

A mixture of this picrate with that of 6-ethylquinoline melted at 147–150°.

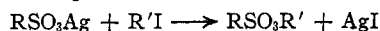
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## Metathetical Reactions of Silver Salts in Solution. II. The Synthesis of Alkyl Sulfonates<sup>1</sup>

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Alkyl sulfonates have normally been prepared by the base-catalyzed action of a sulfonyl chloride upon an alcohol.<sup>2</sup> This method is dependent on the availability of the appropriate alcohol and is limited to the preparation of those esters which are not sensitive to base. A less useful method has been the heating of a silver sulfonate with an alkyl iodide.<sup>2</sup> This procedure is severely limited by the



heterogeneous reaction conditions employed and the relatively high temperatures frequently necessary to effect complete reaction.

We have been able to make a significant improvement in the preparation of alkyl sulfonates by the silver salt method using acetonitrile as a solvent for the reaction. The silver salts of methanesulfonic acid, *p*-toluenesulfonic acid and benzenesulfonic acid are all extremely soluble in acetonitrile at room temperature. Accordingly, the metathetical reaction between these silver salts and primary alkyl halides may be carried out smoothly under mild conditions and with nearly quantitative yields of esters. The following mesylates were all prepared from silver methanesulfonate and the corresponding alkyl iodides except where noted: methyl mesylate (97% yield), ethyl mesylate (94% yield), butyl mesylate (97% yield), allyl mesylate (96% yield from allyl bromide), methallyl mesylate (81% yield from methallyl chloride), methylene bis-mesylate (72% yield from methylene iodide) and benzyl mesylate (92% yield from benzyl bromide). Tosylates were prepared by essentially the same procedure: methyl tosylate (77% yield), ethyl tosylate (76% yield), ethylene bis-tosylate (65% yield from ethylene bromide), methylene bistosylate (88% yield from methylene iodide) and benzyl tosylate (52% yield from benzyl chloride). Methyl benzenesulfonate was also prepared in 69% yield from methyl iodide and silver benzenesulfonate.

The reaction of silver sulfonates in solution with secondary and tertiary halides was, as might be expected, of no synthetic value for the preparation of sulfonates. Under these conditions dehydrohalogenation takes place; indeed, from *t*-butyl bromide and silver tosylate the only product isolated was *p*-toluenesulfonic acid.

### Experimental<sup>3</sup>

The procedures described herein for allyl mesylate and methylene bis-mesylate are typical of those used for prepa-

ration of all the other esters. Physical constants and analytical data are given for those esters which have not been described previously in the literature. The yields reported in the discussion refer in most cases to the distilled product. The silver salts were conveniently prepared by addition of a slight excess of silver oxide to an acetonitrile solution of the sulfonic acid. Evaporation of the solvent gave the silver salts in excellent yield and purity. All melting points and boiling points are uncorrected.

**Allyl Mesylate.**—To a solution of 10.2 g. (0.05 mole) of silver methanesulfonate in 50 ml. of dry acetonitrile was added 7.3 g. (0.06 mole) of allyl bromide. The mixture was allowed to stand one hour and was then filtered. The solvent was removed at reduced pressure and the liquid residue distilled. There was obtained 6.5 g. (96%) of colorless allyl mesylate, b.p. 45–47° (0.05 mm.), *n*<sub>D</sub><sup>20</sup> 1.4435.

*Anal.* Calcd. for C<sub>4</sub>H<sub>9</sub>O<sub>3</sub>S: C, 35.28; H, 5.92; sapn. equiv., 136.2. Found: C, 35.04; H, 5.66; sapn. equiv., 133.0.

**Methylene Bis-mesylate.**—To a hot solution of 22.3 g. (0.11 mole) of silver methanesulfonate in 100 ml. of acetonitrile was added 26.8 (0.1 mole) of methylene iodide. The solution was stirred at reflux for 20 hours. It was then filtered and the volatile solvent removed at reduced pressure. The solid product was dissolved in 150 ml. of warm ethylene dichloride and then filtered to remove the excess silver methanesulfonate. The solvent was removed by distillation yielding the crystalline product which was recrystallized from ethanol; yield 7.4 g. (72%), m.p. 75–76°.

*Anal.* Calcd. for C<sub>3</sub>H<sub>8</sub>O<sub>6</sub>S<sub>2</sub>: C, 17.64; H, 3.95; sapn. equiv., 102.1. Found: C, 17.83; H, 3.87; sapn. equiv., 103.6.

**Methallyl Mesylate.**—This compound was prepared by heating 10.2 g. (0.05 mole) of silver methanesulfonate and 6.4 g. (0.07 mole) of methallyl chloride in 50 ml. of acetonitrile for one hour; yield 6.1 g. (81%), *n*<sub>D</sub><sup>20</sup> 1.4468, b.p. 54–56° (0.02 mm.).

*Anal.* Calcd. for C<sub>5</sub>H<sub>10</sub>O<sub>3</sub>S: C, 39.98; H, 6.71; S, 21.35; sapn. equiv., 150.2. Found: C, 40.39; H, 6.60; S, 20.95; sapn. equiv., 151.5.

**Benzyl Mesylate.**—This ester was prepared from 11.2 g. (0.055 mole) of silver methanesulfonate and 8.5 g. (0.05 mole) of benzyl bromide. The product decomposed on attempted distillation, and the data reported here were obtained from the crude sample; yield 8.6 g. (92%), *n*<sub>D</sub><sup>20</sup> 1.5199.

*Anal.* Calcd. for C<sub>8</sub>H<sub>10</sub>O<sub>3</sub>S: C, 51.59; H, 5.41; S, 17.22; sapn. equiv., 186.2. Found: C, 52.42; H, 5.51; S, 17.32; sapn. equiv., 183.9.

**Methylene Bis-tosylate.**—A solution of 14.0 g. (0.05 mole) of silver *p*-toluenesulfonate and 6.0 g. (0.023 mole) of methylene iodide in 50 ml. of acetonitrile was heated under reflux for 24 hours. The product was worked up in the same manner as methylene bis-mesylate. The crystalline solid was recrystallized from absolute ethanol, yield 7.0 g. (87%), m.p. 116–117°.

*Anal.* Calcd. for C<sub>18</sub>H<sub>16</sub>O<sub>6</sub>S<sub>2</sub>: C, 50.55; H, 4.53; S, 17.99; sapn. equiv., 178.2. Found: C, 50.27; H, 4.44; S, 17.61; sapn. equiv., 182.1.

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## Estimation of Entropy

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Various methods furnish estimates of the standard entropy of a compound with an uncertainty of a few entropy units. A better estimate can be obtained for the members of a substitution series such as CH<sub>4</sub>, CH<sub>3</sub>Cl, . . . , CCl<sub>4</sub> if the standard entropies of two members are known.

Figure 1 shows that the translational and vibra-

(1) This work was carried out under Army Ordnance Contract W-01-021-ORD-334.

(2) C. M. Suter, "The Organic Chemistry of Sulfur," John Wiley and Sons, Inc., New York, N. Y., 1944, p. 514.

(3) We are indebted to Mr. Al Kennedy and Miss Annie Smalley for analytical data.