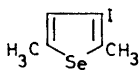


On a Ring-opening Reaction in the Selenophene Series

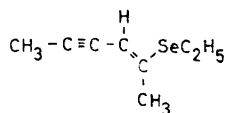
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In connection with work on atropisomerism in biselenienyls we studied the reaction between 2,5-dimethyl-3-iodoselenophene (I) and ethyllithium in order to obtain 2,5-dimethyl-3-selenienyllithium which we planned to use for the synthesis of other selenophene derivatives. Beselin



I



II

and one of us¹ had previously demonstrated that halogen-metal exchange between 2,5-dimethyl-3-iodothiophene and butyllithium proceeds smoothly, giving high yields of 2,5-dimethyl-3-thienyllithium. 2,5-Diethyl-3-iodothiophene behaved similarly.² We were therefore quite surprised to find that no 2,5-dimethyl-3-selenophene-carboxylic acid was formed upon reaction with carbon dioxide. The reaction between I and ethyllithium was carried out under different conditions at temperatures between -70°C and -10°C . The neutral fraction contained several compounds, as was evident from VPC analysis, and IR spectra indicated the formation of acetylenic compounds as the characteristic $\text{C}\equiv\text{C}$ stretching frequency was observed at 2220 cm^{-1} .

When the reaction mixture between I and ethyllithium was hydrolysed the neutral fraction yielded two compounds: 2,5-dimethylselenophene (19% yield), and as the main component (49% yield) 4-methyl-3-selena-4-octen-6-yne (II) (2-ethylseleno-2-hexene-4-yne). The structure of II was determined by spectroscopic methods. Its mass spectrum showed a molecular ion at $m/e=188$, with the characteristic isotope distribution for selenium (^{74}Se : ^{76}Se : ^{77}Se : ^{78}Se : ^{80}Se : ^{82}Se =

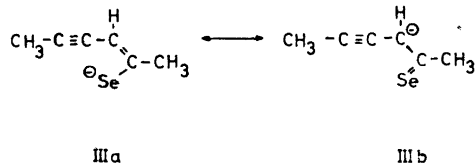
1:9:8:24:50:9). Strong peaks at $m/e=173$, $m/e=159$, and $m/e=145$ are ascribed to the loss of methyl, ethyl, and methylene from the molecular ion and these peaks also show the characteristic selenium isotope distribution. The peak at $m/e=79$ most probably arises from cleavage of the carbon-selenium bond, leaving the ion C_6H_7^+ . The mass spectrum is hardly in accordance with that expected for the isomeric 2,5-dimethyl-3-ethylselenophene. One would expect this compound to give a base peak at $m/e=173$ by loss of a methyl group, and not at the molecular ion, similar to the behaviour of the thiophene analogue.³

The NMR spectrum of II in solution shows five bands at 4.42 τ , 7.21 τ , 7.88 τ , 8.02 τ , and 8.60 τ with the relative intensities 1:2:3:3:3. The peaks at 7.21 τ and 8.60 τ show the characteristic couplings (7.5 c/s) for an ethyl group. The peaks at 7.88 τ and 8.02 τ are assigned to olefinic and acetylenic methyl groups, respectively. These assignments are based on the splittings due to long-range couplings in these bands. The band at 7.88 τ occurs as a quartet with splittings of 0.6 c/s and 1.2 c/s and the band at 8.02 τ shows splittings of 0.6 c/s and 2.4 c/s, while the band at 4.42 τ occurs as a complex multiplet.

Based on these splittings the band at 8.02 τ is assigned to the acetylenic methyl group. It is known that in vinylacetylenes J_{13} is of the order of 2.5 c/s.^{4,5} Hoffman and Gronowitz^{6,7} have shown that methyl substitution at the acetylenic carbon should change the sign of the coupling constant but diminish the absolute value only slightly. One would therefore expect a coupling constant of the observed magnitude for $\text{CH}_3-\text{C}\equiv\text{C}-\text{CH}=\text{}$. In propargyl chloride the long-range coupling between the CH_3 and the CH_2 group has been found to be 2.4 c/s,⁶ although the hybridisation of the CH_2 group is different from that in II. The magnitude of long-range coupling between the olefinic methyl group and the olefinic hydrogen (1.2 c/s) might indicate that the two coupling groups are *trans* to each other. It has been observed in a large number of compounds that while the *trans* coupling falls between 1.1 and 1.3 c/s the corresponding allylic *cis* coupling is 1.5–1.8 c/s.^{6,7} This could indicate that II has the stereochemistry given in the formula with the large substituents *trans* to each other. Due to the unusual nature of the substituents,

further experimental evidence is, however, necessary to strengthen this assignment. The long-range coupling of 0.6 c/s between the methyl group is through seven bonds. The NMR spectrum is not in accordance with that expected for 2,5-dimethyl-3-ethylselenophene. The aromatic hydrogen resonances of 2,5-dimethylselenophene and 2,5-dimethyl-3-iodoselenophene occur at 3.48 τ and 3.30 τ , respectively, and substitution with an ethyl group could not cause such an upfield shift. The observed methyl resonances are not in agreement with those observed in the dimethyl selenophenes (7.20–7.72 τ), nor is the coupling pattern. The IR spectrum of II shows bands at 2220 cm^{-1} , assigned to the $\text{C}\equiv\text{C}$ -stretching frequencies of di-substituted acetylenes, and at 1590 cm^{-1} , assigned to the $\text{C}=\text{C}$ -stretching frequency.⁸ The sulfur analogue of III, 2-ethylthiohex-2-ene-4-yne, has been prepared by the addition of potassium ethyl mercaptide to dimethyldiacetylene,⁹ although the stereochemistry of the product was not discussed. The sulfur analogue showed IR bands at 2216 cm^{-1} and 1594 cm^{-1} .⁹

We believe that II is formed through the alkylation of the anion III with ethyl iodide.



The ethyl iodide could have been formed in the halogen-metal exchange reaction. However, our failure to isolate even traces of 2,5-dimethyl-3-selenophenecarboxylic acid upon carbonation makes it doubtful if 2,5-dimethyl-3-selenienyllithium is at all an intermediate in the reaction. It might be possible that ethyllithium attacks at the selenium atom with ring-opening followed by more or less concerted halogen-metal exchange. Contribution of the carbanion resonance structure IIIb, would allow rotation around the formal double-bond and make possible the formation of the *trans* isomer II. It should perhaps be pointed out that the observed spectral data are not in accordance with a *C*-alkylated product.

From an experiment in which cupric chloride was added to the reaction mixture between I and ethyllithium we found evidence for the formation of the diselenide derived from III, which supports its intermediate formation.

Similar ring-openings have previously been observed in the reaction of 3-bromobenzo[b]furan with butyllithium leading to *ortho*-hydroxyphenylacetylene^{10,11} and quite recently by Bugge¹² in the reaction of 2,3,5-tribromothiopheno[2,3-*b*]thiophene. As far as we could find, such ring-opening has not been reported in the selenophene series. However, the low yield obtained by Yur'ev *et al.*^{13,14} and Paulmier and Pastour¹⁵ in the reaction between 3-iodoselenophene and butyllithium followed by treatment with various reagents might indicate that the ring-opening reaction discovered by us is quite general with selenophenes. In contrast to the above behaviour on attempted halogen-lithium exchange, the Grignard reagent is easily formed in the reaction between I and magnesium and can be used for the preparation of 2,5-dimethyl-3-selenophenecarboxylic acid and other derivatives.¹⁶ In this behaviour I differs from 3-bromobenzo[b]furan.¹⁷

2,5-Dimethyl-3-iodoselenophene was prepared by a modification of the iodination method worked out by Wirth *et al.* using iodine and iodic acid.¹⁸ Omitting the use of sulfuric acid as catalyst and treating the reaction mixture with alkali gave the best yield.

We are continuing our studies on this ring-opening reaction.

Experimental. 2,5-Dimethyl-3-iodoselenophene.

To a mixture of 220 ml of acetic acid, 280 ml of water, 96.5 g (0.380 mole) of iodine, and 33.4 g (0.190 mole) of iodic acid, 117 g (0.736 mole) of 2,5-dimethylselenophene¹⁹ dissolved in 140 ml of carbon tetrachloride was added and the mixture stirred at 50°C for 5 h. 42.0 g (0.749 mole) of potassium hydroxide dissolved in a little water was carefully added and the mixture stirred at room temperature for one hour and then poured into water. The aqueous layer was extracted with ether and the combined ether phases were washed with sodium bisulphite solution and water and dried over magnesium sulphate. Fractionation yielded 112 g (53 %) of 2,5-dimethyl-3-iodoselenophene, b.p. 87–90°C/3 mm Hg, n_D^{20} = 1.6483. NMR (CCl_4): $\tau_{2-\text{CH}_3}$ = 7.61 ppm, $\tau_{5-\text{CH}_3}$ = 7.50 ppm, τ_{CH} = 3.30 ppm, $J_{\text{CH}_2-\text{H}}$ = 1.2 c/s, $J_{\text{CH}_3-\text{CH}_3}$ = 0.6 c/s. (Found: C 25.15; H 2.68;

mol.wt 286. Calc. for C_8H_7ISe : C 25.29; H 2.48; mol.wt 286).

4-Methyl-3-selena-4-octene-6-yne. To 20 ml 1.13 N ethereal ethyllithium cooled to $-70^\circ C$ 5.00 g (0.0175 mole) of 2,5-dimethyl-3-iodoselenophene was added with stirring and under nitrogen. After 10 min, the temperature was allowed to rise to room temperature and the mixture poured into 1 N potassium hydroxide solution. The ethereal layer was washed with potassium hydroxide solution and water. The combined aqueous washings were extracted with ether and the combined ether phases were dried and the ether evaporated *in vacuo* yielding 2.13 g of an oil, which according to NMR analysis contained about 25 % of 2,5-dimethylselenophene and 75 % of the title compound. Fractional distillation yielded pale yellow, evil-smelling 4-methyl-3-selena-4-octene-6-yne, b.p. $110^\circ C/18$ mm Hg. NMR: (see text); mass spectrum: (*m/e*, %) 77, 15.3; 78, 20.2; 79, 22.2; 91, 5.0; 103, 1.3; 104, 1.2; 105, 2.7; 106, 1.0; 107, 4.6; 108, 1.0; 109, 1.2; 115, 0.66; 116, 0.83; 117, 1.5; 118, 0.83; 119, 3.0; 120, 1.5; 121, 0.66; 122, 0.66; 127, 0.33; 128, 0.33; 129, 0.66; 130, 0.5; 131, 1.3; 132, 0.66; 133, 1.2; 134, 0.5; 135, 0.5; 136, 0.5; 141, 2.3; 142, 2.3; 143, 6.0; 144, 0.66; 145, 12.0; 146, 0.83; 147, 2.7; 155, 4.0; 156, 4.3; 157, 10; 158, 3.0; 159, 18.3; 160, 4.3; 161, 3.8; 162, 1.0; 169, 2.2; 170, 2.0; 171, 5.3; 172, 1.0; 173, 10.0; 174, 1.3; 175, 2.0; 176, 0.33; 184, 20.2; 185, 18.9; 186, 50.9; 187, 8.7; 188, 100; 189, 10.0; 190, 20.0. (Found: C 51.00; H 6.52. Calc. for $C_8H_{12}Se$ (187.15): C 51.34; H 6.46).

NMR spectra were recorded with a Varian A60 NMR spectrometer. Mass spectra were obtained with an LKB A 9000 combined gas chromatograph-mass spectrometer. Separation of 4-methyl-3-selena-4-octene-6-yne from 2,5-dimethylselenophene was obtained using an NPGS (5 %) column. IR spectra were recorded on a Perkin-Elmer 257 grating infra-red spectrophotometer.

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The Acid Strengths of Propionic, 2-Bromopropionic and 3-Bromopropionic Acids in Aqueous Potassium Chloride Solutions

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In connection with studies on the magnetic and spectral properties of copper(II) complexes of propionic, 2-bromopropionic, and 3-bromopropionic acids,¹ the values of the dissociation constants of these acids were required. The earlier investigations of the dissociation of bromopropionic acids are few in number and were carried out under differ-