Our value, 2.68, is 25% smaller, and this difference

is much greater than our experimental error which is about 2%. However, it should be remembered that carbonic acid is a peculiar acid in that the proton (or deuteron) must come exclusively from the water. Thus the hydration equilibrium plays an important role and it probably will not be the same in H<sub>2</sub>O and D<sub>2</sub>O. This factor may account for the difference mentioned above.

We are indebted to the Class of 1900 Fund for a

grant which enabled us to purchase the deuterium oxide used in this work.

### Summary

The ratio of the first thermodynamic ionization constants of proto- and deuterio-carbonic acid has been determined potentiometrically using a cell without transference in which the electrodes were quinhydrone and silver-silver chloride. Using 99.1% D<sub>2</sub>O the ratio,  $K_{\rm H}/K_{\rm D}$ , has been found to be 2.68 at  $25^{\circ}$ .

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, STANFORD UNIVERSITY]

WILLIAMSTOWN, MASS.

## Conductivities of Concentrated Mixtures of the Nitrates of Some Uni-, Di-, and Trivalent Cations in Aqueous Solution

## BY PIERRE VAN RYSSELBERGHE AND GOON LEE

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As a further step in our investigation of the conductivity of concentrated mixtures of strong electrolytes1 we have studied a number of nitrates of uni-, di-, and trivalent cations at different total concentrations ranging from 1 to 5 N. All possible types of binary mixtures have been included: two univalent cations, one uni- and one divalent cation, two divalent cations, one uni- and one trivalent cation, one di- and one trivalent cation, two trivalent cations. The method was essentially the same as in our previous work. The conductivities of the pure salts were found to be in close agreement with the existing standard data (I. C. T.; L. B. R.), except in three cases [LiNO<sub>3</sub>, Mg(NO<sub>3</sub>)<sub>2</sub>, Cr-(NO<sub>3</sub>)<sub>8</sub>] for which the standard data seem to be somewhat in error. Moreover, some conductivities of pure salts are reported here for the first time. Others have been obtained for the first time at 25°. The results are recorded in Table I in which we give the conductivities of twenty types of mixtures arranged in series corresponding to the same total equivalent concentration. We represent by x and 1-x the fractions of the total equivalent concentration corresponding to salts 1 and 2, salt 1 being the first in the title of the series. For each solution we give the specific and the equivalent conductivity and the difference  $\Delta \Lambda$ between the measured conductivity and that calculated from the simple, uncorrected mixture rule:

$$\Lambda = x\Lambda_1 + (1 - x)\Lambda_2$$

Two series of mixtures (19 and 20) contain nitric acid as one of the components, the maximum amount of nitric acid present being in both cases half the total normality.

TABLE I							
onductivities of Concentrated Mixtures at 25°							
отро	sition $1 - x$	Specific conductivity	Equivalent Measured	conductivity Calculated	- 44		
	1.1 1 N mixtures of KNO <sub>3</sub> + NaNO <sub>3</sub>						
	0	0.09254	92.54				
4	1/4	.08798	87.98	88.37	0.39		
2	$1/_{2}$	.08324	83.24	84.19	.85		
4	3/4	.07973	79.73	80.02	. 29		
	1	.07585	75.85				
	1.2	2 N mixtures	of KNO3	+ NaNO3			
	0	0.15848	79.24				
4	1/4	14993	74.97	75.20	0.23		
2	$1/_{2}$	. 14104	70.52	71.17	.65		
4	3/4	. 13383	66.92	67.12	. 20		
	1	.12617	63.09				
1.3 3 N mixtures of KNO <sub>3</sub> + NaNO <sub>3</sub>							
	0	0.21042	70.16				
4	1/4	. 19996	65.99	66.00	0.01		
2	$^{1}/_{2}$	. 18413	61.38	61.85	. 48		
4	3/4	.17222	57.41	57.72	. 31		
	1	.16075	53.58				
2 5 N mixtures of NaNO <sub>3</sub> + LiNO <sub>3</sub>							
	0	0.19815	39.65				
4	1/4	.18944	37.89	38.28	0.39		
2	$1/_{2}$	. 18167	36.42	36.72	.30		
;	3/4	. 17511	35.02	35.27	.25		
	1	16010	23 89				

<sup>(1)</sup> Van Rysselberghe and Nutting, THIS JOURNAL, 56, 1435 (1934); 59, 333 (1987); Van Rysselberghe, Grinnell and Carlson, *ibid.*, 59, 336 (1937).

# CONDUCTIVITIES OF MIXED NITRATES

$\begin{array}{cccc} \text{Composition} & Specific Equivalent conductivity Measured Calculated -\Delta A \\ 3.1 & 1 \ N \ \text{mixtures of } KNO_4 + Cd(NO_6)_2 \\ \hline 1 & 0 & 0.09236 & 92.36 \\ \frac{3}{4} & \frac{1}{4} & 0.68392 & 83.92 & 84.84 & 0.92 \\ \frac{1}{2} & \frac{1}{2} & 0.7522 & 75.22 & 77.33 & 2.11 \\ \frac{3}{4} & \frac{3}{4} & 0.06894 & 68.94 & 69.81 & 0.87 \\ \hline 0 & 1 & 0.0230 & 62.30 \\ \hline 3.2 & 2 \ N \ \text{mixtures of } KNO_8 + Cd(NO_8)_2 \\ \hline 1 & 0 & 0.15912 & 79.56 \\ \frac{3}{4} & \frac{1}{4} & .13947 & 69.78 & 71.53 & 1.75 \\ \frac{3}{4} & \frac{1}{4} & .13947 & 69.78 & 71.53 & 1.75 \\ \frac{3}{4} & \frac{1}{4} & .13947 & 69.78 & 71.53 & 1.75 \\ \frac{3}{4} & \frac{1}{4} & .13947 & 69.78 & 71.53 & 1.75 \\ \hline 0 & 1 & .09487 & 47.44 \\ \hline 3.3 & 3 \ N \ \text{mixtures of } KNO_8 + Cd(NO_8)_2 \\ \hline 1 & 0 & 0.21009 & 70.03 \\ \frac{3}{4} & \frac{1}{4} & .18015 & 60.05 & 61.58 & 1.53 \\ \frac{1}{2} & \frac{1}{2} & .15243 & 50.81 & 53.13 & 2.32 \\ \frac{1}{4} & \frac{3}{4} & .12895 & 42.98 & 44.68 & 1.70 \\ \hline 0 & 1 & .10868 & 36.23 \\ \hline 4 & 3 \ N \ \text{mixtures of } KNO_8 + Cn(NO_8)_2 \\ \hline 1 & 0 & 0.21019 & 70.06 \\ \frac{3}{4} & \frac{1}{4} & .14966 & 49.89 & 51.13 & .24 \\ \hline 0 & 1 & .13446 & 44.82 \\ \hline 5.1 \ 2 \ N \ \text{mixtures of } KNO_8 + Cu(NO_8)_2 \\ \hline 1 & 0 & 0.15928 & 79.64 \\ \frac{3}{4} & \frac{1}{4} & .14360 & 71.90 & 73.06 & 1.16 \\ \frac{1}{2} & \frac{1}{2} & .13002 & 65.01 & 66.48 & 1.47 \\ \frac{1}{4} & \frac{3}{4} & .11746 & 58.73 & 59.90 & 1.17 \\ \hline 0 & 1 & .10664 & 53.32 \\ \hline 5.2 \ 3 \ N \ \text{mixtures of } KNO_8 + Cu(NO_8)_2 \\ \hline 1 & 0 & 0.14949 & 48.31 \\ \frac{3}{4} & \frac{1}{4} & .14368 & 47.89 & 48.93 & 1.04 \\ \hline 0 & 1 & .12570 & 11.90 \\ \hline 6.1 \ 3 \ N \ \text{mixtures of } LiNO_8 + Cd(NO_8)_2 \\ \hline 1 & 0 & 0.16910 & 33.82 \\ \frac{3}{4} & \frac{1}{4} & .14368 & 47.89 & 48.93 & 1.04 \\ \hline 0 & 1 & .10881 & 36.27 \\ \hline 6.2 \ 5 \ N \ \text{mixtures of } LiNO_8 + Cd(NO_8)_2 \\ \hline 1 & 0 & 0.16168 & 40.42 \\ \frac{3}{4} & \frac{1}{4} & .1777 & 23.59 & 24.10 & .51 \\ \hline 0 & 1 & .10432 & 20.86 \\ \hline 7 \ 4 \ N \ \text{mixtures of } LiNO_8 + Zn(NO_8)_2 \\ \hline 1 & 0 & 0.16168 & 40.42 \\ \frac{3}{4} & \frac{1}{4} & .14242 & 37.10 & 37.18 & .08 \\ \hline 0 \ 1 \ .10432 & 20.86 \\ \hline \end{array}$		TABLE I	(Continued	()	
3.1   1 N mixtures of KNO <sub>4</sub> + Cd(NO <sub>4</sub> ):     3.1   1 N mixtures of KNO <sub>4</sub> + Cd(NO <sub>4</sub> ):     1   0   0.09236   92.36 $\frac{3}{4}$ 1/4   .08392   83.92   84.84   0.92 $\frac{1}{4}$ 1/2   .07522   75.22   77.33   2.11 $\frac{1}{4}$ .08894   68.94   69.81   0.87     0   1   .06894   68.94   69.81   0.87     0   1   .06894   68.94   69.81   0.87     1   0   0.15912   79.56 $^{*}$ .1.75     1/2   .12313   61.56   63.50   1.94     1/4   .10778   53.89   55.47   1.58     0   1   .09487   47.44   3.3   3 N mixtures of KNO <sub>8</sub> + Cd(NO <sub>8</sub> ):     1   0   0.21009   70.03	Composition	Specific	Equivalent of	Celculated	- 44
1 0 0.09236 92.36 $\frac{3}{4}$ 1/4 0.08392 83.92 84.84 0.92 $\frac{1}{2}$ 1/2 0.7522 75.22 77.33 2.11 $\frac{1}{4}$ 3/4 0.06894 68.94 69.81 0.87 0 1 0.6230 62.30 3.2 2 N mixtures of KNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.15912 79.56 $\frac{3}{4}$ 1/4 .13947 69.78 71.53 1.75 $\frac{1}{2}$ 1/2 12313 61.56 63.50 1.94 $\frac{1}{4}$ 4/4 .10778 53.89 55.47 1.58 0 1 0.9487 47.44 3.3 3 N mixtures of KNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21009 70.03 $\frac{3}{4}$ 1/4 .18015 60.05 61.58 1.53 $\frac{1}{2}$ 1/2 .15243 50.81 53.13 2.32 $\frac{1}{4}$ 3/4 .12895 42.98 44.68 1.70 0 1 .10868 36.23 4 3 N mixtures of KNO <sub>8</sub> + Zn(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21019 70.06 $\frac{3}{4}$ 1/4 .18973 63.24 63.75 0.51 $\frac{1}{2}$ 1/2 .17035 56.78 57.44 .66 $\frac{1}{4}$ 3/4 .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.15928 79.64 $\frac{3}{4}$ .1474 .14380 71.90 73.06 1.16 $\frac{1}{2}$ 1/2 .13002 65.01 66.48 1.47 $\frac{1}{4}$ 3/4 .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21000 70.00 $\frac{3}{4}$ 1/4 .14348 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.14494 48.31 $\frac{3}{4}$ 1/4 .14894 45.01 45.29 0.28 $\frac{1}{2}$ 1/2 .12613 42.04 42.29 .25 $\frac{1}{4}$ 3/4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16910 33.82 $\frac{3}{4}$ 1/4 .14894 29.78 30.57 0.79 $\frac{1}{2}$ 1/2 .12613 42.04 42.29 $\frac{3}{4}$ 1/4 .14894 29.78 30.57 0.79 $\frac{1}{2}$ 1/2 .13045 20.68 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16910 33.82 $\frac{3}{4}$ 1/4 .14894 29.78 30.57 0.79 $\frac{1}{2}$ 1/2 .13263 40.42 $\frac{3}{4}$ .11797 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16168 40.42 $\frac{3}{4}$ 1.44 .15711 39.27 39.33 0.06 $\frac{1}{4}$ 1.440 36.10	3.1 1	N mixtures	of KNO <sub>2</sub> -	$+ Cd(NO_s)$	)2
	1 0	0.09236	92 36		-
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	3/, 1/,	08392	83.92	84.84	0.92
1/4 */4 .06894 68.94 69.81 0.87 0 1 .06230 62.30 3.2 2 N mixtures of KNO <sub>2</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.15912 79.56 */4 1/4 .13947 69.78 71.53 1.75 1/2 1/2 .12313 61.56 63.50 1.94 1/4 */4 .10778 53.89 55.47 1.58 0 1 .09487 47.44 3.3 3 N mixtures of KNO <sub>4</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.21009 70.03 */4 1/4 .18015 60.05 61.58 1.53 1/2 1/2 .15243 50.81 53.13 2.32 1/4 */4 .12895 42.98 44.68 1.70 0 1 .10868 36.23 4 3 N mixtures of KNO <sub>4</sub> + Zn(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.21019 70.06 */4 1/4 .18973 63.24 63.75 0.51 1/2 1/2 .17035 56.78 57.44 .66 1/4 */4 .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>5</sub> + Cu(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.15928 79.64 */4 .1/4 .14380 71.90 73.06 1.16 1/2 1/2 .13002 65.01 66.48 1.47 1/4 */4 .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>5</sub> + Cu(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.21000 70.00 */4 1/4 .14380 71.90 73.06 1.16 1/2 1/2 .13002 65.01 66.48 1.47 1/4 */4 .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>5</sub> + Cu(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.21000 70.00 */4 1/4 .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>5</sub> + Cd(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.16910 33.82 */4 1/4 .14381 36.27 6.2 5 N mixtures of LiNO <sub>5</sub> + Cd(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.16910 33.82 */4 1/4 .14384 20.4 42.29 .25 1/4 */4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>5</sub> + Cd(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.16910 33.82 */4 1/4 .14384 27.89 43.057 0.79 1/2 1/2 .13345 26.69 27.34 .65 1/4 */4 .145711 39.27 39.33 0.06 1/2 1/2 .16277 38.19 38.26 .07 1/4 */4 .14842 37.10 37.18 .08 0 1 .14440 36.10	1/ 1/2	.07522	75.22	77.33	2.11
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1/, 8/,	06894	68 94	69 81	0.87
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	/• /• 0 1	06230	62 30	00.01	0.00
3.2 2 N mixtures of KNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.15912 79.56 */4 1/4 .13947 69.78 71.53 1.75 1/ <sub>9</sub> 1/ <sub>2</sub> .12313 61.56 63.50 1.94 1/ <sub>4</sub> */4 .10778 53.89 55.47 1.58 0 1 .09487 47.44 3.3 3 N mixtures of KNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21009 70.03 */ <sub>4</sub> 1/ <sub>4</sub> .18015 60.05 61.58 1.53 1/ <sub>2</sub> 1/ <sub>4</sub> .15243 50.81 53.13 2.32 1/ <sub>4</sub> */ <sub>4</sub> .12895 42.98 44.68 1.70 0 1 .10868 36.23 4 3 N mixtures of KNO <sub>8</sub> + Zn(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21019 70.06 */ <sub>4</sub> 1/ <sub>4</sub> .18973 63.24 63.75 0.51 1/ <sub>2</sub> 1/ <sub>2</sub> .17035 56.78 57.44 .66 1/ <sub>4</sub> */ <sub>4</sub> .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.15928 79.64 */ <sub>4</sub> 1/ <sub>4</sub> .14966 49.89 51.13 .24 0 1 .13446 53.32 5.2 3 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.15928 79.64 */ <sub>4</sub> 1/ <sub>4</sub> .14380 71.90 73.06 1.16 1/ <sub>2</sub> 1/ <sub>2</sub> .13002 65.01 66.48 1.47 1/ <sub>4</sub> */ <sub>4</sub> .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21000 70.00 */ <sub>4</sub> 1/ <sub>4</sub> .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.14494 48.31 */ <sub>4</sub> 1/ <sub>4</sub> .14364 45.01 45.29 0.28 1/ <sub>2</sub> 1/ <sub>2</sub> .12613 42.04 42.29 .25 1/ <sub>4</sub> */ <sub>4</sub> .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16910 33.82 */ <sub>4</sub> 1/ <sub>4</sub> .14894 29.78 30.57 0.79 1/ <sub>2</sub> 1/ <sub>2</sub> .12613 42.04 42.29 .25 1/ <sub>4</sub> */ <sub>4</sub> .11797 23.59 24.10 .51 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16910 33.82 */ <sub>4</sub> 1/ <sub>4</sub> .14894 29.78 30.57 0.79 1/ <sub>2</sub> 1/ <sub>2</sub> .13345 26.69 27.34 .65 1/ <sub>4</sub> */ <sub>4</sub> .11797 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16168 40.42 */ <sub>4</sub> 1/ <sub>4</sub> .15711 39.27 39.33 0.06 1/ <sub>2</sub> 1/ <sub>4</sub> .16277 38.19 38.26 .07 1/ <sub>4</sub> */ <sub>4</sub> .14424 37.10 37.18 .08 0 1 .14440 36.10	0 1	.00200	0		
1 0 0.15912 79.56 */4 1/4 .13947 69.78 71.53 1.75 1/2 1/2 .12313 61.56 63.50 1.94 1/4 */4 .10778 53.89 55.47 1.58 0 1 .09487 47.44 3.3 3 N mixtures of KNOs + Cd(NOs)s 1 0 0.21009 70.03 */4 1/4 .18015 60.05 61.58 1.53 1/2 1/2 .15243 50.81 53.13 2.32 1/4 */4 .12895 42.98 44.68 1.70 0 1 .10868 36.23 4 3 N mixtures of KNOs + Zn(NOs)s 1 0 0.21019 70.06 */4 1/4 .18973 63.24 63.75 0.51 1/2 1/2 .17035 56.78 57.44 .66 1/4 */4 .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNOs + Cu(NOs)s 1 0 0.15928 79.64 */4 1/4 .14380 71.90 73.06 1.16 1/2 1/2 .13002 65.01 66.48 1.47 1/4 */4 .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNOs + Cu(NOs)s 1 0 0.21000 70.00 */4 1/4 .18482 61.61 62.98 1.37 1/4 */4 .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNOs + Cd(NOs)s 1 0 0.14494 48.31 */4 1/4 .1304 45.01 45.29 0.28 1/4 */4 .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNOs + Cd(NOs)s 1 0 0.16910 33.82 */4 1/4 .14384 29.78 30.57 0.79 1/4 */4 .14384 29.78 30.57 0.79 1/2 1/2 .1304 45.01 45.29 0.28 1/2 1/2 .12613 42.04 42.29 .25 1/4 */4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNOs + Cd(NOs)s 1 0 0.16910 33.82 */4 1/4 .14384 29.78 30.57 0.79 1/2 1/2 .13245 20.69 27.34 .65 1/4 */4 .11797 23.59 24.10 .51 0 1 .10881 36.27 6.2 5 N mixtures of LiNOs + Cd(NOs)s 1 0 0.16168 40.42 */4 1/4 .16711 39.27 39.33 0.06 1/4 */4 .14440 38.10	3.2  2	N mixtures	of KNO <sub>8</sub> -	$- Cd(NO_8)$	2
*/4 1/4 .13947 69.78 71.53 1.75 1/2 1/2 .12313 61.56 63.50 1.94 1/4 */4 .10778 53.89 55.47 1.58 0 1 .09487 47.44 3.3 3 N mixtures of KNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.21009 70.03 */4 1/4 .18015 60.05 61.58 1.53 1/2 1/2 .15243 50.81 53.13 2.32 1/4 */4 .12895 42.98 44.68 1.70 0 1 .10868 36.23 4 3 N mixtures of KNO <sub>3</sub> + Zn(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.21019 70.06 */4 1/4 .18973 63.24 63.75 0.51 1/2 1/2 .17035 56.78 57.44 .66 1/4 */4 .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.15928 79.64 */4 1/4 .14380 71.90 73.06 1.16 1/2 3/4 .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.21000 70.00 */4 1/4 .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.14494 48.31 */4 1/4 .13634 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.16910 33.82 */4 1/4 .14384 29.78 30.57 0.79 1/2 1/2 .1613 42.04 42.29 .25 1/4 */4 .14394 29.78 30.57 0.79 1/2 1/2 .1613 42.04 42.19 .25 1/4 */4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>5</sub> + Zn(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.16910 33.82 */4 1/4 .14384 29.78 30.57 0.79 1/2 1/2 .13345 20.69 27.34 .65 1/4 */4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>5</sub> + Zn(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.16168 40.42 */4 .1/4 .16711 39.27 39.33 0.06 1/2 1/2 .16207 38.19 38.26 .07 1/4 */4 .14440 38.10	1 0	0.15912	79.56		
	<sup>3</sup> /4 <sup>1</sup> /4	.13947	69.78	71.53	1.75
	1/2 $1/2$	.12313	61.56	63.50	1.94
0 1 .09487 47.44 3.3 3 N mixtures of KNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>5</sub> 1 0 0.21009 70.03 $\frac{3}{4}$ 1/4 .18015 60.05 61.58 1.53 $\frac{1}{2}$ 1/2 .15243 50.81 53.13 2.32 $\frac{1}{4}$ $\frac{3}{4}$ .12895 42.98 44.68 1.70 0 1 .10868 36.23 4 3 N mixtures of KNO <sub>3</sub> + Zn(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.21019 70.06 $\frac{3}{4}$ 1/4 .18973 63.24 63.75 0.51 $\frac{1}{2}$ 1/2 .17035 56.78 57.44 .66 $\frac{1}{4}$ $\frac{3}{4}$ .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.15928 79.64 $\frac{3}{4}$ 1/4 .14380 71.90 73.06 1.16 $\frac{1}{2}$ 1/2 .13002 65.01 66.48 1.47 $\frac{1}{4}$ .14746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.21000 70.00 $\frac{3}{4}$ 1/4 .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>3</sub> + Cd(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.14494 48.31 $\frac{3}{4}$ 1/4 .13504 45.01 45.29 0.28 $\frac{1}{2}$ 1/2 .12613 42.04 42.29 .25 $\frac{1}{4}$ 3/4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>5</sub> + Cd(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.16910 33.82 $\frac{3}{4}$ 1/4 .14364 40.42 $\frac{3}{4}$ 1/4 .14374 20.73 30.57 0.79 $\frac{1}{2}$ 1/2 .12613 42.04 42.29 .25 $\frac{1}{4}$ 3/4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>5</sub> + Cd(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.16910 33.82 $\frac{3}{4}$ 1/4 .14364 40.42 $\frac{3}{4}$ 1/4 .14377 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>5</sub> + Cd(NO <sub>5</sub> ) <sub>2</sub> 1 0 0.16168 40.42 $\frac{3}{4}$ 1/4 .14342 37.10 37.18 .08 0 1 .14440 36.10	1/4 8/4	.10778	53.89	55.47	1.58
3.3 3 N mixtures of KNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21009 70.03 $\frac{3}{4}$ $\frac{1}{4}$ .18015 60.05 61.58 1.53 $\frac{1}{2}$ $\frac{1}{2}$ .15243 50.81 53.13 2.32 $\frac{1}{4}$ $\frac{3}{4}$ .12895 42.98 44.68 1.70 0 1 .10868 36.23 4 3 N mixtures of KNO <sub>8</sub> + Zn(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21019 70.06 $\frac{3}{4}$ $\frac{1}{4}$ .18973 63.24 63.75 0.51 $\frac{1}{2}$ $\frac{1}{2}$ .17035 56.78 57.44 .66 $\frac{1}{4}$ $\frac{3}{4}$ .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.15928 79.64 $\frac{3}{4}$ $\frac{1}{4}$ .14380 71.90 73.06 1.16 $\frac{1}{2}$ $\frac{1}{2}$ .13002 65.01 66.48 1.47 $\frac{1}{4}$ $\frac{3}{4}$ .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21000 70.00 $\frac{3}{4}$ $\frac{1}{4}$ .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.14494 48.31 $\frac{3}{4}$ $\frac{1}{4}$ .13504 45.01 45.29 0.28 $\frac{1}{2}$ .16213 42.04 42.29 .25 $\frac{1}{4}$ $\frac{3}{4}$ .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16910 33.82 $\frac{3}{4}$ $\frac{1}{4}$ .143845 26.69 27.34 .65 $\frac{1}{4}$ $\frac{3}{4}$ .11797 23.59 24.10 .51 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16910 33.82 $\frac{3}{4}$ $\frac{1}{4}$ .14571 39.73 39.33 0.06 $\frac{1}{2}$ $\frac{1}{2}$ .15277 38.19 38.26 .07 $\frac{1}{4}$ $\frac{3}{4}$ .11797 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>9</sub> ) <sub>2</sub> 1 0 0.16168 40.42 $\frac{3}{4}$ $\frac{1}{4}$ .14240 36.10	0 1	.09487	47.44		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	3.3 3	N mixtures o	of KNO <sub>8</sub> +	- Cd(NO <sub>3</sub> );	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1 0	0.21009	70.03	• • •	
$\frac{1}{4}, \frac{1}{4}, \frac{1}{2}, \frac$	3/, 1/,	18015	60 05	61 58	1.53
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1/2 1/2	15243	50.81	53.13	2.32
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1/. 8/.	12895	42.98	44 68	1 70
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0 1	10868	36 23	11.00	1.10
1 0 0.21019 70.06 3/4 1/4 .18973 63.24 63.75 0.51 1/2 1/3 .17035 56.78 57.44 .66 1/4 3/4 .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.15928 79.64 3/4 1/4 .14380 71.90 73.06 1.16 1/2 1/2 .13002 65.01 66.48 1.47 1/4 3/4 .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21000 70.00 3/4 1/4 .18482 61.61 62.98 1.37 1/2 1/2 .16200 54.00 55.92 1.95 1/4 $3/4$ .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.14494 48.31 3/4 1/4 .13504 45.01 45.29 0.28 1/2 1/2 .12613 42.04 42.29 .25 1/4 $3/4$ .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16910 33.82 3/4 1/4 .13452 20.86 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16168 40.42 3/4 1/4 .15711 39.27 39.33 0.06 1/2 1/2 .15277 38.19 38.26 .07 1/4 $3/4$ .14440 36.10	4 9 3	Niturna	WNO 1	$\mathcal{T}_{m}(\mathbf{N}(\mathbf{C}))$	
1 0 0.21019 70.06 $\frac{3}{4}$ 1/4 .18973 63.24 63.75 0.51 $\frac{1}{2}$ 1/2 1.7035 56.78 57.44 .66 $\frac{1}{4}$ 3/4 .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.15928 79.64 $\frac{3}{4}$ 1/4 .14380 71.90 73.06 1.16 $\frac{1}{2}$ 1/2 .13002 65.01 66.48 1.47 $\frac{1}{4}$ 3/4 .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.21000 70.00 $\frac{3}{4}$ 1/4 .18482 61.61 62.98 1.37 $\frac{1}{2}$ .16200 54.00 55.92 1.95 $\frac{1}{4}$ 3/4 .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.14494 48.31 $\frac{3}{4}$ 1/4 .13504 45.01 45.29 0.28 $\frac{1}{2}$ .12613 42.04 42.29 .25 $\frac{1}{4}$ 3/4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.16910 33.82 $\frac{3}{4}$ 1/4 .13532 20.86 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.16168 40.42 $\frac{3}{4}$ 1/4 .15711 39.27 39.33 0.06 $\frac{1}{2}$ 1/2 .15277 38.19 38.26 .07 $\frac{1}{4}$ 3/4 .14440 36.10	4 3 4	a alores of	$1 \text{ KNO}_8 +$	$\Sigma \Pi (INO_8)_2$	
*/4/418973 63.24 63.75 0.01 1/2 1/2 1/217035 56.78 57.44 .66 1/4 $3/4$ .14966 49.89 51.13 .24 0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.15928 79.64 */4 1/4 .14380 71.90 73.06 1.16 1/2 1/2 .13002 65.01 66.48 1.47 1/4 $3/4$ .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.21000 70.00 */4 1/4 .18482 61.61 62.98 1.37 1/2 1/2 .16200 54.00 55.92 1.95 1/4 $3/4$ .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.14494 48.31 */2 1/2 .12613 42.04 42.29 .25 1/4 $3/4$ .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16910 33.82 */4 1/4 .14365 40.97 30.57 0.79 1/2 1/2 .13345 26.69 27.34 .65 1/4 */4 .11797 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16116 40.42 */4 1/4 .15711 39.27 39.33 0.06 1/2 1/2 .15277 38.19 38.26 .07 1/4 */4 .14842 37.10 37.18 .08 0 1 .14440 36.10	1 0	0.21019	70.06	00 75	0 51
$\frac{1}{2} = \frac{1}{2} = \frac{1}{2} = \frac{1}{2} + \frac{1}$	<sup>3</sup> /4 <sup>1</sup> /4	. 18973	63.24	63.75	0.51
	$\frac{1}{2}$ $\frac{1}{2}$	. 17035	55.78	57.44	.00
0 1 .13446 44.82 5.1 2 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ): 1 0 0.15928 79.64 $\frac{2}{4}$ 1/4 .14380 71.90 73.06 1.16 $\frac{1}{2}$ 1/2 .13002 65.01 66.48 1.47 $\frac{1}{4}$ 3/4 .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ): 1 0 0.21000 70.00 $\frac{3}{4}$ 1/4 .18482 61.61 62.98 1.37 $\frac{1}{2}$ 1/2 .16200 54.00 55.92 1.95 $\frac{1}{4}$ 3/4 .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ): 1 0 0.14494 48.31 $\frac{2}{4}$ 1/4 .13504 45.01 45.29 0.28 $\frac{1}{2}$ 1/2 .12613 42.04 42.29 .25 $\frac{1}{4}$ 3/4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ): 1 0 0.16910 33.82 $\frac{2}{4}$ 1/4 .14894 29.78 30.57 0.79 $\frac{1}{2}$ 1/2 .13345 26.69 27.34 .65 $\frac{1}{4}$ 3/4 .11797 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>8</sub> ): 1 0 0.16168 40.42 $\frac{2}{4}$ 1/4 .15711 39.27 39.33 0.06 $\frac{1}{2}$ 1/2 .15277 38.19 38.26 .07 1/4 3/4 .14842 37.10 37.18 .08 0 1 .14440 36.10	1/4 8/4	. 14966	49.89	51.13	.24
5.1 2 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> ): 1 0 0.15928 79.64 $\frac{3}{4}$ 1/4 .14380 71.90 73.06 1.16 $\frac{1}{2}$ 1/2 .13002 65.01 66.48 1.47 $\frac{1}{4}$ 3/4 .11746 58.73 59.90 1.17 0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>8</sub> + Cu(NO <sub>8</sub> )2 1 0 0.21000 70.00 $\frac{3}{4}$ 1/4 .18482 61.61 62.98 1.37 $\frac{1}{2}$ 1/2 .16200 54.00 55.92 1.95 $\frac{1}{4}$ 3/4 .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> )2 1 0 0.14494 48.31 $\frac{3}{4}$ 1/4 .13504 45.01 45.29 0.28 $\frac{1}{2}$ 1/2 .12613 42.04 42.29 .25 $\frac{1}{4}$ 3/4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> )2 1 0 0.16910 33.82 $\frac{3}{4}$ 1/4 .13345 26.69 27.34 .65 1/4 3/4 .11797 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>8</sub> )2 1 0 0.16168 40.42 $\frac{3}{4}$ 1/4 .15711 39.27 39.33 0.06 $\frac{1}{2}$ 1/2 .15277 38.19 38.26 .07 1/4 3/4 .14842 37.10 37.18 .08 0 1 .14440 36.10	0 1	.13440	44.82		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	5.1 2	N mixtures	of KNO <sub>8</sub> -	+ Cu(NO <sub>8</sub> )	2
	1 0	0.15928	79.6 <b>4</b>		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	8/4 1/4	.14380	71.90	73.06	1.16
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1/2 $1/2$	. 13002	65.01	66.48	1.47
0 1 .10664 53.32 5.2 3 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.21000 70.00 ${}^{3}/_{4}$ 1/ <sub>4</sub> .18482 61.61 62.98 1.37 1/ <sub>2</sub> 1/ <sub>2</sub> .16200 54.00 55.92 1.95 1/ <sub>4</sub> ${}^{3}/_{4}$ .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.14494 48.31 ${}^{8}/_{4}$ 1/ <sub>4</sub> .13504 45.01 45.29 0.28 1/ <sub>2</sub> 1/ <sub>2</sub> .12613 42.04 42.29 .25 1/ <sub>4</sub> ${}^{8}/_{4}$ .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.16910 33.82 ${}^{3}/_{4}$ 1/ <sub>4</sub> .14894 29.78 30.57 0.79 1/ <sub>2</sub> 1/ <sub>2</sub> .13345 26.69 27.34 .65 1/ <sub>4</sub> ${}^{8}/_{4}$ .11797 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>3</sub> + Zn(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.16168 40.42 ${}^{8}/_{4}$ 1/ <sub>4</sub> .15711 39.27 39.33 0.06 1/ <sub>2</sub> 1/ <sub>2</sub> .15277 38.19 38.26 .07 1/ <sub>4</sub> ${}^{8}/_{4}$ .14842 37.10 37.18 .08 0 1 .14440 36.10	$\frac{1}{4}$ , $\frac{3}{4}$	. 11746	58.73	59.90	1.17
5.2 3 N mixtures of KNO <sub>3</sub> + Cu(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.21000 70.00 $\frac{3}{4}$ 1/4 .18482 61.61 62.98 1.37 1/2 1/2 .16200 54.00 55.92 1.95 1/4 3/4 .14368 47.89 48.93 1.04 0 1 .12570 41.90 6.1 3 N mixtures of LiNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.14494 48.31 $\frac{3}{4}$ 1/4 .13504 45.01 45.29 0.28 1/2 1/2 .12613 42.04 42.29 .25 1/4 3/4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.16910 33.82 $\frac{3}{4}$ 1/4 .14894 29.78 30.57 0.79 1/2 1/2 .13345 26.69 27.34 .65 1/4 8/4 .11797 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>3</sub> + Zn(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.16168 40.42 $\frac{3}{4}$ 1/4 .15711 39.27 39.33 0.06 1/2 1/2 .15277 38.19 38.26 .07 1/4 8/4 .14842 37.10 37.18 .08 0 1 .14440 36.10	0 1	. 10664	53.32		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	5.2 3	N mixtures	of KNO <sub>8</sub> -	$+ Cu(NO_8)$	)2
	1 0	0.21000	70.00		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	3/4 $1/4$	.18482	61.61	62.98	1.37
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\frac{1}{2}$ $\frac{1}{2}$	.16200	54.00	55.92	1.95
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\frac{1}{4}$ $\frac{3}{4}$	. 14368	47.89	48.93	1.04
6.1 3 N mixtures of LiNO <sub>3</sub> + Cd(NO <sub>3</sub> ) <sub>2</sub> 1 0 0.14494 48.31 $\frac{3}{4}$ 1/4 .13504 45.01 45.29 0.28 $\frac{1}{2}$ 1/2 .12613 42.04 42.29 .25 $\frac{1}{4}$ 3/4 .11741 39.13 39.28 .15 0 1 .10881 36.27 6.2 5 N mixtures of LiNO <sub>8</sub> + Cd(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16910 33.82 $\frac{3}{4}$ 1/4 .14894 29.78 30.57 0.79 $\frac{1}{2}$ 1/2 .13345 26.69 27.34 .65 1/4 3/4 .11797 23.59 24.10 .51 0 1 .10432 20.86 7 4 N mixtures of LiNO <sub>8</sub> + Zn(NO <sub>8</sub> ) <sub>2</sub> 1 0 0.16168 40.42 $\frac{3}{4}$ 1/4 .15711 39.27 39.33 0.06 $\frac{1}{2}$ 1/2 .15277 38.19 38.26 .07 $\frac{1}{4}$ 3/4 .14842 37.10 37.18 .08 0 1 .14440 36.10	0 1	. 12570	41.90		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	6.1 3 N mixtures of $LiNO_3 + Cd(NO_3)_2$				
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1 0	0.1 <b>4494</b>	48.31		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	8/4 1/4	. 13504	45.01	45.29	0.28
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1/2 $1/2$	. 12613	42.04	42.29	.25
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	<sup>1</sup> / <sub>4</sub> <sup>8</sup> / <sub>4</sub>	. 11741	39.13	39.28	.15
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0 1	.10881	36.27		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	6.2 5 N mixtures of $LiNO_8 + Cd(NO_8)_2$				
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1 0	0.16910	33.82		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	<sup>3</sup> /4 <sup>1</sup> /4	.14894	29.78	30.57	0.79
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\frac{1}{2}$ $\frac{1}{2}$	.13345	26.69	27.34	.65
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	<sup>1</sup> /4 <sup>8</sup> /4	. 11797	23.59	24.10	. 51
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0 1	.10432	20.86		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	7 4 N mixtures of $LiNO_{3} + Zn(NO_{3})_{2}$				
	1 0	0.16168	40.42		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	3/4 1/4	.15711	39.27	39.33	0.06
$ \begin{array}{ccccccccccccccccccccccccccccccccc$	1/2 $1/2$	.15277	38.19	38.26	.07
0 1 .14440 36.10	1/4 8/4	. 14842	37.10	37.18	.08
	0 1	.14440	36.10		

8 3 N mixtures of $LiNO_8 + Mg(NO_8)_2$					
1	0	0.1 <b>4409</b>	48.03		
3/4	1/4	.14032	46.77	46.87	0.10
$1/_{2}$	$^{1}/_{2}$	.136 <b>79</b>	45.59	45.72	.13
1/4	8/4	.13323	<b>44.41</b>	· <b>4</b> 4.56	.15
0	1	.13120	43.40		
9	.1 2 N	mixtures of	Cu(NO <sub>8</sub> ) <sub>2</sub>	+ Cd(NC)	$()_{3})_{2}$
1	0	0.10664	53.32	•	-,-
3/.	1/,	10369	51 85	51 01	0.06
1/2	1/	10083	50 42	50 50	0.00
1/,	3/,	09805	49 03	49.08	.00
0	1	.09534	47.67	10.00	.00
g	2 3 N	mixtures of	C11(NO <sub>2</sub> ).	+ Cd(NC)	)•)•
1	0	0 12570	41 00	, •==(===	6/2
3/.	1/.	12146	40.40	40 51	0.02
1/.	-/4	11728	30.00	20.01	0.02
1/.	/2 8/.	11203	37 68	37 79	.02
0	1	.10896	36.32	01.12	.04
1(	- 11 2 X	mixtures of	Ma(NO.)	$\perp Cd(N)$	0.).
	).I 0 M		1018(1008)	$2 \pm Cu(1)$	$O_{8/2}$
1	0	0.13120	43.40	41 00	0.00
°/4	1/4	.12420	41.40	41.62	0.22
$\frac{1}{2}$	$\frac{1}{2}$	.11875	39.58	39.84	.26
1/4	°/4	.11373	37.91	38.05	.14
0	1	.10882	36.27		
10	$0.2 5 \Lambda$	mixtures of	Mg(NO <sub>3</sub> )	$_{2} + Cd(N)$	$O_{3})_{2}$
1	0	0.14555	29.11		
3/4	$\frac{1}{4}$	.13102	26.20	27.05	0.75
1/2	$\frac{1}{2}$	. 12119	24.24	24.99	.75
1/4	8/4	.11000	22.00	22. <b>9</b> 2	.92
0	1	.10432	20.86		
1	11 4 N	mixtures of	$Zn(NO_3)_2$	+ Cd(NO)	3)2
1	0	0.14440	36.10		
3/4	1/4	.13549	33.87	33.99	0.12
1/2	1/2	.12683	31.71	31.88	. 17
1/4	3/4	.11808	29.52	29.77	.25
0	1	.11068	27.67		
	12 3	N mixtures o	of KNO <sub>3</sub> -	$+ Al(NO_8)$	8
1	0	0.21019	70.06		
3/4	1/4	. 19026	60.09	61.75	1.66
1/2	1/2	.15467	51.56	53.44	1.88
1/4	3/4	.12971	43.24	45.13	1.89
0	1	.11045	36.82		
13 4 N mixtures of $LiNO_8 + Al(NO_8)_8$					
1	0	0.16168	40.42		
3/4	1/4	.14832	37.08	37.36	0.28
$1/_{2}$	1/2	. 13567	33.92	34.30	. 38
1/4	3/4	.12339	30.85	31.25	. <b>4</b> 0
0	1	.11276	28.19		
	14 2	N mixtures o	of KNO <sub>8</sub> –	$+ Cr(NO_8)$	8
1	0	0.15857	79.29		
8/4	1/4	.13537	67.69	68.46	0.77
1/2	$\frac{1}{2}$	. 11395	56.98	57.64	.66
1/4	3/4	.08986	44.93	46.81	1.88
0	1	.07198	35.99		
	15 3 N	mixtures of	$Zn(NO_8)_2$	$+ Al(NO_{2})$	8) <b>8</b>
1	0	0.13446	44.82		
3/4	1/4	.12701	42.34	42.82	0.48

Ó

1

.09572

47.86

		TABLE I	(Concluded	<i>l</i> )	
Cor	nposition	Specific	Equivalent of Measured	conductivity Calculated	- 44
1/2	1/2	12116	40.39	40.82	43
1/2	3/.	11334	37 78	38.82	1 04
6	1	. 11045	36.82		1.01
	10 4			1 41/270	
	16 4 1	v mixtures of	$Cd(NU_3)_2$	+ AI(NC)	<b>)</b> <sub>3</sub> ) <sub>3</sub>
1	0	0.11058	27.67	07 00	0.00
°/4	1/4 1/	. 11120	27.80	27.80	0.00
1/.	-/2 3/.	11186	27.00	27.90	00
$0^{4}$	1	.11276	28.19	20.00	.00
	17.1 2	N mixtures of	Cd(NO <sub>3</sub> )	$_{2} + Cr(N)$	O3)3
1	0	0.09562	47.81		
3/4	1/4	. 09034	45.17	<b>44.76</b>	-0.41
$^{1}/_{2}$	$^{1}/_{2}$	. 08498	42.49	41.71	78
1/4	3/4	. 0775 <b>2</b>	3 <b>8</b> .76	38.65	11
0	1	.07119	35.60		
	17.2 4	N mixtures o	f Cd(NO <sub>3</sub> )	$_{2} + Cr(N)$	O <sub>8</sub> ) <sub>3</sub>
1	0	0.11040	27.60		
3/4	1/4	. 11170	27.92	27.25	-0.67
$\frac{1}{2}$	1/2	. 11181	27.95	26.89	-1.06
1/4	3/4 1	. 10963	27.40 98 10	20:04	-0.89
	1	. 10471	40.10		
	18.1 1	N mixtures o	of Al(NO <sub>3</sub> )	$_{3} + Cr(N)$	O3)3
. 1	0	0.06264	62.64		
3/4	1/4	.05797	57.97	57.63	-0.34
1/2	1/2	.05349	53.49	52.62	77
1/4 0	°/4	.04828 04260	48.28 42.60	47.01	07
U	18.2 2	N mixtures o	of Al(NO <sub>3</sub> )	s + Cr(N)	$O_3$
1	-0	0.09647	48.24	• • • · ·	- 070
3/4	1/4	.09207	46.04	45.08	-0.96
1/2	1/2	.08617	43.09	41.96	-1.13
1/4	3/4	. 07997	39.9 <b>9</b>	38.82	-1.17
0	1	.07136	35.68		
	18.3 4	N mixtures o	of Al(NO3)	$_{s} + Cr(N)$	O <sub>3</sub> ) <sub>3</sub>
1	0	0.11232	28.08		
3/4	1/4	.11380	28.45	27.54	-0.91
$\frac{1}{2}$	$\frac{1}{2}$	. 11413	28.53	26.99	-1.54
1/4 0	°/4 1	10361	27.02 25.00	20.40	1.07
U	1	. 10501	40.00		
19 2 N mixtures of $HNO_3 + KNO_3$					
1	0	0.00000	(289, 80)	104 50	
1/2	$\frac{1}{2}$	0.36582	183.42	184.59	1.17
*/5 1/	3/5 3/.	25680	100.09	103.04	0.90
-/4 1/.	~/4 '4/.	23726	118.63	121.44	2 81
- 0	1	.15879	79.37		<b></b> . 01
$20 - 2$ N mixtures of HNO: $\perp Cd(NO)$					
1	 	mineuro	(289 80)		012
1/.	1/2	0.32599	163.00	168.83	5.83
2/5	3/5	.27131	135.66	144.63	8.97
1/4	5/4	. 20242	101.21	108.30	7.09
$1/_{5}$	4/5	. 18164	90.82	96.24	5.42

## Discussion

In all the mixtures, except those of chromium nitrate with cadmium nitrate and of chromium nitrate with aluminum nitrate, the conductivity calculated according to the mixture rule is larger than the measured conductivity. As previously observed with other types of mixtures, the maximum difference between measured and calculated conductivities in a series of given total equivalent concentration follows the same trend as the difference between the conductivities of the pure salts. This is shown in Table II where the various groups of mixtures are classified according to the value of the difference  $\lambda$  between the conductivities of the pure salts,  $\Delta\Lambda$  being the largest departure from the mixture rule in the series. If one excludes the mixtures of chromium nitrate with cadmium and aluminum nitrates and those containing nitric acid, Table II could be combined with the corresponding tables of our previous papers. We note, however, that  $\Delta\Lambda$  for 1 N inixtures of  $KNO_3 + NaNO_3$  is larger than for the 1 molal mixtures previously studied.

#### TABLE II

N	Mixtures	λ	$-\Delta\Lambda$
2	$HNO_3 + Cd(NO_3)_2$	241.94	8.97
2	$HNO_3 + KNO_3$	210.43	6. <b>95</b>
<b>2</b>	$KNO_3 + Cr(NO_3)_3$	43.30	1.88
3	$KNO_3 + Cd(NO_3)_2$	33.80	2.32
3	$KNO_3 + Al(NO_3)_3$	33.24	1.89
2	$KNO_3 + Cd(NO_3)_2$	32.12	1.94
1	$KNO_3 + Cd(NO_3)_2$	- 30 . <b>06</b>	2.11
3	$KNO_3 + Cu(NO_3)_2$	28.10	1.95
<b>2</b>	$KNO_3 + Cu(NO_3)_2$	26.3 <b>2</b>	1.47
3	$KNO_3 + Zn(NO_3)_2$	25.24	0.66
1	$Al(NO_3)_3 + Cr(NO_3)_3$	20.04	77
1	$KNO_3 + NaNO_3$	16.69	. 85
3	$KNO_3 + NaNO_3$	16.58	. 48
<b>2</b>	$KNO_3 + NaNO_3$	16.15	. 65
5	$LiNO_3 + Cd(NO_3)_2$	12.96	.79
<b>2</b>	$Al(NO_3)_3 + Cr(NO_3)_3$	12.56	-1.17
4	$LiNO_3 + Al(NO_3)_3$	12.23	0.40
<b>2</b>	$Cd(NO_3)_2 + Cr(NO_3)_3$	12.21	78
3	$LiNO_3 + Cd(NO_3)_2$	12.04	. 28
4	$\operatorname{Zn}(\operatorname{NO}_3)_2 + \operatorname{Cd}(\operatorname{NO}_3)_2$	8. <b>43</b>	.25
5	$Mg(NO_3)_2 + Cd(NO_3)_2$	8.25	. 92
3	$Zn(NO_3)_2 + Al(NO_3)_3$	8.00	1.04
3	$Mg(NO_3)_2 + Cd(NO_8)_2$	7.13	0.26
5	$NaNO_{8} + LiNO_{8}$	5. <b>83</b>	. <b>3</b> 9
<b>2</b>	$Cu(NO_3)_2 + Cd(NO_3)_2$	5. <b>65</b>	. 08
3	$Cu(NO_3)_2 + Cd(NO_3)_2$	5.5 <b>8</b>	. 04
<b>3</b>	$LiNO_3 + Mg(NO_3)_2$	4.63	.15
4	$LiNO_3 + Zn(NO_3)_2$	4.32	. 08
4	$Al(NO_3)_3 + Cr(NO_2)_3$	2.18	-1.54
4	$Cd(NO_3)_2 + Cr(NO_3)_3$	1. <b>42</b>	<b>-1.0</b> 6
4	$Cd(NO_3)_2 + Al(NO_3)_3$	0.52	0.09

The behavior of the  $Cr(NO_3)_3 + Cd(NO_3)_2$  and  $Cr(NO_3)_3 + Al(NO_3)_3$  mixtures seems abnormal, particularly in 4 N solutions where some mixtures exhibit larger conductivities than those of the two pure salts. We have noticed that the slope of the conductivity curve of  $Cr(NO_3)_3$  is, at least in the range of concentrations here studied, appreciably smaller than the slopes for the other nitrates, these being all nearly equal. When the conductivities of  $Cr(NO_3)_3$  and of the other salt in the mixture are nearly equal, there is a positive  $\Delta \Lambda$ due to this difference in the slopes. When the conductivities are quite different, as in the 2 Nmixtures with KNO<sub>3</sub>,  $\Delta\Lambda$  is negative because the effect of this difference is larger than that of the difference in the slopes.

On account of the very large difference between the conductivity of pure nitric acid and that of KNO<sub>3</sub> or Cd(NO<sub>3</sub>)<sub>2</sub> we would expect  $-\Delta\Lambda$  to be much larger than is observed. We found in our previous work that, with salts, a difference of 100 in  $\Lambda$  corresponds to a  $\Delta\Lambda$  of 14 to 16. The abnormal behavior of mixtures containing acids was pointed out in one of our papers and is evidently connected with the peculiar mechanism of proton conductivity. A common ion effect on the degree of ionization of nitric acid would tend to increase the lowering of the conductivity with respect to the mixture rule. Such an effect is to be expected, whether we accept Rao's<sup>2</sup> claim that nitric acid, alone among all nitrates, is incompletely dissociated, or whether we make the less drastic and more reasonable assumption that, at these high concentrations, nitric acid is less completely dissociated than the salts. The

(2) Rao, Proc. Roy. Soc. (London), A127, 279 (1930).

corresponding effect on the conductivity of mixtures containing nitric acid apparently is overshadowed to a certain extent by an effect in the opposite direction due to the adjustment of mobilities.

Strong evidence for the incomplete dissociation of nitrates is provided by Davies'<sup>3a</sup> recent analysis of Van Rysselberghe and Nutting's data<sup>3b</sup> on the conductivity of mixtures of KNO<sub>3</sub> with NaCl and of NaNO<sub>3</sub> with KCl. Davies gives a striking explanation for the fact that the calculated  $\Lambda$ 's are smaller than the experimental values in the former group of mixtures, and larger in the latter. On the basis of dissociation constants previously obtained for KNO<sub>3</sub> and NaNO<sub>3</sub> he is able to calculate  $\Delta\Lambda$  values in excellent agreement with the experimental ones.

### Summary

1. Conductivities of twenty groups of binary mixtures of nitrates of uni-, di-, and trivalent cations have been measured at total equivalent concentrations ranging from 1 to 5 N.

2. All mixtures studied, except those of chromium nitrate with cadmium and aluminum nitrates, exhibit conductivities lower than the values calculated from the simple mixture rule. The departure from the mixture rule is the larger the larger the difference of the conductivities of the pure salts.

3. The behavior of mixtures containing chromium nitrate and of those containing nitric acid is briefly discussed.

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RECEIVED SEPTEMBER 26, 1938 (3) (a) Davies, J. Chem. Soc., 448 (1938); (b) Van Rysselberghe and Nutting, THIS JOURNAL, 59, 333 (1937).