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SALT EFFECTS IN LIQUID-LIQUID EQUILIBRIA

BY

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A THESIS
PRESENTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE
OF
DOCTOR OF ENGINEERING SCIENCE
IN CHEMICAL ENGINEERING
AT
NEWARK COLLEGE OF ENGINEERING

Newark, New Jersey
1964

APPROVAL OF THESIS

FOR

DEPARTMENT OF CHEMICAL ENGINEERING

NEWARK COLLEGE OF ENGINEERING

BY

FACULTY COMMITTEE

APPROVED: ______________________________

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Newark, New Jersey
June, 1964

ABSTRACT

The effect of lithium chloride, sodium chloride and potassium chloride on the distribution of acetic acid, propionic acid and butyric acid between benzene and water at 25° C has been studied. The method of Hand, which has previously been used to correlate tie line data in salt-free ternary systems, has now been successfully employed to correlate distribution data for quaternary systems containing salt.

The slope and intercept of the Hand equations have been expressed as linear functions of the salt concentration in each system studied. Equations for slope and intercept possessing high statistical significance have been formulated using a linear regression in two variables.

The order of decreasing salting out on a weight basis is

$$\mathrm{LiCl} > \mathrm{NaCl} > \mathrm{KCl}$$

for all systems studied. On a mole basis, the effect of lithium chloride diminishes with increase in the number of carbon atoms in the acid, being greater than sodium chloride for acetic acid, equal to sodium chloride for propionic acid, and less than sodium chloride for butyric acid.

ACKNOWLEDGEMENT

The author expresses his sincere appreciation to his thesis adviser, Dr. Joseph Joffe. His encouragement, guidance, and many excellent suggestions during this investigation have been invaluable and have contributed greatly to the quality of this thesis.

Dr. Saul I. Kreps and Dr. John E. McCormick have made suggestions for the interpretation of the results of these studies, and their assistance is gratefully acknowledged.

The author also acknowledges the help of his mother, Mrs. Gustav Eisen, his fiancee, Miss Ann MacKay, and Mr. Donald W. Hagedorn in various parts of this work.

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INTRODUCTION

The unit operation liquid extraction has rapidly assumed major industrial significance as a means of separating the components of a solution. It is of particular utility where the components to be separated have comparable volatilities, are heat sensitive, are relatively non-volatile, or are present in grossly disproportionate quantities. In general, liquid extraction is applied to the separation of molecules of different chemical types, while distillation is used to separate molecules of different size or weight.

The solubility of many organic substances in water is materially decreased by the presence of dissolved inorganic salts. This fact has been applied in the laboratory but has found little industrial use. A reduction in the size and cost of equipment needed to effect a given separation is accompanied by increases in corrosion rate and the cost of salt and its associated handling equipment. The decision to use salt to improve a process must be based on economic considerations.

There is a dearth of quantitative data on the effects of salts on systems usually encountered in chemical engineering. Such data are, of course, necessary for economic evaluation and optimization of extraction processes. In this thesis, the effects of salt on the distribution of three carboxylic acids between benzene and water are investigated and correlated.

SCOPE AND PURPOSE

The complete study of salt effects in ternary equilibria would necessarily involve the use of every element in the periodic table. However, many elements are too expensive to be of practical use. This study may be divided into several sections which will enable the investigator to observe trends within that particular section. These trends may then be compared with other work so that the effect of position in the periodic table on the degree of salting out by a particular element may be determined. It is desirable to correlate the results in a manner which would allow convenient prediction of the effect of salt concentration on the salting out efficiency of a given salt.

The effects of each of three salts on the distribution of each of three carboxylic acids between benzene and water are studied in this thesis. The three acids, acetic acid, propionic acid, and butyric acid, are completely miscible with water and with benzene at 25° C. Their analytical determination has been well established. Three alkali metal chlorides, lithium chloride, sodium chloride, and potassium chloride, are soluble in water and insoluble in benzene and may be readily determined analytically. Benzene, a non-polar liquid, and water, a polar liquid, are practically insoluble in each other.

TERNARY SYSTEMS

Ternary equilibria are usually reported in the scientific literature on equilateral triangular coordinates. Percentages of each component of a mixture may be read directly from this diagram. Since only a single size of such graph paper is ordinarily available and since this places a limit on the accuracy obtainable, the right triangle, two of whose sides coincide with the Cartesian coordinate axes, can be employed. Each scale may be expanded to any extent desired.

The most common method for constructing the solubility curve is the "synthetic" or "cloud point" method (10, 88). Mixtures of known composition of two liquids are titrated with the third to an appearance or disappearance of turbidity. A convenient property of the resulting mixture — density, viscosity, refractive index — is then determined. Tie lines are determined by formulating mixtures in the two-phase region and analyzing the conjugate solutions for the property previously studied. When tie line data is not necessary, the solubility curve may be constructed using a modified "cloud point" method (64).

Tie lines and the limiting solubility curve can be determined simultaneously if two of the three components of the system can be easily determined analytically. Alternatively, if the composition of the original mixture and the composition of one conjugate phase are completely known, the composition of the second phase can be determined by a material balance when only one component of the second phase is known.

Ternary systems may be classified on the basis of the number of partially miscible liquid pairs in the system. A type 1 system possesses one partially miscible liquid pair A-B, the pairs A-C and B-C being miscible in all proportions. In a type 2 system, two partially miscible liquid pairs, A-C and A-B exist, liquids B and C being miscible in all proportions. Typical ternary equilibrium diagrams and distribution graphs are shown in figures 1 and 2.

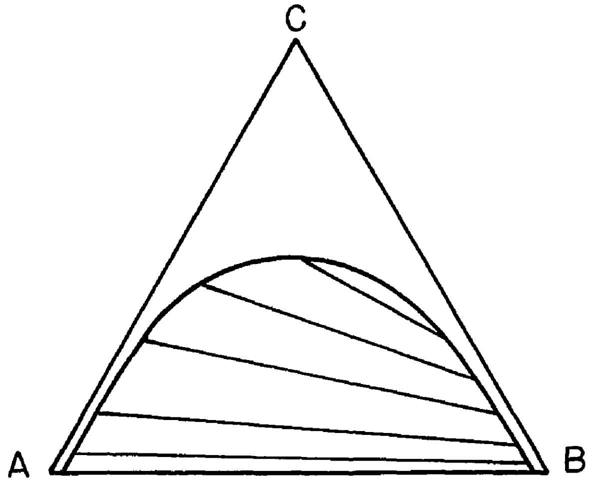
Several summaries of available ternary data have appeared (12, 77, 79, 80, 14, 92), and consultation with the original papers will give further information on special techniques used. Attention is directed to the recent book by Francis (29) which presents an extensive list of ternary and quaternary systems.

The following nomenclature convention will be used in this thesis. The pure components of which the phases are composed will be designated by the letters A, B, C, and D. The concentration in weight per cent will be designated by the letter X with two subscripts. The first subscript refers to the component whose concentration is indicated and the second to the major component of the solution under consideration.

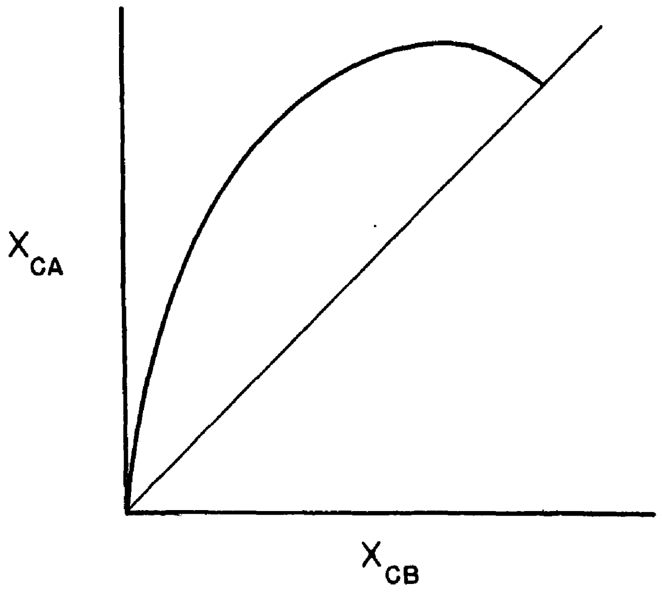
The significance of the first subscript, as employed in this

TERNARY LIQUID EQUILIBRIA

TYPE I SYSTEM



TRIANGULAR DIAGRAM

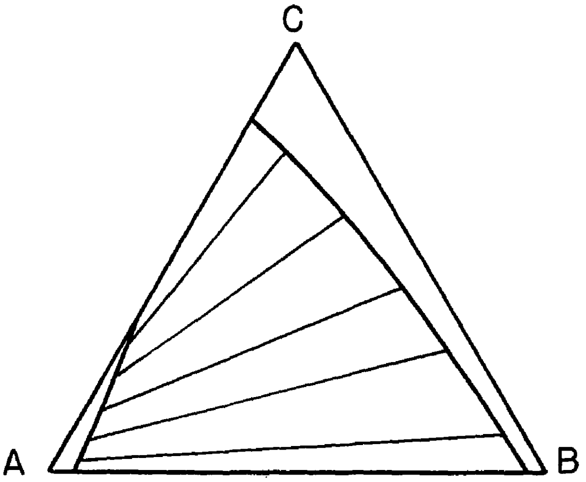


DISTRIBUTION CURVE

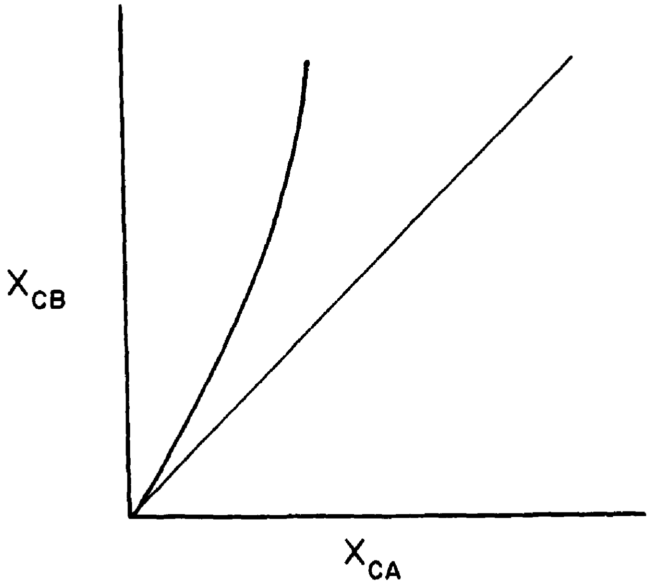
FIGURE I

TERNARY LIQUID EQUILIBRIA

TYPE 2 SYSTEM



TRIANGULAR DIAGRAM



DISTRIBUTION CURVE

FIGURE 2

thesis, is as follows:

A: water

B: benzene

C: acetic acid, propionic acid, or butyric acid

D: lithium chloride, sodium chloride, or potassium chloride

The second subscript refers to the following:

A: aqueous (water-rich) phase

B: organic (benzene-rich) phase

Thus, in the system propionic acid (C) - benzene (B) - water (A) - potassium chloride (D),

X_{CB} = weight per cent propionic acid in the benzene-rich (organic) phase

X_{AA} = weight per cent water in the water-rich (aqueous) phase

Tie line correlations fall into two general categories, graphical and mathematical. Treybal (90) presents an excellent summary of the graphical methods. In general, rather complete data are required for the application of these methods.

The simplest mathematical expression of the distribution law

$$\frac{X_{CA}}{X_{CB}} = K \qquad (1)$$

states that the distribution ratio K, at constant temperature, should be independent of the concentration of component C. In most systems, this is true only in dilute solutions. Nernst (62) ha s considered modifications to the distribution law for cases where association and dissociation occur.

Brancker, Hunter, and Nash (14) found that a recangular plot of X_{AA} against X_{BB} would yield straight lines for many systems, provided a special vertical X_{AA} scale was used. This scale was constructed so as to produce a straight line for the system acetic acid-benzene-water, which served as a reference system. Values of X_{BB} were plotted on a rectangular scale. Bachman (5) plotted X_{BB} against X_{BB}/X_{AA} on rectangular coordinates and was able to obtain straight lines for most of the systems considered. Brown (16) used a modification of Bachman's method, plotting X_{BB}/X_{AA} against X_{AA} to obtain straight lines. Conway and Philips (21) studied the system water-furfural-methyl isobutyl ketone, which has two partially miscible liquid pairs, and were able to correlate their results with a plot of X_{AA} against X_{BB}. Othmer and Tobias (63) showed that a plot of $\log \frac{1 - X_{AA}}{X_{AA}}$ against $\log \frac{1 - X_{BB}}{X_{BB}}$ gave straight lines for many systems. Bhat, Lu, and Johnson (8) used modifications of the Othmer and Tobias plots. Ishida (40) attempted to predict the value of the distribution coefficient from a modified Othmer and Tobias plot.

All the methods listed above permit the determination of the tie lines for a system when a minimum of two tie lines is known. Except for the correlation of Brancker, Hunter and Nash, all can be expressed mathematically by equations of the form $y = mx + b$, and thus eliminate the need for graphical presentation of tie line data. However, in none of these correlations is the distributed component C used in the coordinates.

Hand (37) showed that a plot of log X_{CA}/X_{AA} against log X_{CB}/X_{BB} will give a straight line whose equation is

$$\frac{X_{CB}}{X_{BB}} = a' \left[\frac{X_{CA}}{X_{AA}}\right]^{b'} \qquad (2)$$

Bachman (6), after careful studies, concluded that the Hand equation is not accurate in dilute regions.

Under conditions of immiscibility of components A and B, (X_{BA} and X_{AB} are very small), the Othmer and Tobias equation reduces to the Hand equation.

$$\frac{1 - X_{AA}}{X_{AA}} = b_1 \left[\frac{1 - X_{BB}}{X_{BB}}\right]^{n'} \qquad \text{(3) Othmer-Tobias equation}$$

$$X_{AA} + X_{BA} + X_{CA} = 1 \qquad \text{(4) A-phase material balance}$$

$$X_{AB} + X_{BB} + X_{CB} = 1 \qquad \text{(5) B-phase material balance}$$

$$1 - X_{AA} = X_{BA} + X_{CA} \approx X_{CA} \qquad \text{(4a)}$$

$$1 - X_{BB} = X_{AB} + X_{CB} \approx X_{CB} \qquad \text{(5a)}$$

Substituting in the Othmer-Tobias equation

$$\frac{X_{CA}}{X_{AA}} = b_1 \left[\frac{X_{CB}}{X_{BB}}\right]^{n'} \qquad \text{(6) Hand equation}$$

It must be pointed out that for a large number of systems, the Hand equation and the Othmer-Tobias equation both describe the data. In the special case of immiscible solvents, the equations are identical.

The Hand correlation was chosen for use in the present investigation because of its application to a large number of systems and because the concentration of the distributed component appears in the coordinates.

QUATERNARY SYSTEMS

The complete representation of four-component systems at constant temperature requires a space model. The regular tetrahedron and the right equilateral triangular prism have been employed to depict quaternary systems.

The right equilateral triangular prism has been used in two ways. In the first method, shown in Figure 3, one vertical edge of the prism represents mixtures of two components, while each of the other edges represents one of the remaining two components. The upper face (ABD) represents one ternary system while the lower face (ABC) represents a second. A triangular plane parallel to the base represents quaternary mixtures in which the ratio of components C and D is constant.

In the second method, shown in Figure 4, the percentage of the fourth component is plotted along the lateral edges of the prism perpendicular to the triangular base representing a ternary system. This method is similar to that used to show the effect of temperature on ternary equilibria. A triangular plane parallel to the base represents those quaternary mixtures having a constant percentage of D based on overall composition.

The regular tetrahedron has been used extensively to represent quaternary equilibria because it is less confusing and more convenient to handle than the right equilateral triangular prism. The regular tetrahedron and the equilateral triangle both

QUATERNARY LIQUID EQUILIBRIA

RIGHT EQUILATERAL TRIANGULAR PRISM

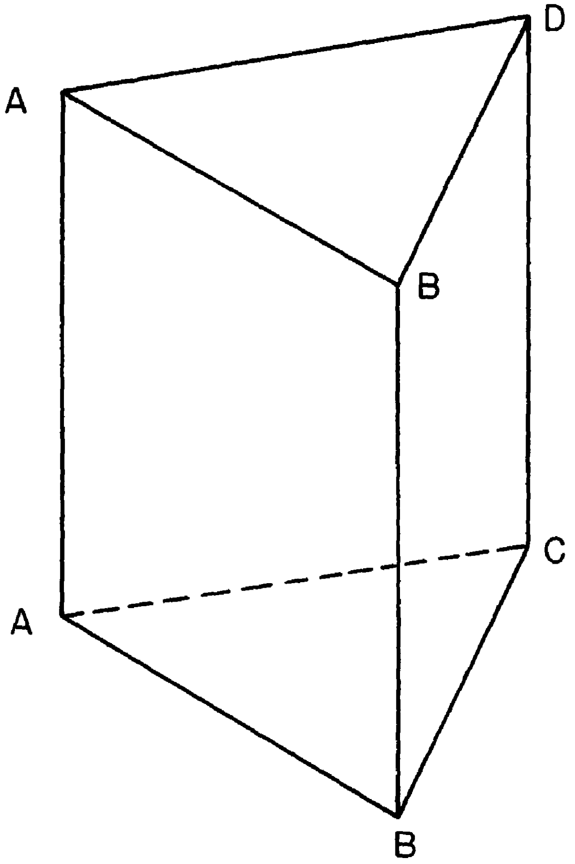


FIGURE 3

QUATERNARY LIQUID EQUILIBRIA

RIGHT EQUILATERAL TRIANGULAR PRISM

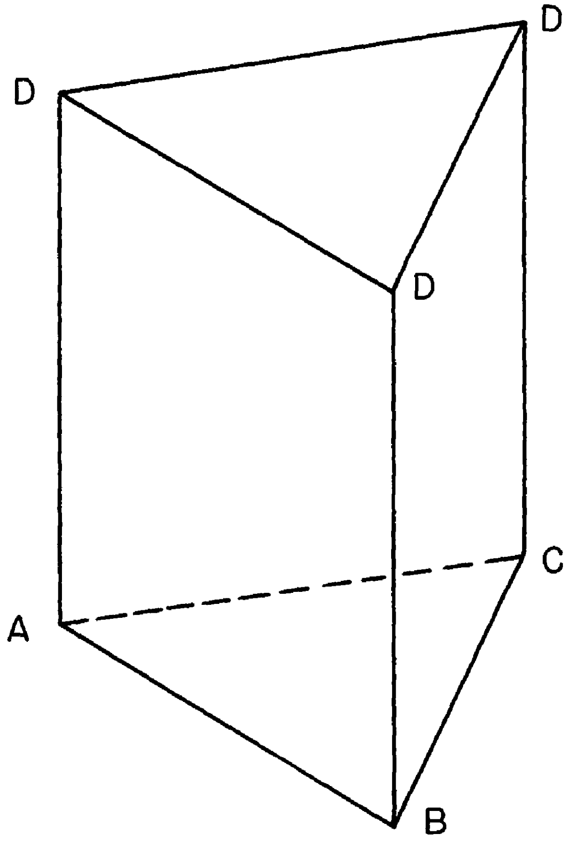


FIGURE 4

possess the geometrical property that the sum of the perpendiculars from any point within the figure to the sides of the figure is equal to the altitude.

Brancker, Hunter, and Nash (15) have studied the system chloroform-acetic acid-acetone-water and have represented their data by the three methods described above. They also present formulas which permit the projection of a point within the solid to be located on one plane of the solid.

Wiegand (99) has replaced the regular tetrahedron with a rectangular tetrahedron, three edges of which coincide with the three axes of a rectangular coordinate system and three faces of which are isosceles triangles. This enables the graphical method to be replaced by an analytical one, based on analytical geometry, with a consequent saving in time required for problem solving.

Cruickshank, Haertsch, and Hunter (23) have projected a regular tetrahedron onto a plane so that a square is formed. Quaternary extraction calculations can be readily performed using Cartesian rather than triangular coordinates.

Several attempts (66, 30, 39, 13) have been made to correlate quaternary equilibrium data with those of ternary systems, but no successful general method has been developed. Smith (78) has represented quaternary tie line data by means of plane graphs of logarithmetic form which permit accurate interpolations. However, construction of these graphs requires extensive data for the quaternary system, and further, the method cannot be employed to predict the quaternary from the ternary systems.

Chang and Moulton (19) have developed a procedure for systematically investigating quaternary equilibria. Representing their data by means of a regular tetrahedron, they were able to describe the inner quaternary two-phase region for several systems. Jodra, Otero, and Solé (41) used this procedure to investigate the system acetic acid-benzene-water-sodium chloride at 25° C.

DISTRIBUTION LAW

A third substance added to a system of two immiscible or slightly miscible liquids will distribute itself between these two liquids in a definite manner. Application of the phase rule to this three-component, two-phase system (the vapor is not in equilibrium) indicates three degrees of freedom. At a given temperature and pressure, specification of a single variable will determine the composition of the entire system.

The chemical potential μ of a substance must be the same in each of two phases in equilibrium. For phase 1

$$\mu_1 = \mu_1^o + RT \ln a_1 \qquad (7)$$

and for phase 2

$$\mu_2 = \mu_2^o + RT \ln a_2 \qquad (8)$$

Here μ_1 and μ_2 are the chemical potentials of the substance in phases 1 and 2 respectively; μ_1^o and μ_2^o are the chemical potentials in the standard state in phases 1 and 2; R is the gas constant; T is the absolute temperature; and a_1 and a_2 are the activities of the substance in the particular solvent phases. At any given temperature, μ_1^o and μ_2^o are constants for a given substance in the particular solvents. Hence,

$$\ln \frac{a_2}{a_1} = k_1 = \frac{\mu_1^o - \mu_2^o}{RT} \qquad (9)$$

since at equilibrium

$$\mu_1 = \mu_2 \qquad (10)$$

Equation 9 may be written in a simpler form

$$\frac{a_2}{a_1} = k_2 \qquad (11)$$

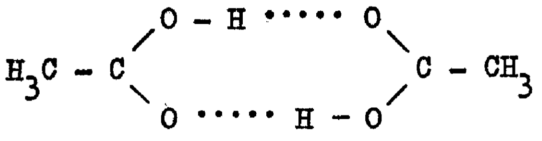
In dilute or ideal solutions, the activity is essentially equal to the concentration, and equation (11) becomes

$$\frac{X_2}{X_1} = K \qquad (12)$$

where X_1 and X_2 are the concentrations (moles per liter) of the distributed substance in phases 1 and 2 respectively.

Equation 12 is a mathematical statement of the distribution law, and the constant K is called the distribution coefficient (sometimes called the partition coefficient) of the solute between the two solvents. The law is valid only when the solute undergoes no molecular change, such as association or dissociation. When such a molecular change occurs, the law applies only to the concentrations of the particular species common to both phases.

The dissociation of acetic acid into hydrogen and acetate ions is well known, the dissociation constant at 25° C being 1.754×10^{-5} (see table 4). Acetic acid forms a dimer in benzene, hydrogen bonds being formed between the oxygen atom of the carbonyl group and the hydrogen atom of the hydroxyl group of a second molecule (65)



The distribution law applies only to the single molecules of acetic acid, which are common to both phases.

The equilibria involved are given below (32, 55, 58, 91):

Water phase

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+ \qquad (13)$$

$$[C_T]_A(1-\alpha) \qquad \alpha[C_T]_A \qquad \alpha[C_T]_A \qquad (14)$$

$$K_i = \frac{[C_T]_A\,\alpha^2}{1-\alpha} \qquad (15)$$

where K_i is the dissociation constant for acetic acid;

α is the degree of ionization; and

$[C_T]_A$ is the total concentration of acetic acid in the water-rich phase (moles per liter)

Benzene phase

$$CH_3COOH \rightleftharpoons \tfrac{1}{2}(CH_3COOH)_2 \qquad (16)$$

$$[C_T]_B(1-\alpha') \qquad \frac{\alpha'}{2}[C_T]_B \qquad (17)$$

$$K_{as} = \frac{\frac{\alpha'}{2}\,[C_T]_B^{\frac{1}{2}}}{(1-\alpha')\,[C_T]_B}$$

where K_{as} is the association constant for acetic acid in benzene;

α' is the degree of association; and

$[C_T]\,B$ is the total concentration of acetic acid in the benzene-rich phase (moles per liter).

Distribution

$$K = \frac{[C_T]_A\,(1-\alpha)}{[C_T]_B(1-\alpha')} \qquad (19)$$

Solving 19 for $[C_T]_B\,(1-\alpha')$ and substituting into 18, the following equation is obtained:

$$K_{as} = \frac{\left(\frac{\alpha'}{2}\right)^{\frac{1}{2}}\,[C_T]_B^{\ \frac{1}{2}}\,K}{[C_T]_A\,(1-\alpha)} \qquad (20)$$

Solving equation 20 for the ratio of the concentrations of the distributed components,

$$\frac{[C_T]_A^2}{[C_T]_B} = \frac{\alpha'\,K^2}{2\,K_{as}^2\,(1-\alpha)^2} \qquad (21)$$

This equation will be used in this thesis to determine the effect of salt on the dimerization of the three carboxylic acids in the benzene-rich phase.

DESCRIPTION OF THE SALT EFFECT

A survey of the literature has revealed general agreement on the physical phenomena responsible for the salt effects. The translation of these phenomena into mathematical expressions has been approached from several different directions. The fact that these expressions are only semiquantitative and cannot be applied under all conditions emphasizes the complexity of the salt effects.

Albright and Williams (2) and Gross (34) have clearly described the physical interactions responsible for the salt effect. Consider a system of non-electrolyte and an aqueous salt solution. Since the dielectric constant of water is usually higher than that of other neutral molecules, the water molecules are preferentially pulled into the field existing around the ion. This forces the less polar non-electrolyte molecules into the regions of the solution remote from the ionic field. The increase in the non-electrolyte to water ratio in these regions results in a reduction of the solubility of the non-electrolyte referred to the total water present. This is the familiar "salting out" effect.

If the dielectric constant of the non-electrolyte is higher than that of water, the non-electrolyte will concentrate in the region of the ions at the expense of the water. Since the non-electrolyte to water ratio in regions removed from the ion is lowered, the water is available to take up more of the neutral molecules, and "salting in" occurs.

Dobry-Duclaux (26) stated two rules concerning the effectiveness of salts in promoting dissolution of non-electrolytes in water:

1. If a salt will produce greater dissolution of a substance than a second salt, it will produce greater dissolution of all other substances (than the second salt).
2. If a non-electrolyte dissolves to a greater extent in the presence of a given salt than another substance, it will dissolve more readily in the presence of any other positive lyotropic salt than the second substance.

(It appears that a "lyotropic salt," as used in the second rule above, becomes more "positive" as its efficiency in promoting solubility, or "salting in," increases. Thus rubidium chloride would be a more "positive lyotropic salt" than potassium chloride.)

Thus the ability of a salt to promote dissolution depends on two parameters, the nature of the salt and the nature of the non-electrolyte.

THEORIES OF THE SALT EFFECT

Two principal theories have been proposed to quantitatively express the salt effect: the hydration theory and the electrostatic theory. Much experimental work has been done to test their validity.

The Hydration Theory.

The hydration theory proposes that one of the primary factors in salting out is a characteristic constancy of binding of a part of the water by the ions, the extent of which is directly proportional to the number of ions. The water so bound is probably removed as a shell of oriented water dipoles around the ions. The bound water thus becomes unavailable as solvent in which the non-electrolyte can be dispersed.

Before considering the salting out effect as expressed by this theory, examination will be made of a Hittorf transport number experiment designed to determine the hydration number of an ion.

A non-electrolyte is dissolved in the solution and its concentration near the electrode is measured before and after the experiment, thus determining the change in its concentration during electrolysis (1). This reference substance must have the following properties (98):

1. It must be stable and must not react with the electrodes or with the solution.

2. It must be a non-electrolyte and must remain stationary with respect to the water when a current is passed through the solution.
3. It must be present at such small concentration that it does not appreciably change the character of the solvent.
4. Since the changes in the ratio of water to reference substance at the electrode will be small, the reference substance must be capable of accurate estimation.

Urea and the sugar raffinose have been successfully used as reference substances (86, 87, 98).

If x_c and x_a are the molecules of water attached to the cation and anion, respectively; T_c and T_a are the "true" transport numbers of these ions (if no water were carried by the ions); and t_c and t_a are the apparent (measured) transport numbers; then the passage of one faraday of charge will cause the cations to carry x_cT_c moles of water in one direction and the anions to carry x_aT_a moles of water in the opposite direction. There will thus be a net transfer of Δx moles of water from the anode to the cathode compartment, according to the following equation:

$$\Delta x = x_cT_c - x_aT_a \qquad (22)$$

Because of this transfer of water, the concentration of the reference substance appears to increase in the anode compartment and to decrease in the cathode compartment. From this change in concentration, Δx can be calculated. If E_s equivalents of salt are dissolved in E_w equivalents of water, then $\Delta x E_s/E_w$ equivalents of salt are associated with Δx moles of water, and this is equal to the difference between the true and apparent transport numbers. For the anode compartment,

$$t_c = T_c - \Delta x \frac{E_s}{E_w} \tag{23}$$

while for the cathode compartment

$$t_a = T_a + \Delta x \frac{E_s}{E_w} \tag{24}$$

Equations 23 and 24 permit T_c and T_a to be calculated if t_c or t_a and Δx are measured. It will be noted that $t_c + t_a = T_c + T_a = 1$.

Absolute values of the degree of hydration, x_c and x_a, cannot be found by this method, since equation 22 contains two unknowns. If the extent of hydration of one ion is assumed, that of the other can be calculated. Assuming that the chloride ion binds four water molecules or the hydrogen (hydronium) ion one molecules, the following are obtained:

Relative Degrees of Hydration of Ions

H^+	Cl^-	Li^+	Na^+	K^+	Cs^+
1	4	14.0	8.4	5.4	4.7

All the above values were obtained in alkali chloride solutions.

Quantitatively, other methods for estimating the degree of hydration agree with the above, but at best, estimates of hydration are very approximate.

MacInnes (56) states that hydration increases with dilution and with decrease in temperature. He gives the following "lyotropic" or "Hofmeister" series of ions in decreasing order of hydration (57):

Li > Na > K > Rb > Cs
Mg > Ca > Sr > Ba
F > $\frac{1}{2}SO_4$ > Cl > Br > NO_3 > I > CNS

Bergen and Long (7) studied salt effects in acidic and basic media. They proposed that the water molecules which hydrate a cation will be oriented with their protons outward and that as a result there will be a net repulsion between these protons and an acidic weak electrolyte and a net attraction between the protons and a basic weak electrolyte. The hydration effects should make a significant contribution to the salting out parameters only for small, highly charged cations for which hydration will be extensive. Thus the disappearance of the acid-base effect for rubidium and cesium is expected.

Sugden (81) has determined the hydration numbers of the alkali chlorides in a water-alcohol mixture. Angelescu and Dutchievici (3) determined these values in an acid-water mixture. In both cases, benzene was the third component. Their results are given below:

Hydration Numbers for Alkali Salts

Salt	Sugden	Angelescu et. al.
LiCl	10.5	- - -
NaCl	8.0	18
KCl	3.4	16.3
NaBr	- -	16.4
KBr	- -	11.5
NaI	- -	10.6
KI	- -	8.3
$NaNO_3$	- -	11.1
KNO_3	- -	4.6

Other investigators (22, 28, 61, 68) have also explained the salting out effect on the basis of the hydration theory.

In view of the large variation in hydration numbers reported by several investigators, it is concluded that this number is strongly influenced by the nature and quantity of the dissolved non-electrolyte. Consideration of the four rules previously listed for the selection of the reference substance used in the Hittorf hydration number experiment shows that rule 3 is probably most important in explaining the results obtained. While the hydration number concept provides a very convenient physical interpretation of the salt effect, its usefulness in predicting the magnitude of the salt effect in various media can only be qualitative.

Electrostatic Theory.

An expression for the salt effect can be obtained by consideration of the action of coulombic forces without the inclusion of other factors.

The theory of Debye and McAulay (25) computes the partial free energy of a molecule relative to the pure solvent from the reversible electrical work. Assuming the ions to be perfect spheres of radius b_j, the electrical work $W(n_j)$ of charging n_j ions of this kind is

$$W(n_j) = \frac{n_j e_j^2}{2 D b_j} \tag{25}$$

where e_j is the electrical charge on the ion; and

D is the dielectric constant of the solution.

Consider a solution containing $n_1 \ldots n_j \ldots n_s$ ions per cubic centimeter. The net electrical work W_{net} of discharging the ions at high dilution in a solvent (water) of dielectric constant D_o and recharging them in a medium of dielectric constant D is

$$W_{net} = \sum_1^s \frac{n_j e_j^2}{2 D b_j} - \sum_1^s \frac{n_j e_j^2}{2 D_o b_j} \tag{26}$$

(The change in dielectric constant from D_o to D may be produced by the addition of either an electrolyte or a non-electrolyte to the solvent.) The amount of additional work $W(k)$ done against the potential due to ionic atmospheres is

$$W(k) = -\frac{k_a}{3D} \sum_{1}^{s} n_j e_j^2 \qquad (27)$$

where $1/k_a$ is the mean radius of the ionic atmosphere. To a first approximation the total electrical work of the charging processes given by equations 25 through 27 above may be set equal to the increase in the work content of the system.

$$\Delta A = \frac{1}{2D} \sum_{1}^{s} \frac{n_j e_j^2}{b_j} - \frac{1}{2D_o} \sum_{1}^{s} \frac{n_j e_j^2}{b_j} - \frac{k_a}{3D} \sum \frac{n_j e_j^2}{b_j} \qquad (28)$$

Again, as a first approximation, the dielectric constant of the mixture may be given by the equation

$$D = D_o (1 - \beta n - \beta' n') \qquad (29)$$

where n and n' are the number of molecules of non-electrolyte and electrolyte, respectively; and β and β' are empirical constants.

Substituting 29 in 28 and neglecting higher powers of n and n' gives

$$\Delta A = \frac{\beta n}{2D_o} \sum_{1}^{s} \frac{n_j e_j^2}{b_j} + \frac{\beta' n'}{2D_o} \sum_{1}^{s} \frac{n_j e_j^2}{b_j} - \frac{k_a}{3D_o} \sum n_j e_j^2 \qquad (30)$$

Since interest is only in the salting out or salting in of electrolytes at extreme dilutions caused by changes in the dielectric constant according to equation 29,

$$\Delta A_s = \frac{\beta n}{2D_o} \sum_1^s \frac{n_j e_j^2}{b_j} + \frac{\beta' n'}{2D_o} \sum_1^s \frac{n_j e_j^2}{b_j} \qquad (31)$$

where ΔA_s is the increase in work content due to salting in or salting out at extreme dilutions.

From this equation the contribution to the chemical potential of the electrolyte ($\Delta\mu_s$ per molecule) caused by the addition of non-electrolyte, or vice versa, can be determined. Thus for a neutral molecule

$$\Delta\mu_s = \frac{\partial A_s}{\partial n} = \frac{\beta}{2D_o} \sum_1^s \frac{n_j e_j^2}{b_j} = kT \ln f_s \qquad (32)$$

or

$$\ln f_s = \frac{\beta}{2kTD_o} \sum_1^s \frac{n_j e_j^2}{b_j} \qquad (33)$$

which is the equation of Debye and McAulay. When β is positive the macroscopic dielectric constant of the medium is decreased, f_s is increased, and salting out takes place. Considering the simplifications and approximations made during the derivation, it is clear that equation 33 is a limiting equation and can be regarded only as a first approximation.

Other equations for the salt effect have been derived by means of a similarly simplified picture. Butler (18) obtained an equation identical with (33) except that D appears in the denominator in place of D_o.

Debye (24) later developed a more exact theory to take into account the heterogeneity of the mixture of water and neutral solute. The total free energy of the system, including the contribution due to the field of the ions, was expressed as a function of the distance r from the ion. The expression obtained is

$$v_2 \ln \frac{N_1}{N_1^o} - v_1 \ln \frac{N_2}{N_2^o} = \frac{e^2}{\pi 8kTD^2}\left[v_2 \frac{\partial D}{\partial n_1} - v_1 \frac{\partial D}{\partial n_2}\right]\frac{1}{r^4} \qquad (34)$$

where N_1^o and N_2^o are the mole fractions of solvent and non-electrolyte, respectively, at great distances from the ion ($r = \infty$);

v_1 and v_2 are the atomic volumes of the pure components; and

r is the distance from the ion.

The other symbols have the meanings previously given.

For a mixture containing a small quantity of component 2 (for example, a solution of benzene in water), and assuming that component 2 is salted out, the following equation may be written:

$$\ln \frac{N_2}{N_2^o} = -\frac{e^2}{8\pi kTv_1D^2}\left[v_2 \frac{\partial D}{\partial n_1} - v_1 \frac{\partial D}{\partial n_2}\right]\frac{1}{r^4} \qquad (35)$$

Letting R^4 equal

$$\frac{e^2}{8\pi kTv_1D^2}\left[v_2 \frac{\partial D}{\partial n_1} - v_1 \frac{\partial D}{\partial n_2}\right] \qquad (36)$$

then

$$N_2 = N_2^{\circ} \exp -\left(\frac{R}{r}\right)^4 \qquad (37)$$

where N_2 is the concentration of component 2 at distance r, expressed as the mole fraction.

For an electrolyte which decreases the dielectric constant of the solvent ($D_1 > D_2$), the activity coefficient is given by

$$\frac{f^0{}_2}{f^1{}_2} = 1 - \frac{4\pi N_{av}}{1000} \sum J_i\, C_i \qquad (38)$$

where J_i is equal to

$$\int_{b_i}^{\infty} \left[1 - \exp-\left[\frac{R_i}{r}\right]^4\right] r^2 \;dr \qquad (39)$$

and N_{av} is Avogadro's number.

For the case of an electrolyte which increases the dielectric constant ($D_1 < D_2$), the value of J_i to be used in equation 38 is

$$\int_{b_i}^{\infty} \left[1 - \exp + \left[\frac{R_i}{r}\right]^4\right] r^2 \;dr \qquad (40)$$

Note that $f^0{}_1 = 1$.

Gross (33) has extended this theory to include the effect of the ionic atmosphere.

Kirkwood (44, 45) has calculated the mutual electrostatic energy of a spherical ion and a neutral molecule represented as a cavity (in the surrounding dielectric) and containing an arbitrary distribution of charges. The theory, originally intended for dipolar ions but generally applicable to neutral molecules, yields a limiting law for the activity coefficient of a non-electrolyte.

In the development of the previous theories, the electrostatic interaction between an ion and a neutral molecule was shown to be short range in nature. Additional interaction terms of the London or van der Waals type must be considered more fully than in the present quantitative theories. Such interaction forces involve the polarizability of salt ions, solvent molecules, and non-electrolyte solute molecules as well as the special force fields originating from any component dipoles that may be present.

Other Theories.

The "internal pressure" concept of Tammann (84) was used by early investigators to relate salt effects to other properties of the salt solutions themselves. The increase in internal pressure of a salt solution was defined in terms of the external pressure that would have to be applied to pure water in order to make properties such as the temperature of maximum density the same as for salt solutions.

More recently, McDevit and Long (59) pointed out that this concept should hold best for strictly non-polar non-electrolytes and have developed a theory for this case. By considering that neutral molecules merely occupy volume and hence modify the ion-water relationship in this simple manner, these authors calculated the free energy of transfer of the non-polar non-electrolyte from pure water to the salt solution and obtained a limiting law for k_s.

$$k_s = \frac{\bar{V}_i^{\,o}\,(V_s - \bar{V}_s^{\,o})}{2.3\ \beta_o RT} \qquad (41)$$

where $\bar{V}_i^{\,o}$ is the partial molar volume of non-electrolyte at infinite dilution;

V_s is the partial molar volume of pure (liquid) electrolyte;

$\bar{V}_s^{\,o}$ is the partial molar volume of the electrolyte at infinite dilution; and

β_o is the compressibility of pure water.

A physical interpretation of equation 41 follows from the fact that the contraction in total volume, $V_s - \bar{V}_s^{\,o}$, which takes place (generally) on mixing salt and water, can be interpreted as a compression of the solvent. This compression makes it more difficult to insert the volume V_i of the neutral solute and results, experimentally, in salting out. In other words, the expression is simply an explicit formulation of the longrecognized concept that when salt is added to an aqueous solution of a non-electrolyte, the increase in internal pressure resulting from the ion-solvent interaction "squeezes out" the non-electrolyte molecules.

LITERATURE SURVEY

Acetic Acid - Benzene - Water

The ternary system acetic acid-benzene-water has been studied at 25° C (37, 38, 46, 49, 53, 67, 85, 89, 97) as well as at higher temperatures up to 120° C (31, 83). At all concentrations the acid favors the aqueous phase. Because of hydrogen bonding, a dimer is formed in the benzene phase. Moelwyn-Hughes (60) determined the association constant for acetic acid in benzene to be 180 at 25° C. Values for the dissociation constants of acetic acid, as well as propionic acid and butyric acid, are given in Table 4.

Propionic Acid - Benzene - Water

Data for the system propionic acid-benzene-water are given in the literature (4, 46, 48). The system exhibits double solutropy, the water phase being favored at low and high acid concentrations and the benzene phase at intermediate concentrations. Biancani (9) reports that a dimer of the acid is formed in the benzene phase.

Butyric Acid - Benzene - Water

The system butyric acid-benzene-water had been studied (46, 47, 51, 52). The acid favors the benzene phase at all concentrations. Fancon (27) has studied the freezing point curve of the water-butyric acid system and has determined the critical solution temperature to be -3.8° C at 40 weight per cent acid.

A eutectic, solidifying at -13.4° C, contained 87.6 weight per cent acid. No hydrate formation was observed. (A monohydrate of butyric acid, $C_3H_7COOH \cdot H_2O$, contains 83.0 per cent butyric acid.)

Mutual Solubility of Benzene and Water

The author did not determine the mutual solubility of benzene and water, these data being available in the literature. Arnold, Plank, Erickson, and Pike (4), using an ultraviolet spectrophotometer, determined the solubility of benzene in water to be 0.174 per cent (by weight) at 24.9° C and 0.177 per cent at 30° C. Bohon and Claussen (11), using a similar procedure, obtained a value of 0.179 per cent at 25° C. Gross and Saylor (35) found 0.185 per cent benzene in water at 30° C. The effect of many inorganic salts on the solubility of benzene in water has been extensively studied, and excellent reviews of the results have appeared (54, 59). Most inorganic salts decrease the solubility of benzene in water.

Joris and Taylor (43), using a titration tracer, found the solubility of water in benzene to be 0.054 per cent (by weight) at 25° C and compared their data with that of five other investigators. Umano and Hayano (94) determined the solubility of water in benzene at temperatures between 25° C and 300° C using an autoclave. The solubility increased to 40 weight per cent water in benzene at 300° C. Studies with several concentrations of sodium chloride showed that increased salt concentration lowered the solubility of water in benzene. No detectable amount of salt was found in the benzene.

Acetic Acid - Benzene - Water - Salt

Rius et. al. (74) studied the system acetic acid-benzene-water-sodium chloride. Jodra, Otero and Solé (41) have made a very thorough study of the limiting solubilities of this system at 25° C and have determined the surfaces inside of the regular tetrahedron used to represent the data. The equilibrium data for the four ternary systems involved are also given. It was found that sodium chloride is insoluble in benzene and acetic acid and in mixtures of these two components. The solubility of the salt in aqueous acetic acid solutions decreases with increase in acid concentration. No attempt was made to correlate tie line data obtained in the studies.

The literature did not disclose any similar work with propionic acid or butyric acid.

Bury and Mends (17) have studied the system water-butyric acid-sodium chloride. As in the case of acetic acid, the solubility of the salt in aqueous acid solutions decreases with increase in acid concentration.

SALT EFFECTS IN VAPOR-LIQUID EQUILIBRIA

Several investigators (42, 36, 70, 73, 72, 93) have studied the effects of salts on the vapor liquid equilibria of some binary mixtures. The addition of a solid substance to a binary liquid system will affect the solubilities and partial vapor pressures of the two liquids.

Rieder and Thompson (70) studied the effect of KNO_3 on the ethanol-water system. A marked increase in the relative volatility of ethanol at high water concentration was observed, but little effect is noted above 90 % ethanol. Potassium nitrate is very soluble in water but only very slightly soluble in ethanol. For this reason, no change was observed in the azeotropic point. In the region between 20 and 50 weight per cent ethanol, two phases were present. In all observations, the system was saturated with KNO_3. The activity coefficient of the ethanol was increased while that of the water was decreased.

Tursi and Thompson (93) studied the effects of Na_2SO_4, K_2SO_4, and $NaNO_3$ on the ethanol-water system and concluded

> "a. the addition of a salt which is relatively soluble only in the high boiling component will cause a greater ease of separation between the components of a binary mixture.
>
> b. the ease of separation increases as the solubility of the salt in the high boiling component increases (93)"

SALT EFFECTS IN LIQUID-LIQUID EQUILIBRIA

Many investigators have studied the effects of electrolytes in lowering the solubilities of gases and of non-electrolytes in water. Excellent reviews of these investigations have appeared in the literature (34, 54, 69).

The first quantitative statement for the salting out effect was given by Setschenow (76). In his work on gas solubilities in aqueous solutions, he found that the change of solubility in the presence of salt could be expressed by

$$\ln \frac{c^o}{c} = k_s X_s \qquad (42)$$

where c^o = concentration of gas in water (moles per liter), no salt present

c = concentration of gas in water (moles per liter), salt present

X_s = concentration of salt in water (moles per liter)

k_s = a constant, commonly called the salting out constant

In using this equation, c and c^o must be aqueous phase concentrations in equilibrium with the <u>same</u> solvent phase if this relationship is to hold for distribution data. The equation has found widespread use and is generally valid for salt concentrations up to 2 or 3 molar. In a few cases, the validity has held for salt concentrations as high as 4 molar (34). Under certain conditions the equation fails in dilute solutions.

Jahn (82) found that the equation

$$c^{o} - c = k_s X_s^{2/3} \tag{43}$$

expressed the solubility of carbon dioxide and of nitrous oxide in water. Rothmund (69) employed a simplified version of the Setschenow equation

$$\frac{c^{o} - c}{c^{o}} = k_s X_s \tag{44}$$

for systems in which the solubility change $c^{o} - c$ is small.

Randall and Failey (69), reviewing the literature, reached the following conclusions about k_s:

1. The value of k_s varies with the salt and with the non-electrolyte.
2. The variation of k_s follows a definite order for the ions of any one atomic grouping.
3. The Setschenow equation is valid for weak electrolytes provided the degree of ionization is considered.

Chase and Kirkpatrick (20) found that the equation

$$v_a = k_3 X_s \tag{45}$$

applies for the solubility of benzoic acid in dilute potassium chloride solutions (less than 0.7 molar). The quantity v_a is the additional volume, in liters, which is required to hold one mole of non-electrolyte in solution at salt concentration X_s (moles per liter), in excess of the volume of water v_o (liters) required for its solution in the absence of salt.

Larsson (50) assumed that the salting out constant, k_s, included contributions from the anion and the cation of the dissolved electrolyte. Thus the Setschenow equation is written

$$\ln \frac{c^o}{c} = (k_+ + k_-)\, X_s \qquad (46)$$

where k_+ and k_- are the contributions to the salting out constant by the cation and anion, respectively. A table of values of k_+ and k_- for about 20 ions is presented. The cation is responsible for salting out while the anion causes salting in. The net effect depends on which ion makes the stronger contribution.

By far the greatest effort in the study of salt effects in liquids has dealt with solubilities of non-electrolytes, particularly benzene, in water. Very little work has been done on the effect of salts on the distribution of a solute between two immiscible liquids, a problem which is of engineering interest. Swabb and Mongan (82) have studied the effect of sodium sulfate on the distribution of acetic acid between benzene and isopropyl ether and were able to correlate their results using the Setschenow equation. Two salt concentrations were employed: the saturation concentration of sodium sulfate in water and one half of the saturation value. The values of k_s obtained were 2.33 (standard deviation = 0.11) for the saturated salt solution and 2.31 (standard deviation = 0.09) for the "half saturated" solution.

COMPARISON OF EMPIRICAL AND THEORETICAL EQUATIONS

It is of interest to compare the Setschenow equation

$$\ln \frac{c^o}{c} = \ln f = k_s X_s \qquad (47)$$

with the Debye-McAulay equation

$$\ln f = \frac{\beta}{2\,k\,T\,D_o} \sum_{1}^{s} \frac{n_j e_j^2}{b_j} \qquad (33)$$

If n_t is defined as the total number of molecules per cubic centimeter and ν_j as the number of ions of kind j per molecule, $n_t \nu_j$ can be substituted for n_j in equation 33 to obtain

$$\ln f = \frac{\beta}{2\,k\,T\,D_o} (n_t) \sum_{1}^{s} \frac{\nu_j e_j^2}{b_j} \qquad (48)$$

Examination of the quantities in equation 48 reveals that

2, k, and T are constants independent of the system;
β depends on the non-electrolyte;
D_o depends on the solvent;
ν_j, e_j^2, and b_j depend on the nature of the electrolyte;
n_t depends on the concentration of the electrolyte.

The temperature is assumed to remain constant.

For a system in which the solvent, non-electrolyte, and electrolyte are specified, the only variable in the Debye-McAulay equation is n_t, the concentration of the electrolyte.

This corresponds to X_s in the Setschenow equation. The constant k_s in equation 47 can be expressed in terms of the Debye-McAulay equation (48) as follows:

$$k_s = \frac{\beta}{2\,k\,T\,D_o} \sum_{1}^{s} \frac{\nu_j\, e_j^2}{b_j} \qquad (49)$$

Several conclusions may now be drawn.

1. Since water has a high dielectric constant, the activity coefficient of most neutral substances should increase in aqueous solutions (β is positive).

Much experimental data are available confirming the statement.

2. The quantity ln f should vary linearly with salt concentration.

The validity of the Setschenow equation supports this.

3. Salt effects should be in the order of the sum of the reciprocals of the ionic radii.

This prediction is not followed, and many exceptions can be noted. The hydration of small ions may be responsible for this disagreement.

4. The salting out constant k_s should be a function of the nature of the solvent, the nature of the solute, and the nature of the electrolyte.

Experimental evidence indicates that the salting out constant varies with the system under consideration.

The situation may be briefly summarized. The Debye-McAulay equation has the form of the empirical Setschenow equation and leads to results of the correct order of magnitude (75). This shows that the electrostatic influence is an important part of the salting out effect. The role of the ionic radius is confused, and the theoretical prediction of the order of effects does not always agree with observed results. The theory requires salting out in an aqueous solution, while numerous instances of salting in occur. These discrepancies might be partially eliminated if investigations were confined to dilute solutions of both the neutral molecules and the salts.

EXPERIMENTAL PROCEDURES

Preparation of Initial Mixture

To a tared, polyethylene-stoppered Erlenmeyer flask were added 1 to 60 ml acid, 20 ml salt solution, and 20 ml benzene. The weights of the respective substances were determined by weighing the flask and contents on a Sartorius balance, capable of being read to 0.1 mg. For mixture volumes less than 70 ml, 125 ml Erlenmeyer flasks were used; for greater volumes, 250 ml flasks were used. The order of addition was determined by the vapor pressure of the substances (see Table 6). In order to minimize evaporation losses during additions to the flask, benzene, having the highest vapor pressure, was added last.

Equilibration

Constant temperature baths consisted of ten-gallon aquaria insulated on all six sides with two-inch sheets of styrofoam. Using glass cooling coils immersed in the bath and a Bronwill constant temperature circulating system, a temperature of $25.00 \pm 0.02^\circ$ C was maintained. Erlenmeyer flasks containing the initial mixtures were affixed to a Burrell "Wrist Action" Shaker fitted with shaker arms designed by the author. Solutions were allowed to equilibrate at constant temperature, with agitation, for at least twenty-four hours.

ANALYTICAL PROCEDURES

Analysis of Aqueous and Organic Phases for Acid

A two milliliter aliquot of the respective phase was transferred to a tared, 300 ml polyethylene-stoppered Erlenmeyer flask containing 15 ml distilled water. The flask and contents were immediately weighed on the Sartorius balance, and the weight of the aliquot was calculated. To prevent organic phase from entering the pipet while extracting the aqueous phase aliquot, air was gently blown through the pipet until the tip dipped into the aqueous phase. The pipet tip was wiped clean with a paper towel before transferring the aliquot to the Erlenmeyer flask.

After addition of one drop of phenolphthalein indicator, the aliquot was titrated with standard sodium hydroxide solution to a pink end point, using a magnetic stirrer for agitation. A blank was run on the distilled water, and suitable corrections were made. Class A burets of 5 ml, 10 ml and 50 ml capacity were used. After titration with NaOH, the organic phase aliquot was retained for further analysis, while the aqueous was discarded.

Addition of the organic phase aliquot to the distilled water in the 300 ml Erlenmeyer flask produced a two phase mixture. Investigation has shown that addition to this mixture of sufficient methanol to maintain homogeneity during the sodium hydroxide titration resulted in a value for the acid concentration of the organic phase which agreed, within experimental error, with that obtained using a heterogeneous system. Therefore, all acid concentration determinations were made without addition of methanol.

Analysis of Organic Phase for Salt

The salt content of the organic phase was too low to produce a visible color change in the dichlorofluorescein indicator. This change occurs at the surface of the colloidal precipitated particles, and the color intensity depends on the number of particles present. A quantity of standard sodium chloride solution added to the organic phase aliquot prior to titration yielded a satisfactory end point. A study of the effect of pH on the end point showed that the sharpest color change occurred at a pH of approximately 4.5. The presence of phenolphthalein indicator did not interfere with the end point.

Three drops of 3% nitric acid solution were added (to remove the pink color of the phenolphthalein and to bring the pH to 4.5) to the same organic phase aliquot used in the determination of acid concentration. After the flask and contents were weighed on the Sartorius balance, two ml of standard sodium chloride solution (1.0 g NaCl solution = 1 ml standard $AgNO_3$) were added and the flask was reweighed. To prevent coagulation of the precipitate particles, 0.1 g dextrin were added. The mixture was titrated with standard silver nitrate solution from a 5 ml class A microburet to the end point.

Analysis of Organic Phase for Water.

The Thomas Magnematic Karl Fischer Titrator, which utilizes electrometric "dead stop" end point detection, was used in the direct titration of water with Fisher Stabilized Karl Fischer Reagent. An anhydrous condition is indicated by an increase in the current passing between two platinum electrodes immersed in the test solution.

A five milliliter hypodermic syringe with stainless steel needle was used to extract an aliquot of the organic phase. After the syringe and sample were weighed on a Sartorius balance, the sample was injected into the titration cell, and the empty syringe was weighed. Titration with standardized Karl Fischer reagent continued until one drop caused the meter deflection to remain greater than 90 a for 60 seconds. From the weight of the organic phase aliquot and the volume of Karl Fischer reagent used, the water content of the organic phase was calculated. The solution was stirred by a magnetic stirrer.

FORMULATION AND ANALYSIS OF STANDARD SOLUTIONS

Standard Sodium Hydroxide Solution

Two gallons of approximately 0.5 N sodium hydroxide solution were prepared by dissolving about 60 g sodium hydroxide (low in carbonate) in distilled water. The solution was standardized with potassium acid phthalate (Mallinckrodt Primary Standard) which had been dried at 110° C for three hours. Quadruplicate determinations were made. The solution bottle was protected from atmospheric water and carbon dioxide with calcium chloride and calcium oxide tubes. The solution was reanalyzed as a check before a new solution was formulated.

Standard Silver Nitrate Solution

Two liters of approximately 0.1 N silver nitrate were prepared by dissolving about 34 g silver nitrate in distilled water. The solution was standardized with sodium chloride which had been dried at 110° C for three hours. Quadruplicate determinations were made.

Two liters of approximately 0.5 N silver nitrate solution, prepared and standardized as above, were used exclusively in the analysis of the stock solutions of lithium chloride, sodium chloride, and potassium chloride, respectively, in concentrations of 14%, 18% and 22%.

Standardization of Karl Fischer Reagent

Sufficient anhydrous methanol (about 25 ml) was added to the 250 ml titration cell to cover the immersed platinum electrodes. After the system was made anhydrous by addition of Karl Fischer reagent, 10 ml of a standard water-in-methanol solution (1 mg water per ml of solution) was transferred to the cell, using a class A pipet. The volume of Karl Fischer reagent needed to again render the system anhydrous was used to calculate the water equivalent of the reagent; i.e. the milligrams water per milliliter Karl Fischer reagent. The solution was stirred by a magnetic stirrer.

The Karl Fischer reagent was standardized daily.

TABLE 1

WATER CONTENT OF ORGANIC CHEMICALS USED IN INITIAL MIXTURE

Substance	Water Content (weight per cent)
Benzene	0.0059
Acetic Acid	0.0139
Propionic Acid	0.0719
Butyric Acid	0.0401

TABLE 2

ANALYSIS OF SALT STOCK SOLUTIONS
BASED ON 100 GRAMS OF SOLUTION

NSC*	Lithium Chloride		Sodium Chloride		Potassium Chloride	
	grams	moles	grams	moles	grams	moles
2	1.970	0.0465	2.002	0.0342	2.001	0.0269
6	5.743	0.1354	5.863	0.1002	5.717	0.0768
10	9.118	0.215	9.403	0.1608	9.287	0.1246
14	13.68	0.323	13.65	0.234	13.74	0.1844
18	17.61	0.416	17.41	0.298	17.14	0.230
22	21.23	0.501	21.33	0.364	21.00	0.282

*Nominal Salt Concentration

Concentrations are expressed as grams of salt per 100 grams of solution and as moles of salt per 100 grams of solution.

TABLE 3

DIELECTRIC CONSTANTS OF SELECTED COMPOUNDS AT 20° C

Compound	Dielectric Constant
Acetic Acid (l)	6.15
Propionic Acid (l)	3.35
Butyric Acid (l)	2.97
Benzene (l)	2.284
Water (l)	80.37
Potassium Chloride (s)	5.03
Sodium Chloride (s)	11.2

Reference: Handbook of Chemistry and Physics, 39th ed., Chemical Rubber Publishing Company, Cleveland, Ohio, 1957. pp. 2331-2341.

TABLE 4

DISSOCIATION CONSTANTS OF SELECTED ACIDS IN WATER AT 25° C

Compound	Dissociation Constant
Acetic Acid	1.754×10^{-5}
Propionic Acid	1.336×10^{-5}
Butyric Acid	1.515×10^{-5}

Reference: Handbook of Chemistry and Physics, 39th ed., Chemical Rubber Publishing Company, Cleveland, Ohio, 1957. pp. 1644-1645.

TABLE 5

SOLUBILITY OF SELECTED SALTS IN WATER

Salt	Solubility	
	20° C	30° C
Lithium Chloride	44.0	45.8
Sodium Chloride	25.6	27.0
Potassium Chloride	26.5	26.6

The solubility is expressed as the weight per cent salt in the saturated solution.

Reference: Handbook of Chemistry and Physics, 39th ed., Chemical Rubber Publishing Company, Cleveland, Ohio, 1957. pp. 1598-1601.

TABLE 6

VAPOR PRESSURE OF SELECTED COMPOUNDS AT 25° C

Compound	Vapor Pressure
Benzene (1)	95.18
Acetic Acid (1)	15.78
Propionic Acid (1)	3.335
Butyric Acid (1)	0.7183
Water (1)	23.76

Vapor pressure is given in millimeters of mercury.

Reference: Lange, N. A. (ed.) : Handbook of Chemistry, 9th ed.
Handbook Publishers, Inc., Sandusky, Ohio, 1956.
pp. 1424-1439.

METHOD OF CALCULATION

The complete composition of the aqueous phase, the acid concentration of which is known, may be calculated from the composition of the initial mixture and the composition of the organic phase, both of which are completely known. The composition of the initial mixture is X_{AI}, X_{BI}, X_{CI}, and X_{DI}, where the components A, B, C, and D are water, benzene, acid, and salt, respectively. The composition of the aqueous phase is X_{AA}, X_{BA}, X_{CA}, and X_{DA}, while that of the organic phase is X_{AB}, X_{BB}, X_{CB}, and X_{DB}. The total weight of the initial mixture, aqueous phase, and organic phase are m_I, m_A, and m_B, respectively.

A total material balance is

$$m_I = m_A + m_B \tag{50}$$

A material balance on the acid is

$$m_I X_{CI} = m_A X_{CA} + m_B X_{CB} \tag{51}$$

Substituting m_I from equation 50 into equation 51 gives

$$(m_A + m_B)\, X_{CI} = m_A X_{CA} + m_B X_{CB} \tag{52}$$

Equation 52 is then solved for the ratio of the weights of the aqueous and organic phases.

$$\frac{m_A}{m_B} = \frac{X_{CB} - X_{CI}}{X_{CI} - X_{CA}} \tag{53}$$

Material balances on the water, benzene, and salt give the following equations:

$$\frac{m_A}{m_B} = \frac{X_{AB} - X_{AI}}{X_{AI} - X_{AA}} \qquad (54)$$

$$\frac{m_A}{m_B} = \frac{X_{BB} - X_{BI}}{X_{BI} - X_{BA}} \qquad (55)$$

$$\frac{m_A}{m_B} = \frac{X_{DB} - X_{DI}}{X_{DI} - X_{DA}} \qquad (56)$$

The composition of the aqueous phase is determined by solving these equations for X_{AA}, X_{BA}, and X_{CA}. A sample calculation and error study is included in the Appendix.

METHODS OF CORRELATION

The best methods of correlating the data appear to be the method of Swabb and Mongan (82), who used the Setschenow equation, and the method based on Hand coordinates. The Hand coordinates have been widely used to correlate tie line data for ternary systems; however, the literature does not report any attempt to use this method to correlate salt effects in ternary systems.

Studying the effect of sodium sulfate on the system acetic acid - isopropyl ether - water, Swabb and Mongan used the Setschenow equation

$$\ln \frac{s^o}{s} = k_{ss} X_{ss} \qquad (42)$$

where s^o = grams of acetic acid per gram of water in the aqueous phase, no salt present;

s = grams of acetic acid per gram of water in the aqueous phase, salt present;

X_{ss} = grams sodium sulfate per gram of water in the aqueous phase; and

k_{ss} = salting out constant.

"In order to use this equation with distribution data, the solution of acid concentration s^o...must be in equilibrium with an ether layer of specified acid concentration. The solution of acid concentration s must also be in equilibrium with an ether layer of the same concentration. Thus in the ratio of the concentrations, the effect of the ether phase divided out....It can be concluded that the nature of the solvent, in this case isopropyl ether, should have no effect on the values of the constant k_{ss}, provided no water or salt enters the solvent phase to change the activity of the acid in that phase. Once values for this constant are determined, they can be used to predict the change in acid distribution due to the addition of sodium sulfate for any liquid system acetic acid-water-non-consolute solvent. (82)"

Swabb and Mongan used the following procedure to obtain the quantities used in the Setschenow equation. On the same graph, the acid concentration in the aqueous phase (salt-free basis) was plotted against acid concentration in the isopropyl ether phase for the salt-free system and for the two salt concentrations used. At equal increments of acid concentration in the ether phase, the acid concentration in the water phase was read for each of the three curves. The salt present at each of these points was read from a plot of salt concentration against acid concentration. The water present at each point was read from a ternary equilibrium diagram (triangular plot) plotted on a salt-free basis. From these data values of k_{ss} were determined.

An attempt was made to correlate the data of this thesis using the method of Swabb and Mongan. Data for acetic acid and lithium chloride, sodium chloride and potassium chloride were used. Representative data are presented in tables 70 to 73 in the Appendix. A large scale plot of X_{CA}/X_{AA} against X_{CB} was prepared and values of the ordinate at constant X_{CB} were read and tabulated. Twelve points were determined at each salt concentration. The ratio of salt to water in the aqueous phase was found to be constant over a wide range of values of X_{CB}, a result to be expected since neither the water nor the salt enter the organic phase to any appreciable extent. The log of the ratio of X_{CA}/X_{AA} with no salt present to X_{CA}/X_{AA} with salt present was divided by X_{ss} to give k_{ss}.

The average values of k_{ss} for nominal concentrations of 2, 6, 10, 14, 18, and 22% lithium chloride were, respectively, 6.01, 5.13, 5.20, 4.46, 4.92, and 4.76. There was also a large variation of k_{ss} among the twelve points at a given salt concentration. At 14% lithium chloride, the value of k_{ss} varied from 5.43 to 4.40. It was felt that this variation was too large to ascribe "constant" behavior to k_{ss}, and it appears that this method is not applicable to the system acetic acid - benzene - water with lithium chloride, sodium chloride and potassium chloride.

By comparison, Swabb and Mongan, working at two concentrations of sodium sulfate, obtained values of 2.33 and 2.31 for k_{ss}, although values of k_{ss} at a given salt concentration varied somewhat.

The term s^0 in the Setschenow equation, 42, as used by Swabb and Mongan, is equal to the grams of acetic acid per gram of water in the aqueous phase, no salt present. In the nomenclature of this thesis, this quantity can be expressed by X_{CA}/X_{AA}. Comparison with the Hand equation used to correlate the results of this thesis, equation 57, shows that this quantity also appears in that equation. This suggests that the salting out constant of the Setschenow equation can be expressed in terms of the empirical constants of the Hand correlation as determined in this thesis.

The mathematical manipulations are detailed in the Appendix. The resulting equation for k_{ss} predicts an inverse variation with salt concentration and a direct variation with the abscissa X_{CB}/X_{BB}. In short, it predicts that k_{ss} is not constant.

The present data indicate that k_{ss} decreases with increase in salt concentration. At a given salt concentration, k_{ss} increases to a maximum value and then decreases, in contrast to the increase predicted by the equation for k_{ss}.

TREATMENT OF DATA

The data of this investigation are correlated using the Hand coordinates. Employing a linear correlation of two variables, the best straight line through each set of data is determined. This "best line" is the one for which the sum of the squares of deviation of one of the variables is a minimum.

Volk (95) has given an excellent description of correlation methods and provided a background for the interpretation of these results. The explanation of the meaning of the correlation coefficient and the probability level presented in the following paragraphs is based primarily on his account.

Assume a set of data $x_1, x_2, x_3, \ldots x_n$ whose corresponding values of y are $y_1, y_2, y_3, \ldots y_n$. The means of x and y are $\bar{x}$ and $\bar{y}$, respectively. Using a straight line correlation $\hat{y} = g + hx$ through these data, a value of $\hat{y}$ can be calculated for each value of x of the original data. The sum of the squares of deviation of y from $\bar{y}$, $\Sigma (y - \bar{y})^2$, is designated by $\Sigma' y^2$ and the sum of the squares of deviation of y from $\hat{y}$, $\Sigma (y - \hat{y})^2$, is designated by $\Sigma' \hat{y}^2$.

The ratio of the sum of squares of deviation removed by the correlation, $\Sigma' y^2 - \Sigma' \hat{y}^2$, to the sum of squares of deviation of the original data, Σy^2, is a measure of the goodness of the correlation. The square root of this ratio is the correlation coefficient, r.

$$r^2 = 1 - \frac{\sum' \hat{y}^2}{\sum' y^2} \qquad (56.1)$$

When there is perfect correlation between x and y, there is no residual deviation of $\hat{y}$ from y and $r^2 = 1.0$. When there is no correlation, $r^2 = 0.0$. It can be shown that r is related to the statistic t. It is therefore possible to tabulate the values of r corresponding to various probability levels and degrees of freedom based on the hypothesis that there is no correlation between the two variables involved. The values of r given in tables are the maximum values that can be expected by chance if there is no correlation. The probability level p indicates the chance of getting a value of r as large as the tabulated value when there is no correlation. A probability level of 0.001 means that the hypothesis that there is no correlation may be rejected with only 0.001 chance of being wrong.

The symbol $s(\hat{y})$ designates the standard error of estimate of log X_{CB}/X_{BB} when the correlation is used (Tables 7 through 10). In tables 11 and 12, this symbol denotes the standard error of estimate of log A_o and B_o, respectively.

RESULTS

The results of this investigation are presented in tables 7 through 12. Tables 7 through 10 list the values of the constants $\log A_o$ and B_o of the equation

$$\log \frac{X_{CB}}{X_{BB}} = \log A_o + B_o \log \frac{X_{CA}}{X_{AA}} \qquad (57)$$

as well as $s(\hat{y})$, the standard error of estimate of $\log X_{CB}/X_{BB}$; r, the correlation coefficient; and p, the probability level. Each equation in these four tables is applicable only at the particular salt concentration listed.

In tables 11 and 12, values of a, b, c, and d in the equations

$$\log A_o = a + b X_s' \qquad (58)$$

$$B_o = c + d X_s' \qquad (59)$$

are listed, together with the values of r, p, and $s(\hat{y})$. The equation for the effect of a particular salt on a particular acid is

$$\log \frac{X_{CB}}{X_{BB}} = a + b X_s' + (c + d X_s') \log \frac{X_{CA}}{X_{AA}} \qquad (60)$$

where a, b, c, and d depend on the nature of the acid, the nature of the salt, and temperature, but are independent of salt concentration.

TABLE 7

CORRELATION OF RESULTS

ACETIC ACID - BENZENE - WATER - SALT

$$\log \frac{X_{CB}}{X_{BB}} = \log A_o + B_o \log \frac{X_{CA}}{X_{AA}}$$

% LiCl	$\log A_o$	B_o	$s(\hat{y})$	r	p
0.000	-1.0002	1.2193	0.01265	0.9996	0.001
1.970	-0.9344	1.1919	0.01381	0.9994	0.001
5.743	-0.8298	1.1899	0.01830	0.9991	0.001
9.118	-0.7338	1.0920	0.00702	0.9997	0.001
13.68	-0.5987	1.1234	0.01509	0.9993	0.001
17.61	-0.4789	1.0488	0.01772	0.9980	0.001
21.23	-0.3933	0.9417	0.00631	0.9997	0.001
% NaCl					
0.000	-1.0002	1.2193	0.01265	0.9996	0.001
2.002	-0.9595	1.2116	0.00821	0.9996	0.001
5.863	-0.9118	1.1861	0.01241	0.9996	0.001
9.403	-0.8603	1.0979	0.01438	0.9987	0.001
13.65	-0.8061	1.0814	0.01576	0.9991	0.001
17.41	-0.7507	1.0098	0.01354	0.9992	0.001
% KCl					
0.000	-1.0002	1.2193	0.01265	0.9996	0.001
2.001	-0.9717	1.1755	0.01094	0.9993	0.001
5.717	-0.9670	1.1890	0.00891	0.9997	0.001
9.287	-0.9518	1.1782	0.00599	0.9999	0.001
13.74	-0.9214	1.1726	0.00843	0.9998	0.001
17.14	-0.9099	1.1408	0.00653	0.9999	0.001

TABLE 8

CORRELATION OF RESULTS

PROPIONIC ACID - BENZENE - WATER - SALT

$$\log \frac{X_{CB}}{X_{BB}} = \log A_o + B_o \log \frac{X_{CA}}{X_{AA}}$$

% LiCl	$\log A_o$	B_o	$s(\hat{y})$	r	p
0.000	0.4554	1.5678	0.01446	0.9993	0.001
5.743	0.9181	1.7273	0.01361	0.9997	0.001
9.118	1.3098	1.9011	0.00489	0.9991	0.001
13.68	1.8880	2.1275	0.01285	0.9994	0.001
17.61	2.4323	2.3820	0.02004	0.9984	0.001
21.23	2.6873	2.4068	0.02738	0.9967	0.001
% NaCl					
0.000	0.4554	1.5678	0.01446	0.9993	0.001
5.863	0.5699	1.4580	0.01162	0.9995	0.001
9.403	0.8089	1.5416	0.01421	0.9993	0.001
13.65	1.3238	1.8563	0.00731	0.9998	0.001
17.41	1.6762	1.9872	0.01603	0.9995	0.001
21.33	1.9860	2.0472	0.01894	0.9992	0.001

TABLE 9

CORRELATION OF RESULTS

*BUTYRIC ACID - BENZENE - WATER - SALT

$$\log \frac{X_{CB}}{X_{BB}} = \log A_o + B_o \log \frac{X_{CA}}{X_{AA}}$$

% LiCl	$\log A_o$	B	$s(\hat{y})$	r	p
0.000	2.2739	2.2163	0.00944	0.9996	0.001
1.970	2.5357	2.1835	0.02041	0.9992	0.001
5.743	2.8909	2.2034	0.01515	0.9995	0.001
9.118	3.3183	2.2951	0.02146	0.9991	0.001
13.68	3.6055	2.2528	0.03181	0.9990	0.001
17.61	4.0692	2.3397	0.01900	0.9992	0.001
21.23	4.1090	2.2318	0.02180	0.9989	0.001
% NaCl					
0.000	2.2739	2.2163	0.00944	0.9996	0.001
2.002	2.4565	2.1505	0.03290	0.9978	0.001
5.863	2.8175	2.2290	0.02491	0.9987	0.001
9.403	3.0898	2.2538	0.01578	0.9995	0.001
13.65	3.3686	2.2487	0.01911	0.9992	0.001
17.41	3.6141	2.2391	0.03226	0.9977	0.001
21.33	3.9618	2.2893	0.03301	0.9976	0.001
% KCl					
0.000	2.2739	2.2163	0.00944	0.9996	0.001
2.001	2.4264	2.1919	0.01674	0.9988	0.001
5.717	2.5106	2.1378	0.02047	0.9991	0.001
9.287	2.5655	2.0796	0.00647	0.9999	0.001
13.74	2.7670	2.1020	0.00981	0.9998	0.001
17.14	2.8782	2.0922	0.02076	0.9991	0.001
21.00	3.1334	2.1499	0.01621	0.9994	0.001

*Data are for lower lines of figures 43, 44, and 45.

TABLE 10

CORRELATION OF RESULTS

*BUTYRIC ACID - BENZENE - WATER - SALT

$$\log \frac{X_{CB}}{X_{BB}} = \log A_o + B_o \log \frac{X_{CA}}{X_{AA}}$$

% LiCl	$\log A_o$	B_o	$s(\hat{y})$	r	p
0.000	3.4366	3.2516	0.08674	0.9954	0.001
1.970	5.5245	4.9146	0.02090	0.9881	0.001
5.743	6.7647	5.2489	0.04889	0.9266	0.02-0.05
9.118	6.5177	4.5568	0.03248	0.9706	0.01-0.001
13.68	8.4341	5.2653	0.01628	0.9964	0.001
17.61	4.9939	2.8399	0.06750	0.8863	0.02-0.05
21.23	8.6307	4.8013	0.03040	0.9972	0.001
% NaCl					
0.000	3.4366	3.2516	0.08674	0.9954	0.001
2.002	4.5461	4.0584	0.02667	0.9842	0.001
5.863	5.8149	4.6698	0.07031	0.8944	0.01-0.02
9.403	6.4443	4.7591	0.05381	0.9535	0.001
13.65	8.7112	5.8449	0.03615	0.9801	0.001
17.41	7.7055	4.7847	0.05111	0.9607	0.001
21.33	7.8050	4.5373	0.02694	0.9812	0.01-0.001
% KCl					
0.000	3.4366	3.2516	0.08674	0.9954	0.001
2.001	3.6279	3.2748	0.02453	0.9911	0.001
5.717	6.0051	5.2322	0.03596	0.9671	0.01-0.001
9.287	5.1393	4.1397	0.05021	0.9682	0.01-0.001
13.74	4.9314	3.7196	0.03911	0.9695	0.01-0.001
17.14	6.5906	4.8300	0.03440	0.9730	0.01-0.001
21.00	5.5864	3.8331	0.03090	0.9862	0.001

*Data are for upper lines of figures 43, 44, and 45.

TABLE 11

CORRELATION OF RESULTS

$\log A_o$ - SALT CONCENTRATION

$$\log A_o = a + b\,X_s'$$

System	a	b	$s(\hat{y})$	r	p
HOAc-LiCl	-0.9949	0.02877	0.00668	0.9997	0.001
HOAc-NaCl	-0.9947	0.01403	0.00545	0.9987	0.001
HOAc-KCl	-0.9929	0.00492	0.00750	0.9798	0.001
HOPr-LiCl	0.3694	0.11093	0.09167	0.9956	0.001
HOPr-NaCl	0.2672	0.07756	0.15081	0.9760	0.001
Lower Line:*					
HOBu-LiCl	2.3690	0.08969	0.11670	0.9891	0.001
HOBu-NaCl	2.3149	0.07707	0.03986	0.9982	0.001
HOBu-KCl	2.2879	0.03687	0.05709	0.9841	0.001
Upper Line:*					
HOBu-LiCl	4.8518	0.14911	1.56723	0.6389	0.10-0.15
HOBu-NaCl	4.2232	0.21392	1.89591	0.8956	0.01-0.001
HOBu-KCl	3.9827	0.10799	0.88568	0.7231	0.05-0.10

*Data are for lines shown in figures 43, 44, and 45.

TABLE 12

CORRELATION OF RESULTS

B_o - SALT CONCENTRATION

$$B_o = c + d X'_s$$

System	c	d	$s(\hat{y})$	r	p
HOAc-LiCl	1.2291	-0.01149	0.03769	0.9361	0.01-0.001
HOAc-NaCl	1.2329	-0.01223	0.01973	0.9778	0.001
HOAc-KCl	1.2046	-0.00314	0.01559	0.8364	0.02-0.05
HOPr-LiCl	1.5301	0.04352	0.06003	0.9878	0.001
HOPr-NaCl	1.4199	0.02866	0.12996	0.8872	0.01-0.001
Lower Line:*					
HOBu-LiCl	2.1706	+0.006320	0.05501	0.7081	0.05-0.10
HOBu-NaCl	2.1546	+0.006525	0.03074	0.8793	0.01-0.001
HOBu-KCl	2.1421	-0.001672	0.03973	0.3398	0.40-0.50
Upper Line:*					
HOBu-LiCl	4.4262	-0.001511	1.06497	0.0124	- - - -
HOBu-NaCl	3.9625	+0.05984	0.68755	0.6034	0.10-0.20
HOBu-KCl	3.7466	+0.29825	0.78486	0.3102	0.40-0.50

*Data are for lines shown in figures 43, 44, and 45.

DISCUSSION OF CORRELATION

The equations used to calculate the various quantities needed to correlate the data are given in the Appendix. The IBM 1620 Computer at the Newark College of Engineering Computing Center was used to perform the calculations.

The equations for acetic acid, propionic acid, and butyric acid (lower line) at specific levels of salt concentration (tables 7 through 9) gave probability levels of less than 0.001. Data for the upper line of butyric acid (table 10) showed probability levels as high as 0.02-0.05. Generally, the correlation was excellent.

The correlation of log A_o with salt concentration (table 11) gave probability levels of less than 0.001 for acetic acid, propionic acid, and butyric acid (lower line). For butyric acid (upper line), p was as high as 0.10-0.15.

The correlation of B_o with salt concentration was the least reliable of those made. The maximum value of p for acetic acid systems was 0.05 and for propionic acid, 0.01. For the upper line of butyric acid, p reached 0.40-0.50. The upper line for butyric acid-lithium chloride showed no correlation while for potassium chloride, p was 0.40-0.50.

GRAPHICAL PRESENTATION

OF

EFFECTS OF SALTS

ACETIC ACID - BENZENE - WATER - LITHIUM CHLORIDE

EFFECT OF LITHIUM CHLORIDE ON DISTRIBUTION OF ACETIC ACID

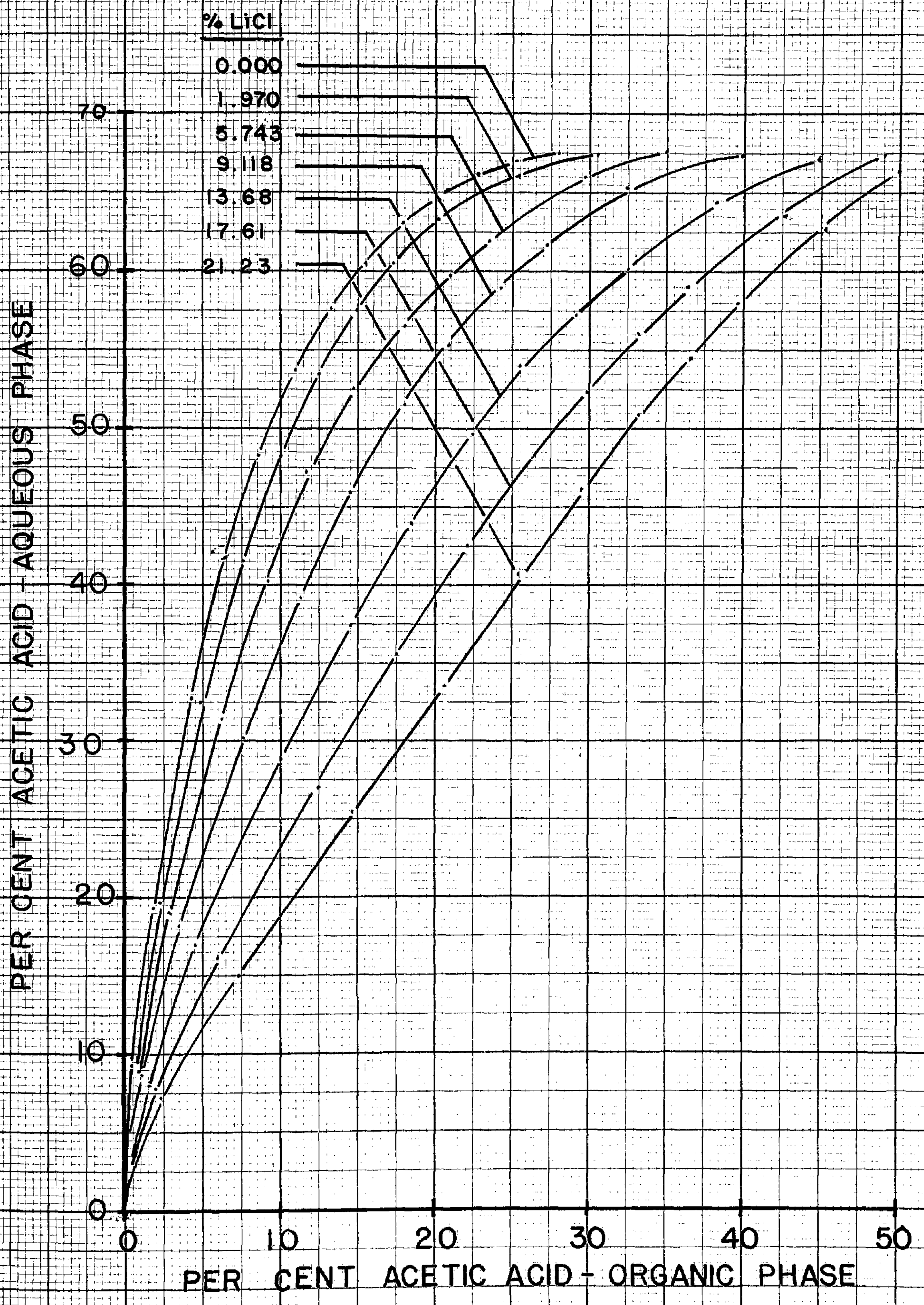
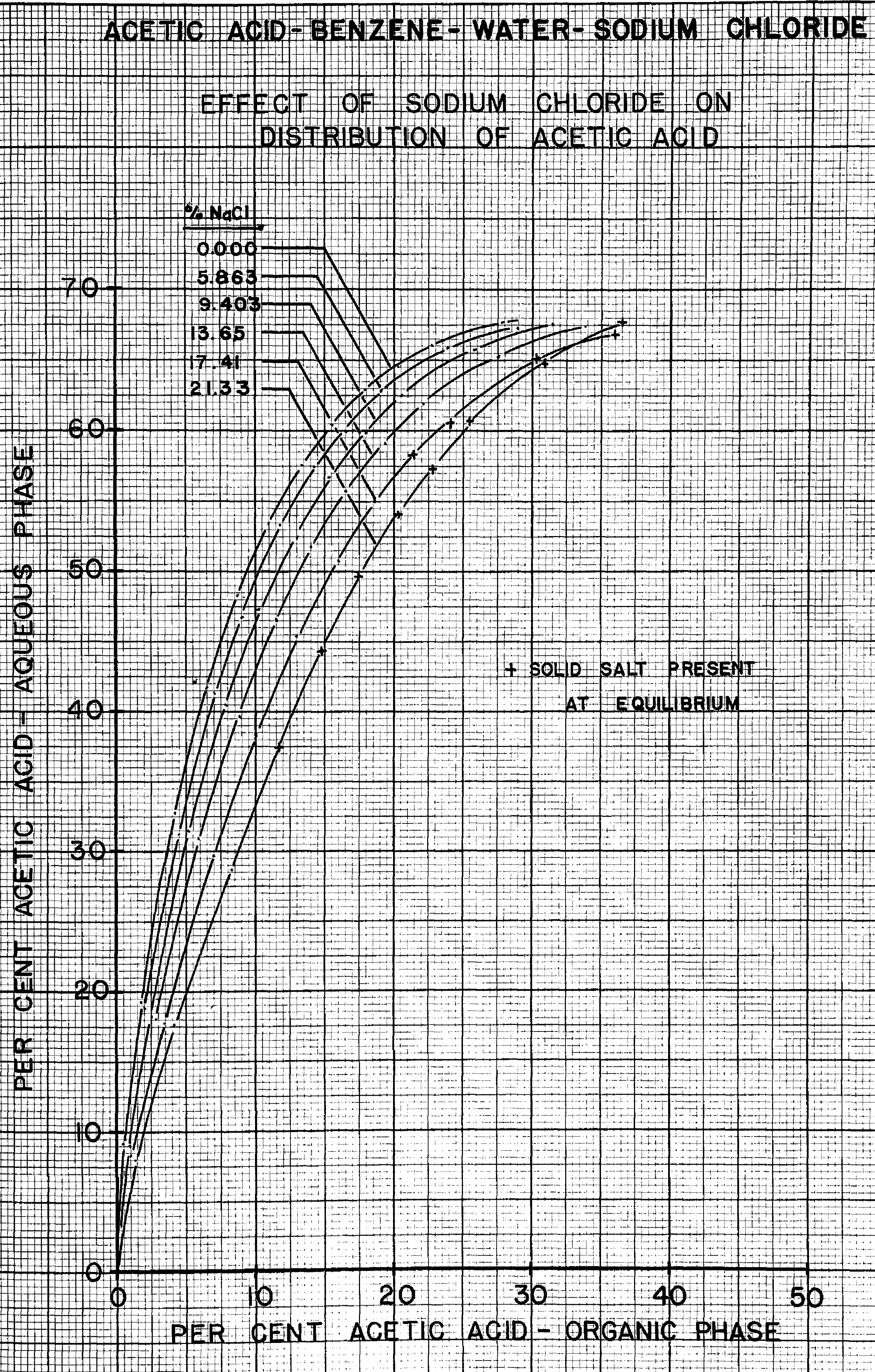


FIGURE 5



ACETIC ACID-BENZENE-WATER-SODIUM CHLORIDE

EFFECT OF SODIUM CHLORIDE ON DISTRIBUTION OF ACETIC ACID

FIGURE 6

ACETIC ACID - BENZENE - WATER - POTASSIUM CHLORIDE

EFFECT OF POTASSIUM CHLORIDE ON DISTRIBUTION OF ACETIC ACID

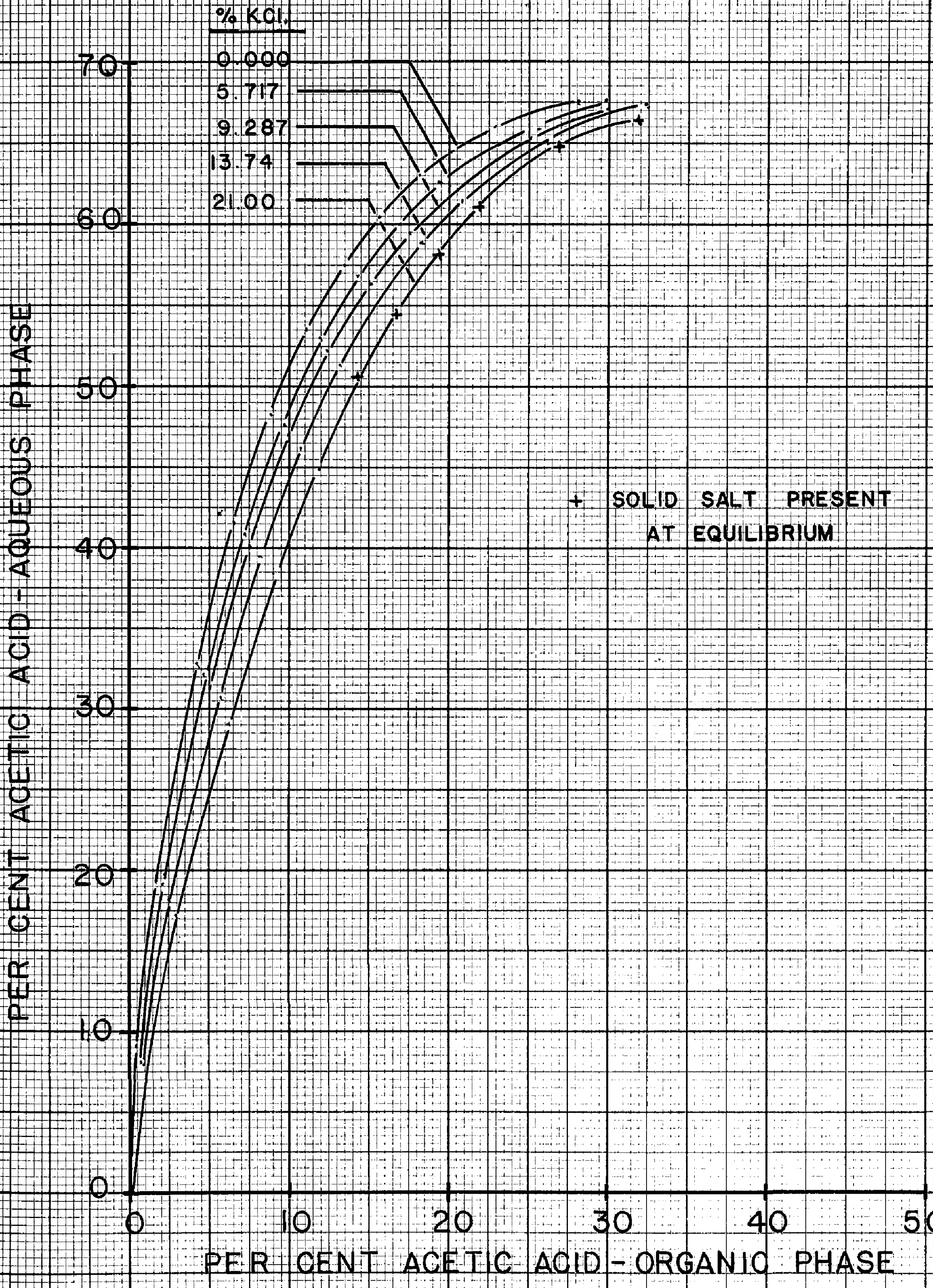
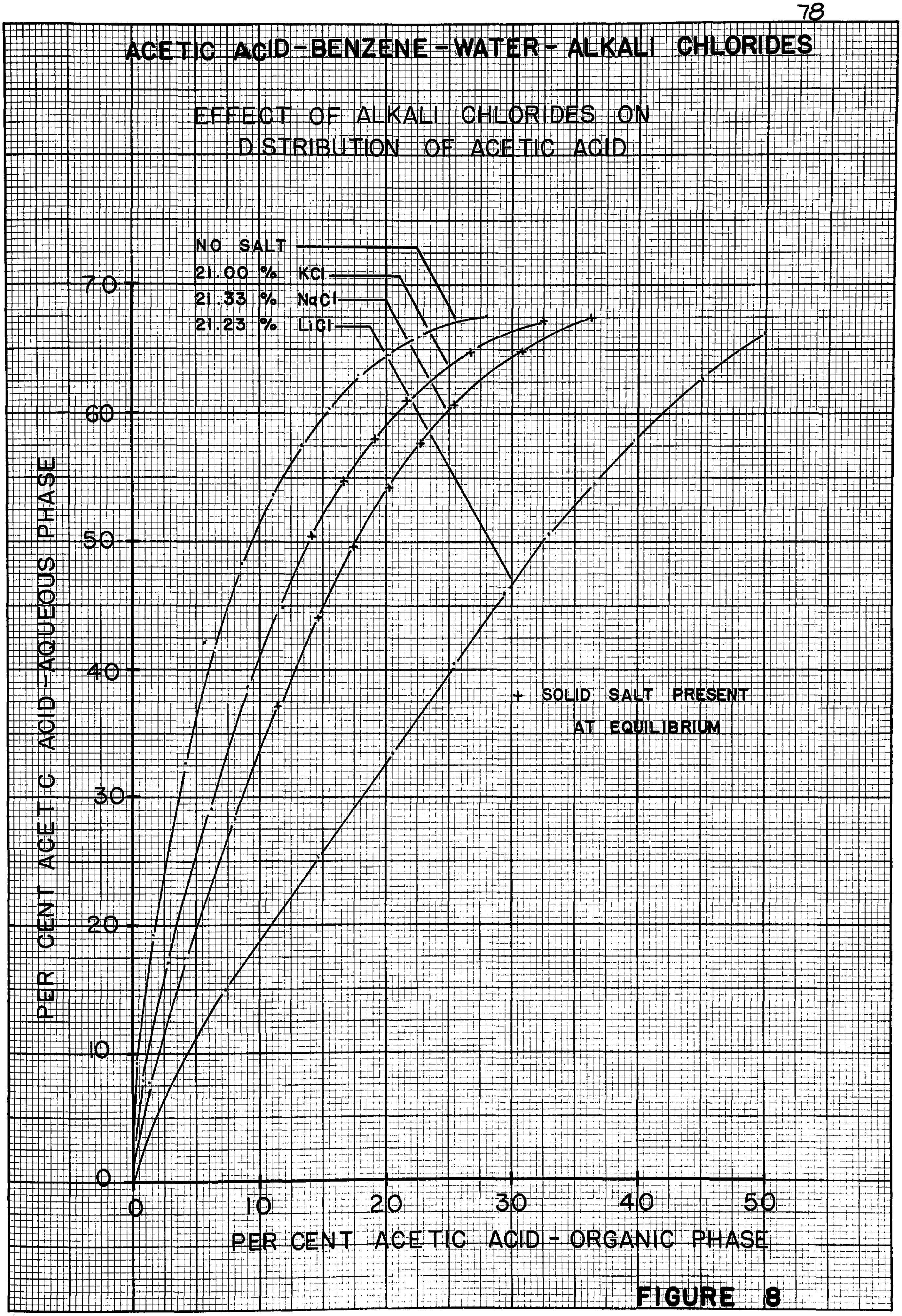


FIGURE 7



ACETIC ACID-BENZENE-WATER-ALKALI CHLORIDES

EFFECT OF ALKALI CHLORIDES ON DISTRIBUTION OF ACETIC ACID

FIGURE 8

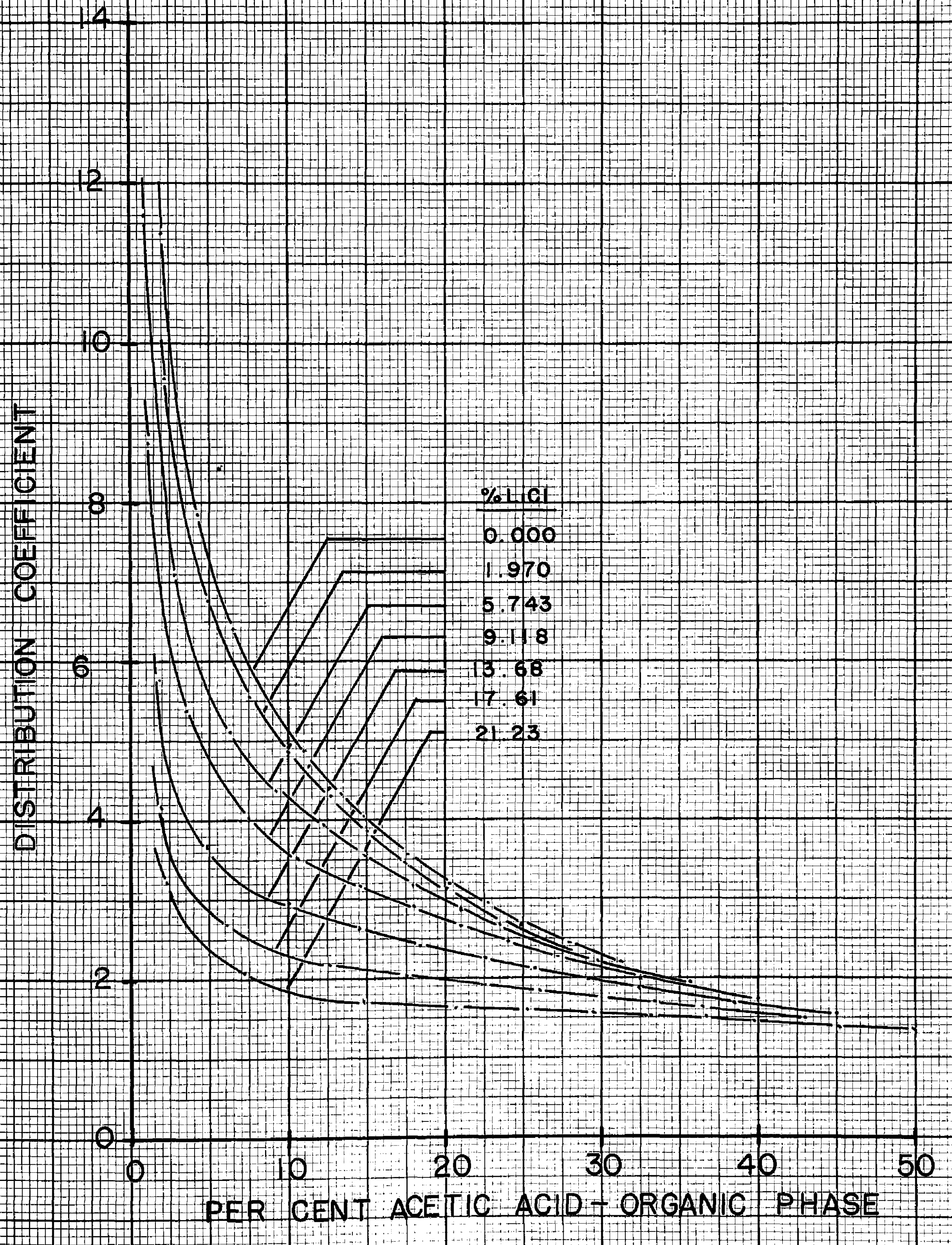

ACETIC ACID-BENZENE-WATER-LITHIUM CHLORIDE
EFFECT OF LITHIUM CHLORIDE ON DISTRIBUTION COEFFICIENT OF ACETIC ACID
DISTRIBUTION COEFFICIENT
PER CENT ACETIC ACID-ORGANIC PHASE
0
2
4
6
8
10
12
14
0
10
20
30
40
50
%LiCl
0.000
1.970
5.743
9.118
13.68
17.61
21.23

FIGURE 9

ACETIC ACID-BENZENE-WATER-SODIUM CHLORIDE

EFFECT OF SODIUM CHLORIDE ON DISTRIBUTION COEFFICIENT OF ACETIC ACID

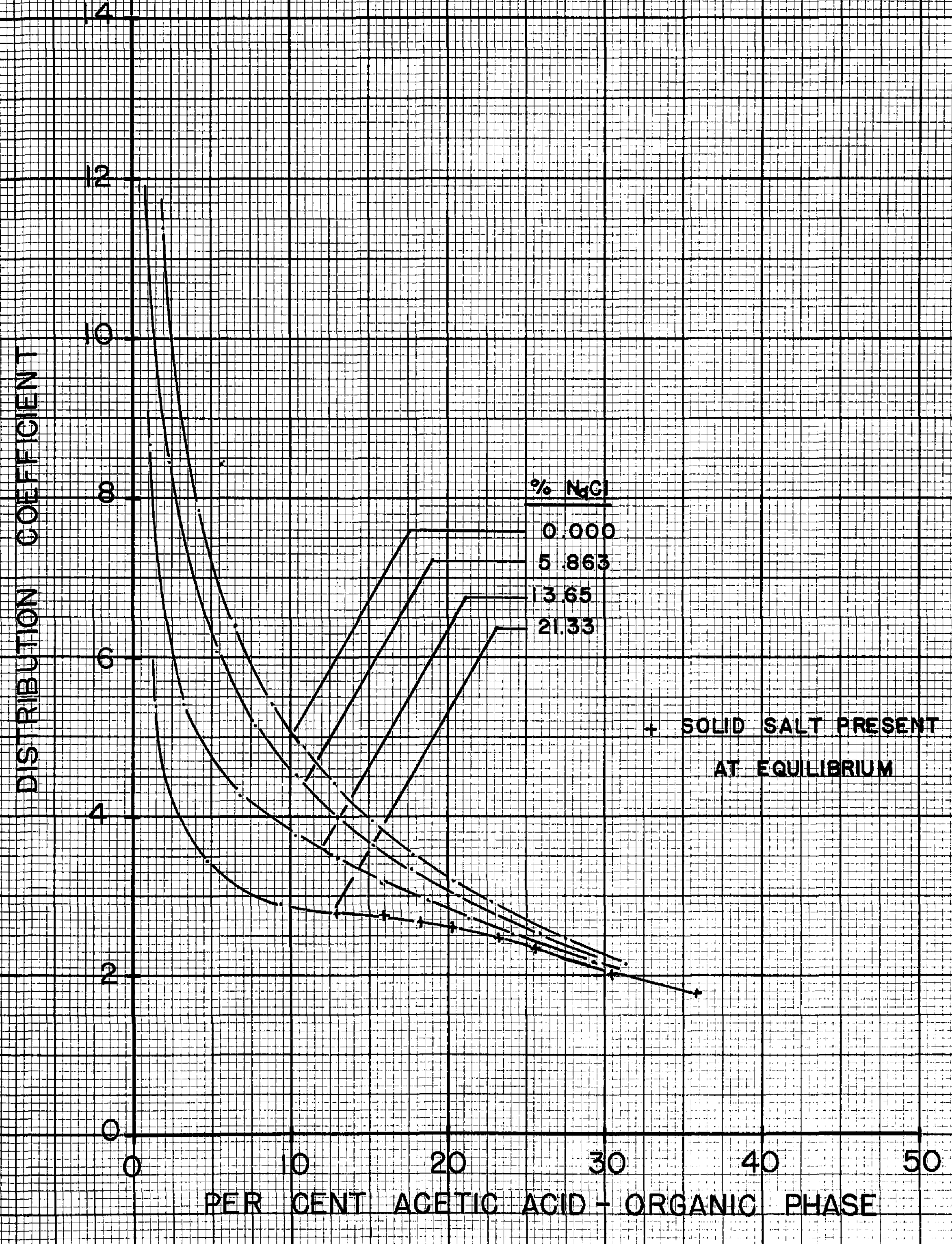


FIGURE 10

ACETIC ACID-BENZENE-WATER-POTASSIUM CHLORIDE

EFFECT OF POTASSIUM CHLORIDE ON DISTRIBUTION COEFFICIENT OF ACETIC ACID

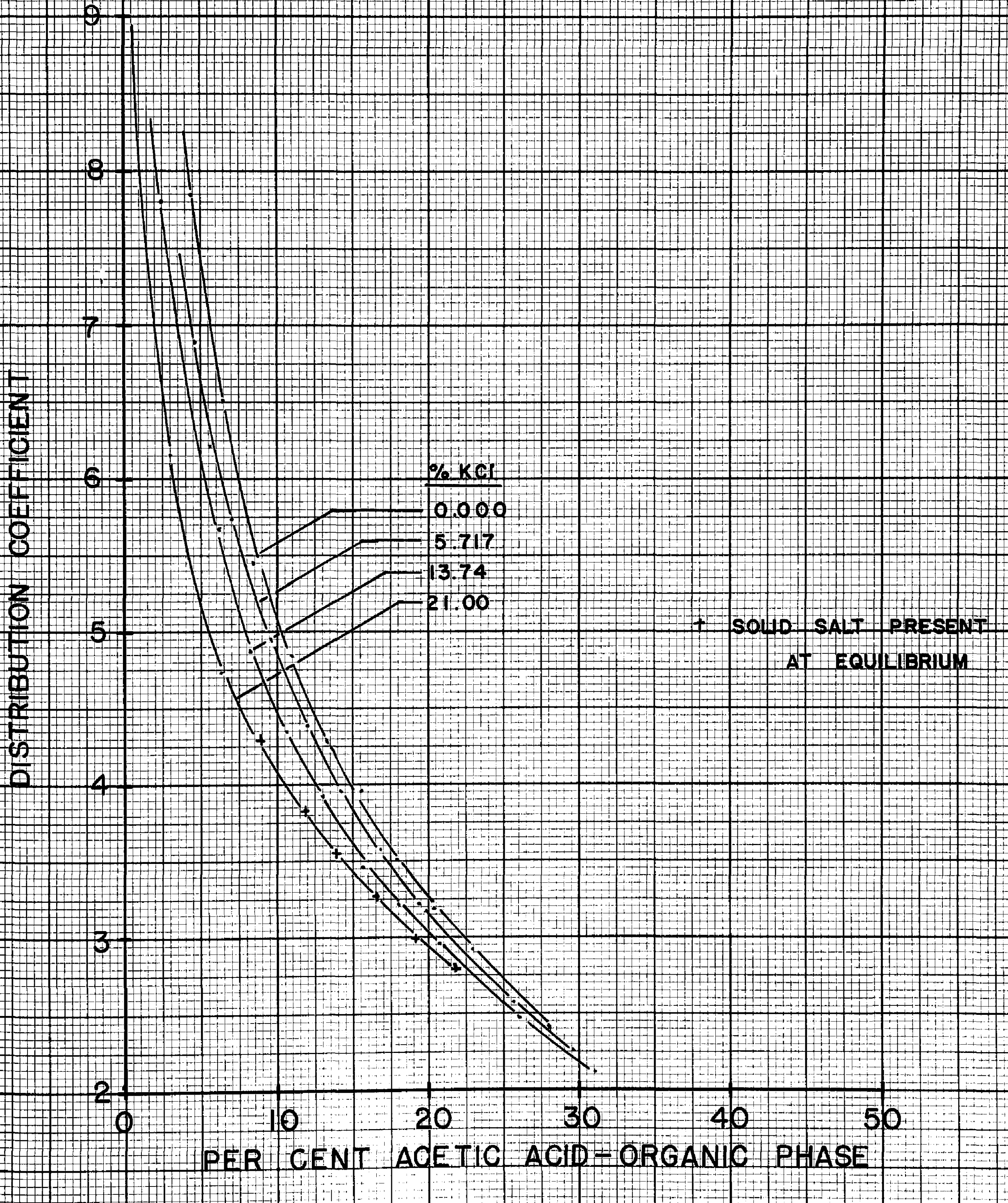


FIGURE 11

ACETIC ACID- BENZENE- WATER - ALKALI CHLORIDES

EFFECT OF ALKALI CHLORIDES ON DISTRIBUTION COEFFICIENT OF ACETIC ACID

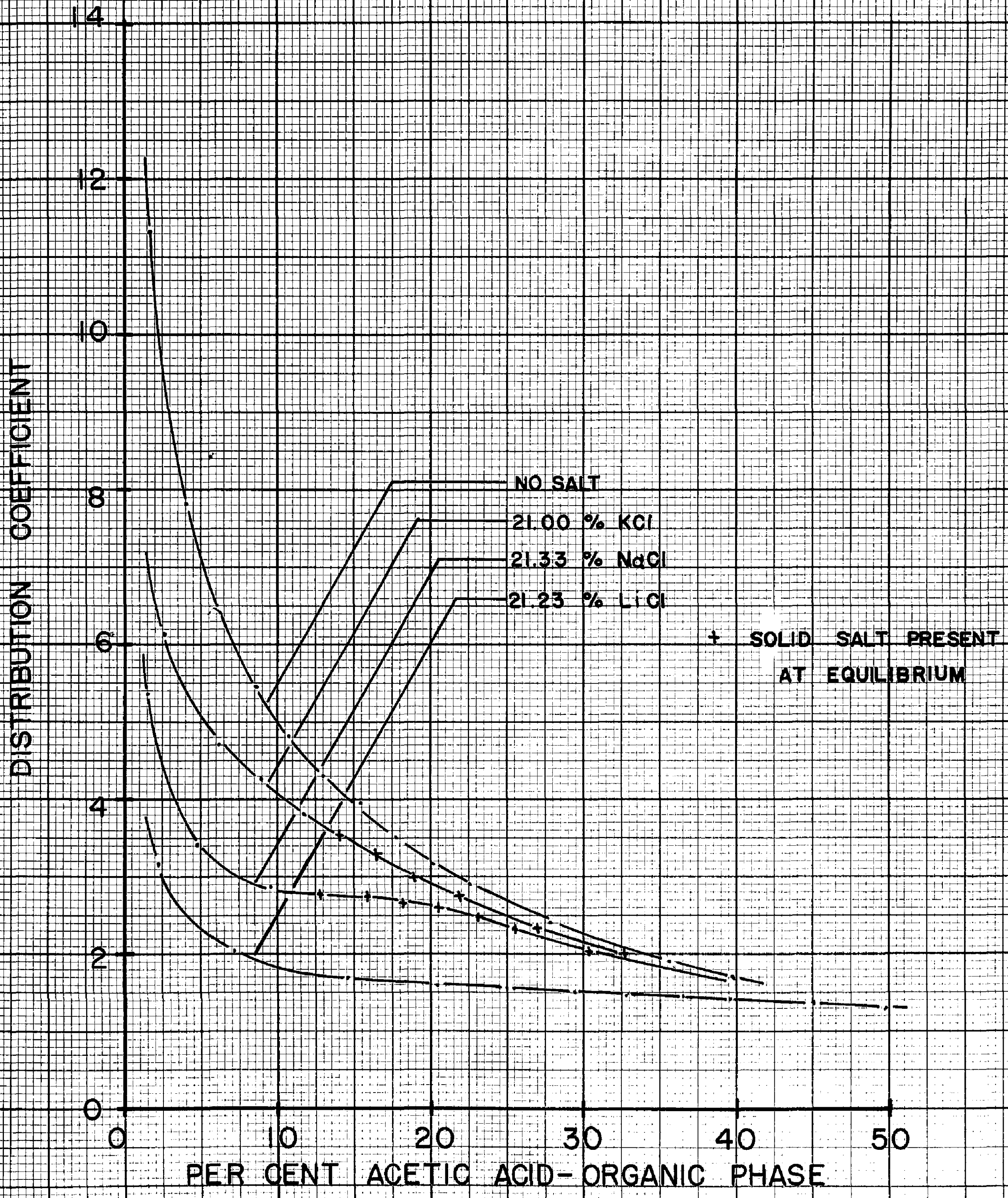


FIGURE 12

ACETIC ACID-BENZENE-WATER-LITHIUM CHLORIDE

HAND COORDINATES

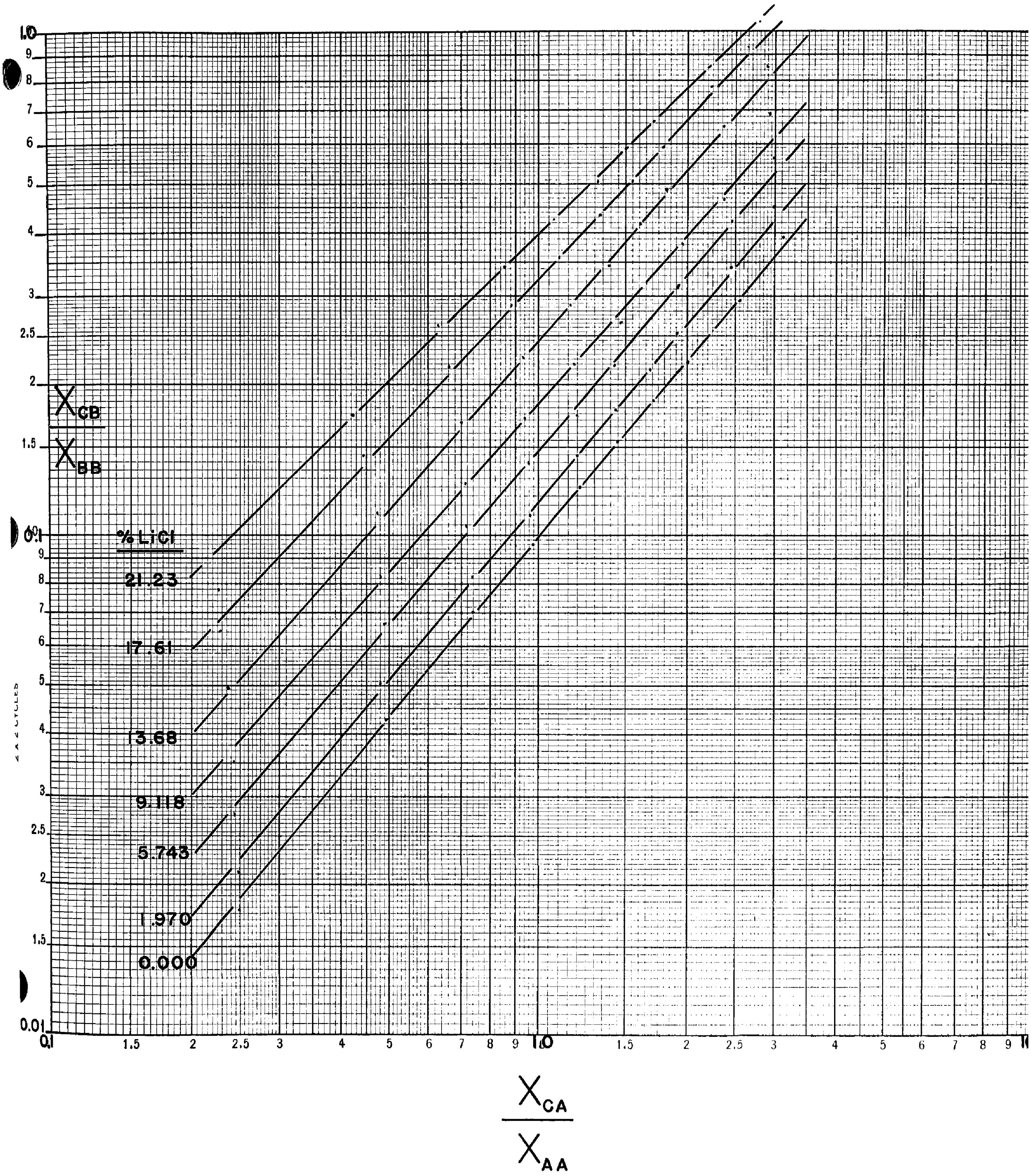


FIGURE 13

ACETIC ACID-BENZENE-WATER-SODIUM CHLORIDE

HAND COORDINATES

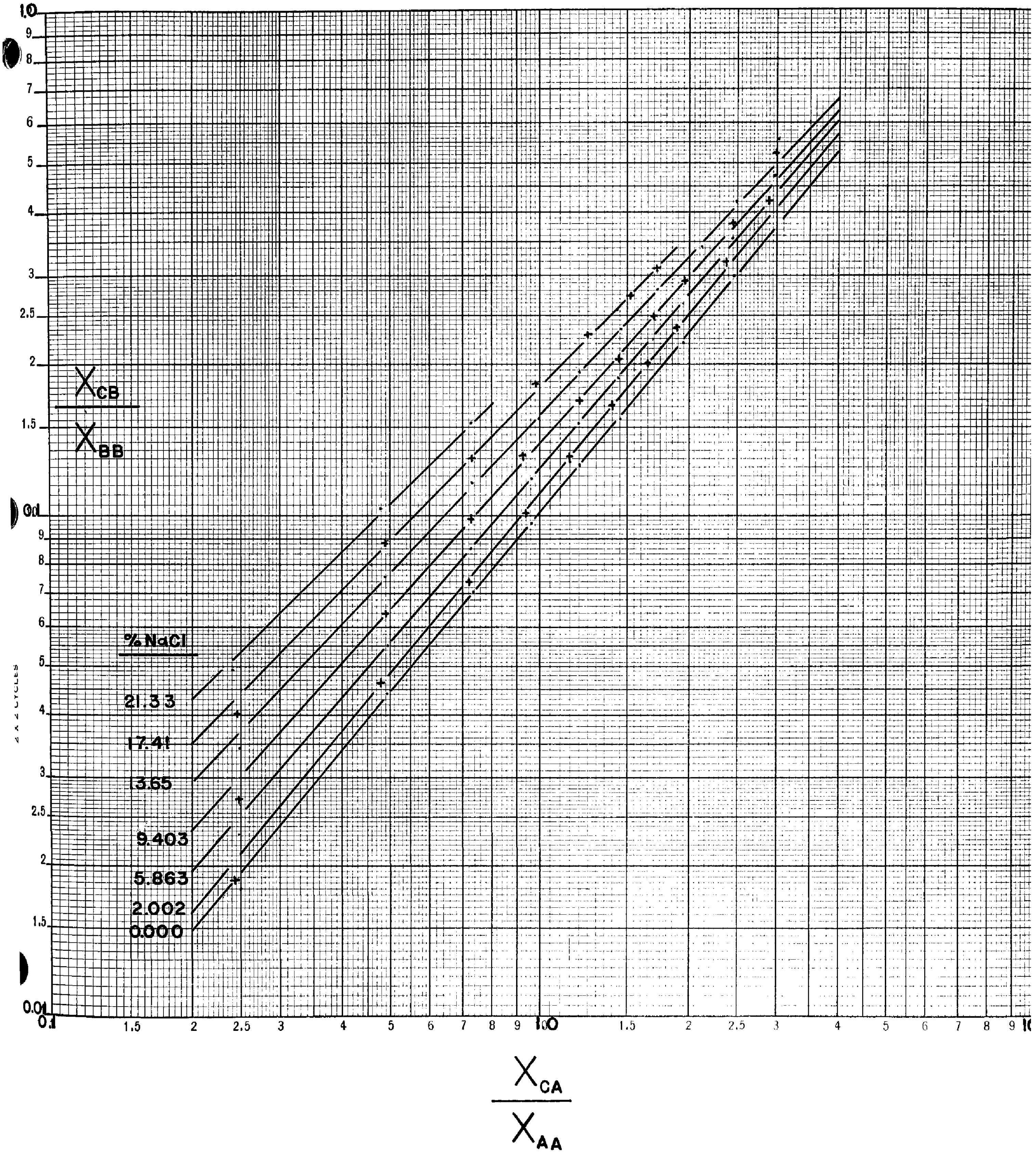


FIGURE 14

ACETIC ACID-BENZENE-WATER-POTASSIUM CHLORIDE

HAND COORDINATES

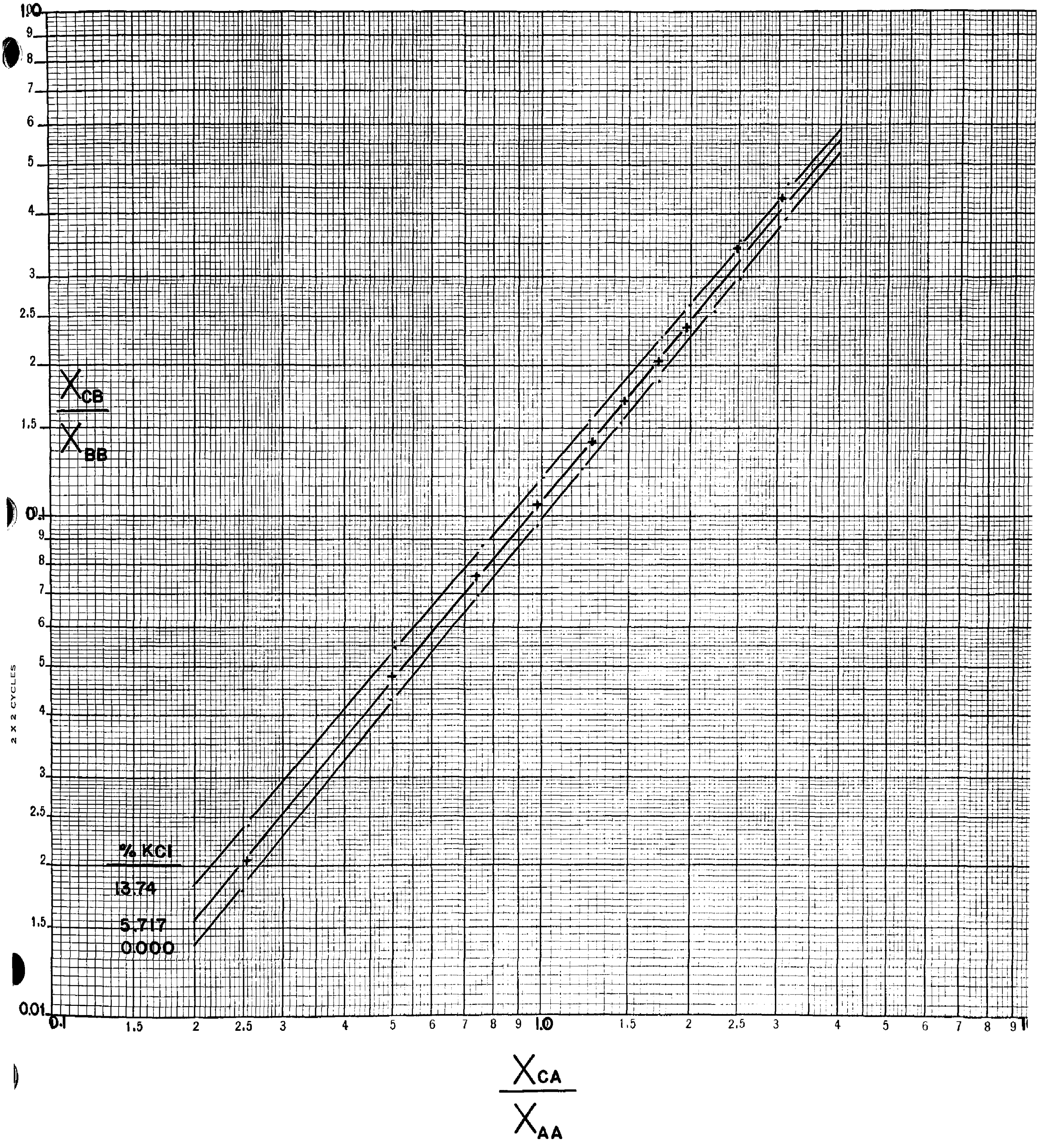


FIGURE 15

ACETIC ACID- BENZENE-WATER-ALKALI CHLORIDES

ORDINATE OF HAND PLOT AT $X_{CA}/X_{AA} = 1.0$ VS. ALKALI CHLORIDE CONCENTRATION (WEIGHT BASIS)

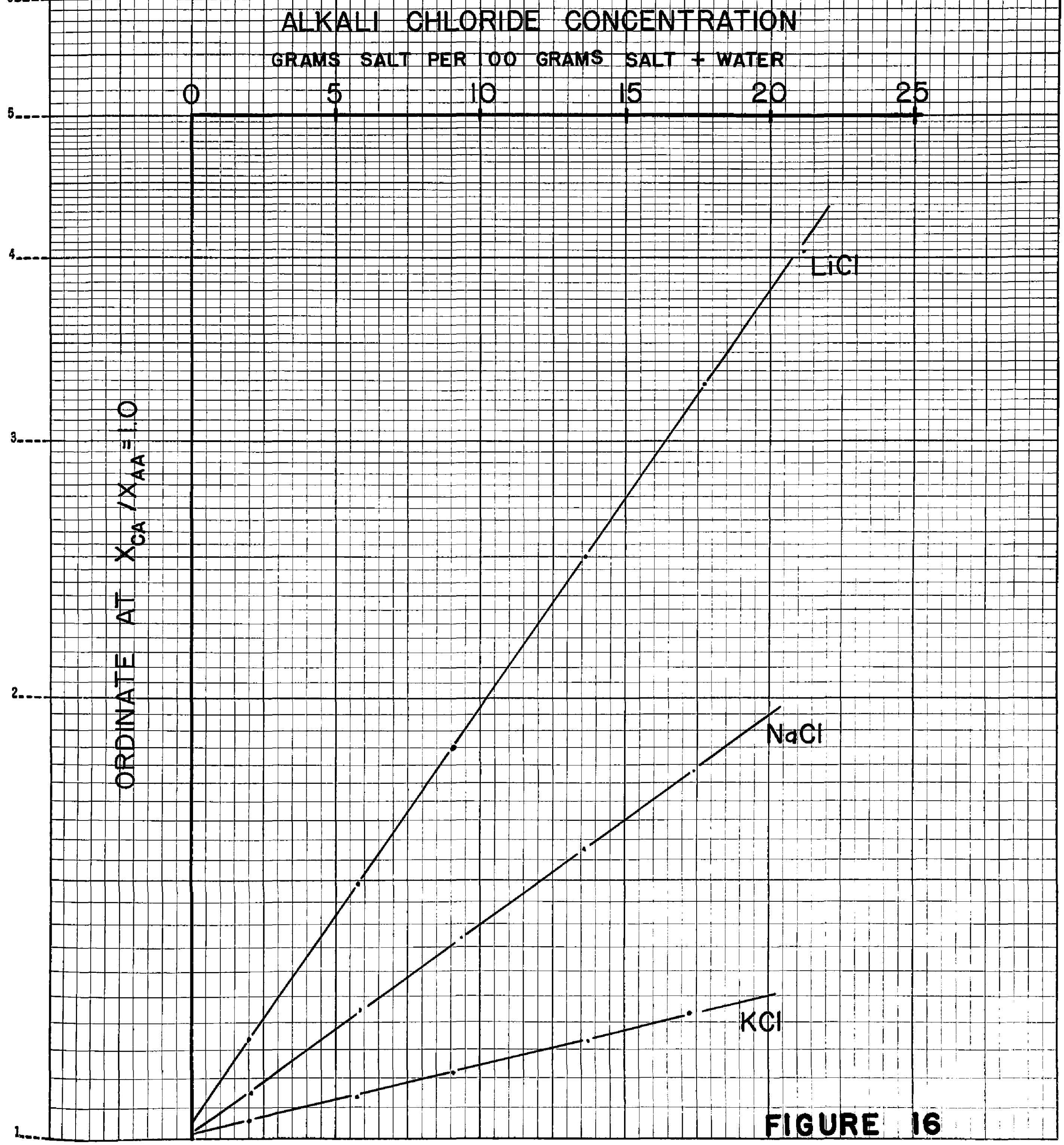


FIGURE 16

ACETIC ACID-BENZENE-WATER-ALKALI CHLORIDES

ORDINATE OF HAND PLOT AT X_{CA}/X_{AA} = 1.0 VS. ALKALI CHLORIDE CONCENTRATION (MOLE BASIS)

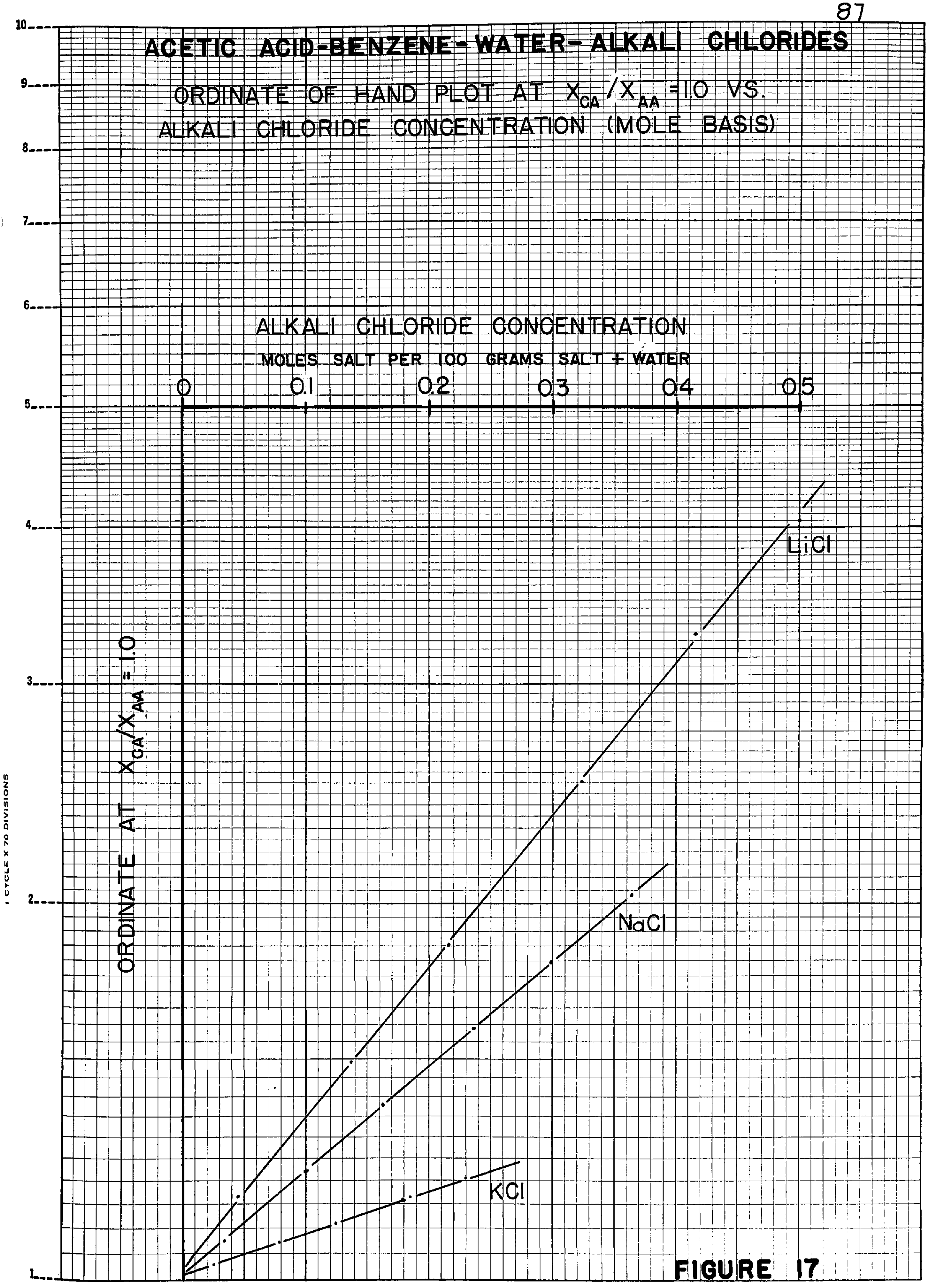


FIGURE 17

ACETIC ACID-BENZENE-WATER-LITHIUM CHLORIDE

EFFECT OF LITHIUM CHLORIDE ON
WATER CONTENT OF ORGANIC PHASE

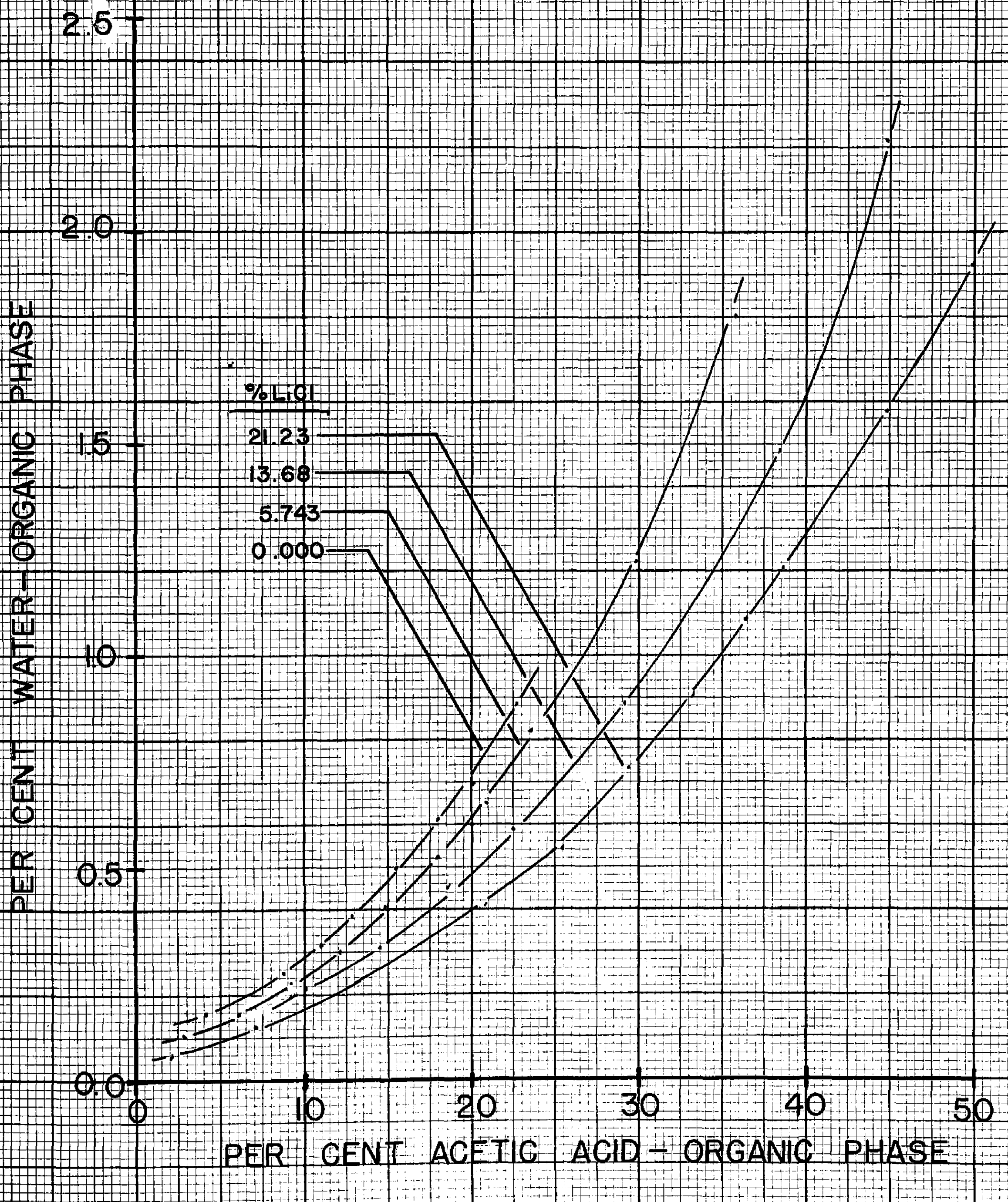


FIGURE 18

ACETIC ACID-BENZENE-WATER-SODIUM CHLORIDE
EFFECT OF SODIUM CHLORIDE ON WATER CONTENT OF ORGANIC PHASE

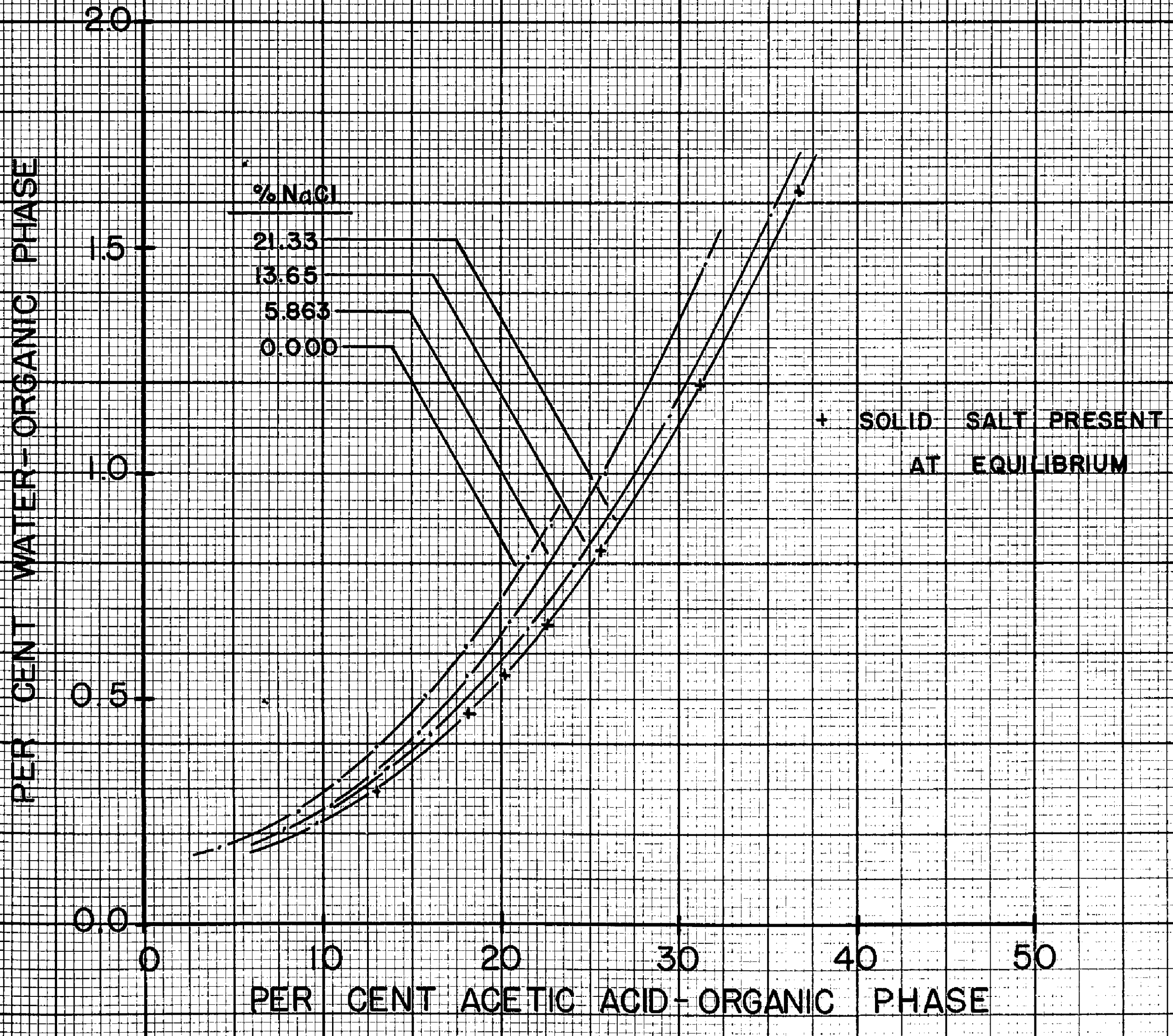


FIGURE 19

ACETIC ACID-BENZENE-WATER-POTASSIUM CHLORIDE

EFFECT OF POTASSIUM CHLORIDE ON WATER CONTENT OF ORGANIC PHASE

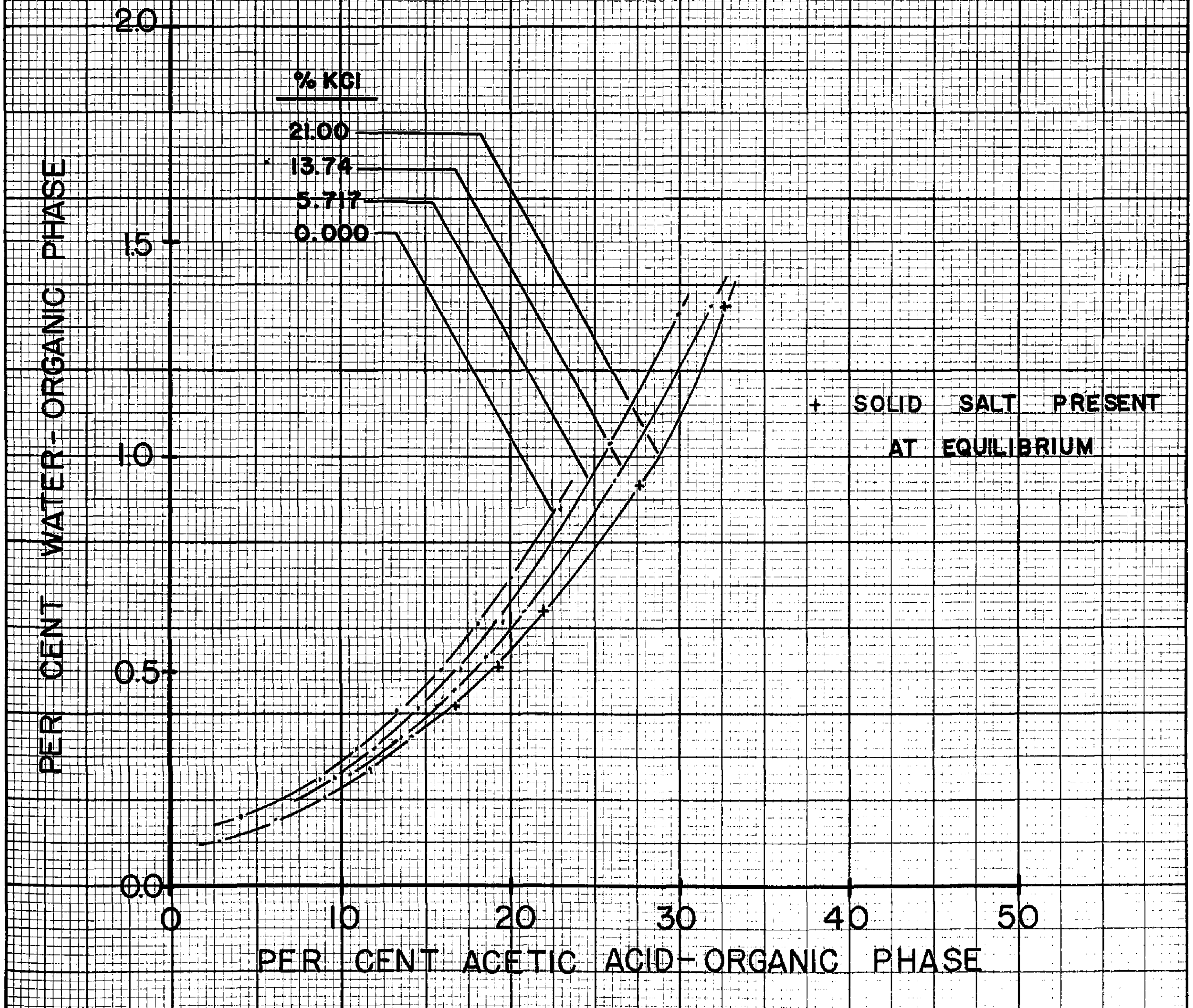


FIGURE 20

PROPIONIC ACID-BENZENE-WATER-LITHIUM CHLORIDE

EFFECT OF LITHIUM CHLORIDE ON DISTRIBUTION OF PROPIONIC ACID

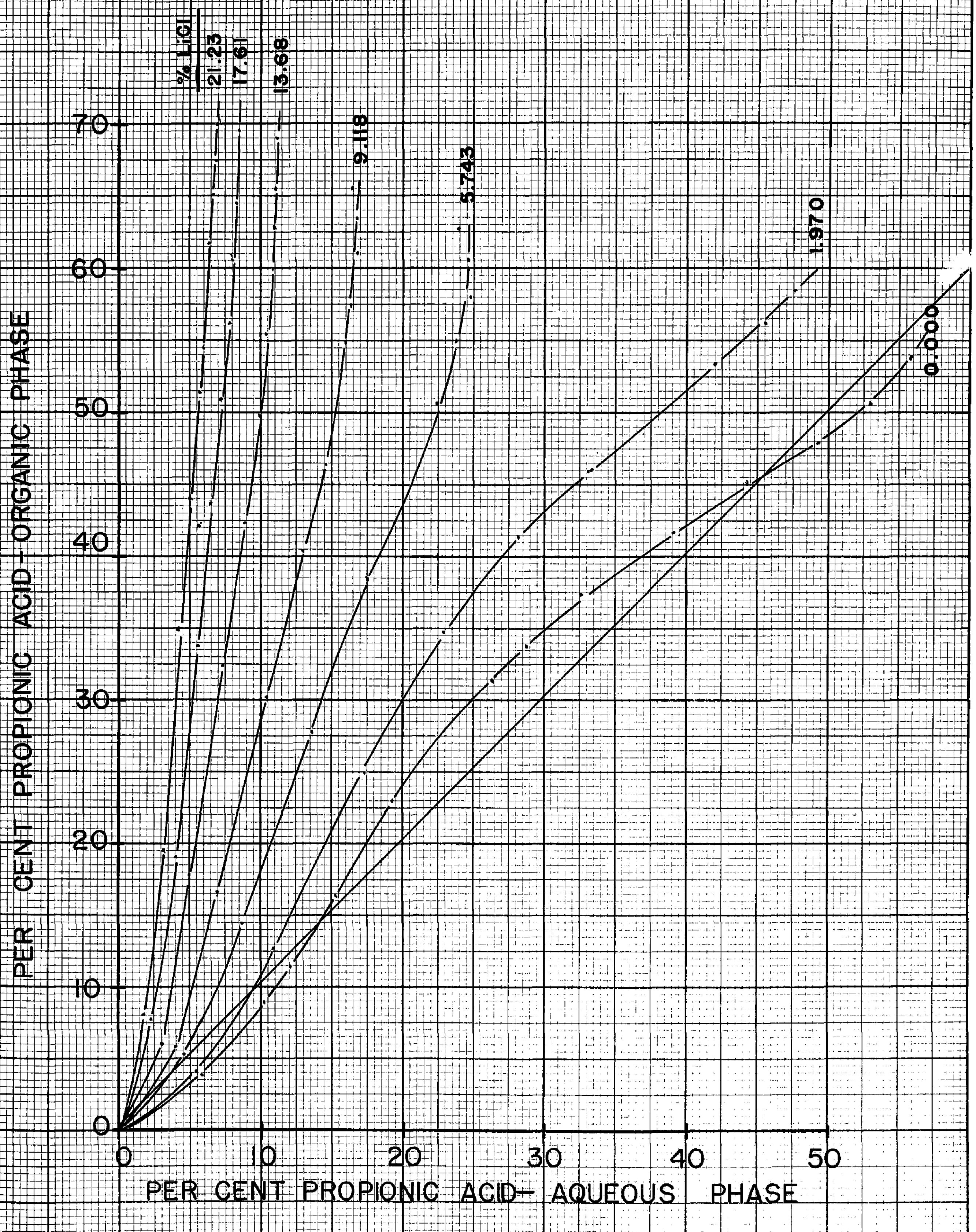


FIGURE 21

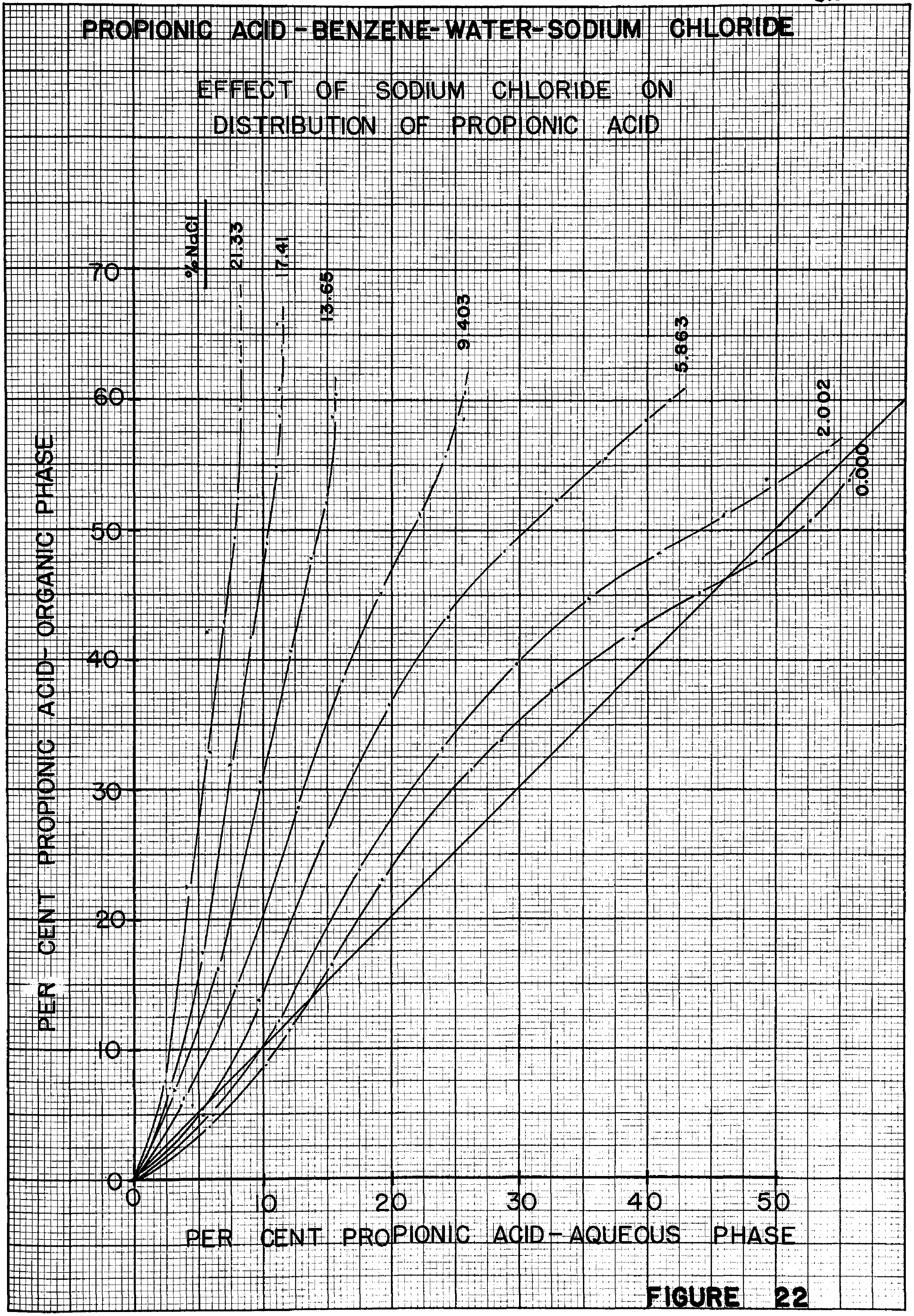

PROPIONIC ACID - BENZENE - WATER - SODIUM CHLORIDE
EFFECT OF SODIUM CHLORIDE ON DISTRIBUTION OF PROPIONIC ACID
% NaCl
21.33
17.41
13.65
9.403
5.863
2.002
0.000
PER CENT PROPIONIC ACID - ORGANIC PHASE
70
60
50
40
30
20
10
0
PER CENT PROPIONIC ACID - AQUEOUS PHASE
10
20
30
40
50

FIGURE 22

PROPIONIC ACID-BENZENE-WATER-POTASSIUM CHLORIDE

EFFECT OF POTASSIUM CHLORIDE ON DISTRIBUTION OF PROPIONIC ACID

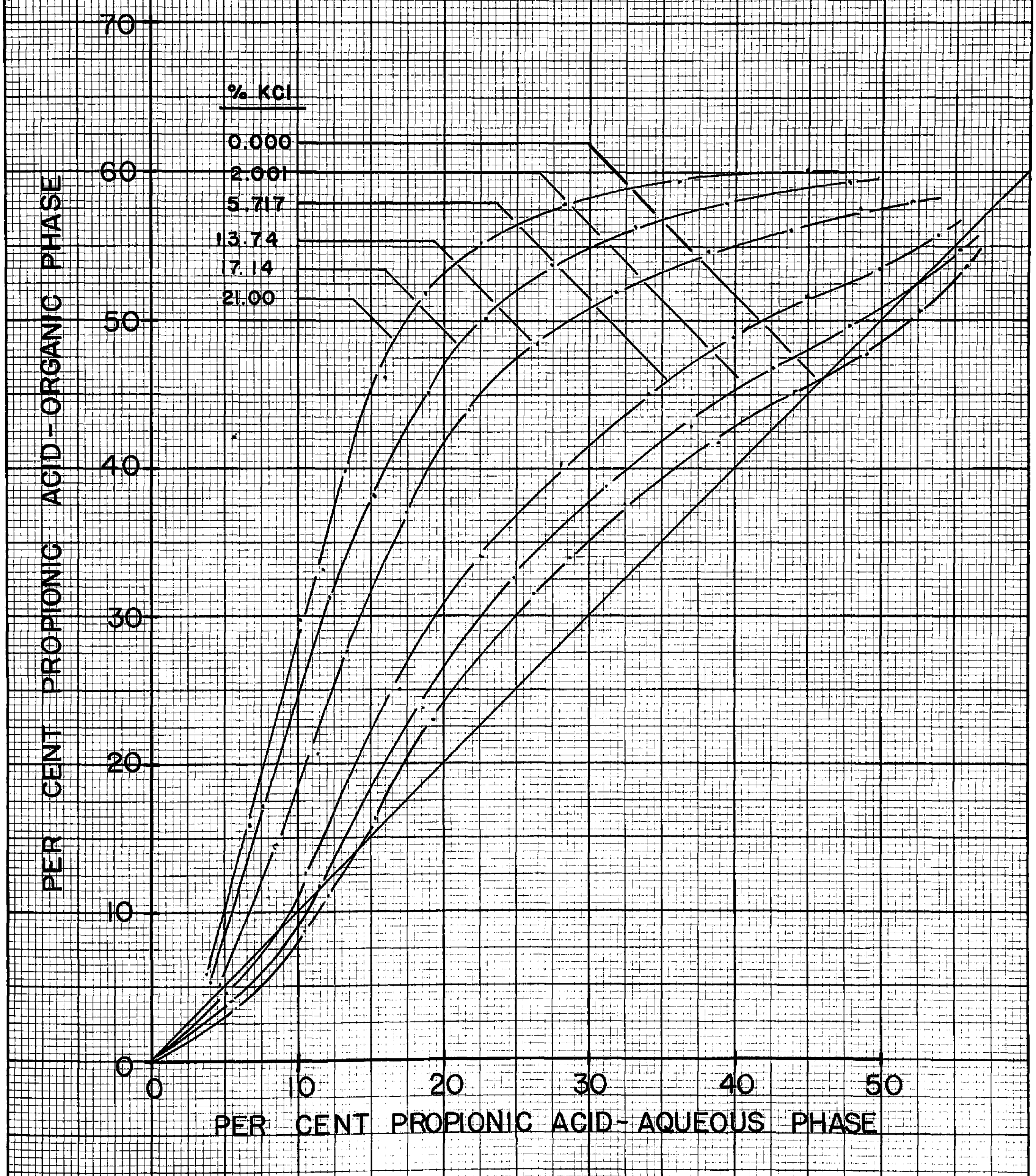


FIGURE 23

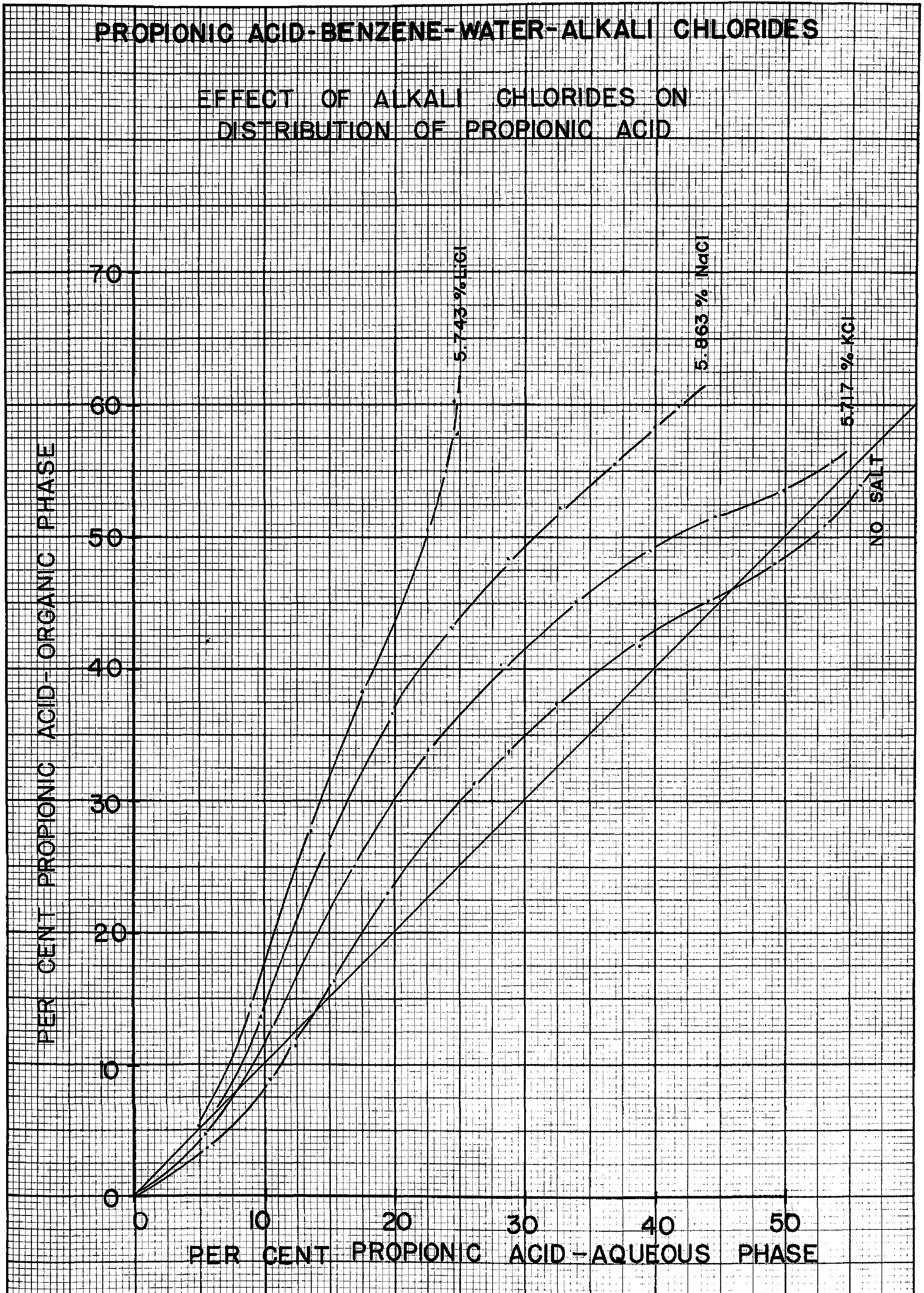

PROPIONIC ACID-BENZENE-WATER-ALKALI CHLORIDES
EFFECT OF ALKALI CHLORIDES ON DISTRIBUTION OF PROPIONIC ACID
5.743 % LiCl
5.863 % NaCl
5.717 % KCl
NO SALT
PER CENT PROPIONIC ACID-ORGANIC PHASE
0
10
20
30
40
50
60
70
0
10
20
30
40
50
PER CENT PROPIONIC ACID-AQUEOUS PHASE

FIGURE 24

PROPIONIC ACID-BENZENE-WATER-ALKALI CHLORIDES

EFFECT OF ALKALI CHLORIDES ON DISTRIBUTION OF PROPIONIC ACID

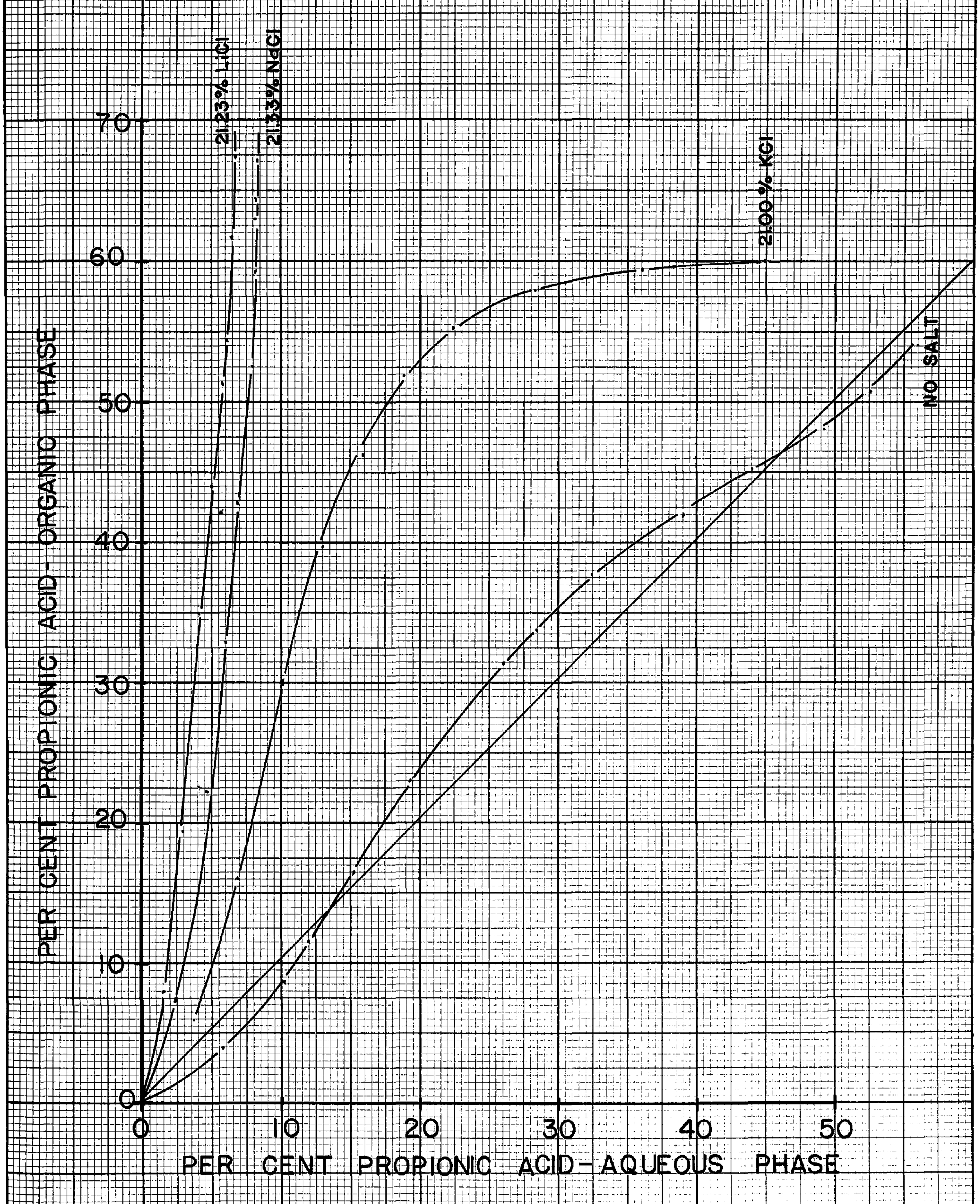


FIGURE 25

PROPIONIC ACID-BENZENE-WATER-LITHIUM CHLORIDE

EFFECT OF LITHIUM CHLORIDE ON
DISTRIBUTION COEFFICIENT OF PROPIONIC ACID

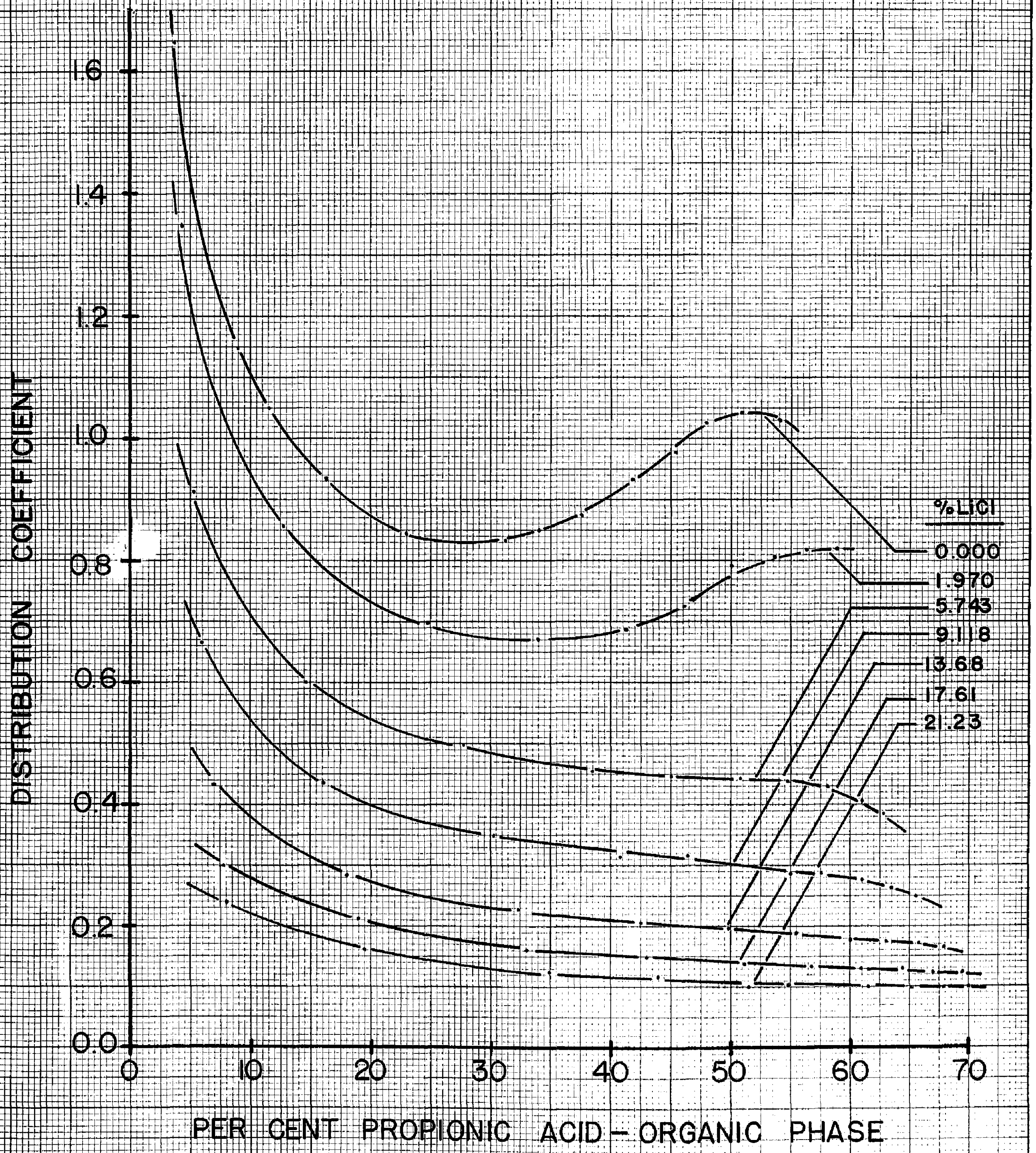


FIGURE 26

PROPIONIC ACID — BENZENE — WATER - SODIUM CHLORIDE

EFFECT OF SODIUM CHLORIDE ON DISTRIBUTION COEFFICIENT OF PROPIONIC ACID

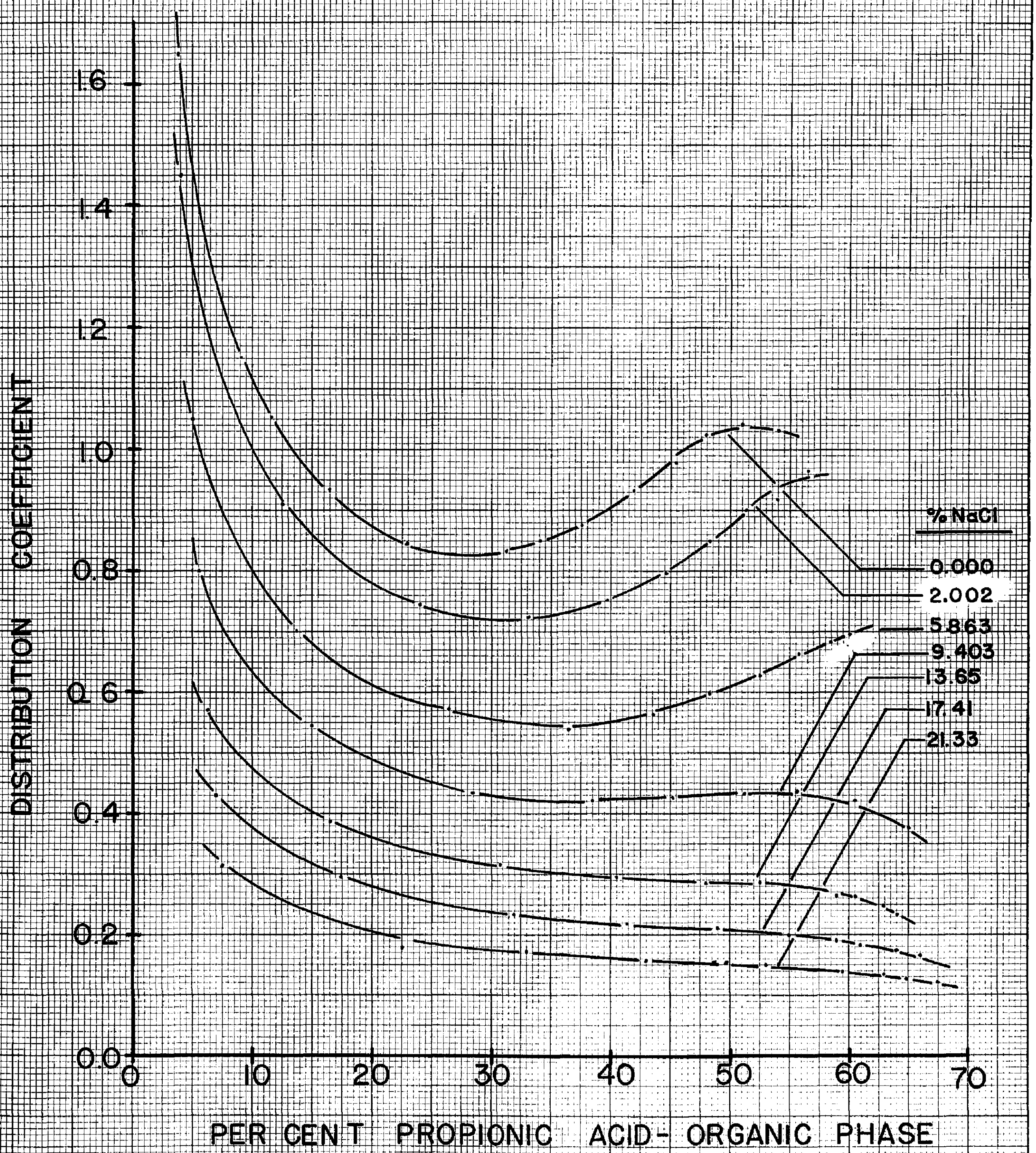


FIGURE 27

PROPIONIC ACID-BENZENE-WATER-POTASSIUM CHLORIDE

EFFECT OF POTASSIUM CHLORIDE ON DISTRIBUTION COEFFICIENT OF PROPIONIC ACID

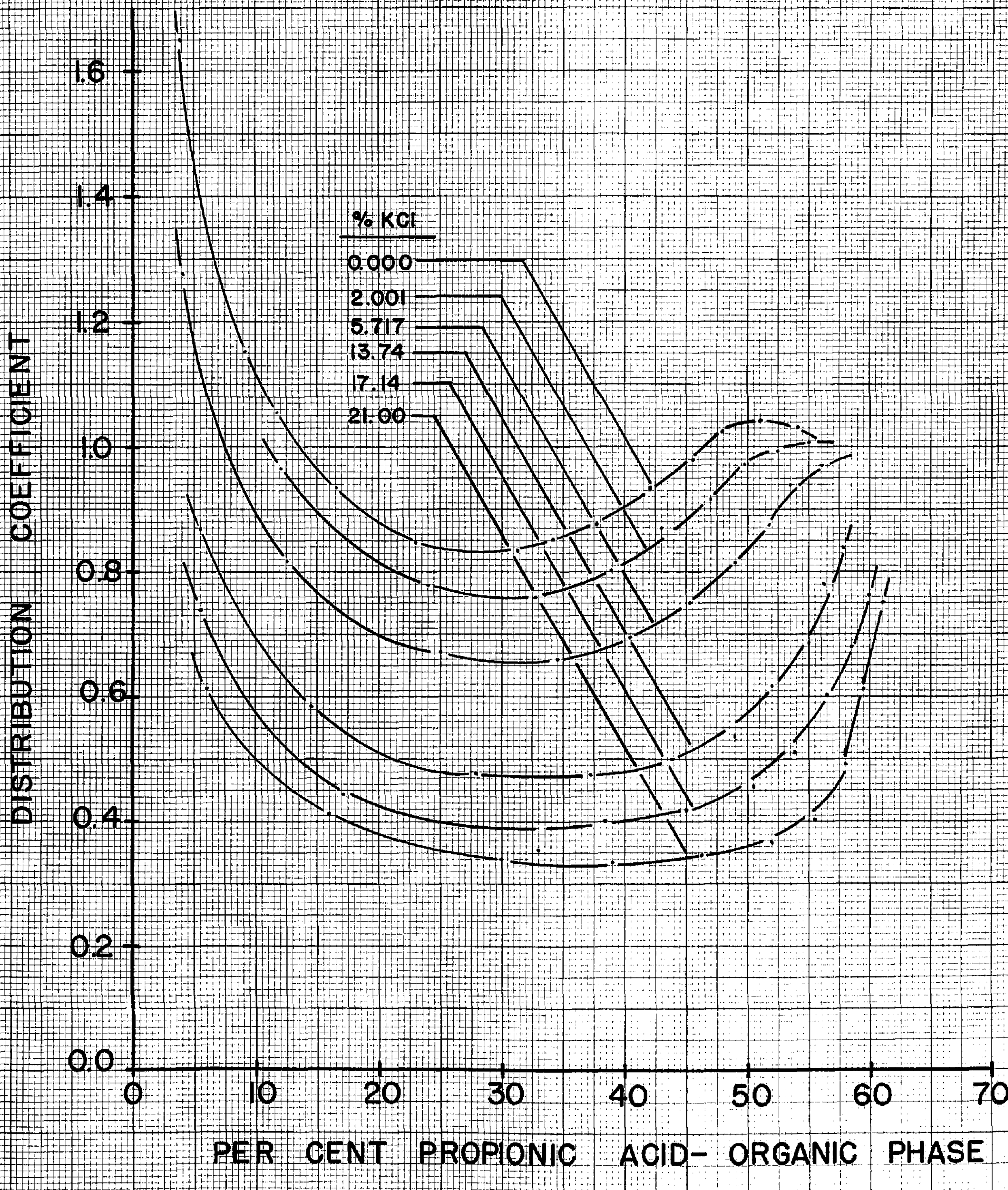


FIGURE 28

PROPIONIC ACID-BENZENE-WATER-ALKALI CHLORIDES

EFFECT OF ALKALI CHLORIDES ON
DISTRIBUTION COEFFICIENT OF PROPIONIC ACID

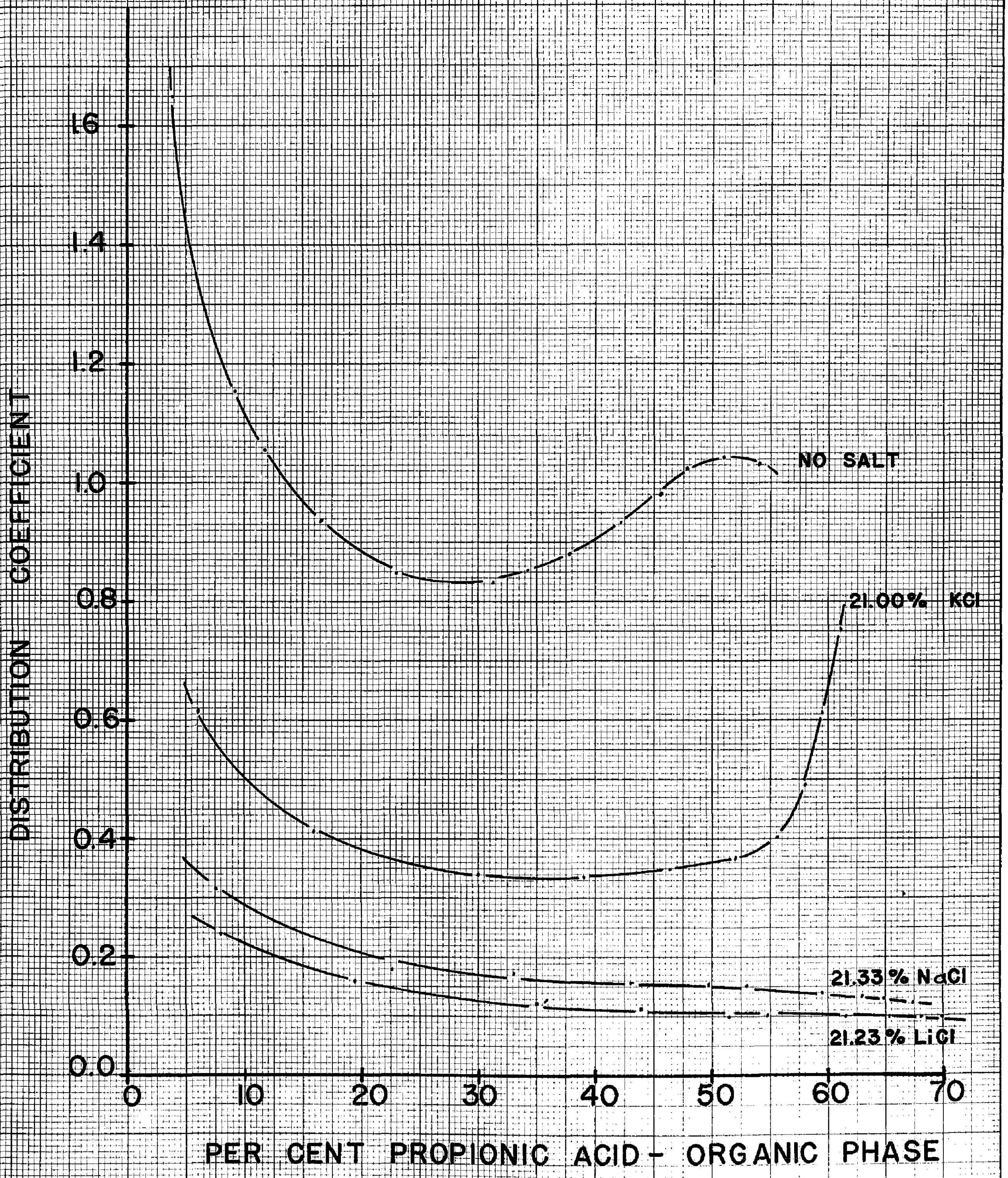


FIGURE 29

PROPIONIC ACID-BENZENE-WATER-LITHIUM CHLORIDE

HAND COORDINATES

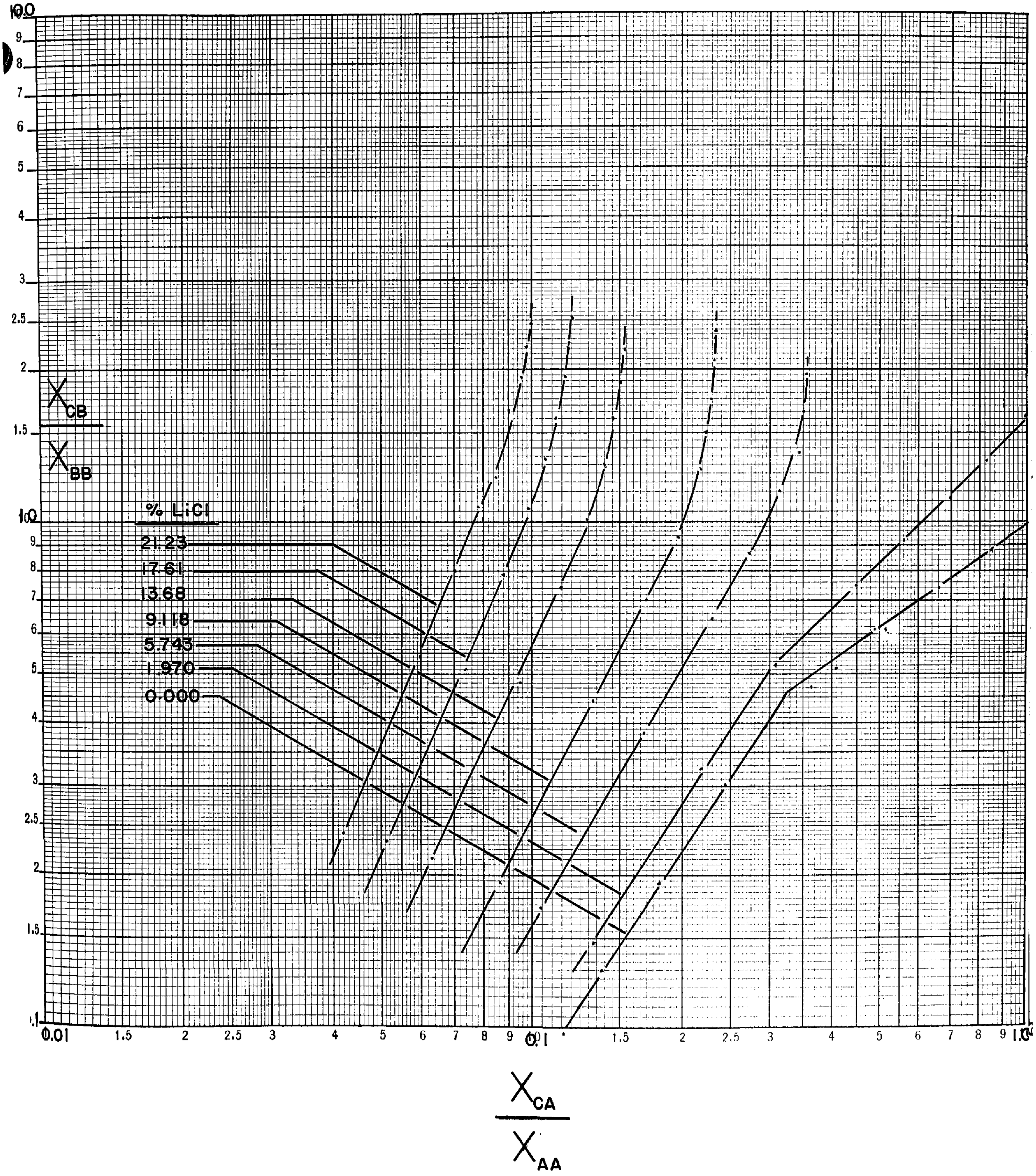


FIGURE 30

PROPIONIC ACID-BENZENE-WATER-SODIUM CHLORIDE

HAND COORDINATES

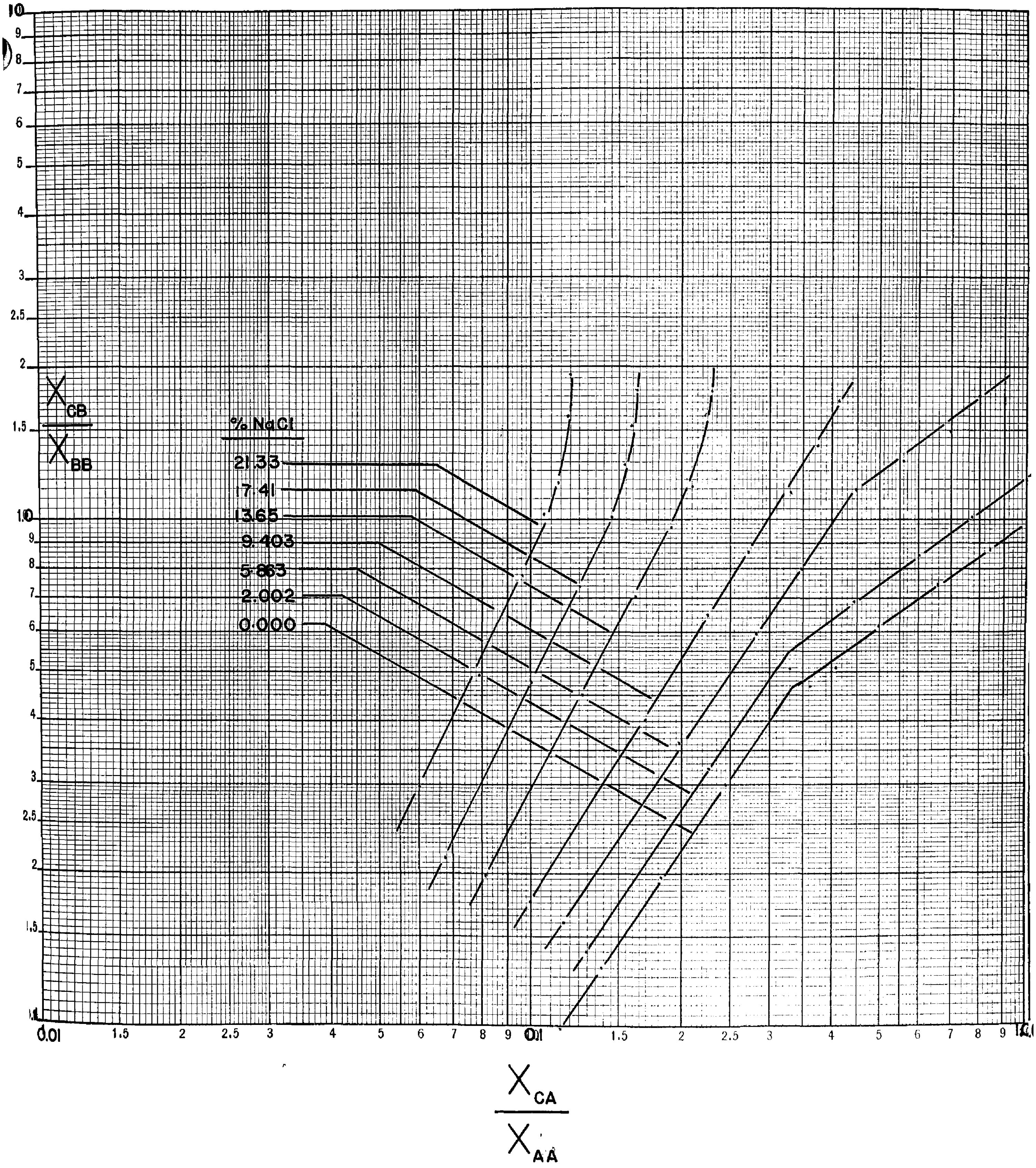


FIGURE 31

PROPIONIC ACID-BENZENE-WATER-POTASSIUM CHLORIDE

HAND COORDINATES

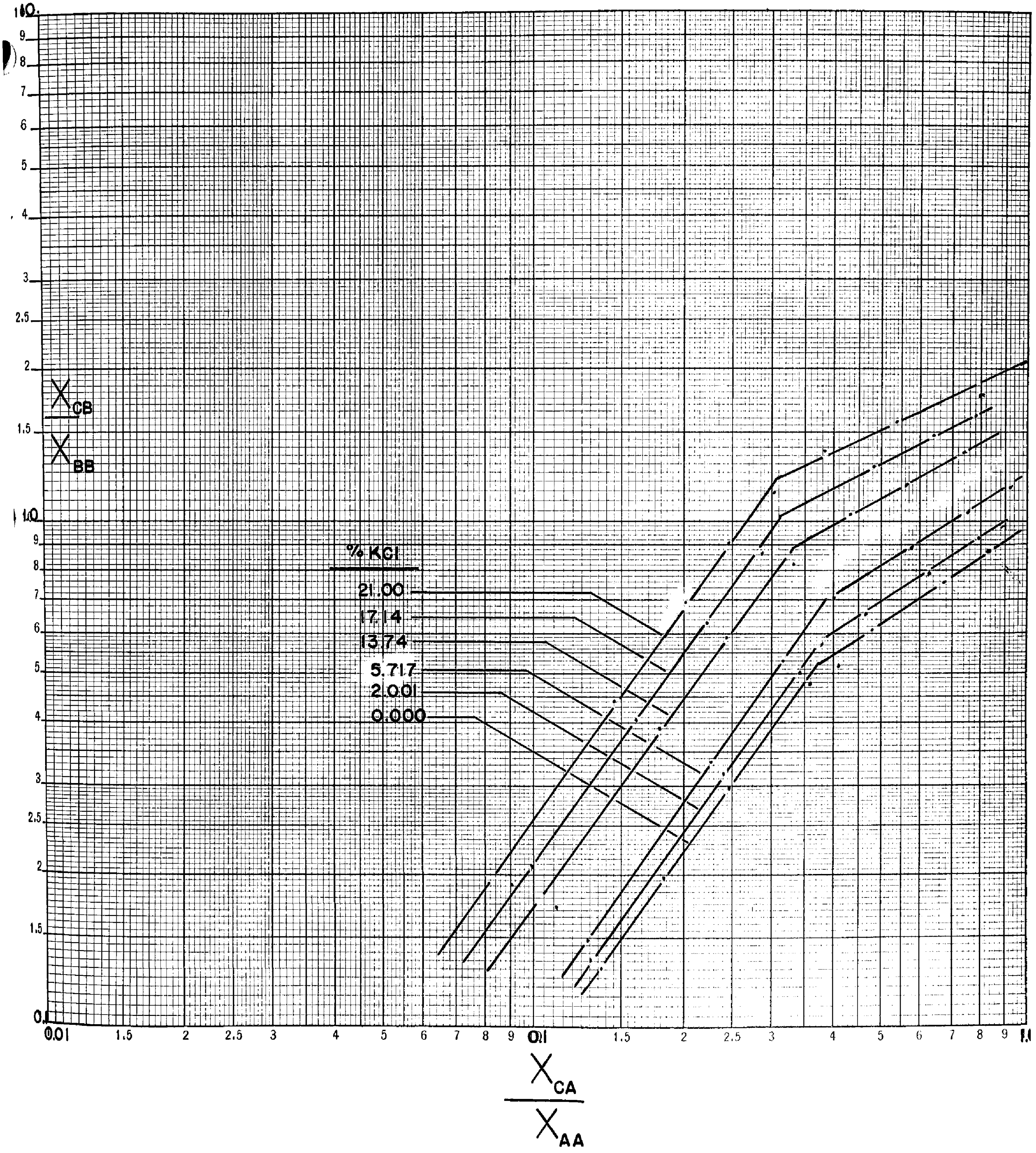
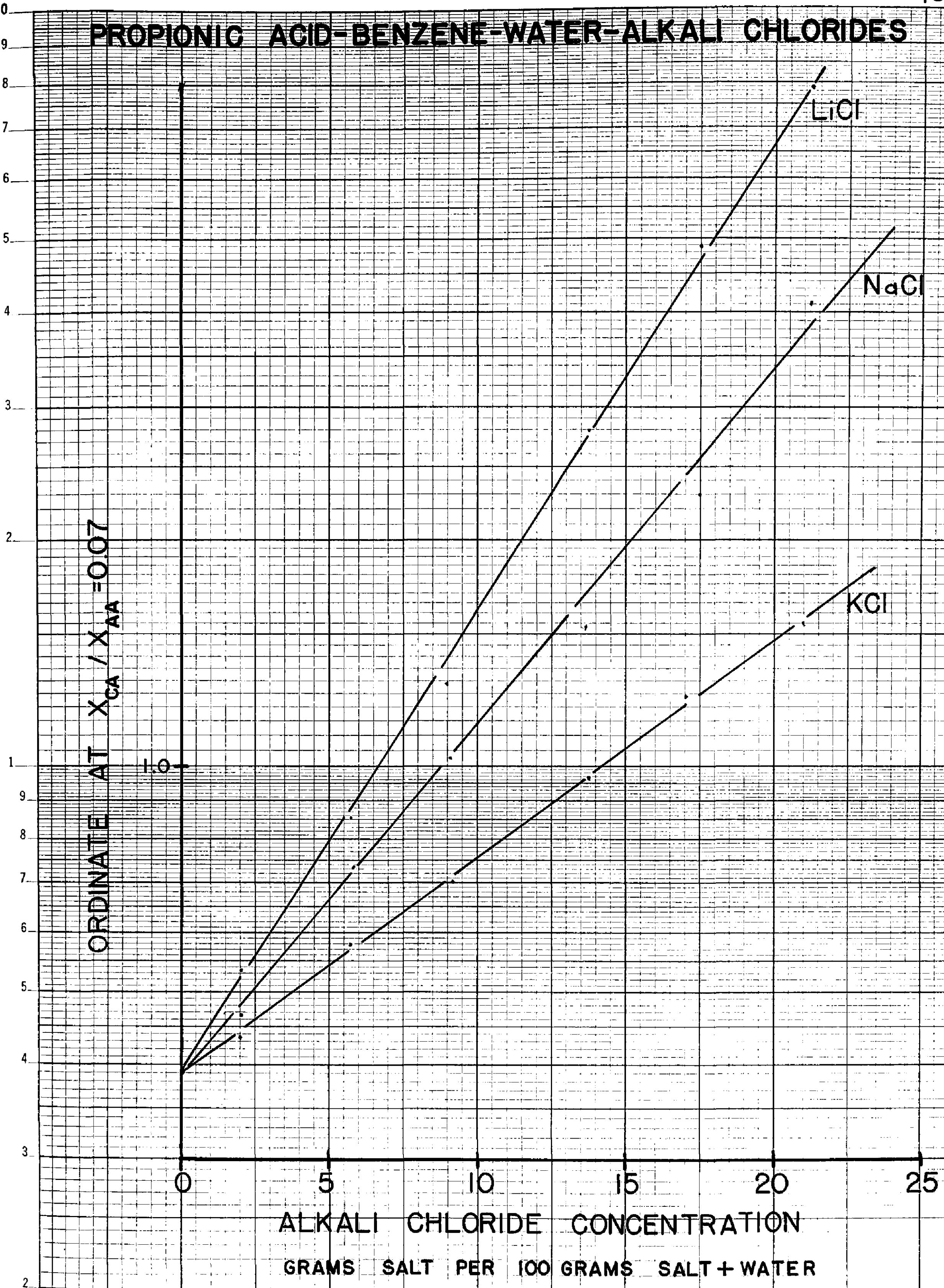
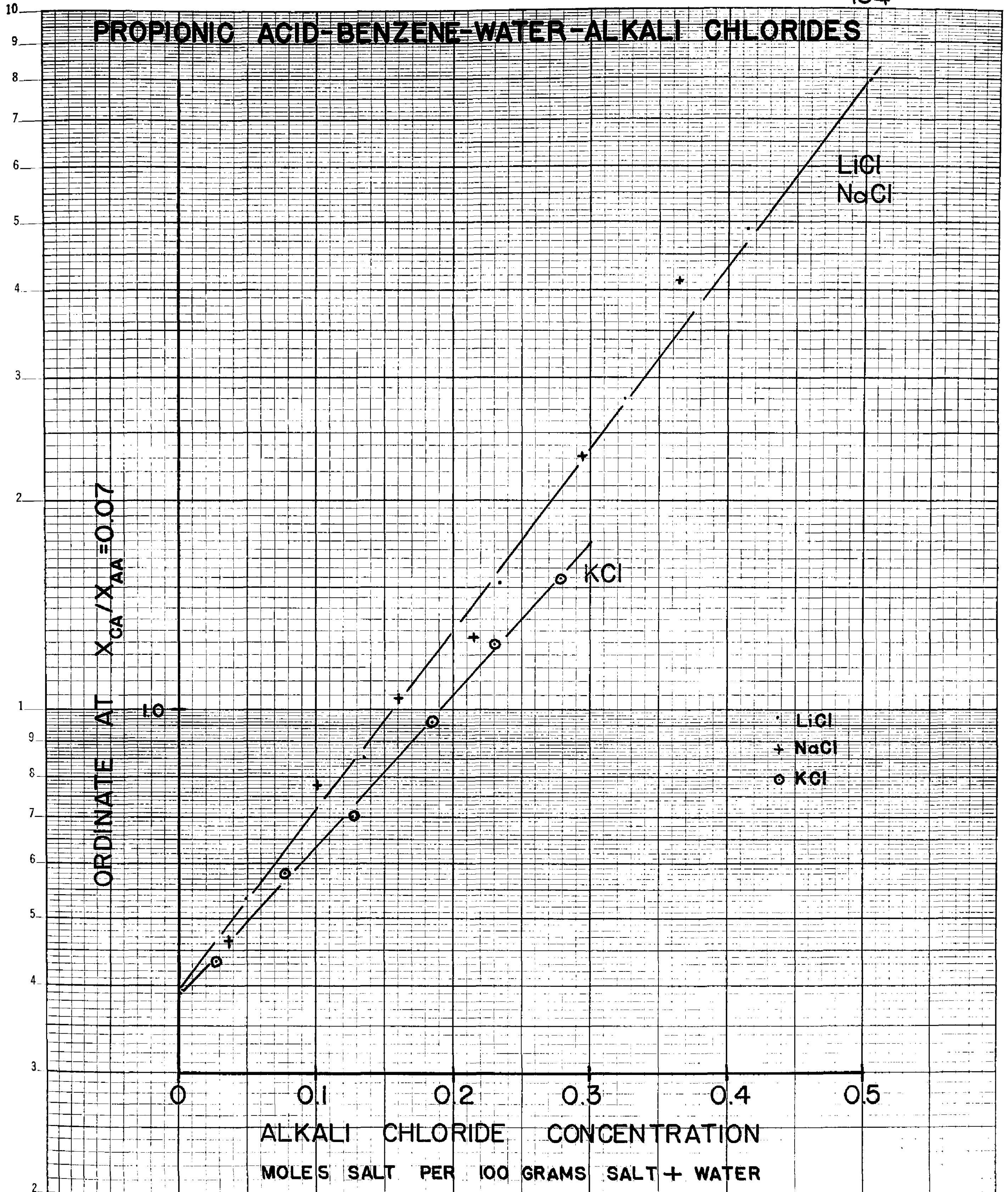


FIGURE 32



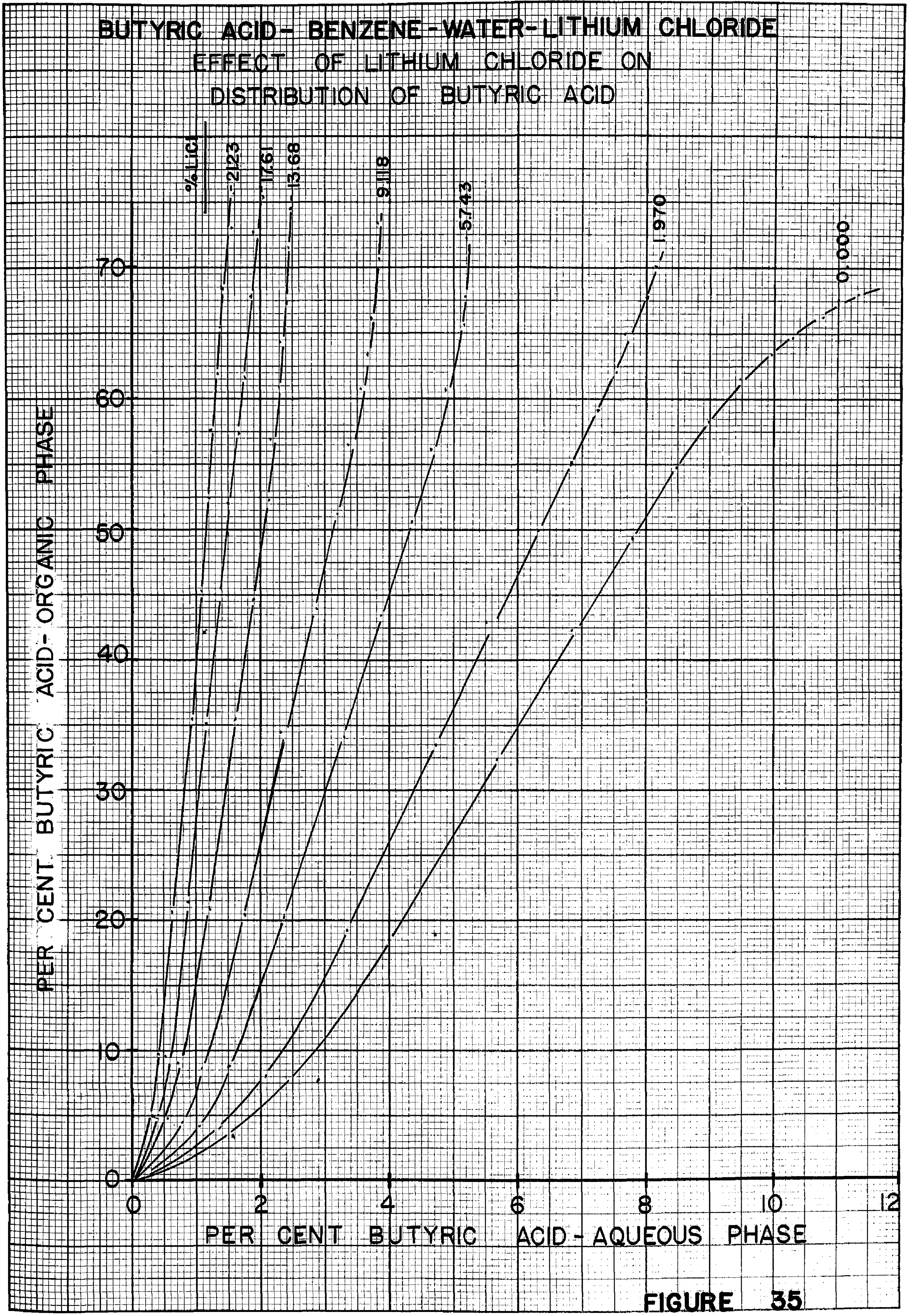
ORDINATE OF HAND PLOT AT $X_{CA}/X_{AA}=0.07$ VS. ALKALI CHLORIDE CONCENTRATION (WEIGHT BASIS)

FIGURE 33



ORDINATE OF HAND PLOT AT $X_{CA}/X_{AA} = 0.07$ VS.
ALKALI CHLORIDE CONCENTRATION (MOLE BASIS)

FIGURE 34



BUTYRIC ACID - BENZENE - WATER - LITHIUM CHLORIDE
EFFECT OF LITHIUM CHLORIDE ON
DISTRIBUTION OF BUTYRIC ACID

FIGURE 35

BUTYRIC ACID-BENZENE-WATER-SODIUM CHLORIDE
EFFECT OF SODIUM CHLORIDE ON DISTRIBUTION OF BUTYRIC ACID

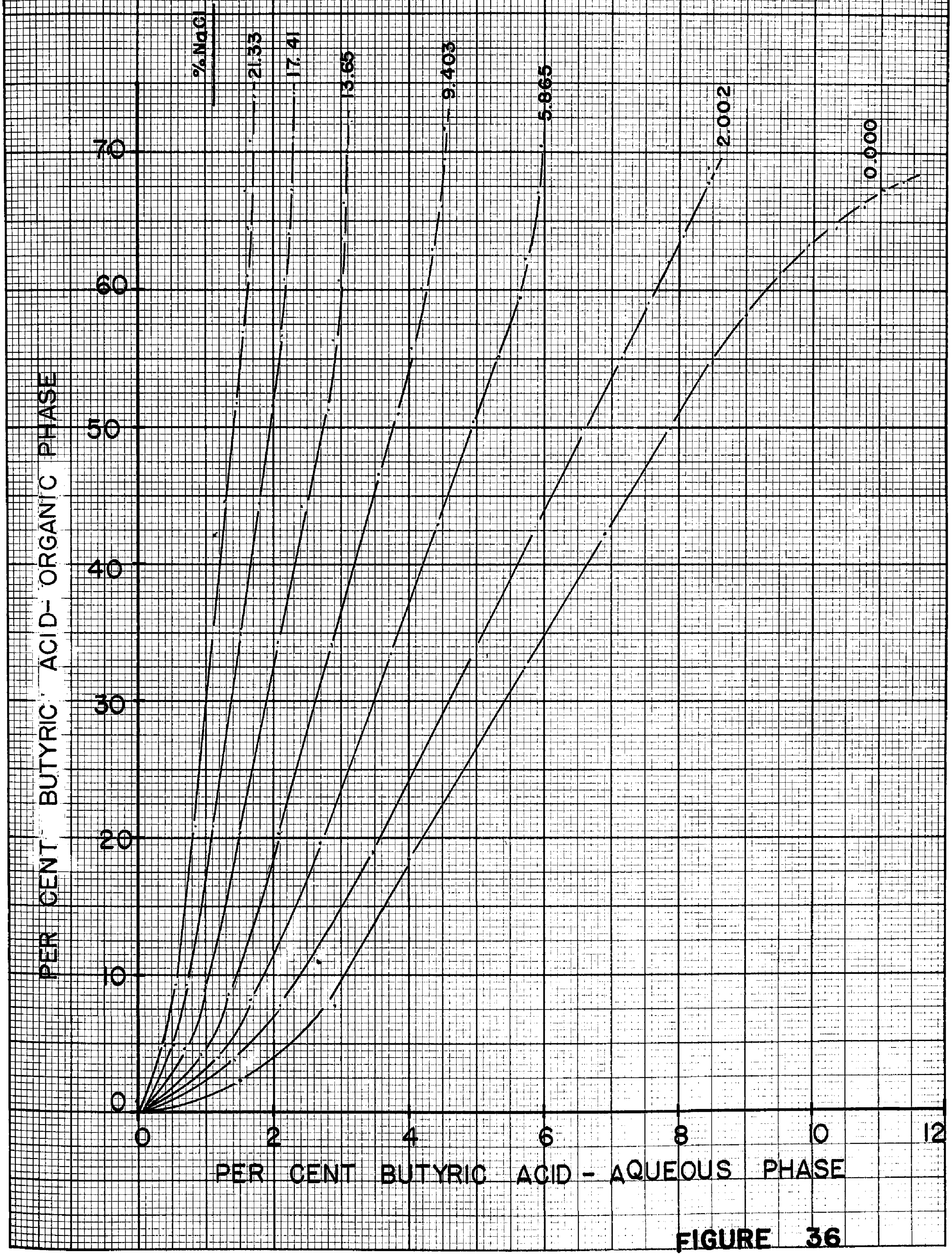


FIGURE 36

BUTYRIC ACID-BENZENE-WATER-POTASSIUM CHLORIDE
EFFECT OF POTASSIUM CHLORIDE ON DISTRIBUTION OF BUTYRIC ACID

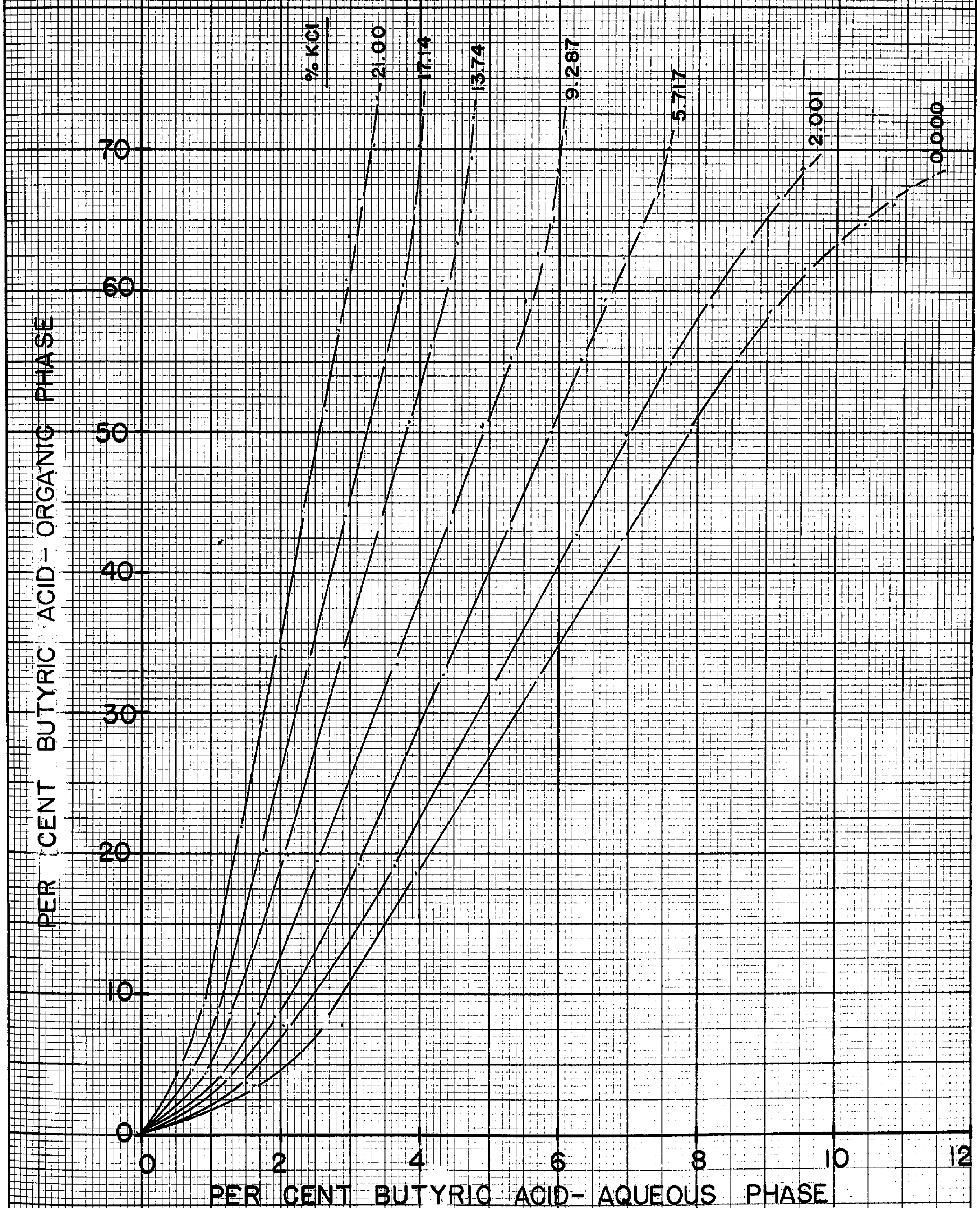
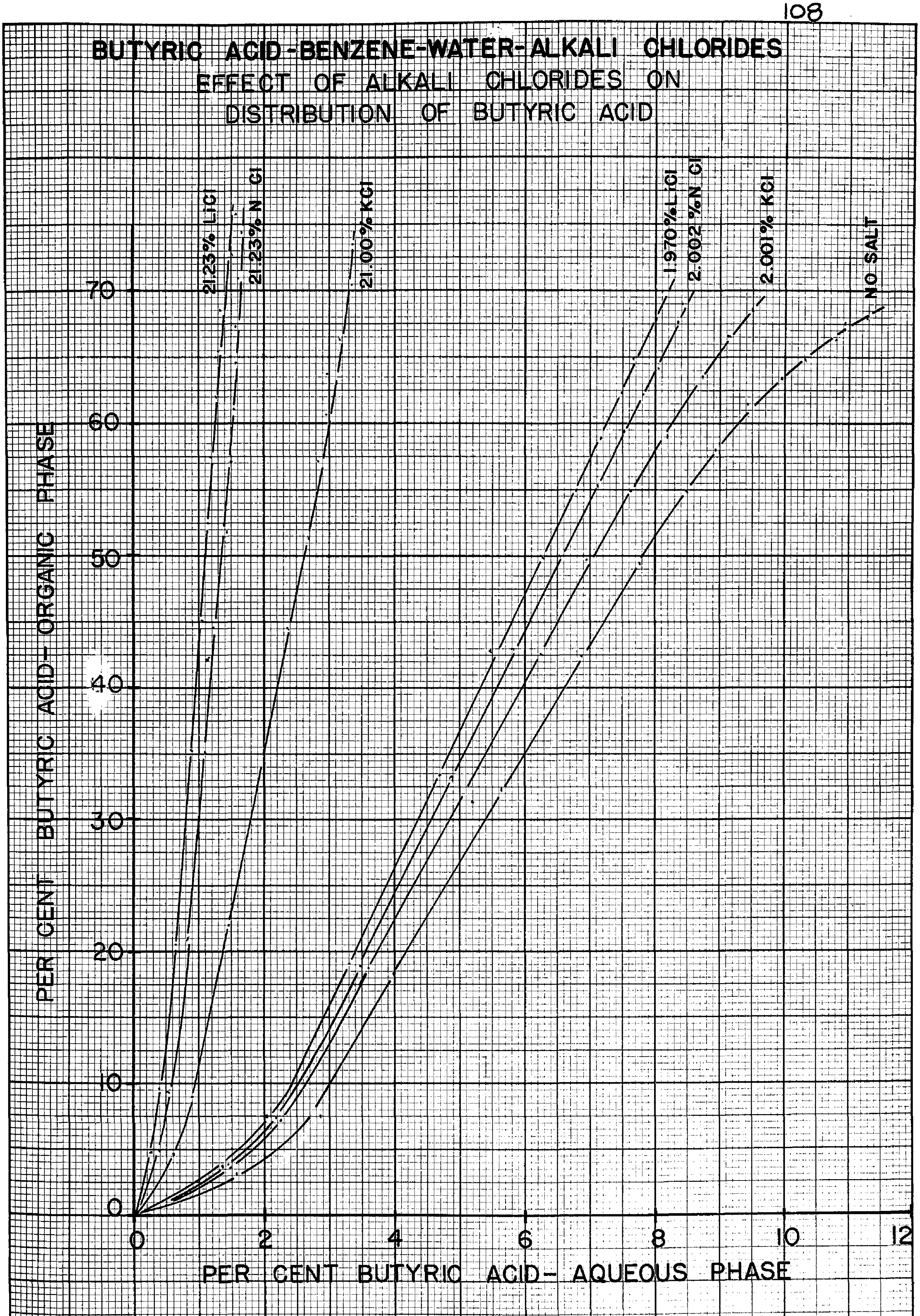


FIGURE 37



BUTYRIC ACID-BENZENE-WATER-ALKALI CHLORIDES
EFFECT OF ALKALI CHLORIDES ON
DISTRIBUTION OF BUTYRIC ACID

FIGURE 38

BUTYRIC ACID-BENZENE-WATER-LITHIUM CHLORIDE

EFFECT OF LITHIUM CHLORIDE ON DISTRIBUTION COEFFICIENT OF BUTYRIC ACID

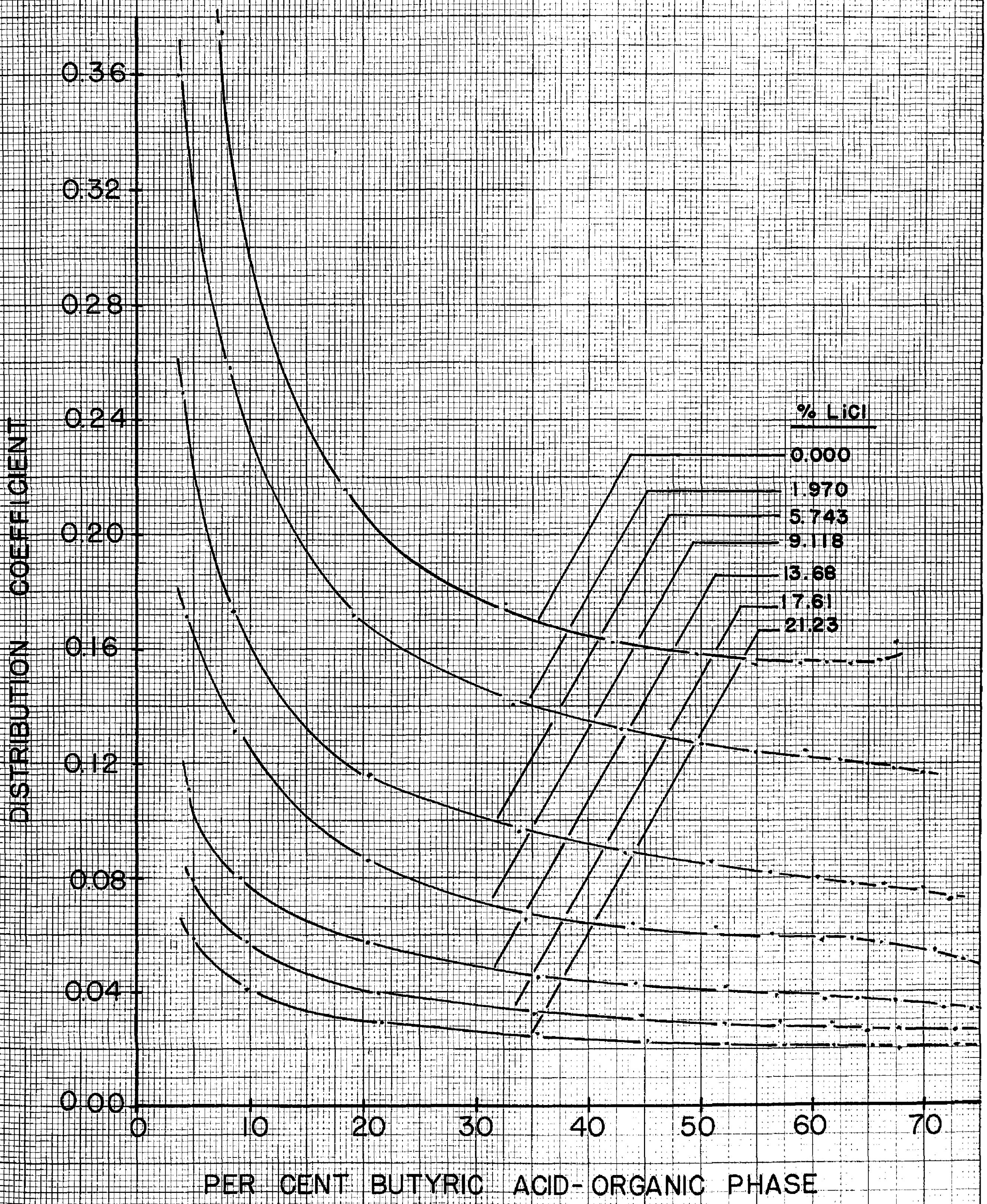


FIGURE 39

BUTYRIC ACID-BENZENE-WATER-SODIUM CHLORIDE

EFFECT OF SODIUM CHLORIDE ON DISTRIBUTION COEFFICIENT OF BUTYRIC ACID

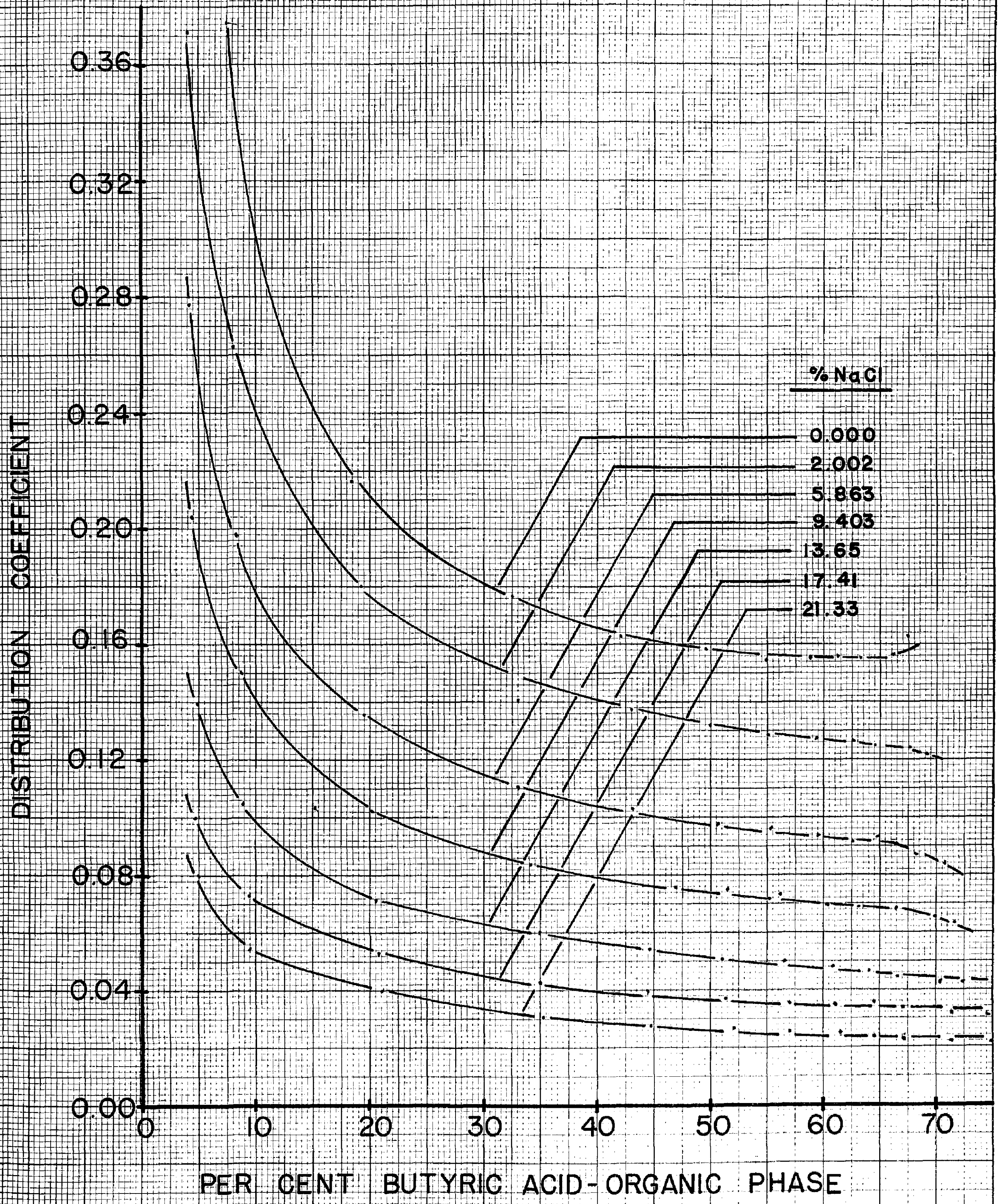


FIGURE 40

BUTYRIC ACID-BENZENE-WATER-POTASSIUM CHLORIDE

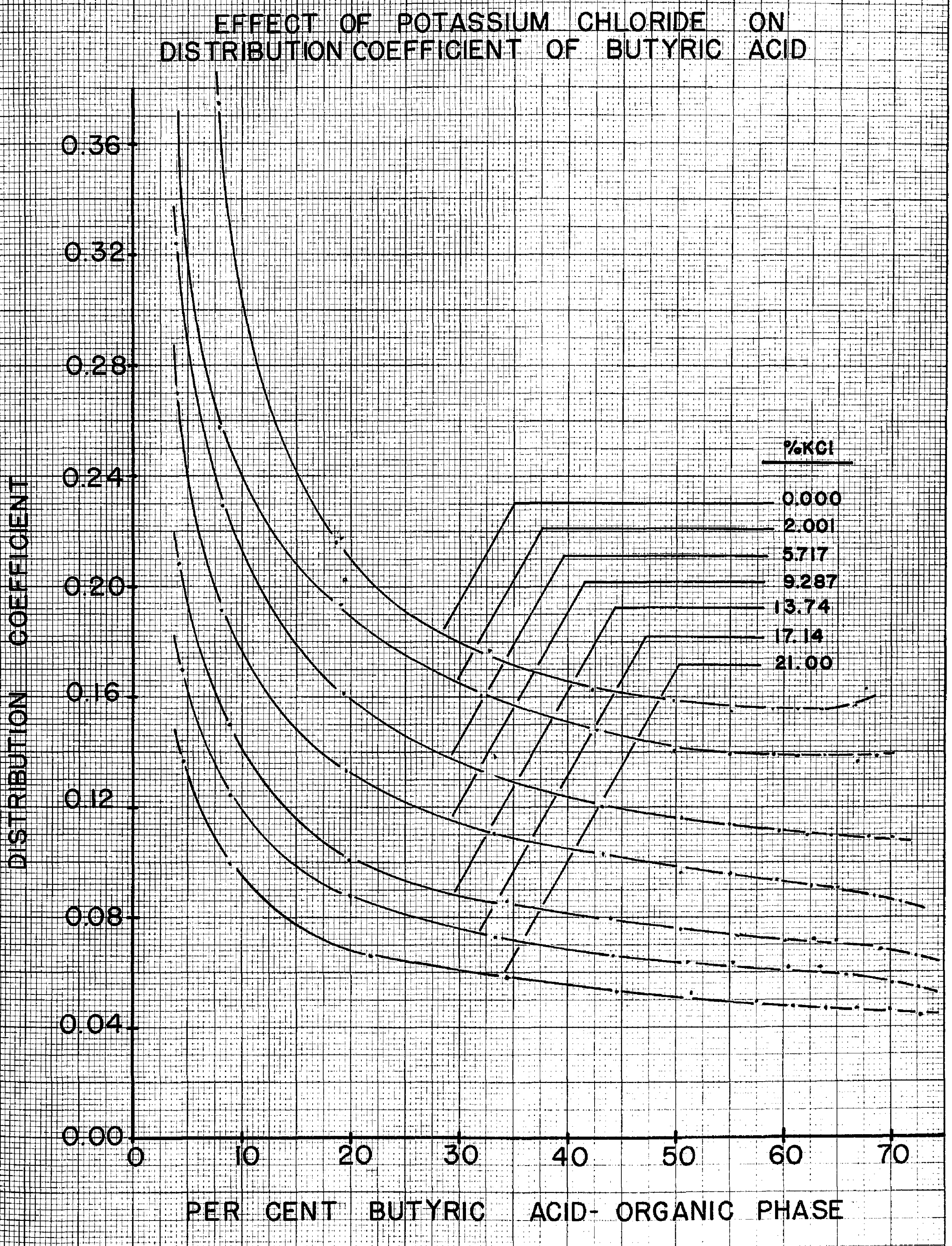


FIGURE 41

BUTYRIC ACID-BENZENE-WATER-ALKALI CHLORIDES

EFFECT OF ALKALI CHLORIDES ON DISTRIBUTION COEFFICIENT OF BUTYRIC ACID

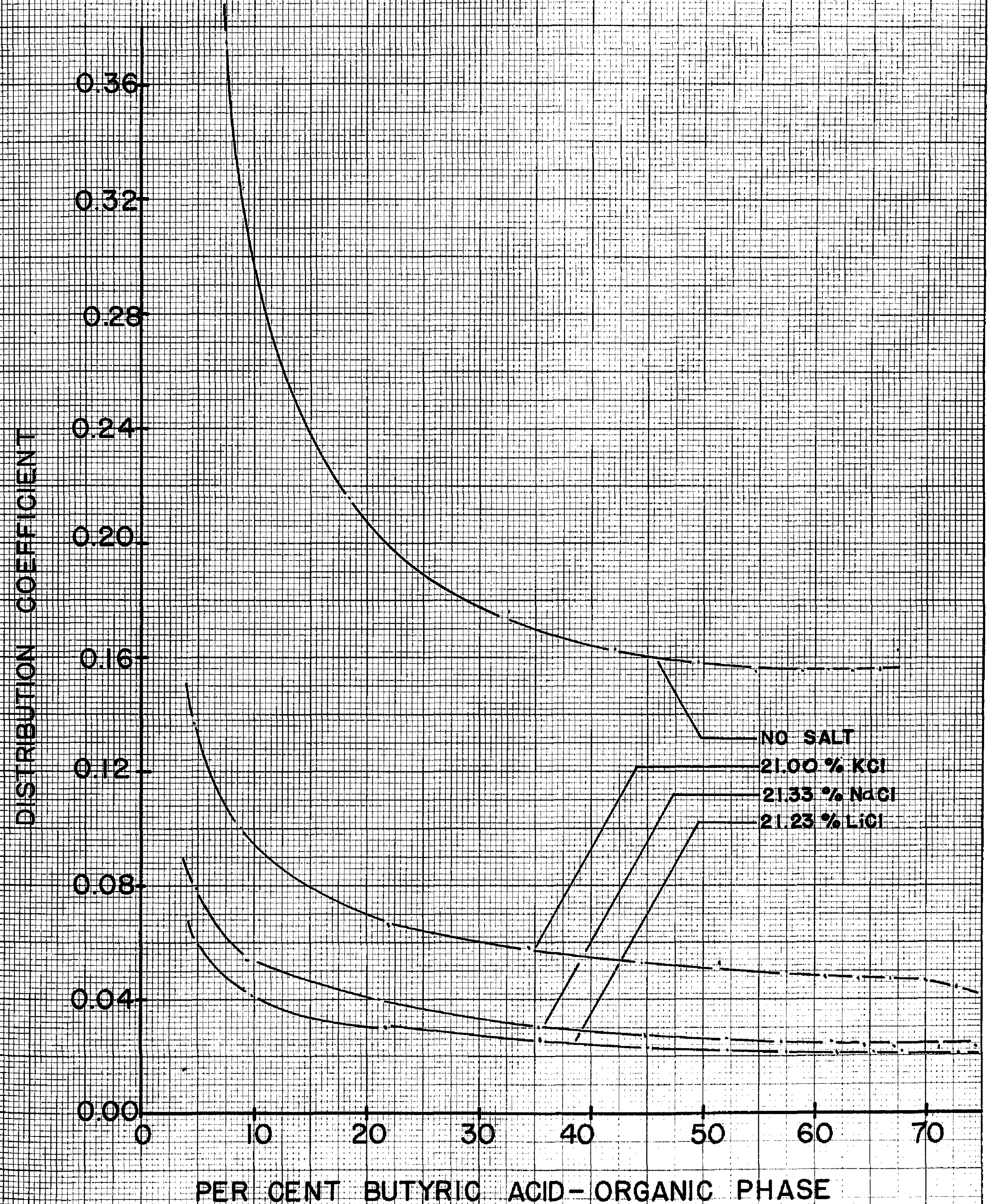


FIGURE 42

BUTYRIC ACID-BENZENE-WATER-LITHIUM CHLORIDE

HAND COORDINATES

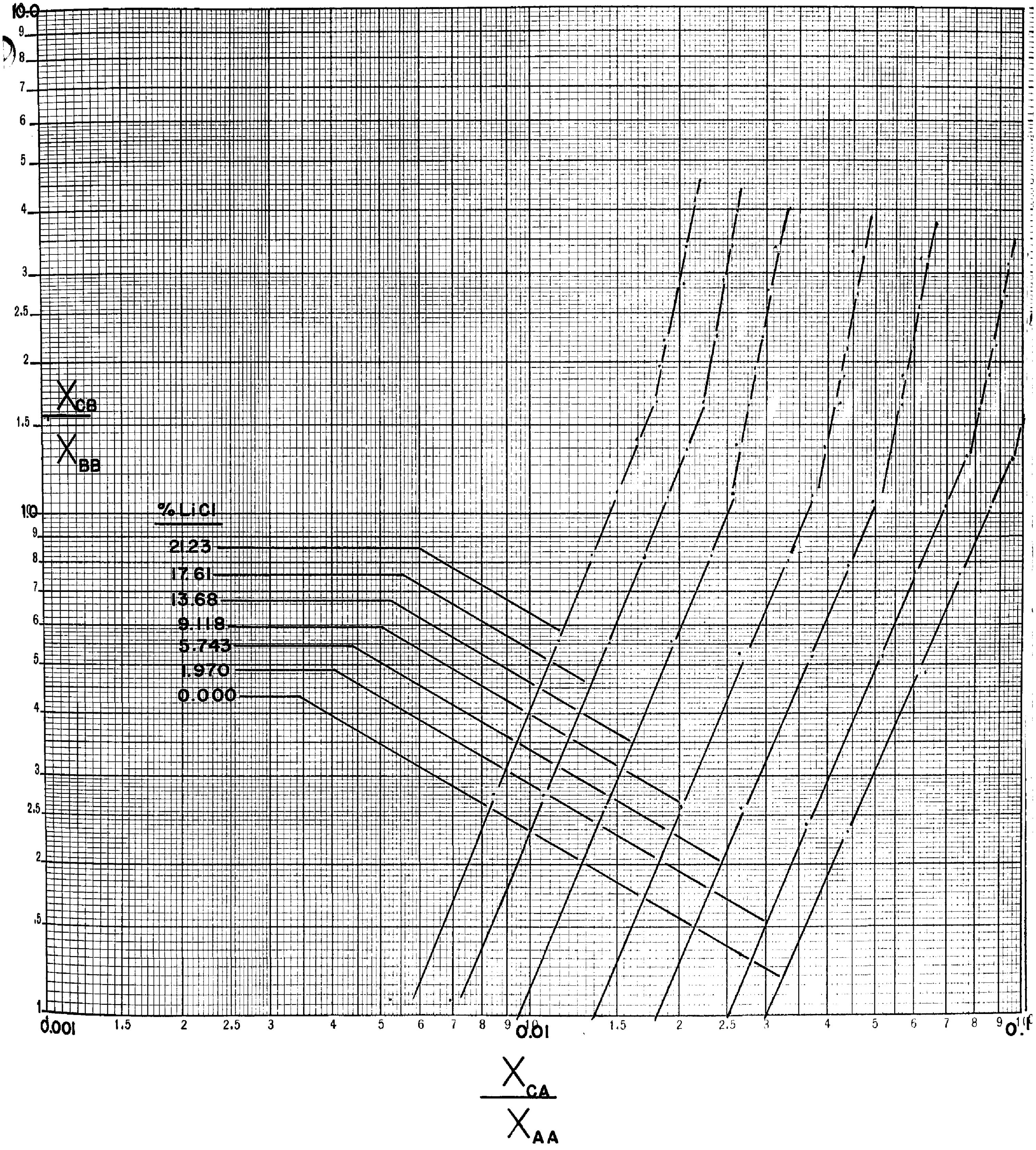


FIGURE 43

BUTYRIC ACID-BENZENE-WATER-SODIUM CHLORIDE

HAND COORDINATES

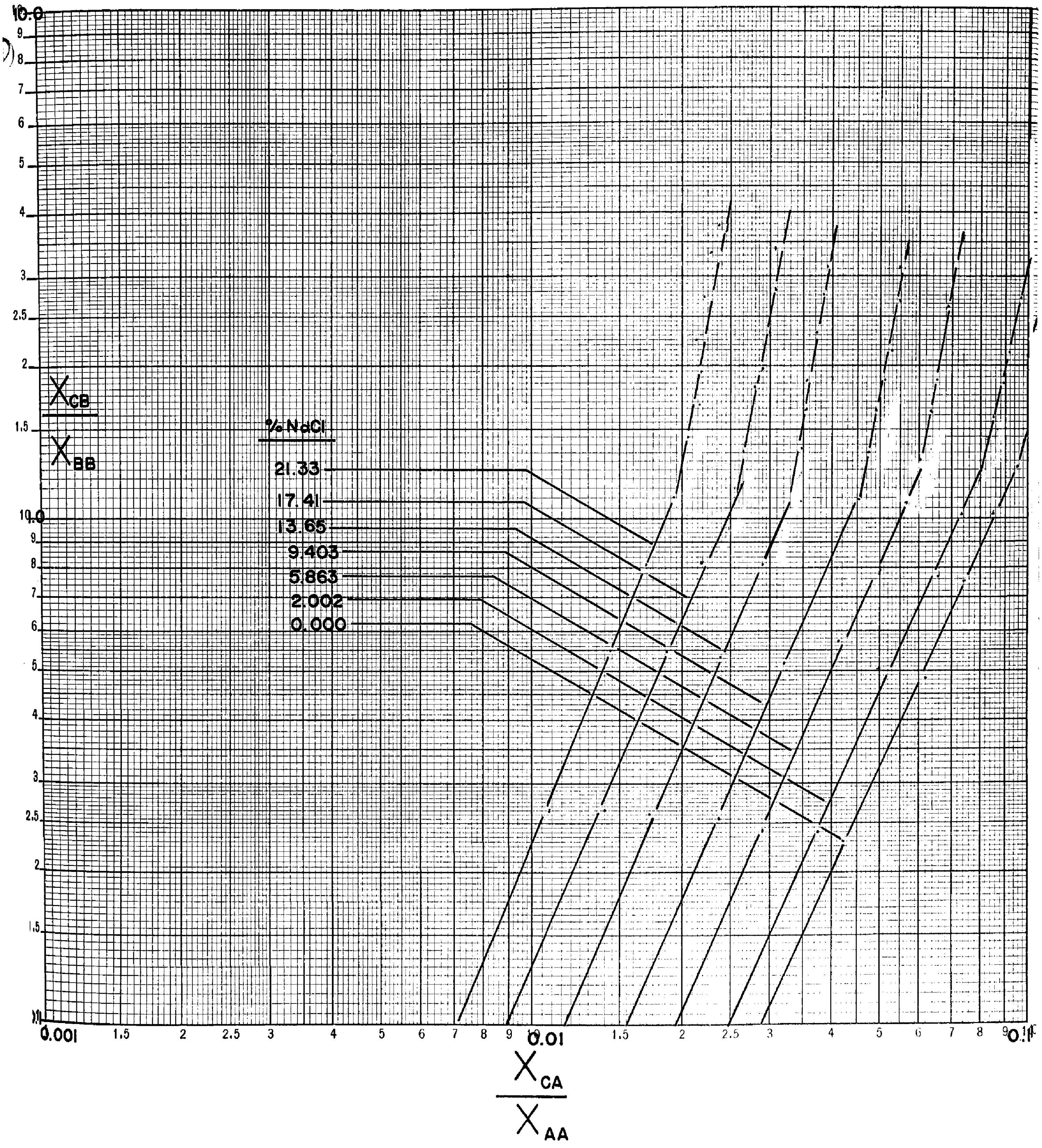


FIGURE 44

BUTYRIC ACID-BENZENE-WATER-POTASSIUM CHLORIDE

HAND COORDINATES

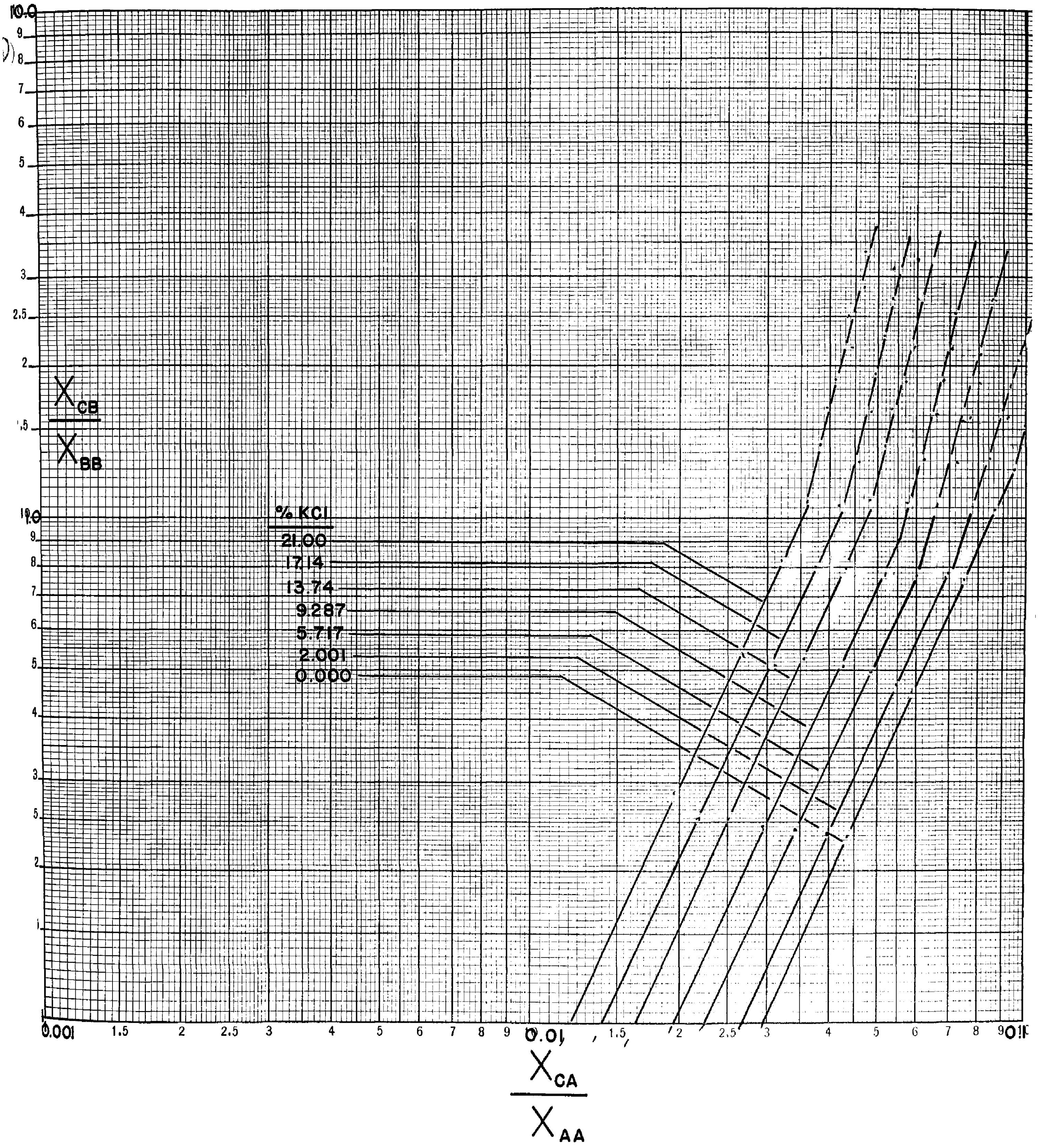
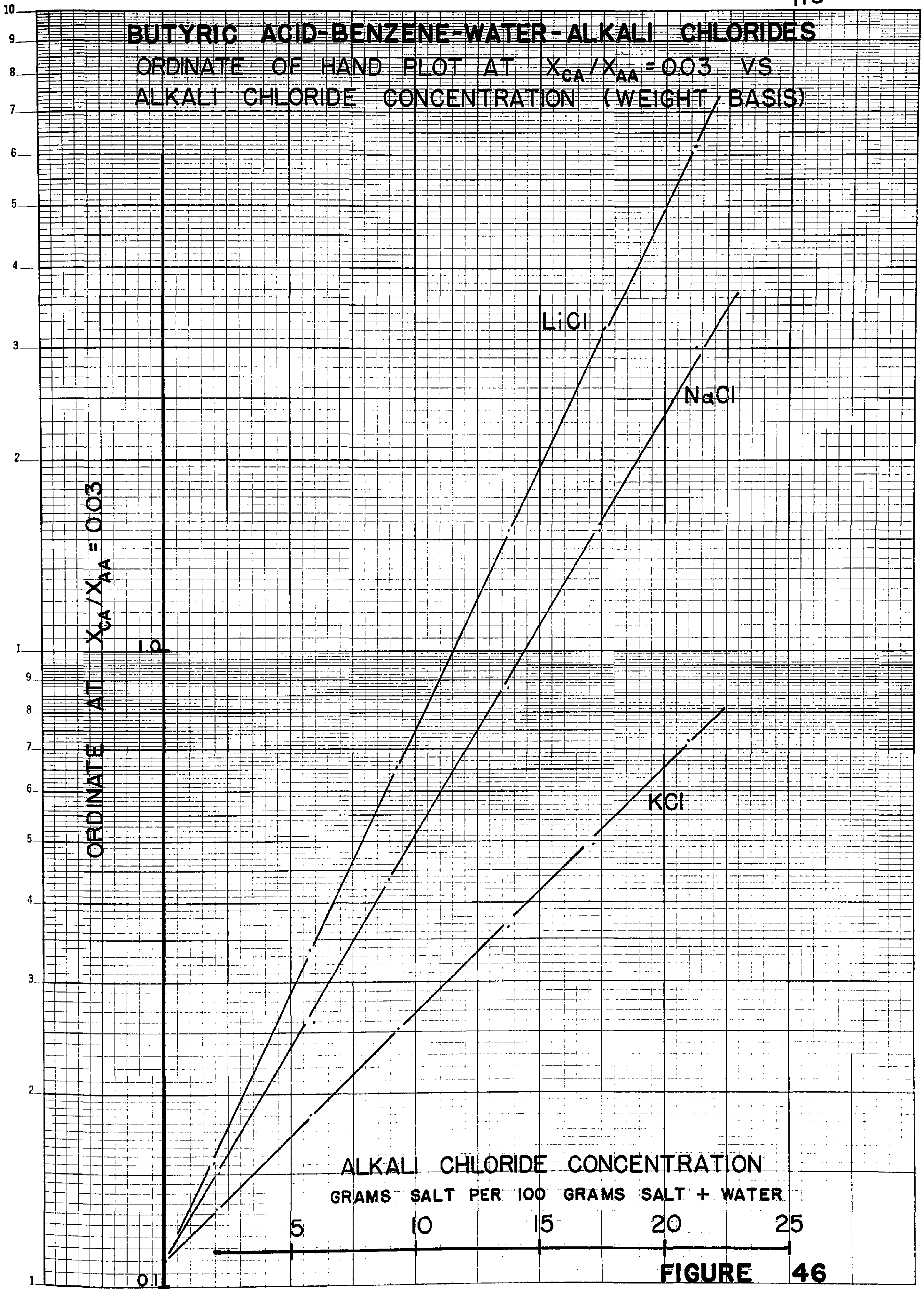
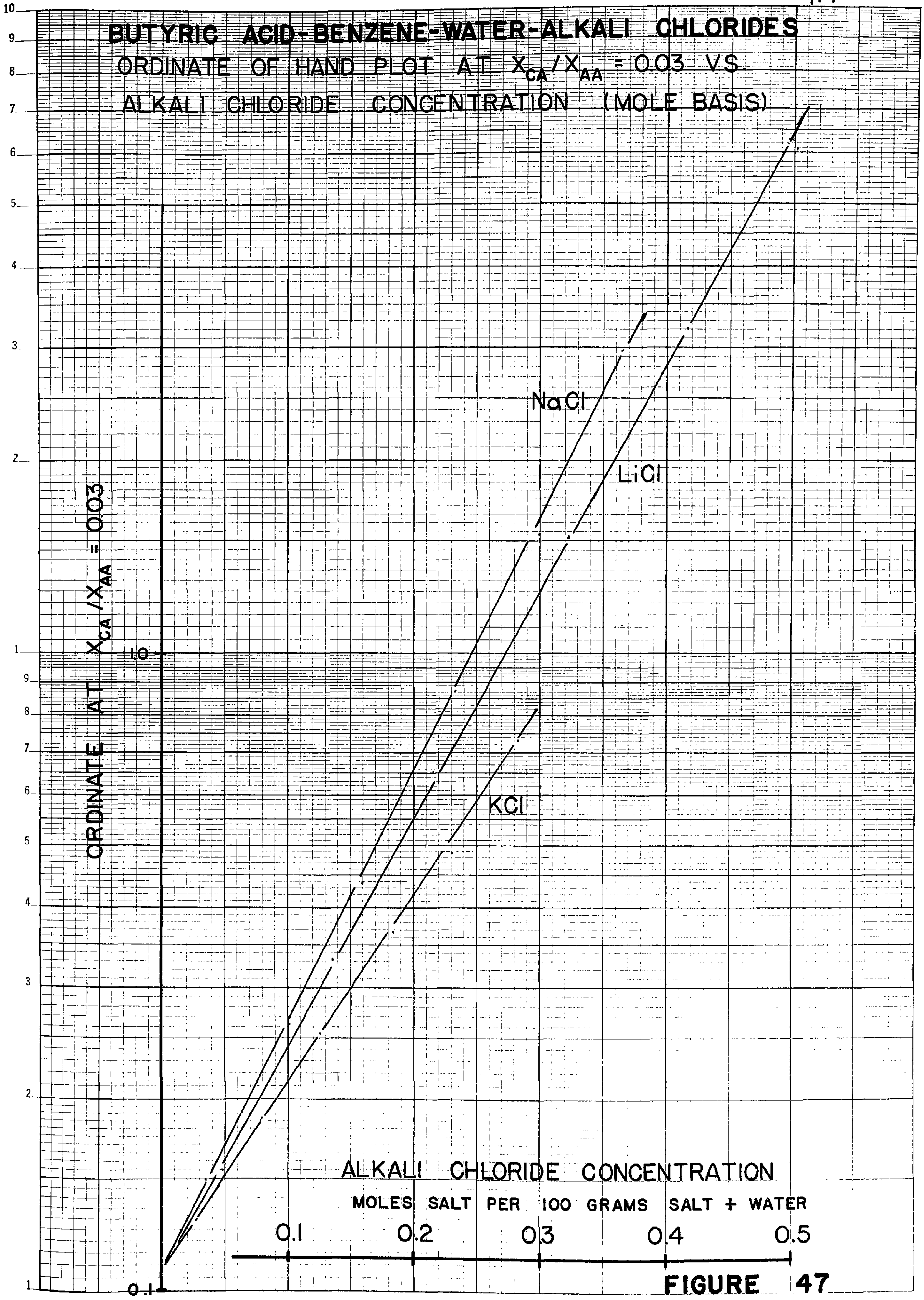


FIGURE 45



BUTYRIC ACID-BENZENE-WATER-ALKALI CHLORIDES
ORDINATE OF HAND PLOT AT $X_{CA}/X_{AA} = 0.03$ VS
ALKALI CHLORIDE CONCENTRATION (WEIGHT BASIS)

FIGURE 46



BUTYRIC ACID-BENZENE-WATER-ALKALI CHLORIDES

ORDINATE OF HAND PLOT AT $X_{CA}/X_{AA} = 0.03$ VS.
ALKALI CHLORIDE CONCENTRATION (MOLE BASIS)

FIGURE 47

DISCUSSION OF RESULTS

The effect of lithium chloride, sodium chloride, and potassium chloride on the distribution of acetic acid is shown in figures 5 through 8. Similar data for propionic acid appears in figures 21 through 25 and for butyric acid in figures 35 through 38. Figures 8, 25, and 38 show the effects of 22 % salt solutions on the salting out of the three acids.

With salt concentration expressed as grams of salt per 100 g salt solution, the order of effectiveness in salting acid out of the aqueous phase is

$$\mathrm{LiCl} > \mathrm{NaCl} > \mathrm{KCl}$$

The effects of a 22 % potassium chloride solution, a 14 % sodium chloride solution and a 9 % lithium chloride solution in salting out acetic acid are approximately equal. With butyric acid, solutions of 22 % potassium chloride, 14 % sodium chloride, or 11 % lithium chloride are equivalent. A 14 % sodium chloride solution was as effective as a 10 % lithium chloride solution in salting out propionic acid.

The effectiveness of salts in breaking the double solutrope of the propionic acid-benzene-water system may be observed in figures 21 through 25. It seems that the solutrope at low acid concentration is more stable than that at high acid concentration, since a higher salt concentration is required to break the latter solutrope. Vriens and Medcalf (96) found that addition of salt (8 % sodium chloride solution) removed the solutrope in the system pyridine-benzene-water.

The addition of salts changes the system butyric acid-benzene-water from a type 1 (binodal curve) to a type 2 (band) system. There is a similarity between the distribution curves at high salt concentration and and the curve of figure 4. It is concluded that addition of salt in sufficiently large amount makes the binary system butyric acid-water partially miscible at 25° C. The critical solubility temperature of this binary system is -3.8° C at 40 weight per cent butyric acid. Thus addition of salt affects a system in a manner similar to lowering the temperature.

Figure 38 reveals that a 2 % potassium chloride solution does not seem to effect partial miscibility in the butyric acid-water system. However, it appears that 6 % solutions of sodium chloride or lithium chloride produce partial miscibility, as does a 9% potassium chloride solution. The formation of two liquid phases in the system butyric acid-water in the presence of moderate amounts of each of the three salts has been experimentally confirmed.

The effect of lithium chloride and sodium chloride on propionic acid is similar to that on butyric acid in that a type 2 system is apparently formed. While partial miscibility in the system propionic acid-water has been observed upon addition of moderate amounts of lithium chloride, similar experimental verification with sodium chloride could not be obtained.

The effect of potassium chloride on the propionic acid-benzene-water system is unlike that of the other two chlorides in that there is no tendency toward the formation of a type 2 system. There is a close resemblence between figure 5 and figure 23. In both cases, the binodal curve is retained; but a marked shift in tie line slope occurs.

The variation of the distribution coefficient with concentration of acetic acid in the organic phase is shown in figures 9 through 12 for acetic acid. Results for propionic acid appear in figures 26 through 29 and for butyric acid in figures 39 through 42. The distribution coefficient has been consistently defined as X_{CA}/X_{CB} for all three acids. The effect of potassium chloride on propionic acid is quite different from the other systems in that at high salt concentration the curve appears rectangular.

The correlation of tie line data, using Hand coordinates, is shown graphically in figures 13 to 15 for acetic acid, 30 to 32 for propionic acid, and 43 to 45 for butyric acid. Two important statements may be made about the effect of salts on the Hand coordinate plots of ternary systems.

1. The addition of salt will not alter the general shape of the curve obtained for the salt-free system.

2. Addition of salt will change the slope and intercept of the Hand coordinate curve to an extent dependent on the nature and quantity of the salt added.

While the first statement apparently does not apply to the system propionic acid-benzene-water, it should be pointed out that removal of two solutropes and transformation from a type 1 to a type 2 system constitute an extraordinary degree of change in the system. The rule does apply when potassium chloride is added to the above system (a type 2 system is not formed).

The ternary system acetic acid-benzene-water is represented by a single line on Hand coordinates, while the corresponding systems with propionic acid and butyric acid each require two lines. Addition of salt to the acetic acid system resulted in a family of single straight lines for each salt. Lithium chloride produced the greatest "spread" (which is related to the magnitude of the salting out effect) while potassium chloride produced the least. The effect can be shown quantitatively by comparing the coefficient b in equation 58 for each salt (table 11). For lithium chloride b is 0.029 while for sodium chloride it is 0.014 and for potassium chloride it is 0.005. In figures 16 and 17, the value of X_{CB}/X_{BB} at a given value of X_{CA}/X_{AA} is plotted against salt concentration expressed on a weight basis and a mole basis, respectively. The effectiveness of the salts cannot be explained solely by the number of ions in solution but depends also on the nature of the salt.

Figures 30 to 32 show that addition of lithium chloride and sodium chloride to the propionic acid system results in a change from a two-line to a single-line-plus-curve plot on Hand coordinates. By comparing figures 30 and 31 with the corresponding distribution diagrams figures 21 and 22, it is concluded that the disappearance of the two-line plot is related to the bending of the distribution curve toward the 45° line (which represents equal acid concentration in each phase). This bending occurs at 1.970 % lithium chloride but not at 5.743 % (figure 21). The Hand plot at 1.970 % consists of two lines, while that at 5.743 % is a single-line-plus-curve. Bending occurs at 2.002 % and 5.863 % sodium chloride and seems to just disappear at 9.403 % (figure 22). The Hand plots show two lines at 2.002 % and 5.743 % and a single straight line with no curve at 9.403 % sodium chloride. Potassium chloride produces bending at all salt concentrations (figure 23) and also gives two lines on Hand coordinates.

In the case of lithium chloride, the transformation to two-line Hand plots seems to be related to the transformation from a type 1 to a type 2 system. However, results with sodium chloride do not comply with this reasoning.

The addition of salts to the system butyric acid-water-benzene also produces a family of curves. Correlations were obtained for both lines. The correlation for the lower line is valid for values of X_{CB}/X_{BB} up to 1.35 for lithium chloride, 1.15 for sodium chloride, and 1.00 for potassium chloride. Above these values the correlation for the upper line should be used. Figures 46 and 47, which show plots of X_{CB}/X_{BB} (at a given value of X_{CA}/X_{AA}) against salt concentration, indicate that on a mole basis, sodium chloride is more effective than lithium chloride in salting out butyric acid.

Comparison of figures 17, 34, and 47 indicates that while potassium chloride is always less effective (on a mole basis) than sodium chloride, the effectiveness of lithium chloride decreases as the number of carbon atoms in the carboxylic acid increases.

Figures 18, 19, and 20 show the effect of salts in decreasing the concentration of water in the organic phase in the acetic acid system. Lithium chloride dries more efficiently than sodium and potassium chlorides, whose effect is about the same. The same trends are observed with butyric acid. The salts are less effective in removing water from the organic phase in the propionic acid system, with potassium chloride having virtually no drying effect.

Distribution

In discussing modifications to the distribution law for cases in which association and dissociation occur, the following equation was derived.

$$\frac{\left[C_T\right]_A^2}{\left[C_T\right]_B} = \frac{\alpha'}{2}\left[\frac{K}{K_{as}(1 - \alpha)}\right]^2 \qquad (21)$$

This equation was derived for dimerization in the benzene phase. For the general case in which n molecules are associated, the equation is

$$\frac{\left[C_T\right]_A^n}{\left[C_T\right]_B} = \frac{\alpha'}{n}\left[\frac{K}{K_{as}(1 - \alpha)}\right]^n \qquad (61)$$

The concentration of the distributed component in moles per liter, $\left[C_T\right]_A$, can be expressed in terms of the weight per cent of the distributed component, X_{CA}, through use of the following equation:

$$\left[C_T\right]_A = X_{CA}\,\frac{\rho_A}{MW_C}\,(0.01) \qquad (62)$$

where ρ_A is the density of the A-rich phase and MW_C is the molecular weight of the distributed component C. Substituting equation 62 into equation 61 for $\left[C_T\right]_A$ and similarly for $\left[C_T\right]_B$, equation 63 results.

$$\frac{\left(X_{CA}\right)^n}{X_{CB}} = \left(\frac{MW_C}{0.01}\right)^{n-1}\frac{\rho_B}{\rho_A^n}\,\frac{\alpha'}{n}\left[\frac{K}{K_{as}(1 - \alpha)}\right]^n \qquad (63)$$

Taking logarithms of both sides gives the following equation:

$$\log X_{CB} = n\ \log X_{CA} - \log\left(\frac{MW_C}{0.01}\right)^{n-1}\frac{\alpha'\rho_B}{n\,\rho_A^n}\left[\frac{K}{K_{as}(1-\alpha)}\right]^n \qquad (64)$$

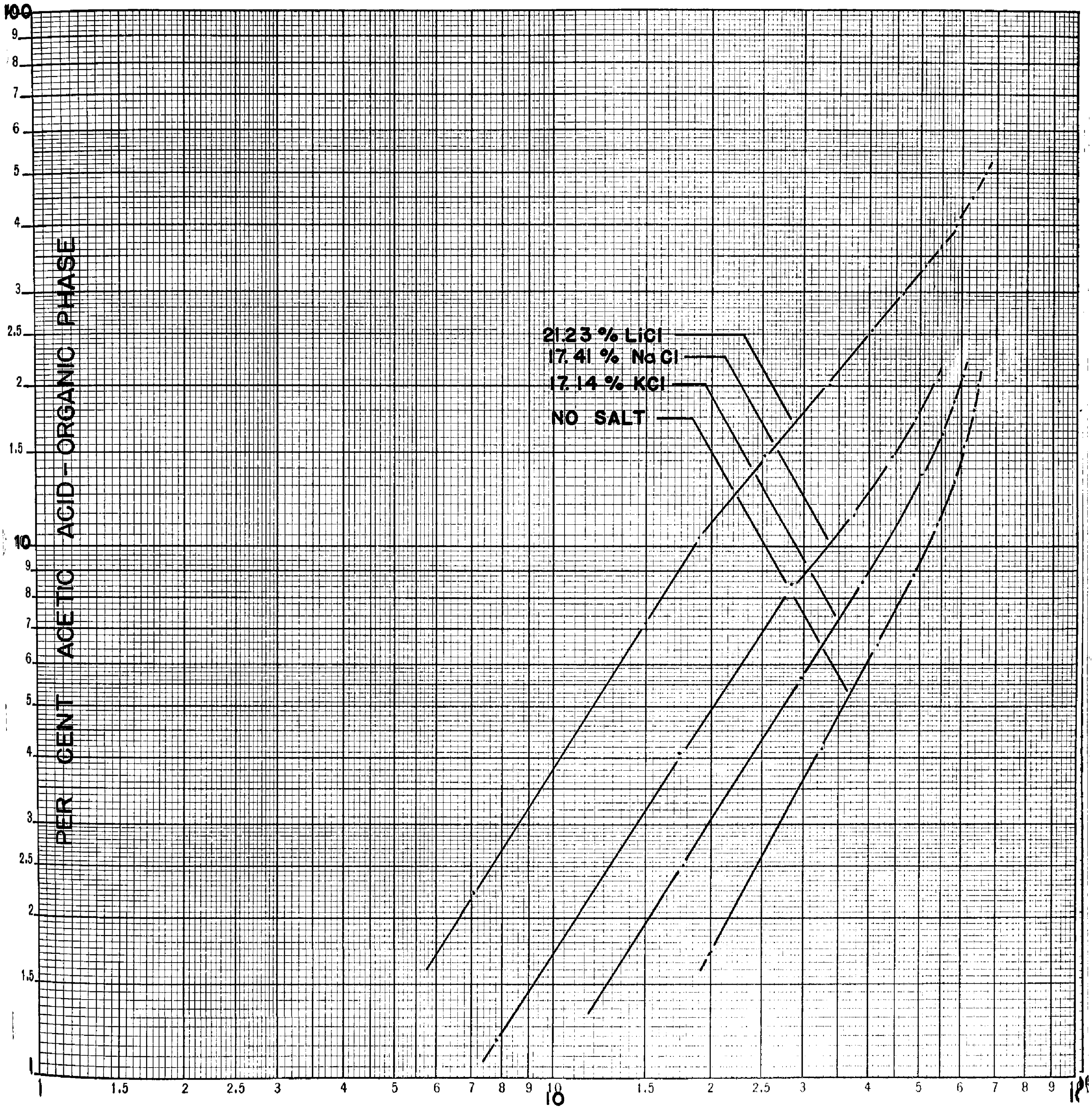
A plot of log X_{CB} against log X_{CA} should yield a straight line whose slope approximates n.

Figures 48, 50, and 51 show these plots for acetic acid, propionic acid, and butyric acid, respectively. The results for 22 % solutions of each of the salts are compared with the salt-free system. For acetic acid, n is 1.82 for the salt-free system and about 1.63 for the salt systems. There was no definite trend of n with the nature of the salt. With propionic acid, n is 1.80 both with and without salt. For butyric acid, n was 1.74 both with and without salt. Figure 49 shows the effect of concentration of lithium chloride on the distribution of acetic acid on logarithmetic coordinates. No trend of n with salt concentration was observed.

The results suggest that each of the acids forms a dimer in the benzene phase.

ACETIC ACID - BENZENE - WATER - ALKALI CHLORIDES

EFFECT OF ALKALI CHLORIDES ON DISTRIBUTION OF ACETIC ACID



PER CENT ACETIC ACID - AQUEOUS PHASE

FIGURE 48

ACETIC ACID - BENZENE-WATER-LITHIUM CHLORIDE

EFFECT OF LITHIUM CHLORIDE ON DISTRIBUTION OF ACETIC ACID

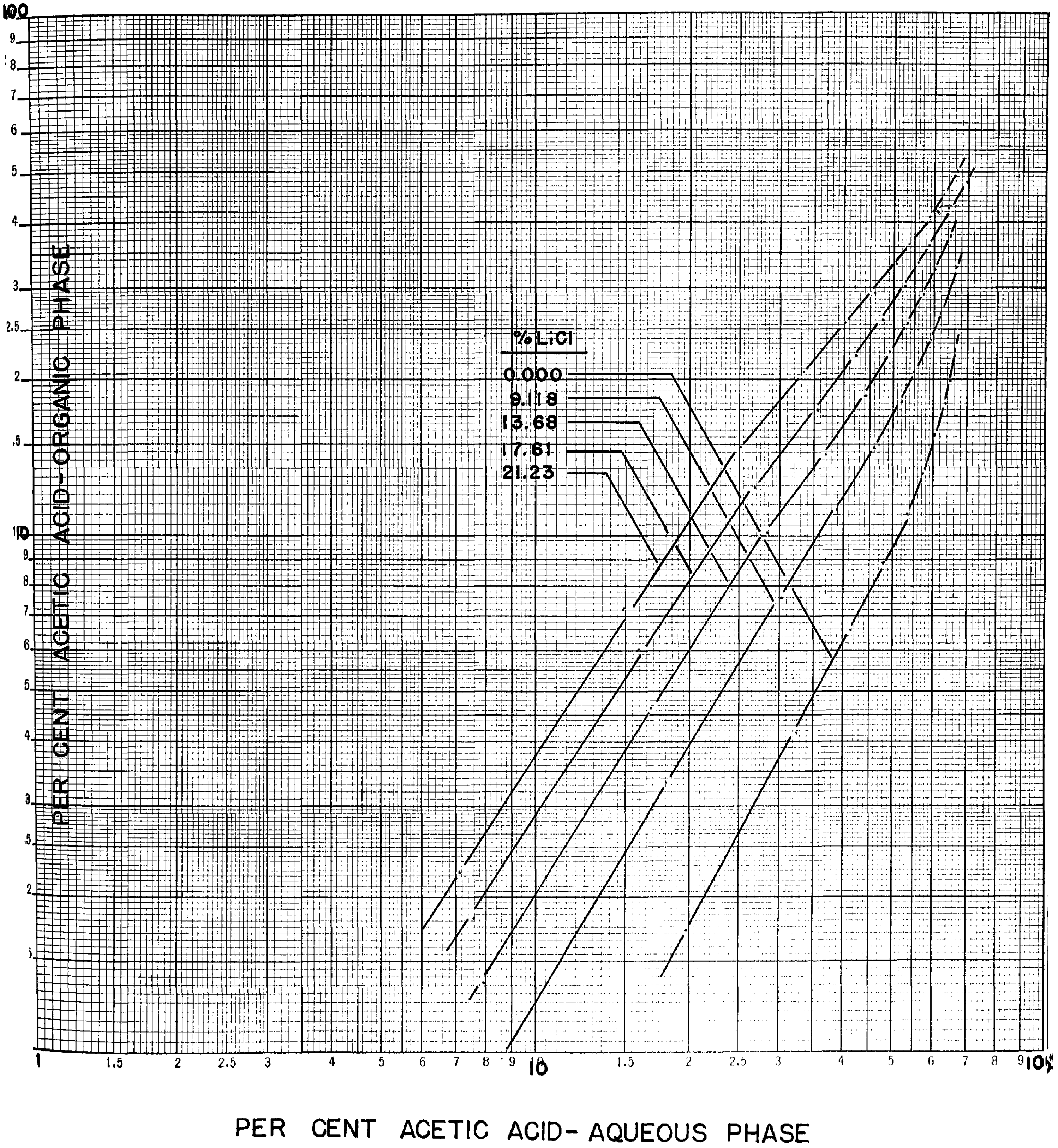
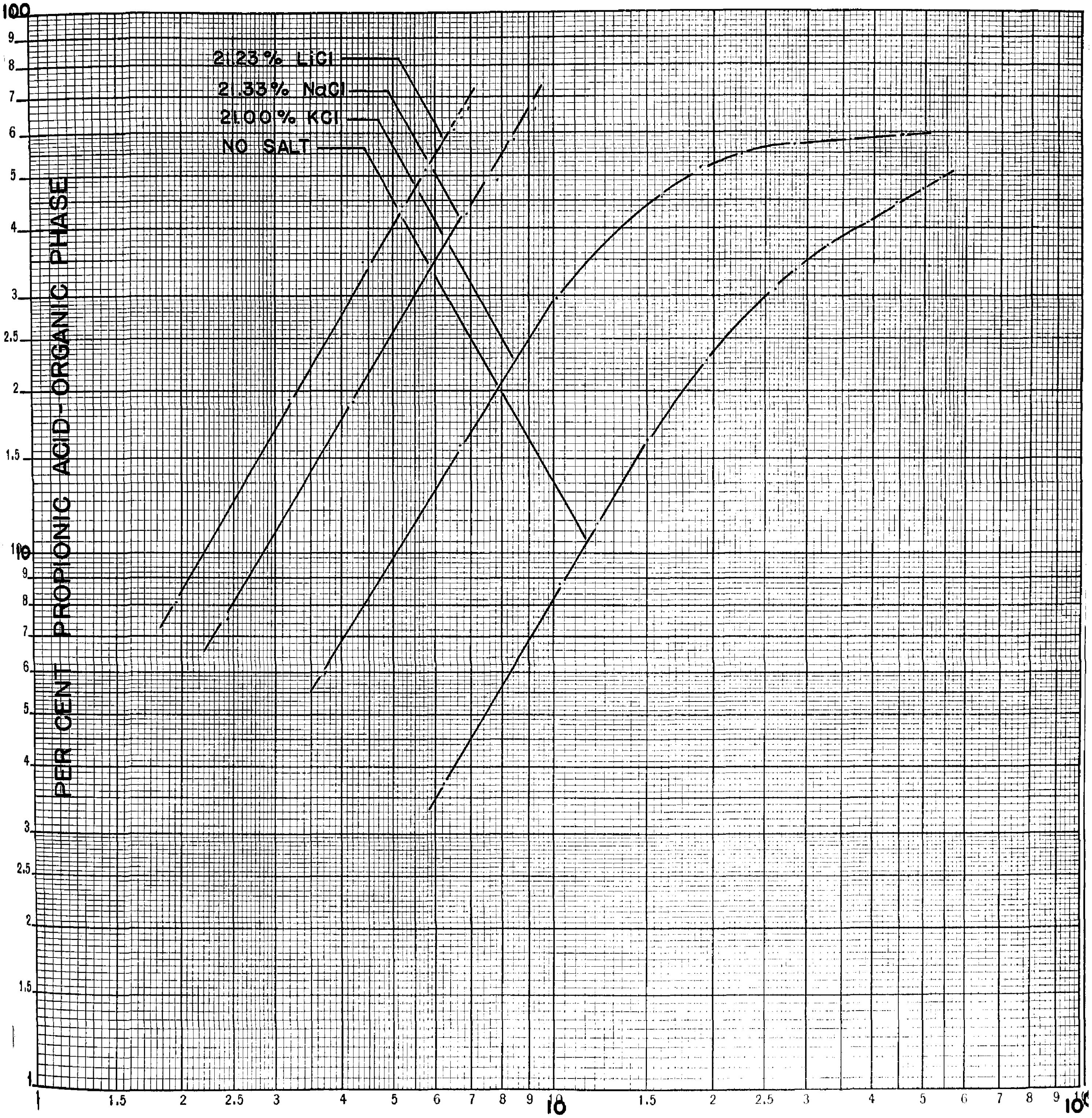


FIGURE 49

PROPIONIC ACID- BENZENE-WATER-ALKALI CHLORIDES

EFFECT OF ALKALI CHLORIDES ON DISTRIBUTION OF PROPIONIC ACID



PER CENT PROPIONIC ACID- AQUEOUS PHASE

FIGURE 50

BUTYRIC ACID-BENZENE-WATER-ALKALI CHLORIDES
EFFECT OF ALKALI CHLORIDES ON DISTRIBUTION OF BUTYRIC ACID

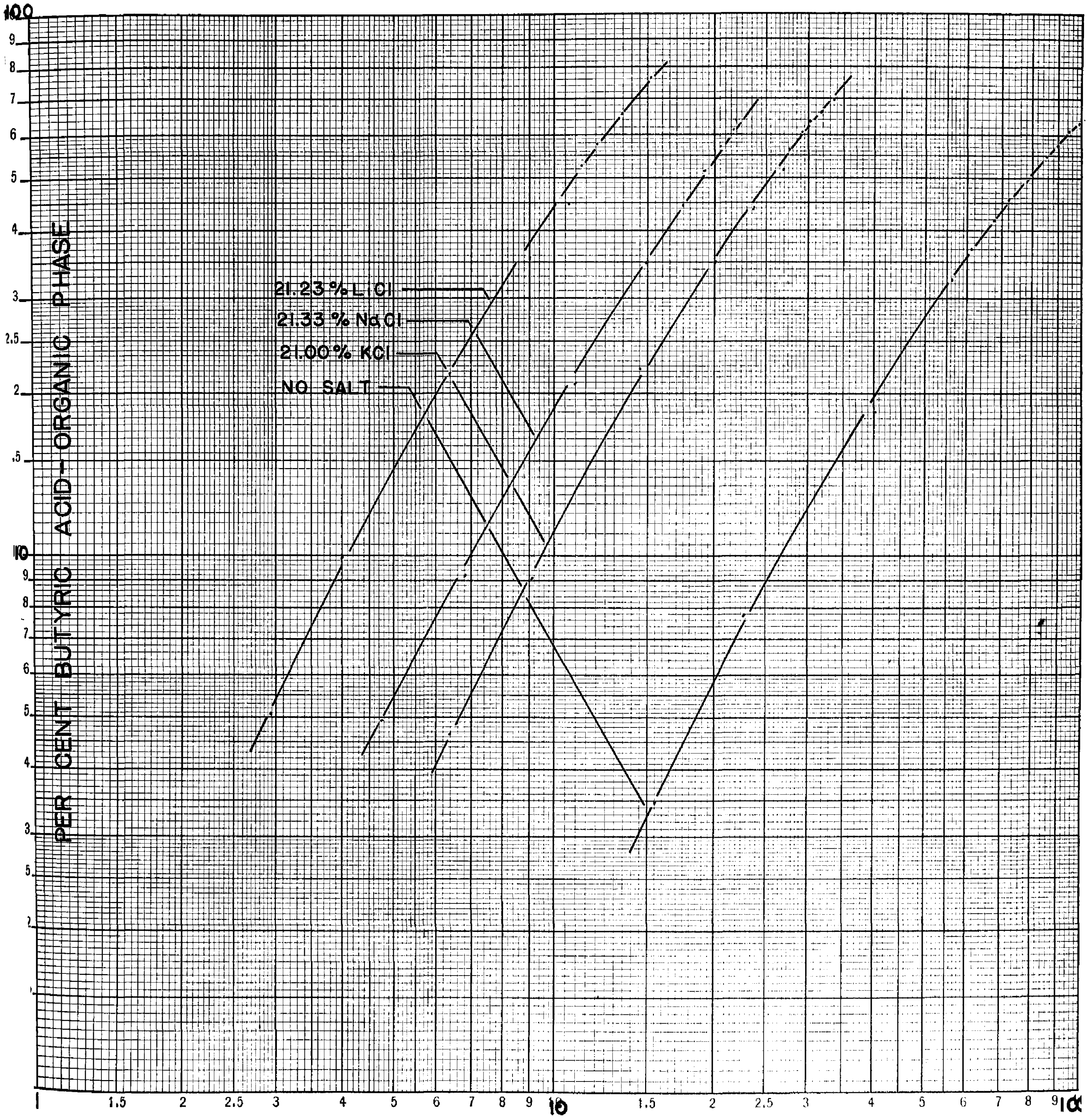


FIGURE 51

CONCLUSIONS

The effect of lithium chloride, sodium chloride, and potassium chloride on the distribution of acetic acid, propionic acid, and butyric acid between benzene and water is correlated by the equation

$$\log \frac{X_{CB}}{X_{BB}} = a + b\,X_s' + (c + dX_s')\log \frac{X_{CA}}{X_{AA}}$$

where a, b, c, and d are constants which depend on the nature of the acid, the nature of the salt, and temperature, but which are independent of salt concentration.

NOMENCLATURE

$\log A_o$	constant in equation 57
ΔA	work content, equation 28
ΔA_s	work content due to salting in or salting out, equation 31
A	component A, water
a'	constant, equation 2
a	constant, equation 58
a_1	activity of distributed component, phase 1
a_2	activity of distributed component, phase 2
B_o	constant in equation 57
B	component B, benzene
b'	constant, equation 2
b	constant, equation 58
b_1	constant, equation 3
C_i	concentration of species i, moles/liter
$\left[C_T\right]_A$	total concentration of acid in aqueous phase; moles/liter
$\left[C_T\right]_B$	total concentration of acid in organic phase; moles/liter
c	constant, equation 59
c^o	concentration of gas in water, no salt present; moles/liters
c	concentration of gas in water, salt present; moles/liter
D_o	dielectric constant of pure solvent
D	dielectric constant of solution containing electrolyte
d	constant, equation 60
E_s	quantity of salt in Hittorf cell; equivalents
E_w	quantity of water in Hittorf cell; moles

e	charge on ion; e.s.u.
f_s	activity coefficient of non-electrolyte, equation 33
f_2^o	activity coefficient of component 2, no salt present
f_2^1	activity coefficient of component 2, salt present
J_i	variable defined by equations 39 and 40
K	distribution coefficient, defined by equations 1 and 12
K_{as}	association constant; $(\text{liters/mole})^{\frac{1}{2}}$
K_i	ionization constant; moles/liter
k	Boltzmann constant; ergs/^{o}K
k_1	constant, equation 9
k_2	constant, equation 11
k_3	constant, equation 45
k_a	reciprocal of mean radius of ion atmosphere; cm^{-1}
k_s	salting out constant; liters/mole
k_{ss}	salting out constant; grams water/gram salt
k_s'	salting out constant; 100 grams solution/gram salt
k_+	contribution by cation to salting out constant; liters/mole
k_-	contribution by anion to salting out constant; liters/mole
MW_C	molecular weight of component C (acid); grams/mole
m_A	total weight of aqueous phase; grams
m_B	total weight of organic phase; grams
m_I	total weight of initial mixture; grams
N_{av}	Avogadro's number
N_1^o	mole fraction solvent, infinite distance from ion
N_2^o	mole fraction non-electrolyte, infinite distance from ion
N_1	mole fraction solvent, distance r from ion

N_2	mole fraction non-electrolyte, distance r from ion
n	number of molecules of non-electrolyte, equation 29
n'	number of molecules of electrolyte, equation 29
n	number of molecules associated in solvent phase, equations 61-64
n'	exponent
n_j	number of molecules of kind j per cm^3
n_t	total number of molecules of electrolyte, per cm^3
p	probability level
r	correlation coefficient defined by equation 56.1
r	distance from ion; cm
s	acid concentration in aqueous phase, salt present; grams acid per gram water
s^o	acid concentration in aqueous phase, no salt present; grams acid per gram water
$s(\hat{y})$	standard error in dependent variable calculated from correlation equation
T	absolute temperature; ^oK
T_a	true transport number of anion
T_b	true transport number of cation
t_a	apparent transport number of anion
t_b	apparent transport number of cation
V_i	partial molar volume of non-electrolyte; liters
$\bar{V}_i^o$	partial molar volume of electrolyte at infinite dilution; liters
V_s	partial molar volume of pure (liquid) electrolyte; liters
$\bar{V}_s^o$	partial molar volume of pure (liquid) electrolyte at infinite dilution; liters
v_a	additional volume to dissolve one mole of non-electrolyte in presence of salt; liters

v_1	atomic volume of component 1
v_2	atomic volume of component 2
$W(k)$	electrical work done against potential due to ionic atmosphere
$W(n_j)$	electrical work of charging n_j ions
$W(net)$	net electrical work given by equation 26
X_{AA}	weight per cent water in aqueous phase
X_{BA}	weight per cent benzene in aqueous phase
X_{CA}	weight per cent carboxylic acid in aqueous phase
X_{DA}	weight per cent alkali chloride in aqueous phase
X_{AB}	weight per cent water in organic phase
X_{BB}	weight per cent benzene in organic phase
X_{CB}	weight per cent carboxylic acid in organic phase
X_{DB}	weight per cent alkali chloride in organic phase
X_{AI}	weight per cent water in initial mixture
X_{BI}	weight per cent benzene in initial mixture
X_{CI}	weight per cent carboxylic acid in initial mixture
X_{DI}	weight per cent alkali chloride in initial mixture
X_s	salt concentration in aqueous phase; moles/liter
X_{ss}	salt concentration in aqueous phase; grams salt/gram water
X_s'	salt concentration in aqueous phase; grams salt/100 grams solution
x_a	molecules of water attached to anion
x_c	molecules of water attached to cation
Δx	net quantity of water transferred to cathode compartment; moles/faraday

Greek letters

α	degree of ionization, equation 14
α'	degree of association, equation 17
β, β'	constants, equation 29
β_o	compressibility of pure water
μ	chemical potential of distributed component
μ_1	chemical potential of distributed component, phase 1
μ_2	chemical potential of distributed component, phase 2
μ_1^o	chemical potential of distributed component in standard state in phase 1
μ_2^o	chemical potential of distributed component in standard state in phase 2
$\Delta\mu_s$	chemical potential of non-electrolyte per molecule
ρ_A	density of aqueous phase; grams/ml
ρ_B	density of organic phase; grams/ml

APPENDIX

ERRORS OF MEASUREMENT

The errors in experimental measurements will be expressed in terms of the probable error. The probable error p is the error such that the number of errors greater than p is equal to the number of errors which are less than p. If y is a function of the independent variables x, z, w,..., it may be shown that the probable error p in y is

$$p = \pm \sqrt{\left(\frac{\partial y}{\partial x}\right)^2 r_x{}^2 + \left(\frac{\partial y}{\partial z}\right)^2 r_z{}^2 + \left(\frac{\partial y}{\partial w}\right)^2 r_w{}^2 + \dots} \qquad (65)$$

where r_x is the probable error in x, etc.

Equation 65 may be used to show that the probable error of the sum or difference of two quantities A and B, respectively, affected with probable errors ±a and ±b, is

$$p = \pm \sqrt{a^2 + b^2} \qquad (66)$$

In the case of multiplication, the probable error of the product of two quantities A and B is

$$p = \pm \sqrt{(Ab)^2 + (Ba)^2} \qquad (67)$$

The probable error of the quotient B/A of two quantities A and B is

$$p = \pm \frac{1}{A} \sqrt{b^2 + \frac{B^2a^2}{A^2}} \qquad (68)$$

SAMPLE CALCULATION AND ERROR STUDY

Data from Run 31-20 will be used.

I. Initial mixture

Tare, Benzene, Acetic Acid, KCl solution	121.5795 g ± 0.2 mg
Tare, Acetic Acid, KCl solution	104.0357 g ± 0.2 mg
Tare, KCl solution	83.1647 g ± 0.2 mg
Tare	62.0075 g ± 0.2 mg

A. Weights of Individual components

Benzene	17.5438 ± 0.0003 g
Acetic Acid	20.8710 ± 0.0003 g
KCl solution	21.1572 ± 0.0003 g
Total weight	59.5720 ± 0.0003 g

$$p = \pm \sqrt{(0.0002)^2 + (0.0002)^2}$$

$$p = \pm\ 0.0003\ g$$

B. Composition - Weight Per Cent

$$\left[\frac{20.8710 \pm 0.0003}{59.7520 \pm 0.0003}\right] \times\ 100\ \% \;=\; 35.0349\ \%\ \text{Acetic Acid}$$

$$p = \pm \frac{1}{59{,}572.0} \sqrt{(0.0003)^2 + (0.350349)^2(0.0003)^2}$$

$$p = \pm\ 0.0005\ \%$$

Water Content of Acetic Acid = 0.0139 ± 0.0005 %

$$(35.0349 \pm 0.0005)\ (0.000139 \pm 0.000005) = 0.0049\ \%\ \text{water}$$

$$p = \pm \sqrt{(35.0349)^2(5 \cdot 10^{-6})^2 + (0.000139)^2(0.0005)^2}$$

$$p = \pm\ 0.0002\ \%$$

Per Cent Pure Acetic Acid

$$(35.0349 \pm 0.0005) - (0.0049 \pm 0.0002) = 35.0300\ \%$$

$$p = \pm \sqrt{(5 \cdot 10^{-4})^2 + (2 \cdot 10^{-4})^2}$$

$$p = \pm\ 0.0066\ \%$$

Per Cent Acetic Acid = 35.030 ± 0.001 %

2. Benzene

$$\left[\frac{17.5438 \pm 0.0003}{59.5720 \pm 0.0003}\right] \times 100\ \% = 29.4497\ \%\ \text{Benzene}$$

$$p = \pm \frac{1}{59{,}572.0} \sqrt{(0.0003)^2 + (0.294497)^2\ (0.0003)^2}$$

$$p = \pm\ 0.0005\ \%$$

Water content of Benzene = 0.0059 ± 0.0003 %

$$(29.4497 \pm 0.0005)\ (0.000059 \pm 3 \cdot 10^{-6}) = 0.0017\ \%\ \text{Water}$$

$$p = \pm \sqrt{(29.4497)^2(3\cdot10^{-6})^2 + (5.9\cdot10^{-5})^2(5\cdot10^{-4})^2}$$

$$p = \pm\ 0.0001\ \%$$

Per Cent Pure Benzene

$$(29.4497 \pm 0.0005) - (0.0017 \pm 0.0001) = 29.4480\ \%$$

$$p = \pm \sqrt{(0.0005)^2 + (0.0001)^2}$$

$$p = \pm\ 0.0006\ \%$$

Per Cent Benzene = 29.448 ± 0.001 %

3. KCl solution

$$\left[\frac{21.1572 \pm 0.0003}{59.5720 \pm 0.0003}\right] \times 100\ \% = 35.5154\ \%\ \text{KCl solution}$$

$$p = \pm \frac{1}{59{,}570.0} \sqrt{(0.0003)^2 + (0.355154)^2\ (0.0003)^2}$$

$$p = \pm\ 0.0005\ \%$$

4. KCl

Salt content of KCl solution is 9.287 ± 0.003 %

$$(35.5154 \pm 0.0005)\ (0.09287 \pm 0.00003) = 3.298\ \%\ \text{KCl}$$

$$p = \pm \sqrt{(35.5154)^2\ (0.00003)^2 + (0.09287)^2\ (0.0005)^2}$$

$$p = \pm\ 0.001\ \%$$

Per Cent KCl = 3.298 ± 0.001 %

5. Water

Total KCl solution	35.5154 ± 0.0005 %
KCl	3.298 ± 0.001 %
Water in KCl solution	32.317 %
Water in Acetic Acid	0.0049 ± 0.0002 %
Water in Benzene	0.0017 ± 0.0001 %
Total Water	32.224 %

$$p = \pm \sqrt{(0.0005)^2 + (0.0001)^2 + (0.0002)^2 + (0.0001)^2}$$

$$p = \pm 0.001 \%$$

Per Cent Water = 32.224 ± 0.001 %

6. Composition - Initial Mixture

Acetic Acid	35.030 ± 0.001 %
Benzene	29.448 ± 0.001 %
KCl	3.298 ± 0.001 %
Water	32.224 ± 0.001 %

II. Organic Phase

A. Per Cent Acetic Acid

Tare, Organic Phase aliquot	128.5732 g ± 0.2 mg
Tare	126.0897 g ± 0.2 mg
Organic Phase Aliquot	2.4835 g

$$p = \pm \sqrt{(0.0002)^2 + (0.0002)^2}$$

$p = \pm 0.0003$ g

Normality of Sodium Hydroxide standard solution

$N = 0.6514 \pm 0.0003$ equivalents per liter

Acetic Acid equivalent of NaOH standard solution

$$(0.6514 \pm 0.0003)\ (60.054 \pm 0.005) = 39.12\ \frac{\text{mg acetic acid}}{\text{ml NaOH solution}}$$

$$p = \pm \sqrt{(0.6514)^2\ (0.005)^2 + (60.054)^2\ (0.0003)^2}$$

$p = \pm 0.02$ mg acetic acid

1.000 ml NaOH solution = 39.12 ± 0.02 mg acetic acid

Volume NaOH solution to neutralize acetic acid in organic phase aliquot = 6.308 ± 0.003 ml

$$(6.308 \pm 0.003 \text{ ml NaOH})\ (39.12 \pm 0.02\ \frac{\text{mg HOAc})}{\text{ml NaOH}} = 246.8 \text{ mg HOAc}$$

$$p = \pm \sqrt{(6.308)^2\ (0.02)^2 + (39.12)^2\ (0.003)^2}$$

$p = \pm 0.2$ mg acetic acid

Weight acetic acid in organic phase aliquot = 246.8 ± 0.2 mg

$$\left[\frac{246.8 \pm 0.2}{2483.5 \pm 0.3}\right] \times 100\ \% = 9.936\ \% \text{ Acetic Acid}$$

$$p = \pm \frac{1}{2483.5} \sqrt{(0.2)^2 + (0.09936)^2\ (0.3)^2}$$

$p = \pm 0.008$ %

Organic phase contains 9.936 ± 0.008 % acetic acid.

B. Per Cent Water

Tare, Organic phase aliquot	30.7828 g ± 0.2 mg
Tare	26.9256 g ± 0.2 mg
Organic phase aliquot	3.8572 g

$$p = \pm \sqrt{(0.0002)^2 + (0.0002)^2}$$

$$p = \pm\ 0.0003\ g$$

Organic phase aliquot is 3.8572 ± 0.0003 g

Standardization of Karl Fischer Reagent

Volume methanol-water standard taken	10.00 ml ± 0.01 ml
Weight water per ml standard	1.00 mg ± 0.01 mg
Karl Fischer Reagent used per 10 ml methanol-water standard	1.70 ml ± 0.01 ml

$$(10.00 \pm 0.01\ \text{ml standard})\left(1.00 \pm 0.01\ \frac{\text{mg water}}{\text{ml standard}}\right) = 10.0\ \text{mg water}$$

$$p = \pm \sqrt{(10.00)^2(0.01)^2 + (1.00)^2(0.01)^2}$$

$$p = \pm\ 0.1\ \text{mg water}$$

Water in 10.00 ml methanol-water standard is 10.0 ± 0.1 mg

$$\left[\frac{10.00 \pm 0.1\ \text{mg water}}{1.70 \pm 0.01\ \text{ml K.F.}}\right] = 5.88\ \frac{\text{mg water}}{\text{ml K. F.}}$$

$$p = \pm \frac{1}{1.70} \sqrt{(0.1)^2 + (5.88)^2(0.01)^2}$$

$$p = \pm\ 0.07\ \frac{\text{mg water}}{\text{ml K.F. reagent}}$$

Karl Fischer factor is $5.88 \pm 0.07\ \frac{\text{mg water}}{\text{ml K.F. reagent}}$

$$(1.65 \pm 0.02\ \text{ml K.F.})(5.88 \pm 0.07\ \frac{\text{mg water}}{\text{ml K.F.}}) = 9.70\ \text{mg water}$$

$$p = \pm \sqrt{(1.65)^2(0.07)^2 + (5.88)^2(0.02)^2}$$

$$p = \pm\ 0.16\ \text{mg water}$$

Organic phase aliquot contains 9.70 ± 0.16 mg water

$$\left[\frac{9.70 \pm 0.16\ \text{mg water}}{3{,}857.2 \pm 0.3\ \text{mg org. phase}}\right](100\%) = 0.252\%\ \text{water}$$

$$p = \pm \frac{1}{3{,}857.2}\sqrt{(0.16)^2 + (0.00252)^2(0.3)^2}$$

$$p = \pm\ 0.004\%$$

Water content of organic phase is 0.252 ± 0.004 %

C. Per Cent Potassium Chloride

Organic phase aliquot	2.4835 g ± 0.3 mg
Tare + NaCl standard solution	160.5993 g ± 0.2 mg
Tare	158.5514 g ± 0.2 mg
NaCl standard solution	2.0479 g ± 0.3 mg

$$p = \pm \sqrt{(0.2)^2 + (0.2)^2}$$

$p = \pm 0.3$ mg $= \pm 0.0003$ g

Weight standard NaCl solution taken is 2.0479 ± 0.0003 g

Volume silver nitrate solution used 2.173 ± 0.005 ml
Normality of silver nitrate solution 0.1008 ± 0.0001 N

NaCl solution equivalency:

1.0000 g NaCl solution = 1.0420 ± 0.0006 ml $AgNO_3$ solution

$$(2.0479 \pm 0.0003 \text{ g})(1.0420 \pm 0.0006 \frac{\text{ml } AgNO_3}{\text{g NaCl}}) = 2.134 \text{ ml } AgNO_3$$

$$p = \pm \sqrt{(2.0479)^2(0.0006)^2 + (1.0420)^2(0.0003)^2}$$

$$p = \pm 0.001 \text{ ml } AgNO_3$$

Weight standard N_aCl solution taken is equivalent to 2.134 ± 0.001 ml silver nitrate solution.

$$2.173 \pm 0.005 \text{ ml} - 2.134 \pm 0.001 \text{ ml} = 0.39 \text{ ml } AgNO_3$$

$$p = \pm \sqrt{(0.005)^2 + (0.001)^2}$$

$$p = \pm 0.005 \text{ ml } AgNO_3$$

$$(0.039 \pm 0.005 \text{ ml})(0.1008 \pm 0.0001 \frac{\text{meq}}{\text{ml}}) = 0.0039 \text{ meq}$$

$$p = \pm \sqrt{(0.039)^2(0.0001)^2 + (0.1008)^2(0.005)^2}$$

$$p = \pm 0.0005 \text{ meq}$$

$$(0.0039 \pm 0.0005 \text{ meq})\ 74.557 \pm 0.001 \frac{\text{mg KCl})}{\text{meq}} = 0.291 \text{ mg KCl}$$

$$p = \pm \sqrt{(0.0039)^2(0.001)^2 + (74.557)^2(0.0005)^2}$$

$$p = \pm 0.037 \text{ mg KCl}$$

Organic phase aliquot contains 0.291 ± 0.037 mg KCl

$$\left[\frac{0.291 \pm 0.037 \text{ mg KCl}}{2{,}483.5 \pm 0.3 \text{ mg}}\right] (100\%) = 0.0117\% \text{ KCl}$$

$$p = \pm \frac{1}{2{,}483.5} \sqrt{(0.037)^2 + (0.0117)^2(0.3)^2}$$

$$p = \pm 0.0015 \% \text{ KCl}$$

KCl content of organic phase is 0.012 ± 0.001 %

D. Per Cent Benzene

Per Cent Acetic Acid	9.936 ± 0.008 %
Per Cent Water	0.252 ± 0.004 %
Per Cent KCl	0.012 ± 0.0015 %
Total	10.200

$$p = \pm \sqrt{(0.008)^2 + (0.004)^2 + (0.0015)^2}$$

$$p = \pm 0.009 \%$$

Per cent Benzene = 100.0000 % - 10.200 ± 0.01 %

Per cent Benzene = 89.80 ± 0.01 %

E. Analysis of Organic Phase

Per cent Acetic Acid	9.936 ± 0.008 %
Per cent Water	0.252 ± 0.004 %
Per cent Benzene	89.80 ± 0.01 %
Per cent Potassium Chloride	0.012 ± 0.001 %

III. Aqueous Phase

A. Per Cent Acetic Acid

Tare, aqueous phase aliquot	126.0728 ± 0.0002 g
Tare	123.8046 ± 0.0002 g
Aqueous phase aliquot	2.2682 g

$$p = \pm \sqrt{(0.0002)^2 + (0.0002)^2}$$

$$p = \pm 0.0003 \text{ g}$$

Weight of aqueous phase aliquot is 2.2682 ± 0.0003 g

$$(27.20 \pm 0.03 \text{ ml NaOH})(39.12 - 0.02 \ \frac{\text{mg HOAc}}{\text{ml NaOH}}) = 1064 \text{ mg HOAc}$$

$$p = \pm \sqrt{(27.20)^2(0.03)^2 + (39.12)^2(0.02)^2}$$

$$p = \pm 1.1 \text{ mg acetic acid}$$

Aqueous phase aliquot contains 1064 ± 1.1 mg acetic acid.

$$\left[\frac{1064 - 1.1 \text{ mg HOAc}}{2{,}268.2 \pm 0.3 \text{ mg}}\right](100\%) = 46.91\ \%\text{ acetic acid}$$

$$p = \pm\frac{1}{2{,}268.2}\sqrt{(1.1)^2 + (0.4691)^2(0.3)^2}$$

$$p = \pm 0.05\ \%$$

Aqueous phase contains 46.91 ± 0.05 % acetic acid

B. Ratio of Weights of Organic and Aqueous Phases

X_{CA} = % acetic acid in aqueous phase 46.91 ± 0.05 %

X_{CI} = % acetic acid in initial mixture 35.030 ± 0.001 %

X_{CB} = % acetic acid in organic phase 9.936 ± 0.008 %

Using equation 53, the ratio of weight of organic phase to weight of aqueous phase is given by

$$\frac{X_{CA} - X_{CI}}{X_{CI} - X_{CB}} = \frac{m_B}{m_A}$$

$$\left[\frac{46.91 \pm 0.05 \quad - \quad 35.030 \pm 0.001}{35.030 \pm 0.001 \quad - \quad 9.936 \pm 0.008}\right] = 0.473$$

$$p_n = \pm\sqrt{(0.05)^2 + (0.001)^2}$$

$$p_n = \pm 0.05$$

$$p_d = \pm \sqrt{(0.001)^2 + (0.008)^2}$$

$$p_d = \pm 0.008$$

$$\left[\frac{11.88 \pm 0.05}{25.094 \pm 0.008}\right] = 0.473$$

$$p = \pm \frac{1}{25.094} \sqrt{(0.05)^2 + (0.473)^2(0.008)^2}$$

$$p = \pm 0.002$$

Ratio of weight of organic phase to weight of aqueous phase is 0.473 ± 0.002

C. Per Cent Water

$$\frac{X_{AA} - X_{AI}}{X_{AI} - X_{AB}} = 0.473 \pm 0.002$$

$X_{AI} = 32.224 - 0.001\ \%$

$X_{AB} = 0.252 - 0.004\ \%$

X_{AA} = Per cent water in aqueous phase

$$X_{AI} - X_{AB} = 32.224 \pm 0.001 - 0.252 \pm 0.004 = 31.972\ \%$$

$$p = \pm \sqrt{(0.001)^2 + (0.004)^2}$$

$p = \pm\ 0.004\ \%$

$(0.473 - 0.002)(31.972 - 0.004) = 15.12\ \%$

$p = \pm \sqrt{(0.473)^2(0.004)^2 + (31.965)^2(0.002)^2}$

$p = \pm\ 0.06\ \%$

$X_{AA} = 15.12 \pm 0.06\ \% + 32.224 \pm 0.001\ \% = 47.34\ \%$

$p = \pm \sqrt{(0.06)^2 + (0.001)^2}$

$p = \pm\ 0.06\ \%$

Aqueous phase contains 47.34 ± 0.06 % water.

D. Per Cent Potassium Chloride

$$\frac{X_{DA} - X_{DI}}{X_{DI} - X_{DB}} = 0.473 \pm 0.002$$

$X_{DI} = 3.298 \pm 0.001$

$X_{DB} = 0.012 \pm 0.0015$

X_{DA} = Per cent potassium chloride in aqueous phase.

$X_{DI} - X_{DB} = 3.298 \pm 0.001 - 0.012 \pm 0.0015 = 3.286$

$p = \pm \sqrt{(0.001)^2 + (0.0015)^2}$

$p = \pm\ 0.002\ \%$

$(0.473 \pm 0.002)(3.286 \pm 0.002) = 1.554$

$$p = \pm \sqrt{(0.473)^2(0.002)^2 + (3.286)^2(0.002)^2}$$

$p = \pm 0.007$ %

$X_{DA} = 1.554 \pm 0.007\% + 3.298 \pm 0.001\% = 4.852$ %

$$p = \pm \sqrt{(0.007)^2 + (0.001)^2}$$

$p = \pm 0.007$ %

Aqueous phase contains 4.852 ± 0.007 % potassium chloride

E. Per Cent Benzene

% acetic acid	46.91 ± 0.05 %
% water	47.34 ± 0.06 %
% potassium chloride	4.852 ± 0.007 %
Total	99.102

$$p = \pm \sqrt{(0.05)^2 + (0.06)^2 + (0.007)^2}$$

$p = \pm 0.08$ %

Per cent benzene = 100.000 - 99.10 = 0.90 %

Aqueous phase contains 0.90 ± 0.08 % benzene.

F. Analysis of Aqueous Phase

Acetic Acid	46.91 ± 0.05 %
Water	47.34 ± 0.06 %
Benzene	0.90 ± 0.08 %
Potassium Chloride	4.852 ± 0.007 %

IV. Distribution Coefficient

Distribution coefficient: $\frac{X_{CA}}{X_{CB}}$

$X_{CA} = 46.91 \pm 0.05\ \%$

$X_{CB} = 9.936 \pm 0.008\ \%$

$$\frac{X_{CA}}{X_{CB}} = 4.721$$

$$p = \pm \frac{1}{9.936} \sqrt{(0.05)^2 + (4.72)^2(0.008)^2}$$

$$p = \pm 0.006$$

Distribution coefficient is 4.721 ± 0.006

V. Calculation of Coordinates for Hand Plot

$X_{CB} = 9.936 \pm 0.008\ \%$

$X_{BB} = 89.80 \pm 0.01\ \%$

$X_{CA} = 46.91 \pm 0.05\ \%$

$X_{AA} = 47.34 \pm 0.06\ \%$

$$\frac{X_{CB}}{X_{BB}} = \frac{9.936 \pm 0.008}{89.80 \pm 0.01} = 0.1106$$

$$p = \pm \frac{1}{89.80} \sqrt{(0.008)^2 + (0.1106)^2(0.01)^2}$$

$$p = \pm 0.0001 \%$$

$$\frac{X_{CA}}{X_{AA}} = \frac{46.91 \pm 0.05}{47.34 \pm 0.06} = 0.991$$

$$p = \pm \frac{1}{47.34} \sqrt{(0.05)^2 + (0.991)^2(0.06)^2}$$

$$p = \pm 0.0012$$

Hand coordinates are: $\frac{X_{CB}}{X_{BB}} = 0.1106 \pm 0.0001$

$$\frac{X_{CA}}{X_{AA}} = 0.991 \pm 0.001$$

VI. Determination of Water Content of Acetic Acid

Volume Karl Fischer Reagent used	0.29 ± 0.02 ml
Karl Fischer factor	$6.02 \pm 0.04 \frac{\text{mg water}}{\text{ml}}$
Weight acetic acid titrated	12.5416 ± 0.0003 g

$$(0.29 \pm 0.02 \text{ ml})\ (6.02 \pm 0.04 \ \frac{\text{mg}}{\text{ml}}) = 1.75 \text{ mg water}$$

$$p = \pm \sqrt{(0.29)^2(0.04)^2 + (6.02)^2(0.02)^2}$$

$$p = \pm 0.12 \text{ mg water}$$

$$\left[\frac{1.75 \pm 0.12}{12{,}541.6 \pm 0.3}\right](100\ \%) = 0.014\ \%\text{ water}$$

$$p = \pm \frac{1}{12{,}541.6}\sqrt{(0.12)^2 + (0.00014)^2(0.3)^2}$$

$$p = \pm 0.001\ \%$$

Water content of acetic acid is 0.014 ± 0.001 %

RESULTS OF

ANALYSES AND CALCULATIONS

TABLE 13

ACETIC -ACID - BENZENE - WATER

RUN NUMBER	14-2	14-5	14-10	14-15	14-20	14-25	14-30	14-35	14-40	14-45	14-50	14-60
Composition of Initial Mixture*												
Acetic Acid	5.284	12.229	21.794	29.519	35.805	41.058	45.548	49.390	52.791	55.675	58.253	62.608
Benzene	44.226	40.983	36.516	32.919	29.973	27.523	25.437	23.618	22.039	20,690	19.486	17.448
Water	50.489	46.787	41.690	37.561	34.221	31.419	29.015	26.991	25.169	23.635	22.260	19.943
Composition of Aqueous Phase*												
Acetic Acid	9.164	19.74	32.59	41.71	48.37	53.55	57.55	60.49	62.94	64.58	66.23	67.61
Benzene	0.27	0.63	0.92	1.32	1.61	2.09	2.77	3.63	4.79	6.30	8.06	10.8
Water	90.56	79.73	66.49	56.79	50.02	44.36	39.68	35688	32.37	29.12	25.71	21.63
Composition of Organic Phase*												
Acetic Acid	0.443	1.729	4.142	6.504	8.844	11.04	13.33	15.60	17.94	20.34	22.72	28.02
Benzene	99.48	98.17	95.70	93.28	91.91	88.64	86.27	83.92	81.45	78.97	76.40	70.63
Water	0.082	0.101	0.159	0.216	0.243	0.317	0.394	0.479	0.606	0.692	0.875	1.35
Hand Coordinates												
X_{cb}/X_{bb}	0.00446	0.01761	0.0433	0.0696	0.0961	0.1246	0.1547	0.1860	0.220	0.257	0.297	0.396
X_{ca}/X_{aa}	0.1011	0.247	0.485	0.727	0.966	1.207	1.449	1.680	1.950	2.19	2.46	2.99
Distribution Coefficient												
X_{ca}/X_{cb}	20.68	11.41	7.869	6.412	5.469	4.850	4.316	3.973	3.508	3.715	2.914	2.413

*All compositions are given in weight per cent.

TABLE 14

ACETIC ACID - BENZENE - WATER - 1.970 % LITHIUM CHLORIDE

RUN NUMBER	23-2	23-5	23-10	23-15	23-20	23-25	23-30	23-35	23-40	23-50	23-60
Composition of Initial Mixture*											
Acetic Acid	5.252	12.248	21.746	29.447	35.655	41.059	45.485	49.272	52.641	58.128	62.452
Benzene	44.062	40.857	36.376	32.853	29.923	27.402	25.357	23.590	22.037	19.432	17.454
Water	49.687	45.971	41.053	36.960	33.744	30.917	28.584	26.607	24.823	21.997	19.698
Lithium Chloride	0.999	0.924	0.825	0.743	0.678	0.621	0.574	0.535	0.499	0.442	0.396
Composition of Aqueous Phase*											
Acetic Acid	9.049	19.70	32.30	41.46	48.08	53.43	57.46	60.51	63.26	66.13	67.52
Benzene	0.24	0.51	0.79	1.14	1.38	1.73	2.29	2.98	3.77	6.21	9.40
Water	88.91	78.19	65.55	56.25	48.54	43.95	39.45	35.79	32.32	27.12	22.62
Lithium Chloride	1.803	1.597	1.363	1.146	1.001	0.887	0.795	0.718	0.656	0.544	0.455
Composition of Organic Phase*											
Acetic Acid	0.552	2.058	4.787	7.494	9.946	12.62	15.01	17.38	20.12	25.24	30.72
Benzene	99.37	97.84	94.06	92.31	89.78	87.09	84.56	82.09	79.20	73.76	67.80
Water	0.073	00.095	0.144	0.194	0.263	0.280	0.419	0.519	0.665	0.964	1.45
Lithium Chloride	0.003	0.003	0.006	0.007	0.010	0.010	0.012	0.014	0.018	0.022	0.027
Hand Coordinates											
X_{cb}/X_{bb}	0.00556	0.0211	0.0508	0.0810	0.1108	0.1450	0.1775	0.212	0.254	0.342	0.452
X_{ca}/X_{aa}	0.1007	0.247	0.475	0.727	0.965	1.202	1.460	1.688	1.920	2.44	2.98
Distribution Coefficient											
X_{ca}/X_{cb}	16.38	9.572	6.749	5.533	4.834	4.335	3.829	3.482	3.145	2.620	2.198

*All compositions are given in weight per cent.

TABLE 15

ACETIC ACID - BENZENE - WATER - 5.743 % LITHIUM CHLORIDE

RUN NUMBER	24-2	24-5	24-10	24-15	24-20	24-25	24-30	24-35	24-40	24-50	24-60
Composition of Initial Mixture*											
Acetic Acid	5.226	12.060	21.569	29.170	35.399	40.776	45.194	49.039	52.278	57.909	62.198
Benzene	43.498	40.415	36.043	32.534	29.638	27.267	25.134	23.430	21.886	19.399	17.400
Water	48.331	44.796	39.953	36.096	32.955	30.122	27.969	25.949	24.352	21.389	19.230
Lithium Chloride	2.944	2.729	2.434	2.199	2.008	1.835	1.704	1.581	1.484	1.303	1.172
Composition of Aqueous Phase*											
Acetic Acid	8.789	18.91	31.39	40.31	47.27	52.47	56.54	59.74	61.95	66.01	67.45
Benzene	0.21	0.44	0.66	0.97	1.16	1.39	1.85	2.47	3.22	5.10	7.94
Water	85.71	75.93	63.97	55.29	48.54	43.48	39.20	35.61	32.85	27.22	23.20
Lithium Chloride	5.291	4.717	3.982	3.427	3.025	2.656	2.408	2.180	1.987	1.673	1.412
Composition of Organic Phase*											
Acetic Acid	0.759	2.665	6.153	9.290	12.17	14.77	17.95	21.06	23.54	29.88	35.76
Benzene	99.16	97.23	93.68	90.47	87.52	84.82	81.52	78.29	75.64	68.88	62.42
Water	0.078	0.103	0.159	0.236	0.299	0.406	0.516	0.644	0.802	1.22	1.80
Lithium Chloride	0.003	0.004	0.006	0.009	0.010	0.011	00.013	0.016	0.021	0.024	0.030
Hand Coordinates											
X_{cb}/X_{bb}	0.00767	0.0274	0.0657	0.1028	0.1392	0.1740	0.220	0.269	0.312	0.434	0.574
X_{ca}/X_{aa}	0.1010	0.244	0.486	0.717	0.954	1.208	1.436	1.683	1.918	2.43	2.96
Distribution Coefficient											
X_{ca}/X_{cb}	11.58	7.097	5.102	4.340	3.884	3.553	3.151	2.836	2.632	2.209	1.895

*All compositions are given in weight per cent.

TABLE 16

ACETIC ACID - BENZENE - WATER - 9.118 % LITHIUM CHLORIDE

RUN NUMBER	25-2	25-5	25-10	25-15	25-20	25-25	25-30	25-35	25-40	25-50	25-60
Composition of Initial Mixture											
Acetic Acid	5.160	11.919	21.390	28.975	35.272	40.459	44.914	48.771	52.104	57.574	61.937
Benzene	43.140	40.001	35.718	32.300	29.372	27.055	25.039	23.282	21.772	19.289	17.279
Water	46.986	43.697	38.982	35.194	32.133	29.524	27.307	25.399	23.742	21.028	18.889
Lithium Chloride	4.714	4.384	3.911	3.531	3.223	2.962	2.740	2.548	2.382	2.110	1.895
Composition of Aqueous Phase*											
Acetic Acid	8.464	18.07	30.16	39.21	46.01	51.45	55.58	59.04	61.78	65.32	67.36
Benzene	0.17	0.36	0.56	0.77	0.98	1.14	1.46	1.91	2.81	4.55	6.81
Water	82.94	74.07	62.90	54.46	48.10	43.00	39.01	35.45	32.11	27.37	23.47
Lithium Chloride	8.425	7.503	6.379	5.563	4.905	4.406	3.954	3.602	3.302	2.761	2.355
Composition of Organic Phase*											
Acetic Acid	0.965	3.357	7.523	11.24	14.62	18.10	20.97	24.11	27.25	32.79	40.04
Benzene	98.97	96.52	92.29	88.49	85.01	81.40	78.42	75.10	71.74	65.78	57.97
Water	0.062	0.114	0.178	0.261	0.357	0.478	0.596	0.770	0.988	1.40	1.97
Lithium Chloride	0.004	0.005	0.007	0.009	0.011	0.014	0.016	0.018	0.021	0.028	0.035
Hand Coordinates											
X_{cb}/X_{bb}	0.00974	0.0347	0.0816	0.1270	0.1720	0.222	0.268	0.321	0.380	0.464	0.691
X_{ca}/X_{aa}	0.1005	0.241	0.475	0.709	0.945	1.175	1.415	1.650	1.891	2.38	2.93
Distribution Coefficient											
X_{ca}/X_{cb}	8.773	5.382	4.008	3.489	3.148	2.842	2.651	2.448	2.267	1.992	1.682

*All compositions are given in weight per cent.

TABLE 17

ACETIC ACID - BENZENE - WATER - 13.66 % LITHIUM CHLORIDE

RUN NUMBER	60-2	60-5	60-10	60-15	60-20	60-25	60-30	60-35	60-40	60-50	60-60
Composition of Initial Mixture*											
Acetic Acid	5.099	11.773	21.346	28.570	34.888	40.118	44.562	48.382	51.747	57.300	61.647
Benzene	42.537	39.508	35.719	32.142	29.208	26.839	24.880	23.126	21.655	19.149	17.208
Water	45.201	42.055	37.062	33.914	30.992	28.822	26.377	24.594	22.955	20.330	18.253
Lithium Chloride	7.163	6.665	5.874	5.375	4.912	4.520	4.180	3.898	3.639	3.222	2.893
Composition of Aqueous Phase*											
Acetic Acid	7.931	16.89	28.86	37.37	44.06	49.57	53.80	57.29	60.23	64.49	67.19
Bnezene	0.14	0.28	0.44	0.61	00.76	0.88	1.17	1.47	2.24	3.83	5.73
Water	79.32	71.40	60.93	53.30	47.54	42.84	38.82	35.54	32.30	27.24	23.25
Lithium Chloride	12.61	11.43	9.770	8.715	7.643	6.713	6.214	5.703	5.225	4.442	3.833
Composition of Organic Phase*											
Acetic Acid	1.378	4.614	10.04	14.43	18.42	22.46	25.65	29.24	32.42	38.52	44.94
Benzene	98.55	95.24	89.74	85.25	81.14	77.36	73.65	69.86	66.38	59.19	51.78
Water	0.069	0.106	0.219	0.306	0.429	0.580	0.681	0.882	1.18	1.58	2.22
Lithium Chloride	0.004	0.005	0.007	0.009	0.011	0.015	0.017	0.019	0.023	0.034	0.061
Hand Coordinates											
X_{cb}/X_{bb}	0.0140	0.0485	0.1116	0.1695	0.227	0.290	0.348	0.419	0.489	0.651	0.869
X_{ca}/X_{aa}	0.0996	0.234	0.469	0.682	0.918	1.141	1.381	1.608	1.851	2.34	2.85
Distribution Coefficient											
X_{ca}/X_{cb}	5.756	3.661	2.878	2.589	2.392	2.272	2.097	1.959	1.858	1.674	1.495

*All compositions are given in weight per cent.

TABLE 18

ACETIC ACID - BENZENE - WATER - 17.61 % LITHIUM CHLORIDE

RUN NUMBER	61-2	61-5	61-10	61-15	61-20	61-25	61-30	61-35	61-40	61-50	61-60
Composition of Initial Mixture*											
Acetic Acid	5.025	11.702	20.941	28.473	34.624	39.849	44.262	48.115	51.451	56.939	61.334
Benzene	42.039	39.154	35.116	31.661	29.001	26.603	24.634	22.968	21.501	19.063	17.104
Water	43.614	40.490	36.281	32.846	29.969	27.641	25.629	23.825	22.285	19.772	17.765
Lithium Chloride	9.322	8.654	7.755	7.020	6.406	5.908	5.478	5.092	4.763	4,226	3.797
Composition of Aqueous Phase*											
Acetic Acid	7.456	15.89	26.85	35.50	42.36	47.81	52.29	55.97	59.23	63.82	68.56
Benzene	0.11	0.21	0133	0.46	0.58	0.71	0.93	1.16	1.75	2.84	4.43
Water	76.06	68.94	59.66	52.42	46.65	42.14	38.22	35.08	31.81	27.06	21.17
Lithium Chloride	16.37	14.96	13.16	11.62	10.41	9.340	8.562	7.794	7.214	6.276	5.839
Composition of Organic Phase*											
Acetic Acid	1.811	5.955	12.48	17.75	22.26	26.17	30.04	33.37	36.40	42.89	48.15
Benzene	97.11	93.92	87.27	81.84	77.18	73.10	69.16	65.53	62.33	55.37	49.66
Water	0.073	0.120	0.247	0.405	0.554	0.716	0.887	1.078	1.247	1.706	2.124
Lithium Chloride	0.004	0.005	0.006	0.008	0.010	0.013	0.016	00.021	0.025	0.040	0.074
Hand Coordinates											
X_{cb}/X_{bb}	0.01865	0.0644	0.1431	0.217	0.289	0.358	0.435	0.509	0.584	0.775	0.970
X_{ca}/X_{aa}	0.0987	0.227	0.437	0.656	0.875	1.105	1.320	1.556	1.786	2.23	2.58
Distribution Coefficient											
X_{ca}/X_{cb}	4.118	2.668	2.151	2.000	1.903	1.826	1.741	1.677	1.627	1.488	1.424

*All compositions are given in weight per cent.

TABLE 19

ACETIC ACID - BENZENE - WATER - 21.23 % LITHIUM CHLORIDE

RUN NUMBER	62-2	62-5	62-10	62-15	62-20	62-25	62-30	62-35	62-40	62-50	62-60
Composition of Initial Mixture*											
Acetic Acid	5.001	11.614	20.782	28.234	34.370	39.602	44.144	47.887	51.131	56.763	61.148
Benzene	41.749	38.820	34.743	31.501	28.793	26.497	24.491	22.858	21.446	18.984	17.066
Water	41.945	39.044	35.033	31.717	29.017	26.704	24.706	23.044	21.609	19.104	17.161
Lithium Chloride	11.305	10.523	9.442	8.548	7.821	7.197	6.659	6.211	5.822	5.149	4.625
Composition of Aqueous Phase*											
Acetic Acid	7.096	14.91	25.24	33.57	40.43	46.18	50.85	54.60	57.92	62.80	66.31
Benzene	0.08	0.15	0.23	0.32	0.42	0.51	0.72	0.91	1.39	2.10	3.12
Water	72.98	66.60	58.09	51.46	46.04	41.40	37.69	34.54	31.44	27.24	23.91
Lithium Chloride	19.84	18.34	16.44	14.65	13.11	11.91	10.74	9.952	9.249	7.859	6.655
Composition of Organic Phase*											
Acetic Acid	2.230	7.186	14.77	20.77	25.42	29.60	33.25	36.79	39.67	45.53	50.01
Benzene	97.69	92.68	84.97	78.81	74.01	69.71	65.81	62.09	59.10	52.93	47.98
Water	0.073	0.127	0.255	0.411	0.554	0.773	0.913	1.089	1.187	1.574	1.918
Lithium Chloride	0.004	0.006	0.008	0.011	0.014	0.017	0.024	0.031	0.036	0.059	0.092
Hand Coordinates											
X_{cb}/X_{bb}	0.0228	0.0765	0.1738	0.264	0.344	0.424	0.505	0.592	0.671	0.859	1.043
X_{ca}/X_{aa}	0.0963	0.220	0.415	0.620	0.836	1.057	1.291	1.501	1.700	2.20	2.76
Distribution Coefficient											
X_{ca}/X_{cb}	3.182	2.076	1.709	1.617	1.590	1.560	1.529	1.484	1.460	1.382	1.326

*All compositions are given in weight per cent.

TABLE 20

ACETIC ACID - BENZENE - WATER - 2.002 % SODIUM CHLORIDE

RUN NUMBER	26-2	26-5	26-10	26-15	26-20	26-25	26-30	26-35	26-40	26-50	26-60
Composition of Initial Mixture*											
Acetic Acid	5.266	12.138	21.764	29.319	35.680	40.937	45.441	49.251	52.565	58.089	62.419
Benzene	43.980	40.775	36.264	32.715	29.742	27.394	25.303	23.573	22.011	19.427	17.405
Water	49.738	46.145	41.132	37.205	33.885	31.035	28.670	26.631	24.915	22.033	19.773
Sodium Chloride	1.016	0.943	0.840	0.760	0.692	0.634	0.586	0.544	0.509	0.450	0.404
Composition of Aqueous Phase*											
Acetic Acid	9.105	19.45	32.32	41.34	48.22	53.36	57.51	60.07	63.02	66.24	67.43
Benzene	0.26	0.51	0.81	1.13	1.43	1.93	2.56	3.44	4.37	7.25	9.98
Water	88.81	78.95	65.52	56.33	49.34	43.80	39.13	35.78	31.96	25.96	22.13
Sodium Chloride	1.829	1.604	1.345	1.203	1.012	0.913	0.800	0.713	0.654	0.545	0.455
Composition of Organic Phase*											
Acetic Acid	0.516	1.859	4.494	6.928	9.368	11.78	14.13	16.59	18.99	23.99	29.19
Benzene	99.40	97.19	95.35	92.87	90.36	87.88	85.45	82.87	80.35	75.04	69.32
Water	0.077	0.094	0.135	0.184	0.250	0.314	0.394	0.506	0.619	0.925	1.372
Sodium Chloride	0.010	0.014	0.015	0.018	0.022	0.029	0.031	0.035	0.043	0.052	0.068
Hand Coordinates											
X_{cb}/X_{bb}	0.00504	0.01851	0.0456	0.0722	0.1001	0.1295	0.1653	0.200	0.236	0.320	0.421
X_{ca}/X_{aa}	0.0983	0.236	0.473	0.723	0.937	1.143	1.409	1.650	1.880	2.38	2.90
Distribution Coefficient											
X_{ca}/X_{cb}	17.64	10.47	7.184	5.968	5.148	4.532	4.070	3.621	3.319	2.762	2.310

*All compositions are given in weight per cent.

TABLE 21

ACETIC ACID - BENZENE - WATER - 5.863 % SODIUM CHLORIDE

RUN NUMBER	27-2	27-5	27-10	27-15	27-20	27-25	27-30	27-35	27-40	27-50	27-60
Composition of Initial Mixture*											
Acetic Acid	5.126	12.011	21.476	29.006	35.253	40.609	44.937	48.938	52.204	57.701	62.081
Benzene	43.371	40.228	35.971	32.445	29.568	27.139	25.207	23.335	21.859	19.336	17.337
Water	48.483	44.961	40.059	36.289	33.117	30.360	28.105	26.101	24.416	21.616	19.375
Sodium Chloride	3.020	2.800	2.495	2.260	2.626	1.891	1.750	1.626	1.521	1.346	1.207
Composition of Aqueous Phase*											
Acetic Acid	8.711	18.92	31.46	40.34	47.36	52.51	56.67	60.07	62.59	66.07	67.84
Benzene	0.23	0.43	0.65	0.92	1.24	1.71	2.31	3.12	3.86	6.48	9.11
Water	85.66	75.88	63.88	55.28	48.35	43.06	38.59	34.62	31.55	25.77	21.62
Sodium Chloride	5.402	4.771	4.015	3.460	3.057	2.729	2.435	2.199	2.008	1.688	1.433
Composition of Organic Phase*											
Acetic Acid	0.594	2.232	5.167	7.835	10.43	13.15	15.47	18.10	20.70	25.99	31.50
Benzene	99.32	97.66	94.67	91.94	89.28	86.46	84.08	81.31	78.59	72.97	66.97
Water	0.074	0.100	0.148	0.206	0.272	0.355	0.420	0.545	0.665	0.994	1.47
Sodium Chloride	0.008	0.012	0.013	0.019	0.024	0.028	0.032	0.039	0.044	0.052	0.070
Hand Coordinates											
X_{cb}/X_{bb}	0.00599	0.0229	0.0546	0.0853	0.1169	0.1514	0.1841	0.223	0.263	0.356	0.466
X_{ca}/X_{aa}	0.1005	0.247	0.489	0.725	0.964	1.198	1.448	1.700	1.940	2.44	2.98
Distribution Coefficient											
X_{ca}/X_{cb}	14.65	8.477	6.089	5.149	4.541	3.710	3.663	3.319	3.022	2.542	2.154

*All compositions are given in weight per cent.

TABLE 22

ACETIC ACID - BENZENE - WATER - 9.403 % SODIUM CHLORIDE

RUN NUMBER	28-2	28-5	28-10	28-15	28-20	28-25	28-30	28-35	28-40	28-50	28-60
Composition of Initial Mixture*											
Acetic Acid	5.194	11.783	21.278	28.767	34.406	40.361	44.654	48.582	51.950	57.443	61.777
Benzene	42.837	39.795	35.604	32.159	28.953	26.919	24.913	23.228	21.751	19.207	17.254
Water	47.082	43.868	39.063	35.399	33.195	29.643	27.572	25.539	23.827	21.155	18.997
Sodium Chloride	4.887	4.553	4.054	3.674	3.445	3.077	2.862	2.651	2.473	2.196	1.971
Composition of Aqueous Phase*											
Acetic Acid	8.615	18.18	30.69	39.68	46.59	51.84	55.87	59.21	61.87	65.46	67.34
Benzene	0.18	0.35	0.51	0.71	1.08	1.43	2.08	2.82	3.35	5.73	8.47
Water	82.95	73.76	62.27	53.93	47.05	42.32	38.05	34.36	31.50	26.04	21.84
Sodium Chloride	8.257	7.714	6.533	5.677	5.272	4.410	3.997	3.606	3.282	2.774	2.353
Composition of Organic Phase*											
Acetic Acid	0.763	2.595	5.930	8.827	11.56	14.09	16.69	19.48	22.11	27.65	33.85
Benzene	99.16	97.27	93.91	90.94	88.13	85.51	82.82	79.91	77.09	71.25	64.59
Water	0.073	0.111	0.151	0.222	0.289	0.376	0.461	0.579	0.754	1.06	1.50
Sodium Chloride	0.008	0.012	0.012	0.016	0.021	0.025	0.030	0.036	0.040	0.047	0.058
Hand Coordinates											
X_{cb}/X_{bb}	0.00770	0.0267	0.0631	0.0969	0.1312	0.1668	0.201	0.244	0.287	0.388	0.524
X_{ca}/X_{aa}	0.1031	0.244	0.488	0.727	0.918	1.221	1.455	1.710	1.963	2.46	2.99
Distribution Coefficient											
X_{ca}/X_{cb}	11.29	7.007	5.175	4.496	4.030	3.679	3.348	3.040	2.798	2.368	1.989

*All compositions are given in weight per cent.

TABLE 23

ACETIC ACID - BENZENE - WATER - 13.65 % SODIUM CHLORIDE

RUN NUMBER	63-2	63-5	63-10	63-15	63-20	63-25	63-30	63-35	63-40	63-50	63-60
Composition of Initial Mixture*											
Acetic Acid	5.072	11.710	20.949	28.432	24.653	39.913	44.287	48.203	51.473	56.991	61.381
Benzene	42.136	39.191	35.098	31.802	29.009	26.668	24.726	23.010	21.549	19.097	17.150
Water	45.586	42.398	37.954	34.338	31.379	28.857	26.757	24.858	23.396	20.648	18.539
Sodium Chloride	7.206	6.702	6.000	5.428	4.960	4.562	4.230	3.930	3.682	3.264	2.931
Composition of Aqueous Phase*											
Acetic Acid	8.144	17.50	29.52	38.42	45.45	50.72	54.95	58.44	60.61	64.99	66.87
Benzene	0.16	0.26	0.39	0.55	0.89	1.17	1.76	2.34	2.89	5.22	7.83
Water	79.17	71.20	60.42	52.62	46.55	41.48	37.30	33.85	31.60	25.69	21.77
Sodium Chloride	12.53	11.04	9.672	8.411	7.108	6.631	5.986	5.370	4.908	4.201	3.532
Composition of Organic Phase*											
Acetic Acid	0.936	3.231	6.975	10.30	12.98	16.09	18.77	21.51	24.28	29.47	35.12
Benzene	98.98	96.65	92.84	89.43	86.67	83.47	80.64	77.80	74.89	69.37	63.25
Water	0.076	0.111	0.175	0.258	0.330	0.417	0.563	0.653	0.794	1.13	1.57
Sodium Chloride	0.007	0.008	0.011	0.015	0.019	0.021	0.027	0.033	0.037	0.041	0.057
Hand Coordinates											
X_{cb}/X_{bb}	0.00947	0.0334	0.0752	0.1152	0.1499	0.1910	0.232	0.276	0.344	0.425	0.555
X_{ca}/X_{aa}	0.1024	0.248	0.484	0.724	1.001	1.215	1.457	1.730	2.01	2.47	3.03
Distribution Coefficient											
X_{ca}/X_{cb}	8.697	5.418	4.232	3.731	3.502	3.133	2.928	2.716	2.497	2.206	1.904

*All compositions are given in weight per cent.

TABLE 24

ACETIC ACID - BENZENE - WATER - 17.41 % SODIUM CHLORIDE

RUN NUMBER	64-2	64-5	64-10	64-15	64-20	64-25	64-30	64-35	64-40	64-50	64-60
								s	s	s	s
Composition of Initial Mixture*											
Acetic Acid	5.039	12.115	20.685	28.176	34.301	39.601	44.118	47.831	51.143	56.691	61.102
Benzene	41.452	38.415	34.721	31.449	28.789	26.370	24.603	22.830	21.361	18.972	17.022
Water	44.193	40.858	36.828	33.346	30.490	28.104	26.066	24.231	22.709	20.100	18.067
Sodium Chloride	9.216	8.613	7.763	7.029	6.426	5.925	5.495	5.108	4.787	4.237	3.809
Composition of Aqueous Phase*											
Acetic Acid	7.864	17.51	28.44	37.49	44.30	49.77	54.30	57.87	60.93	65.43	67.11
Benzene	0.13	0.19	0.28	0.44	0.71	1.00	1.42	1.97	2.49	4.84	6.46
Water	75.91	67.89	58.72	51.10	45.28	40.58	36.43	33.01	29.97	24.09	22.02
Sodium Chloride	16.10	14.41	12.56	10.97	9.707	8.651	7.845	7.154	6.609	5.640	4.405
Composition of Organic Phase*											
Acetic Acid	1.164	4.109	8.147	11.61	14.77	17.57	20.41	22.91	25.59	30.54	35.80
Benzene	98.10	95.67	91.66	88.10	84.85	81.97	79.01	76.39	73.57	68.29	62.50
Water	0.074	0.112	0.180	0.274	0.363	0.444	0.553	0.669	0.806	1.13	1.65
Sodium Chloride	0.004	0.006	0.009	0.013	0.016	0.020	0.025	0.027	0.031	0.037	0.047
Hand Coordinates											
X_{cb}/X_{bb}	0.01187	0.0430	0.0890	0.1318	0.1741	0.214	0.258	0.300	0.348	0.447	0.573
X_{ca}/X_{aa}	0.1031	0.257	0.478	0.729	0.966	1.219	1.468	1.718	1.960	2.47	0.314
Distribution Coefficient											
X_{ca}/X_{cb}	6.756	4.261	3.491	3.229	2.999	2.833	2.660	2.526	2.381	2.143	1.819

*All compositions are given in weight per cent.

s indicates solid salt is present at equilibrium.

TABLE 25

ACETIC ACID - BENZENE - WATER - 21.33 % SODIUM CHLORIDE

RUN NUMBER	65-2	65-5	65-10	65-15 s	65-20 s	65-25 s	65-30 s	65-35 s	65-40 s	65-50 s	65-60 s
Composition of Initial Mixture*											
Acetic Acid	4.916	11.419	20.510	27.859	34.018	39.141	43.583	47.483	50.716	56.274	60.697
Benzene	40.926	38.074	34.204	31.008	28.362	26.187	24.254	22.590	21.205	18.813	16.866
Water	42.606	39.734	35.626	32.360	29.595	27.277	25.302	23.544	22.091	19.600	17.652
Sodium Chloride	11.552	10.773	9.660	8.774	8.024	7.396	6.860	6.383	5.990	5.314	4.786
Composition of Aqueous Phase*											
Acetic Acid	7.597	16.05	27.32	36.30	43.93	49.75	54.46	58.33	61.35	65.60	67.89
Benzene	0.10	0.14	0.20	0.32	0.53	0.81	1.14	1.54	2.04	4.15	5.20
Water	72.83	65.69	56.85	49.59	43.16	38.29	34.29	30.91	28.08	22.96	20.65
Sodium Chloride	19.47	18.12	15.63	13.79	12.38	11.15	10.11	9.221	8.526	7.294	6.262
Composition of Organic Phase*											
Acetic Acid	1.414	4.640	9.486	13.13	15.79	18.29	20.68	23.19	25.69	30.94	36.28
Benzene	97.83	95.23	90.30	86.57	83.81	81.21	78.74	76.07	73.46	67.83	61.98
Water	0.076	0.123	0.203	0.289	0.384	0.470	0.554	0.724	0.824	1.20	1.70
Sodium Chloride	0.003	0.005	0.008	0.013	0.015	0.019	0.023	0.026	0.030	0.035	0.043
Hand Coordinates											
X_{cb}/X_{bb}	0.01443	0.0487	0.1050	0.1516	0.1880	0.225	0.268	0.305	0.350	0.456	0.586
X_{ca}/X_{aa}	0.1043	0.240	0.475	0.722	0.980	1.243	1.524	1.728	2.00	2.50	2.97
Distribution Coefficient											
X_{ca}/X_{cb}	5.374	3.459	2.881	2.765	2.782	2.719	2.633	2.515	2.388	2.120	1.872

*All compositions are given in weight per cent.

s indicates solid salt is present at equilibrium.

TABLE 26

ACETIC ACID - BENZENE - WATER - 2.001 % POTASSIUM CHLORIDE

RUN NUMBER	29-2	29-5	29-10	29-15	29-20	29-25	29-30	29-35	29-40	29-50	29-60
Composition of Initial Mixture*											
Acetic Acid	5.311	12.330	21.786	29.417	35.731	41.027	45.982	49.212	53.272	58.086	62.500
Benzene	44.032	40.730	36.527	32.794	29.849	27.455	25.323	23.615	22.295	19.472	17.448
Water	49.643	46.001	41.208	37.032	33.731	30.889	28.611	26.629	25.190	21.991	19.651
Potassium Chloride	1.014	0.939	0.841	0.756	0.689	0.631	0.584	0.543	0.514	0.449	0.401
Composition of Aqueous Phase*											
Acetic Acid	9.122	19.84	32.38	41.63	48.27	53.58	57.28	60.58	62.88	66.08	67.37
Benzene	0.25	0.49	0.78	1.08	1.41	1.87	2.47	3.38	4.24	6.94	9.85
Water	88.82	78.07	65.50	56.12	49.31	43.65	39.44	35.32	27.23	26.43	22.33
Potassium Chloride	1.805	1.603	1.343	1.165	1.005	0.891	0.798	0.723	0.651	0.545	0.454
Composition of Organic Phase*											
Acetic Acid	0.480	1.834	4.318	6.963	9.077	11.42	14.44	16.12	18.77	23.36	29.00
Benzene	99.44	98.07	95.54	92.85	90.67	88.36	85.16	83.39	80.62	75.73	69.62
Water	0.076	0.088	0.138	0.178	0.234	0.299	0.374	0.469	0.584	0.867	1.33
Potassium Chloride	0.010	0.012	0.015	0.015	0.017	0.018	00.020	0.022	0.025	0.032	0.039
Hand Coordinates											
X_{cb}/X_{bb}	0.00483	0.01870	0.0457	0.0751	0.1001	0.1291	0.1699	0.1981	0.233	0.310	0.417
X_{ca}/X_{aa}	0.1041	0.252	0.490	0.718	0.975	1.187	1.451	1.701	1.961	2.46	3.02
Distribution Coefficient											
X_{ca}/X_{cb}	19.02	10.82	7.500	5.979	5.318	4.691	3.966	3.758	3.350	2.829	2.322

*All compositions are given in weight per cent.

TABLE 27

ACETIC ACID - BENZENE - WATER - 5.717 % POTASSIUM CHLORIDE

RUN NUMBER	30-2	30-5	30-10	30-15	30-20	30-25	30-30	30-35	30-40	30-50	30-60
Composition of Initial Mixture*											
Acetic Acid	5.222	12.135	21.582	29.170	35.386	40.712	45.158	49.007	52.288	57.882	62.196
Benzene	43.492	40.296	36.039	32.510	29.620	27.193	25.180	23.367	21.917	19.293	17.361
Water	48.354	44.849	39.957	36.129	32.993	30.261	27.967	26.046	24.320	21.521	19.275
Potassium Chloride	2.932	2.720	2.423	2.191	2.001	1.835	1.696	1.579	1.475	1.305	1.169
Composition of Aqueous Phase*											
Acetic Acid	8.940	19.30	31.93	40.99	47.78	52.97	56.94	60.34	62.68	66.04	67.49
Benzene	0.22	0.41	0.63	0.87	1.15	1.67	2.28	3.10	3.64	6.41	9.06
Water	85.59	75.66	63.55	54.78	48.09	42.71	38.45	34.45	31.77	25.92	22.10
Potassium Chloride	5.247	4.631	3.893	3.358	2.978	2.549	2.333	2.112	1.934	1.629	1.353
Composition of Organic Phase*											
Acetic Acid	0.527	1.976	4.625	7.136	9.598	12.05	14.39	16.87	19.48	25.76	29.76
Benzene	99.40	97.92	95.23	92.66	90.14	87.62	85.17	82.61	79.90	74.27	68.85
Water	0.069	0.094	0.136	0.187	0.244	0.320	0.414	0.496	0.594	0.936	1.34
Potassium Chloride	0.009	0.010	0.013	0.015	0.015	0.016	0.020	0.022	0.025	0.032	0.041
Hand Coordinates											
X_{cb}/X_{bb}	0.00531	0.0205	0.0476	0.0761	0.1066	0.1434	0.1720	0.204	0.238	0.347	0.432
X_{ca}/X_{aa}	0.1031	0.253	0.497	0.733	0.973	1.260	1.478	1.734	1.979	2.47	3.04
Distribution Coefficient											
X_{ca}/X_{cb}	16.95	9.769	6.903	5.744	4.978	4.397	3.955	3.577	3.218	2.564	2.268

*All compositions are given in weight per cent.

TABLE 28

ACETIC ACID - BENZENE - WATER - 9.287 % POTASSIUM CHLORIDE

RUN NUMBER	31-2	31-5	31-10	31-15	31-20	31-25	31-30	31-35	31-40	31-50	31-60
Composition of Initial Mixture*											
Acetic Acid	5.138	11.975	21.315	28.882	35.030	40.376	44.780	48.661	52.006	57.482	61.901
Benzene	43.108	39.923	35.638	32.305	29.448	27.044	25.050	23.250	21.770	19.216	17.247
Water	46.948	43.634	39.051	35.298	32.224	29.555	27.369	25.481	23.789	21.137	18.916
Potassium Chloride	4.806	4.467	3.998	3.614	3.298	3.026	2.802	2.609	2.435	2.164	1.937
Composition of Aqueous Phase*											
Acetic Acid	8.661	18.78	31.16	40.17	46.91	52.30	56.28	59.48	62.26	65.36	66.74
Benzene	0.19	0.34	0.50	0.68	0.90	1.43	2.03	2.78	3.30	6.09	8.38
Water	82.64	73.32	61.95	53.63	47.34	41.96	37.81	34.24	31.23	25.87	22.48
Potassium Chloride	8.512	7.556	6.390	5.516	4.852	4.313	3.884	3.508	3.210	2.682	2.397
Composition of Organic Phase*											
Acetic Acid	0.568	2.140	4.866	7.436	9.936	12.43	14.98	17.54	20.18	25.07	30.61
Benzene	99.36	97.75	94.98	92.38	89.80	87.23	84.60	81.94	79.18	73.09	68.04
Water	0.072	0.093	0.141	0.186	0.252	0.319	0.402	0.499	0.609	0.901	1.31
Potassium Chloride	0.006	0.008	0.007	0.009	0.012	0.017	0.016	0.021	0.028	0.035	0.045
Hand Coordinates											
X_{cb}/X_{bb}	0.00571	0.0219	0.0502	0.0805	0.1106	0.1425	0.1790	0.215	0.255	0.331	0.452
X_{ca}/X_{aa}	0.1042	0.255	0.500	0.747	0.991	1.243	1.490	1.741	1.992	2.51	3.32
Distribution Coefficient											
X_{ca}/X_{cb}	15.26	8.773	6.403	5.403	4.721	4.208	3.758	3.391	3.085	2.607	2.180

*All compositions are given in weight per cent.

TABLE 29

ACETIC ACID - BENZENE - WATER - 13.74 % POTASSIUM CHLORIDE

RUN NUMBER	66-2	66-5	66-10	66-15	66-20	66-25	66-30	66-35	66-40	66-50	66-60
Composition of Initial Mixture*											
Acetic Acid	4.949	11.768	21.077	28.565	34.777	39.943	44.398	48.228	51.579	57.085	61.514
Benzene	42.505	39.155	35.189	31.857	29.029	26.713	24.777	23.082	21.594	19.124	17.147
Water	45.337	42.334	37.725	34.140	31.221	28.763	26.590	24.749	23.141	20.523	18.408
Potassium Chloride	7.220	6.743	6.009	5.438	4.973	4.582	4.235	3.942	3.686	3.269	2.932
Composition of Aqueous Phase*											
Acetic Acid	8.218	18.20	30.40	39.41	46.23	51.44	55.50	58.89	61.50	65.16	66.50
Benzene	0.15	0.26	0.39	0.55	0.78	1.26	1.82	2.46	3.03	5.54	7.73
Water	78.97	70.20	59.65	51.72	45.66	40.76	36.80	33.31	30.60	25.19	22.36
Potassium Chloride	12.67	11.34	9.562	8.315	7.326	6.537	5.886	5.338	4.870	4.114	3.409
Composition of Organic Phase*											
Acetic Acid	0.620	2.330	5.366	8.105	10.64	13.11	15.66	18.27	20.88	26.14	31.38
Benzene	99.30	97.57	94.47	91.66	89.08	86.53	83.37	81.16	78.46	72.89	67.22
Water	0.079	0.095	0.156	0.226	0.263	0.342	0.460	0.541	0.640	0.945	1.35
Potassium Chloride	0.006	0.008	0.009	0.011	0.014	0.017	0.018	0.020	0.024	0.031	0.052
Hand Coordinates											
X_{cb}/X_{cc}	0.00625	0.0239	0.0548	0.0885	0.1195	0.1578	0.1865	0.225	0.271	0.358	0.466
X_{ca}/X_{aa}	0.1033	0.256	0.507	0.756	1.005	1.256	1.867	1.762	2.02	2.54	3.14
Distribution Coefficient											
X_{ca}/X_{cb}	13.24	7.814	5.666	4.862	4.343	3.923	3.718	3.222	2.946	2.493	2.119

*All compositions are given in weight per cent.

TABLE 30

ACETIC ACID - BENZENE - WATER - 17.14 % POTASSIUM CHLORIDE

RUN NUMBER	67-2	67-5	67-10	67-15	67-20	67-25	67-30	67-35	67-40	67-50	67-60
Composition of Initial Mixture*											
Acetic Acid	4.993	11.602	20.805	28.330	34.485	39.651	44.083	48.069	51.253	56.793	61.237
Benzene	41.807	38.862	34.806	31.549	28.834	26.525	24.627	22.815	21.402	18.978	17.062
Water	44.082	41.046	36.781	33.245	30.393	28.027	25.927	24.136	22.657	20.075	17.982
Potassium Chloride	9.119	8.491	7.608	6.877	6.287	5.798	5.363	4.991	4.686	4.513	3.720
Composition of Aqueous Phase*											
Acetic Acid	8.123	17.62	29.70	38.78	47.12	50.89	55.07	58.55	61.10	65.18	67.34
Benzene	0.13	0.19	0.29	0.44	0.63	1.12	1.64	2.24	2.84	5.07	6.95
Water	75.98	66.18	57.88	50.28	42.98	39.70	35.82	32.43	29.84	24.44	21.23
Potassium Chloride	15.77	14.11	12.13	10.50	9.274	9.294	7.468	6.775	6.217	5.313	4.483
Composition of Organic Phase*											
Acetic Acid	0.701	2.521	5.685	8.537	11.06	13.58	16.17	18.86	21.22	26.64	31.88
Benzene	99.23	97.35	94.16	91.24	88.65	86.06	83.38	80.58	78.12	72.40	66.74
Water	0.068	0.123	0.146	0.208	0.273	0.335	0.423	0.530	0.636	0.928	1.33
Potassium Chloride											
Hand Coordinates											
X_{cb}/X_{bb}	0.00705	0.0259	0.0564	0.0935	0.1248	0.1634	0.1990	0.239	0.277	0.358	0.466
X_{ca}/X_{aa}	0.1066	0.258	0.507	0.765	1.098	1.272	1.530	1.798	2.05	2.56	3.14
Distribution Coefficient											
X_{ca}/X_{cb}	11.59	6.991	5.225	4.543	4.259	3.746	3.405	3.104	2.880	2.447	2.113

*All compositions are given in weight per cent.

TABLE 31

ACETIC ACID - BENZENE - WATER - 21.00 % POTASSIUM CHLORIDE

RUN NUMBER	68-2	68-5	68-10	68-15	68-20	68-25	68-30	68-35 s	68-40 s	68-50 s	68-60 s
Composition of Initial Mixture*											
Acetic Acid	4.947	11.451	20.599	28.001	33.628	39.342	43.718	47.623	50.926	56.526	60.944
Benzene	41.311	38.375	34.529	31.286	28.121	26.328	24.425	22.721	21.307	18.876	16.961
Water	42.457	39.638	35.449	32.164	28.936	27.121	25.167	23.429	21.936	19.433	17.455
Potassium Chloride	11.286	10.537	9.423	8.550	7.692	7.209	6.690	6.228	5.831	5.166	4.640
Composition of Aqueous Phase*											
Acetic Acid	7.886	17.13	29.05	38.60	44.78	50.36	54.72	58.26	61.14	65.19	67.30
Benzene	0.10	0.14	0.20	0.34	0.51	0.97	1.40	1.93	2.54	4.43	6.23
Water	72.75	65.30	55.82	47.72	43.11	38.32	34.48	31.16	28.45	23.70	20.81
Potassium Chloride	19.27	17.43	14.93	13.34	11.60	10.35	9.401	8.650	7.867	6.680	5.660
Composition of Organic Phase*											
Acetic Acid	0.793	2.778	6.149	8.943	11.69	14.14	16.64	19.27	21.79	27.07	32.41
Benzene	99.13	97.12	93.69	90.84	88.02	85.50	82.93	80.19	77.54	71.97	66.18
Water	0.071	0.097	0.151	0.205	0.272	0.346	0.415	0.513	0.650	0.937	1.35
Potassium Chloride	0.004	0.007	0.009	0.010	0.012	0.015	0.017	0.020	0.024	0.029	0.062
Hand Coordinates											
X_{cb}/X_{bb}	0.00801	0.0286	0.0655	0.0984	0.1327	0.1655	0.201	0.240	0.281	0.376	0.490
X_{ca}/X_{aa}	0.1087	0.261	0.516	0.770	1.098	1.298	1.553	1.817	2.08	2.52	3.21
Distribution Coefficient											
X_{ca}/X_{cb}	9.950	6.166	4.725	4.316	3.832	3.562	3.288	3.023	2.807	2.408	2.077

*All compositions are given in weight per cent.

s indicates solid salt is present at equilibrium.

TABLE 32

PROPIONIC ACID - BENZENE - WATER

RUN NUMBER	13-2	13-4	13-5	13-7	13-10	13-15	13-17	13-20	13-25	13-30	13-35	13-40	13-45
Composition of Initial Mixture*													
Propionic Acid	5.024	9.575	11.671	15.618	20.889	28.390	30.984	34.567	39.800	44.241	48.061	51.384	54.329
Benzene	44.313	42.249	41.257	39.414	36.968	33.466	32.259	30.570	28.119	26.038	24.256	22.705	21.337
Water	50.663	48.176	47.072	44.969	42.143	38.144	36.757	34.862	32.083	29.721	27.683	25.912	24.333
Composition of Aqueous Phase*													
Propionic Acid	6.179	10.27	12.05	15.21	19.40	26.26	28.79	32.68	39.01	44.01	49.34	53.10	55.89
Benzene	0.08	0.18	0.28	0.41	0.53	0.89	0.97	1.24	2.44	3.58	5.78	11.28	14.74
Water	93.74	89.55	87.67	84.38	80.06	71.95	70.24	66.08	58.55	52.09	45.88	35.62	29.37
Composition of Organic Phase*													
Propionic Acid	3.734	8.899	11.46	16.33	23.02	31.41	33.81	37.42	41.74	45.28	48.00	50.88	54.07
Benzene	96.13	90.90	88.28	83.37	76.34	67.35	65.62	61.63	56.43	51.94	46.80	42.16	35.79
Water	0.133	0.202	0.265	0.398	0.640	1.24	1.57	1.96	2.83	3.87	5.16	7.06	10.13
Hand Coordinates													
X_{cb}/X_{bb}	0.0388	0.0980	0.1298	0.1957	0.301	0.467	0.509	0.610	0.738	0.871	1.028	1.203	1.510
X_{ca}/X_{aa}	0.0657	0.1142	0.1373	0.1802	0.243	0.365	0.410	0.495	0.666	0.851	1.074	1.485	1.900
Distribution Coefficient													
X_{ca}/X_{cb}	1.654	1.154	1.051	0.9308	0.8427	0.8359	0.8516	0.8782	0.9346	0.9788	1.027	1.044	1.034

*All compositions are given in weight per cent.

TABLE 33

PROPIONIC ACID - BENZENE - WATER - 1.970 % LITHIUM CHLORIDE

RUN NUMBER	15-2	15-5	15-10	15-15	15-20	15-25	15-30	15-35	15-40	15-45
Composition of Initial Mixture*										
Propionic Acid	4.972	11.593	20.790	28.272	34.408	39.654	44.050	47.896	51.229	54.160
Benzene	44.099	41.079	36.780	33.306	30.473	27.997	25.970	24.187	22.632	21.276
Water	49.926	46.396	41.594	37.665	34.427	31.712	29.379	27.367	25.623	24.081
Lithium Chloride	1.003	0.932	0.836	0.757	0.692	0.637	0.590	o.549	0.515	0.484
Composition of Aqueous Phase*										
Propionic Acid	5.673	10.84	17.31	23.01	28.36	33.37	39.61	42.39	46.03	48.25
Benzene	0.08	0.24	0.43	0.67	0.97	1.38	2.13	3.02	4.13	5.12
Water	92.38	87.24	80.70	74.84	69.27	63.96	57.09	53.55	48.91	45.77
Lithium Chloride	1.873	1.637	1.568	1.483	1.400	1.293	1.178	1.044	0.934	0.867
Composition of Organic Phase*										
Propionic Acid	4.208	12.72	24,89	34.27	41.32	46.06	50.10	53.45	56.35	58.72
Benzene	95.64	86.97	74.36	64.34	56.54	50.54	45.19	40.27	35.17	29.64
Water	0.142	0.285	0.723	1.36	2.11	3.36	4.66	6.20	8.38	11.49
Lithium Chloride	0.007	0.008	0.019	0.027	0.034	0.039	0.048	0.075	0.095	0.148
Hand Coordinates										
X_{cb}/X_{bb}	0.0440	0.1460	0.335	0.533	0.766	0.911	1.110	1.329	1.599	1.980
X_{ca}/X_{aa}	0.0613	0.1241	0.215	0.308	0.411	0.523	0.695	0.794	0.943	1.055
Distribution Coefficient										
X_{ca}/X_{cb}	1.348	0.8560	0.6954	0.6714	0.6864	0.7250	0.7906	0.7931	0.8169	0.8216

*All compositions are given in weight per cent.

TABLE 34

PROPIONIC ACID - BENZENE - WATER - 5.743 % LITHIUM CHLORIDE

RUN NUMBER	16-2	16-5	16-10	16-15	16-20	16-25	16-30	16-35	16-40	16-45
Composition of Initial Mixture*										
Propionic Acid	4.947	11.498	20.612	28.781	34.165	39.370	43.825	47.636	50.965	53.886
Benzene	43.612	40.599	36.408	32.692	30.219	27.825	25.785	24.020	22.494	21.160
Water	48.487	45.162	40.512	36.314	33.571	30.922	28.645	26.717	25.016	23.521
Lithium Chloride	2.954	2.752	2.468	2.213	2.045	1.884	1.745	1.628	1.524	1.433
Composition of Aqueous Phase*										
Propionic Acid	4.780	8.777	13.59	17.58	20.07	22.46	24.07	24.86	24.78	24.65
Benzene	0.09	0.20	0.31	0.38	0.45	0.56	0.68	0.80	0.88	0.98
Water	90.36	86.27	81.36	77.34	74.85	72.28	70.45	69.31	69.08	68.54
Lithium Chloride	4.778	4.765	4.741	4.709	4.634	4.703	4.804	5.036	5.267	5.836
Composition of Organic Phase*										
Propionic Acid	5.241	14.66	27.69	38.60	45.13	50.86	54.81	58.11	61.03	62.77
Benzene	94.62	85.04	72.53	59.80	52.23	45.46	40.03	35.37	31.05	28.06
Water	0.131	0.301	0.767	1.57	2.61	3.65	5.11	6.47	7.83	9.05
Lithium Chloride	0.006	0.009	0.017	0.024	0.031	0.037	0.045	0.061	0.085	0.122
Hand Coordinates										
X_{cb}/X_{bb}	0.0553	0.1725	0.382	0.645	0.864	1.140	1.360	1.641	1.968	2.24
X_{ca}/X_{aa}	0.0557	0.1032	0.1697	0.232	0.273	0.316	0.347	0.352	0.356	0.351
Distribution Coefficient										
X_{ca}/X_{cb}	0.9120	0.5989	0.4909	0.4555	0.4447	0.4417	0.4391	0.4279	0.4060	0.3831

*All compositions are given in weight per cent.

TABLE 35

PROPIONIC ACID - BENZENE - WATER - 9.118 % LITHIUM CHLORIDE

RUN NUMBER	17-2	17-5	17-10	17-15	17-20	17-25	17-30	17-35	17-40	17-45
Composition of Initial Mixture*										
Propionic Acid	4.888	11.416	20.446	27.943	33.912	39.144	43.771	47.339	50.756	53.668
Benzene	43.262	40.274	36.116	32.846	30.018	27.667	25.794	23.896	22.385	21.046
Water	47.122	43.905	39.478	35.636	32.781	30.164	27.661	26.143	24.411	22.981
Lithium Chloride	4.728	4.405	3.961	3.575	3.289	3.026	2.775	2.623	2.449	2.306
Composition of Aqueous Phase*										
Propionic Acid	3.968	7.097	10.50	12.91	14.67	15.91	16.44	16.81	16.71	16.49
Benzene	0.10	0.17	0.24	0.31	0.37	0.44	0.51	0.58	0.63	0.65
Water	87.25	84.35	81.31	79.02	77.08	75.62	74.89	74.02	73.81	72.56
Lithium Chloride	8.694	8.392	7.957	7.763	7.885	8.031	8.165	8.598	8.857	10.30
Composition of Organic Phase*										
Propionic Acid	5.983	16.18	30.27	40.69	46.46	55.10	57.64	61.00	63.57	65.66
Benzene	93.87	83.49	68.84	57.74	50.08	41.25	37.83	33.50	30.04	27.11
Water	0.138	0.323	0.879	1.55	2.43	3.62	4.48	5.45	6.31	7.13
Lithium Chloride	0.005	0.008	0.015	0.023	0.029	0.032	0.041	0.048	0.074	0.087
Hand Coordinates										
X_{cb}/X_{bb}	0.0637	0.1935	0.440	0.705	0.930	1.333	1.523	1.820	2.12	2.42
X_{ca}/X_{aa}	0.0456	0.0860	0.1338	0.1703	0.1963	0.210	0.224	0.232	0.232	0.227
Distribution Coefficient										
X_{ca}/X_{cb}	0.6632	0.4386	0.3468	0.3173	0.3158	0.2887	0.2858	0.2755	0.2629	0.2511

*All compositions are given in weight per cent.

TABLE 36

PROPIONIC ACID - BENZENE - WATER - 13.68 % LITHIUM CHLORIDE

RUN NUMBER	51-2	51-5	51-10	51-15	51-20	51-25	51-30	51-35	51-40	51-45
Composition of Initial Mixture*										
Propionic Acid	4.793	11.276	20.259	27.590	33.678	38.842	43.263	47.075	50.388	53.325
Benzene	42.773	39.812	35.764	32.544	29.763	27.416	25.423	23.721	22.221	20.913
Water	45.261	42.221	37.961	34.412	32.295	29.126	27.030	25.208	23.644	22.237
Lithium Chloride	7.173	6.691	6.016	5.454	5.118	4.616	4.284	3.995	3.747	3.524
Composition of Aqueous Phase*										
Propionic Acid	3.000	5.135	7.346	8.775	9.792	10.41	10.81	11.05	11.22	11.32
Benzene	0.07	0.14	0.19	0.24	0.28	0.33	0.39	0.43	0.48	0.49
Water	83.79	81.81	80.03	79.64	77.48	76.77	76.25	75.67	75.15	74.78
Lithium Chloride	13.14	12.92	12.44	12.35	12.45	12.49	12.55	12.85	13.15	13.41
Composition of Organic Phase*										
Propionic Acid	6.946	17.86	32.31	42.39	49.82	55.40	59.92	63.14	65.74	68.01
Benzene	92.92	81.82	66.85	56.26	48.12	41.92	36.76	32.84	29.92	27.23
Water	0.128	0.316	0.829	1.32	2.03	2.65	3.28	3.98	4.28	4.69
Lithium Chloride	0.005	0.008	0.014	0.021	0.026	0.032	0.038	0.043	0.062	0.068
Hand Coordinates										
X_{cb}/X_{bb}	0.0747	0.218	0.483	0.753	1.035	1.320	1.630	1.923	2.20	2.50
X_{ca}/X_{aa}	0.0367	0.0631	0.0953	0.1150	0.1300	0.1392	0.1471	0.1518	0.1543	0.1564
Distribution Coefficient										
X_{ca}/X_{cb}	0.4319	0.2875	0.2273	0.2070	0.1965	0.1878	0.1804	0.1750	0.1706	0.1664

*All compositions are given in weight per cent.

TABLE 37

PROPIONIC ACID - BENZENE - WATER - 17.61 % LITHIUM CHLORIDE

RUN NUMBER	52-2	52-5	52-10	52-15	52-20	52-25	52-30	52-35	52-40	52-45
Composition of Initial Mixture*										
Propionic Acid	4.795	11.153	20.125	27.383	33.396	38.567	42.974	46.774	50.066	53.065
Benzene	42.158	39.385	35.338	32.256	29.511	27.254	25.315	23.564	22.124	20.805
Water	43.706	41.070	36.694	33.253	30.561	28.160	26.127	24.438	22.913	21.528
Lithium Chloride	9.342	8.392	7.843	7.108	6.532	6.019	5.584	5.223	4.897	4.601
Composition of Aqueous Phase*										
Propionic Acid	2.377	4.014	5.516	6.527	7.262	7.744	8.073	8.342	8.529	8.593
Benzene	0.08	0.10	0.15	0.19	0.21	0.25	0.29	0.32	0.35	0.38
Water	80.87	79.48	78.13	77.13	76.48	75.84	75.37	74.93	74.43	74.19
Lithium Chloride	16.68	16.41	16.21	16.16	16.05	16.17	16.27	16.41	16.70	16.84
Composition of Organic Phase*										
Propionic Acid	7.712	18.91	33.80	43.72	51.27	56.76	61.10	64.58	67.10	69.57
Benzene	92.17	80.86	65.50	55.17	47.16	41.23	36.50	32.64	29.85	27.10
Water	0.117	0.224	0.685	1.09	1.54	1.99	2.38	2.75	3.00	3.28
Lithium Chloride	0.004	0.007	0.013	0.019	0.024	0.028	0.034	0.042	0.055	0.061
Hand Coordinates										
X_{cb}/X_{bb}	0.0837	0.234	0.516	0.791	1.085	1.375	1.671	1.973	2.25	2.56
X_{ca}/X_{aa}	0.0297	0.0511	0.0734	0.0878	0.0984	0.1068	0.1124	0.1170	0.1193	0.1218
Distribution Coefficient										
X_{ca}/X_{aa}	0.3082	0.2123	0.1632	0.1493	0.1416	0.1364	0.1321	0.1292	0.1271	0.1235

*All compositions are given in weight per cent.

TABLE 38

PROPIONIC ACID - BENZENE - WATER - 21.23 % LITHIUM CHLORIDE

RUN NUMBER	53-2	53-5	53-10	53-15	53-20	53-25	53-30	53-35	53-40	53-45
Composition of Initial Mixture*										
Propionic Acid	4.710	11.056	19.918	27.010	33.226	38.336	42.647	46.520	49.817	52.821
Benzene	41.764	39.005	35.103	32.079	29.277	27.070	25.098	23.428	21.998	20.636
Water	42.162	39.347	35.430	32.225	29.535	27.249	25.407	23.672	22.201	20.908
Lithium Chloride	11.364	10.605	9.549	8.685	7.960	7.344	6.848	6.380	5.984	5.635
Composition of Aqueous Phase*										
Propionic Acid	1.929	3.150	4.351	5.138	5.718	6.132	6.463	6.720	6.881	7.055
Benzene	0.06	0.07	0.10	0.12	0.15	0.18	0.18	0.22	0.25	0.28
Water	77.41	76.31	75.13	75.04	74.36	73.86	73.47	73.09	72.69	72.06
Lithium Chloride	20.61	20.47	20.42	19.71	19.78	19.83	19.89	19.97	20.18	20.61
Composition of Organic Phase*										
Propionic Acid	8.093	19.55	34.88	44.18	51.55	54.72	61.58	65.19	67.80	69.89
Benzene	91.78	80.19	64.55	54.94	47.28	43.82	36.66	32.83	29.99	27.93
Water	0.124	0.251	0.552	0.856	1.15	1.44	1.73	1.94	2.16	2.32
Lithium Chloride	0.003	0.006	0.012	0.018	0.022	0.025	0.031	0.043	0.052	0.057
Hand Coordinates										
X_{cb}/X_{bb}	0.0881	0.244	0.544	0.805	1.090	1.237	1.682	1.987	2.26	2.50
X_{ca}/X_{aa}	0.0252	0.0420	0.0600	0.0711	0.0791	0.0857	0.0913	0.0963	0.0981	0.1003
Distribution Coefficient										
X_{ca}/X_{cb}	0.2384	0.1611	0.1247	0.1163	0.1109	0.1121	0.1050	0.1031	0.1015	0.1004

*All compositions are given in weight per cent.

TABLE 39

PROPIONIC ACID - BENZENE - WATER - 2.002 % SODIUM CHLORIDE

RUN NUMBER	18-2	18-5	18-10	18-15	18-20	18-25	18-30	18-35	18-40	18-45
Composition of Initial Mixture*										
Propionic Acid	4.991	11.606	20.752	28.261	34.482	39.638	44.069	47.878	51.199	54.108
Benzene	44.078	40.964	36.771	33.276	30.457	28.021	25.915	24.198	22.628	21.299
Water	49.917	46.481	41.626	37.694	34.260	31.695	29.416	27.365	25.649	24.101
Sodium Chloride	1.020	0.950	0.850	0.770	0.702	0.648	0.601	0.559	0.523	0.492
Composition of Aqueous Phase*										
Propionic Acid	6.055	11.19	17.91	23.96	29.85	35.58	41.09	46.38	49.48	54.27
Benzene	0.09	0.24	0.46	0.79	0.99	2.14	3.05	4.04	8.64	9.52
Water	92.25	86.99	80.07	73.80	67.85	61.13	54.87	48.80	41.07	35.39
Sodium Chloride	1.614	1.582	1.565	1.453	1.313	1.148	0.991	0.782	0.816	0.824
Composition of Organic Phase*										
Propionic Acid	4.169	12.22	24.08	33.02	39.62	44.64	48.36	51.34	53.98	56.10
Benzene	95.72	87.51	75.15	65.64	58.27	52.30	47.39	43.05	38.76	34.10
Water	0.108	0.263	0.763	1.32	2.09	3.03	4.21	5.57	7.21	9.73
Sodium Chloride	0.008	0.009	0.014	0.017	0.024	0.030	0.038	0.045	0.050	0.071
Hand Coordinates										
X_{cb}/X_{bb}	0.0434	0.1398	0.320	0.503	0.680	0.853	1.020	1.191	1.390	1.641
X_{ca}/X_{aa}	0.0656	0.1309	0.228	0.333	0.450	0.604	0.776	1.012	1.175	1.538
Distribution Coefficient										
X_{ca}/X_{cb}	1.452	0.9153	0.7439	0.7257	0.7535	0.7971	0.8497	0.9034	0.9166	0.9673

*All compositions are given in weight per cent.

TABLE 40

PROPIONIC ACID - BENZENE - WATER - 5.863 % SODIUM CHLORIDE

RUN NUMBER	19-2	19-5	19-10	19-15	19-20	19-25	19-30	19-35	19-40	19-45
Composition of Initial Mixture*										
Propionic Acid	4.944	11.503	20.518	27.952	34.167	39.306	43.774	47.499	50.818	53.666
Benzene	43.441	40.474	36.345	32.985	30.118	27.741	25.749	24.012	22.501	21.170
Water	48.590	45.207	40.610	36.772	33.622	31.021	28.690	26.819	25.117	23.689
Sodium Chloride	3.026	2.816	2.529	2.290	2.094	1.932	1.787	1.670	1.564	1.475
Composition of Aqueous Phase*										
Propionic Acid	5.254	9.647	15.16	19.87	24.39	28.73	32.88	36.92	39.97	41.75
Benzene	0.10	0.21	0.38	00.73	00.94	1.33	1.72	2.08	2.46	2.80
Water	89.17	85.01	79.65	75.00	70.36	65.81	61.45	57.30	54.00	51.67
Sodium Chloride	5.487	5.145	4.815	4.407	4.317	4.138	3.957	3.708	3.573	3.769
Composition of Organic Phase*										
Propionic Acid	5.020	13.74	26.41	36.60	43.24	48.36	52.48	55.76	58.48	60.10
Benzene	94.86	85.95	72.80	61.96	54.23	42.08	40.44	37.52	32.97	28.83
Water	0.125	0.305	0.767	1.43	2.49	3.52	5.03	6.65	8.40	10.82
Sodium Chloride	0.010	0.012	0.016	0.026	0.035	0.043	0.053	0.080	0.145	0.247
Hand Coordinates										
X_{cb}/X_{bb}	0.0527	0.1599	0.360	0.591	0.797	1.150	1.298	1.487	1.778	2.08
X_{ca}/X_{aa}	0.0589	0.1169	0.1974	0.284	0.351	0.455	0.564	0.700	0.797	0.811
Distribution Coefficient										
X_{ca}/X_{cb}	1.047	0.7023	0.5738	0.5430	0.5640	0.5942	0.6265	0.6621	0.6834	0.6947

*All compositions are given in weight per cent.

TABLE 41

PROPIONIC ACID - BENZENE - WATER - 9.403 % SODIUM CHLORIDE

RUN NUMBER	20-2	20-5	20-10	20-15	20-20	20-25	20-30	20-35	20-40	20-45
Composition of Initial Mixture*										
Propionic Acid	4.879	11.296	20.327	27.690	33.644	38.939	43.371	47.220	50.561	53.564
Benzene	42.918	39.898	35.973	32.645	29.947	27.532	25.542	23.818	22.283	21.026
Water	47.295	44.216	39.591	35.936	32.985	30.376	28.164	26.239	24.597	23.021
Sodium Chloride	4.908	4.589	4.109	3.730	3,424	3.153	2.923	2.723	2.553	2.389
Composition of Aqueous Phase*										
Propionic Acid	4.503	8.178	12.73	16.29	19.27	22.20	24.27	25.75	25.61	24.29
Benzene	0.09	0.18	0.27	0.38	0.46	0.58	0.67	0.79	0.81	0.80
Water	86.88	83.48	79.16	75.60	72.66	69.69	67.49	65.85	65.85	67.25
Sodium Chloride	8.531	8.178	7.849	7.735	7.615	7.530	7.574	7.616	7.636	7.669
Composition of Organic Phase*										
Propionic Acid	5.576	14.96	28.62	38.50	45.25	51.34	55.47	58.79	60.71	64.59
Benzene	94.27	84.70	70.59	59.95	52.31	45.09	39.51	34.30	30.44	25.15
Water	0.143	0.320	0.771	1.53	2.40	3.51	4.94	6.78	8.60	9.90
Sodium Chloride	0.009	0.016	0.023	0.031	0.038	0.059	0.077	0.132	0.243	0.400
Hand Coordinates										
X_{cb}/X_{bb}	0.0591	0.1765	0.405	0.642	0.864	1.135	1.402	1.711	1.992	2.57
X_{ca}/X_{aa}	0.0519	0.0981	0.1691	0.225	0.272	0.333	0.375	0.414	0.389	0.351
Distribution Coefficient										
X_{ca}/X_{cb}	0.8076	0.5465	0.4449	0.4232	0.4259	0.4323	0.4376	0.4380	0.4218	0.3761

*All compositions are given in weight per cent.

TABLE 42

PROPIONIC ACID - BENZENE - WATER - 13.65 % SODIUM CHLORIDE

RUN NUMBER	54-2	54-5	54-10	54-15	54-20	54-25	54-30	54-35	54-40	54-45
Composition of Initial Mixture*										
Propionic Acid	4.790	11.109	20.096	27.354	33.378	38.626	42.911	46.793	50.092	52.961
Benzene	42.;50	39.368	35.286	32.120	29.512	27.177	25.294	23.500	22.092	20.731
Water	45.817	42.764	38.528	34.995	32.045	29.529	27.455	25.652	24.019	22.717
Sodium Chloride	7.243	6.760	6.090	5.532	5.066	4.668	4.340	4.044	3.797	3.591
Composition of Aqueous Phase*										
Propionic Acid	3.616	6.424	9.662	11.99	13.74	15.00	15.67	15.87	15.60	14.96
Benzene	0.08	0.14	0.21	0.30	0.37	0.43	0.51	0.58	0.63	0.65
Water	83.30	80.83	78.03	75.76	74.05	72.32	71.17	70.72	70.48	69.55
Sodium Chloride	13.01	12.61	12.06	11.95	11.84	12.25	12.65	12.83	13.49	14.84
Composition of Organic Phase*										
Propionic Acid	6.262	16.52	30.72	40.53	47.97	52.30	58.90	60.62	62.87	64.05
Benzene	93.59	83.13	68.44	57.84	49.50	44.01	36.26	33.28	29.85	27.43
Water	0.143	0.342	0.828	1.60	2.50	3.64	4.77	5.97	7.07	8.22
Sodium Chloride	0.007	0.009	0.015	0.023	0.031	0.047	0.074	0.129	0.204	0.310
Hand Coordinates										
X_{cb}/X_{bb}	0.0671	0.1983	0.448	0.702	0.968	1.188	1.625	1.822	2.10	2.33
X_{ca}/X_{aa}	0.0439	0.0806	0.1261	0.1612	0.1911	0.210	0.222	0.226	0.222	0.215
Distribution Coefficient										
X_{ca}/X_{cb}	0.5775	0.2890	0.3146	0.2959	0.2864	0.2867	0.2660	0.2618	0.2481	0.2336

*All compositions are given in weight per cent.

TABLE 43

PROPIONIC ACID - BENZENE - WATER - 17.41 % SODIUM CHLORIDE

RUN NUMBER	55-2	55-5	55-10	55-15	55-20	55-25	55-30	55-35	55-40	55-45
Composition of Initial Mixture*										
Propionic Acid	4.720	10.970	19.822	26.955	33.094	38.238	42.640	46.436	49.717	52.723
Benzene	41.649	38.908	35.045	31.962	29.263	27.038	25.046	23.422	21.976	20.665
Water	44.294	41.396	37.276	33.930	31.089	28.679	26.689	24.895	23.379	21.979
Sodium Chloride	9.337	8.726	7.858	7.153	6.553	6.045	5.626	5.248	4.928	4.633
Composition of Aqueous Phase*										
Propionic Acid	2.973	5.157	7.539	9.130	10.26	10.96	11.29	11.37	11.22	10.94
Benzene	0.08	0.13	0.16	0.21	0.26	0.34	0.39	0.45	0.50	0.48
Water	80.05	78.28	76.32	74.98	73.90	72.87	72.02	71.29	70.64	70.37
Sodium Chloride	16.90	16.44	15.99	15.68	15.58	15.83	16.30	16.89	17.64	18.21
Composition of Organic Phase*										
Propionic Acid	6.906	17.54	31.96	41.88	49.10	54.98	58.96	61.00	64.11	66.17
Benzene	92.94	82.11	67.17	56.59	48.53	42.75	36.85	33.93	29.99	27.13
Water	0.148	0.344	0.852	1.51	2.34	3.23	4.12	4.95	5.72	6.44
Sodium Chloride	0.007	0.009	0.018	0.024	0.030	0.043	0.072	0.118	0.174	0.264
Hand Coordinates										
X_{cb}/X_{bb}	0.0743	0.216	0.476	0.740	1.010	1.287	1.600	1.800	2.14	2.44
X_{ca}/X_{aa}	0.0383	0.0672	0.1001	0.1240	0.1410	0.1518	0.1583	0.1610	0.1591	0.1559
Distribution Coefficient										
X_{ca}/X_{cb}	0.4306	0.2949	0.2359	0.2180	0.2089	0.1993	0.1914	0.1864	0.1750	0.1653

*All compositions are given in weight per cent.

TABLE 44

PROPIONIC ACID - BENZENE - WATER - 21.33 % SODIUM CHLORIDE

RUN NUMBER	56-2	56-5	56-10	56-15	56-20	56-25	56-30	56-35	56-40	56-45
Composition of Initial Mixture*										
Propionic Acid	4.680	10.830	19.561	26.775	32.840	37.846	42.243	46.092	49.356	52.312
Benzene	41.021	38.361	34.627	31.528	28.936	26.762	24.856	23.204	21.826	20.537
Water	42.717	39.972	36.040	32.803	30.071	27.842	25.884	24.155	22.671	21.360
Sodium Chloride	11.582	10.838	9.772	8.894	8.153	7.549	7.018	6.549	6.147	5.791
Composition of Aqueous Phase*										
Propionic Acid	2.401	4.044	5.756	6.869	7.618	8.501	8.314	8.367	8.332	8.192
Benzene	0.08	0.08	0.10	0.13	0.14	0.18	0.24	0.28	0.33	0.32
Water	76.92	75.79	74.34	73.28	71.94	71.27	70.63	70.33	69.81	69.50
Sodium Chloride	20.60	20.09	19.81	19.73	20.31	20.50	20.82	21.03	21.53	21.99
Composition of Organic Phase*										
Propionic Acid	7.607	22.85	32.94	43.07	49.69	52.58	59.43	63.03	64.79	67.59
Benzene	92.25	76.82	66.26	56.41	48.22	44.62	37.04	32.75	30.53	27.11
Water	0.136	0.324	0.784	1.49	2.06	2.74	3.44	4.08	4.60	5.08
Sodium Chloride	0.005	0.007	0.017	0.023	0.029	0.050	0.084	0.134	0.185	0.232
Hand Coordinates										
X_{cb}/X_{bb}	0.0825	0.297	0.496	0.760	1.024	1.160	1.602	1.923	2.12	2.49
X_{ca}/X_{aa}	0.0313	0.0546	0.0780	0.0953	0.1060	0.1135	0.1178	0.1198	0.1192	0.1183
Distribution Coefficient										
X_{ca}/X_{cb}	0.3157	0.1770	0.1747	0.1595	0.1533	0.1531	0.1399	0.1327	0.1286	0.1211

*All compositions are given in weight per cent.

TABLE 45

PROPIONIC ACID - BENZENE - WATER - 2.001 % POTASSIUM CHLORIDE

RUN NUMBER	21-2	21-5	21-10	21-15	21-20	21-25	21-30	21-35	21-40	21-45
Composition of Initial Mixture*										
Propionic Acid	5.002	11.602	20.805	28.299	34.418	39.652	44.076	47.902	51.244	54.165
Benzene	44.053	40.984	36.736	33.309	30.433	27.997	25.943	24.161	22.623	21.260
Water	49.926	46.466	41.609	37.624	34.446	31.704	29.355	27.378	25.586	24.083
Potassium Chloride	1.019	0.949	0.850	0.768	0.703	0.647	0.600	0.559	0.523	0.492
Composition of Aqueous Phase*										
Propionic Acid	5.930	11.50	18.58	24.94	31.29	37.27	42.90	48.18	52.08	56.56
Benzene	0.07	0.23	0.46	0.78	1.07	2.18	3.10	5.11	10.10	13.14
Water	92.26	86.70	79.41	72.77	66.19	59.25	52.79	45.62	36.90	30.44
Potassium Chloride	1.741	1.571	1.553	1.517	1.459	1.307	1.217	1.093	0.928	0.862
Composition of Organic Phase*										
Propionic Acid	3.975	11.89	23.86	32.78	38.94	43.14	46.93	49.41	51.47	54.00
Benzene	95.92	87.84	75.49	65.96	59.15	54.16	49.23	45.65	42.21	37.16
Water	0.099	0.256	0.624	1.24	1.89	2.77	3.80	4.87	6.20	8.60
Potassium Chloride	0.006	0.010	0.018	0.022	0.030	0.035	0.044	0.065	0.118	0.240
Hand Coordinates										
X_{cb}/X_{bb}	0.0636	0.1351	0.316	0.496	0.658	0.796	1.080	1.111	1.271	1.368
X_{ca}/X_{aa}	0.0641	0.1328	0.233	0.343	0.473	0.629	0.811	1.055	1.410	1.858
Distribution Coefficient										
X_{ca}/X_{cb}	1.478	0.9667	0.7784	0.7603	0.8036	0.8640	0.9154	0.9543	0.9925	1.010

*All compositions are given in weight per cent.

TABLE 46

PROPIONIC ACID - BENZENE - WATER - 5.717 % POTASSIUM CHLORIDE

RUN NUMBER	11-2	11-5	11-10	11-15	11-20	11-25	11-30	11-35	11-40	11-45
Composition of Initial Mixture*										
Propionic Acid	4.935	11.467	20.563	28.134	34.108	39.336	43.734	47.551	50.944	53.836
Benzene	43.549	40.529	36.411	32.828	30.184	27.788	25.775	24.030	22.463	21.147
Water	48.570	45.260	40.566	36.806	33.667	30.997	28.748	26.794	25.073	23.587
Potassium Chloride	2.945	2.744	2.560	2.232	2.042	1.880	1.743	1.625	1.520	1.430
Composition of Aqueous Phase*										
Propionic Acid	5.520	10.54	16.90	22.53	28.26	34.13	40.08	45.33	50.22	54.12
Benzene	0.06	0.19	0.40	0.67	0.94	1.85	2.64	4.38	8.54	11.89
Water	89.06	84.10	77.74	72.10	66.28	59.74	53.24	46.37	37.45	30.35
Potassium Chloride	5.361	5.172	4.961	4.700	4.526	4.287	4.044	3.928	3.791	3.641
Composition of Organic Phase*										
Propionic Acid	4.314	12.91	25.07	34.09	40.52	45.39	49.13	51.81	53.50	54.97
Benzene	95.50	86.82	74.20	64.55	57.39	51.74	47.11	43.39	40.58	36.14
Water	0.184	0.267	0.711	1.34	2.06	2.82	3.69	4.69	5.75	7.57
Potassium Chloride	0.008	0.012	0.020	0.027	0.038	0.051	0.068	0.097	0.162	0.318
Hand Coordinates										
X_{cb}/X_{bb}	0.0451	0.1488	0.338	0.528	0.706	0.876	1.043	1.191	1.319	1.548
X_{ca}/X_{aa}	0.0620	0.1254	0.218	0.313	0.426	0.572	0.753	0.977	1.342	1.782
Distribution Coefficient										
X_{ca}/X_{cb}	1.280	0.8165	0.6740	0.6610	0.6975	0.7521	0.8157	0.8749	0.9387	0.9670

*All compositions are given in weight per cent.

TABLE 47

PROPIONIC ACID - BENZENE - WATER - 9.287 % POTASSIUM CHLORIDE

RUN NUMBER	22-2	22-5	22-10	22-15	22-20	22-25	22-30	22-35	22-40	22-45
Composition of Initial Mixture*										
Propionic Acid	4.879	11.407	20.388	27.687	33.878	39.032	43.438	47.265	50.565	53.541
Benzene	43.052	40.132	36.037	32.710	29.945	27.597	25.613	23.864	22.378	21.030
Water	47.234	43.961	39.529	35.926	32.818	30.272	28.075	26.190	24.544	23.066
Potassium Chloride	4.836	4.501	4.047	3.678	3.360	3.099	2.874	2.681	2.513	2.362
Composition of Aqueous Phase*										
Propionic Acid	4.119	7.789	12.38	16.50	20.66	25.23	29.88		38.84	42.56
Benzene										
Water										
Potassium Chloride										
Composition of Organic Phase*										
Propionic Acid	3.804	11.05	21.02	28.80	34.62	38.19	41.11		44.58	46.55
Benzene	96.07	88.68	78.28	70.92	63.32	58.83	54.93		49.38	46.02
Water	0.119	0.261	0.693	1.25	2.01	2.92	3.86		5.82	7.03
Potassium Chloride	0.008	0.012	0.016	0.025	0.040	0.071	0.097		0.214	0.390
Hand Coordinates										
X_{cb}/X_{bb}	0.0396	0.1242	0.268	0.406	0.547	0.648	0.749		0.905	1.010
X_{ca}/X_{aa}										
Distribution Coefficient										
X_{ca}/X_{cb}	1.336	0.8696	0.7267	0.7066	0.7363	0.8149	0.8965		0.9123	0.9347

*All compositions are given in weight per cent.

TABLE 48

PROPIONIC ACID - BENZENE - WATER - 13.74 % POTASSIUM CHLORIDE

RUN NUMBER	57-2	57-5	57-10	57-15	57-20	57-25	57-30	57-35	57-40	57-45
Composition of Initial Mixture*										
Propionic Acid	4.801	11.192	20.171	27.446	33.498	38.648	43.094	46.920	50.265	53.159
Benzene	42.418	39.559	35.545	32.325	29.644	27.292	25.376	23.627	22.147	20.866
Water	45.529	40.808	38.200	34.701	31.794	29.380	27.198	25.406	23.798	22.417
Potassium Chloride	7.252	6.767	6.085	5.527	5.064	4.680	4.332	4.047	3.791	3.569
Composition of Aqueous Phase*										
Propionic Acid	4.519	8.472	13.28	17.48	21.70	26.44	31.99	37.90	43.94	48.74
Benzene	0.04	0.13	0.27	0.45	0.64	1.18	1.71	2.84	5.62	8.93
Water	82.37	79.08	74.56	71.02	66.99	62.26	56.69	51.51	43.01	35.87
Potassium Chloride	13.08	12.32	11.89	11.05	10.67	10.13	9.619	7.753	7.430	6.463
Composition of Organic Phase*										
Propionic Acid	5.184	14.49	27.84	37.18	44.06	49.13	51.89	55.17	56.24	57.71
Benzene	94.69	85.30	71.39	61.40	53.70	47.58	43.97	39.72	37.61	34.48
Water	0.126	0.301	0.752	1.39	2.20	3.20	4.00	4.91	5.83	7.22
Potassium Chloride	0.006	0.010	0.020	0.029	0.046	0.092	0.142	0.200	0.325	0.586
Hand Coordinates										
X_{cb}/X_{bb}	0.0548	0.1700	0.390	0.605	0.821	1.031	1.181	1.389	1.497	1.673
X_{ca}/X_{aa}	0.0533	0.1121	0.1818	0.254	0.334	0.434	0.568	0.751	1.030	1.312
Distribution Coefficient										
X_{ca}/X_{cb}	0.8717	0.5846	0.4769	0.4702	0.4925	0.5383	0.6164	0.6870	0.7814	0.8444

*All compositions are given in weight per cent.

TABLE 49

PROPIONIC ACID - BENZENE - WATER - 17.14 % POTASSIUM CHLORIDE

RUN NUMBER	58-2	58-5	58-10	58-15	58-20	58-25	58-30	58-35	58-40	58-45
Composition of Initial Mixture*										
Propionic Acid	4.756	11.085	19.837	27.126	33.236	38.391	42.784	46.656	49.873	52.837
Benzene	41.945	39.108	33.150	32.071	29.388	27.081	25.143	23.488	22.050	20.759
Water	44.163	41.269	37.117	33.810	30.970	28.610	26.575	24.740	23.265	21.878
Potassium Chloride	9.135	8.537	7.678	6.994	6.406	5.918	5.497	5.118	4.812	4.526
Composition of Aqueous Phase*										
Propionic Acid	4.122	7.574	11.73	15.32	18.89	22.96	27.59	33.37	39.50	45.61
Benzene	0.03	0.11	0.23	0.35	0.49	0.83	1.26	2.10	4.12	7.42
Water	79.75	76.65	73.04	69.85	66.68	62.85	58.73	52.92	46.21	38.27
Potassium Chloride	16.10	15.67	15.00	14.48	13.94	13.36	12.42	11.61	10.17	8.702
Composition of Organic Phase*										
Propionic Acid	5.586	17.16	33.28	38.27	45.32	50.45	54.00	56.50	58.15	59.69
Benzene	94.27	82.52	65.95	60.28	52.43	46.36	41.74	38.12	35.33	32.21
Water	0.138	0.309	0.744	1.42	2.19	3.09	4.08	5.07	5.98	7.25
Potassium Chloride	0.008	0.013	0.022	0.027	0.055	0.102	0.191	00.309	0.534	0.855
Hand Coordinates										
X_{cb}/X_{bb}	0.0592	0.208	0.505	0.634	0.862	1.088	1.292	1.482	1.648	1.852
X_{ca}/X_{aa}	0.0518	0.1013	0.1625	0.225	0.290	0.375	0.484	0.651	0.879	1.228
Distribution Coefficient										
X_{ca}/X_{cb}	0.7380	0.4415	0.3523	0.4004	0.4167	0.4551	0.5110	0.5906	0.6792	0.7641

*All compositions are given in weight per cent.

TABLE 50

PROPIONIC ACID - BENZENE - WATER - 21.00 % POTASSIUM CHLORIDE

RUN NUMBER	59-2	59-5	59-10	59-15	59-20	59-25	59-30	59-35	59-40	59-45
Composition of Initial Mixture*										
Propionic Acid	4.705	10.907	19.707	26.860	32.949	38.067	42.403	46.258	49.475	52.538
Benzene	41.451	38.612	34.767	31.788	29.078	26.892	25.022	23.349	21.922	20.608
Water	42.536	39.880	35.966	32.669	29.998	27.682	25.734	24.010	22.596	21.215
Potassium Chloride	11.307	10.601	9.561	8.684	7.974	7.539	6.841	6.382	6.007	5.639
Composition of Aqueous Phase*										
Propionic Acid	3.693	6.633	10.19	13.08	15.95	18.92	22.48	28.52	36.25	45.43
Benzene	0.02	0.09	0.20	0.27	0.36	0.53	0.81	1.25	2.53	6.38
Water	76.39	73.71	70.81	68.45	65.83	63.25	59.89	54.78	48.09	38.27
Potassium Chloride	19.90	19.57	18.80	18.20	17.86	17.30	16.82	15.35	13.13	9.921
Composition of Organic Phase*										
Propionic Acid	6.036	15.95	29.98	39.40	46.41	51.95	55.54	58.03	59.42	60.26
Benzene	93.82	83.72	69.27	59.14	51.39	45.65	40.25	36.48	33.88	31.18
Water	0.141	0.311	0.735	1.43	2.14	3.25	3.95	5.07	6.15	7.58
Potassium Chloride	0.008	0.016	0.024	0.032	0.064	0.145	0.260	0.433	0.651	0.986
Hand Coordinates										
X_{cb}/X_{bb}	0.0643	0.1902	0.434	0.678	0.903	1.139	1.380	1.576	1.751	1.932
X_{ca}/X_{aa}	0.0494	0.0904	0.1460	0.1911	0.245	0.309	0.383	0.542	0.816	1.345
Distribution Coefficient										
X_{ca}/X_{cb}	0.6119	0.4158	0.3398	0.3321	0.3436	0.3643	0.4047	0.4915	0.6101	0.7540

*All compositions are given in weight per cent.

TABLE 51

BUTYRIC ACID - BENZENE - WATER

RUN NUMBER	32-1	32-2	32-5	32-10	32-15	32-20	32-25	32-30	32-35	32-40	32-45	32-50	32-55	32-60
Composition of Initial Mixture*														
Butyric Acid	2.435	4.866	11.320	20.282	27.687	33.762	38.986	43.331	47.211	50.427	53.454	56.064	58.414	60.541
Benzene	45.594	44.500	41.549	37.368	33.864	31.023	28.612	26.497	24.684	23.175	21.794	20.642	19.527	18.489
Water	51.971	50.635	47.132	42.350	38.449	35.216	32.402	30.173	28.105	26.398	24.751	23.295	22.059	20.970
Composition of Aqueous Phase*														
Butyric Acid	1.562	2.883	4.008	5.674	6.846	7.805	8.490	9.014	9.487	9.983	10.19	10.45	10.83	10.99
Benzene	0.15	0.23	0.32	0.40	0.52	0.60	0.70	0.78	0.76	0.83	0.84	0.90	0.92	0.90
Water	98.29	96.89	95.68	93.93	92.64	91.60	90.81	90.21	90.16	89.19	88.97	88.65	88.25	88.11
Composition of Organic Phase*														
Butyric Acid	3.467	7.648	18.55	32.47	42.27	49.57	54.78	58.32	61.55	63.44	64.86	66.17	66.65	67.53
Benzene	96.43	92.19	81.12	66.79	56.37	48.40	42.33	37.99	33.60	30.63	28.15	25.83	24.31	22.32
Water	0.102	0.157	0.327	0.735	1.36	2.03	2.87	3.79	4.85	5.93	6.99	8.00	9.039	10.15
Hand Coordinates														
X_{cb}/X_{bb}	0.0359	0.0828	0.229	0.486	0.750	1.026	1.295	1.535	1.832	2.07	2.31	2.56	2.76	3.00
X_{ca}/X_{aa}	0.0163	0.0326	0.0424	0.0650	0.0748	0.0870	0.0950	0.1000	0.1055	0.1108	0.1128	0.1170	0.1221	0.1248
Distribution Coefficient														
X_{ca}/X_{cb}	0.4506	0.3770	0.2160	0.1748	0.1620	0.1575	0.1550	0.1546	0.1541	0.1573	0.1570	0.1580	0.1625	0.1628

*All compositions are given in weight per cent.

TABLE 52

BUTYRIC ACID - BENZENE - WATER - 1.970 % LITHIUM CHLORIDE

RUN NUMBER	33-1	33-2	33-5	33-10	33-15	33-20	33-25	33-30	33-35	33-40	33-50	33-60
Composition of Initial Mixture*												
Butyric Acid	2.477	4.833	11.262	20.263	27.546	33.577	38.859	43.178	47.056	50.276	55.877	60.294
Benzene	45.390	44.293	41.252	37.113	33.651	30.917	28.508	26,457	24.539	23.091	20.505	18.469
Water	51.628	49.872	46.551	41.784	37.987	34.807	32.149	29.766	27.846	26.108	23.154	20.819
Lithium Chloride	1.027	1.002	0.935	0.840	0.763	0.699	0.646	0.598	0.560	0.525	0.465	0.418
Composition of Aqueous Phase*												
Butyric Acid	1.367	2.073	3.350	4.719	5.655	6.326	6.823	7.273	7.571	7.641	8.052	8.154
Benzene	0.10	0.17	0.22	0.28	0.36	0.49	0.47	0.61	0.68	0.74	0.78	0.81
Water	96.67	95.90	94.59	93.20	92.17	91.76	90.86	90.24	89.85	89.67	89.05	88.67
Lithium Chloride	1.879	1.860	1.840	1.819	1.823	1.831	1.853	1.884	1.908	1.954	2.123	2.371
Composition of Organic Phase*												
Butyric Acid	3.804	8.260	19.33	33.37	43.13	50.02	55.05	59.26	62.62	64.91	68.18	70.10
Benzene	96.09	91.81	80.33	65.89	55.59	48.02	42.24	37.31	33.10	30.02	25.36	22.37
Water	0.101	0.154	0.323	0.735	1.26	1.95	2.70	3.41	4.35	5.04	6.42	7.60
Lithium Chloride	0.009	0.010	0.013	0.014	0.017	0.017	0.021	0.022	0.028	0.034	0.039	0.044
Hand Coordinates												
X_{cb}/X_{bb}	0.0396	0.0875	0.241	0.522	0.776	1.041	1.301	1.588	1.890	2.16	2.68	3.13
X_{ca}/X_{aa}	0.01442	0.0223	0.0365	0.0526	0.0601	0.0708	0.0767	0.0820	0.0863	0.0880	0.0925	0.0938
Distribution Coefficient												
X_{ca}/X_{cb}	0.3594	0.2583	0.1733	0.1412	0.1312	0.1265	0.1239	0.1227	0.1209	0.1195	0.1181	0.1163

*All compositions are given in weight per cent.

T A B L E 5 3

BUTYRIC ACID - BENZENE - WATER - 5.743 % LITHIUM CHLORIDE

RUN NUMBER	34-1	34-2	34-5	34-10	34-15	34-20	34-25	34-30	34-35	34-40	34-50	34-60
Composition of Initial Mixture*												
Butyric Acid	2.459	4.784	11.163	20.090	27.369	33.415	38.562	42.962	46.789	50.166	55.672	60.054
Benzene	44.892	43.873	40.852	36.685	33.419	30.622	28.189	26.231	24.398	22.801	20.406	18.362
Water	49.626	48.379	45.229	40.742	36.961	33.898	31.339	29.038	27.159	25.481	22.548	20.345
Lithium Chloride	3.024	2.948	2.756	2.482	2.252	2.065	1.910	1.769	1.655	1.553	1.374	1.240
Composition of Aqueous Phase*												
Butyric Acid	1.045	1.489	2.386	3.306	3.885	4.335	4.645	4.865	4.976	5.213	5.215	5.140
Benzene	0.08	0.07	0.10	0.18	0.13	0.19	00.23	0.28	0.26	0.29	0.32	0.41
Water	93.27	92.96	92.23	91.08	90.53	89.99	89.62	89.32	88.98	88.60	88.05	87.83
Lithium Chloride	5.617	5.499	5.292	5.446	5.469	5.493	5.519	5.548	5.793	5.903	6.424	6.626
Composition of Organic Phase*												
Butyric Acid	4.181	8.579	20.66	34.08	43.69	50.99	56.16	60.72	63.30	66.33	69.13	72.32
Benzene	95.70	91.27	79.01	65.19	55.16	48.33	41.61	36.52	33.34	29.78	26.22	22.33
Water	0.109	0.154	0.323	0.719	1.14	1.67	2.21	2.78	3.33	3.87	4.62	5.31
Lithium Chloride	0.008	0.010	0.011	0.013	0.017	0.018	0.021	0.022	0.024	0.024	0.027	0.038
Hand Coordinates												
X_{cb}/X_{bb}	0.0437	0.0939	0.262	0.523	0.792	1.053	1.349	1.664	1.900	2.23	2.64	3.24
X_{ca}/X_{aa}	0.0116	0.0165	0.0266	0.0373	0.0439	0.0496	0.0551	0.0570	0.0569	0.0612	0.0608	0.0606
Distribution Coefficient												
X_{ca}/X_{cb}	0.2498	0.1736	0.1155	0.0970	0.0889	0.0850	0.0827	0.0801	0.0786	0.0786	0.0754	0.0711

*All compositions are given in weight per cent.

TABLE 54

BUTYRIC ACID - BENZENE - WATER - 9.118 % LITHIUM CHLORIDE

RUN NUMBER	35-1	35-2	35-5	35-10	35-15	35-20	35-25	35-30	35-35	35-40	35-50	35-60
Composition of Initial Mixture*												
Butyric Acid	2.459	4.722	11.038	19.861	27.102	33.138	38.265	42.686	46.451	49.794	55.400	59.851
Benzene	44.394	43.357	40.511	36.473	33.227	30.455	28.168	26.123	24.393	22.289	20.934	18.272
Water	48.301	47.186	44.034	39.685	36.055	33.087	30.507	28.347	26.497	24.881	22.091	19.883
Lithium Chloride	4.846	4.734	4.418	3.982	3.617	3.320	3.061	2.844	2.658	2.496	2.216	1.995
Composition of Aqueous Phase*												
Butyric Acid	0.781	1.104	1.752	2.282	2.843	3.172	3.338	3.577	3.636	3.712	3.836	3.720
Benzene	0.11	0.07	0.15	0.11	0.13	0.18	0.12	0.16	0.19	0.16	0.22	0.23
Water	90.22	90.00	89.33	88.87	88.31	87.90	87.69	87.33	86.93	86.70	86.41	86.03
Lithium Chloride	8.893	8.830	8.772	8.743	8.726	8.759	8.861	8.940	9.277	9.437	9.543	10.02
Composition of Organic Phase*												
Butyric Acid	4.533	8.427	20.44	34.45	44.21	51.34	56.58	60.79	63.50	66.22	70.83	73.61
Benzene	95.36	91.41	79.25	64.88	54.72	47.07	41.51	36.78	33.82	30.73	25.55	22.22
Water	0.0985	0.155	0.301	0.651	1.05	1.58	1.89	2.51	2.66	3.03	3.60	4.14
Lithium Chloride	0.006	0.009	0.010	0.012	0.014	0.016	0.019	0.021	0.022	0.023	0.025	0.032
Hand Coordinates												
X_{cb}/X_{bb}	0.0475	0.0925	0.258	0.530	0.809	1.089	1.360	1.655	1.880	2.16	2.77	3.31
X_{ca}/X_{aa}	0.00895	0.01267	0.0202	0.0264	0.0332	0.0371	0.0392	0.0422	0.0430	0.0441	0.0457	0.0448
Distribution Coefficient												
X_{ca}/X_{cb}	0.1722	0.1310	0.0857	0.0662	0.0643	0.0618	0.0590	0.0588	0.0573	0.0561	0.0542	0.0505

*All compositions are given in weight per cent.

TABLE 55

BUTYRIC ACID - BENZENE - WATER - 13.68 % LITHIUM CHLORIDE

RUN NUMBER	42-1	42-2	42-5	42-10	42-15	42-20	42-25	42-30	42-35	42-40	42-50	42-60
Composition of Initial Mixture*												
Butyric Acid	2.429	4.648	10.884	19.661	27.131	32.960	37.996	42.333	46.169	49.438	55.022	59.433
Benzene	43.810	42.798	40.042	36.085	32.728	30.062	27.818	25.896	24.158	22.691	20.210	18.193
Water	46.407	45.365	42.360	38.200	34.650	31.919	29.510	27.425	25.618	24.058	21.380	19.313
Lithium Chloride	7.355	7.190	6.713	6.054	5.491	5.059	4.677	4.346	4.060	3.813	3.388	3.061
Composition of Aqueous Phase*												
Butyric Acid	0.525	0.728	1.189	1.609	1.938	2.129	2.151	2.258	2.317	2.396	2.449	2.484
Benzene	0.03	0.06	0.00	0.08	0.07	0.13	0.18	0.12	0.16	00.18	0.13	0.15
Water	85.82	85.75	85.58	85.33	84.88	84.47	84.21	84.03	83.83	83.61	83.50	83.01
Lithium Chloride	13.63	13.47	13.24	12.99	13.12	13.28	13.46	13.60	13.70	13.82	13.93	14.36
Composition of Organic Phase*												
Butyric Acid	4.733	9.131	20.69	35.62	44.75	52.33	56.89	61.06	64.53	67.41	71.79	74.73
Benzene	95.17	90.73	79.01	63.80	54.31	46.44	41.56	37.13	33.40	30.25	25.62	22.04
Water	0.098	0.132	0.292	0.571	0.929	1.22	1.53	1.79	2.05	2.31	2.66	3.21
Lithium Chloride	0.004	0.007	0.008	0.009	0.011	0.014	0.018	0.020	0.021	0.022	0.024	0.026
Hand Coordinates												
X_{cb}/X_{bb}	0.0496	0.1000	0.262	0.559	0.824	1.105	1.370	1.644	1.935	2.23	2.80	3.40
X_{ca}/X_{aa}	0.00620	0.00891	0.01419	0.01925	0.0234	0.0257	0.0263	0.0276	0.0283	0.0290	0.0306	0.0315
Distribution Coefficient												
X_{ca}/X_{cb}	0.1109	0.0798	0.0575	0.0452	0.0433	0.0405	0.0378	0.0369	0.0359	0.0363	0.0341	0.0333

*All compositions are given in weight per cent.

TABLE 56

BUTYRIC ACID - BENZENE - WATER - 17.61 % LITHIUM CHLORIDE

RUN NUMBER	43-1	43-2	43-5	43-10	43-15	43-20	43-25	43-30	43-35	43-40	43-50	43-60
Composition of Initial Mixture*												
Butyric Acid	2.396	4.649	10.856	19.517	26.639	32.626	37.748	42.075	45.821	49.219	54.736	59.243
Benzene	43.385	42.383	39.329	35.740	32.619	29.904	27.607	25.739	24.007	22.534	20.082	18.065
Water	44.671	43.640	41.043	36.865	33.569	30.871	28.544	26.518	24.858	23.273	20.747	18.696
Lithium Chloride	9.548	9.328	8.773	7.880	7.175	6.598	6.101	5.668	5.313	4.974	4.435	3.996
Composition of Aqueous Phase*												
Butyric Acid	0.392	0.551	0.841	1.144	1.353	1.487	1.630	1.750	1.630	1.826	1.865	2.035
Benzene	0.07	0.02	0.08	0.04	00.00	0.01	0.09	0.13	0.14	0.12	0.18	0.15
Water	82.44	82.39	82.04	81.72	81.52	81.33	81.05	80.85	80.93	80.65	80.47	80.09
Lithium Chloride	17.10	17.04	17.04	17.10	17.13	17.18	17.23	17.27	17.30	17.38	17.49	17.74
Composition of Organic Phase*												
Butyric Acid	4.928	9.598	21.48	35.19	44.83	52.11	57.49	61.80	65.34	68.14	73.01	75.77
Benzene	94.98	90.27	78.27	64.33	54.45	46.93	41.34	36.84	33.13	30.15	25.02	21.99
Water	0.092	0.124	0.243	0.475	0.711	0.945	1.15	1.34	1.51	1.70	1.95	2.21
Lithium Chloride	0.004	0.006	0.008	0.010	0.011	0.015	0.018	0.019	0.019	0.021	0.023	0.024
Hand Coordinates												
X_{cb}/X_{bb}	0.0519	0.1061	0.275	0.548	0.824	1.111	1.390	1.678	1.972	2.26	2.92	3.44
X_{ca}/X_{aa}	0.00490	0.00688	0.01058	0.01441	0.01716	0.01885	0.0208	0.0224	0.0211	0.0238	0.0245	0.0268
Distribution Coefficient												
X_{ca}/X_{cb}	0.0795	0.0574	0.0391	0.0325	0.0302	0.0284	0.0283	0.0283	0.0249	0.0268	0.0255	0.0269

*All compositions are given in weight per cent.

TABLE 57

BUTYRIC ACID - BENZENE - WATER - 21.23 % LITHIUM CHLORIDE

RUN NUMBER	44-1	44-2	44-5	44-10	44-15	44-20	44-25	44-30	44-35	44-40	44-50	44-60
Composition of Initial Mixture*												
Butyric Acid	2.352	4.597	10.719	19.287	26.475	32.381	37.466	41.813	45.542	48.945	54.523	58.925
Benzene	42.855	41.864	39.049	35.347	32.168	29.671	27.447	25.555	23.858	22.440	19.974	18.035
Water	43.161	42.173	39.567	35.734	32.753	29.892	27.638	25.704	24.104	22.541	20.168	18.149
Lithium Chloride	11.633	11.366	10.664	9.631	8.779	8.057	7.449	6.928	6.497	6.075	5.436	4.891
Composition of Aqueous Phase*												
Butyric Acid	0.295	0.398	0.635	0.908	1.055	1.129	1.224	1.286	1.365	1.368	1.513	1.537
Benzene	0.07	0.01	0.00	0.02	0.06	0.09	0.03	0.02	0.07	0.15	0.13	0.09
Water	78.98	79.02	78.82	78.51	78.30	78.18	78.07	77.96	77.78	77.64	77.42	77.27
Lithium Chloride	20.66	20.58	20.55	20.57	20.59	20.61	20.68	20.74	20.79	20.85	20.94	21.11
Composition of Organic Phase*												
Butyric Acid	5.001	9.777	21.60	35.45	45.36	52.39	57.81	62.05	65.70	68.76	73.11	76.14
Benzene	94.92	90.12	78.19	64.16	54.06	46.86	41.28	36.91	33.18	30.87	25.45	22.28
Water	0.076	0.102	0.207	0.381	0.569	0.740	0.894	1.02	1.10	1.46	1.43	1.65
Lithium Chloride	0.003	0.004	0.005	0.008	0.010	0.014	0.017	0.020	0.022	0.023	0.025	0.026
Hand Coordinates												
X_{cb}/X_{bb}	0.0528	0.1083	0.276	0.552	0.838	1.117	1.402	1.681	1.981	2.23	2.87	3.42
X_{ca}/X_{aa}	0.00384	0.00519	0.00835	0.01132	0.01335	0.01498	0.01659	0.01805	0.01831	0.01865	0.01960	0.0208
Distribution Coefficient												
X_{ca}/X_{cb}	0.0589	0.0407	0.0294	0.0256	0.0233	0.0216	0.0212	0.0209	0.0208	0.0199	0.0209	0.0200

*All compositions are given in weight per cent.

TABLE 58

BUTYRIC ACID - BENZENE - WATER - 2.002 % SODIUM CHLORIDE

RUN NUMBER	36-1	36-2	36-5	36-10	36-15	36-20	36-25	36-30	36-35	36-40	36-50	36-60
Composition of Initial Mixture*												
Butyric Acid	2.479	4.823	11.225	20.259	37.525	33.579	38.762	43.176	46.968	50.317	55.839	60.275
Benzene	45.266	44.189	41.187	36.914	33.603	30.750	28.430	26.365	24.599	23.039	20.514	17.383
Water	51.209	49.967	46.636	41.970	38.094	34.957	32.152	29.850	27.864	26.111	23.173	20.863
Sodium Chloride	1.046	1.021	0.953	0.857	0.778	0.714	0.657	0.610	0.569	0.533	0.473	0.426
Composition of Aqueous Phase*												
Butyric Acid	1.419	2.084	3.443	4.509	5.875	6.579	7.123	7.539	7.853	8.099	8.419	8.464
Benzene	0.11	0.18	0.13	0.19	0.27	0.28	0.33	0.41	0.50	0.48	0.52	0.58
Water	96.59	95.86	94.56	93.46	92.07	91.30	90.69	90.16	89.70	89.40	88.80	88.23
Sodium Chloride	1.895	1.883	1.872	1.859	1.853	1.857	1.865	1.900	1.954	2.034	2.279	2.734
Composition of Organic Phase*												
Butyric Acid	3.807	7.927	19.19	33.35	42.90	49.96	55.43	59.33	62.25	64.43	67.87	69.17
Benzene	96.09	91.91	80.47	65.88	55.79	48.96	41.81	37.00	33.27	30.22	26.27	22.52
Water	0.096	0.157	0.321	0.754	1.30	2.07	2.73	3.64	4.45	5.32	6.92	8.37
Sodium Chloride	0.007	0.010	0.012	0.014	0.015	0.017	0.020	0.025	0.028	0.032	0.036	0.038
Hand Coordinates												
X_{cb}/X_{bb}	0.0396	0.0852	0.238	0.506	0.769	1.020	1.325	1.603	1.875	2.13	2.61	3.07
X_{ca}/X_{aa}	0.01550	0.0229	0.0382	0.0500	0.0657	0.0737	0.0805	0.0852	0.0896	0.0925	0.0967	0.0978
Distribution Coefficient												
X_{ca}/X_{cb}	0.3727	0.2629	0.1794	0.1412	0.1369	0.1317	0.1285	0.1271	0.1261	0.1257	0.1240	0.1224

*All concentrations are given in weight per cent.

TABLE 59

BUTYRIC ACID - BENZENE - WATER - 5.863 % SODIUM CHLORIDE

RUN NUMBER	37-1	37-2	37-5	37-10	37-15	37-20	37-25	37-30	37-35	37-40	37-50	37-60
Composition of Initial Mixture*												
Butyric Acid	2.462	4.754	11.089	19.976	27.199	33.293	38.463	42.767	46.575	49.963	55.501	59.914
Benzene	44.600	43.534	40.587	36.584	33.371	30.546	28.130	26.157	24.433	22.865	20.326	18.295
Water	49.834	48.681	45.491	40.938	37.118	34.041	31.448	29.254	27.292	25.578	22.755	20.513
Sodium Chloride	3.072	3.032	2.833	2.550	2.312	2.120	1.959	1.822	1.700	1.593	1.417	1.278
Composition of Aqueous Phase*												
Butyric Acid	1.138	1.641	2.676	3.740	4.442	4.959	5.300	5.571	5.704	5.916	5.982	5.969
Benzene	0.13	0.09	0.18	0.23	0.31	0.25	0.27	0.19	0.23	0.33	0.35	0.32
Water	93.00	92.58	91.55	90.51	89.67	89.14	88.67	88.44	88.03	87.47	86.94	86.52
Sodium Chloride	5.749	5.692	5.601	5.527	5.586	5.667	5.768	5.804	6.046	6.293	6.737	7.206
Composition of Organic Phase*												
Butyric Acid	4.101	8.291	19.67	33.80	43.18	50.58	55.29	59.54	62.56	65.20	68.34	71.16
Benzene	95.79	91.55	80.00	66.47	55.70	47.54	42.04	37.04	33.41	30.08	25.95	22.32
Water	0.101	0.150	0.325	0.716	1.21	1.86	2.65	3.39	4.01	4.70	5.67	6.49
Sodium Chloride	0.007	0.010	0.011	0.014	0.016	0.017	0.021	0.026	0.027	0.030	0.038	0.042
Hand Coordinates												
X_{cb}/X_{bb}	0.0429	0.0906	0.246	0.572	0.775	1.065	1.315	1.611	1.873	2.17	2.63	3.19
X_{ca}/X_{aa}	0.01265	0.01825	0.0298	0.0418	0.0500	0.0560	0.0600	0.0638	0.0653	0.0704	0.0690	0.0696
Distribution Coefficient												
X_{ca}/X_{cb}	0.2775	0.1979	0.1361	0.1107	0.1029	0.0980	0.0959	0.0936	0.0912	0.0938	0.0875	0.0839

*All compositions are given in weight per cent.

TABLE 60

BUTYRIC ACID - BENZENE - WATER - 9.403 % SODIUM CHLORIDE

RUN NUMBER	38-1	38-2	38-5	38-10	38-15	38-20	38-25	38-30	38-35	38-40	38-50	38-60
Composition of Initial Mixture*												
Butyric Acid	2.433	4.688	10.942	19.662	29.204	33.030	38.044	42.446	46.246	49.646	55.252	59.652
Benzene	43.829	42.963	40.131	36.168	31.874	30.149	27.892	25.936	24.231	22.613	20.105	18.182
Water	48.685	47.427	44.327	40.017	35.262	33.358	30.861	28.645	26.747	25.133	22.326	20.082
Sodium Chloride	5.052	4.922	4.599	4.153	3.660	3.462	3.203	2.979	2.776	2.609	2.317	2.084
Composition of Aqueous Phase*												
Butyric Acid	0.892	1.298	2.081	2.870	3.516	3.832	4.064	4.187	4.342	4.495	4.558	4.528
Benzene	0.14	0.16	0.17	0.23	0.24	0.19	0.28	0.25	0.23	0.19	0.31	0.28
Water	89.81	89.45	88.72	87.91	87.15	86.82	86.45	86.26	85.81	85.50	84.77	84.11
Sodium Chloride	9.168	9.109	9.030	8.993	9.101	9.165	9.216	9.313	9.571	9.828	10.37	11.09
Composition of Organic Phase*												
Butyric Acid	4.369	8.664	20.12	34.02	46.81	51.31	56.04	60.22	63.19	66.23	69.77	71.87
Benzene	95.52	91.17	79.53	65.23	51.79	46.92	41.70	36.96	33.47	30.92	25.51	22.78
Water	0.104	0.151	0.339	0.737	1.39	1.76	2.26	2.79	3.31	3.82	4.68	5.31
Sodium Chloride	0.008	0.011	0.012	0.015	0.016	0.018	0.021	0.027	0.029	0.031	0.039	0.044
Hand Coordinates												
X_{cb}/X_{bb}	0.0457	0.0950	0.253	0.521	0.903	1.095	1.345	1.638	1.889	2.14	2.72	3.15
X_{ca}/X_{aa}	0.01001	0.01492	0.0239	0.0322	0.0408	0.0445	0.0476	0.0491	0.0516	0.0535	0.0543	0.0540
Distribution Coefficient												
X_{ca}/X_{cb}	0.2042	0.1499	0.1043	0.0844	0.0751	0.0747	0.0725	0.0695	0.0687	0.0679	0.0654	0.0630

*All compositions are given in weight per cent.

TABLE 61

BUTYRIC ACID - BENZENE - WATER - 13.65 % SODIUM CHLORIDE

RUN NUMBER	45-1	45-2	45-5	45-10	45-15	45-20	45-25	45-30	45-35	45-40	45-50	45-60
Composition of Initial Mixture*												
Butyric Acid	2.436	4.596	10.778	19.443	26.679	32.578	37.724	42.074	45.886	49.094	54.718	59.158
Benzene	43.259	42.371	39.619	35.647	32.576	29.853	27.641	25.748	23.981	22.591	20.068	18.090
Water	46.893	45.794	42.830	38.779	35.184	32.441	29.908	27.786	26.021	24.167	21.773	19.647
Sodium Chloride	7.413	7.239	6.771	6.130	5.562	5.128	4.728	4.392	4.113	3.865	3.442	3.106
Composition of Aqueous Phase*												
Butyric Acid	0.657	0.945	1.456	2.044	2.392	2.656	2.866	2.934	3.002	3.024	3.087	3.122
Benzene	0.08	0.10	0.09	0.15	0.17	0.13	0.14	0.22	0.20	0.25	0.27	0.23
Water	85.87	85.62	85.16	84.60	84.26	83.92	83.53	83.24	82.98	82.73	82.01	81.57
Sodium Chloride	13.40	13.34	13.30	13.21	13.18	13.30	13.47	13.61	13.82	14.00	14.64	15.08
Composition of Organic Phase*												
Butyric Acid	4.712	8.920	20.41	34.47	44.37	51.17	56.50	60.81	63.94	66.51	70.41	72.39
Benzene	95.17	90.92	79.26	65.94	54.50	47.16	41.39	36.69	34.12	29.10	25.63	23.07
Water	0.108	0.145	0.322	00.687	1.11	1.65	2.09	2.47	2.91	3.35	3.92	4.49
Sodium Chloride	0.007	0.011	0.013	0.012	0.014	0.016	0.020	0.026	0.028	0.033	0.039	0.048
Hand Coordinates												
X_{cb}/X_{bb}	0.0495	0.0982	0.258	0.527	0.813	1.083	1.365	1.653	1.874	2.29	2.75	3.14
X_{ca}/X_{aa}	0.00781	0.01124	0.01739	0.0245	0.0288	0.0324	0.0341	0.0357	0.0367	0.0374	0.0380	0.0388
Distribution Coefficient												
X_{ca}/X_{cb}	0.1394	0.1059	0.0714	0.0593	0.0539	0.0519	0.0507	0.0482	0.0469	0.0454	0.0439	0.0431

*All compositions are given in weight per cent.

TABLE 62

BUTYRIC ACID - BENZENE - WATER - 17.41 % SODIUM CHLORIDE

RUN NUMBER	46-1	46-2	46-5	46-10	46-15	46-20	46-25	46-30	46-35	46-40	46-50	46-60
Composition of Initial Mixture*												
Butyric Acid	2.356	4.555	10.596	19.247	26.334	32.278	37.348	41.659	45.502	48.785	54.341	58.778
Benzene	42.710	41.788	39.044	35.332	32.230	29.609	27.419	25.506	23.802	22.396	19.951	18.048
Water	45.370	44.316	41.593	37.513	34.223	31.478	29.098	27.119	25.352	23.802	21.232	19.140
Sodium Chloride	9.564	9.342	8.768	7.908	7.214	6.636	6.134	5.717	5.344	5.017	4.476	4.035
Composition of Aqueous Phase*												
Butyric Acid	0.484	0.690	1.109	1.499	1.740	1.939	2.077	2.179	2.231	2.273	2.299	2.308
Benzene	0.03	0.10	0.14	0.07	0.12	0.14	0.10	0.18	0.15	0.19	0.27	0.21
Water	82.52	82.36	81.98	81.58	81.20	80.91	80.69	80.41	80.19	79.95	79.31	79.06
Sodium Chloride	16.97	16.85	16.78	16.86	16.94	17.02	17.14	17.24	17.43	17.59	18.13	18.43
Composition of Organic Phase*												
Butyric Acid	4.770	9.294	20.84	34.89	44.53	51.75	56.93	61.15	64.36	67.34	71.24	74.40
Benzene	95.11	90.54	78.85	64.48	54.43	46.81	41.30	36.74	33.18	29.88	25.51	22.07
Water	0.112	0.156	0.303	0.621	1.02	1.43	1.75	2.09	2.43	2.74	3.22	3.57
Sodium Chloride	0.007	0.012	0.014	0.016	0.017	0.019	0.023	0.028	0.033	0.036	0.043	0.052
Hand Coordinates												
X_{cb}/X_{bb}	0.0495	0.1028	0.264	0.541	0.817	1.106	1.378	1.811	1.939	2.25	2.79	3.37
X_{ca}/X_{aa}	0.00603	0.00859	0.01389	0.01844	0.0221	0.0247	0.0264	0.0279	0.0287	0.0299	0.0302	0.0304
Distribution Coefficient												
X_{ca}/X_{cb}	0.1015	0.0742	0.0532	0.0430	0.0391	0.0374	0.0365	0.0356	0.0347	0.0336	0.0323	0.0310

*All compositions are given in weight per cent.

TABLE 63

BUTYRIC ACID - BENZENE - WATER - 21.23 % SODIUM CHLORIDE

RUN NUMBER	47-1	47-2	47-5	47-10	47-15	47-20	47-25	47-30	47-35	47-40	47-50	47-60
Composition of Initial Mixture*												
Butyric Acid	2.339	4.485	10.489	19.014	26.016	31.950	37.009	41.275	45.063	48.420	54.027	58.495
Benzene	42.034	41.170	38.608	34.829	31.914	29.254	27.165	25.315	23.658	22.236	19.796	17.883
Water	43.762	42.753	40.045	36.311	33.097	30.520	28.185	26.284	24.608	23.085	20.593	18.583
Sodium Chloride	11.865	11.592	10.858	9.845	8.974	8.275	7.642	7.127	6.672	6.259	5.583	5.039
Composition of Aqueous Phase*												
Butyric Acid	0.393	0.521	0.834	1.096	1.254	1.460	1.557	1.607	1.615	1.641	1.666	1.686
Benzene	0.00	0.10	0.01	0.08	0.13	0.06	0.12	0.18	0.22	0.17	0.13	0.17
Water	78.82	78.66	78.39	78.03	77.77	77.51	77.25	77.07	76.86	76.60	76.00	75.53
Sodium Chloride	20.79	20.72	20.77	20.80	20.85	20.97	21.08	21.15	21.31	21.59	22.21	22.62
Composition of Organic Phase*												
Butyric Acid	4.927	9.511	21.05	35.30	44.69	51.93	57.19	61.35	64.75	67.42	71.46	74.59
Benzene	95.97	90.32	78.65	64.11	54.43	46.83	41.12	36.59	33.17	30.29	25.88	22.41
Water	0.100	0.156	0.283	0.578	0.865	1.21	1.67	2.04	2.04	2.24	2.61	2.95
Sodium Chloride	0.008	0.012	0.015	0.017	0.019	0.021	0.024	0.029	0.036	0.043	0.049	0.058
Hand Coordinates												
X_{cb}/X_{bb}	0.0513	0.1052	0.267	0.551	0.821	1.099	1.390	1.678	1.952	2.22	2.76	3.33
X_{ca}/X_{aa}	0.00511	0.00680	0.01093	0.01441	0.01661	0.01935	0.0207	0.0216	0.0217	0.0227	0.0230	0.0238
Distribution Coefficient												
X_{ca}/X_{cb}	0.0797	0.0548	0.0396	0.0311	0.0281	0.0281	0.0272	0.0262	0.0249	0.0232	0.0226	0.0226

*All compositions are given in weight per cent.

TABLE 64

BUTYRIC ACID - BENZENE - WATER - 2.001 % POTASSIUM CHLORIDE

RUN NUMBER	39-1	39-2	39-5	39-10	39-15	39-20	39-25	39-30	39-35	39-40	39-50	39-60
Composition of Initial Mixture*												
Butyric Acid	2.529	4.830	11.178	20.315	27.620	33.640	39.009	43.212	47.023	50.311	55.863	60.286
Benzene	45.286	44.224	41.233	37.064	33.651	30.841	28.256	26.372	24.609	23.073	20.534	18.459
Water	51.141	49.926	46.637	41.768	37.955	34.809	32.080	29.807	27.800	26.083	23.131	20.834
Potassium Chloride	1.044	1.019	0.952	0.853	0.775	0.711	0.655	0.609	0.567	0.532	0.472	0.425
Composition of Aqueous Phase*												
Butyric Acid	1.508	2.030	3.562	5.013	6.239	6.980	7.612	8.213	8.584	8.821	9.132	9.509
Benzene	0.20	0.13	0.19	0.24	0.32	0.28	0.48	0.45	0.56	0.63	0.70	0.77
Water	96.32	95.92	94.38	92.91	91.60	90.86	90.01	89.40	88.86	88.47	87.84	87.02
Potassium Chloride	1.945	1.928	1.870	1.845	1.850	1.880	1.903	1.949	2.006	2.085	2.333	2.713
Composition of Organic Phase*												
Butyric Acid	3.548	7.882	18.89	31.37	42.71	49.85	54.96	58.98	61.68	63.74	66.84	68.76
Benzene	96.34	91.95	80.76	67.87	55.98	48.15	42.11	37.38	33.76	30.77	25.95	22.52
Water	0.111	0.157	0.333	0.747	1.30	1.98	2.91	3.62	4.53	5.45	7.17	8.68
Potassium Chloride	0.004	0.007	0.011	0.013	0.016	0.018	0.021	0.023	0.025	0.030	0.035	0.042
Hand Coordinates												
X_{cb}/X_{bb}	0.0368	0.0858	0.234	0.462	0.764	1.035	1.304	1.578	1.825	2.07	2.57	3.05
X_{ca}/X_{aa}	0.01645	0.0222	0.0400	0.0555	0.0701	0.0781	0.0851	0.0925	0.0971	0.1004	0.1045	0.1092
Distribution Coefficient												
X_{ca}/X_{cb}	0.4250	0.2581	0.1933	0.1602	0.1461	0.1400	0.1385	0.1393	0.1390	0.1384	0.1366	0.1383

*All compositions are given in weight per cent.

TABLE 65

BUTYRIC ACID - BENZENE - WATER - 5.717 % POTASSIUM CHLORIDE

RUN NUMBER	40-1	40-2	40-5	40-10	40-15	40-20	40-25	40-30	40-35	40-40	40-50	40-60
Composition of Initial Mixture*												
Butyric Acid	2.475	4.788	11.134	20.012	27.334	33.361	38.469	42.924	46.666	49.926	55.747	59.984
Benzene	44.771	43.712	40.746	36.699	33.289	30.490	28.231	26.203	24.487	22.949	20.422	18.350
Water	49.738	48.555	45.368	40.815	37.126	34.082	31.397	29.108	27.199	25.574	22.657	20.427
Potassium Chloride	3.016	2.942	2.751	2.475	2.251	2.067	1.904	1.765	1.649	1.551	1.374	1.239
Composition of Aqueous Phase*												
Butyric Acid	1.290	1.898	3.101	4.652	5.215	5.827	6.306	6.622	6.896	7.130	7.408	7.453
Benzene	0.08	0.13	0.11	0.18	0.25	0.23	0.28	0.38	0.47	0.43	0.51	0.53
Water	93.21	92.62	91.45	89.86	89.16	88.52	87.89	87.41	86.86	86.00	85.86	85.50
Potassium Chloride	5.442	5.365	5.335	5.312	5.371	5.429	5.521	5.597	5.776	5.945	6.223	6.526
Composition of Organic Phase*												
Butyric Acid	3.957	8.290	19.21	33.37	43.17	50.13	56.20	59.43	62.26	64.62	68.16	70.44
Benzene	95.92	91.43	80.43	66.85	55.47	47.89	42.11	37.47	33.56	30.42	25.50	21.92
Water	0.116	0.274	0.343	0.765	1.34	1.96	2.67	3.18	4.19	4.92	6.29	7.56
Potassium Chloride	0.006	0.008	0.011	0.015	0.018	0.019	0.022	0.027	0.031	0.042	0.052	0.085
Hand Coordinates												
X_{cb}/X_{bb}	0.0413	0.0906	0.239	0.499	0.778	1.049	1.311	1.586	1.853	2.13	2.67	3.21
X_{ca}/X_{aa}	0.01443	0.0214	0.0351	0.0489	0.0597	0.0670	0.0727	0.0770	0.0805	0.0835	0.0865	0.0873
Distribution Coefficient												
X_{ca}/X_{cb}	0.3259	0.2290	0.1614	0.1387	0.1208	0.1162	0.1142	0.1114	0.1108	0.1103	0.1087	0.1058

*All compositions are given in weight per cent.

TABLE 66

BUTYRIC ACID - BENZENE - WATER - 9.287 % POTASSIUM CHLORIDE

RUN NUMBER	41-1	41-2	41-5	41-10	41-15	41-20	41-25	41-30	41-35	41-40	41-50	41-60
Composition of Initial Mixture*												
Butyric Acid	2.432	4.732	10.977	19.777	26.987	33.006	38.205	42.550	46.360	49.686	55.225	59.698
Benzene	44.265	43.120	40.218	36.285	33.002	30.290	28.052	25.987	24.299	22.821	20.267	18.236
Water	48.353	47.305	44.272	39.858	36.295	33.295	30.686	28.541	26.616	24.940	22.233	20.016
Potassium Chloride	4.950	4.843	4.532	4.081	3.716	3.408	3.142	2.922	2.725	2.552	2.276	2.049
Composition of Aqueous Phase*												
Butyric Acid	1.114	1.620	2.593	3.690	4.464	4.900	5.333	5.576	5.720	5.950	5.998	6.120
Benzene	0.08	0.12	0.18	0.13	0.17	0.23	0.25	0.22	0.27	0.29	0.31	0.35
Water	89.97	89.55	88.50	87.47	86.61	86.02	85.37	85.00	84.67	84.23	83.39	82.61
Potassium Chloride	8.841	8.717	8.733	8.713	8.764	8.852	9.052	9.214	9.342	9.535	10.32	10.43
Composition of Organic Phase*												
Butyric Acid	4.108	8.425	19.68	33.59	43.48	50.49	55.40	59.52	62.84	65.30	68.71	71.21
Benzene	95.77	91.41	79.97	65.69	55.32	47.71	42.18	37.47	33.47	30.46	26.91	22.45
Water	0.117	0.158	0.338	0.702	1.18	1.78	2.39	3.08	3.64	4.18	5.32	6.21
Potassium Chloride	0.008	0.009	0.013	0.018	0.020	0.023	0.027	0.034	0.041	0.061	0.074	0.124
Hand Coordinates												
X_{cb}/X_{bb}	0.0254	0.0922	0.248	0.511	0.785	1.072	1.313	1.590	1.870	2.15	2.55	3.17
X_{ca}/X_{aa}	0.01279	0.01859	0.0297	0.0426	0.0518	0.0569	0.0625	0.0655	0.0675	0.0706	0.0715	0.0733
Distribution Coefficient												
X_{ca}/X_{cb}	0.2713	0.1923	0.1331	0.1099	0.1027	0.0970	0.0963	0.0937	0.0911	0.0910	0.0873	0.0859

*All compositions are given in weight per cent.

TABLE 67

BUTYRIC ACID - BENZENE - WATER - 13.74 % POTASSIUM CHLORIDE

RUN NUMBER	48-1	48-2	48-5	48-10	48-15	48-20	48-20	48-30	48-35	48-40	48-50	48-60
Composition of Initial Mixture*												
Butyric Acid	2.396	4.644	10.832	19.572	26.751	32.669	37.795	42.153	45.947	49.278	54.836	59.261
Benzene	43.519	42.387	39.742	35.792	32.689	29.970	27.736	25.753	24.110	22.597	20.123	18.115
Water	46.658	45.691	42.634	38.503	34.988	32.228	29.733	27.685	25.829	24.260	21.600	19.516
Potassium Chloride	7.432	7.278	6.791	6.133	5.573	5.134	4.736	4.410	4.114	3.864	3.441	3.109
Composition of Aqueous Phase*												
Butyric Acid	0.894	1.307	2.095	2.938	3.513	3.867	4.170	4.345	4.559	4.736	4.740	4.746
Benzene	0.07	0.05	0.04	0.09	0.14	0.13	0.10	0.17	0.22	0.22	0.24	0.29
Water	85.72	85.39	84.65	83.80	83.23	82.78	82.39	82.03	81.40	80.91	80.28	97.47
Potassium Chloride	13.32	13.26	13.22	13.18	13.12	13.23	13.34	13.46	13.83	14.12	14.64	15.49
Composition of Organic Phase*												
Butyric Acid	4.280	8.702	20.03	34.15	43.89	50.84	56.36	60.37	63.25	65.76	69.60	72.21
Benzene	95.69	91.13	79.62	65.09	54.89	47.50	41.35	36.77	33.36	30.39	25.52	22.08
Water	0.122	0.155	0.328	0.734	1.19	1.64	2.26	2.81	3.34	3.78	4.78	5.56
Potassium Chloride	0.007	0.013	0.016	0.023	0.025	0.028	0.040	0.047	0.053	0.069	0.092	0.147
Hand Coordinates												
X_{cb}/X_{bb}	0.0428	0.0955	0.251	0.525	0.800	1.092	1.361	1.640	1.893	2.16	2.73	3.27
X_{ca}/X_{aa}	0.01065	0.01569	0.0253	0.0356	0.0431	0.0479	0.0519	0.0539	0.0571	0.0593	0.0596	0.0598
Distribution Coefficient												
X_{ca}/X_{cb}	0.2088	0.1502	0.1046	0.0860	0.0800	0.0761	0.0740	0.0720	0.0721	0.0720	0.0681	0.0653

*All compositions are given in weight per cent.

TABLE 68

BUTYRIC ACID - BENZENE - WATER - 17.14 % POTASSIUM CHLORIDE

RUN NUMBER	49-1	49-2	49-5	49-10	49-15	49-20	49-25	49-30	49-35	49-40	49-50	49-60
Composition of Initial Mixture*												
Butyric Acid	2.377	4.588	10.709	19.343	26.448	32.481	37.523	41.896	45.704	48.999	54.624	59.055
Benzene	43.010	41.928	39.344	35.544	32.378	29.750	27.559	25.609	23.928	22.436	20.012	18.014
Water	45.252	44.317	41.387	37.381	34.116	31.296	28.934	26.925	25.163	23.669	21.017	19.001
Potassium Chloride	9.361	9.167	8.561	7.732	7.057	6.474	5.985	5.570	5.205	4.896	4.348	3.930
Composition of Aqueous Phase*												
Butyric Acid	0.766	1.109	1.784	2.454	2.932	3.232	3.512	3.759	3.846	3.930	3.968	4.020
Benzene	0.10	0.10	0.07	0.05	0.10	0.14	0.19	0.16	0.17	0.21	0.25	0.23
Water	82.64	82.37	81.70	81.03	80.44	79.92	79.42	79.15	78.84	78.17	77.44	76.74
Potassium Chloride	16.50	16.43	16.47	16.49	16.53	16.71	16.88	16.93	17.15	17.69	18.35	19.01
Composition of Organic Phase*												
Butyric Acid	4.489	8.858	20.37	33.65	44.09	51.15	55.16	60.41	63.79	65.97	70.20	72.81
Benzene	95.50	90.98	79.30	65.66	54.87	47.93	42.74	36.99	33.10	30.51	25.18	23.12
Water	0.103	0.151	0.317	0.685	1.12	1.62	2.06	2.55	3.07	3.45	4.51	4.91
Potassium Chloride	0.010	0.016	0.020	0.023	0.028	0.037	0.042	0.052	0.059	0.079	0.106	0.162
Hand Coordinates												
X_{cb}/X_{bb}	0.0470	0.0974	0.257	0.510	0.805	1.071	1.291	1.632	1.928	2.28	2.79	3.15
X_{ca}/X_{aa}	0.00948	0.01387	0.0217	0.0313	0.0374	0.0414	0.0452	0.0488	0.0491	0.0517	0.0527	0.0536
Distribution Coefficient												
X_{ca}/X_{cb}	0.1706	0.1252	0.0876	0.0729	0.0665	0.0641	0.0637	0.0623	0.0603	0.0596	0.0565	0.0552

*All compositions are given in weight per cent.

TABLE 69

BUTYRIC ACID - BENZENE - WATER - 21.00 % POTASSIUM CHLORIDE

RUN NUMBER	50-1	50-2	50-5	50-10	50-15	50-20	50-25	50-30	50-35	50-40	50-50	50-60
Composition of Initial Mixture*												
Butyric Acid	2.361	4.500	10.585	19.146	26.230	32.158	37.160	41.557	45.333	48.634	54.251	58.692
Benzene	42.387	41.477	38.823	35.103	32.095	29.481	27.278	25.379	23.716	22.308	19.886	17.924
Water	43.649	42.678	39.967	36.144	32.923	30.305	28.094	26.121	24.451	22.956	20.432	18.474
Potassium Chloride	11.603	11.345	10.624	9.608	8.752	8.056	7.468	6.943	6.500	6.102	5.431	4.911
Composition of Aqueous Phase*												
Butyric Acid	0.637	0.910	1.465	2.021	2.375	2.685	2.817	2.906	2.994	3.180	3.284	3.332
Benzene	0.04	0.00	0.01	0.08	0.09	00.14	0.13	0.18	0.12	0.17	0.22	0.24
Water	78.96	78.75	78.25	77.58	77.14	76.59	76.35	76.12	75.75	75.26	74.76	74.25
Potassium Chloride	20.37	20.34	20.28	20.32	20.40	20.59	20.71	20.80	21.14	21.39	21.74	22.18
Composition of Organic Phase*												
Butyric Acid	4.460	9.019	22.08	34.50	44.56	51.47	57.23	60.88	63.91	66.61	70.73	73.85
Benzene	95.25	90.82	77.60	64.82	54.40	47.13	40.71	36.76	33.31	30.24	25.44	21.77
Water	0.101	0.144	0.304	0.652	1.03	1.46	2.01	2.29	2.66	3.05	3.68	4.20
Potassium Chloride	0.012	0.018	0.022	0.026	0.030	0.036	0.044	0.065	0.073	0.096	0.151	0.182
Hand Coordinates												
X_{cb}/X_{bb}	0.0487	0.0994	0.284	0.532	0.819	1.091	1.406	1.659	1.920	2.20	2.78	3.39
X_{ca}/X_{aa}	0.00832	0.01188	0.01931	0.0267	0.0316	0.0359	0.0380	0.0395	0.0410	0.0438	0.0464	0.0467
Distribution Coefficient												
X_{ca}/X_{cb}	0.1372	0.1009	0.0664	0.0586	0.0533	0.0522	0.0492	0.0477	0.0468	0.0477	0.0464	0.0451

*All concentrations are given in weight per cent.

TABLE 70

ACETIC ACID - BENZENE - WATER - LITHIUM CHLORIDE

SALTING OUT CONSTANT IN SETSCHENOW EQUATION

X_{CB}	s^o	1.970% Lithium Chloride			5.743% Lithium Chloride		
		s	X_{ss}	k_{ss}	s	X_{ss}	k_{ss}
4	0.460	0.403	0.0201	6.57	0.326	0.0611	5.63
6	0.678	0.586	0.0201	7.38	0.474	0.0611	5.65
8	0.890	0.778	0.0201	6.61	0.625	0.0611	5.76
10	1.100	0.970	0.0201	6.21	0.785	0.0611	5.69
12	1.310	1.165	0.0201	5.77	0.950	0.0611	5.27
14	1.523	1.358	0.0201	5.68	1.117	0.0611	5.09
16	1.740	1.550	0.0201	5.68	1.283	0.0611	4.97
18	1.948	1.740	0.0201	5.68	1.450	0.0611	4.85
20	2.165	1.933	0.0201	5.64	1.617	0.0611	4.76
22.	2.375	2.120	0.0202	5.63	1.783	0.0612	4.72
24	2.590	2.310	0.0203	5.64	1.949	0.0614	4.64
26	2.800	2.500	0.0204	5.63	2.115	0.0616	4.57

TABLE 71

ACETIC ACID - BENZENE - WATER - LITHIUM CHLORIDE

SALTING OUT CONSTANT IN SETSCHENOW EQUATION

		9.118% Lithium Chloride			13.68% Lithium Chloride		
X_{CB}	s^o	s	X_{ss}	k_{ss}	s	X_{ss}	k_{ss}
4	0.460	0.265	0.1002	5.54	0.200	0.1587	5.25
6	0.678	0.390	0.1002	5.55	0.285	0.1587	5.43
8	0.890	0.505	0.1002	5.66	0.374	0.1587	5.43
10	1.100	0.632	0.1002	5.55	0.469	0.1587	5.40
12	1.310	0.763	0.1002	5.42	0.563	0.1587	5.32
14	1.523	0.899	0.1002	5.38	0.673	0.1588	5.14
16	1.740	1.032	0.1002	5.29	0.781	0.1589	5.06
18	1.948	1.173	0.1003	5.20	0.893	0.1590	4.91
20	2.165	1.322	0.1004	5.06	1.006	0.1591	4.91
22	2.375	1.472	0.1006	4.78	1.123	0.1593	4.72
24	2.590	1.630	0.1008	4.56	1.248	0.1596	4.59
26	2.800	1.793	0.1010	4.43	1.383	0.1599	4.40

TABLE 72

ACETIC ACID - BENZENE - WATER - LITHIUM CHLORIDE

SALTING OUT CONSTANT IN SETSCHENOW EQUATION

X_{CB}	s^o	17.61% Lithium Chloride			21.23% Lithium Chloride		
		s	X_{ss}	k_{ss}	s	X_{ss}	k_{ss}
4	0.460	0.170	0.214	4.69	0.143	0.270	4.33
6	0.678	0.229	0.214	5.09	0.187	0.270	4.77
8	0.890	0.290	0.214	5.25	0.238	0.270	4.89
10	1.100	0.358	0.214	5.25	0.284	0.270	5.02
12	1.310	0.427	0.214	5.25	0.337	0.270	5.03
14	1.523	0.502	0.214	5.19	0.394	0.270	5.02
16	1.740	0.587	0.214	5.09	0.455	0.270	4.98
18	1.948	0.679	0.215	4.92	0.528	0.270	4.84
20	2.165	0.773	0.215	4.78	0.602	0.271	4.74
22	2.375	0.869	0.215	4.69	0.680	0.272	4.64
24	2.590	0.968	0.215	4.46	0.764	0.272	4.52
26	2.800	1.073	0.216	4.46	0.862	0.273	4.37

TABLE 73

ACETIC ACID - BENZENE - WATER - ALKALI CHLORIDES

SALTING OUT CONSTANT IN SETSCHENOW EQUATION

X_{CB}	s^o	5.863% Sodium Chloride			9.287% Potassium Chloride		
		s	X_{ss}	k_{ss}	s	X_{ss}	k_{ss}
4	0.460	0.360	0.0623	4.75	- - -	- - -	- -
6	0.678	0.505	0.0623	4.32	0.620	0.1028	0.856
8	0.890	0.680	0.0623	3.79	0.820	0.1028	0.810
10	1.100	0.860	0.0623	3.74	1.015	0.1028	0.793
12	1.310	1.035	0.0623	3.68	1.215	0.1028	0.731
14	1.523	1.220	0.0623	3.68	1.415	0.1028	0.712
16	1.740	1.395	0.0623	3.44	1.615	0.1028	0.731
18	1.948	1.575	0.0623	3.38	1.810	0.1028	0.704
20	2.165	1.760	0.0623	3.33	2.010	0.1028	0.731
22	2.375	1.940	0.0624	3.26	2.210	0.1028	0.701
24	2.590	2.120	0.0624	3.19	2.415	0.1030	0.726
26	2.800	2.310	0.0625	3.13	2.615	0.1032	0.680

REGRESSION ANALYSIS

Equation:

$$\text{Log } Y = \text{Log } A + B \log X$$

$$\left[\hat{y} = a + b\,x\right]$$

Data:

x	x_1	x_2	x_3	$\cdots$	x_n
y	y_1	y_2	y_3	$\cdots$	y_n

Definitions:

N = total number of data points

$\Sigma x = x_1 + x_2 + x_3 + \ldots + x_n$

$\Sigma y = y_1 + y_2 + y_3 + \ldots + y_n$

$\Sigma x^2 = x_1^2 + x_2^2 + x_3^2 + \ldots + x_n^2$

$\Sigma y^2 = y_1^2 + y_2^2 + y_3^2 + \ldots + y_n^2$

$\Sigma' x^2 = (x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + (x_3 - \bar{x})^2 + \ldots + (x_n - \bar{x})^2$

$\Sigma' y^2 = (y_1 - \bar{y})^2 + (y_2 - \bar{y})^2 + (y_3 - \bar{y})^2 + \ldots + (y_n - \bar{y})^2$

$\Sigma' xy = (x_1 - \bar{x})(y_1 - \bar{y}) + (x_2 - \bar{x})(y_2 - \bar{y}) + (x_3 - \bar{x})(y_3 - \bar{y}) + \ldots +$
$(x_n - \bar{x})(y_n - \bar{y})$

$\Sigma xy = x_1y_1 + x_2y_2 + x_3y_3 + \ldots + x_ny_n$

$$\bar{x} = \frac{\sum x}{N}$$

$$\bar{y} = \frac{\sum y}{N}$$

$$\sum{}' C^2 = b \sum{}' xy$$

$$s^2(C) = r^2 \sum{}' y^2$$

$$s^2(b) = \frac{s^2(\hat{y})}{\sum{}' x^2}$$

Slope (In equation $\hat{y} = a + b\,x$):

$$b = \frac{\sum{}' xy}{\sum{}' x^2}$$

Intercept (In equation $\hat{y} = a + b\,x$):

$$a = \bar{y} - b\,\bar{x}$$

Correlation Coefficient:

$$r = \sqrt{\frac{\sum{}' C^2}{\sum{}' y^2}}$$

Variance of Estimate:

$$s^2(\hat{y}) = \frac{(1 - r^2) \sum{}' y^2}{N - 2}$$

Standard Error of Estimate:

$$s(\hat{y}) = \sqrt{\frac{(1 - r^2) \sum' y^2}{N - 2}}$$

Standard Error in Slope b:

$$s(b) = \sqrt{\frac{s^2(\hat{y})}{\sum' x^2}}$$

The statistic t:

$$t = \frac{b}{s(b)}$$

COMPUTER PROGRAM

```
C       LINEAR REGRESSION (IN TWO VARIABLES)  -  LEAST SQUARES FIT
    104 FORMAT(///5H FOR I4,14H  OBSERVATIONS)
    106 FORMAT(/26X,7H Y  =  F10.4,5H    +F10.4,3H  X)
    108 FORMAT(/26X,7H Y  =  F10.4,3H  X)
    110 FORMAT(/35X,8H MEAN = F10.4)
    111 FORMAT(/16X,27H CORRELATION COEFFICIENT = F10.7)
    112 FORMAT(/13X,30H STANDARD ERROR OF ESTIMATE = F10.4)
    113 FORMAT(/43H       STANDARD ERROR OF COEFFICIENT,  B  = F10.7)
    114 FORMAT(/23X,20H THE STATISTIC  T = F10.5)
    116 FORMAT(/25H TABLE SHOULD BE CHECKED F6.0,19H DEGREES OF FREEDOM
    117 FORMAT(/16X,27H STANDARD DEVIATION OF X = F10.5)
    118 FORMAT(/16X,27H STANDARD DEVIATION OF Y = F10.5)
    119 FORMAT(///49H ESTIMATION DATA FOR EQUATION RELIABILITY STUDIES)
    120 FORMAT(/I4,F10.4,F10.5,F10.4,F10.5,F10.4,F10.5)
    121 FORMAT(/I4,F10.4,F10.5,F10.4,F10.5,F10.4,F10.5,8H BAD OBS)
    122 FORMAT(///9X,1HY,8X,2HDY,9X,1HX,8X,2HDX,7X,5HY EST,4X,6HDY EST)
    123 FORMAT(///18H CASE IS COMPLETED)
  125 FORMAT(/24X, 13H SALT CONC =   F10.3, 15H  LICL NACL KCL  )
    3 READ,N,M
      4 EN=N
        EM=M
        SX=0.
        SY=0.
        SXY=0.
        SX2=0.
        SY2=0.
        DO5I=1,N
       READ,XS,AA,BB
       X=  .4343*LOG(AA)
       Y= .4343*LOG(BB)
        SX=SX+X
        SY=SY+Y
        SXY=SXY+X*Y
        SX2=SX2+X*X
      5 SY2=SY2+Y*Y
        XBAR=SX/EN
        YBAR=SY/EN
        CX2=SX*SX/EN
        CXY=SX*SY/EN
        VX2=SX2-CX2
        VXY=SXY-CXY
        B=VXY/VX2
        A=YBAR-B*XBAR
        C=SXY/SX2
        R=(((EN*SXY-SX*SY)**2)/((EN*SX2-SX*SX)*(EN*SY2-SY*SY)))**.5
        IF(R)6,7,7
      6 RA=-R
        GO TO 8
      7 RA=R
      8 S2SX=(EN*SX2-SX*SX)/(EN*(EN-1.))
        S2SY=(EN*SY2-SY*SY)/(EN*(EN-1.))
  YGX=((EN-1.)/(EN-2.))*(S2SY-B*B*S2SX)
       SYGX=YGX**.5
        SB=SYGX/((S2SX*(EN-1.))**.5)
        IF(B)9,10,10
      9 BA=-B
        GO TO 11
     10 BA=B
```

```
   11 T=BA/SB
      IF(T)12,13,13
   12 TA=-T
      GO TO 14
   13 TA=T
   14 DF2=EN-2.
      SEX=((SX2-SX*SX/EN)/(EN-1.))**.5
      SEY=((SY2-SY*SY/EN)/(EN-1.))**.5
      PUNCH, XS, N
     PUNCH106,A,B
     PUNCH, C,XBAR
      PUNCH, SEX, SEY
      PUNCH, RA, SYGX, SB
      PUNCH, TA,DF2
     IF(SENSESWITCH3)16,3
   16 SEXM=SEX*EM
      SEYM=SEY*EM
      SGM=SYGX*EM
      DO31I=1,N
      KW=0
     READ, XS,AA,BB
     Y=   .4343*LOG(BB)
      X=   .4343*LOG(AA)
      YES=A+B*X
      SDO=Y-YES
      IF(XD)17,18,18
   17 XD=-XD
   18 IF(YD)19,20,20
   19 YD=-YD
   20 IF(SDO)21,22,22
   21 SDO=-SDO
   22 IF(XD-SEXM)24,24,23
   23 KW=1
      GOTO28
   24 IF(YD-SEYM)26,26,25
   25 KW=1
      GOTO28
   26 IF(SDO-SGM)28,28,27
   27 KW=1
   28 IF(I-1)282,281,282
 281  PUNCH119
     PUNCH122
  282 IF(KW)29,29,30
   29 PUNCH120,I,Y,YD,X,XD,YES,SDO
      GOTO31
   30  PUNCH120,I,Y,YD,X,XD,YES,SDO
   31 CONTINUE
     PUNCH123
      STOP
      END
```

COMPARISON OF HAND CORRELATION AND SETSCHENOW EQUATION

The equation of Setschenow, as employed by Swabb and Mongan, may be written

$$\log \frac{\left[\frac{X_{CA}}{X_{AA}}\right]_{sf}}{\left[\frac{X_{CA}}{X_{AA}}\right]_{s}} = k_{ss} \frac{X_{DA}}{X_{AA}} \qquad (69)$$

where the subscript sf refers to the salt-free system and the subscript s refers to the system containing salt. The Hand correlation is written for the salt-free system (equation 70) and for the system containing salt, equation 71.

$$\log \left[\frac{X_{CB}}{X_{BB}}\right]_{sf} = \log A_{sf} + B_{sf} \log \left[\frac{X_{CA}}{X_{AA}}\right]_{sf} \qquad (70)$$

$$\log \left[\frac{X_{CB}}{X_{BB}}\right]_{s} = \log A_{s} + B_{s} \log \left[\frac{X_{CA}}{X_{AA}}\right]_{s} \qquad (71)$$

Equations 70 and 71 are solved in terms of X_{CA}/X_{AA}.

$$\log \left[\frac{X_{CA}}{X_{AA}}\right]_{sf} = -\frac{1}{B_{sf}} \log A_{sf} + \frac{1}{B_{sf}} \log \left[\frac{X_{CB}}{X_{BB}}\right]_{sf} \qquad (72)$$

$$\log \left[\frac{X_{CA}}{X_{AA}}\right]_{s} = -\frac{1}{B_{s}} \log A_{s} + \frac{1}{B_{s}} \log \left[\frac{X_{CB}}{X_{BB}}\right]_{s} \qquad (73)$$

Equation 73 is subtracted from equation 72 and rearranged

$$\log \frac{\left[\frac{X_{CA}}{X_{AA}}\right]_{sf}}{\left[\frac{X_{CA}}{X_{AA}}\right]_{s}} = \frac{1}{B_{sf}B_{s}} B_{sf} \log A_{sf} - B_{s} \log A_{s} + B_{s} \log \left[\frac{X_{CB}}{X_{BB}}\right]_{sf} - B_{sf} \log \left[\frac{X_{CB}}{X_{BB}}\right]_{s} \qquad (74)$$

But $$\left[\frac{X_{CB}}{X_{BB}}\right]_{sf} = \left[\frac{X_{CB}}{X_{BB}}\right]_{s} \qquad (75)$$

$$B_{sf} = (c + d\, X_{s}')_{sf} \qquad (76)$$

$$B_{s} = (c + d\, X_{s}')_{s} \qquad (77)$$

$$\log A_{sf} = (a + b\, X_{s}')_{sf} \qquad (78)$$

$$\log A_{s} = (a + b\, X_{s}')_{s} \qquad (79)$$

Since B_{sf} and $\log A_{sf}$ are written for the salt-free solutions, X_s is 0, and $B_{sf} = c$; $\log A_{sf} = a$.

$$\log \frac{\left[\frac{X_{CA}}{X_{AA}}\right]_{sf}}{\left[\frac{X_{CA}}{X_{AA}}\right]_{s}} = \frac{X_{s}'}{c(c + d\, X_{s}')} \left[cb - ad + d \log \frac{X_{CB}}{X_{BB}} \right] \qquad (80)$$

Since X_s' is weight per cent $= \frac{X_{DA}}{X_{AA} + X_{DA}} \times 100\%$, multiplication of equation 69 by $\frac{X_{AA}}{(0.01)\, X_{AA} + X_{DA}}$ and introduction of a new new constant k_s' gives

$$\log \frac{\left[\frac{X_{CA}}{X_{AA}}\right]_{sf}}{\left[\frac{X_{CA}}{X_{AA}}\right]_{s}} = k_s' X_s' \tag{81}$$

Combining equations 80 and 81 shows that

$$k_s' = \frac{1}{c(c + d\, X_s')} \left[cb - ad + d \log \frac{X_{CB}}{X_{BB}} \right] \tag{82}$$

SUPPLIERS OF CHEMICALS

J. T. Baker Chemical Company

("Baker Analyzed" Reagent Grade)

- Lithium Chloride
- Sodium Chloride
- Potassium Chloride
- Acetic Acid - Glacial
- Benzene - Thiophene Free
- Sodium Hydroxide - Low in Carbonate
- Methanol - Anhydrous
- Silver Nitrate

Mallinckrodt Chemical Works

(A. R. Primary Standard Grade)

- Potassium Acid Phthalate

Matheson, Coleman and Bell, Inc.

- Dichlorofluorescein

Fisher Scientific Company

("Fisher Certified" Reagent Grade)

- Karl Fischer Reagent - Stabilized
- Water in Methanol Standard
- Phenolphthalein Indicator Solution

Union Carbide Chemicals Company

Propionic Acid

Butyric Acid

Specification Limits

	Propionic Acid	Butyric Acid
Distillation 760 mm		
ibp	138.5°C min	158.0°C min
Dp	142.5°C min	165.0°C max
Per Cent Acid, by weight	99.5 % min	99.0 % min
Specific Gravity 20°C/20°C	0.993 to 0.997	0.957 to 0.961
Color, platinum-cobalt	15 max	15 max
Suspended matter	substantially free	substantially free
Flash point, open cup	136°F	170°F
Chlorides	- - - -	nil
Heavy metals, as Pb	5 ppm max	- - - -
Aldelhydes, as propionaldehyde	0.05 % max	- - - -
Water	0.15 % max	- - - -
Non-Volatile matter	0.010% max	- - - -
Oxidizables, as formic acid	0.05 % max	- - - -

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