Studies on organomercury(II) complexes with piperidine and 2-aminopyridine dithiocarbamates

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The complexes of organomercury (II) chloride [RHgCl, where R= C6H5 (phenyl), p-Cl C6H4 (p-chlorophenyl), p-Br C6H4 (p-bromophenyl), o-, p-HOC6H4 (o-, p-hydroxyphenyl)] with piperidine dithiocarbamate (L1) and 2-aminopyridine dithiocarbamate (L2) have been synthesized and characterised by IR, UV and 1H NMR spectral studies. Conductance measurement reveals that the compounds are non-electrolytes. Thermogravimetric (TG) and differential thermal analysis (DTA) curves and their variations have been correlated with some structural parameters of the complexes. Activity of all the complexes vs. E. Coli, Z. mobilis bacterial strains and activity vs. A. niger, C. cucurbita fungal strains have been studied and the general order of activity has been deduced.

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Dithiocarbamates are antibacterial and antifungal substances and are known to inhibit the growth of bacteria and fungi1,2. Since the activity of the ligand is altered in the presence of metal ions and the metal complexes of these ligands are of relatively high stability, it was thought worthwhile to synthesise and characterise some organomercury (II) complexes of piperidine dithiocarbamates (L1) and 2-aminopyridine dithiocarbamates (L2).

Experimental

2-Aminopyridine was purchased from CDH Pvt. Ltd, Mumbai, India. Piperidine and mercury were purchased from E Merck, (India) Limited. All reagents were of AR grade. Chlorine, bromine and sulphur were determined gravimetrically as silver chloride, silver bromide and barium sulphate, respectively. Mercury was estimated gravimetrically as mercuric sulphide, HgS. The bactericidal activities were evaluated by cup-agar diffusion method3, while the fungi were cultured on Czapek Dox Nutrient method1.

The conductance measurements were carried out on an Elico Conductivity Bridge Model CM-102, India. The IR and UV Spectra were recorded on a FTIR spectrometer Spectrum 2000 and a Shimatzu UV-visible spectrophotometer model 260, respectively. The 1H NMR spectra were recorded on a Hitachi R-600 FT NMR spectrometer at a spectral width of 60 MHz and Brucker spectrospin advance 300 spectrometer at a spectral width of 300 MHz. Rigaku Thermoflex, model PTC-10A. Rigaku Corporation, Japan was used for simultaneous recording of TG-DTA curves of the complexes in air at a heating rate of 10° min⁻¹. For TG, the instrument was calibrated using calcium oxide while DTA calibration was done using indium metal, both were supplied along with the instrument. A flat bed type Al-crucible was used with α-alumina (99% pure) as the reference material for DTA.

Preparation of sodium piperidine dithiocarbamate (L1)

It was prepared by the modified method given by Gilman and Blatt4. A three-necked 500 ml flask was used in which the middle neck was fitted with a mechanical stirrer; second neck with a separating funnel and the third neck was loosely stoppered. The flask was placed in a freezing mixture of common salt and ice. Sodium hydroxide (10.0 g, 0.25 mole), dissolved in minimum amount of water, was added to the flask. Pure carbon disulphide (15.1 ml, 0.25 mole) was also added to the flask, through the separating funnel. To the stirred mixture, pure piperidine (21.28 g, 0.25 mole) was added dropwise through the separating funnel in about 30 min. The contents were stirred mechanically for about 30 min. Sodium piperidine dithiocarbamate precipitated out, dried and recrystallised from acetone. The reaction proceeds in the manner shown below:

\[
\text{Piperidine + S}_{2} + \text{NaOH} \rightarrow \text{Sodium piperidine dithiocarbamate} \quad \text{Na}^{+} + \text{H}_{2}O
\]

Analysis: Found: C= 39.67%, H=5.95%, N=7.75%, S=35.40% Calc: C=39.31%, H=5.46%, N=7.64%, S=35.02%. IR (KBr), cm⁻¹: ν(C= N), 1475; ν(C=S), 964, 1025.

Preparation of sodium 2-aminopyridine dithiocarbamate (L2)

This compound was prepared by the same procedure (Gilman and Blatt4) as adopted in the case.
of sodium piperidine dithiocarbamate. The reaction proceeds in the manner shown below:

\[
\begin{align*}
\text{Piperidine} & \quad \text{C} & \quad \text{S} & \quad \text{NaOH} & \quad \text{Sodium 2-amino piperidine dithiocarbamate} \\
\text{H} & \quad \text{N} & \quad \text{C} & \quad \text{H} & \quad \text{Hg} & \quad \text{Water} & \quad \text{Na}^+ \\
\end{align*}
\]

Analysis: Found: C=37.65%, H=2.85%, N=14.45%, S=33.40% Calc: C=37.47%, H=2.60%, N=14.57%, S=33.38%, IR (KBr), cm\(^{-1}\): ν(C=N), 1488; ν(C=S), 970, 1019.

Phenylmercuric chloride, \(p\)-chloro and \(p\)-bromo phenylmercuric chloride were prepared as reported in literature.

Synthesis of sodium piperidine dithiocarbamate complexes

A solution of sodium piperidine dithiocarbamate (\(L^1\), 3.6 g, 0.02 mole) in 25 ml THF was added slowly to a solution of RHgCl (0.02 mole) in 25 ml THF. The contents were stirred for about 5 h at room temperature. The reaction mixture was reduced to one-fourth of its original volume by evaporating the solvent under vacuum. The complexes were precipitated on addition of dry petroleum ether. These were dried in vacuum desiccator over anhydrous CaCl\(_2\).

Results and discussion

The complexes isolated are pure, powder like, colourless and are soluble only in DMSO. The molar conductance measurements for these complexes are found to be <10 \(\text{ohm}^{-1} \text{mol}^{-1} \text{cm}^2\). indicating that these compounds are nonelectrolytes. The analytical data of the complexes along with the decomposition temperature are given in Table 1.

<table>
<thead>
<tr>
<th>Complex</th>
<th>Empirical formula</th>
<th>Dec. temp, °C</th>
<th>C</th>
<th>H</th>
<th>N</th>
<th>S</th>
<th>Cl</th>
<th>Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>(p)-ClC(_6)H(_2)Hg((L^2)) (1)</td>
<td>C(_6)H(_6)NS(_2)Hg((p)-ClC(_6)H(_4))</td>
<td>227</td>
<td>30.20</td>
<td>(30.49)</td>
<td>2.52</td>
<td>(2.96)</td>
<td>2.46</td>
<td>(2.96)</td>
</tr>
<tr>
<td>(p)-BrC(_6)H(_2)Hg((L^1)) (2)</td>
<td>C(_6)H(_6)NS(_2)Hg((p)-BrC(_6)H(_4))</td>
<td>225</td>
<td>28.21</td>
<td>(27.87)</td>
<td>2.22</td>
<td>(2.70)</td>
<td>2.34</td>
<td>(2.70)</td>
</tr>
<tr>
<td>(p)-OHCl(_6)H(_2)Hg((L^1)) (3)</td>
<td>C(_6)H(_6)NS(_2)Hg((p)-OHCl(_6)H(_4))</td>
<td>210</td>
<td>31.03</td>
<td>(31.73)</td>
<td>3.85</td>
<td>(3.30)</td>
<td>3.87</td>
<td>(3.08)</td>
</tr>
<tr>
<td>(o)-OHCl(_6)H(_2)Hg((L^1)) (4)</td>
<td>C(_6)H(_6)NS(_2)Hg((o)-OHCl(_6)H(_4))</td>
<td>248</td>
<td>32.01</td>
<td>(31.73)</td>
<td>3.02</td>
<td>(3.30)</td>
<td>2.91</td>
<td>(3.08)</td>
</tr>
<tr>
<td>(C(_6)H(_6)Hg((L^1)) (5)</td>
<td>C(_6)H(_6)NS(_2)HgС(_6)H(_3)</td>
<td>265</td>
<td>32.07</td>
<td>(32.89)</td>
<td>3.61</td>
<td>(3.42)</td>
<td>2.96</td>
<td>(3.19)</td>
</tr>
<tr>
<td>(p)-ClC(_6)H(_2)Hg((L^2)) (6)</td>
<td>C(_6)H(_6)NS(_2)Hg((p)-ClC(_6)H(_4))</td>
<td>212</td>
<td>29.02</td>
<td>(29.92)</td>
<td>2.44</td>
<td>(1.87)</td>
<td>5.08</td>
<td>(5.81)</td>
</tr>
<tr>
<td>(p)-BrC(_6)H(_2)Hg((L^2)) (7)</td>
<td>C(_6)H(_6)NS(_2)Hg((p)-BrC(_6)H(_4))</td>
<td>240</td>
<td>27.03</td>
<td>(27.39)</td>
<td>2.02</td>
<td>(1.71)</td>
<td>5.61</td>
<td>(5.32)</td>
</tr>
<tr>
<td>(p)-OHCl(_6)H(_2)Hg((L^2)) (8)</td>
<td>C(_6)H(_6)NS(_2)Hg((p)-OHCl(_6)H(_4))</td>
<td>253</td>
<td>30.91</td>
<td>(31.11)</td>
<td>2.61</td>
<td>(2.16)</td>
<td>6.77</td>
<td>(6.05)</td>
</tr>
<tr>
<td>(o)-OHCl(_6)H(_2)Hg((L^2)) (9)</td>
<td>C(_6)H(_6)NS(_2)Hg((o)-OHCl(_6)H(_4))</td>
<td>250</td>
<td>30.84</td>
<td>(31.11)</td>
<td>2.76</td>
<td>(2.16)</td>
<td>6.62</td>
<td>(6.05)</td>
</tr>
<tr>
<td>(C(_6)H(_6)Hg((L^2)) (10)</td>
<td>C(_6)H(_6)NS(_2)HgС(_6)H(_3)</td>
<td>246</td>
<td>32.67</td>
<td>(32.43)</td>
<td>2.00</td>
<td>(2.23)</td>
<td>5.59</td>
<td>(6.26)</td>
</tr>
</tbody>
</table>
In IR spectra, the absorption at 1450-1550 cm\(^{-1}\) in case of the ligand was assigned to \(v(C \rightarrow N)\) vibration of S\(_2\)C\(=\)NR\(_2\) bond. The second region in the range 950-1050 cm\(^{-1}\) was associated with the \(v(C \rightarrow S)\) vibration. In dithiocarbamate complexes one strong band around 1000 cm\(^{-1}\), indicating that all the dithiocarbamate ligands are bidentate and symmetrically bounded, in case of monodentate dithiocarbamate\(^{9,10}\) ligand a doublet arises around 1000 cm\(^{-1}\) separated by \(> 20\) cm\(^{-1}\) which is due to non-equivalence of two \(C \rightarrow S\) stretching vibrations. Far IR spectra contained the M-S stretching appearing in the region 400-800 cm\(^{-1}\). The band at \(\approx 370\) cm\(^{-1}\) was assigned to M-Cl vibrations. The CH\(_2\) stretching appeared in the region 2900-3000 cm\(^{-1}\). The \(v(C \rightarrow C)\) aromatic stretching frequencies, coupled with the symmetric and asymmetric inplane stretching vibrational bands appeared in the region 1400-1600 cm\(^{-1}\) (ref. 12). The C-H asymmetric in-plane aromatic deformation occurs at \(\approx 1370\) cm\(^{-1}\), \(\approx 1300\) cm\(^{-1}\), \(\approx 1070\) cm\(^{-1}\). The IR band at \(\approx 800\) cm\(^{-1}\) was assigned to C-H out of phase deformation.

In UV spectra of sodium piperidine dithiocarbamate two bands at 270 nm (log \(e = 1.765\)) and 288 nm (log \(e = 1.790\)) were observed due to \(\pi - \pi^*\) transition of \(N \rightarrow C \rightarrow S\) groups and \(n - \pi^*\) electronic transition involving lone pair of electrons located on the sulphur atom respectively. Two absorption bands were observed for sodium 2-aminopyridine dithiocarbamate at 275 nm (log \(e = 1.740\)) and 290 nm (log \(e = 1.608\)). These bands shifted to lower wavelength on complexation, showing the involvement of NCS\(_2\) group in complexation in all the complexes. In all the dithiocarbamate complexes one band at 350-354 nm appeared which was due to metal \(\rightarrow\) ligand charge transfer.

The \(^1\)H NMR spectra of piperidine dithiocarbamate complexes showed signals in \(\delta 6.7-7.2\) (m, 15H, Ar-H), 1.7-1.9 (t, 6H\(^b\), -CH\(_2\)), 3.4-3.5 (d, 4H\(^a\), -CH\(_2\)), and 3.3 (S, 6H, -CH\(_2\)) regions. In free sodium piperidine dithiocarbamate ligand, the signals have been reported in \(\delta 1.62\) (t, 6H\(^b\), -CH\(_2\)) and \(\delta 3.1-3.2\) (d, 4H\(^a\), -CH\(_2\)). The \(^1\)H NMR spectra of 2-aminopyridine dithiocarbamate complexes showed signals in \(\delta 7.0-7.2\) (m, 15H, Ar-H), 3.2-3.5 (S, 6H, -CH\(_2\)), 7.3-7.5 (m, 1H\(^b\), -CH), 7.5-7.6 (m, 1H\(^a\), -CH), 8.0-8.2 (m, 1H\(^b\), -CH), 8.6-8.8 (d, 1H\(^a\), -CH), 5.0-5.2 (S, 1H\(^a\), -NH). In free sodium 2-aminopyridine dithiocarbamate ligand, the signals have been reported in \(\delta 6.9-7.0\) (m, 1H\(^b\), -CH), 7.42-7.45 (m, 1H\(^a\), -CH), 7.7-7.8 (m, 1H\(^b\), -CH), 8.45 (d, 1H\(^a\), -CH) and 4.7-4.9 (S, 1H\(^a\), -NH) regions.

A downfield shift in the position of resonance signals of the complexes in comparison to the free ligands may be attributed as a result of co-ordination of the ligand to metal ion. The spectra showed no trace of the free ligands, indicating that the complexes did not dissociate on dissolution.

**Thermal studies**

The thermogravimetric studies show that the complexes decomposed to the oxides of mercury and finally volatilization of HgO occurs. The mass loss data of the complexes is recorded. The mass loss data and thermogravimetric evaluations are compiled in Table 2. The order of the reaction (\(n\)) and the activation energy (\(E_a\)) of the thermal decomposition reaction have been elucidated by the method of Coats and Redfern\(^{13}\). The entropy of activation (\(S^a\)) has been calculated by the method of Zsaka\(^{14}\).

The TG data of the \(p\)-OHC\(_6\)H\(_4\)Hg(L\(^1\)), \(o\)-OHC\(_6\)H\(_4\)Hg(L\(^1\)), \(p\)-BrC\(_6\)H\(_4\)Hg(L\(^2\)) and \(o\)-OHC\(_6\)H\(_4\)Hg(L\(^2\)) shows continuous weight loss of 95.22, 87.90, 89.60 and 92.00%, respectively. This shows that the complex decomposes and volatilizes simultaneously and no separate indication of HgO formation is observed.

The order of thermal decomposition reaction in all the complexes is found to be one. The energy of activation reflects the kinetic lability of the complexes. The compound with lower \(E_a\) values are more labile as compared to those with higher \(E_a\) values.

The apparent activation entropy has a positive value for all the complexes. Hence, thermal degradation of these complexes is a spontaneous process.

The TG data of the complexes is supplemented by DTA studies. DTA evaluations are compiled in Table 3.
The heat of reaction (ΔH) for the thermal decomposition reaction has been enumerated from the DTA curves\(^{15,16}\). The temperature dependent calibration coefficient has been obtained from the Curell Equation.

**Microbial assay**

All the complexes have been screened for bactericidal activity against pathogenic strains of *Escherichia coli* (*E. coli*) and *Zanthomonas mobilis* (*Z. mobilis*) using the respective ligands as the standard for comparing the activities. The samples have been screened at three concentrations (25 µg mL\(^{-1}\), 50 µg mL\(^{-1}\) and 100 µg mL\(^{-1}\)) in DMSO. The inhibitory power of the complexes was greater than the control. The complexes, in general, inhibited the growth of bacteria to a greater extent as the concentration increased. The order of activity with respect to the microorganisms was: *Z. mobilis* > *E. coli*.

All the complexes were tested for fungicidal activity at three concentrations (25 µg mL\(^{-1}\), 50 µg mL\(^{-1}\) and 100 µg mL\(^{-1}\)) against *Aspergillus niger* and *Cerveleria*. The complexes, in general, inhibited the growth of fungi to a greater extent as the concentration increased. The order of fungicidal activity with respect to the fungus species was: *A. niger* > *Cerveleria*.

**References**