Table I. γ-Radiolysis and Radioracemization of Crystalline Isovaline and Leucine

amino acid	dose, rads × 10^{-8}	decompn, %	racemizn, %
D-Ival	9.0	79.6	4.9
L-Ival	9.0	78.0	4.7
D-Leu	8.1	67.9	5.6
L-Leu	8.1	68.0	5.0

Crystalline samples of D- and L-isovaline (shown to be optically pure by gas chromatographic (GC) analyses of their diastereomeric *N*-TFA-isovalylleucine isopropyl ester derivatives[8] (I)) were irradiated in a 3000-Ci ^{60}Co γ-ray source with radiation doses selected to cause significant but not complete radiolysis. Each irradiated sample was quantitatively divided and the separate portions were converted to the appropriate I derivative and examined by GC for racemization and degradation (using the "enantiomeric marker" technique[9]). All GC analyses were performed in replicate with the previously obtained precision[10] using 50-m capillary columns coated with enantiomeric phases[11] consisting of *N*-docosanoyl-D- (or L-) valine *tert*-butylamide. GC conditions were such that the GC peaks of the unidentified radiolysis products in no way interfered with the peaks of the residual isovaline during the GC analyses. A comparison of the radiolysis and radioracemization of isovaline with those previously found[5,6] for leucine is shown in Table I.

Table I shows that the percent radioracemization (i.e., 2 × percent of opposite antipode produced) accompanying the γ-radiolysis of D- and L-isovaline is roughly comparable with that noted[5,6] for the common aliphatic α-amino acids D- and L-leucine. While the enantiomeric composition of the isovaline in the Murchison meteorite was found[2] to be *approximately* 50:50 D:L, the presently observed radioracemization of isovaline suggests the desirability of reevaluating the earlier conclusion[2,3] that the primordial enantiomeric composition of isovaline and the other amino acids in the Murchison meteorite must therefore have been racemic. While the "cosmic ray exposure age" of the Murchison chondrite (i.e., the time since its parent body fragmented) is only 1.2×10^6 years,[12] resulting in a cosmic ray radiation dose of $\sim 0.3 \times 10^8$ rads during this period (based on 10^8 rads during 3.5×10^6 years for the Orgueil meteorite[13,14]), natural radioactivity in the parent body has provided an integrated dose of some 5×10^8 rads during the 4.5×10^9 years of its existence.[14,15] Thus the isovaline in the Murchison has received a total dose of $\sim 5.3 \times 10^8$ rads, some 60% of the radiation dose in Table I which caused 4.8% racemization of crystalline isovaline. While it is not known how such radioracemization might be altered by the mineral matrix of the metorite, it is clear that significant racemization of any nonracemic amino acids indigenous to meteorite parent bodies might be expected during the 4.5×10^9 years since their primeval origin. While the above data carry no implications whatsoever that the racemic amino acids in meteorites were originally optically active, the phenomenon or radioracemization nevertheless, in principle, makes the question of the primordial enantiomeric composition of amino acids in meteorites an indeterminate one.

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Raman Scattering from Glucagon–Dimyristoyllecithin[1] Complexes. A Model System for Serum Lipoproteins

Sir:

Raman spectroscopic studies of intact biological membranes are difficult since the fluorescent emission from trace components obscures the weaker Raman signal from the lipid and protein moities. The technique is well suited for studies of lipid–protein interaction in reconstituted systems since conformational changes in both components can be monitored and fluorescent entities can be excluded. The polypeptide hormone glucagon interacts with dimyristoyllecithin (DMPC) when the latter is in its gel state (below 23 °C) to produce a soluble complex which has features similar to those found in serum lipoproteins.[2] We have found that the glucagon–DMPC complex can be concentrated sufficiently in solution to yield high quality Raman spectra. Detailed information as to the effect of protein on lipid conformation has thereby been obtained. The spectra arise from the DMPC component in the complex since that component is present in large molar excess (30:1).

Complexes were formed as described by Epand et al.[2a] and prepared for Raman spectroscopy by (i) removal of the ammonium acetate buffer by dialysis and (ii) concentration by partial lyophilization to a concentration of 50 mg/mL. Typical Raman spectra are shown in Figure 1 for two spectral regions (2700–3100 and 900–1200 cm^{-1}) of the complex and two control systems: DMPC in multibilayer form and DMPC in small unilamellar vesicles. The C–C stretching region (1050–1150 cm^{-1}) is sensitive to trans–gauche isomerization in the DMPC hydrocarbon chains. The intensity ratio $I(1130/1100)$ has been correlated with the number of CH_2 groups in the all-trans conformation.[3] The temperature dependence of $I(1130/1100)$ is shown in Figure 2 for the three systems studied. A sigmoid-shaped variation is observed for DMPC in both sonicated and multibilayer form, with the sharp discontinuity at 23 °C reflecting the gel–liquid crystal phase transition.[4,5] The change in $I(1130/1100)$ during melting indicates the cooperative loss of four–five trans bonds in the DMPC hydrocarbon chains (as calculated by the method of Gaber and Peticolas[3]). Also evident is the noncooperative formation of two–three gauche rotamers prior to the main chain melt. The DMPC–glucagon complex exhibits significant differences from the control systems in the 7–20 °C range. At 7 °C, $I(1130/1100)$ is reduced by 25–30% from the control systems, indicating an additional two–three gauche rotations

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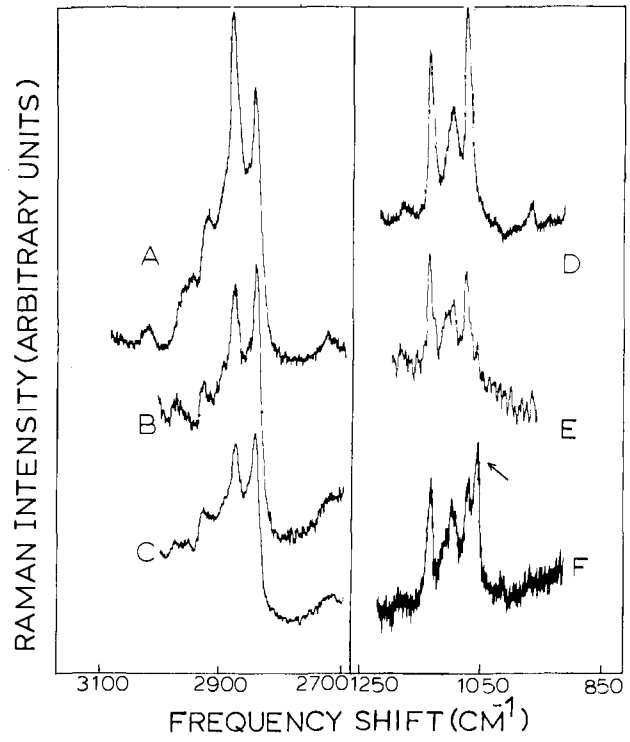

Figure 1. Typical Raman spectra of the C-H (A, B, C) and C-C (D, E, F) stretching regions under the following conditions: (A, D) DMPC multilayers, 7.5 °C; (B, E) DMPC sonicated dispersions, 7.5 °C; (C, F) DMPC-glucagon complex (30:1 phospholipid to protein ratio), 7.5 °C. The arrow in F indicates a feature that arises from stray light in the instrument and is not due to a Raman band. Typical spectral conditions: 5145-Å laser excitation; 300-mW power; 6-cm^{-1} resolution. In order to estimate $I(1130/1100)$, base lines were drawn connecting minima in the spectra near 1000 and 1150 cm^{-1}.

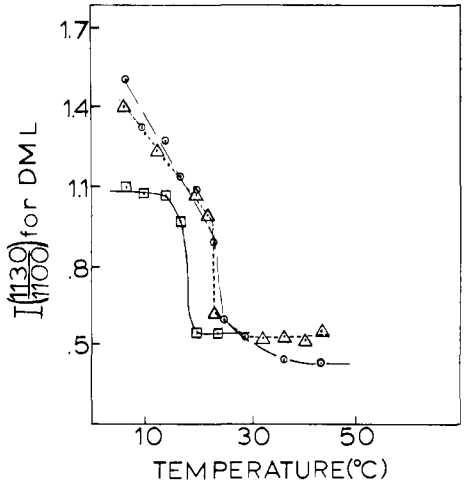

Figure 2. Temperature-induced variation in the $I(1130/1100)$ intensity ratio for DMPC in multilayers (- -△- -), sonicated dispersions (— —○— —), and complexed with glucagon (—□—). Precision of duplicate measurements is 4-6%.

in the chains. The relatively slight variation in $I(1130/1100)$ below 20 °C in the complex suggests that noncooperative formation of gauche rotamers is inhibited in comparison with the control systems. This indicates that, while the phospholipid chains in the complex exist in conformations containing gauche rotations, they are relatively immobile. Above the DMPC melting temperature, extensive precipitation of complex is noted, and the average lipid conformation is similar to that of the controls.

The second parameter used to characterize phospholipid structure is the intensity ratio of the antisymmetric to the

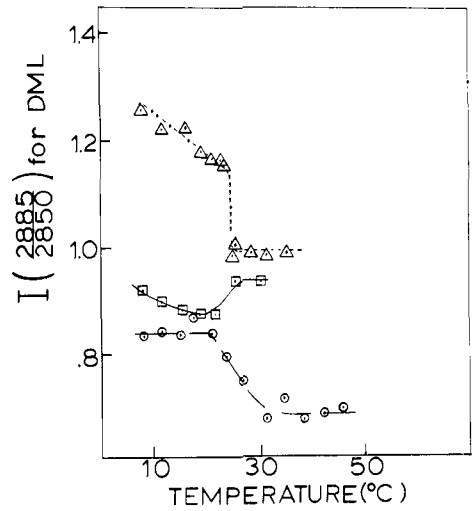

Figure 3. Temperature-induced variation in the $I(2885/2850)$ ratio for DMPC in multilayers (- -△- -), sonicated dispersions (— —○— —), and complexed with glucagon (—□—). Precision of duplicate measurements is 2-4%.

symmetric C-H stretching vibrations at 2885 and 2850 cm^{-1}, respectively. This ratio responds both to alterations in the lateral packing of the hydrogen chains and to the formation of gauche rotations. The sensitivity to lateral packing arises since part of the 2885-cm^{-1} intensity arises from vibrational interaction (e.g., Fermi resonance) between C-H units on adjacent hydrocarbon chains.[3,6] When lateral packing between chains is disrupted, the 2885-cm^{-1} intensity is reduced. The temperature dependence of $I(2885/2850)$ is shown in Figure 3. DMPC multilayers exhibit the highest values of the intensity parameter, reflecting high order in the hydrocarbon chains. A sharp discontinuity is observed at T_m indicating loss of that fraction of the $I(2885/2850)$ intensity derived primarily from gauche rotamer formation. The formation of single-walled DMPC vesicles disrupts lateral packing of the chains as monitored by reduction of the intensity parameter compared with the multilayers at all temperatures. The imperfect chain packing causing the reduction results from the small radius of curvature in vesicle systems.[7] The gel-liquid crystal phase transition is observed in the C-H spectral region over a broadened temperature range (20-30 °C).

As seen in Figure 3, the lateral interactions between DMPC chains in the complex (7-20 °C) have been disrupted and the $I(2885/2850)$ ratio approaches that of sonicated vesicles. At temperatures where the complex precipitates, the lateral interactions are restored (perhaps owing to multilayer formation in the precipitate) and the C-H intensity parameter reaches a value close to that for the multilayer system.

The Raman results impose the following constraints on models for glucagon-DMPC interaction. (1) The loss of interchain lateral interaction indicates that the phospholipid in the complex is not in any extensive array requiring well-packed hydrocarbon chains. (2) A strong interaction occurs between the phospholipid hydrocarbon chains and (presumably) the hydrophobic regions of glucagon. The interaction results in the formation of two-three additional gauche rotamers per phospholipid chain in the complex. The DMPC is somewhat immobilized by the protein, inhibiting the noncooperative formation of gauche rotamers seen over the same temperature range in DMPC vesicles and/or multilayers.

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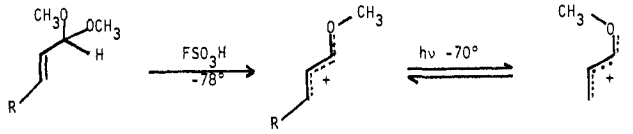
Photochemical and Thermal Isomerizations of 1-Methoxyallyl Cations. A Further Photoisomerization Pathway of Protonated Enones

Sir:

There have been several investigations into the photoisomerizations of protonated unsaturated carbonyl compounds in strong acid solutions and a variety of molecular rearrangements of these systems have been described.[1,2] We report here that a further, fundamental type of reaction can occur, namely photoisomerism about the carbon–oxygen partial double bond.

Such reactions have previously remained undetected, presumably as a result of competing exchange reactions between the proton on oxygen and the acid solvent pool.[3,4] To avoid this complication, we chose to work with the corresponding *O*-methyl derivatives of some of these cations and describe here the preparation, photoisomerism and thermal rearrangements of some 1-methoxyallyl cations.

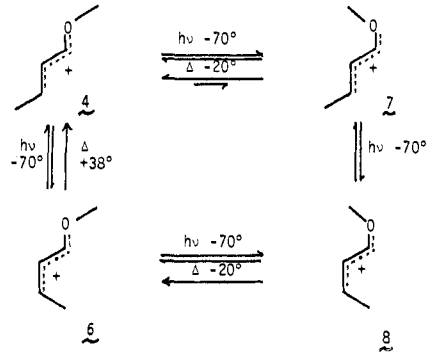
Extraction of the acetals **1** and **2** from Freon 11 into FSO_3H at −78 °C gave solutions of the cations **3** and **4**, respectively.



1, R=H
2, R=CH_3
3, R=H λ_{max} 234 nm, log ε 3.97
4, R=CH_3 λ_{max} 256 nm, log ε 4.28
5

The overall identity of the cations was clearly shown by their ^1H NMR spectra, (Table I) which are similar to those of protonated acrolein[5] and protonated (2*E*)-crotonaldehyde.[2] In each case, one of the two possible C–O bond stereoisomers predominates to a very large extent and, on the basis of the known steric preferences of protonated enals,[4] these have been assigned the C_1O, *E* configuration.

Scheme I



Irradiation of a FSO_3H solution of **3** at −70 °C, using light of 254-nm wavelength, caused it to partially isomerize to a new cation. While this new cation could not be isolated, it was clear from ^1H NMR spectra of the mixture that it had the structure indicated by **5** (Table I).[6] A photostationary state was established between **3** and **5** consisting of 73% **3** and 27% **5**. When the acid solution was warmed to −20 °C, **5** isomerized back to **3** with a first-order rate constant of 1.1×10^{-4} s^{-1}. A careful examination of the NMR spectra of solutions of **3** showed that **5** was in thermal equilibrium with **3** (96% **3**; 4% **5** at −40 °C).

The cation **4** behaved similarly to **3** with the additional possibility of isomerism about the C_2–C_3 bond. Thus, irradiation of **4** (−70 °C, λ 254 nm) led to the establishment of a photostationary state consisting of a mixture of four cations, Scheme I. At −20 °C, two of these ions were thermally labile and reverted to the other two ($k \sim 6 \times 10^{-4}$ s^{-1} at −20 °C). The two remaining ions were identified as **4** and **6** on the basis of a comparison of their ^1H NMR spectra with those of the corresponding protonated crotonaldehydes.[2] The NMR spectra of the two less stable ions were consistent with the structures of **7** and **8**. At +38 °C, **6** isomerized to **4** ($k = 4.4 \times 10^{-4}$ s^{-1}). A thermodynamic equilibrium between **7** and **4** were eventually set up consisting of **7** (13%) and **4** (87%) at +40 °C.

Comparable photoisomerizations of **3** and **4** occurred in FSO_3H/SbF_5 media. Minor changes were seen in the rates of the thermal stereomutations about the C_1–O bonds in this more strongly acidic medium (**5** → **4**, $k = 2.8 \times 10^{-5}$ s^{-1} at −20 °C; **7** and **8** to **4** and **6**, $k \sim 4 \times 10^{-4}$ s^{-1} at −20 °C). As was found with the protonated crotonaldehydes,[2] the barrier to isomerization about the C_2–C_3 bond was greatly affected by the addition of SbF_5 to FSO_3H (**6** → **4**, $k = 4.0 \times 10^{-6}$ s^{-1} at +50 °C in 3:1 FSO_3H/SbF_5).

Several points emerge from these results, two of which will be commented on here. Firstly, it is quite clear that a photoinduced stereomutation can occur about the carbon–oxygen bond in these systems. It would seem very probable that comparable photoisomerizations can also occur with protonated carbonyl compounds and, while such processes might remain undetected because of proton exchange reactions, they could represent an important way in which the excited states of

Table I. ^1H Chemical Shifts of Cations

cation	chemical shifts, ppm[a]					coupling constants, Hz		
	H_1	H_2	H_3	H_4	OCH_3	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$
3	9.21 (d)	7.16 (m)	7.83 (d), 7.76 (d)		5.01 (s)	9	10, 16.5	
5	9.30 (d)	7.43 (m)	8.06 (d), 7.96 (d)		4.87 (s)	10	10, 16	
4	8.96 (d)	6.99 (dd)	8.54 (dq)	2.55 (d)	4.84 (s)	9	15	7
6	9.50 (d)	6.91 (t)	8.45 (dq)	2.60 (d)	4.89 (s)	10	10.5	7
7	9.06 (d)	7.40	(8.7)[b]	2.65	4.68 (s)	8		
8	9.56 (d)	(7.4)[b]	(8.7)[b]	(2.7)[b]	4.70 (s)	10.5		

[a] All shifts are relative to $(CH_3)_4N^+BF_4^-$ taken as δ 3.1; d = doublet, m = multiplet, q = quartet, s = singlet. [b] Peak is obscured by resonances of the cations and exact chemical shift uncertain.

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