrared (Nujol mull), broad hydroxyl, ~3185 cm^{-1}; no carbonyl bands] consistent with the assigned structure. Under ambient conditions, bromonium bromide **3** (29.9 mg) gradually (~10.5 days) decomposes to a 1.06:1.00 mixture of bromophenol **2** and 2,6-di-*t*-butyl-4-bromophenol (**4**) in ~96% yield.[3]



1 **2** **3** **4**

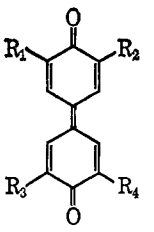
Bromonium bromide **3** is considered to arise *via* hydrobromination[4] of a resonance-stabilized intermediate bromonium ylide, **5**, a product of electrophilic attack of carbene **6** upon bromophenol **2**.[5]



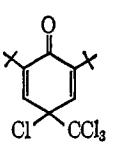
5 **5a** **6**

Regeneration of ylide **5** (or **5a**) through the action of triethylamine on bromonium salt **3** (36.5 mg in ethanolic chloroform) leads to the deeply colored diphenoquinones **7** (3.2 mg), **8** (7.2 mg), and **9** (0.7 mg).[6,7] In this "coupling reaction," the behavior of bromonium ylides **5** and **5a** is reminiscent of the behavior of some sulfonium and ammonium ylides.[8]

Diphenoquinones **7**, **8**, and **9** have been isolated directly from the photoreaction (~7.9 × 10^{-2} M in diazooxide **1** and 0.24 M in bromophenol **2**) in yields of 9, 12, and 2%, respectively.[9,10] The formation of these cross-bred "coupling" products is explained by partial tautomerization (through hydroxyl proton exchange) of initially formed ylide **5** to ylide **5a**. Present simultaneously, bromonium ylides **5** and **5a** may either lead to **7**, **8**, and **9** or be trapped as salt **3** by hydrogen bromide.[4]



7, R_1, R_2, R_3, R_4 = *t*-butyl
8, R_1, R_2 = *t*-butyl; R_3, R_4 = isopropyl
9, R_1, R_2, R_3, R_4 = isopropyl



10

Diphenoquinone formation from diazooxide **1** in isopropyl bromide (4.7 × 10^{-2} M in **1**) or iodobenzene (4.3 × 10^{-2} M in **1**) leads to the formation of **7** isolable in 38 and 55% yields, respectively. However, photolysis of **1** (2.9 × 10^{-2} M) in carbon tetrachloride gives cyclohexadienone **10**, the product of carbon–chlorine insertion, in 91% yield (nmr).[11] Diphenoquinone **7** could not be detected in crude **10** by nmr spectroscopy. Failure of **1** to produce appreciable quantities (<3%) of **7** upon irradiation in carbon tetrachloride indicates that the chloronium ylide is either not formed or does not behave as do the analogous bromonium and iodonium ylides.[12,13] The intermediacy of halonium ylides in certain carbon–halogen insertion reactions of carbenes has been previously suggested,[14,15] but alternative

(2) Owing to the formation of highly colored decomposition products which obscure the end points, the titrimetric methods used for determination of ionic bromide gave imprecise results usually ranging between 12 and 14%. We are grateful to Mr. J. Németh for his patient analyses of the unstable bromonium salt **3**.

(3) These values were determined by glpc analysis using 2,6-di-*t*-butylphenol as an internal standard and using a 5 ft × 0.25 in. column of 20% SE-30 on Chromosorb W at ~160°. Phenols **2** and **4** were identified by comparing retention times with those of authentic samples.

(4) The source of hydrogen bromide is uncertain.

(5) For a review of the formation of diarylbromonium salts upon thermolysis of aryldiazonium salts in bromobenzene, see A. N. Nesmeyanov, *et al.*, *Tetrahedron*, **1**, 145 (1957).

(6) Yields were determined by preparative thin layer chromatography (silica gel; methylene chloride) on aliquots followed by visible (~426 mμ) spectral assay of the eluted diphenoquinones.

(7) Under these reaction conditions 110 mg of a 1:1 mixture of bromophenols **2** and **4** gave negligible amounts (<0.05 mg) of diphenoquinones.

(8) For example, thermolysis of trimethylammoniumfluorenylide and 2-nitrofluorenyldimethylsulfurane gives the corresponding difluorenylidenes. See A. William Johnson, "Ylid Chemistry," Academic Press Inc., New York, N. Y., 1966, pp 258, 320–321, and references cited therein.

(9) The reported yields are for purified products and are lower than the actual yields.

(10) Diphenoquinones **7** and **9** were identified by nmr, infrared, and visible spectral comparisons with authentic samples prepared by iodine oxidation of the corresponding phenols in dimethylformamide solution saturated with potassium carbonate. Both **7** and **9** have been previously reported. See M. J. Zabik and R. D. Scheutz, *J. Org. Chem.*, **32**, 300 (1967), and H. Hart and F. A. Cassis, Jr., *J. Am. Chem. Soc.*, **73**, 3179 (1951). Diphenoquinone **8** (mp 192–194°) was identified by its elemental composition (*Anal.* Calcd for $C_{26}H_{36}O_2$: C, 82.11; H, 9.47. Found: C, 82.23; H, 9.76) and spectra [visible (chloroform), λ_{max} 426 mμ (ε 65,244); infrared (carbon tetrachloride), carbonyl at 1600 cm^{-1} (vs), shoulders at 1633 and 1572 cm^{-1}; nmr (carbon tetrachloride, TMS) *t*-butyl δ 1.38 (s), isopropyl 1.23 (d, J = 6.8 Hz), vinyl 7.65 (s) and 7.77 (s), isopropyl methine 3.24 (m, J = 6.8 Hz)].

(11) The structural assignment of **10** rests on its elemental composition (*Anal.* Calcd for $C_{15}H_{20}Cl_4O$: C, 50.30; H, 5.63; Found: C, 50.43; H, 5.76) and spectral properties [nmr (carbon tetrachloride, TMS), crude product, *t*-butyl δ 1.27 (s), vinyl 6.82 (s); infrared (chloroform), carbonyl doublet at 1643 and 1664 cm^{-1}; mass spectrometrically determined molecular weight, 358; four chlorine atoms present].

(12) Neiland and coworkers have reported the isolation of a series of iodoniumbetaines by the reaction of iodosobenzene and its derivatives with a variety of β-dicarbonyl compounds in alkaline media. See O. Neiland and G. Vanag, *Proc. Acad. Sci. USSR*, **129**, 983 (1959); **131**, 425 (1960); **141**, 1232 (1961); O. Neiland and B. Karele, *J. Org. Chem. USSR*, **2**, 491 (1966). When the reaction was extended to phenol or resorcinol, the corresponding iodonium ylides were not isolated, and only unidentified decomposition products were reported. We have observed that addition of iodosobenzene to 2,6-di-*t*-butylphenol affords diphenoquinone **7** (~24%), possibly *via* the intermediacy of the iodonium ylide.

(13) Prior reports concerning the synthesis and acidity of hydroxydiphenyliodonium salts make no mention of ylide-like behavior of these compounds in the presence of base. See A. R. Fox and K. H. Pausacker, *J. Chem. Soc.*, 295 (1957), and F. M. Beringer and I. Lillian, *J. Am. Chem. Soc.*, **82**, 5141 (1960).

(14) J. Hine, "Divalent Carbon," The Ronald Press Co., New York, N. Y., 1964, p 139.

(15) C. D. Gutsche and M. Hillman, *J. Am. Chem. Soc.*, **76**, 2236 (1954).

mechanisms were, at that time, considered equally satisfying.

We consider the isolation of bromonium salt **3** clear evidence that carbene **6** attacks bromophenol **2** to afford the reactive bromonium ylide **5**, which subsequently affords diphenoquinones **7**, **8**, and **9**. The formation of **7**–**9** upon regeneration of ylide **5** (or **5a**) by treatment of salt **3** with triethylamine is corroborative evidence for this view. Clearly, salt **3** is a convenient source of bromonium ylides **5** and **5a** and offers an unambiguous approach to the study of these remarkable intermediates. Halonium ylides may prove to be of unusual synthetic utility;[16] accordingly, this area is being further investigated.

Acknowledgment. This research was supported by grants in aid from Du Pont and Rohm and Haas and stimulated by discussions with Professor J. C. Martin.

(16) For example, protonation of the bromonium ylide presumed to arise upon photolysis of **1** in isopropyl bromide might lead to an isolable alkylarylbromonium salt, a type of compound not yet synthesized. See J. B. Dence and J. D. Roberts, *J. Org. Chem.*, **33**, 1251 (1968).

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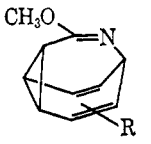
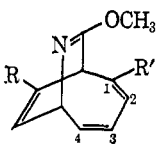
Pyrolysis of Azabullvalenes and 7-Azabicyclo[4.2.2]deca-2,4,7,9-tetraenes[1,2]

Sir:

Recently the first member of the azabullvalene class of fluxional heterocycles (**1a**) was described.[3,4] The four-step synthesis began with the 1,4 addition of chlorosulfonyl isocyanate to cyclooctatetraene followed by hydrolysis of this (N-chlorosulfonyl)lactam, conversion of the resulting lactam to imino ether **2a**, and irradiation of **2a**. In the present communication we describe the thermal behavior **1a** and **2a** and several of their monomethyl analogs.



1a, R = H
b, R = CH_3



2a, R = R′ = H
b, R = CH_3; R′ = H
c, R = H; R′ = CH_3

This study was prompted by reports that heating bicyclo[4.2.2]deca-2,4,7,9-tetraene (**3**) (245°, 4 hr) gave rise to *cis*-9,10-dihydronaphthalene (**4**) (20%) and naphthalene (80%)[5] and that partial decomposition of bullvalene (**6**) (350°, flow system) afforded **4** as the only product.[6] Although Doering and Rosenthal implicated novel mechanistic pathways in these thermal interconversions, they were not able to define the precise mechanism(s) in the absence of more definitive evidence.

In the cases of **1a** and **2a**, the nitrogen- and methoxyl-bearing carbon atoms can serve as internal probes of the various reorganization processes; the behavior of these imino ethers at elevated temperatures then becomes of particular interest because the nature of the pyrolysis products could effectively limit the number of mechanistic possibilities. The additional methyl substituent of **1b**, **2b**, and **2c** can be expected to reduce further the number of alternatives. We propose to demonstrate herein that this goal has been attained.

Methoxyazabullvalene (**1a**) proved to be remarkably stable; below 500°, this substance could be sublimed into a glass-bead packed quartz tube (28 cm × 16 mm) at 20 mm and be recovered quantitatively. When this procedure was repeated at 550°, or better, at 600° (almost total conversions), **1a** was cleanly converted in high yield to a mixture of 12 products. Interestingly, **2a** afforded the identical product mixture under these conditions. Preparative-scale gas chromatography (8 ft × 0.25 in. stainless steel column packed with 20% Apiezon L-KOH (4:1) on 60–80 mesh Chromosorb W) permitted the isolation and complete characterization of quinoline (75%; picrate mp 203°), 2-methoxyquinoline (10.3%; picrate mp 183–184.5°), 1-methoxyisoquinoline (6.6%; picrate mp 160–162°),[7] and 3-methoxyisoquinoline (~1%; picrate mp 197–198°). 3-Methoxyisoquinoline was prepared independently from 3-hydroxyisoquinoline[8] and diazomethane in a DMF–*t*-BuOH–ether–$CHCl_3$ solvent system. The remaining eight products (combined yield, 7%) were not characterized because of limited quantities; however, it was established by independent synthesis that 5-methoxyquinoline[9] and 6-methoxyisoquinoline[10] had not been produced in detectable quantities. The various methoxy-substituted quinolines and isoquinolines are stable to the conditions of pyrolysis, thereby indicating that quinoline is not an artifact of these thermal reorganizations.

Investigation of the pyrolytic behavior of **1b**, **2b**, and **2c** has provided still more interesting results. At ~600°, decomposition of **2b** and **2c** leads to the formation (~95% yield) of all possible monomethylquinolines *except 2-methylquinoline* (Table I). Furthermore, the yields of the individual nitrogen aromatics are quite similar in the two cases. Each product was identified by comparison of infrared curves, nmr spectra, and vpc retention times with those of authentic samples; in addition, each quinoline was resubmitted to the pyrolysis procedure and was recovered unaltered.

Pyrolysis of **1b** affords again a mixture of methylquinolines (~95% yield), but, in contrast, *2-methylquinoline* (picrate mp 194–195°) *is now the major product* (Table I).

Mechanistic considerations denote clearly that several modes of thermal isomerization are available to **1** and **2**, the most precedented of which[5,6,11,12] include: (a)

(1) Unsaturated Heterocyclic Systems. XLII. For the previous paper in this series, see L. A. Paquette and M. Rosen, *J. Org. Chem.*, in press.

(2) The authors wish to express their gratitude to the National Institutes of Health and the Alfred P. Sloan Foundation for their generous financial support of this work.

(3) L. A. Paquette and T. J. Barton, *J. Am. Chem. Soc.*, **89**, 5480 (1967).

(4) L. A. Paquette, T. J. Barton, and E. B. Whipple, *ibid.*, **89**, 5481 (1967).

(5) W. von E. Doering and J. W. Rosenthal, *Tetrahedron Letters*, 349 (1967).

(6) W. von E. Doering and J. W. Rosenthal, *J. Am. Chem. Soc.*, **88**, 2078 (1966).

(7) R. A. Robinson, *ibid.*, **69**, 1939 (1947); M. M. Robison and B. L. Robison, *ibid.*, **80**, 3443 (1958).

(8) J. H. Boyer and L. T. Wolford, *J. Org. Chem.*, **21**, 1297 (1956).

(9) L. Bradford, T. J. Elliott, and F. M. Rowe, *J. Chem. Soc.*, 437 (1947).

(10) R. A. Robinson, *J. Am. Chem. Soc.*, **69**, 1934, 1939 (1947).

(11) M. Jones, Jr., and L. T. Scott, *ibid.*, **89**, 150 (1967).

(12) G. Schröder, *Chem. Ber.*, **97**, 3140 (1964).