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ISOTACHOPHORESIS

THE QUALITATIVE SEPARATION OF ANIONS

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SUMMARY

Separations of anions by isotachophoresis can be carried out in different ways. Differences in mobilities and/or differences in pK values can be used for the simultaneous separation of anions. The separations of anions, using both the differences in mobilities and/or the differences in pK values, were studied in this work. Experimental values for about one hundred anions are given. Equations are derived for the separation of anions in buffered systems and the experimental results are compared with calculated values in order to check the theory.

INTRODUCTION

In a previous paper¹ the theory for the use of buffered systems for separations of cations was described. Some operational systems that are useful for the separations of cations in both water and methanol were given.

A comparison of the results obtained by calculations and by experiments showed that corrections have to be made; the influence of relaxation and electrophoretic effects are important, while the influence of the temperature of the zones is negligible for relative calculations.

In this paper we discuss the equations derived for buffered systems and useful for the separation of anions. Some artefacts of the experiments carried out are given.

The results of the experiments are divided into two groups. The experimental results for the first group of anions are compared with calculated values. For the second group, only the experimental results are given.

THEORETICAL

In a similar manner and with the same assumptions as described by BECKERS AND EVERAERTS¹, who investigated the separations of cations, the following equations can be set up*.

Equilibrium equations

$$K_{A,i} = c_H \cdot c_{A,i} / c_{A,i-1} \quad (1)$$

* Here the sample ions are anions, and the counter-ions are cations with buffering capacity.

$$K_{B,i} = c_H \cdot c_{B,i-1} / c_{B,i} \quad (2)$$

$$c_{A,i} = K_{A,i} \cdot c_{A,i-1} / c_H \quad (3)$$

$$c_{B,i} = c_{B,i-1} \cdot c_H / K_{B,i} \quad (4)$$

Substituting in eqns. 3 and 4 for $c_{A,i-1}$ and $c_{B,i-1}$, etc.:

$$c_{A,i} = c_{A,0} \prod_{j=1}^i K_{A,j} / c_H^i \quad (5)$$

$$c_{B,i} = c_{B,0} \cdot c_H^i / \prod_{j=1}^i K_{B,j} \quad (6)$$

For

$$M_i = \prod_{j=1}^i K_{A,j} / c_H^i \quad (7)$$

$$N_i = c_H^i / \prod_{j=1}^i K_{B,j} \quad (8)$$

eqns. 5 and 6 will be

$$c_{A,i} = M_i \cdot c_{A,0} \quad (9)$$

$$c_{B,i} = N_i \cdot c_{B,0} \quad (10)$$

The total concentrations of the buffer and the anion present are

$$c_A^t = c_{A,0} \cdot \left(1 + \sum_{i=1}^{n_A} M_i \right) \quad (11)$$

$$c_B^t = c_{B,0} \cdot \left(1 + \sum_{j=1}^{n_B} N_j \right) \quad (12)$$

Isotachophoretic conditions

$$E_U \cdot m_{AU} = E_V \cdot m_{AV} \quad (13)$$

with

$$m_{AU} = \frac{\sum_{i=1}^{n_A} M_{Ui} \cdot m_{AUi}}{\left(1 + \sum_{i=1}^{n_A} M_{Ui} \right)} \quad (14)$$

Mass balance

$$c_{BU}^t \cdot (1 + m_{BU}/m_{AU}) = c_{BV}^t \cdot (1 + m_{BV}/m_{AV}) \quad (15)$$

with

$$m_{BU} = \frac{\sum_{i=1}^{n_B} N_{Ui} \cdot m_{BUI}}{\left(1 + \sum_{i=1}^{n_B} N_{Ui} \right)} \quad (16)$$

Electroneutrality

$$c_{OHU} + c_{AU}^t \cdot \sum_{i=1}^{n_A} i \cdot M_{Ui} / \left(1 + \sum_{i=1}^{n_A} M_{Ui} \right) = c_{HU} + c_{BU}^t \cdot \sum_{i=1}^{n_B} i \cdot N_{Ui} / \left(1 + \sum_{i=1}^{n_B} N_{Ui} \right) \quad (17)$$

Modified Ohm's law

$$I/K' = \text{constant} = E_U \cdot \left(c_{\text{OHU}} \cdot m_{\text{OHU}} + c_{\text{HU}} \cdot m_{\text{HU}} + \sum_{i=1}^{n_A} i \cdot c_{\text{AUI}} \cdot m_{\text{AUI}} + \sum_{i=1}^{n_B} i \cdot c_{\text{BUI}} \cdot m_{\text{BUI}} \right) \quad (18)$$

Assuming the right-hand terms of eqn. 18 are Q_1 and Q_U for the first and the U th zone, respectively, then the function

$$QU = Q_1/Q_U - I \quad (19)$$

must be zero.

With these equations, a similar computer program can be written, as described earlier¹.

APPARATUS

The experiments are carried out with the apparatus described by BECKERS AND EVERAERTS². Instead of a differential thermocouple, a differentiator³ is used.

EXPERIMENTAL

In isotachopheresis, ions can be separated if their effective mobilities differ sufficiently.

The effective mobility can be defined as

$$m_{\text{eff}} = \sum_i \alpha_i \cdot m_i \cdot \gamma_i \quad (20)$$

The degree of dissociation, α_i , depends mainly on the values of the pK , the temperature of the zone and the pH chosen. The value of γ_i , a correction factor used in the Onsager relation, depends mainly on the ionic concentrations. The value of m_i depends on several effects, such as solvation, dielectric constant, viscosity of the solvent, and the radius and charge of the ion. All parameters influence the effective mobility and a well considered choice of the system to be used, makes a good separation possible.

The separation of anions can be carried out in different ways, as follows:

(1) The differences in absolute mobilities can be used for the separations of anions. A particular pH of the buffered system is chosen such that all anions are almost completely dissociated.

(2) The differences in the pK values of the anions can also be used for the separation. A particular pH is chosen such that most anions are not completely dissociated, especially if many anions have about the same absolute mobilities. According to eqn. 20, a pH is chosen such that maximum differences in effective mobilities are obtained.

Separations according to mobilities

To demonstrate separations according to mobilities, the pHs of the buffered systems are chosen as 6 and 7. Many acids have pK values up to 5.5, so that most acids will be almost completely ionised.

TABLE I

SOME EXPERIMENTAL AND CALCULATED VALUES FOR ANIONS FOR THE SYSTEM Hist/HCl

No.	Ionic species	$I/\lambda \cdot 10^3$ without correc- tions	$I/\lambda \cdot 10^3$ with correc- tions	Calculated concentration of the ionised part (mole/l)	pH	Step-height (mm)
1	Acetic acid	2.036	2.195	0.0082 ^a	6.12	366
2	Benzoic acid	2.504	2.689	0.0078	6.13	430
3	<i>m</i> -Nitrobenzoic acid	2.561	2.749	0.0078	6.13	440
4	<i>p</i> -Nitrobenzoic acid	2.560	2.764	0.0078	6.13	442
5	Capric acid	3.075	3.246	0.0070	6.19	511
6	Caprylic acid	3.064	3.235	0.0070	6.19	510
7	Chloric acid	1.236	1.349	0.0097	6.04	243
8	Crotonic acid	2.414	2.591	0.0078	6.14	416
9	Formic acid	1.474	1.608	0.0092	6.06	276
10	Glycolic acid	1.996	2.160	0.0084	6.10	360
11	Hydrofluoric acid	1.468	1.600	0.0092	6.06	277
12	Iodic acid	1.977	2.142	0.0085	6.09	358
13	Lactic acid	2.268	2.450	0.0081	6.11	391
14	Nicotinic acid	2.526	2.697	0.0076	6.16	436
15	Nitric acid	1.120	1.225	0.0099	6.03	220
16	Nitrous acid	1.115	1.219	0.0099	6.03	217
17	Methacrylic acid	2.295	2.469	0.0080	6.12	404
18	Pelargonic acid	3.100	3.286	0.0070	6.20	494
19	Picric acid	2.648	2.832	0.0077	6.14	446
20	β -Chloropropionic acid	2.283	2.461	0.0081	6.12	399
21	Salicylic acid	2.334	2.512	0.0080	6.13	408
22	Sulphamic acid	1.623	1.766	0.0090	6.07	304
23	Sulphanilic acid	2.483	2.672	0.0078	6.13	420
24	Isovaleric acid	2.660	2.831	0.0075	6.16	460
25	Adipic acid	1.543	1.869	0.0045 ^b	6.06	334
26	Maleic acid	1.689	1.900	0.0030	6.11	312
27	Malic acid	1.402	1.655	0.0042	6.07	286
28	Malonic acid	1.257	1.520	0.0047	6.04	280
29	Oxalic acid	1.098	1.331	0.0049	6.03	236
30	Pimelic acid	1.626	1.972	0.0044	6.07	345
31	Succinic acid	1.511	1.759	0.0013	6.09	304
32	Sulphuric acid	0.996	1.204	0.0050	6.02	224
33	Tartaric acid	1.257	1.521	0.0047	6.04	280
34	Tartronic acid	1.203	1.458	0.0048	6.04	256

^a Concentration of the monovalent anion.^b Concentration of the divalent anion.

The system Hist/HCl. The leading electrolyte used was a mixture of histidine and hydrochloric acid at pH 6.02. The concentration of the leading ion, Cl⁻, was 0.01 N. The current was stabilised at 70 μ A.

The step-heights measured for all the ionic species, for which the experimental results were compared with calculated values, are given in Table I. The step-heights measured for the other ionic species are given in Table II. The step-heights refer to 0 μ A.

Many anions have the same or almost the same step-heights because their effective mobilities are almost equal, *i.e.*, they cannot be separated. From our experiments, we can state that anions can be separated if they differ by about 10% in step-height, by using a thermometric detector.

TABLE II

SOME EXPERIMENTAL VALUES FOR ANIONS FOR THE SYSTEMS Hist/HCl AND Imid/HCl

sl. means that an indefinite step-height was obtained. The signal slides slowly to an end-point.
t.sl. means too slow. The mobility of the anion was too low to finish the experiment, because of the limited potential delivered by the power supply.

<i>Ionic species</i>	<i>System Hist/HCl</i>	<i>System Imid/HCl</i>	<i>Ionic species</i>	<i>System Hist/HCl</i>	<i>System Imid/HCl</i>
Acetylsalicylic acid	474	380	Indolylacetic acid	t.sl.	t.sl.
Allomucic acid	319	250	Kynurenic acid	470	383
Azelaic acid	365	274	Laevulinic acid	430	—
<i>m</i> -Aminobenzoic acid	454	340	Mandelic acid (dl)	456	364
<i>o</i> -Aminobenzoic acid	408	—	Molybdic acid	335	185
<i>p</i> -Aminobenzoic acid	454	350	Naphthalene-2-sulphonic acid	496	358
5-Bromo-2,3-dihydroxybenzoic acid	460	316	Orotic acid	454	310
2,4-Dihydroxybenzoic acid	459	354	Periodic acid	358	250
Benzyl- <i>dl</i> -aspartic acid	531	440	Peroxodisulphuric acid	212	162
Butyric acid	428	356	Phenidon	t.sl.	t.sl.
α -Hydroxybutyric acid	470	375	Phenylacetic acid	448	366
Cacodylic acid	620	400	<i>o</i> -Phosphoric acid	408	266
Caffeic acid	526	420	<i>o</i> -Phthalic acid	328	246
Caproic acid	478	386	Pycrolonic acid	t.sl.	—
Carbonic acid	520 sl.	320 sl.	Pyrazine 2,3-dicarboxylic acid	298	—
Chromic acid	259	173	Pyrazole 3,5-dicarboxylic acid	301	235
Cinnamic acid	500	368	Pyrophosphoric acid	—	204
Citric acid	292	200	Pyrosulphuric acid	224	—
Dichromic acid	149	174	Pyrosulphurous acid	224	172
EDTA	334	285	Sulphosalicylic acid	283	228
Galacturonic acid (D)	t.sl.	—	Sulphurous acid	286	170
Glucuronic acid	509	420	Tiglic acid	410	332
Glutamic acid	476	386	Trichloroacetic acid	399	316
Glyoxylic acid	399	290	Trimethylacetic acid	470	363
Guanidoacetic acid	t.sl.	t.sl.	Uric acid	424	360
2-Ketogulonic acid	496	395	γ -Oxoiminovaleric acid	466	382
Hippuric acid	490	391	Vanadic acid	320 sl.	184
4,5-Imidazoledicarboxylic acid	326	240	Vitamin C	510	390
			Xanthurenic acid	484	353

Fig. 1 shows the electropherogram for the separation of a mixture of nitric, oxalic, tartronic, formic, citric, maleic, adipic, iodine, trichloroacetic and mandelic acids. Vitamin C was used as the terminator.

In Fig. 2, the electropherogram is given for the separation of sulphate, chlorate, chromate, malonate, pyrazole 3,5-dicarboxylate, adipate, acetate, β -chloropropionate and phenyl acetate. The terminator used was vitamin C. The concentrations of all the above anions in the samples were about 0.001 *N*. The sample tap volume was about 20 μ l.

The system Imid/HCl. The leading electrolyte used was a mixture of imidazole and hydrochloric acid at pH 7.05. The concentration of the leading ion, Cl⁻, was 0.01 *N*. The current was stabilised at 70 μ A.

The absolute mobility of the counter-ion is larger than the mobility of the counter-ion applied in the system Hist/HCl. This means that all the zone resistances

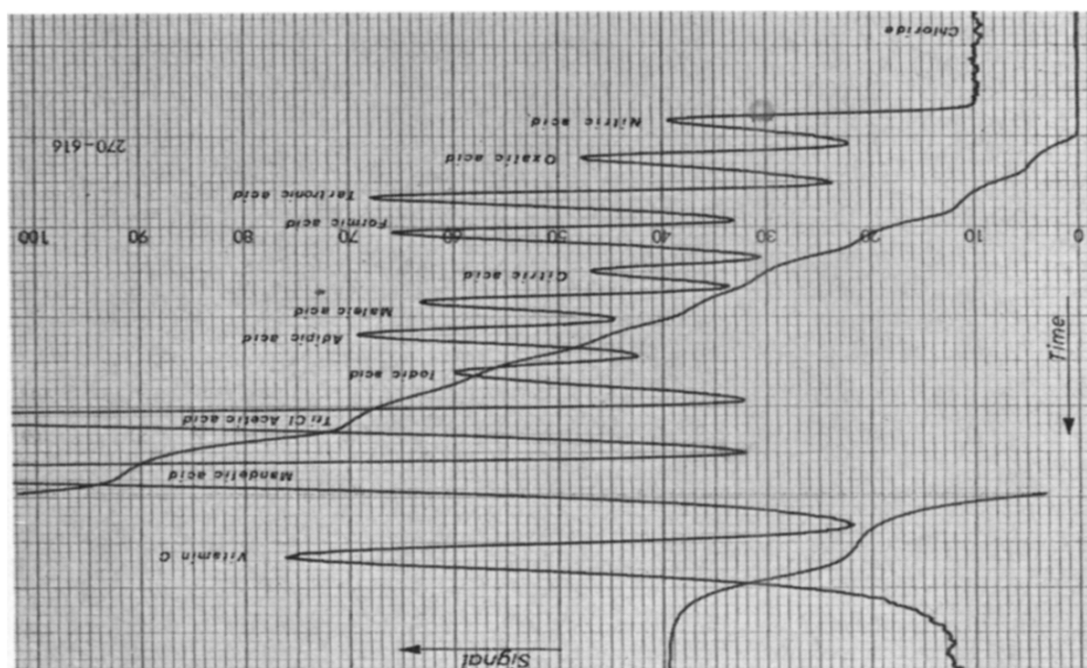
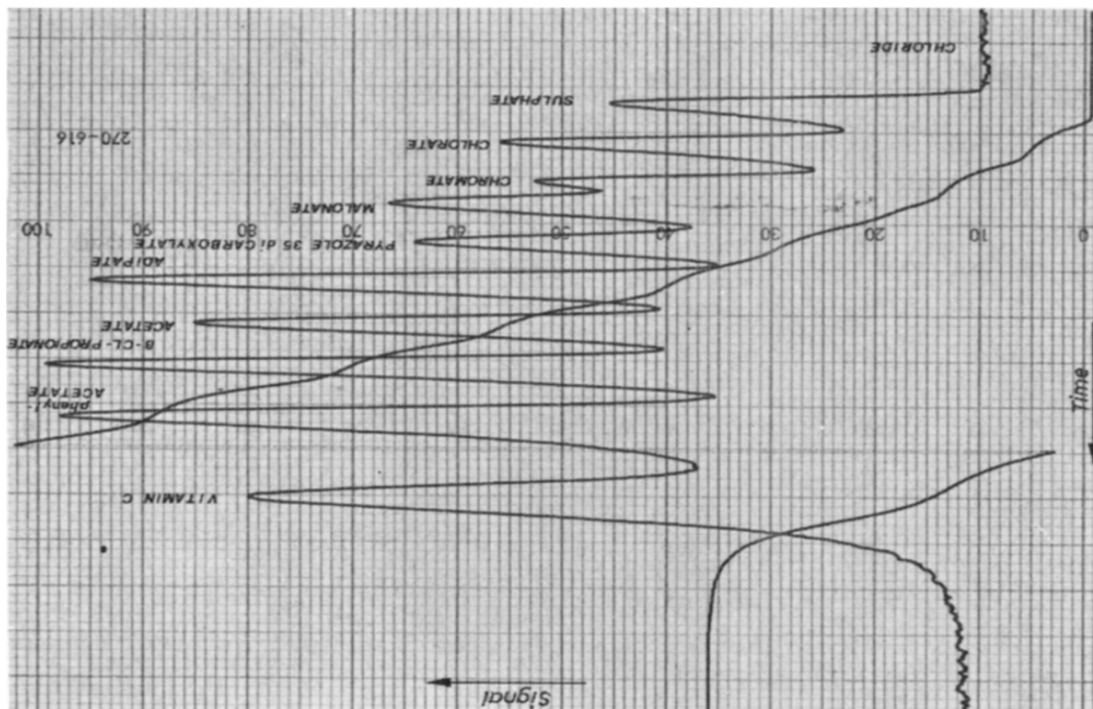


Fig. 1. Electropherogram for the separation of anions in the system Hist/HCl at pH_L = 6.02.

Fig. 2. Electropherogram for the separation of anions in the system Hist/HCl at pH_L = 6.02.

are smaller; consequently, all the step-heights decrease. However, their step-heights correlate correctly with the calculated zone resistances.

Some step-height shifts are remarkable. This can be ascribed to a dissociation, which is more complete in the system Imid/HCl.

Some examples of shifts are citric acid ($pK_3 = 6.4$), orthophosphoric acid ($pK_2 = 7.21$) and chromic acid ($pK_2 = 6.49$). All step-heights are given in Tables II and III.

In Fig. 3, the electropherogram is shown for the separation of a mixture of sulphate, oxalate, chlorate, formate, pyrazole 3,5-dicarboxylate, adipate, iodate, β -chloropropionate and nicotinate. The terminator used was vitamin C. In this system,

TABLE III

SOME EXPERIMENTAL AND CALCULATED VALUES FOR ANIONS FOR THE SYSTEM Imid/HCl

No.	Ionic species	$I/\lambda \cdot 10^3$ without correc- tions	$I/\lambda \cdot 10^3$ with correc- tions	Calculated concentration of the ionised part (mole/l)	pH	Step-height (mm)
1	Acetic acid	1.5049	1.5821	0.0075 ^a	7.13	281
2	Benzoic acid	1.9019	1.9711	0.0065	7.18	340
3	<i>m</i> -Nitrobenzoic acid	1.9610	2.0357	0.0064	7.19	340
4	<i>p</i> -Nitrobenzoic acid	1.9608	2.0299	0.0064	7.19	345
5	Caprylic acid	2.2575	2.3104	0.0059	7.23	400
6	Caprylic acid	2.2567	2.3016	0.0059	7.23	400
7	Chloric acid	0.9482	1.0156	0.0093	7.03	190
8	Crotonic acid	1.7952	1.8668	0.0068	7.17	326
9	Formic acid	1.1259	1.2013	0.0087	7.06	216
10	Glycolic acid	1.5239	1.6009	0.0074	7.13	286
11	Hydrogen fluoride	1.1236	1.1985	0.0087	7.06	218
12	Iodic acid	1.5171	1.5920	0.0074	7.13	290
13	Lactic acid	1.7388	1.8144	0.0069	7.16	314
14	Nicotinic acid	1.8520	1.9182	0.0066	7.18	342
15	Nitric acid	0.8594	0.9232	0.0097	7.01	174
16	Nitrous acid	0.8536	0.9137	0.0098	7.01	170
17	Methacrylic acid	1.7407	1.8715	0.0068	7.16	312
18	Pelargonic acid	2.2594	2.3100	0.0059	7.23	393
19	Picric acid	1.7893	1.8493	0.0068	7.17	350
20	β -Chloropropionic acid	1.7398	1.8140	0.0069	7.16	316
21	Salicylic acid	1.7894	1.8632	0.0068	7.17	323
22	Sulphamic acid	1.2454	1.3197	0.0082	7.08	244
23	Sulphanilic acid	1.8972	1.9654	0.0066	7.18	344
24	Isovaleric acid	1.968	2.0322	0.0064	7.19	360
25	Adipic acid	1.1783	1.3499	0.0042 ^b	7.07	252
26	Maleic acid	1.0679	1.2207	0.0042	7.06	216
27	Malic acid	1.0014	1.1510	0.0045	7.04	222
28	Malonic acid	—	1.0831	0.0046	7.18	204
29	Oxalic acid	0.8422	0.9634	0.0049	7.01	180
30	Pimelic acid	1.2458	1.4228	0.0041	7.08	264
31	Succinic acid	1.0411	1.1946	0.0044	7.05	224
32	Sulphuric acid	0.7681	0.8931	0.0051	6.99	169
33	Tartaric acid	0.9611	1.1083	0.0046	7.03	216
34	Tartronic acid	0.9182	1.0642	0.0047	7.02	195

^a Concentration of the monovalent anion.

^b Concentration of the divalent anion.

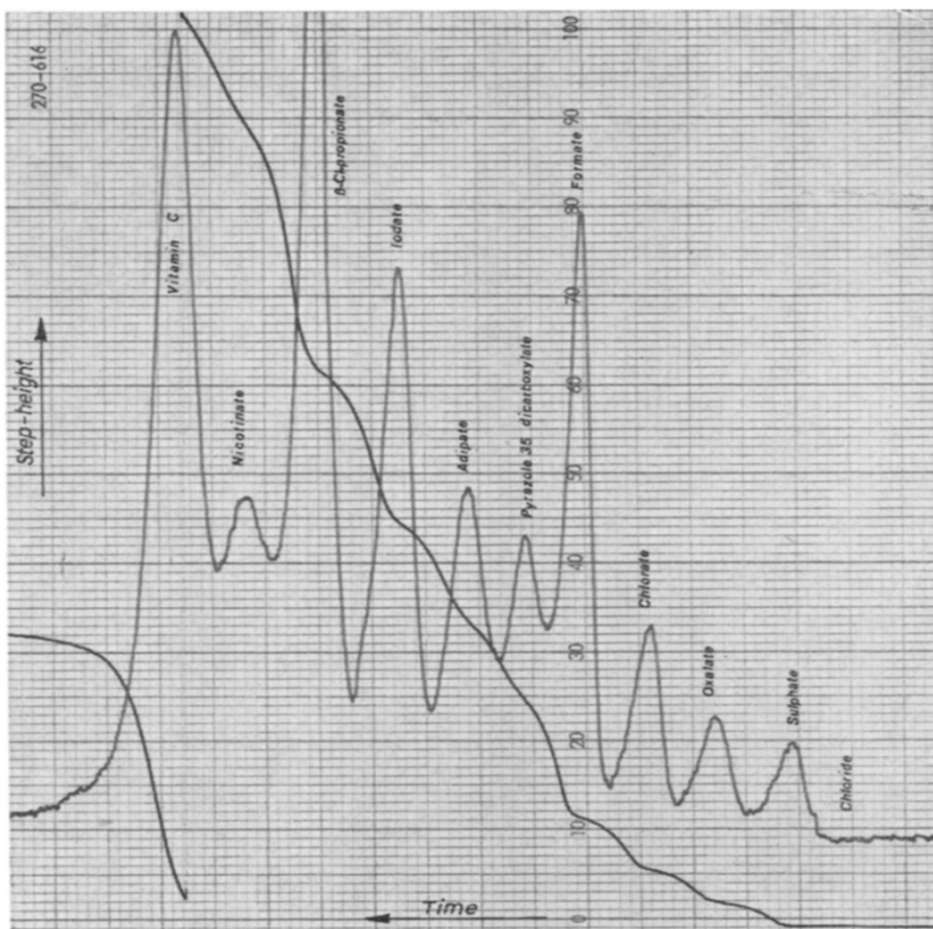


Fig. 3. Electropherogram for the separation of anions in the system Imid/HCl at $\text{pH}_L = 7.05$.

ions can be separated simultaneously if the differences in their step-heights are about 10%.

Separations according to pK values

As mentioned above, separations of anions can be carried out by using the differences between pK values, especially if the anions have about the same absolute mobilities. A pH is chosen such that different effective mobilities are obtained according to eqn. 20.

The choice of the pH of the leading electrolyte is limited. A minimum effective mobility of the ion species is required. If the pH of a zone is more than one unit lower than the pK value of the ionic species, such a low effective mobility is obtained that the potential required rises above the maximum potential of the stabilised direct-current power supply. Another limitation is due to the buffering capacity of the counter-ion. A maximum buffering effect is obtained if $\text{p}K_B + 1 > \text{pH}_{\text{zone}} > \text{p}K_B - 1$. If the pH of the leading electrolyte is chosen, the pH s of the following zones can be such that the buffering capacity of the counter-ion will be at a minimum in these zones. The relationship $\text{p}K_{\text{ionic species}}$ and pH_{zone} is shown in Fig. 4 for a $\text{p}K_B$ value of 6 and a pH value of the leading electrolyte (pH_L) of 5.75.

Fig. 4 shows clearly that a buffer will have a minimum buffering effect if its pK value is more than one unit lower than the pK of the ionic species.

To demonstrate the possibility of separation according to pK values, eleven anions that cannot be separated in the system Hist/HCl ($pH_L = 6.02$) were selected. With a computer program, the effective mobilities were computed for five systems at lower pHs and the step-heights for the different systems were measured for the eleven anions. Table IV shows the conditions for the different systems. In Table V, the calculated effective mobilities and the measured step-heights are given.

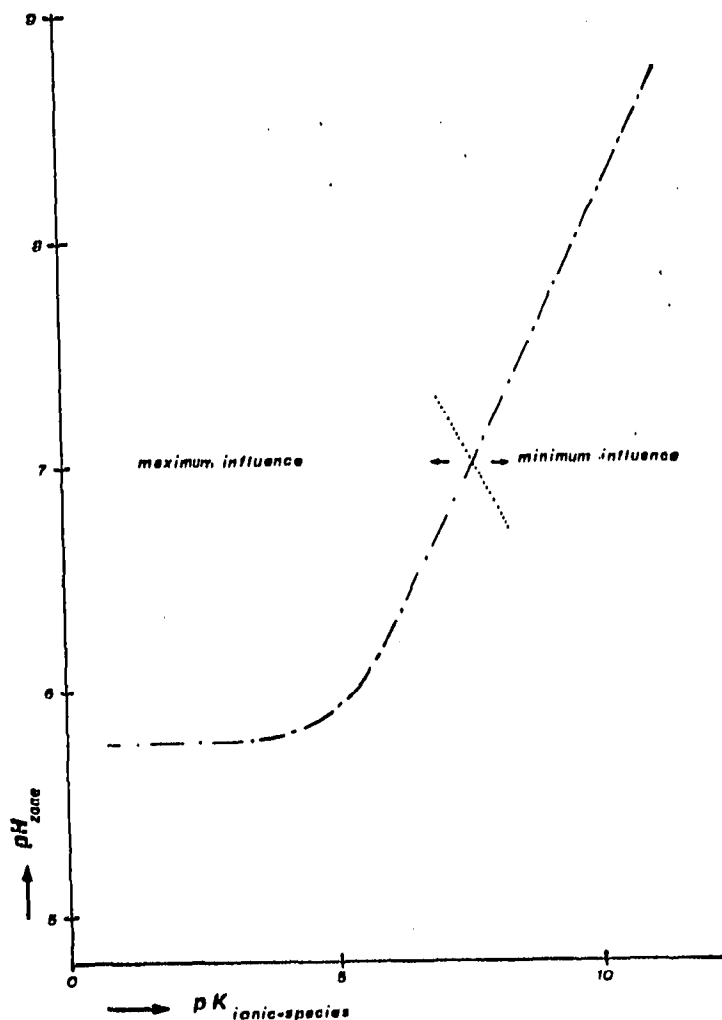


Fig. 4. Relationship between pH_{zone} and the pK value of an ionic species.

In Fig. 5, the step-heights are plotted for the different systems. Fig. 5 shows that the differences in step-heights are much greater, to obtain a good separation, at lower pH values of the leading electrolyte.

Some separations were carried out. Fig. 6 shows the electropherogram for the separation of a mixture of trichloroacetate, β -chloropropionate, benzoate, crotonate, *p*-aminobenzoate and trimethylacetate at a pH_L value of 6.02. The terminator was glutamate and the leading ion was chloride. No complete separation could be achieved.

In Fig. 7, the separation is shown for the same mixture in system E (Table V) at a pH_L value of 4. Trimethylacetate was used as the terminator. A complete separation could be obtained easily.

TABLE IV

CONDITIONS OF THE ELECTROLYTE SYSTEMS USED FOR THE SEPARATIONS ACCORDING TO pK VALUES

System	Leading electrolyte	pH_L	I (μA)
A	0.01 N HCl + pyridine	5.5	70
B	0.01 N HCl + pyridine	5.0	70
C	0.01 N HCl + aniline	5.0	70
D	0.01 N HCl + aniline	4.5	70
E	0.01 N HCl + aniline	4.0	70

TABLE V

EXPERIMENTAL AND CALCULATED VALUES FOR ANIONS FOR THE SYSTEMS A, B, C, D AND E

No.	Ionic species	System A		System B		System C		System D		System E	
		m_{eff}	$H(mm)$	m_{eff}	$H(mm)$	m_{eff}	$H(mm)$	m_{eff}	$H(mm)$	m_{eff}	$H(mm)$
1	Trimethylacetic acid	26.33	428	22.39	—	21.42	590	16.76	722	13.81	810
2	<i>p</i> -Aminobenzoic acid	28.13	424	24.36	455	23.41	533	18.62	629	15.44	722
3	Butyric acid	29.59	403	25.94	432	25.08	518	20.20	618	16.85	688
4	Crotonic acid	31.20	380	27.81	413	27.08	478	22.19	547	18.65	624
5	Benzoic acid	32.21	377	30.45	382	30.24	428	26.78	477	23.31	522
6	β -Chloropropionic acid	34.58	338	33.26	363	33.15	394	30.25	435	26.86	449
7	<i>p</i> -Nitrobenzoic acid	31.16	377	30.80	377	30.79	429	29.80	426	27.99	433
8	Sulphanilic acid	31.97	372	31.16	360	31.12	398	29.15	404	26.41	409
9	Picric acid	30.24	380	30.24	373	30.24	418	30.24	408	30.24	408
10	Salicylic acid	34.26	361	34.10	347	34.09	379	33.60	382	32.49	392
11	Trichloroacetic acid	36.60	344	36.60	343	36.60	370	36.60	372	36.60	370

CALCULATIONS

With the computer program used, the concentrations, pHs and zone resistances of the zones, following the leading electrolyte were computed* for some anions in the systems Hist/HCl and Imid/HCl. The results are given in Table I for the system Hist/HCl and in Table III for the system Imid/HCl.

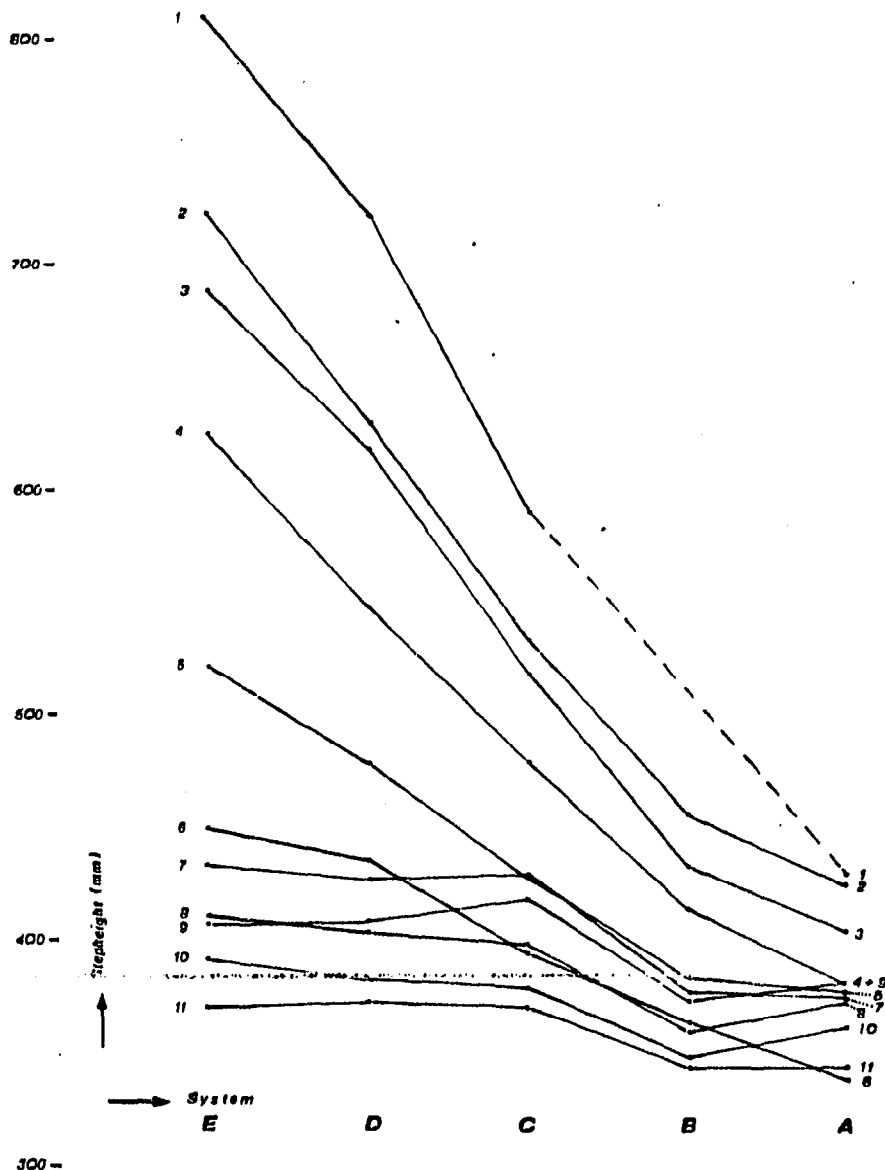


Fig. 5. Graphical representation of the step-heights measured in the various systems.

The computations were first made without applying corrections for the influence of the temperature and the relaxation and electrophoretic effects.

Figs. 8a and 9a show the relationships between the measured step-heights and calculated zone resistances for the systems Hist/HCl and Imid/HCl, respectively. Two distinguishable curves are obtained for the mono- and divalent anions.

* Data required for the computations were taken from refs. 4-6.

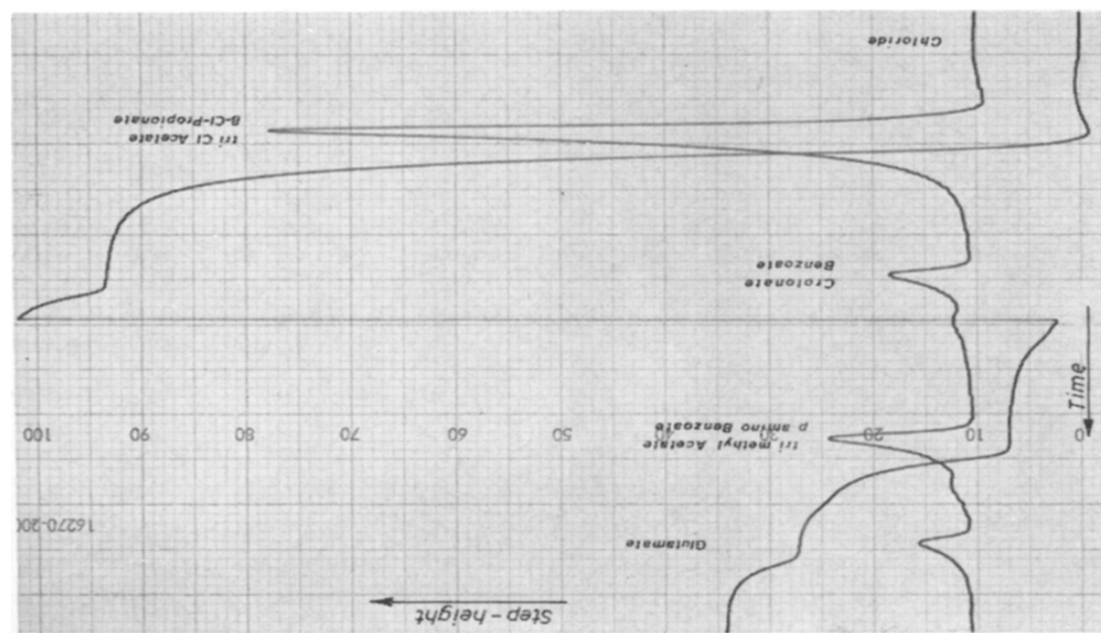
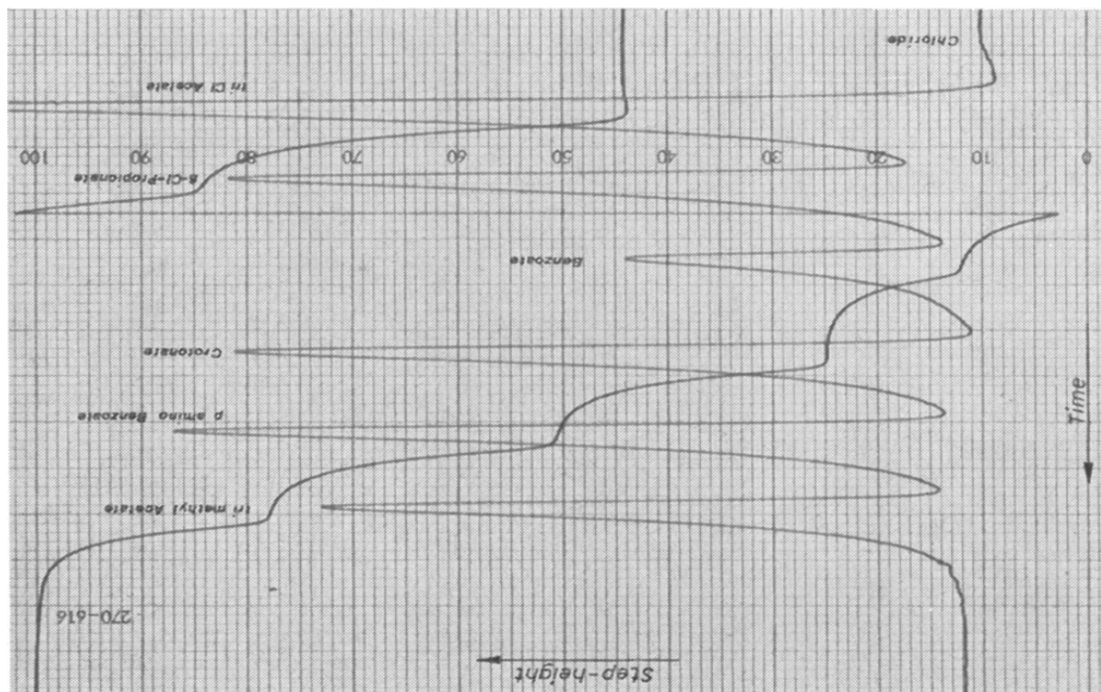


Fig. 6. Electropherogram for the separation of anions in the system Hist/HCl at $pH_L = 6.02$. The separation is not complete.

Fig. 7. Electropherogram for the separation of anions of the same sample mixture as used for the separation in Fig. 6, in system E at $pH_L = 4.0$. Complete separation has been obtained.

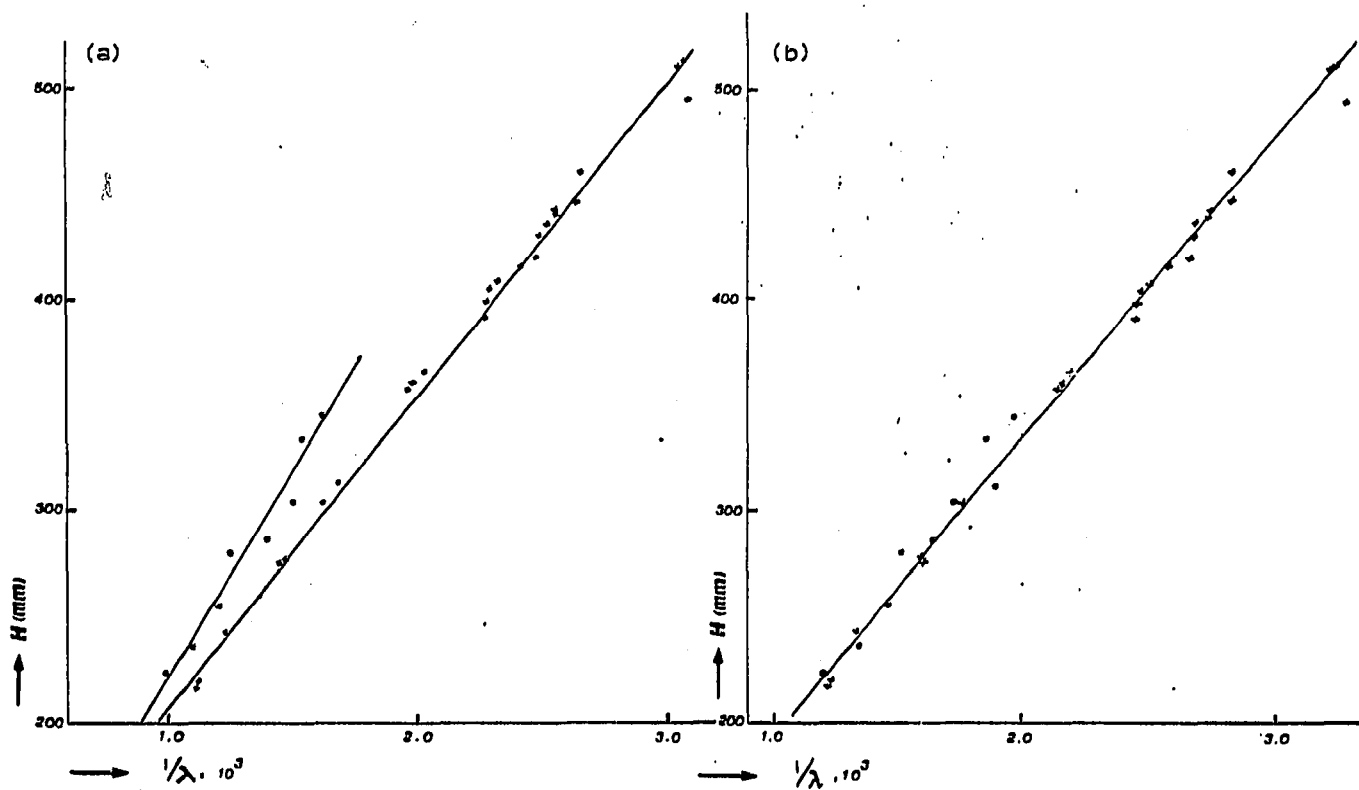


Fig. 8 (a). Relationship between the measured step-heights and the calculated zone resistances for some anions in the system Hist/HCl. No corrections were made in the computation. (b) The same relationship as shown in Fig. (a) but with corrections made in the computations.

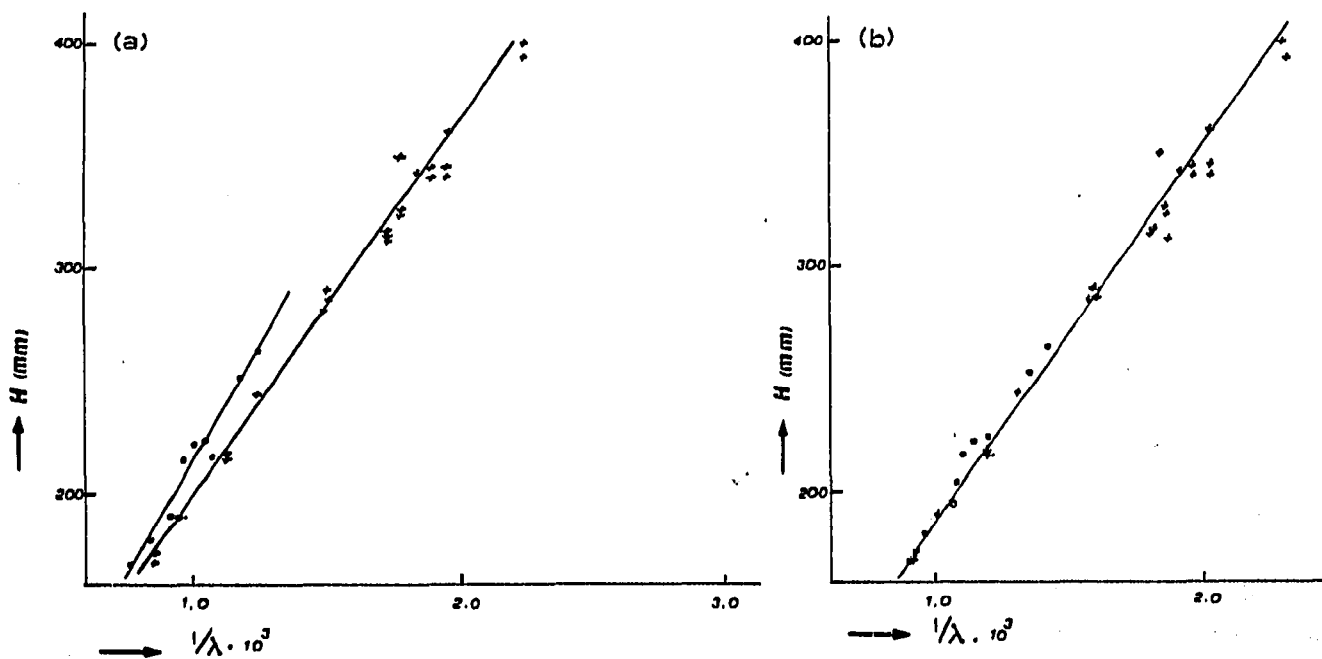


Fig. 9 (a). Relationship between the measured step-heights and the calculated zone resistances for some anions in the system Imid/HCl. No corrections were made in the computation. (b) The same relationship as shown in Fig. (a), but with corrections made in the computations.

This can be understood easily. If the zone resistance is computed without applying corrections for the Onsager relation, deviations with the resistances actually present will occur. The zone resistances calculated will be smaller than the resistances actually present because the relaxation and electrophoretic effects are neglected. These effects decrease the mobility. Consequently, the resistance of the zone increases. Because these effects are greater for divalent anions, two distinguishable curves can be expected, as shown in Figs. 8a and 9a. The influence of temperature is about the same for both mono- and divalent anions. Taking into account the influences of all these effects, one curve can be constructed.

After applying corrections for the influences of temperature and the Onsager effects, one curve is really obtained for both the mono- and divalent anions. Figs. 8b and 9b show these curves for the system Hist/HCl and Imid/HCl, respectively. curve is really obtained for both the mono- and divalent anions. Figs. 8b and 9b show these curves for the system Hist/HCl and Imid/HCl, respectively.

In all instances, the pH values before and after applying the corrections do not differ appreciably. For most ionic species, they differ by not more than about 0.1 pH unit. For this reason, no pH measurements were used as a check on the theory. However, reasonable values were obtained by EVERAERTS AND ROUTS⁷.

CONCLUSION

In this paper, we have used only the differences in pK values and mobilities for the separations of anions.

Changing the conditions as well as the combination of systems may be a help in solving certain problems.

A very important part of the analyses, the quantitative aspect of the separations, is being studied at present and will be discussed in a later paper.

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LIST OF SYMBOLS

c	Concentration, mole/l
c^t	Total concentration, mole/l
E	Potential gradient, V/cm
I	Electric current intensity, μA
K	Equilibrium constant
K'	Constant
m	Mobility, $cm^2/V \cdot sec$
m_{eff}	Effective mobility, $cm^2/V \cdot sec$
M_i	Computation constant
n	Valence
N_i	Computation constant

- α Degree of dissociation
 γ Correction factor

Indices

- A Anion A
B Buffer ion B
 i i^{th} step of dissociation, *i.e.*, for an anion i negative charges and for a cation i positive charges
H H^+ ion
OH OH^- ion
o Undissociated part
U U^{th} zone
V V^{th} zone
L Leading zone

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