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MERCAPTAN ADDITION TO ALLYLGLUCOSIDES

N. N. Sidamonidze,* R. O. Vardiashvili, and M. O. Nutsubidze

UDC 577.1

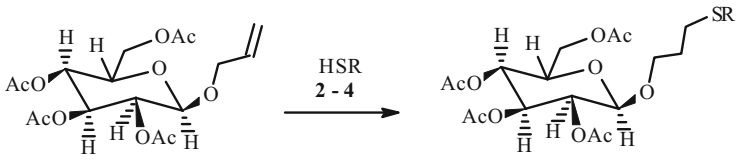
*Addition of ethyl-, n-propyl-, and butylmercaptans to 1-*O*-allyl-2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose in the presence of two catalysts, benzoyl peroxide and cobalt octacarbonyl, to produce the corresponding 1-*O*-(3-ethylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose, 1-*O*-(3-propylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose, and 1-*O*-(3-butylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose was studied for the first time. It was found that these reactions occurred mainly according to the Farmer rule.*

Keywords: mercaptan addition, allylglucopyranoside, mercaptans, benzoyl peroxide, cobalt octacarbonyl.

Modification of carbohydrates by various types of organic compounds has recently played a significant role in the synthesis of new types of biologically and pharmacologically active compounds [1, 2].

We have previously studied mercaptan addition to 1-*O*-allyl-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranose in the presence of benzoyl peroxide catalyst and found several features of this reaction [3].

The goal of the present work was to study mercaptan addition (ethyl-, propyl-, and butylmercaptans, **2**-**4**) to 1-*O*-allyl-2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranose (**1**) in the presence of two different catalysts, benzoyl peroxide $(C_6H_5COO)_2$ and cobalt octacarbonyl $Co_2(CO)_8$. The reaction was carried out in dry $CHCl_3$ under N_2 using a 1:1 molar ratio of reactants (water bath temperature 70–75°C).



1 **5 - 7**

R = C_2H_5 (**2**, **5**); C_3H_7 (**3**, **6**); C_4H_9 (**4**, **7**)

The synthesized compounds 1-*O*-(3-ethylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranose (**5**), 1-*O*-(3-propylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranose (**6**), and 1-*O*-(3-butylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranose (**7**) were crystalline yellow compounds that were very soluble in $CHCl_3$, tetrachloroethane, and EtOH. The yields decreased as the chain length grew, possibly due to steric factors.

These mercaptan additions followed mainly the Farmer rule although a small amount (6–9%) of the Markovnikov addition product was also produced. The mixture was separated over a column of silica gel (L 50/100, benzene:$CHCl_3$, 2:1).

Addition of ethylmercaptan (**2**) to **1** was selected to study the pathway and mechanism of the model reaction.

Quantum-chemical computations using CS MOPAC (Chem 3D Ultraversion 8.03) were performed in order to justify theoretically the pathway of this reaction. Each computation by the AM1 method [4] (Austin Model 1) was preceded by optimization of the compound, i.e., minimization of the energy by molecular mechanics (MM) and the quantum-chemical method. This reaction was examined in two directions, according to the Farmer and Markovnikov rules.

I. Javakhishvili Tbilisi State University, Georgia, e-mail: sidamonidzeneli@yahoo.com. Translated from Khimiya Prirodnykh Soedinenii, No. 4, pp. 436–438, July–August, 2010. Original article submitted January 19, 2010.

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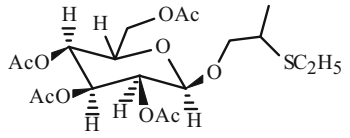
Mercaptan addition according to the Farmer rule would produce 1-*O*-(3-ethylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranose (**5**) whereas addition according to the Markovnikov rule would give 1-*O*-(2-ethylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranose (**8**):



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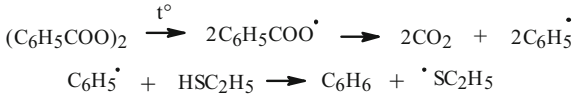
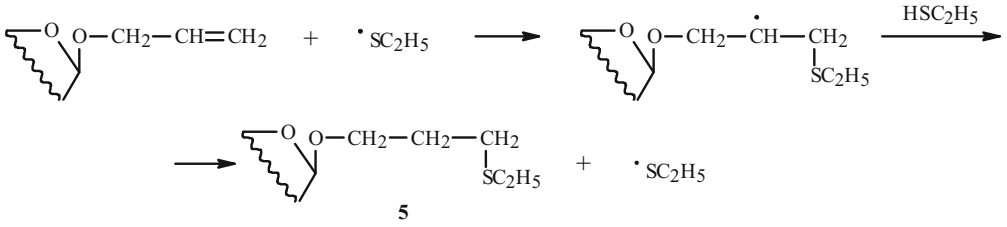
The calculated heats of formation of the products showed that production of **5** was highly probable because for it $\Delta H_{form} = -1885.30$ kJ/mol and $\Delta H_{react} = -178.65$ kJ/mol (for product **8**, $\Delta H_{form} = -1846.84$ kJ/mol and $\Delta H_{react} = -140.15$ kJ/mol).

As was shown above, addition of ethylmercaptan to **1** occurred in the presence of two different catalysts, benzoyl peroxide and cobalt octacarbonyl, and gave the same product **5**.

The reaction in the presence of benzoyl peroxide probably occurred through a radical mechanism. Benzoyl peroxide decomposes thermally to form CO_2 and the phenyl radical. The latter attacks readily ethylmercaptan to form benzene and the thioethyl radical:



The resulting thioethyl radical reacts with allylglucoside **1**. The last reaction with ethylmercaptan gives product **5**:



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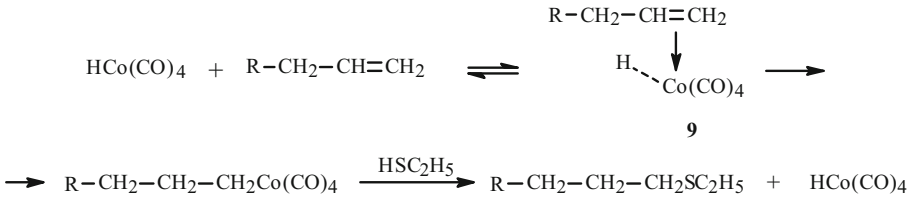
The first step is initiating. The others occur due to intramolecular bond energies.

The reaction in the presence of $Co_2(CO)_8$ probably occurred according to the following mechanism. Because $Co_2(CO)_8$ itself cannot catalyze mercaptan addition, the first step in the formation of the active catalyst species, $HCo(CO)_4$, is important and results from the reaction of $Co_2(CO)_8$ with the mercaptan:

It is known that $HCo(CO)_4$ adds readily to olefins to form intermediate **9** that is unstable because of the excess of electron density on the metal and tends to convert into the saturated Co complex **9a** by loss of the most labile ligand, in this instance hydride. The last step of the mechanism is formation of the final product and regeneration of the catalyst:



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The proposed mechanism of mercaptan addition to allylglucosides agrees well with the experimental results.

EXPERIMENTAL

^{13}C NMR spectra were recorded on a Bruker AM-300 spectrometer (75.5 MHz, $CDCl_3$). The purity of the products and the R_f values were determined on Silufol UV-254 using solvent systems MeOH:$CHCl_3$ (1:5, system a); benzene:$CHCl_3$ (3:2, system b; 2:1, system c); hexane:EtOH (2:1, system d). Optical rotation was measured on an SU-3 universal saccharimeter.

1-*O*-Allyl-2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose (1), mp 85–86°C, R_f 0.35 (system a), $[\alpha]_D^{18}$ +44° ($CHCl_3$), $C_{17}H_{24}O_{10}$ [5].

1-*O*-(3-Ethylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose (5). A mixture of ethylmercaptan (0.62 g, 0.01 mol) in dry $CHCl_3$ (15 mL) and $Co_2(CO)_8$ (0.1 g) were treated with a solution of 1-*O*-allyl-2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose (**1**, 3.88 g, 0.01 mol) in dry $CHCl_3$ (30 mL). The reaction was carried out under N_2 with constant stirring for 5 h (water bath temperature 70–75°C). The mixture was cooled and separated over a column (silica gel L, 50/100, system b) to afford chromatographically pure **5** (2.95 g, 65.5%), mp 117.5–118°C, R_f 0.35 (system c), $[\alpha]_D^{18}$ +48.2° (*c* 0.47, $CHCl_3$), $C_{19}H_{30}O_{10}S$.

^{13}C NMR spectrum (δ, ppm): 94.42 (C-1), 7.04 (C-2), 77.3 (C-3), 66.8 (C-4), 72.3 (C-5), 61.6 (C-6), 169.1–170.2 (4O–$\underline{C}$O–CH_3), 20.8–17.5 (4O–CO–$\underline{C}H_3$), 70.2 (1–O–$\underline{C}H_2$–CH_2–), 32.4 (1–O–CH_2–$\underline{C}H_2$–), 28.1(1–O–CH_2–CH_2–$\underline{C}H_2$–S–), 18.3 [1–O–$(CH_2)_3$–S–$\underline{C}H_2$–), 9.84 [1–O–$(CH_2)_3$–S–CH_2–$\underline{C}H_3$].

1-*O*-(3-Propylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose (6). Analogous addition of propylmercaptan (0.76 g, 0.01 mol) to **1** (3.88 g, 0.01 mol) in the presence of $Co_2(CO)_8$ (0.1 g) synthesized **6** (2.75 g, 59.9%), mp 130–131°C, R_f 0.48 (system b), $[\alpha]_D^{17}$ +76° (*c* 0.41, $CHCl_3$), $C_{20}H_{32}O_{10}S$.

^{13}C NMR spectrum (δ, ppm): 99.25 (C-1), 71.2 (C-2), 76.8 (C-3), 66.8 (C-4), 72.9 (C-5), 61.8 (C-6), 168.5–171.4 (4O–$\underline{C}$O–CH_3), 19.8–21.6 (4O–CO–$\underline{C}H_3$), 72.2 (1–O–$\underline{C}H_2$–CH_2–), 28.8 (1–O–CH_2–$\underline{C}H_2$–), 19.2(1–O–CH_2–CH_2–$\underline{C}H_2$–S–), 14.6 [1–O–$(CH_2)_3$–S–$\underline{C}H_2$–], 12.6 [1–O–$(CH_2)_3$–S–CH_2–$\underline{C}H_2$–], 8.3 [1–O–$(CH_2)_3$–S–$(CH_2)_2$–$\underline{C}H_3$].

1-*O*-(3-Butylthiopropyl)-2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose (7). Addition of butylmercaptan (0.9 g, 0.01 mol) to **1** (3.88 g) in the presence of $Co_2(CO)_8$ (0.1 g) synthesized **7** (2.64 g, 55.1%), mp 142–143°C, R_f 0.71 (system d), $[\alpha]_D^{17}$ +112.7° (*c* 0.53, $CHCl_3$), $C_{21}H_{34}O_{10}S$.

^{13}C NMR spectrum (δ, ppm): 90.8 (C-1), 70.4 (C-2), 77.5 (C-3), 66.8 (C-4), 72.2 (C-5), 62.7 (C-6), 168.2–174.4 (4O–$\underline{C}$O–CH_3), 20.5–22.6 (4O–CO–$\underline{C}H_3$), 69.9 (1–O–$\underline{C}H_2$–CH_2–), 30.0 (1–O–CH_2–$\underline{C}H_2$–), 27.8(1–O–CH_2–CH_2–$\underline{C}H_2$–S–), 12.57 [1–O–$(CH_2)_3$–S–$\underline{C}H_2$–], 10.5 [1–O–$(CH_2)_3$–S–CH_2–$\underline{C}H_2$–], 9.22 [1–O–$(CH_2)_3$–S–$(CH_2)_2$–$\underline{C}H_3$].

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