

KURROL'S SALTS

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Abstract. The reaction and application chemistry of alkali metal Kurrol's salts is briefly reviewed. Attention is directed toward the phase state and structure of potassium Kurrol's salts crystallized from ultraphosphate melts. The distribution of phosphates between crystalline and amorphous phases is analysed. Equations are derived to predict the theoretical limits for how much crystalline and amorphous phases will result when potassium Kurrol's salt is crystallized from systems of varying concentrations of phosphoric oxide in an ultraphosphate phase system.

Key words: phosphates, alkali metal poly-, meta- and ultraphosphates.

I. INTRODUCTION

In the late 1880's, Gustav Tammann, a famous physical chemist, initiated studies of metaphosphates while he was still a laboratory assistant. He prepared more than forty metaphosphate compositions, measured their properties, and calculated formulas for the compositions. Unfortunately, many of the compounds reported by Tammann do not exist. At the time Tammann did his work phosphate science had not developed sufficiently to distinguish pure compounds from overall compositions. Nevertheless, his work provided the background for developments that continue until today.

In 1890 Tammann defended his Doctor's thesis, *Metamerism of Metaphosphates*. He published his results [1–3]. Later (1892–1902) he became the head of the Department of Chemistry of Tartu (Dorpat) University. Julius Kurrol was one of Dr. Tammann's assistants at Tartu. In the course of his studies Kurrol heated monosodium orthophosphate, NaH_2PO_4 . He observed that the salt first melts and then recrystallizes to a "porcelain-like" mass that remelts when heated to higher temperatures. If the melt of the "porcelain-like" mass is slowly cooled it crystallizes to a long chain sodium polyphosphate with a metaphosphate composition, $[\text{NaPO}_3]_n$. The salt is very slowly soluble in pure water, but is much more rapidly soluble in solutions containing diverse alkali metal ions, such as lithium, potassium, etc. Tammann named the fibrous salt for Julius Kurrol, its discoverer.

Julius Kurrol was born in Pärnu, Livonia, in 1865. Livonia was a province of Russia and its northern part now belongs to the Republic of Estonia. He studied at Pärnu High School (1876–1883) and at Tartu University (1883–1891) [4]. In 1891 he successfully defended his Candidate's thesis, *Insoluble Sodium and Potassium Metaphosphates*.

The name, Kurrol, could not be found in the **author index** of either *Chemical Abstracts* or *Chemisches Zentralblatt*. Little is known of his life after his graduation from the university. Even a rigid definition of a Kurrol's salt is as elusive as the chemist for whom the compounds are named.

J. R. Van Wazer wrote an excellent, well documented history of Kurrol's salts in *Phosphorus and Its Compounds* [5]. There is little more, if anything, that can be added to the classic works of Van Wazer to improve the historical overview. Attention will be directed to the chemistry, patents, and uses of Kurrol's salts developed after 1958.

Only two alkali metal polyphosphates are usually referred to as Kurrol's salts. These are sodium and potassium salts, but there are similar compounds for each of the alkali metals. The literature dealing with these salts is extensive. An incomplete search yielded more than one thousand citations. No attempt will be made to review more than a small part of the literature and much of the work reviewed will be that of the senior author.

Kurrol's salts will be defined in the following way. The name will be restricted to the $[\text{NaPO}_3]_n$ and $[\text{KPO}_3]_n$ systems. They are crystalline polyphosphates with a $\text{M}_2\text{O}-\text{P}_2\text{O}_5$ ratio of unity, composed of very long chain helixes, and the crystals are fibrous when crushed or milled. There are two crystal forms of the sodium Kurrol's salt and it has been reported that there are three forms of the potassium salt^[6,7], but there is no indication of a phase transition of $[\text{KPO}_3]_n$ in the $\text{K}_2\text{O}-\text{P}_2\text{O}_5$ phase diagram [8]. In our laboratory the preparation of hundreds of potassium Kurrol's salt samples, under a wide variety of conditions, has always yielded one unique X-ray powder pattern. Kurrol's salts differ from Maddrell's salts in the way the chains pack into the crystal lattice and Kurrol's salts are usually, but not always, more fibrous. There is no potassium Maddrell's salt.

II. PREPARATION OF KURROL'S SALTS

A. Background

Kurrol's salts are usually prepared by heating monophosphates, MH_2PO_4 , to temperatures above 200°C , where $\text{M}=\text{Na}$ or K , but similar compounds can be prepared when M is Li , Rb , or Cs . M is defined as one equivalent of metal ion. In cases, as with sodium, where Kurrol's salt is not a thermodynamically stable salt in its phase system, more involved heating regimes are required^[9,10].

Kurrol's salts are very long chain polyphosphates of a metaphosphate composition, $[\text{MPO}_3]_n$. The $\text{M}_2\text{O}/\text{P}_2\text{O}_5$ ratio is equal to unity in the crystalline salt, but not necessarily in the melt system from which the crystals are grown [11]. Whether Kurrol's salts are grown from systems rich in metal oxide, K_2O , or in systems slightly depleted of metal oxides (ultraphosphate melts), has a pronounced influence on aqueous solution properties of these phosphates.

Potassium Kurrol's salt is interesting because it is the unique salt in the $\text{K}_2\text{O}-\text{P}_2\text{O}_5$ phase system with a $\text{M}_2\text{O}-\text{P}_2\text{O}_5$ ratio of unity. These potassium systems with $\text{K}_2\text{O}-\text{P}_2\text{O}_5$ ratios of 1 or greater are extremely difficult to quench to a clear glass because the systems crystallize almost instantaneously. The corresponding sodium system exhibits two forms of sodium Kurrol's salt, two forms of Maddrell's salt, several

forms of cyclic sodium triphosphate and Graham's salt, a clear glass, if the melt system is quenched rapidly.

The hydrogen phosphate system contains no crystals of polyphosphates with chains greater than two, although it was claimed that crystalline $[\text{HPO}_3]_n$ can be prepared [12]. All attempts to prepare this acid have failed and the crystals were probably SiP_2O_7 . Two commercial forms of ammonium polyphosphates, used in intumescent paints and as fire retardants, are also similar to Kurrol's salts.

Potassium Kurrol's salt when prepared in an ultraphosphate melt has been called cross-linked Kurrol's salt, but some recent work questions whether or not cross-linked Kurrol's salt is a stable crystalline phase. These salts are probably polyphosphates of super long chains, but may also contain very small levels of cross-linking [11]. This can be presumed by the behaviour of calcium polyphosphates grown under similar conditions while preparing phosphate fibres [13-15].

B. Experimental Studies

When pure monopotassium orthophosphate, KH_2PO_4 , is heated to a melt and allowed to crystallize, in theory, 100% crystalline Kurrol's salt can be obtained. If small quantities of KOH or K_2CO_3 are added to KH_2PO_4 and the experiment repeated, in theory, a 100% crystalline system can be obtained that is a mixture of potassium Kurrol's salt and $\text{K}_3\text{P}_3\text{O}_{10}$, potassium triphosphate. The composition of this system is easily calculated and theory agrees with experimental results. If, however, H_3PO_4 or P_4O_{10} is added to KH_2PO_4 and the experiment repeated, the new results are not as easily predictable. $[\text{KPO}_3]_n$ is the only potassium phosphate known to crystallize in anhydrous systems in which the $\text{K}_2\text{O}-\text{P}_2\text{O}_5$ ratio is less than unity. The tempered and cooled system is therefore composed of $[\text{KPO}_3]_n$ crystals suspended in an ultraphosphate amorphous matrix.

In this work a large stock sample of potassium Kurrol's salt, $[\text{KPO}_3]_n$, with an $\text{M}_2\text{O}-\text{P}_2\text{O}_5$ ratio of unity was prepared by heating KH_2PO_4 to a melt at 850°C and the melt was then allowed to crystallize. To prepare systems with $\text{K}_2\text{O}-\text{P}_2\text{O}_5$ ratios less than unity the required amounts of P_4O_{10} were thoroughly mixed with Kurrol's salt in a sealed container before the mixture was heated to a clear melt in an open dish. It is usually advantageous to use $[\text{KPO}_3]_n$ and P_4O_{10} , because water is difficult to remove from the system, unless the salt is crystallized twice, as it is when starting with crystalline $[\text{KPO}_3]_n$.

Assume that when preparing cross-linked Kurrol's salt, all phosphoric oxide added to crystalline $[\text{KPO}_3]_n$ enters potassium Kurrol's salt as a cross-linking agent. Assume that all phosphate crystallizes to cross-linked Kurrol's salt. If these assumptions are true, cross-linked Kurrol's salt is an ultraphosphate and not a polyphosphate. Moreover, there must be two different compounds present in the phase system, exhibiting different X-ray patterns.

Two different compounds, one cross-linked, one linear chains, do not appear in the phase diagram, nor could a crystalline compound other than potassium Kurrol's salt be found in the systems. The only other choices are: 1) an amorphous phase is formed or 2) some new undetected crystalline potassium ultraphosphate is formed. No other crystalline potassium ultraphosphates are known, and no new ones were discovered in this work. Both phase studies and X-ray analyses suggest that an amorphous phase is formed in all potassium Kurrol's salt systems crystallized in the ultraphosphate phase systems.

In an ultraphosphate the number of triply connected POP linkages can be calculated from the equation,

$$N_x = (P - M)/2 \quad (1)$$

where N_x is the number of POP linkages in excess of the metaphosphate composition [13], P is the number of phosphorus atoms or moles and M is the number of equivalents of ions or cationic groups associated with the phosphate. The $M_2O-P_2O_5$ ratio $r = M/P$. In a metaphosphate there is one POP linkage per phosphorus atom. It is therefore possible to calculate the number of linkages in any phosphate system if the $M_2O-P_2O_5$ ratio is known [16].

C. Structural Considerations

All single chains in a polyphosphate system can be linked together to form double chains by adding only one PO_3 cross-linking group for each two chains. Moreover, only one PO_3 group must be added per chain to build an infinite network of connected chains. For example, assume that a Kurrol's salt with an average chain length of 5,000 is mixed with P_4O_{10} to cross-link the system. One P atom in 5001 P atoms, or 0.02% of the phosphorus in the system must come from added P_4O_{10} . Then $r = 0.9998$. Any phosphate, PO_3 , in excess of this value will tighten the cross-linked structure and should lessen its aqueous solution behaviour in an idealized case. (The cross-linked Kurrol's salts produce very viscous aqueous solutions even when the Kurrol's salt is dissolved to make solutions of 0.1% or less.) These facts were well recognized by Pfansteil and Iler in their classic work relating cross-linking to behaviour in aqueous solutions [17].

Polyphosphates crystallized in an ultraphosphate melt may be super long chains of linear molecules with only "defect cross-linking" [11]. Also cross-linking may be contained in an amorphous phase where it is very difficult to detect directly, rather than as a part of the crystal structure. Cross-linking is probably a random event and does not constitute a thermodynamically stable state, even in the absence of moisture. In their very carefully executed work Pfansteil and Iler demonstrated that as the $K_2O-P_2O_5$ was reduced from 0.998 the influence of cross-linking in solutions of Kurrol's salt diminished, if it was not eliminated entirely. The behaviour expected for very long chains persists after the expected behaviour for cross-linkages is gone, as judged from the viscosities of aqueous solutions obtained from salts with $K_2O-P_2O_5$ ratios below 0.98.

D. Amorphous Phase Content

A question of interest arises in predicting the ratio of amorphous phase to crystalline phase in a Kurrol's salt system prepared in the ultraphosphate region. Since Kurrol's salt is very slowly soluble in distilled water and ultraphosphate glasses are infinitely and quickly soluble in water, it is possible to estimate the quantity of amorphous phase contained in a well crystallized Kurrol's salt system. The mixture of crystalline and amorphous phases is first milled to a fine powder and then the soluble phase dissolved from the crystalline phase with distilled water. The aqueous solution is then analysed both for ratios and concentrations. The soluble part of the mixture should be amorphous since potassium Kurrol's salt is almost insoluble under these conditions.

Samples of Kurrol's salts weighing 20 g, with $K_2O-P_2O_5$ ratios ranging from 1.00 to 0.60, were stirred in 480 g of distilled water for twenty hours, at room temperature. Three methods were employed (I, II, III) to determine how much sample dissolved. The solutions were filtered from the crystalline Kurrol's salt and the $K_2O-P_2O_5$ ratios and concentration of the dissolved salt were determined.

E. Analysis

Method I: The filtered residue solids were air dried for 2 days and then weighed. The percent solubles were calculated from the differences.

Method II: A precisely weighed sample of filtered solution was mixed with a pre-ignited crucible containing ZnO and dried at 110°C for one hour, followed by heating at 550°C for 30 minutes. The cooled, desiccated samples were again weighed at room temperature.

Method III: Samples of the filtered liquids were analysed by Inductive Coupling Plasmas and Atomic Absorption. These results are presented in the Table.

A comparison of the quantity of amorphous phase by analysis and by calculation

tR Total system	gR Amorphous phase	Measured % amorphous			Calculated % amorphous
		I	II	III	
1.00	1.00*	2.20	2.55	1.17	0.00
0.98	0.77	7.50	8.92	7.19	7.96
0.94	0.77	29.65	29.17	29.59	24.27
0.75	0.66	72.90	75.05	73.79	70.60
0.65	0.61	88.22	88.77	87.86	88.08
0.60	0.59	96.67	96.04	95.93	97.10
0.50	0.50				100.00

* Analysed value

F. Theoretical

It is the objective of this section to determine the quantity of amorphous solid contained in an ideal potassium Kurrol's salt system in which the tR , the $M_2O-P_2O_5$ ratio of the total system, is less than unity.

1. It is known that at least one crystalline phase, $[KPO_3]_n$, is found in systems with ratios $1 > K_2O/P_2O_5 > 0.5$. Only one crystalline phase can be detected by X-ray analyses.
2. All attempts to crystallize ultraphosphates with $K_2O-P_2O_5$ ratios of 0.5 or less have been unsuccessful. The thermal analyses reveal an endothermic region extending from about 200°C to the "eutectic temperature" at 450°C. This amorphous region becomes more and more pronounced as the $M_2O-P_2O_5$ ratio is decreased to 0.5, where the total system is amorphous.
3. No potassium **ultraphosphates** in the composition range $1 > K_2O/P_2O_5 > 0.5$ are crystalline.
4. All ultraphosphate systems considered here have a $K_2O-P_2O_5$ mole ratio, tR , such that $1 > {}^tR > 0.5$.

It is desired to derive equations relating the crystal phase, the amorphous phase, and the total composition of the systems studied. The following notation will be used to specify phases: c for the crystalline, g for the glassy phase and t for the total system. The derivation is simpler if it is assumed that one mole of K_2O is contained in the total system and is divided between the crystalline and amorphous phases.

$${}^tR = {}^tK_2O / {}^tP_2O_5 \quad (2)$$

For ease of calculation consider two moles of KPO_3 as $K_2O \cdot P_2O_5$. Add z moles of P_2O_5 to two moles of KPO_3 to adjust the ratio, tR .

$${}^tR = \frac{K_2O}{P_2O_5 + z} \quad (3)$$

One mole of K_2O is distributed between the crystalline phases and the amorphous phases. Therefore

$${}^gK_2O + {}^cK_2O = 1 \quad (4)$$

and

$${}^gP_2O_5 + {}^cP_2O_5 = 1 + z, \quad (5)$$

$${}^tR = \frac{1}{1 + z} \quad (6)$$

${}^cR = 1$, by definition, if KPO_3 is the only crystalline phase.

$${}^gR = \frac{{}^gK_2O}{{}^gP_2O_5} = \frac{{}^gK_2O}{1 + z - {}^cP_2O_5} = \frac{1 - {}^cK_2O}{1 + z - {}^cP_2O_5} \quad (7)$$

When assumed that $[KPO_3]_n$ is the only crystalline phase then the amorphous phase must contain at least z moles of P_2O_5 . Therefore the amorphous phase must contain

$$zP_2O_5 + yP_2O_5 + yK_2O \text{ moles (gram-ions)}. \quad (8)$$

y is the moles of $2KPO_3$ dissolved into the amorphous phase.

$${}^gR = \frac{y}{z + y} \quad (9)$$

$$y = \frac{{}^gR}{1 - {}^gR} z \quad (10)$$

When ${}^gR = 0.5$, $y = z$ and the total system is amorphous. This agrees with experimental results. The phase status of the solidified melts is controlled by the $K_2O - P_2O_5$ ratio, tR , and thermal history of the sample. Recalling that z is the moles of P_2O_5 added per two moles of KPO_3 it can be shown that

$$z = \frac{1 - {}^tR}{{}^tR} \quad (11)$$

and therefore

$$y = \frac{{}^gR(1 - {}^tR)}{{}^tR(1 - {}^gR)} \quad (12)$$

When ${}^tR = 0.5$, ${}^gR = 0.5$, then $y = 1$ and the conditions correspond to a completely amorphous system.

Then under these conditions

$$y = \frac{1 - {}^tR}{{}^tR} = z. \quad (13)$$

It is possible to predict the percent of amorphous phase formed in the system provided the ratio sR is determined. From Eq. (6)

$$z = \frac{1 - {}^tR}{{}^tR} \quad (14)$$

and therefore

$$y = \frac{{}^sR}{1 - {}^sR} \times \frac{1 - {}^tR}{{}^tR} \quad (15)$$

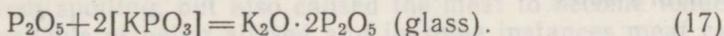
The weight percent glass in the crystallized system is then

$$\% \text{ amorphous} = \frac{236.14y + 141.94z}{236.14 + 141.94z} \times 100 \quad (16)$$

The Table compares the measured values with the predicted values for the quantity of amorphous phase formed. It is noted that even at a ratio as large as 0.98 a relatively large percentage of amorphous phase (7.96%) should be formed in a potassium Kurrol's salt system. The measured analytical results support the prediction.

The calculated results are in remarkably good agreement with the analysed values. The solubles in the sample of $[KPO_3]_n$ from the system with a ratio of unity suggest that the sample was not exactly unity or that it was not homogeneous. In the other cases the calculated value is probably better than the analytical value when the ratio of the solubles is known exactly.

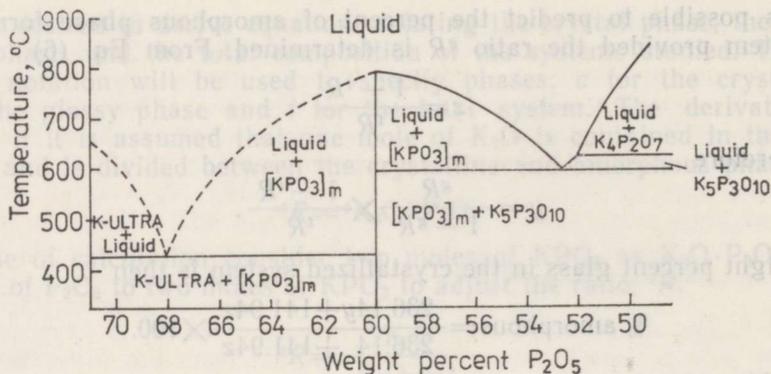
When sufficiently large quantities of P_2O_5 , z , are added to react with all of the crystalline phase in a system the reaction between potassium Kurrol's salt and P_2O_5 may be written as



Each gram of P_4O_{10} added to 1.66 grams or more of potassium Kurrol's salt forms 2.66 grams of amorphous phase when the system is heated to a melt and allowed to cool to glass. Eq. (17) is unique for the preparation of a system with a ratio of 0.50.

G. Phase Diagram

The non-equilibrium extension to the $K_2O-P_2O_5$ phase diagram [11] (Fig.) requires additional work to understand the system. The eutectic behaviour in the P_2O_5 rich portion of the diagram is probably a solubility temperature with $[KPO_3]_n$ being the only crystalline phase. All samples of Kurrol's salt subjected to thermal analysis (heating curves only) exhibited an endothermic reaction in the temperature range from 200°C to 450°C. This reaction is believed to be the thermal mobilizing of the amorphous phase and the solubilizing of crystalline $[KPO_3]_n$ at 450°C, where there is a strong endothermic reaction. No phosphate crystals of any kind can be formed in an anhydrous system with a $K_2O-P_2O_5$ ratio less than 0.5. The 0.5 ratio is the minimum ratio at which $[KPO_3]_n$ crystals can form. The "eutectic" behaviour is the dissolution of $[KPO_3]_n$ crystals in a melt with a ratio near the "eutectic" composition when the system contains less than 68% P_2O_5 . When all of the amorphous phase with a P_2O_5 concentration greater than the "eutectic" composition is depleted the temperature of the system must be increased to dissolve the remainder of the $[KPO_3]_n$ crystals in a melt that is richer in K_2O than the "eutectic" composition. This is an explanation of the behaviour of the system, but still leaves unanswered whether or not crystalline Kurrol's salts contain cross-linkages.



An extension of the $K_2O-P_2O_5$ phase diagram into the ultraphosphate region. The section labelled K-Ultra is amorphous to X-ray and is ultraphosphate glass. (Reproduced from [1].)

It is concluded that the cross-linking of Kurrol's salts is a random, transient event that occurs because the system is not at equilibrium. Allowed sufficient time these systems will become mixtures of linear $[KPO_3]_n$ molecules and an amorphous phase. A sample which was held at temperatures just below the melting point for five days lost much of the aqueous solution properties usually associated with cross-linked Kurrol's salts.

III PROPERTIES AND USES

While potassium Kurrol's salt is very simple to prepare sodium Kurrol's salt can be difficult to prepare in the laboratory. For this reason most work done with Kurrol's salts has been directed toward the potassium system. It is probably true that aqueous solutions chemistry of these salts is similar enough for most conclusions to apply to both systems, but there will surely be exceptions. Aqueous solutions of sodium or potassium Kurrol's salt can be prepared more quickly if diverse ions such as sodium, lithium, hydrogen, etc. are supplied.

A. Drag Reduction

Perhaps one of the more interesting and potentially useful properties of Kurrol's salts is their drag reducing property in aqueous solutions. A drag reducing agent is a substance that will cause a flowing liquid to resist a transition from laminar flow to turbulent flow as the rate of shear of the liquid is increased. Liquids transported in pipes are subject to turbulent flow as the velocity of the liquid is increased. Turbulent flow adds resistance to flow and costs extra energy to maintain flow velocity in a pipe. It is also true that turbulence of a medium can inhibit the movement of an object moving through the medium. Streamlining of a vehicle is a mechanical method for reducing turbulence of flow about an object. Drag reducing agents therefore allow an increase rate of flow of a medium before a turbulent transition occurs [18].

There are several useful consequences of an effective drag reducing agent. More water can be pumped through a fire-hose for the same pressure head if an effective drag reducing agent is applied. A boat can be propelled through water more rapidly for the same expenditure of energy if a drag reducing agent is pumped into the water immediately in front of a craft. A less obvious use of drag reducing agents is their injection into a filter medium. In de-watering paper pulp they cause pulp to drain drier, more quickly. It has also been learned that paper can be shredded for recycling at lower energy inputs or at more concentrated pulp slurries.

B. Bath Salts

Kurrol's salts, particularly those prepared from melts in which the R is less than unity, have a very pleasing feel to the skin when dissolved in bath water. The product has been tested extensively in this application, but has never been sold commercially for this use.

C. Foods

Kurrol's salts have been used for many years in the curing of meat, particularly ham. In this application a solution of sodium chloride and potassium Kurrol's salt was pumped into the veins of the ham to be cured. The ham was then suspended in a brine solution which caused salt and water to invade the tissue of the ham. This not only helped keep the meat from spoiling, but also caused the meat to become tender. The practice is capable of being abused and in some instances meat can be caused to absorb excessive quantities of water.

D. Medication

Potassium is vital for the proper functioning of living systems. Patients requiring medication for hypertension often have excessive loss of potassium in their urine. It is standard practice to give the patients potassium chloride to reestablish their electrolyte balance. Not only is potassium chloride extremely distasteful, but it often leads to irritation of the intestines and causes nausea.

Potassium Kurrol's salt, $(KPO_3)_n$, contains almost as high a percentage of potassium as does KCl and is very pleasant tasting. Since the Kurrol's salt degrades to the buffering agent KH_2PO_4 it helps buffer the stomach from irritation. Recently a patent was granted by the United States Patent Office for this use of potassium Kurrol's salt [19].

E. Oil Well Propping Agent

The potassium Kurrol's salts prepared in the ultraphosphate region of the phase systems produce solutions that have the property of suspending light weight solids as nut hulls. Nut hulls are often used to prop open oil well strata that have been opened by pressure fracture. The salts work well provided the water contained in an oil well is not salty. As with the drag reducing properties, potassium Kurrol's salts are easily salted out of solution and therefore lose their effectiveness in sour and salty oil wells [20].

F. Coal Slurry Pipeline Transportation

The properties of drag reduction, suspending, and deflocculation can be helpful while transporting aqueous coal slurries in pipes. Kurrol's salt has been tested in this application and performed well.

G. Draining Aids for Paper

In manufacturing paper pulp is usually suspended in water and then this water is removed from the pulp by vacuum just before the pulp is dried in an oven. It is beneficial if paper pulp is as dry as practical before it is placed in an oven. If the ovens become overloaded paper production rates are retarded.

It was learned that potassium Kurrol's salt would enhance the removal of water from pulp. Since Kurrol's salt is a drag reducing agent it reduces the resistance to flow in capillaries between fibres. This allows the water contained in paper to be vacuumed away more rapidly than would occur without Kurrol's salt treatment [21].

H. Pulping Aid for Paper

With the need for optimum utilization of resources paper recycling has become much more acceptable in recent years. To regain a pulp from used paper it is usually necessary to suspend the paper by shearing it in water. It was learned that paper could be shredded much more easily in potassium Kurrol's solutions than it could be in untreated water and that the water usage could be reduced substantially [22].

IV. CONCLUSIONS

The systems of Kurrol's salts prepared from ultraphosphate melts are composed of two phases. One is crystalline, having a $K_2O-P_2O_5$ ratio equal to unity, and the other, amorphous, with a $K_2O-P_2O_5$ ratio equal to 0.5. Kurrol's salts cannot be crystallized from systems richer in P_2O_5 than those with $R \leq 0.5$. It is yet to be determined whether the cross-linkages responsible for the extremely high viscosities of aqueous solutions of $K_2O-P_2O_5$ systems slightly less than unity reside in amorphous or crystalline phosphates.

The potential uses for Kurrol's salts are many and new uses are certain to be found as the properties of these remarkable compounds are explored in greater detail. Full use has not been made of Pfanstiel and Iler's elegant discovery of "cross-linked Kurrol's salts". The current interest in cross-linking in potassium phosphate systems is one of detail rather than general concept.

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KURROLI SOOLAD

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On esitatud ülevaade Kurroli soolade esmasünteesist Tartu Ülikoolis, nende reaktsioonidest, omadustest ja kasutamisest. On kirjeldatud ultrafosfaatide sulandist kristalliseerunud Kurroli kaaliumisoola faasiolekut ja struktuuri ning fosfaatide jaotust kristallilise ja amorfse faasi vahel. On tuletatud võrrandid nende faaside piirhulga arvutamiseks Kurroli kaaliumisoola kristalliseerumisel erineva P_2O_5 sisaldusega ultrafosfaatide sulanditest.

СОЛИ КУРРОЛА

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Представлен обзор о первом синтезе солей Куррола в Тартуском университете, об их реакциях, свойствах и областях применения. Описаны фазовое состояние и структура калиевой соли Куррола, кристаллизующейся из расплава ультрафосфатов, распределение фосфатов между кристаллической и аморфной фазами. Выведены формулы для расчета предельного количества этих фаз при кристаллизации калиевой соли Куррола из ультрафосфатного расплава с варьирующим содержанием P_2O_5 .