The purified compound was obtained in the form of light yellow amorphous powder, easily soluble in water, and stable in solution as well as in solid form. When it is exposed for a long time to the action of direct sunlight, it changes its color from yellow to greenish-gray. The solution is yellow in color when dilute, cherry-red when concentrated, and has a ferruginous taste. It is acid to litmus, and can be neutralized and even made distinctly alkaline to litmus by adding sodium carbonate or sodium hydroxide, without precipitating iron. When the solution was titrated with sodium hydroxide, using an external indicator, the amount of alkali closely correponded to the amount necessary for the formation of a sodium salt of basic ferri-gluconic acid, which can be isolated from a neutralized solution by precipitation with alcohol. The usual quantitative tests show that the iron in our compound is in ferric condition.

Elementary analysis and other experimental evidence suggests that the compound is a basic ferri-gluconic acid rather than one in which the iron is attached to the chain with all three valences, as in the complex iron and barium compounds of certain polyhydroxy alcohols and acids prepared by Traube, Kuhbier and Harting [*Ber.*, **66**, 1545 (1933)].

Anal. Calcd. for $C_6H_{13}O_9Fe$: C, 25.28; H, 4.60; Fe, 19.61. Found: C, 25.86; H, 4.61; Fe, 19.60.

The position of the iron in the chain is as yet not definitely determined. There is evidence of intermediate compounds containing sulfur being formed in the course of the reaction, the mechanism of which we continue to study.

Clinical tests of the compound have proved it to be of definite value in the treatment of secondary anemia.

RESEARCH LABORATORY A. PROSKOURIAKOFF
DEPARTMENT FOR DISEASES OF THE CHEST
JEFFERSON HOSPITAL R. J. TITHERINGTON
PHILADELPHIA, PENNSYLVANIA

RECEIVED FEBRUARY 19, 1934

THE VALIDITY OF FREUDENBERG'S DISPLACEMENT RULE

Sir:

The importance of Freudenberg's displacement rule, especially as it is founded on optical dispersion and absorption spectra, cannot be overemphasized; for it permits the determination of the optical configuration of such substances as α-chloropropionic acid [W. Kuhn, Freudenberg and Wolf, *Ber.*, **63**, 2367 (1930)] and methyl-tertiary-butylcarbinol [Stevens, THIS JOURNAL, **55**, 4237 (1933)] when direct chemical methods fail due either to Walden inversion or to rearrangement.

Recently Levene and Meyer [*ibid.*, **56**, 244 (1934)] reported to have found two legitimate exceptions to the displacement rule. Obviously, any such exceptions would throw doubt on the validity of the configurations of the substances mentioned above. For this reason the pertinent part of Levene and Meyer's work has been carefully repeated with the result that their first exception has been found to be incorrect.

TABLE I

$[M]_D^{25}$

	Free acid	Ethyl ester	*p*-Nitrophenyl ester	
1 $C_2H_5—CH[CH_3]—COOH$	−18.0	−22.9	−52.5	
2 $C_4H_9—CH[CH_3]—COOH$	−24.3	−30.7	−65.7	
3 $C_2H_5—CH[CH_3]—CH_2—COOH$	−10.4	−11.5	−20.0	
4 $C_3H_7—CH[CH_3]—CH_2—COOH$	+ 3.6	+ 0.7	+ 5.0	**−5.4**
5 $C_5H_{11}—CH[CH_3]—CH_2—COOH$	+ 8.1	+ 4.2	+11.2	

The table contains the values found by Levene and Meyer for the rotations of five configurationally related acids and esters. The corrected value as determined by the author for the rotation of the *p*-nitrophenyl ester of methylpropylpropionic acid [No. 4 in table] is in bold-faced type. According to this corrected value, the shift in rotation, as evidenced by the change in sign on passing from the ethyl to the *p*-nitrophenyl ester is in complete accord with the displacement rule.

An investigation of Levene and Meyer's second exception, that of methylamylpropionic acid and esters [No. 5 in table] is now in progress.

Levo β-Methyl-β-propylpropionic Acid.—The acid was prepared from 2-bromopentane and ethyl malonate and resolved with cinchonidine according to the directions of Levene and Marker [*J. Biol. Chem.*, **91**, 77 (1931)]. After resolution the acid was dissolved in aqueous sodium carbonate and washed with alcohol-free ether. The solution was then acidified, and the acid extracted with alcohol-free ether: b. p. (17 mm.) 113.5–114.5°, (bath 150°). This material was redistilled: b. p. (14 mm.) 109.0–109.5° (bath 142°), α_D^{25} −1.53°, $[M]_D^{25}$ −2.19°, d_4^{25} 0.9111, n_D^{25} 1.4190, *Molecular Refraction.* Calcd. 36.06; found 36.06.

Dextro *p*-Nitrophenyl Ester of Levo β-Methyl-β-propylpropionic Acid.—Ten grams of the acid [α_D^{25} −1.53°] was treated with 30 cc. of redistilled thionyl chloride. The mixture was boiled for two hours on the steam-bath, and then allowed to stand overnight. The next morning the excess thionyl chloride was removed *in vacuo*. Dry benzene was added and the material again boiled out *in vacuo*. This was done three times. The resulting colorless acid chloride was taken up in benzene and added to a benzene suspension of 12.3 g. of sodium *p*-nitrophenoxide. Considerable heat was evolved at the outset. The reaction was completed by boiling for two and one-half hours on the steam-bath. The mixture was then cooled, thoroughly extracted with water, aqueous sodium carbonate and water, dried over sodium sulfate and evaporated *in vacuo* at 95°. The crude phenolic ester, 15.5 g., yield 80%, was distilled in a Hickman molecular still at 0.001 mm. (bath 100°) taking two fractions, (A): α_D^{24} +1.51°, n_D^{25} 1.5106; (B) α_D^{24} +1.20°, n_D^{25} 1.5114. There was almost no residue. (A) and (B) were combined and redistilled in a Claisen flask yielding (C): b. p. (0.3 mm.) 128–135° (bath 176°), α_D^{23} +1.51°, d_4^{25} 1.1128, n_4^{25} 1.5109, and a residue (1 cc.) α_D^{23} +0.70°, n_D^{25} 1.5120. The former (C) was then separated into two fractions at 0.15 mm. (bath 160°), (E) b. p. 118–123°, $\alpha_D^{23.5}$ +1.52°, n_D^{25} 1.5114; (F) b. p. 124–125°, α_D^{23} +1.45°, $[M]_D^{25}$ +3.27°, $[M]_D^{25}$ max. +5.4°, d_4^{25} 1.1121, n_D^{25} 1.5113. Fractions (E) and (F) were light yellow and gave only a weak Beilstein test for halogen. The residue (0.5 cc.) was orange, dextrorotatory and gave a stronger Beilstein test for halogen.

Anal. (micro). Calcd. for $C_{13}H_{17}O_4N$: C, 62.12; H, 6.82; N, 5.58. Found: Fraction C: C, 62.00; H, 6.82; N, 5.52. Fraction F: C, 62.22; H, 6.66; N, 5.63.

Sodium *p*-Nitrophenoxide.—This salt was thrice recrystallized from water, dried at 120° *in vacuo* for twenty-four hours and allowed to cool *in vacuo* over phosphorus pentoxide. It was bright red and when hydrolyzed with dilute hydrochloric acid, formed *p*-nitrophenol, m. p. 110–112°.

THE RESEARCH LABORATORY OF ORGANIC CHEMISTRY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CONTRIBUTION NO. 109 PHILIP G. STEVENS

RECEIVED MARCH 15, 1934

SOME PROPERTIES OF HEAVY WATER

Sir:

Experience gained in the production of comparatively large quantities of heavy water leads us to believe that the maximum density attainable by the electrolytic method is somewhat greater than that reported by Lewis and Macdonald [THIS JOURNAL, **55**, 3057 (1933)] for water containing less than 0.01% light hydrogen. Lewis and Luten [*ibid.*, **55**, 5061 (1933)] state the ratio of specific gravities of heavy and light waters at 25° to be 1.1056. We find d_{25}^{25} 1.1079. We also find the difference in refractive indices to be −0.00462 at 20° for the sodium D line.

Such water, of which we have prepared over 100 cc., has been subjected to prolonged electrolysis in order to determine whether any further increase in density takes place. For this purpose 25 cc. of maximum density water was placed in a carefully dried cell with 2% pure NaOD. The electrolytic gas was passed through a trap to remove spray and was ignited at a minute nozzle. The recovered water was not allowed to come into contact with the atmosphere. The density of the recovered water was taken at approximately 1-cc. intervals. The densities plotted against total weight recovered are shown in Fig. 1. Some time after constant density had been reached, the residual water in the cell was removed and repeatedly distilled. The density d_4^{20} was 1.1059. The fact that only 95% heavy water was obtained in the first 2 cc. illustrates the extreme readiness with which pure D_2O takes up moisture from the air and possibly from the glass walls of the apparatus. A cc. of water d_4^{20} 1.1038 was exposed to the atmosphere overnight and the density fell to 1.1016. Pure D_2O must be handled like any other anhydrous liquid.

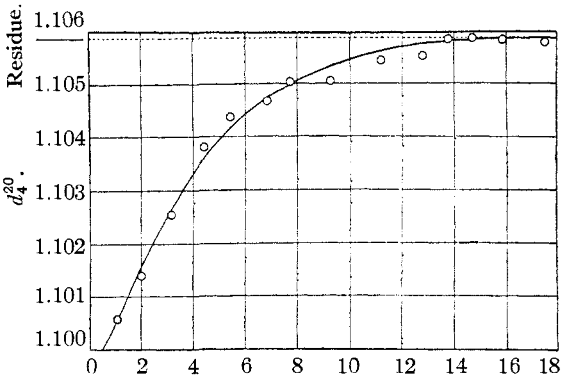

Fig. 1.—Density of recovered water in prolonged final electrolysis.

The ratio of the specific rates of discharge of light and heavy hydrogen at these high concentrations is about 6, which in view of the fairly large probable error cannot be considered as sensibly different from that obtaining throughout the more dilute stages of the process with either iron or nickel electrodes.

We find the freezing point of our maximum density water to be 3.82°, and the viscosity at 20°, 12.6 millipoises. An earlier report on the viscosity by Selwood and Frost [THIS JOURNAL, **55**, 4335 (1933)] was marred by an unfortunate error in calibration.

It may be of interest to add that prolonged fractional freezing of 90% D_2O has yielded no concentration. This is the result to be expected