CHAPTER III

CHROMATOGRAPHIC SEPARATIONS OF METAL IONS AND METAL DITHIZONATES ON WHATMAN NO.1 FILTER PAPERS

3.1 INTRODUCTION

Chromatography is a versatile technique and this very simple experimental method is adoptable to many apparently difficult separations. It is also possible to develop modifications of the technique and the available range of characteristics can be considerably extended. Unidimensional paper chromatograms can be run into two dimensions or the paper can be impregnated with various materials.

In this chapter, Whatman No.1 filter paper is used for the separation of metal ions and metal dithizonates by using various solvent systems. This work is used as a reference for evaluation of the work presented in the next two chapters. The work on separation of metal dithizonates has been done for the first time. However, the work on metal ions separation on Whatman No.1 filter paper is scattered through literature which is presented as a consolidated report.

3.2 EXPERIMENTAL

The experimental technique, details of the preparation of reagent solutions and analytical solutions are described in second chapter.

3.3 RESULTS

3.3.1 Experimental details

Chromatographic separations of the following metal ions Ni^{+2}, Co^{+2}, Cu^{+2}, Mn^{+2}, Zn^{+2}, Cd^{+2}, Hg^{+2}, Bi^{+3} and Fe^{+3} were carried out.

Similarly separations of the following metal dithizonates $Ni(HDz)_2$, $Co(HDz)_2$, $Cu(HDz)_2$, $Mn(HDz)_2$, $Zn(HDz)_2$, $Cd(HDz)_2$, $Hg(HDz)_2$, $Bi(HDz)_3$ and $Fe(HDz)_3$ were also carried out.

For the experiment, the solvent compositions used were as follows :

(1) Methanol + 10 M hydrochloric acid + acetone

(2) 10 M Hydrochloric acid + acetone + ethanol

(3) Acetone + 10 M hydrochloric acid + n-butanol

(4) 4 M Nitric acid + acetone + n-propanol

(5) Ethyl methyl ketone + n-butanol + 50 % hydrochloric acid

Whatman No.1 filter paper was used for chromatographic work.

The experimental results are presented in the following order.

Set I - Methanol + 10 M hydrochloric acid + acetone system for metal ions (Table 3.1) and metal dithizonates (Table 3.2).

Set II - 10 M Hydrochloric acid + acetone + ethanol system for metal ions (Table 3.3) and metal dithizonates (Table 3.4).

Set III - Acetone + 10 M hydrochloric acid + n-butanol system for metal ions (Table 3.5) and metal dithizonates (Table 3.6).

Set IV - 4 M Nitric acid + acetone + n-propanol system for metal ions(Table 3.7) and metal dithizonates(Table 3.8)

Set V - Ethyl methyl ketone + n-butanol + 50 % hydrochloric acid system for metal ions (Table 3.9) and metal dithizonates (Table 3.10).

3.3.2 Observation Tables

(a) For Set I, the various compositions of methanol + 10 M hydrochloric acid + acetone (M:H:A) system used are (1:1:1), (1:1:2), (2:1:2), (2:1:1), (1:2:1), (1:2:2) and (2:2:1).

The results of the above compositions are given in Tables 3.1 and 3.2.

(b) For Set II, the various compositions of 10 M hydrochloric acid + acetone + ethanol (H:A:E) system used are (1:1:1), (1:2:1), (1:2:2), (1:1:2), (2:1:1), (2:2:1) and (2:1:2).

The results of the above compositions are given in Tables 3.3 and 3.4.

(c) For Set III, the various compositions of acetone + 10 M hydrochloric acid + n-butanol (A:H:B) system used are (1:1:1), (2:1:1), (2:1:2), (1:1:2), (1:2:1), (2:2:1) and (1:2:2).

The results of the above compositions are given in Tables 3.5 and 3.6.

(d) For Set IV, the various compositions of 4 M nitric acid + acetone + n-propanol (N:A:P) system used are (3:3:3), (2:4:2), (4:2:2), (2:2:4), (4:3:3), (3:4:3) and (3:2:4).

The results of the above compositions are given in Tables 3.7 and 3.8.

(e) For Set V, the various compositions of ethyl methyl ketone + n-butanol + 50 % hydrochloric acid (EMK:B:H) system used are (6:3:6), (3:6:1), (6:3:1), (3:6:6), (6:6:3), (3:4:3) and (1:3:6).

The results of the above compositions are given in Tables 3.9 and 3.10.

Table 3.1 Chromatographic separations of metal ions on Whatman No.1 filter paper.

Time required - 70 minutes

Compositions of (M:H:A)	R_F values of metal ions								
	Ni^{+2}	Co^{+2}	Cu^{+2}	Mn^{+2}	Zn^{+2}	Cd^{+2}	Hg^{+2}	Bi^{+3}	Fe^{+3}
1:1:1	0.39	0.46	0.59	0.60	0.75	0.65	0.82	0.62	0.89
1:1:2	0.47	0.52	0.76	0.72	0.87	0.83	0.91	0.79	0.96
2:1:2	0.58	0.61	0.79	0.75	0.88	0.85	0.89	0.82	0.94
2:1:1	0.62	0.69	0.82	0.85	0.89	0.88	0.89	0.87	0.92
1:2:1	0.56	0.60	0.76	0.78	0.90	0.85	0.87	0.88	0.91
1:2:2	0.60	0.70	0.79	0.80	0.87	0.79	0.86	0.82	0.90
2:2:1	0.35	0.51	0.72	0.73	0.84	0.80	0.90	0.76	0.95

Table 3.2 Chromatographic separations of metal dithizonates on Whatman No.1 filter paper.

Time required - 55 minutes

Compositions of (M:H:A)	R_F values of metal dithizonates								
	$Ni(HDz)_2$	$Co(HDz)_2$	$Cu(HDz)_2$	$Mn(HDz)_2$	$Zn(HDz)_2$	$Cd(HDz)_2$	$Hg(HDz)_2$	$Bi(HDz)_3$	$Fe(HDz)_3$
1:1:1	0.43	0.50	0.61	0.55	0.80	0.68	0.85	0.70	0.92
1:1:2	0.51	0.55	0.78	0.65	0.90	0.85	0.93	0.80	0.97
2:1:2	0.60	0.65	0.83	0.58	0.91	0.88	0.91	0.84	0.95
2:1:1	0.67	0.72	0.85	0.68	0.93	0.90	0.95	0.90	0.96
1:2:1	0.59	0.63	0.79	0.70	0.91	0.87	0.89	0.88	0.93
1:2:2	0.62	0.72	0.84	0.76	0.81	0.89	0.90	0.85	0.94
2:2:1	0.42	0.55	0.74	0.65	0.87	0.83	0.92	0.81	0.98

Table 3.3 Chromatographic separations of metal ions on Whatman No. 1 filter paper.

Time required - 90 minutes

Compositions of (H:A:E)	R_F values of metal ions								
	Ni^{+2}	Co^{+2}	Cu^{+2}	Mn^{+2}	Zn^{+2}	Cd^{+2}	Hg^{+2}	Bi^{+3}	Fe^{+3}
1:1:1	0.42	0.49	0.58	0.60	0.73	0.67	0.76	0.65	0.93
1:2:1	0.25	0.31	0.52	0.56	0.63	0.59	0.72	0.60	0.91
1:2:2	0.22	0.28	0.54	0.58	0.70	0.63	0.79	0.69	0.88
1:1:2	0.33	0.40	0.53	0.60	0.79	0.67	0.88	0.62	0.94
2:1:1	0.39	0.31	0.61	0.69	0.83	0.75	0.85	0.71	0.85
2:2:1	0.45	0.50	0.59	0.62	0.76	0.67	0.83	0.65	0.90
2:1:2	0.30	0.33	0.63	0.70	0.80	0.76	0.84	0.72	0.85

Table 3.4 Chromatographic separations of metal dithizonates on Whatman No.1 filter paper.

Time required - 70 minutes

Compositions of (H:A:E)	R_F values of metal dithizonates								
	$Ni(HDz)_2$	$Co(HDz)_2$	$Cu(HDz)_2$	$Mn(HDz)_2$	$Zn(HDz)_2$	$Cd(HDz)_2$	$Hg(HDz)_2$	$Bi(HDz)_3$	$Fe(HDz)_3$
1:1:1	0.80	0.96	0.75	0.77	0.96	0.97	0.94	0.94	0.95
1:2:1	0.87	0.94	0.78	0.47	0.95	0.84	0.95	0.86	0.96
1:2:2	0.78	0.94	0.81	0.49	0.98	0.93	0.95	0.86	0.96
1:1:2	0.79	0.95	0.90	0.63	0.95	0.93	0.96	0.90	0.95
2:1:1	0.77	0.93	0.79	0.54	0.95	0.77	0.92	0.94	0.93
2:2:1	0.86	0.93	0.81	0.63	0.96	0.95	0.94	0.87	0.96
2:1:2	0.76	0.95	0.79	0.61	0.95	0.75	0.97	0.91	0.95

Table 3.5 Chromatographic separations of metal ions on Whatman No.1 filter paper.

Time required - 60 minutes

Compositions of (A:H:B)	R_F values of metal ions								
	Ni^{+2}	Co^{+2}	Cu^{+2}	Mn^{+2}	Zn^{+2}	Cd^{+2}	Hg^{+2}	Bi^{+3}	Fe^{+3}
1:1:1	0.20	0.34	0.55	0.57	0.65	0.68	0.93	0.67	0.81
2:1:1	0.09	0.23	0.42	0.45	0.55	0.53	0.83	0.89	0.88
2:1:2	0.12	0.25	0.35	0.40	0.51	0.45	0.85	0.82	0.79
1:1:2	0.15	0.20	0.43	0.49	0.71	0.57	0.84	0.72	0.76
1:2:1	0.18	0.29	0.51	0.60	0.78	0.67	0.82	0.85	0.86
2:2:1	0.21	0.28	0.45	0.51	0.69	0.60	0.87	0.84	0.89
1:2:2	0.15	0.23	0.56	0.62	0.80	0.69	0.88	0.77	0.86

Table 3.6 Chromatographic separations of metal dithizonates on Whatman No.1 filter paper.

Time required - 80 minutes

Compositions of (A:H:B)	R_F values of metal dithizonates								
	$Ni(HDz)_2$	$Co(HDz)_2$	$Cu(HDz)_2$	$Mn(HDz)_2$	$Zn(HDz)_2$	$Cd(HDz)_2$	$Hg(HDz)_2$	$Bi(HDz)_3$	$Fe(HDz)_3$
1:1:1	0.90	0.88	0.95	0.95	0.94	0.81	0.96	0.96	0.95
2:1:1	0.95	0.77	0.97	0.85	0.94	0.95	0.95	0.89	0.96
2:1:2	0.97	0.88	0.98	0.94	0.94	0.86	0.96	0.96	0.97
1:1:2	0.93	0.91	0.97	0.95	0.94	0.84	0.94	0.91	0.98
1:2:1	0.95	0.80	0.97	0.61	0.90	0.64	0.88	0.80	0.85
2:2:1	0.96	0.86	0.98	0.60	0.95	0.75	0.95	0.86	0.96
1:2:2	0.94	0.79	0.96	0.91	0.96	0.85	0.90	0.95	0.93

Table 3.7 Chromatographic separations of metal ions on Whatman No.1 filter paper.

Time required - 90 minutes

Compositions of (N:A:P)	R_F values of metal ions								
	Ni^{+2}	Co^{+2}	Cu^{+2}	Mn^{+2}	Zn^{+2}	Cd^{+2}	Hg^{+2}	Bi^{+3}	Fe^{+3}
3:3:3	0.54	0.59	0.78	0.70	0.66	0.60	0.88	0.77	0.91
2:4:2	0.36	0.43	0.69	0.62	0.55	0.81	0.96	0.96	0.94
4:2:2	0.70	0.74	0.78	0.72	0.79	0.70	0.90	0.83	0.97
2:2:4	0.29	0.37	0.43	0.59	0.61	0.75	0.53	0.84	0.93
4:3:3	0.55	0.60	0.72	0.61	0.65	0.69	0.65	0.74	0.95
3:4:3	0.50	0.67	0.77	0.69	0.62	0.68	0.83	0.77	0.89
3:2:4	0.57	0.60	0.75	0.70	0.65	0.72	0.89	0.78	0.93

Table 3.8 Chromatographic separations of metal dithizonates on Whatman No.1 filter paper.

Time required - 85 minutes

Compositions of (N:A:P)	R_F values of metal dithizonates								
	$Ni(HDz)_2$	$Co(HDz)_2$	$Cu(HDz)_2$	$Mn(HDz)_2$	$Zn(HDz)_2$	$Cd(HDz)_2$	$Hg(HDz)_2$	$Bi(HDz)_3$	$Fe(HDz)_3$
3:3:3	0.58	0.63	0.80	0.76	0.70	0.64	0.91	0.82	0.93
2:4:2	0.40	0.45	0.72	0.63	0.61	0.83	0.93	0.95	0.96
4:2:2	0.71	0.77	0.80	0.78	0.83	0.73	0.89	0.85	0.99
2:2:4	0.37	0.43	0.51	0.54	0.65	0.76	0.62	0.88	0.95
4:3:3	0.58	0.66	0.75	0.67	0.69	0.78	0.69	0.78	0.95
3:4:3	0.55	0.69	0.79	0.74	0.70	0.72	0.87	0.80	0.90
3:2:4	0.60	0.66	0.82	0.78	0.68	0.79	0.89	0.83	0.95

Table 3.9 Chromatographic separations of metal ions on Whatman No.1 filter paper.

Time required - 60 minutes

Compositions of (EMK:B:H)	R_F values of metal ions								
	Ni^{+2}	Co^{+2}	Cu^{+2}	Mn^{+2}	Zn^{+2}	Cd^{+2}	Hg^{+2}	Bi^{+3}	Fe^{+3}
6:3:6	0.26	0.27	0.51	0.38	0.95	0.88	0.91	0.94	0.97
3:6:1	0.05	0.05	0.25	0.11	0.86	0.80	0.90	0.85	0.63
6:3:1	0.03	0.07	0.36	0.13	0.85	0.65	0.88	0.62	0.84
3:6:6	0.33	0.30	0.58	0.38	0.95	0.94	0.94	0.89	0.95
6:6:3	0.06	0.13	0.29	0.34	0.92	0.83	0.89	0.73	0.82
3:4:3	0.08	0.17	0.35	0.14	0.91	0.88	0.82	0.94	0.95
1:3:6	0.46	0.64	0.71	0.17	0.95	0.95	0.89	0.94	0.95

Table 3.10 Chromatographic separations of metal dithizonates on Whatman No.1 filter paper.

Time required - 70 minutes

Compositions of (EMK:B:H)	R_F values of metal dithizonates								
	$Ni(HDz)_2$	$Co(HDz)_2$	$Cu(HDz)_2$	$Mn(HDz)_2$	$Zn(HDz)_2$	$Cd(HDz)_2$	$Hg(HDz)_2$	$Bi(HDz)_3$	$Fe(HDz)_3$
6:3:6	0.92	0.93	0.76	0.77	0.94	0.97	0.94	0.85	0.95
3:6:1	0.94	0.91	0.73	0.81	0.81	0.98	0.94	0.94	0.91
6:3:1	0.93	0.96	0.57	0.88	0.95	0.97	0.92	0.88	0.92
3:6:6	0.91	0.91	0.75	0.77	0.95	0.96	0.93	0.80	0.95
6:6:3	0.93	0.88	0.85	0.72	0.93	0.96	0.94	0.86	0.92
3:4:3	0.83	0.82	0.75	0.80	0.97	0.93	0.93	0.92	0.95
1:3:6	0.87	0.94	0.81	0.77	0.98	0.97	0.90	0.92	0.83

3.4 DISCUSSION

Set I -

From methanol + 10 M hydrochloric acid + acetone solvent system, it is observed that there is significant change in R_F values of various metal ions on Whatman No.1 filter paper. The chromatographic separation is possible for metal ions Ni^{+2}, Co^{+2}, Cu^{+2}, Zn^{+2} and Fe^{+3} for 2:2:1 and 1:1:1 solvent compositions. For all the solvent compositions, Zn^{+2}, Cd^{+2}, Hg^{+2} and Bi^{+3} show almost same R_F values, therefore separation is difficult. Fe^{+3} shows highest R_F values, while that of Ni^{+2} shows lowest R_F values for all the solvent compositions of this system.

Except manganese dithizonate, R_F values of metal dithizonates are higher than those of metal ions. When the solvent composition changes, $Ni(HDz)_2$ and $Mn(HDz)_2$ show variable R_F values. Separation is quite effective for $Ni(HDz)_2$, $Mn(HDz)_2$, $Cd(HDz)_2$ and $Hg(HDz)_2$ for 1:1:1 solvent composition and for $Ni(HDz)_2$, $Co(HDz)_2$, $Cu(HDz)_2$, $Zn(HDz)_2$ and $Fe(HDz)_3$ for 2:2:1 solvent composition.

Set II -

In 10 M hydrochloric acid + acetone + ethanol solvent system, separation is possible for almost all the metal ions for all the compositions. There is significant change in R_F values of Ni^{+2} and Co^{+2} when solvent composition changes. Ni^{+2} shows lowest R_F value for 1:2:2 composition. The separation is possible for the metal ions Co^{+2}, Cu^{+2}, Zn^{+2},

Hg^{+2} and Fe^{+3} for 1:2:1 composition for Ni^{+2}, Cu^{+2}, Bi^{+3} and Hg^{+2} for 1:2:2 composition and for Ni^{+2}, Cu^{+2}, Cd^{+2} and Fe^{+3} for 2:1:2 composition.

All the metal dithizonates show higher R_F values than those of the metal ions of all the solvent compositions of this system. Only $Ni(HDz)_2$, $Cu(HDz)_2$, and $Mn(HDz)_2$ show variable R_F values when solvent composition changes. While rest of the metal dithizonates show almost same R_F values, therefore, separation is impossible. Still there is separation of $Mn(HDz)_2$, $Ni(HDz)_2$, $Bi(HDz)_3$ and $Zn(HDz)_2$ for 1:2:2 composition and of $Mn(HDz)_2$, $Cu(HDz)_2$ and $Fe(HDz)_3$ for 1:2:1 composition.

Set III -

From acetone + 10 M hydrochloric acid + n-butanol system, it is seen that Ni^{+2} shows lowest R_F values than other metal ions. The R_F values are variable for all the metal ions for all the solvent compositions of this system. The chromatographic separation is quite good for Ni^{+2}, Co^{+2}, Mn^{+2}, Zn^{+2} and Hg^{+2} metal ions for 2:1:1 composition, for Ni^{+2}, Co^{+2}, Cu^{+2}, Zn^{+2} and Fe^{+3} metal ions for 2:1:2 composition and for Ni^{+2}, Co^{+2}, Cu^{+2}, Bi^{+3}, Fe^{+3} and Hg^{+2} for 1:1:1 composition.

Metal dithizonates show very high values, while there is no any change in R_F values for all the metal dithizonates when solvent composition changes. $Mn(HDz)_2$ shows lowest R_F values for 1:2:1 and 2:2:1 solvent compositions. Chromatographic

separation is possible for $Mn(HDz)_2$, $Co(HDz)_2$ and $Cu(HDz)_2$ for 1:2:1 composition.

Set IV -

It is observed from 4 M nitric acid + acetone + n-propanol solvent system that, there is no any significant change in R_F values for all the metal ions except Ni^{+2} and Co^{+2}, Fe^{+3} shows highest R_F values for all the solvent compositions of this system. Metal ions Ni^{+2}, Co^{+2}, Cu^{+2}, Mn^{+2}, Cd^{+2}, Bi^{+3} and Fe^{+3} for 2:2:4 composition and Ni^{+2}, Zn^{+2}, Cu^{+2}, Cd^{+2} and Bi^{+3} for 2:4:2 composition show quite effective separation.

There is no any significant change in R_F values in metal dithizonates. For 2:2:4 solvent composition, the separation of $Ni(HDz)_2$, $Cu(HDz)_2$, $Zn(HDz)_2$, $Cd(HDz)_2$ and $Bi(HDz)_3$ is possible, while for 2:4:2 solvent composition, the separation of $Co(HDz)_2$, $Zn(HDz)_2$, $Cu(HDz)_2$, $Cd(HDz)_2$ and $Fe(HDz)_3$ is possible.

Set V -

In ethyl methyl ketone + n-butanol + 50 % hydrochloric acid system, the solvent compositions 3:6:1, 6:3:1, 6:6:3 and 3:4:3 show lowest R_F values for Ni^{+2} and Co^{+2}. While Zn^{+2}, Cd^{+2}, Hg^{+2}, Bi^{+3} and Fe^{+3} show almost same R_F values. There is quite effective chromatographic separation of metal ions Ni^{+2}, Co^{+2}, Cu^{+2}, Hg^{+2} and Fe^{+3} for 3:4:3 composition of Ni^{+2}, Mn^{+2}, Cu^{+2}, Bi^{+3} and Hg^{+2} for 6:3:1 composition and of Co^{+2}, Mn^{+2}, Cu^{+2}, Fe^{+3}, Cd^{+2} and Zn^{+2} for 3:6:1 composition.

All metal dithizonates except $Cu(HDz)_2$ and $Mn(HDz)_2$ show very high and almost same R_F values. Therefore, separation is difficult. Still for metal dithizonates, $Cu(HDz)_2$, $Mn(HDz)_2$ and $Cd(HDz)_2$ for 6:3:1 solvent composition separation is possible.

3.5 CONCLUSION

From the study of all these five solvent systems, it has been observed that in methanol + 10 M hydrochloric acid + acetone system the chromatographic separation of Ni^{+2}, Co^{+2}, Cu^{+2}, Zn^{+2} and Fe^{+3} for 2:2:1 and 1:1:1 solvent compositions is possible. Also the separation can be carried out for $Ni(HDz)_2$, $Mn(HDz)_2$, $Cd(HDz)_2$ and $Hg(HDz)_2$ for 2:2:1 composition.

For the system 10 M hydrochloric acid + acetone + ethanol, chromatographic separation can be carried out of metal ions, Co^{+2}, Cu^{+2}, Zn^{+2}, Hg^{+2} and Fe^{+3} for 1:2:1 solvent composition, of Ni^{+2}, Cu^{+2}, Bi^{+3} and Hg^{+2} for 1:2:2 solvent composition and of Ni^{+2}, Cu^{+2}, Cd^{+2} and Fe^{+3} for 2:1:2 composition.

Acetone + 10 M hydrochloric acid + n-butanol system shows that separation is possible for Ni^{+2}, Co^{+2}, Mn^{+2}, Zn^{+2} and Hg^{+2} for 2:1:1 composition, for Ni^{+2}, Co^{+2}, Cu^{+2}, Zn^{+2} and Fe^{+3} for 2:1:2 composition and for Ni^{+2}, Co^{+2}, Cu^{+2}, Bi^{+3}, Fe^{+3} and Hg^{+2} for 1:1:1 composition. Separation can also be carried out of metal dithizonates namely $Mn(HDz)_2$, $Co(HDz)_2$ and $Cu(HDz)_2$ for 1:2:1 solvent composition.

It has been observed that in 4 M nitric acid + acetone + n-propanol solvent system, the composition 2:2:4 shows the separation of Ni^{+2}, Co^{+2}, Cu^{+2}, Mn^{+2}, Cd^{+2}, Bi^{+3} and Fe^{+3}, while the 2:4:2 composition shows the separation of Ni^{+2}, Zn^{+2}, Cu^{+2}, Cd^{+2} and Bi^{+3}. The chromatographic separation can also be carried out of metal dithizonates, $Ni(HDz)_2$, $Cu(HDz)_2$, $Zn(HDz)_2$, $Cd(HDz)_2$ and $Bi(HDz)_3$ for 2:2:4 solvent composition and $Co(HDz)_2$, $Zn(HDz)_2$, $Cu(HDz)_2$, $Cd(HDz)_2$ and $Fe(HDz)_3$ for 2:4:2 solvent composition.

In ethyl methyl ketone + n-butanol + 50 % hydrochloric acid system, the separation of Ni^{+2}, Co^{+2}, Cu^{+2}, Hg^{+2} and Fe^{+3} for 3:4:3 composition, the separation of Ni^{+2}, Mn^{+2}, Cu^{+2}, Bi^{+3} and Hg^{+2} for 6:3:1 composition and the separation of Co^{+2}, Mn^{+2}, Cu^{+2}, Fe^{+3}, Cd^{+2} and Zn^{+2} for 3:6:1 composition can be carried out.

From the results, it has been also observed that several dithizonates show very high and same R_F values than those of metal ions. Hence separation is difficult.

The results of the best chromatographic separations of various metal ions and metal dithizonates from other metal ions and metal dithizonates respectively on Whatman No.1 filter paper for various solvent systems and various solvent compositions are summarized in table 3.11.

Table 3.11 Chromatographic separations of metal ions/metal dithizonates from other metal ions/metal dithizonates on Whatman No.1 filter papers

Metal ions or Metal dithizonates	R_F values	Solvent systems	Solvent compositions	Separation from other metal ions or metal dithizonates
Ni^{+2}	0.35	M:H:A	2:2:1	Co^{+2}, Cu^{+2}, Zn^{+2} and Fe^{+3}
Cu^{+2}	0.59	M:H:A	1:1:1	Ni^{+2}, Co^{+2}, Zn^{+2} and Fe^{+3}
$Co(HDz)_2$	0.55	M:H:A	2:2:1	$Ni(HDz)_2$, $Cu(HDz)_2$, $Zn(HDz)_2$ and $Fe(HDz)_3$
Mn^{+2}	0.56	H:A:E	1:2:1	Ni^{+2}, Co^{+2}, Hg^{+2} and Fe^{+3}
Cd^{+2}	0.63	H:A:E	1:2:2	Co^{+2}, Cu^{+2}, Hg^{+2} and Fe^{+3}
Ni^{+2}	0.09	A:H:B	2:1:1	Co^{+2}, Cu^{+2}, Zn^{+2} and Bi^{+3}
Zn^{+2}	0.51	A:H:B	2:1:2	Ni^{+2}, Co^{+2}, Cu^{+2} and Hg^{+2}
Cu^{+2}	0.43	N:A:P	2:2:4	Ni^{+2}, Mn^{+2}, Cd^{+2}, Bi^{+3} and Fe^{+3}
Zn^{+2}	0.55	N:A:P	2:4:2	Ni^{+2}, Co^{+2}, Cu^{+2}, Cd^{+2} and Hg^{+2}

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Metal ions or metal dithizonates	R_F values	Solvent systems	Solvent Compositions	Separation from other metal ions or metal dithizonates
$Ni(HDz)_2$	0.37	N:A:P	2:2:4	$Cu(HDz)_2$, $Mn(HDz)_2$, $Cd(HDz)_2$ and $Fe(HDz)_3$
Mn^{+2}	0.11	EMK:B.H	3:6:1	Co^{+2}, Cu^{+2}, Fe^{+3}, Cd^{+2} and Hg^{+2}
Co^{+2}	0.13	EMK:B:H	6:6;3	Ni^{+2}, Cu^{+2}, Bi^{+3}, Cd^{+2} and Zn^{+2}
$Cu(HDz)_2$	0.57	EMK:B:H	6:3:1	$Mn(HDz)_2$ and $Cd(HDz)_2$

From the above studies, it can concluded that by using metal dithizonates instead of simple salts like nitrates and chlorides it is possible to achieve the separation of some binary and ternary mixtures. This can be advantageously used for specific analytical purpose.