involved in dimethylbenzene ring formation in B_{12} biosynthesis.

Biochemical analogies would predict that the remaining carbon atom of DBI (C-2) is derived from a biological C-1 unit. If formation of the imidazole ring of DBI were analogous to the biosynthesis of histidine[17] or the purines,[18] the C-2 carbon atom would be derived from formate.

Table I illustrates that precursors of labeled C-1 units were found to be poor precursors of DBI, and that no preferential incorporation into the C-2 carbon from precursors of labeled C-1 units occurs. In *P. pentosaceum* erythritol is metabolized to formaldehyde and dihydroxyacetone phosphate.[19] The incorporation of erythritol-U-^{14}C was investigated in *P. shermanii* to determine if labeled formaldehyde produced by this route could serve as a C-1 unit for DBI biosynthesis. The data indicate that erythritol-U-^{14}C shows a marked specificity for incorporation into the dimethylbenzene portion of B_{12} and does not lead to significant labeling of the C-2 carbon of DBI. Since all tested precursors of labeled C-1 units result in approximately random C-2 labeling (11%), we conclude that the C-2 carbon of DBI is not derived from a biological C-1 unit.

The incorporation of ribose-1-^{14}C into DBI was significantly greater than that of any other precursor investigated, and since 40% of the label incorporated from ribose-1-^{14}C is localized in the C-2 position, we propose that ribose-1-^{14}C is a specific precursor of this carbon.[20]

Plaut and Broberg[21] observed that incorporation patterns of labeled glucose into the ribityl chain of riboflavin indicated incorporation of ribose formed by oxidative and nonoxidative pentose cycle reactions. Our observations of differential labeling of the C-2 atom of DBI by glucose-1-^{14}C and glucose-6-^{14}C, and the preferential incorporation of ribose-1-^{14}C into this position, are therefore analogous to observations concerning the labeling of the C-1′ carbon of the ribityl chain of riboflavin.

These observations regarding DBI biosynthesis and previous observations regarding riboflavin biosynthesis[16,21] serve to emphasize that the 1,2-diamino-4,5-dimethylbenzene unit is confined in biological systems to riboflavin and DBI, and that the 1-amino-4,5-dimethyl-2-ribitylaminobenzene unit in riboflavin may also be present in the biosynthetic precursor of DBI. We propose that these similarities cannot be ascribed to coincidence and that the biosyntheses of riboflavin and DBI are connected, as originally suggested by Woolley.[22] Experiments designed to test this proposal are in progress.

(17) C. Mitoma and E. E. Snell, *Proc. Nat. Acad. Sci. U. S.*, **41**, 891 (1955).
(18) J. M. Buchanan, J. C. Sonne, and A. M. Delluva, *J. Biol. Chem.*, **173**, 69 (1948).
(19) E. J. Wawszkiewicz and H. A. Barker, *ibid.*, **243**, 1948 (1968).
(20) Table I indicates that acetate-2-^{14}C also leads to specific labeling of C-2. In view of the extremely low incorporation of acetate and the resulting experimental uncertainty in the determinations, we feel no significance should be attached to this observation.
(21) G. W. E. Plaut and P. L. Broberg, *J. Biol. Chem.*, **219** 131 (1956).
(22) D. W. Woolley, *J. Exp. Med.*, **93**, 13 (1951).
(23) NSF–URP 1968 summer participant at Tulane University.

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Methoxymethyl Methanesulfonate. A Novel Active Oxyalkylating Agent

Sir:

Further research into the chemistry of mixed sulfonic–carboxylic anhydrides[1] has led us to investigate the reactions of such reagents with acetals and ketals. We wish, at this stage, to record the preparation and some of the properties of methoxymethyl methanesulfonate (**2**), the simplest member of a series of compounds of potential use as powerful oxyalkylating agents.

Equimolar admixture at 0° of acetyl methanesulfonate (**1**) and dimethoxymethane under anhydrous conditions led to rapid formation, in essentially quantitative yield, of the title compound **2**, plus methyl acetate. Room temperature evaporation left the sulfonate **2** which was distilled as a colorless oil, bp 73–75° (10^{-2} mm), characterized by microanalysis and by its nmr spectrum: three singlets at δ 3.10 (3 H, OSO_2CH_3), 3.60 (3 H, OCH_3), and 5.38 (2 H, OCH_2O).

$$\underset{\mathbf{1}}{CH_3COOSO_2CH_3} + CH_3OCH_2OCH_3 \longrightarrow \underset{\mathbf{2}}{CH_3OCH_2OSO_2CH_3} + CH_3COOCH_3$$

The sulfonate **2**, which was rapidly hydrolyzed in moist air, was stable at room temperature and, in the absence of acid, up to 150°, when rapid decomposition ensued, resulting in the formation of methyl methanesulfonate (**3**) and polymeric material derived from

$$\underset{\mathbf{2}}{CH_3OCH_2OSO_2CH_3} \xrightarrow{150^\circ} \underset{\mathbf{3}}{CH_3OSO_2CH_3} + [CH_2O]_n$$

formaldehyde. The efficacy of sulfonate as a leaving group led us to anticipate that the product **2** would have a greatly enhanced activity over the corresponding α-haloalkyl ethers[2] in introducing at nucleophilic sites the methoxymethyl group. An analogous consideration has been found to hold for mixed sulfonic–carboxylic anhydrides which are powerfully enhanced as acylating agents by the lability of the sulfonate group.[1]

Our work, summarized in Table I, has shown such anticipation to be justified. With primary and secondary alcohols reaction proceeded swiftly and cleanly, the only volatile product being the mixed acetal isolated in high yield by distillation. Tertiary amines gave the respective quaternary methanesulfonate salts in quantitative yield.[3]

(1) M. H. Karger, and Y. Mazur, *J. Amer. Chem. Soc.*, **90**, 3878 (1968).
(2) L. Summers, *Chem. Rev.*, **55**, 301 (1955).
(3) C–N bond formation was shown to be reversible in the following manner: when N-methoxymethyl-N,N-dimethylbenzylamine methanesulfonate was refluxed for 16 hr in mesitylene a 70% yield of bis(2,4,6-trimethylphenyl)methane resulted. Alternate C–N bond cleavage to give phenyl(2,4,6-trimethylphenyl)methane by reaction of benzyl carbonium ion with mesitylene was not observed.

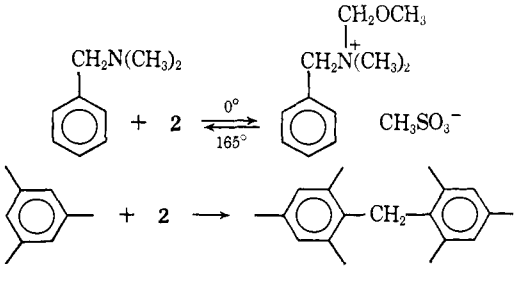
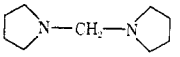
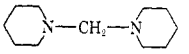
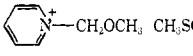
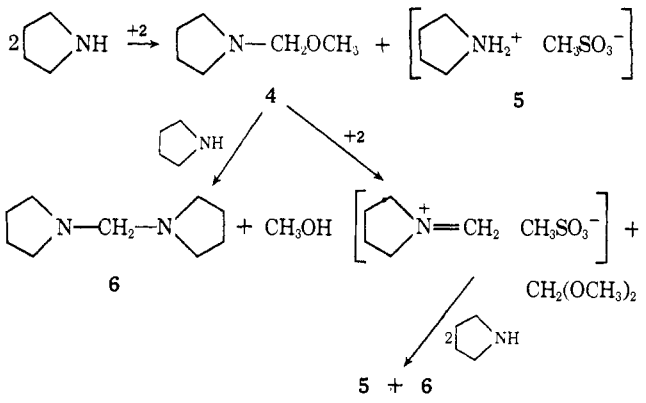


Table I. Reactions of Methoxymethyl Methanesulfonate

Run	Substrate	Reaction conditions	Product	Yield, %
1	C_2H_5OH	25°, 5 min	$C_2H_5OCH_2OCH_3$	86
2	$(CH_3)_2CHOH$	25°, 5 min	$(CH_3)_2CHOCH_2OCH_3$	83
3		0°, 5 min, in ether		73
4		0°, 5 min, in ether		61
5	$C_6H_5N(CH_3)_2$	0°, 5 min, in ether	$C_6H_5\overset{+}{N}(CH_3)_2(CH_2OCH_3)\ CH_3SO_3^-$	97
6		0°, 5 min, in ether		99
7	$C_6H_5CH_2N(CH_3)_2$	0°, 5 min, in ether	$C_6H_5CH_2\overset{+}{N}(CH_3)_2(CH_2OCH_3)\ CH_3SO_3^-$	96
8		0°, 30 min, in CH_3CN	$CH_3OCH_2OCH_2CH_2OSO_2CH_3$	41
9		80°, 16 hr	$CH_3OCH_2O(CH_2)_4OSO_2CH_3$	32
10	C_6H_6	25°, 3 hr	$(C_6H_5)_2CH_2$[a]	94[b] (21)
11	$C_6H_5CH_3$	25°, 5 min	$(C_6H_4CH_3)_2CH_2$[a]	80[c] (86)
12	C_6H_5Cl	120°, 2 hr	$(C_6H_4Cl)_2CH_2$[a]	54[d] (11)
13	$C_6H_5OCH_3$	0°, 20 min	$(C_6H_4OCH_3)_2CH_2$[a]	81[d]
14	$C_6H_5OC_2H_5$	0°, 20 min	$(C_6H_4OC_2H_5)_2CH_2$[a]	78[d]
15	$C_6H_5CH_2OC_2H_5$	25°, 24 hr	$(C_6H_5)_2CH_2$[a]	76[d]

[a] Mixture of diarylmethane and higher telomers. The yield figure represents the total yield, the figure in parentheses the yield of diarylmethane as a percentage of the total yield after separation by distillation. [b] Yield based on benzene in a reaction in which the product is formed by the reaction of 2 mol of benzene with 2 mol of the sulfonate **2**. [c] Yield based on sulfonate **2** in a reaction in which the product is formed by the reaction of 2 mol of toluene with 1 mol of the sulfonate **2**. [d] Yield based on substrate, the sulfonate **2** being in excess.

With primary and secondary amines reaction was more complex, leading ultimately to the respective aminal and the amine sulfonate salt. In addition both methanol and dimethoxymethane were identified as the volatile by-products of the reaction, testifying to the duality of the mechanism shown. In confirmation



N-methoxymethylpyrrolidine (**4**) was synthesized and shown to undergo both reactions under identical mild conditions.

An interesting application of the reagent **2** lies in its behavior toward benzene derivatives. Thus, admixture of benzene itself with the reagent **2** at room temperature led to a separation, complete after 3 hr, into two layers. The lower of these was the quantitative amount of methanesulfonic acid, the upper a benzene solution of diphenylmethane. Alkylated benzenes, halobenzenes, anisole, and other substituted benzenes follow a similar course (Table I), the reaction of toluene, for example, proceeding instantly and exothermally at room temperature to give an isomeric mixture of ditolylmethanes.[4]

This high reactivity is in contrast with that of chloromethyl ethers which proceed markedly slower even in acid solution. Thus, the reactivity of the title compound **2** toward benzene is faster by at least a factor of 10^4 than that of chloromethyl methyl ether in acetic acid,[5] and by a similar factor than that of acetoxymethyl methyl ether.[6]

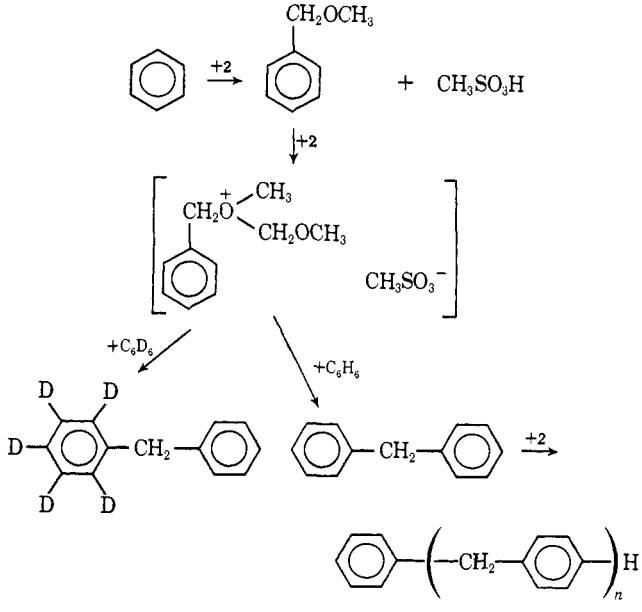
The formation of diphenylmethanes is explained by Scheme I. A number of observations testifying to the validity of this reaction sequence were made: (a) dimethoxymethane could be isolated from the reaction mixture in quantitative yield implying the consumption of 2 mol of the sulfonate **2** in the over-all reaction; (b) treatment of alkyl benzyl ethers with molar equivalents of the sulfonate **2** and methanesulfonic acid gave diphenylmethane at the original rate and yield; and (c) in the presence of perdeuterated benzene this latter reaction gave diphenylmethane with only one ring deuterated.[7] With activated benzenes a different mechanism predominated.

(4) In addition to diphenylmethanes these reactions gave rise to variable proportions of higher molecular weight telomers of formula $Ar(CH_2Ar)_nH$ in which $n = 2, 3, 4$, etc. The use of this reaction for the selective production of telomeric polybenzyls is currently under study. Thus, in a typical reaction benzene and the sulfonate **2** gave an oil containing diphenylmethane and polybenzyls in a yield of 94% based on 2 mol of the sulfonate **2** per 2 mol of benzene. Of this mixture 20% consisted of diphenylmethane, 20% of a mixture of the next two higher telomers ($n = 2$ and 3 above), and the remaining 60% of average mol wt 608 (corresponding to an average structure of $n = 6$ above). This was separable into fractions of crystalline material of increasing average molecular weight by column chromatography.

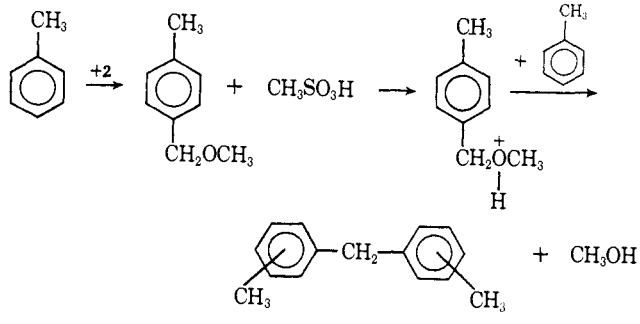
(5) G. Vavon, J. Boole, and J. Calin, *Bull. Soc. Chim. Fr.*, [5] 6, 1025 (1939). These workers showed that the reaction between benzene and chloromethyl methyl ether in acetic acid requires 600 hr at 65° for 30% conversion in contrast with the maximal 3 hr at 25° for 100% reaction required for methoxymethyl methanesulfonate in pure benzene.

(6) L. Summers, *J. Amer. Chem. Soc.*, 76, 3481 (1954). The least activated benzene derivative capable of reaction with acetoxymethyl ether appears to be that of mesitylene, which goes to completion in 2 hr at 65°. Reaction of **2** with mesitylene at 0° is violently exothermic being complete on contact.

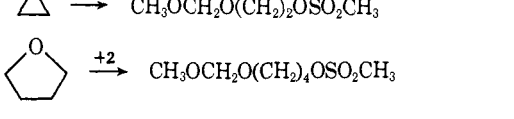
Scheme I



Thus toluene reacted with the sulfonate **2** to give a mixture of polytolylmethanes in 80% yield together with methanol. Distillation of the mixture gave ditolylmethanes as the major (86%) products.



We have also demonstrated the ability of the sulfonate **2** to cleave a number of ethers. As well as the benzyl ethers, whose cleavage is described above, cyclic ethers are also cleaved. Thus, ethylene oxide reacts at 0° to give the methoxymethyl glycol methanesulfonate, in 41% yield, while overnight reflux of the sulfonate **2** in tetrahydrofuran gives a 30% yield of the analogous methoxymethylbutanediol methanesulfonate. Studies of this type of ether cleavage continue.



By these reactions we have demonstrated a wide range of utility for methoxymethyl methanesulfonate. This, coupled with its high reactivity, make it a potentially useful synthetic reagent whose utility is currently under further study.

(7) A similar explanation can now be advanced for the observation that reaction between benzene derivatives and chloromethyl ether gives predominantly benzyl chloride rather than the expected benzyl ether.[2] With the sulfonate **2** and benzene, diphenylmethane is the observed product, since benzyl methanesulfonate, the anticipated product, is known to spontaneously dissociate to yield methanesulfonic acid and products derived from the benzyl carbonum ion; see J. K. Kochi and G. S. Hammond, *J. Amer. Chem. Soc.*, **75**, 3443 (1953). In the chloromethyl ether–benzene reaction, however, the analogous intermediate, benzyl chloride, is stable and is the product isolated.

(8) Weizmann Fellow, 1967–1969.

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Received May 13, 1969

Electrocyclic Additions to Pentacyclo[4.4.0.0^{2,5}.0^{3,8}.0^{4,7}]deca-9-ene[1]

Sir:

We have found that the strained hydrocarbon pentacyclo[4.4.0.0^{2,5}.0^{3,8}.0^{4,7}]deca-9-ene (**1**)[2] undergoes thermal addition of maleic anhydride and tetracyanoethylene in manner similar to tetracyclo[3.2.0.0^{2,7}.0^{4,6}]-heptane.[3] Thus, maleic anhydride adds to **1** (in CCl_4 at 65° for 2 days) forming the 1:1 adduct **2** [65% yield; mp 152–155° (in preheated bath), solidifies and remelts at 220–222°; ν^{KBr} 1840, 1775 (anhydride), 1538 cm^{-1} (olefin); τ ($DCCl_3$) 4.0 (q, 2 H), 4.39 (t, 2 H), 6.7 (m, 4 H), 7.0 (t, 2 H), 7.4 (m, 2 H)] and the 2:1 adduct **3** [32% yield; mp >300°; ν^{KBr} 1840, 1787 cm^{-1} (anhydride)]. **3** can also be prepared in 83% yield from **1** by heating with excess maleic anhydride in chlorobenzene at 100° for 26 hr. Heating **2** (at 95° for 15 hr) opens the cyclobutene ring and affords the triene **4** [92% yield; mp 220–222°; ν^{KBr} 1850, 1775 (anhydride), 1600 cm^{-1} (olefin); τ ($DCCl_3$) 3.6 (m, 2 H), 4.6 (m, 4 H), 6.75 (m, 4 H), 7.05 (m, 2 H)]. Heating **4** with maleic anhydride yields **3** in 81% yield.

The *exo,exo* conformation of the anhydride groups in **3** is supported by the following: first, conversion of **3** (with methanol and H_2SO_4) to a tetramethyl ester, **5** [90% yield; mp 227–228°; τ ($DCCl_3$) 4.22 (q, 4 H), 6.49 (m, 12 H), 7.30 (m, 4 H), 7.2 (m, 4 H), 7.98 (s, 2 H)]; the nmr spectrum of **5** indicates that two planes of symmetry are present; thus, the carboxyl functions are either all *exo* or all *endo;* second, bromination of **5** affords a saturated bromo five-membered-ring lactone, **6** or **7** [mp 244–245°; ν^{KBr} 1760 (lactone), 1732, 1724 (ester C=O) cm^{-1}; τ ($DCCl_3$) 5.32 (>CHBr), 5.65 (>CHO–), 6.25, 6.30, and 6.32 (–CO_2CH_3)]. Thus, only the all-*exo* conformations of the carboxyl functions will allow for lactone formation.

The close proximity of the olefinic bonds in **2**, **4**, and **5** is shown by the facile photoinduced ring closure affording the three new hexacyclics **8** [85% yield from **2**; mp 212–213°; ν^{KBr} 1845, 1780 cm^{-1} (anhydride); τ ($DCCl_3$) 6.8 (m, 6 H), 7.1 (m, 4 H), 7.6 (m, 2 H)], **9** [63% yield from **4**; mp 174–175°; τ ($DCCl_3$) 3.49 (t, 1 H), 3.93 (t, 1 H), 6.82 (m, 4 H), 7.44 (m, 5 H), 8.08 (m, 1 H)], and **10** [80% yield from **5**; mp 181–182°; τ ($DCCl_3$) 6.42 (s, 12 H, methyl ester), 6.81 (m, 4 H), 7.28 (m, 4 H), 7.80 (m, 2 H), 8.14 (m, 4 H)]. Bis decarboxylation (lead tetraacetate in pyridine) of the diacid **11** [97% from **8**; mp 212–213°; ν^{KBr} 1720 cm^{-1} (carboxylic acid)] affords the hexacyclic olefin **12** [48% yield; mp 122–124°; ν^{KBr} 1610, 680 cm^{-1} (*cis*-disubstituted al-

(1) E. LeGoff, S. Oka, and W. G. Deadman, 158th National Meeting of the American Chemical Society, New York, N. Y., Sept 1969, Abstract ORGN 57.

(2) S. Masamune, H. Cuts, and M. G. Hogben, *Tetrahedron Lett.*, 1017 (1966); W. G. Dauben and D. L. Whalen, *ibid.*, 3743 (1966); R. Furstoss and J.-M. Lehn, *Bull. Soc. Chim. Fr.*, 2497 (1966).

(3) C. D. Smith, *J. Amer. Chem. Soc.*, **88**, 4273 (1966).