sulfide was complete. After filtration, the filtrate was evaporated *in vacuo* to yield a yellow sirup which was used directly for the next step in the synthesis.

In another similar preparation, the sirup was treated with absolute alcohol and anhydrous ether and allowed to crystallize in an icebox. The small amount of crystalline material separating was recrystallized from *n*-butanol–ether, needles m. p. 134° dec. Due to the unstable nature of (II), satisfactory analytical figures were not obtained.

2-Mercapto-4(5)-methyl-5(4)-(β-hydroxyethyl)-imidazole (III)[8] was obtained in good yield from the unstable crystalline (II). More conveniently it was prepared as follows: The crude sirup resulting from the reduction of 14 g. of (I) was taken up in 50 cc. of ethanol, 10 g. of potassium thiocyanate and 10 cc. of water were added and the mixture was heated for two hours in a bath maintained at about 60°. The reaction mixture was transferred to an evaporating dish, evaporated at about 50° and the residual dry yellow powder extracted with hot alcohol. The extracts were evaporated to a sirup which was taken up in a small amount of water and the solution allowed to stand in the icebox. After two days 9.6 g. of substantially pure (III) had crystallized out (56% from (I)), m. p. 201° from *n*-butyl alcohol, absorption maxima at 263 mμ, 209 mμ, minimum at 230 mμ (in water).[9]

Anal. Calcd. for $C_6H_{10}N_2OS$: C, 45.54; H, 6.37; N, 17.71. Found: C, 45.64; H, 6.41; N, 17.60.

Mother liquors from various preparations of (I) (60 g. of oil and crystals) were reduced essentially as given above and, after detinning and evaporation, the residue (containing large amounts of ammonium chloride) was heated for twenty-four hours with 60 g. of potassium thiocyanate and 65 cc. of water in a bath maintained at 100°. After evaporation the reaction mixture was extracted with 250 cc. of hot absolute alcohol, the extract cooled and filtered from potassium thiocyanate. After concentration to about 150 cc., an additional amount of potassium thiocyanate was filtered off and the filtrate seeded; after reworking of the mother liquors a total of 16 g. of (III) was obtained.

4(5)-Methyl-5(4)-(β-hydroxyethyl)-imidazole (IV).—To a solution of 3.2 g. of crude (III) dissolved in 100 cc. of water was added a solution of 19.6 g. of anhydrous ferric chloride[10] in 100 cc. of water. After heating the mixture at 100° for one-half hour, 300 cc. of sodium carbonate solution was added and after filtration the filtrate was concentrated *in vacuo*. The residue was extracted with two 100-cc. portions of hot absolute alcohol, the extract[11] evaporated to a small volume, 3.6 g. of picric acid added and the mixture heated and allowed to cool. The resulting picrate was recrystallized from alcohol; yield 3.0 g. (41%) m. p. 157.5°.

Anal. Calcd. for $C_{12}H_{13}N_5O_8$: C, 40.57; H, 3.69; N, 19.71. Found: C, 40.68; H, 3.61; N, 19.75.

The picrate was treated with dilute hydrochloric acid and the mixture extracted with ethyl acetate to remove picric acid. Next, excess sodium carbonate was added, the whole evaporated *in vacuo* and the residue extracted with hot absolute alcohol. After evaporation of the alcohol the residue was taken up in hot ethyl acetate and the ethyl acetate solution evaporated to a small volume. On long standing, crystals of (IV) separated, m. p. 96.5° from ethyl acetate (crystallization takes place very slowly); solution in water practically transparent above 250 mμ, $\lambda_{max.}$ 222 mμ, ε 6308,[12] character of spectrum not appreciably affected by *p*H change.

Anal. Calcd. for $C_6H_{10}N_2O$: C, 57.12; H, 7.99; N, 22.21. Found: C, 57.07; H, 7.76; N, 22.10.

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[9] 2-Mercaptoimidazole exhibited $\lambda_{max.}$ 252 mμ, 208 mμ, $\lambda_{min.}$ 223 mμ (in water); 2-ethylmercapto-4-methylimidazole $\lambda_{max.}$ 251 mμ, 224 mμ, $\lambda_{min.}$ 235 mμ (in water).

[10] Compare Pyman, *J. Chem. Soc.*, **99**, 2172 (1911).

[11] In other experiments (IV) was isolated directly from such extracts without going through the picrate.

[12] A sample of 4-methylimidazole was found to have $\lambda_{max.}$ 215 mμ (in water).

Nicotinic Acid Esters

BY JEROME G. KAUFMAN[1]

Esters of nicotinic acid can be obtained by direct esterification of reaction mixtures that result when nicotine, quinoline or β-picoline is oxidized in the liquid phase. This direct synthesis is of interest because of the importance of these esters as intermediates in the preparation of the widely used nicotinamide. In addition, the esters, since they are capable of hydrolytic conversion to nicotinic acid in the body, can be classified as biologically active pyridine derivatives. It has been demonstrated that ethyl nicotinate, when administered orally, exhibits anti-black-tongue activity.[2]

This Laboratory[3] has shown that good yields of nicotinic acid are obtained when nicotine, quinoline or β-picoline is oxidized by concentrated sulfuric acid in the presence of mercuric sulfate or selenium. In order to isolate the nicotinic acid formed, the sulfuric acid, always used in excess, is neutralized, and the product is precipitated as copper nicotinate. The latter is then converted to nicotinic acid in the usual way. If nicotinic acid esters were desired, it was necessary to esterify by any of the known methods.[4,5,6,7]

Experimental

Methyl Nicotinate.—A mixture of 650 cc. of 95% sulfuric acid, 75 g. of selenium and 129 g. (1 mole) of quinoline was heated together for one hour. The maximum temperature attained was 300°. During this time 240 cc. of water was distilled over. To the cooled mass was added 300 cc. of methanol, after which the mixture was refluxed for six hours on the steam-bath. The reaction mixture was then poured onto three times its volume of cracked ice, made alkaline with ammonium hydroxide, and extracted with ether. The combined ether extracts were washed with water and dried over anhydrous potassium carbonate. After the ether was removed, the product was vacuum-distilled. It yielded 82.5 g. of methyl nicotinate (b. p. (3 mm.) 70–72°), which immediately crystallized to beautiful white crystals in the receiver (m. p. 38°). The yield was 60.2%.

Ethyl Nicotinate.—With essentially the same procedure as described for methyl nicotinate, 83 g. of ethyl nicotinate (b. p. (4 mm.) 72–74°) was obtained; this yield was 55%.

Propyl Nicotinate.—Substitution of *n*-propyl alcohol for the methanol and ethanol used in the preceding experi-

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[1] Present address: Van Ameringen-Haebler, Inc., Elizabeth, N. J.

[2] Woolley, Strong, Madden and Elvehjem, *J. Biol. Chem.*, **124**, 715 (1938).

[3] Woodward, Badgett and Kaufman, *Ind. Eng. Chem.*, **36**, 544 (1944).

[4] Pollak, *Monatsh.*, **16**, 46 (1895).

[5] Engler, *Ber.*, **27**, 1787 (1894).

[6] Camps, *Arch. Pharm.*, **240**, 353 (1902).

[7] LaForge, THIS JOURNAL, **50**, 2477 (1928).

ments resulted in the formation of 93.5 g. of *n*-propyl nicotinate (b. p. (1 mm.) 80–82°). This represented a yield of 56.7%.

Nicotine and *β*-picoline behaved in a similar manner and gave yields of the esters in direct proportion to their ease of oxidation to nicotinic acid.[3]

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Dehydration of Tetrahydrofurfuryl Alcohol[1]

BY CHARLES HOWARD KLINE, JR.,[2] AND JOHN TURKEVICH

In the course of study of the catalytic synthesis of pyridine from furfural derivatives, the dehydration of tetrahydrofurfuryl alcohol was investigated. Paul[3] has found that the dehydration of tetrahydrofurfuryl alcohol over alumina results in the formation of 1,2-dihydropyrane, C_5H_8O, but did not investigate in detail the yields produced due to variation in temperature, contact body or lifetime of the catalyst.

The materials and experimental procedure were the same as those described by the authors in the publication of the catalytic synthesis of pyridine.[4]

Over alumina it was found that tetrahydrofurfuryl alcohol is unattacked at 250° but is readily dehydrated at 300 and 350°. The latter temperature is the optimum temperature for the dehydration and yields about 70% dihydropyrane. At 400° and above, high boiling material is chiefly formed and much of the feed alcohol is lost either as cracked gases (19% carbon dioxide, 57% unsaturates, 13% hydrogen and 11% saturated hydrocarbons) or catalyst deposit. Condensation of the tetrahydrofurfuryl alcohol residues appears to predominate at these temperatures. The alumina catalyst did not lose activity at 300° and at 350° the activity fell only moderately during four days of continuous operation. In all cases carbonaceous material was left on the surface of the catalyst. It is of further interest that at 300° the dehydration of tetrahydrofurfuryl alcohol poisoned the subsequent dehydration of absolute ethanol even though it did not poison *further* dehydration of the tetrahydrofurfuryl alcohol. Undoubtedly the tetrahydrofurfuryl alcohol poisons the catalyst for ethanol dehydration by being strongly adsorbed on the surface. This view is confirmed by the fact that only fifteen minutes after the start of the reaction, does the product come out of the catalyst exit tube. Further confirmation is the forty-degree rise in temperature of the catalyst bed on the introduction of the tetrahydrofurfuryl alcohol. This is to be contrasted with a nine degree rise when the ammonia is simultaneously introduced.

Over silica, tetrahydrofurfuryl alcohol is stable up to 400°, at which point some decomposition sets in. Dihydropyrane was not the only product of the reaction but there was material boiling below and above this substance. At 450° about 20% water was formed and most of the non-aqueous product appeared as high boiling still residues.

Over thoria, tetrahydrofurfuryl alcohol was stable up to 450°. The low-boiling material collected during the 550° run polymerized on standing and had a sharp odor. These facts and its boiling point suggest that it may have consisted of pentenes and pentadienes. It should be pointed out that the recovery of tetrahydrofurfuryl alcohol was high. The inactivity of the thoria for the dehydration was not due to its general lack of catalytic activity. After revivification following the 450° run, the catalyst could be used to dehydrate anhydrous ethanol. One is thus faced with the interesting fact that on alumina the efficient dehydration of tetrahydrofurfuryl alcohol poisons the alumina for the dehydration of ethanol, while on thoria the inefficient dehydration of tetrahydrofurfuryl alcohol does not poison the dehydration of ethanol.

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(2) Ensign, U. S. N. R.

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A Relation between Viscosity and Refractive Index

BY R. T. LAGEMANN

During an attempt to estimate the viscosity of higher members of some homologous series, it was noted that the viscosity and the refractive index for liquids are functionally related. A linear relation is found to hold for every homologous series if the molecular refraction R is plotted against the viscosity constant I, which is defined by Souders[1] as

$$I = \frac{M}{d}\{\log_{10}(\log_{10}\eta) + 2.9\}$$

where η is the viscosity in millipoises. For such a plot and for determining the constants of the equations, data for I may be obtained from Souders[1] and values of R from Eisenlohr,[2] Herz[3] and the Landolt–Börnstein tables.

In Table I are given the values of the constants a and b as calculated for several series by the method of least squares on the assumption that $I = aR + b$. From this table it may be seen that the slopes are very nearly identical for all the series examined, while the intercepts vary. That linear curves represent the relations very well may be deduced from the fact that use of the constants of Table I allows one to calculate values of I averaging within $^1/_3$ of one per cent. of the experimental values. As a consequence, if the density and molecular weight of a liquid belonging to any of the series of Table I are known, the viscosity

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