Thermochimica Acta, 71 (1983) 209–214
Elsevier Science Publishers B V , Amsterdam – Printed in The Netherlands

Note

SOLUTION CHEMISTRY OF Cu(II)-, Co(II)-, Ni(II)-, Mn(II)- AND Zn(II)-*p*-AMINOBENZALDEHYDE THIOSEMICARBAZONE SYSTEMS

S S SAWHNEY and SURYA K CHANDEL
Chemistry Department, D A V (P.G) College, Dehra Dun 248001 (India)

(Received 13 June 1983)

In recent years, metal complexes of the derivatives of semicarbazide and thiosemicarbazide [1–9] have assumed importance due to their carcinostatic properties and have further attracted the attention of the scientists engaged the world over to combat cancer. Hypotheses followed by their evaluation based upon emperical data on the application of these compounds have been propounded. Sawhney and Sati [10] also attempted to understand the solution chemistry of the interaction of metals with *p*-nitrobenzaldehyde thiosemicarbazone.

A survey of the literature further reveals the absence of any study on the interaction of metals with *p*-aminobenzaldehyde thiosemicarbazone in solution; so plans on these lines were made with a view to understanding the behaviour of *p*-aminobenzaldehyde thiosemicarbazone in the presence of metal ions in solution.

EXPERIMENTAL

All the chemicals used were of AnalaR grade. Metal solutions were prepared in double distilled water and standardised by the standard procedures. *p*-Aminobenzaldehyde thiosemicarbazone was dissolved in acetone. The pH values of the solutions (total volume: 50 ml; medium: 50% acetone–water) (a) 4×10^{-3} M HCl, 1×10^{-1} M KCl; (b) 4×10^{-3} M HCl, 1×10^{-1} M KCl, 1×10^{-3} M ligand; (c) 4×10^{-3} M HCl, 1×10^{-1} M KCl, 1×10^{-3} M ligand, 2×10^{-5} M metal, titrated with 0.1 N NaOH (in 50% acetone–water), were recorded with a Beckman pH-meter H-2, equipped with a glass and calomel electrode assembly, duly standardised with buffers. The pH values, corrected for volume and for non-aqueous media according to Van Uitert and Haas [11] were plotted against 0.1 N NaOH; the ensuing curves were of the usual shape.

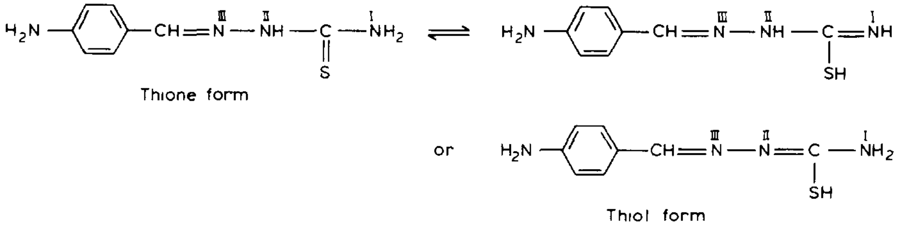
For the isolation of *p*-aminobenzaldehyde thiosemicarbazone, Pandey's procedure [12], involving the mixing of *p*-aminobenzaldehyde (Riedel) in acetone and thiosemicarbazide (LOBA) in distilled water, followed by refluxing for an hour, extracting the liquid layer with ether and solidifying by distilling off ether, was adopted. The *p*-aminobenzaldehyde thiosemicarbazone was recrystallised from acetone. Chemical analysis data tallied the composition of the final product.

Found: C, 49.04%, H, 5.50%, N, 29.67%, S, 15.97%.

Calcd for $[C_8H_{10}N_4S]$· C, 49.48%; H, 5 16%; N, 28.87%; S, 16 49%.

RESULTS AND DISCUSSION

Like *p*-nitrobenzaldehyde thiosemicarbazone (*p*-N BzH · THSMC) [10], *p*-aminobenzaldehyde thiosemicarbazone (*p*-A · BzH · THSMC) undergoes tautomerism in solution, changing from the thione form to the thiol form, with a distinctly acidic sulphahydryl hydrogen capable of forming soluble sodium/potassium salts.



The thiol form with conjugation (=N–N=C–) dominates in solution.

The protonation constant ($^{P}K^{H}$) of *p*-A · BzH · THSMC was determined (Table 1) using Irving and Rossotti's expression [13]

$$\bar{n}_H = Y - \left[\frac{(V'' - V')(N^0 + E^0)}{(V^0 + V')TC_L^0}\right] \tag{1}$$

where the terms have the usual meanings and

$$\log {}^{P}K_n^H = B + \log\frac{\bar{n}_H - (\bar{n} - 1)}{n - \bar{n}_H} \tag{2}$$

where B = the pH-meter reading.

The formation function ($\bar{n}$) was calculated using the Bjerrum method [14]. For the determination of pL (free ligand exponent), eqn (3) was used.

$$pL = \log\left[\frac{1 + (H^+)(^{P}K^{H})}{T_L - (ML) - 2(ML_2) \quad .N(ML_N)}\right] \tag{3}$$

Formation curves ($\bar{n}$ vs. pL) were complete at both ends. At both temperatures (28 and 38°C), the computation of log k_1 and log k_2 at $\bar{n} = 0.5$ and 1 5, respectively, employing the method of interpolation at half $\bar{n}$ values,

TABLE 1

Protonation constants of p-A BzH · THSMC

	28°C	38°C
$\log {}^{P}K^{H}$	12 90	10 75

resulted in a far smaller value of $\log k_1/k_2$ at both 28 or 38°C, ruling out the application of the method for all systems except Mn(II)-p-A · BzH · THSMC, in which a value for $\log k_1/k_2 > 2.5$ was observed. For the evaluation of the constants, the aid of a pointwise calculation method utilising eqns. (4) and (5) and Bjerrum's eqn. (6) [14] was sought

$$\log k_1 = \text{pL} + \log\frac{\bar{n}}{1-\bar{n}} \tag{4}$$

$$\log k_2 = \text{pL} + \log\frac{\bar{n}-1}{2-\bar{n}} \tag{5}$$

$$\frac{\bar{n}}{(\bar{n}-1)\text{L}} + k_1 + \frac{(\bar{n}-2)\text{L}}{\bar{n}-1}k_1k_2 = 0 \quad (N=2) \tag{6}$$

Table 2 gives the values of the constants and thermodynamic functions for the systems.

Each set comprised of five-fold of ligand and one-fold of metal in addition to other ingredients to avoid hydrolysis of the metal. Further, the separation of the metal-p-A · BzH · THSMC curve from p-A · BzH · THSMC constituted strong evidence in favour of the presence of the thiol form in solution and further led to the proposal that in complexation, the anion of p-A · BzH · THSMC participated

For all the systems, $\bar{n}$ approached 2, indicating the presence of complex species with stoichiometries of 1 : 1 and 1 : 2 in solution.

It is shown in Table 2 that $\log {}^{P}K_{H}$, $\log k_1$ and $\log k_2$ decrease in all systems as the temperature rises, emphasising the low temperature as favourable for complexation because of the decrease in number of collisions with decrease in kinetic energy of molecules participating in the reaction and hence the stability of the system is lowered. The free energy change, ΔG^0, assumed a negative value in all the systems, suggesting the spontaneity of the reactions; further, the feasibility of the reactions under study lessened at 38°C as ΔG^0 became less negative with rise of temperature. All the reactions with negative values of ΔH^0 and ΔS^0, are enthalpy controlled; the higher value of $-\Delta H^0$ for all the systems also indicated the considerable degree of covalency in the metal complexes, probably through the terminal hydrazine nitrogen (N^{III}) atom, established through IR and X-ray structure determination of some thiosemicarbazide derivatives [15–19]. Interaction between Cu(II), Co(II), Ni(II), Mn(II), Zn(II) and p-A BzH · THSMC proceeded exothermically as the systems had negative ΔH^0 values and this experimen-

TABLE 2

Stability constants and thermodynamic parameters of metal chelates of *p*-aminobenzaldehyde thiosemicarbazone

Metal ion	Temp (°C)	Method [a]	log k_1	log k_2	log k_1/k_2	log β_2	ΔG^0 (kcal mole^{-1})	ΔH^0 (kcal mole^{-1})	ΔS^0 (cal mole^{-1} °C^{-1})
Cu(II)	28	A	11.70	9.20	2.50	20.90			
		B	11.48	9.03		20.51			
		C	11.65	9.18		20.83			
		Mean	11.61	9.14		20.75	−28.58		
	38	A	10.40	8.95	1.45	19.35			
		B	10.44	8.22		18.66			
		C	10.70	9.62		20.32			
		Mean*	10.57	8.92		19.49	−27.74	−53.97	−84.34
Ni(II)	28	A	12.60	11.04	1.56	23.64			
		B	12.69	10.88		23.57			
		C	12.72	11.09		23.81			
		Mean*	12.71	10.99		23.70	−32.64		
	38	A	10.62	9.34	1.28	19.16			
		B	11.14	8.54		19.68			
		C	11.27	8.54		19.81			
		Mean*	11.21	8.54		19.75	−28.11	−169.20	−483.67
Co(II)	28	A	11.90	10.30	1.60	22.20			
		B	11.99	10.32		22.31			
		C	11.90	10.35		22.25			
		Mean*	11.95	10.34		22.29	−30.70		

	38	A	9.90	7 30	2.60	17 20			
		B	9 97	7.20		17.17			
		C	9 75	6 79		16 54			
		Mean	9 87	7.10		16.97	−24.15	−227 89	−655 11
Mn(II)	28	A	12.40	8 40	4 00	20.80			
		B	12 07	8 31		20 38			
		C	11 96	8 97		20 93			
		Mean	12.14	8.56		20.70	−28 51		
	38	A	10 60	7.05	3.55	17 65			
		B	10 13	6.97		17.10			
		C	9 25	7 41		16 66			
		Mean	9.99	7 14		17 13	−24 38	−152 93	−413 34
Zn(II)	28	A	11 50	9.90	1 60	21 40			
		B	11 53	9 67		21.20			
		C	11.10	9.25		20 35			
		Mean*	11 32	9 46		20.78	−28.62		
	38	A	8 60	6 30	2 30	14.90			
		B	8.63	6 54		15 17			
		C	8 85	6.44		15 29			
		Mean*	8 74	6.49		15 23	−21.67	−237 74	−694 76

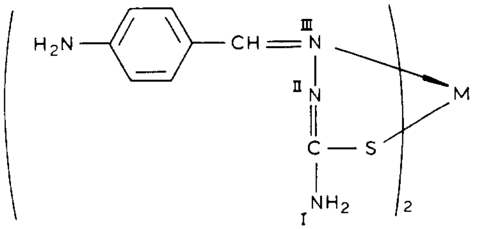
---

[a] A = Bjerrum half integral method, B = pointwise calculation method [eqns (4) and (5)], C = Bjerrum eqn (6) Mean* = mean value of methods B and C.

tal observation further extended support to low temperature as favourable for complexation. The entropy for the systems, being negative, could not favour the reactions.

Stability data (Table 2) on metal-*p*-A · BzH · THSMC complexes at both temperature follow neither the Maley and Mellor order [20] nor the Irving and Williams rule [21].

Utilizing the dominating form of *p*-A · BzH · THSMC in solution with conjugation, i.e. the thiol form, together with present study data and data furnished by other investigators proposing the involvement of the terminal hydrazine, N^{III}, atom in complexation, the following structures are suggested for the complexes.



REFERENCES

1 N Orlova, V A Aksensova, D A Selidovkin, N S Bogdanova and G N Perskin, Russ Pharmacol Toxicol, 60 (1968) 348

2 D J Bauer, L S Vincent, C H Kempe and A W Downie, Lancet, 20 (1963) 494

3 H G Petering, H H Buskirk and G E. Underwood, Cancer Res , 64 (1964) 367

4 G Domagk, R. Behenisch, F Mierzsch and H Schmidt, Naturwissenschaften, 33 (1946) 315

5 D R Williams, Chem Rev , 72 (1972) 203

6 A Furst and R T Haro, Progr Exp Tumor Res., 12 (1969) 102

7 F P Dwyer, E. Mayhew, E M F Roe and A Shulman, Br J Cancer, 19 (1965) 195

8 J A Crim and H G Petering, Cancer Res , 27 (1967) 1278

9 H G Petering and G J Van-Giessen, The Biochemistry of Copper, Academic Press, New York, 1966, pp 197–208

10 S S Sawhney and R M Sati, Thermochim. Acta, 61 (1983) 365

11 L G Van Uitert and C Haas, J Am Chem Soc , 75 (1953) 451

12 U N Pandey, J Indian Chem Soc , 55 (1978) 645

13 H Irving and H Rossotti, J Chem Soc , (1953) 3397, (1954) 2904

14 J Bjerrum, Metal Ammine Formation in Aqueous Solution, Haase, Copenhagen, 1941, p 298

15 R Goronback and S E. Rasmussen, Acta Chem Scand , 16 (1962) 2325

16 C Calzolari, L. Coassini Lokar, P Benci and L Favretto, Ann Chim (Rome), 63(5/6) (1973) 363

17 M A Malic and J D Phillips, Aust J Chem , 28 (1975) 305

18 A R Haines and K.W K Sun, Can J Chem , 20 (1968) 3241.

19 B Beecroft, M J M Campbell and R Grzeskowiak, J Inorg Nucl Chem , 36 (1974) 55

20 L E Maley and D P Mellor, Nature (London), 159 (1947) 394, 161 (1948) 436

21 H Irving and R.J P Williams, Nature (London), 162 (1948) 746