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S. G. Measamer
Iowa State College

O. R. Sweeney
Iowa State College

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ESTIMATION OF THE COMPOSITION OF THREE-COMPONENT LIQUID MIXTURES

S. G. MEASAMER AND O. R. SWEENEY

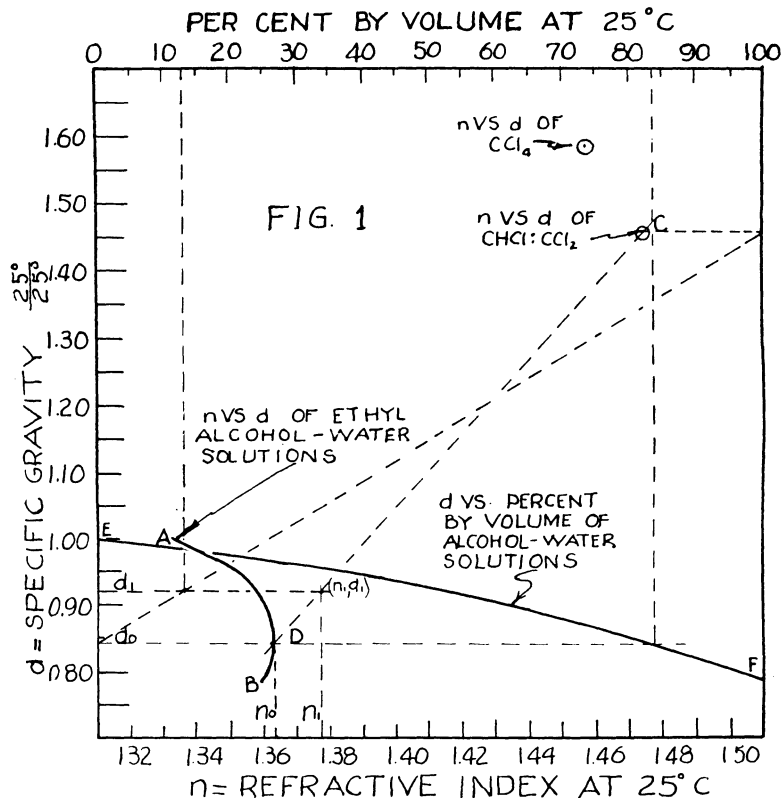
While carrying out research on the extraction of oil from soybeans using mixtures of various solvents, it was quite often necessary to know the composition of a mixture of liquids containing three components. A search of the literature for ways of obtaining the composition of such mixtures by the use of physical constants revealed a very convenient method employing a combination of density and refractive index. Before this method can be used, however, solutions covering the entire ternary system must be made up accurately, their refractive indices and densities taken and plotted in such a manner that the composition of solutions of constant refractive index and solutions of constant specific gravity can be determined. Finally a triangular diagram must be constructed showing the lines of constant refractive index and constant specific gravity as related to the composition (1, 2).

It can be seen that the work required for such a procedure is considerable and would be extremely time-consuming if as many as half a dozen systems were to be analyzed.

Since a great deal of work was done on the use of mixtures of ethyl alcohol and trichlorethylene in the extraction of oil from soybeans, it was necessary to know if the moisture from the beans would accumulate in the solvent as it was recovered and reused in a continuous extraction process. In order to check the composition of the recovered solvent a chart was made up as described in the foregoing paragraphs covering a portion of the system trichlorethylene-ethanol-water. However on plotting the specific gravities and refractive indices of various binary mixtures it was noticed that the per cent by volume of one of the components was often a linear function, or approximately a linear function, of both the refractive index and the specific gravity. Examples are the binary systems ethanol-trichlorethylene, methanol-trichlorethylene, soybean oil-trichlorethylene and soybean oil-carbon tetrachloride. Also, in the ternary system trichlorethylene-ethanol-water, it was noted that the per cent by volume of trichlorethylene in solutions containing water and ethanol in a constant ratio, when plotted against specific gravity and refractive index, gave straight lines.

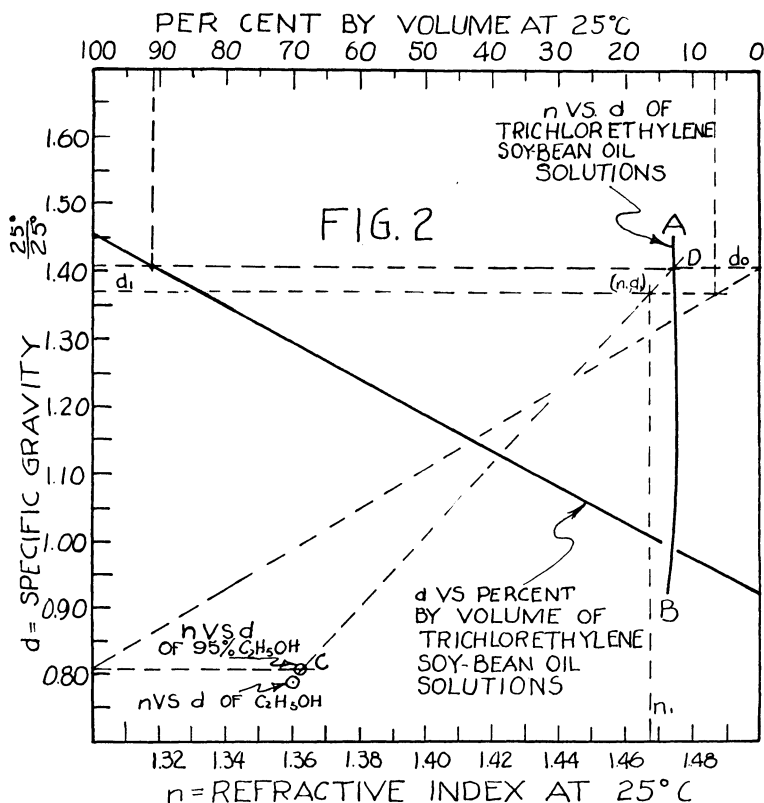
By making use of the relationships just stated, it is an easy matter to construct a diagram from which one can obtain a close approximation of the composition of any single phase mixture of a number of ternary systems knowing the refractive index and specific gravity of the mixture in question. The procedure employed, using the system trichlorethylene-ethanol-water as an illustration, is as follows.

Since both the specific gravity and the refractive index are linear functions of the per cent trichlorethylene in solutions containing a constant ratio of alcohol to water, the specific gravity of such solutions will be a linear function of the refractive index. A plot of specific gravity against refractive index of mixtures of water and ethanol containing no trichlorethylene is first made and is shown in figure 1 as curve AB. The data for this curve can be obtained from hand books. The point representing the specific gravity and refractive index of trichlorethylene is plotted and is shown as point C. Conveniently placed on the same diagram one can lay out a



per cent scale calibrated from 0 to 100 per cent and the per cent by volume of ethanol in ethanol-water solutions can be plotted against specific gravity. This plot is shown in figure 1 as line EF. This same per cent scale is used to graphically obtain the per cent trichlorethylene by volume as will be explained later.

Consider a solution of unknown composition. The refractive index and specific gravity are determined and these values, designated by n_1 and d_1 respectively are plotted on the diagram as point (n_1, d_1) . Through this point and through point C a line is drawn intersecting curve AB at point D. Point D represents the specific gravity d_0 and the refractive index n_0 of a solution of ethanol and water containing no trichlorethylene and having the same ratio of alcohol to water as in the unknown solution, because, as was explained before, the specific gravity is a linear function of the refractive index in mixtures of trichlorethylene, ethanol and water in which the ratio of alcohol to water is constant. This ratio in the unknown solution can be determined by locating the intersec-



tion of d_0 with the per cent vs. specific gravity curve of ethanol and water. In order to obtain the per cent trichlorethylene, one can now assume that a binary mixture is present in which one component is a mixture of ethanol and water and the other component is pure trichlorethylene. Since the per cent by volume of trichlorethylene in this mixture is a linear function of the specific gravity, a line drawn from the specific gravity of the pure ethanol-water mixture, d_0 , on the 0 ordinate of the per cent scale to the specific gravity of pure trichlorethylene on the 100 per cent ordinate will intersect the specific gravity line, d_1 , on the ordinate representing the per cent trichlorethylene by volume in the solution.

The diagram can be used to estimate the composition of other ternary systems such as carbon tetrachloride-ethanol-water. It is only necessary to plot the point representing the specific gravity and refractive index of carbon tetrachloride on the same diagram. The procedure for obtaining the composition is exactly the same as outlined above except the point representing the specific gravity and refractive index of carbon tetrachloride is now taken as point C instead of the point representing the specific gravity and refractive index of trichlorethylene.

A similar diagram for determining compositions in the system trichlorethylene-soybean oil-ethanol is shown in figure 2. Line AB here represents the plot of the specific gravity against refractive

Table I. The Composition of Various Ternary Mixtures as Made up Compared to the Composition Given by the Use of the Diagrams Explained in This Paper

<i>Composition as made up Percentage by Volume</i>			<i>Composition Given by Diagrams Percentage by Volume</i>		
<i>Trichlorethylene-ethanol-water</i>					
Tri	Alcohol	Water	Tri	Alcohol	Water
9.41	81.5	9.09	9.5	81.0	9.5
7.85	75.3	16.85	7.5	73.8	18.7
6.05	65.7	28.25	5.8	64.5	29.7
1.08	49.42	49.5	1.3	49.3	49.3
<i>Carbon tetrachloride-ethanol-water</i>					
CCl ₄	Alcohol	Water	CCl ₄	Alcohol	Water
10.4	76.6	13.0	10.7	75.5	13.9
10.7	67.2	22.1	10.2	65.7	24.1
3.85	54.2	42.0	3.3	55.0	42.7
<i>Trichlorethylene-soybean oil—95 per cent ethanol</i>					
Tri	Oil	Alcohol	Tri	Oil	Alcohol
65.6	17.4	17.0	66.7	16.7	16.6
60.0	9.0	31.0	60.6	9.1	31.5
47.9	3.6	48.5	48.5	3.2	48.4
37.5	6.7	55.8	37.1	7.4	55.6
80.5	7.0	12.5	80.0	8.0	12.0

index of mixtures of trichlorethylene and soybean oil. Point C represents the specific gravity and refractive index of 95 per cent ethyl alcohol. The point representing the specific gravity and refractive index of absolute ethyl alcohol is also shown. Thus figure 2 can be used to estimate the composition of any single phase mixture of the systems trichlorethylene-ethanol-soybean oil and trichlorethylene-95 per cent ethanol-soybean oil. Other points may be added to figure 1 and figure 2 to provide means of estimating the composition of a great many ternary systems.

Table I shows a comparison of the compositions of various ternary mixtures as made up to the compositions given by use of the diagrams explained in this paper. The specific gravities were taken by means of a Westphal balance. The refractive indices were taken with an Abbe refractometer. The diagrams used were constructed on ordinary 8.5 in. by 11 in. coordinate paper. The diagrams included in this paper are reduced for publication making them unsuited for anything but explanatory purposes.

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DEPARTMENT OF CHEMICAL ENGINEERING,
IOWA STATE COLLEGE,
AMES, IOWA.