boiling 2-propanol failed to dissolve the impurities. The product was successfully purified by triturating with boiling anhydrous ethanol, cooling to room temperature, filtering, and washing with ethanol, then ether, then air drying to give the pure complex as a pale yellow solid.

Isolation of Quinaldines. Each complex from above was placed in a separatory funnel and shaken with ~150 ml of cold water. To this slurry was added ~50 ml of concentrated ammonium hydroxide and the slurry was shaken again. The resulting oil or solid was extracted into ether (two or three times), dried ($MgSO_4$), filtered, and evaporated to dryness. Except in the cases of quinaldine and 8-methylquinaldine (yellow-brown oils), the products were obtained as yellow or white crystalline solids which were >98% pure by VPC. The yields were approximately quantitative. To obtain the melting points listed in Table I, the quinaldines were transferred to a filter funnel with cold hexane and air dried.

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Registry No.—Crotonaldehyde, 4170-30-3; $ZnCl_2$, 7646-85-7.

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Carbohydrate Thio Ortho Esters. 3.[1] Transformation to Thioglycosides with Deactivated Raney Nickel

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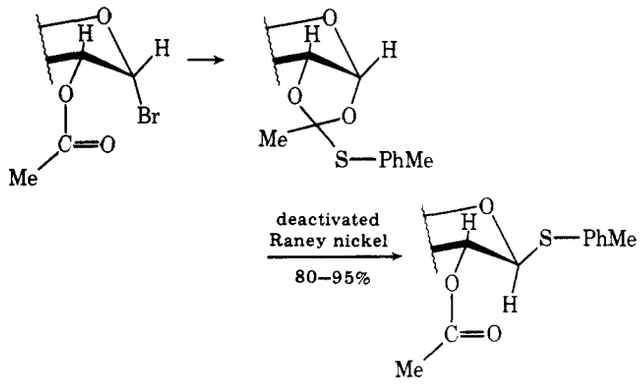
Phenyl 1-thioglycosides have been used inter alia for affinity chromatography (linked by a *p*-amino group substituent and a spacer to an insoluble matrix such as Sepharose) of glycosidases,[2] for stereoselective Hg^{2+}-mediated solvolysis to *O*-glycosides[3] and for synthesis of glycosyl benzoates and halides.

The phenyl 1-thioglycoside grouping has been synthesized by a number of different routes, for instance, nucleophilic substitution of the bromine in acetobromo sugars by sodium or potassium thiolates,[4] reduction of dithioacetals,[5] and thermal decomposition of arylazothioglycosides.[6] I now wish to report an improved, rapid, and efficient high-yield synthesis of peracetylated *p*-methylphenyl 1,2-*trans*-1-thioglycopyranosides using the route shown in Scheme I.

As mentioned in a previous report,[1] treatment of *p*-methylphenyl thio ortho esters in ethanol or 2-propanol with active Raney nickel gave the corresponding ethyl and isopropyl ortho esters in high yield instead of the expected 1,2-ethylidene acetals. An attempt to make cyclohexyl ortho esters by this method in toluene with azeotropically dried Raney nickel, gave a mixture of products, many of which still contained sulfur. Obviously the Raney nickel was deactivated by the toluene distillation so that desulfurization could not occur. Analysis of the reaction mixture revealed that the main

Scheme I



product formed was the *p*-methylphenyl 1,2-*trans*-1-thioglycoside. After testing different reaction conditions, a preparatively useful method was found for the synthesis of these compounds. Thioglycosides with the D-gluco, D-galacto, D-xylo, D-lacto, and D-glucurono configurations have been prepared in 80–95% yield.

The procedure is simple and consists of stirring the appropriate thio ortho ester[7] (mixture of exo and endo diastereomers) with deactivated Raney nickel (see Experimental Section) and a trace of *p*-methylthiophenol in toluene for ca. 10 min followed by filtration and evaporation. The residue (a colorless oil) was pure (TLC, NMR) 1-thioglycoside that crystallized on addition of a few drops of ethanol (except for the lacto derivative). The starting thio ortho esters were prepared from the appropriate acetobromo sugars and *p*-methylthiophenol.[7] The only detectable by-products in the preparation of the thio ortho esters are the corresponding thioglycoside and di-*p*-methylphenyl disulfide but these can easily be removed by chromatography if desired (cf. below).

A trial preparation of the thioglucoside, without purification of the thio ortho ester by chromatography, was made using a two-step sequence from acetobromoglucose. Treatment of the crude product with deactivated Raney nickel and a trace amount of *p*-methylthiophenol gave the *p*-methylphenyl 1-thio-β-D-glucopyranoside in ca. 80% overall yield. The only contaminant that could be detected was di-*p*-methylphenyl disulfide.

To give some idea of the mechanism of the present Raney nickel reaction, a test was made omitting the *p*-methylthiophenol. The reaction time had to be increased ca. tenfold to allow all the thio ortho ester to react and several by-products were found. It thus seems as if the reaction does *not* proceed via a fully developed acetoxonium ion that is stabilized only by the solvent but rather via a close ion pair with the *p*-methylthiophenoxy anion reversibly adsorbed to the nickel surface. Free *p*-methylthiophenol (which is regenerated in the reaction) can then make a nucleophilic attack at the anomeric center giving the thioglycoside. Evidence for ion-pair formation in thio ortho esters was also found when using active Raney nickel in ethanol[1] (see above).

Experimental Section

Melting points are uncorrected. IR spectra were run as KBr pellets. ^1H NMR spectra were run in $CDCl_3$ (Me_4Si) on a JEOL PMX-60 spectrometer and mass spectra on a Varian MAT 311 spectrometer. Deactivated Raney nickel was prepared as follows. Raney nickel in water (Merck hydrogenation catalyst) was washed with five portions of absolute ethanol and five portions of toluene (centrifugation). The catalyst was heated (toluene reflux) for 1 h and then dried by azeotropic distillation of the toluene. The resulting catalyst could be stored (in toluene) at room temperature without any noticeable decrease in reactivity.

General Procedure for Preparation of the Thioglycosides. The appropriate peracetylated thio ortho ester[7] (200 mg, mixture of exo and endo diastereomers) and *p*-methylthiophenol (<1 mg) were

dissolved in dry toluene (5 ml). Deactivated Raney nickel (ca. 2 g) was added using a few milliliters of toluene (gas evolution was noticed) and the mixture was stirred (magnet) at room temperature. When the reaction was complete (ca. 10 min, TLC: SiO_2/ethyl acetate–light petroleum; 1:2 for monosaccharides and 3:2 for the disaccharide) the mixture was filtered by suction through a pad of Celite. The residue was washed several times with ether and the filtrate was evaporated. This gave pure (TLC, NMR) thioglycoside as a colorless oil that crystallized (except for the lacto derivative) on addition of a few drops of ethanol.

***p*-Methylphenyl 2,3,4,6-Tetra-*O*-acetyl-1-thio-β-D-glucopyranoside.** Yield 83%. Recrystallization from ethanol gave an analytical sample. For melting point, optical rotation, IR, ^{1}H NMR, ^{13}C NMR, and MS data, see ref 7.

***p*-Methylphenyl 2,3,4,6-Tetra-*O*-acetyl-1-thio-β-D-galactopyranoside.** Yield 94%. Recrystallization from ethanol gave an analytical sample: mp 117–118 °C; $[\alpha]^{24}_{578}$ +5.0° (*c* 1.0; $CHCl_3$) (lit.[8] mp 113–115 °C; $[\alpha]^{23}_D$ +4.4°); IR 1740, 804 cm^{-1}; NMR δ 7.37, 7.09 (rough AB q, 2 H each, J_{AB} = 8.4 Hz, aromatic H), 3.70–5.50 (m, 7 H, OCH), 2.34 (s, 3 H, C**H**$_3$Ph), 2.10 (s, 6 H, CH_3COO), 2.03, 1.96 ppm (s, 3 H each, CH_3COO); mass spectrum *m/e* (rel intensity) 454 (M$^+$, 0.1, $C_{21}H_{26}O_9S$), 331 (60), 271 (1), 229 (3), 187 (2), 169 (100, base peak), 127 (30), 109 (73).

Anal. Calcd for $C_{14}H_{19}O_9$: mol wt, 331.1029. Found: mol wt, 331.0998 (M − C_7H_7S).

***p*-Methylphenyl 2,3,4-Tri-*O*-acetyl-1-thio-β-D-xylopyranoside.** Yield 95%. Recrystallization from ethanol gave an analytical sample: mp 108–109 °C; $[\alpha]^{24}_{578}$ −68.4° (*c* 2.0; $CHCl_3$); IR 1747, 803 cm^{-1}; NMR δ 7.37, 7.13, (rough AB q, 2 H each, J_{AB} = 8.4 Hz, aromatic H), 3.10–5.35 (m, 6 H, OCH), 2.35 (s, 3 H, C**H**$_3$Ph), 2.09 (s, 3 H, CH_3COO), 2.03 ppm (s, 6 H, CH_3COO); mass spectrum *m/e* (rel intensity) 382 (M$^+$, 0.4, $C_{18}H_{22}O_7S$), 259 (50), 199 (37), 157 (79), 139 (84), 97 (100, base peak).

Anal. Calcd for $C_{18}H_{22}O_7S$: mol wt, 382.1085. Found: mol wt, 382.1059. Calcd: C, 56.5; H, 5.8; S, 8.4. Found: C, 56.4; H, 5.8; S, 8.3.

***p*-Methylphenyl 2,3,6-Tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-1-thio-β-D-glucopyranoside.** Yield 80%. Column chromatography (SiO_2, 15 g, ethyl acetate–light petroleum, 3:2) gave an analytical sample: syrup; $[\alpha]^{24}_{578}$ −17.6° (*c* 1.7; $CHCl_3$); IR 1754, 809 cm^{-1}; NMR δ 7.34, 7.08 (rough AB q, 2 H each, J_{AB} = 8.2 Hz, aromatic H), 3.53–5.35 (m, 14 H, OCH), 2.33 (s, 3 H, C**H**$_3$Ph), 2.12, 2.07, 2.01, 1.94 ppm (s, 21 H, CH_3COO); mass spectrum *m/e* (rel intensity) 742 (M$^+$, 0.05, $C_{33}H_{42}O_{17}S$), 619 (50), 559 (37), 457 (14), 397 (2), 395 (6), 331 (70), 169 (100, base peak).

Anal. Calcd for $C_{26}H_{35}O_{17}$: mol wt, 619.1873. Found: mol wt, 619.1868 (M − C_7H_7S). Calcd for $C_{33}H_{42}O_{17}S$: S, 4.3. Found: S, 4.3.

***p*-Methylphenyl 2,3,4-Tri-*O*-acetyl-1-thio-β-D-glucopyranuronic Acid (Methyl Ester).** Yield 89%. Recrystallization from ethanol gave an analytical sample: mp 127–128 °C; $[\alpha]^{24}_{578}$ −25.0° (*c* 0.9; $CHCl_3$); IR 1763, 1744, 804 cm^{-1}; NMR δ 7.40, 7.14 (rough AB q, 2 H each, J_{AB} = 8.4 Hz, aromatic H), 3.87–5.50 (m, 5 H, OCH), 3.76 (s, 3 H, OCH_3), 2.35 (s, 3 H, C**H**$_3$Ph), 2.08 (s, 3 H, CH_3COO), 1.98 ppm (s, 6 H, CH_3COO); mass spectrum *m/e* (rel intensity) 440 (M$^+$, 0.4, $C_{20}H_{24}O_9S$), 317 (19), 257 (20), 215 (9), 197 (15), 155 (100, base peak), 127 (64).

Anal. Calcd for $C_{13}H_{17}O_9$: mol wt, 317.0872. Found: mol wt, 317.0877 (M − C_7H_7S). Calcd for $C_{20}H_{24}O_9S$: C, 54.5; H, 5.5. Found: C, 54.4; H, 5.6.

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Registry No.—*p*-Methylphenyl 2,3,4,6-tetra-*O*-acetyl-1-thio-β-D-glucopyranoside, 28244-94-2; *p*-methylphenyl 2,3,4,6-tetra-*O*-acetyl-1-thio-β-D-galactopyranoside, 28244-99-7; *p*-methylphenyl 2,3,4-tri-*O*-acetyl-1-thio-β-D-xylopyranoside, 61025-08-9; *p*-methylphenyl 2,3,6-tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-1-thio-β-D-glucopyranoside, 29019-41-8; *p*-methylphenyl 2,3,4-tri-*O*-acetyl-1-thio-β-D-glucopyranuronic acid methyl ester, 61025-09-0; *p*-methylphenyl peracetyl-α-D-glucopyranosethio ortho ester isomer A, 60426-93-9; *p*-methylphenyl peracetyl-α-D-glucopyranosethio ortho ester isomer B, 60410-57-3; *p*-methylphenyl peracetyl-α-D-galactopyranosethio ortho ester isomer A, 60410-58-4; *p*-methylphenyl peracetyl-α-D-galactopyranosethio ortho ester isomer B, 60439-00-1; *p*-methylphenyl peracetyl-α-D-xylopyranosethio ortho ester isomer A, 60410-59-5; *p*-methylphenyl peracetyl-α-D-xylopyranosethio ortho ester isomer B, 60410-60-8; *p*-methylphenyl peracetyl-4-*O*-(β-D-galactopyranosyl)-α-D-glucopyranosethio ortho ester isomer A, 61091-25-6; *p*-methylphenyl peracetyl-4-*O*-(β-D-galactopyranosyl)-α-D-glucopyranosethio ortho ester isomer B, 60410-61-9; *p*-methylphenyl peracetyl-α-D-glucopyranuronic acid methyl ester thio ortho ester isomer A, 60410-62-0; *p*-methylphenyl peracetyl-α-D-glucopyranuronic acid methyl ester thio ortho ester isomer B, 60410-63-1; *p*-methylthiophenol, 106-45-6.

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Metal Catalysis in Organic Reactions. 3. Nickel-Promoted Reaction of Triisobutylaluminum with Terminal Acetylenes as a Synthetic Route to (*E*)-2,4-Dialkyl-1,3-butadienes and/or Trialkylbenzenes

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Recently we reported that the reaction of triisobutylaluminum with terminal acetylenes affords products which correspond to metalation, reduction, and carbalumination of the substrate.[1] In connection with studies on nickel-catalyzed organic reactions,[2] we have now investigated the influence of soluble nickel(II) complexes, such as bis(*N*-methylsalicylaldimine)nickel [Ni(mesal)$_2$],[3] on the selectivity of the above reaction.[1]

The stoichiometric reaction of triisobutylaluminum with terminal alkynes, at 25 °C and in the absence of solvent, is accelerated by the presence of catalytic amounts of Ni(mesal)$_2$ and a "head-to-tail" dimer [(*E*)-2,4-dialkyl-1,3-butadiene] and trialkylbenzenes are formed as main products (Table I). Thus, 1-hexyne is completely converted by this procedure into a mixture containing (*E*)-5-methylene-6-undecene (**5**),[4] 1,3,5-tri-*n*-butylbenzene (**6**), and 1,2,4-tri-*n*-butylbenzene (**7**), together with those products whose formation occurs even in the absence of the nickel complex[1] and minor amounts of linear trimers and C_{16} dienes[5] (Table I). The yields both of the dimer and the cyclotrimers are dependent on the molar ratio (i-C_4H_9)$_3$Al to Ni(mesal)$_2$, at least in the stoichiometric reaction of 1-alkynes with triisobutylaluminum. In fact, decreasing the molar ratio (i-C_4H_9)$_3$Al to Ni(mesal)$_2$ up to 60 substantially depresses the formation of the metalation (**1**) and reduction (**2**) products whereas it increases the yields of **5**, **6**, and **7** (entries 1–4). The use of higher nickel concentrations is not advisable because of the increasing formation of the by-products.

The extremely high selectivity in the dimerization of 1-hexyne had prompted us to explore the validity of the nickel-catalyzed reaction between 1-alkynes and triisobutylaluminum as a synthetic route to preparing 2,4-dialkyl-1,3-butadienes, whose preparation cannot be easily achieved using conventional methods.[6] For this purpose, some 3-alkyl-,