SPECTRAL STUDIES ON SOME ORGANIC COMPLEXES OF URANYL ION

Part I. Absorption Spectra of Pyridine Complexes.

BY D. N. SANWAL AND D. D. PANT

(Physics Department, Th.D.S.B. Govt. College, Nainital)

Received June 17, 1968

(Communicated by Dr. R. K. Asundi, F.A.Sc.)

ABSTRACT

The absorption spectra of new crystalline uranyl complexes with pyridine, at 80 ~Kare described. Pyridine uranyl chloride crystallises in two forms, both forms give sharp line like bands at low temperatures. In Form I the bands are analysed in terms of five electronic transitions F, M, D, U and SU of which the former four were suggested for uranyl ion by Dieke et al. Results on analogous compounds with deuteropyridine are also reported. Chloride complex seems to have pyridine in the first co-ordination sphere while the acetate complex is of the type of double salt.

INTRODUCTION

INVESTIGATIONS on the spectroscopic properties of uranyl ion under the action of various ligands already exist in literature.1-4 A simple organic complexing agent is, however, the pyridine molecule. The effect of this molecule in the sphere of solvation or co-ordination of uranyl ion was found rather interesting and was pursued in some detail. New crystalline uranyl compounds were obtained by the complexing of pyridine with various uranyl salts. Some analogous compounds with deuteropyridine* were also studied. We describe in this paper the absorption spectra of some uranyl complexes with pyridine.

EXPERIMENTAL

Absorption spectra of solutions were obtained on the Hilger Uvispec Spectrophotometer. The spectra of crystalline compounds were photographed on a Bausch and Lomb 1.5 meter grating spectrograph, having

*Kindly sent by Prof. M. Kasha, Department of Chemistry, Florida State University.
a dispersion of 16 Å per mm. The chemicals used were A.R. grade. Purification of pyridine was done by conventional methods.

Pyridine complex with uranyl chloride was found to crystallise in two forms. We call the microcrystalline precipitate obtained on adding pyridine to the solution of uranyl chloride in concentrated HCl as form I which redissolves in excess of pyridine and also crystallises as hexagonal plates. Also if the Form I crystals are left in the mother liquor itself for a couple of days at temperatures below 5°C, crystals of Form II having a different morphology begin to grow, those of Form I dissolving as Form II crystals appear. On heating to about 25°C, or above crystals of Form II are converted to Form I. Both Form I and Form II are highly fluorescent and give very sharp bands at low temperatures. With uranyl nitrate and acetate also new crystalline compounds were obtained. The details in the absorption of nitrate complex, however, could not be studied.

(a) Absorption Spectra in Pyridine Solutions

Unlike aqueous solutions, the absorption curves of solutions in pyridine for various uranyl salts consist of broad unresolved bands except for uranyl chloride. In this case eight bands were observed at 4950 Å, 4800 Å, 4640 Å, 4465 Å, 4322 Å, 4195 Å, 4075 Å and 3955 Å respectively. The first band is red shifted with respect to the corresponding band in aqueous solutions.

(b) Absorption Spectra of Crystalline Pyridine Complexes

(i) Chloride.—The spectra, at 80°C, for Form I and Form II are shown in Figs. 1 and 2. The spectra have been photographed both by taking a single crystal of microcrystalline powder pressed between two quartz plates. Various series, starting from the longer wavelength side, are termed as fluorescence (F), magnetic (M), diffuse (D), ultraviolet (U) and second ultraviolet (SU). The first four electronic transitions in uranyl salts were suggested by Dieke and Duncan. Starting of a new transition after the U series was first observed by Pande in this laboratory. Evidence for these vibronic transitions has also been obtained from spectra of uranyl solutions.

Form I.—On the basis of intensity considerations and vibrational analysis the five electronic transitions are clearly observed in Form I. The positions of observed bands are given in Table I which also contains the positions of prominent bands for the analogous compound with deutero-pyridine and the vibrational analysis. The spectra for the two compounds are similar, there is no appreciable shift within 2 cm⁻¹ in the positions of
**Table I**

Absorption bands of pyridine uranyl chloride and deutero-pyridine uranyl chloride Form I at 80°C K.

<table>
<thead>
<tr>
<th>Nature</th>
<th>Pyridine uranyl chloride</th>
<th>Deutero-pyridine uranyl chloride</th>
<th>Designation</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Position in cm.⁻¹</td>
<td>Δν</td>
<td>Position in cm.⁻¹</td>
<td>Δν</td>
</tr>
<tr>
<td>w, s</td>
<td>20064</td>
<td>..</td>
<td>20063</td>
<td>..</td>
</tr>
<tr>
<td>w, s</td>
<td>20081</td>
<td>17</td>
<td>20080</td>
<td>17</td>
</tr>
<tr>
<td>m, s</td>
<td>20154</td>
<td>90</td>
<td>20155</td>
<td>92</td>
</tr>
<tr>
<td>w, s</td>
<td>20260</td>
<td>196</td>
<td>20260</td>
<td>197</td>
</tr>
<tr>
<td>m, s</td>
<td>20311</td>
<td>247</td>
<td>20312</td>
<td>249</td>
</tr>
<tr>
<td>m, b</td>
<td>20395</td>
<td>331</td>
<td>20394</td>
<td>331</td>
</tr>
<tr>
<td>S, b</td>
<td>20422</td>
<td>358</td>
<td>20416</td>
<td>353</td>
</tr>
<tr>
<td>vw, b</td>
<td>20452</td>
<td>388</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>vw, b</td>
<td>20477</td>
<td>413</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>vw, b</td>
<td>20500</td>
<td>436</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, b</td>
<td>20536</td>
<td>472</td>
<td>20538</td>
<td>475</td>
</tr>
<tr>
<td>vw, b</td>
<td>20548</td>
<td>484</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>S, b</td>
<td>20660</td>
<td>596</td>
<td>20656</td>
<td>593</td>
</tr>
<tr>
<td>w, s</td>
<td>20770</td>
<td>706</td>
<td>20767</td>
<td>704</td>
</tr>
<tr>
<td>m, s</td>
<td>20787</td>
<td>723</td>
<td>20782</td>
<td>718</td>
</tr>
<tr>
<td>m, s</td>
<td>20798</td>
<td>734</td>
<td>20794</td>
<td>731</td>
</tr>
<tr>
<td>m, s</td>
<td>20860</td>
<td>796</td>
<td>20859</td>
<td>796</td>
</tr>
<tr>
<td>m, s</td>
<td>20962</td>
<td>898</td>
<td>20960</td>
<td>897</td>
</tr>
<tr>
<td>m, s</td>
<td>21014</td>
<td>950</td>
<td>21015</td>
<td>952</td>
</tr>
<tr>
<td>m, b</td>
<td>21098</td>
<td>1034</td>
<td>21096</td>
<td>1033</td>
</tr>
<tr>
<td>S, b</td>
<td>21120</td>
<td>1056</td>
<td>21117</td>
<td>1054</td>
</tr>
<tr>
<td>m, b</td>
<td>21238</td>
<td>1134</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>S, b</td>
<td>21346</td>
<td>1288</td>
<td>21338</td>
<td>1275</td>
</tr>
<tr>
<td>S, b</td>
<td>21358</td>
<td>1294</td>
<td>21353</td>
<td>..</td>
</tr>
<tr>
<td>m, b</td>
<td>21369</td>
<td>1305</td>
<td>..</td>
<td>1290</td>
</tr>
<tr>
<td>m, s</td>
<td>21472</td>
<td>1408</td>
<td>21467</td>
<td>1407</td>
</tr>
<tr>
<td>m, s</td>
<td>21488</td>
<td>1424</td>
<td>21484</td>
<td>1421</td>
</tr>
<tr>
<td>m, b</td>
<td>21568</td>
<td>1504</td>
<td>21570</td>
<td>1507</td>
</tr>
<tr>
<td>m, b</td>
<td>21578</td>
<td>1514</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>vw, b</td>
<td>21662</td>
<td>1598</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>vw, s</td>
<td>21716</td>
<td>1652</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, b</td>
<td>21793</td>
<td>1729</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>S, b</td>
<td>21814</td>
<td>1750</td>
<td>21808</td>
<td>1745</td>
</tr>
<tr>
<td>m, b</td>
<td>21839</td>
<td>1775</td>
<td>21832</td>
<td>1769</td>
</tr>
<tr>
<td>w, s</td>
<td>21961</td>
<td>1897</td>
<td>21963</td>
<td>1900</td>
</tr>
<tr>
<td>m, b</td>
<td>22030</td>
<td>1966</td>
<td>22024</td>
<td>1961</td>
</tr>
<tr>
<td>m, b</td>
<td>22048</td>
<td>1984</td>
<td>22045</td>
<td>1962</td>
</tr>
</tbody>
</table>
### Table I—Contd.

<table>
<thead>
<tr>
<th>Nature</th>
<th>Pyridine uranyl Chloride</th>
<th>Deutero-pyridine uranyl chloride</th>
<th>Designation</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Position in cm$^{-1}$</td>
<td>$\Delta \nu$</td>
<td>Position in cm$^{-1}$</td>
<td>$\Delta \nu$</td>
</tr>
<tr>
<td>$w, s$</td>
<td>22154</td>
<td>2090</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$s, s$</td>
<td>22168</td>
<td>2104</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>22210</td>
<td>2146</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>22232</td>
<td>2168</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, b &amp; d$</td>
<td>22253</td>
<td>2189</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, b &amp; d$</td>
<td>22266</td>
<td>2202</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$w, b$</td>
<td>22404</td>
<td>2340</td>
<td>22409</td>
<td>2346</td>
</tr>
<tr>
<td>$m, b$</td>
<td>22496</td>
<td>2432</td>
<td>22480</td>
<td>2416</td>
</tr>
<tr>
<td>$m, b$</td>
<td>22524</td>
<td>2460</td>
<td>22519</td>
<td>2456</td>
</tr>
<tr>
<td>$m, d$</td>
<td>22644</td>
<td>2580</td>
<td>22648</td>
<td>2582</td>
</tr>
<tr>
<td>$w, d$</td>
<td>22713</td>
<td>2649</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$S, d$</td>
<td>22738</td>
<td>2674</td>
<td>22747</td>
<td>2684</td>
</tr>
<tr>
<td>$S, d$</td>
<td>22759</td>
<td>2694</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$w, d$</td>
<td>22784</td>
<td>2720</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$w, d$</td>
<td>22872</td>
<td>2808</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$w, d$</td>
<td>22904</td>
<td>2840</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>22939</td>
<td>2875</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>22952</td>
<td>2888</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>22992</td>
<td>2928</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$S, d$</td>
<td>23015</td>
<td>2951</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$S, d$</td>
<td>23037</td>
<td>2973</td>
<td>23023</td>
<td>2960</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23098</td>
<td>3034</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23119</td>
<td>3055</td>
<td>23144</td>
<td>3061</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23157</td>
<td>3093</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, s, s$</td>
<td>23208</td>
<td>3144</td>
<td>23209</td>
<td>3146</td>
</tr>
<tr>
<td>$w, s$</td>
<td>23233</td>
<td>3179</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$w, d$</td>
<td>23306</td>
<td>3242</td>
<td>23299</td>
<td>3236</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23349</td>
<td>3275</td>
<td>23346</td>
<td>3283</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23389</td>
<td>3325</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23416</td>
<td>3352</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$S, d$</td>
<td>23443</td>
<td>3379</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$vS, d$</td>
<td>23464</td>
<td>3399</td>
<td>23460</td>
<td>3397</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23491</td>
<td>3427</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23571</td>
<td>3507</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23615</td>
<td>3551</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23663</td>
<td>3599</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23687</td>
<td>3623</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$S, d$</td>
<td>23712</td>
<td>3648</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$vS, d$</td>
<td>23737</td>
<td>3673</td>
<td>23725</td>
<td>3662</td>
</tr>
<tr>
<td>$S, b$</td>
<td>23819</td>
<td>3155</td>
<td>23824</td>
<td>3761</td>
</tr>
</tbody>
</table>
### TABLE I—Contd.

<table>
<thead>
<tr>
<th>Nature</th>
<th>Pyridine uranyl chloride</th>
<th>Deutero-pyridine uranyl chloride</th>
<th>Designation</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Position in cm$^{-1}$</td>
<td>$\Delta \nu$</td>
<td>Position in cm$^{-1}$</td>
<td>$\Delta \nu$</td>
</tr>
<tr>
<td>w, b</td>
<td>23912</td>
<td>3858</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>m, d</td>
<td>23987</td>
<td>3923</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>m, d</td>
<td>24046</td>
<td>3982</td>
<td>24048</td>
<td>3985</td>
</tr>
<tr>
<td>m, d</td>
<td>24094</td>
<td>4030</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>m, d</td>
<td>24123</td>
<td>4059</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>S, d</td>
<td>24144</td>
<td>4080</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>vS, d</td>
<td>24172</td>
<td>4106</td>
<td>24161</td>
<td>4098</td>
</tr>
<tr>
<td>w, d</td>
<td>24271</td>
<td>4207</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, d</td>
<td>24318</td>
<td>4254</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, d</td>
<td>24333</td>
<td>4269</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>m, d</td>
<td>24378</td>
<td>4314</td>
<td>24376</td>
<td>4353</td>
</tr>
<tr>
<td>S, d</td>
<td>24412</td>
<td>4348</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>vS, b</td>
<td>24435</td>
<td>4371</td>
<td>24423</td>
<td>4360</td>
</tr>
<tr>
<td>m, d</td>
<td>24512</td>
<td>4458</td>
<td>24509</td>
<td>4446</td>
</tr>
<tr>
<td>w, d</td>
<td>24539</td>
<td>4475</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, d</td>
<td>24743</td>
<td>4679</td>
<td>24750</td>
<td>4687</td>
</tr>
<tr>
<td>S, d</td>
<td>24850</td>
<td>4786</td>
<td>24862</td>
<td>4799</td>
</tr>
<tr>
<td>S, d</td>
<td>24874</td>
<td>4810</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, d</td>
<td>24959</td>
<td>4895</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, d</td>
<td>24991</td>
<td>4827</td>
<td>24982</td>
<td>4919</td>
</tr>
<tr>
<td>m, s</td>
<td>25036</td>
<td>4972</td>
<td>25039</td>
<td>4976</td>
</tr>
<tr>
<td>w, s</td>
<td>25058</td>
<td>4994</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>S, b</td>
<td>25106</td>
<td>5042</td>
<td>25103</td>
<td>5040</td>
</tr>
<tr>
<td>S, b</td>
<td>25129</td>
<td>5063</td>
<td>25128</td>
<td>5065</td>
</tr>
<tr>
<td>w, b</td>
<td>25221</td>
<td>5157</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>m, b</td>
<td>25434</td>
<td>5370</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>S, d</td>
<td>25550</td>
<td>5486</td>
<td>25556</td>
<td>5493</td>
</tr>
<tr>
<td>w, b</td>
<td>25567</td>
<td>5503</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>vw, d</td>
<td>25659</td>
<td>5595</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>vw, d</td>
<td>25684</td>
<td>5620</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>m, s</td>
<td>25730</td>
<td>5666</td>
<td>25732</td>
<td>5669</td>
</tr>
<tr>
<td>m, s</td>
<td>25751</td>
<td>5685</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>m, b</td>
<td>25798</td>
<td>5734</td>
<td>25795</td>
<td>5732</td>
</tr>
<tr>
<td>w, b</td>
<td>25819</td>
<td>5755</td>
<td>25820</td>
<td>5757</td>
</tr>
<tr>
<td>m, s</td>
<td>25964</td>
<td>5898</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, d</td>
<td>26224</td>
<td>6160</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, d</td>
<td>26246</td>
<td>6182</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, s</td>
<td>26363</td>
<td>6299</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>w, s</td>
<td>26400</td>
<td>6336</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>m, d</td>
<td>26487</td>
<td>6423</td>
<td>26480</td>
<td>6417</td>
</tr>
<tr>
<td>m, d</td>
<td>26508</td>
<td>6444</td>
<td>..</td>
<td>..</td>
</tr>
</tbody>
</table>
sharp bands and the uranyl frequencies are not changed. There is a doublet in the first group of fluorescence series, i.e., $a_0$ at ca 22663 cm$^{-1}$ ($\Delta \nu = 17$ cm$^{-1}$). The three uranyl vibrations associated with this series $v_1'$, $v_2'$ and $v_3'$ are 704 cm$^{-1}$, 245 cm$^{-1}$ and 732 cm$^{-1}$ respectively and the series can be traced to its third member. The $v_1'$ which alone can be identified with certainty in other series has an approximate value of 760 cm$^{-1}$. The $M$, $D$ and $U$ series have two components each with ca 265 cm$^{-1}$, 280 cm$^{-1}$ and 180 cm$^{-1}$ respectively. Finally, there is observed a series of strong and sharp bands, with a doublet structure ($\Delta \nu = 45$ cm$^{-1}$) starting at about 7707 cm$^{-1}$ above $a_0$. Only two members are observed with a frequency interval of ca 696 cm$^{-1}$ and after this the absorption reaches a high value resulting in a continuous absorption. This series is designated as SU (second ultraviolet series). A complete microphotometer tracing of the absorption spectrum is given in Fig. 1 to demonstrate the presence of this series.

Form II.—The observed bands for Form II are given in Table II both for pyridine and deuteropyridine compounds. Both spectra are similar, however, the crystal for the case of deuteropyridine happened to be of
### Table II

Absorption bands of pyridine uranyl chloride and deutero-pyridine uranyl chloride Form II at 80°K.

<table>
<thead>
<tr>
<th>Nature</th>
<th>Pyridine uranyl chloride</th>
<th>Deutero-pyridine uranyl chloride</th>
<th>Designation</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Position in cm.⁻¹</td>
<td>Position in cm.⁻¹</td>
<td>Δν</td>
<td>Δν</td>
</tr>
<tr>
<td>w, s</td>
<td>20027 .</td>
<td>20026 .</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>vw, s</td>
<td>20041 17</td>
<td>20043 17</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>v w, d</td>
<td>20156 130</td>
<td>20269 243</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, d</td>
<td>20270 243</td>
<td>20332 306</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, b</td>
<td>20338 310</td>
<td>20389 362</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, d</td>
<td>20456 429</td>
<td>20453 427</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, b</td>
<td>20479 453</td>
<td>20564 538</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, s</td>
<td>20598 571</td>
<td>20603 577</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>S, b</td>
<td>20734 707</td>
<td>20978 952</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, s</td>
<td>20748 722</td>
<td>20992 966</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, s</td>
<td>20763 736</td>
<td>21041 1015</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, d</td>
<td>21096 1070</td>
<td>21140 1114</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, d</td>
<td>21163 1136</td>
<td>21180 1154</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, s</td>
<td>21242 1216</td>
<td>21242 1242</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>v w, s</td>
<td>21301 1274</td>
<td>21309 1273</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>S, b</td>
<td>21429 1404</td>
<td>21428 1403</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, s</td>
<td>21445 1418</td>
<td>21445 1419</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>S, s</td>
<td>21460 1433</td>
<td>21661 1435</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, b</td>
<td>21499 1472</td>
<td>21488 1462</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, b</td>
<td>21503 1477</td>
<td>21526 1500</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, d</td>
<td>21564 1538</td>
<td>21564 1538</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, s</td>
<td>21607 1581</td>
<td>21607 1581</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, d</td>
<td>21601 1655</td>
<td>21601 1655</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, d</td>
<td>21687 1660</td>
<td>21695 1669</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>v w, d</td>
<td>21744 1717</td>
<td>21741 1715</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>v w, d</td>
<td>21791 1764</td>
<td>21795 1769</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>w, d</td>
<td>21859 1747</td>
<td>21873 1747</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Nature</td>
<td>Pyridine uranyl chloride</td>
<td>Deutero-pyridine uranyl chloride</td>
<td>Designation</td>
<td>Interpretation</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------</td>
<td>---------------------------------</td>
<td>-------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Position in cm.$^{-1}$</td>
<td>Position in cm.$^{-1}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$vw, s$</td>
<td>21997</td>
<td>21960</td>
<td>$b_2 + L_3$</td>
<td></td>
</tr>
<tr>
<td>$S, b$</td>
<td>21997</td>
<td>1997</td>
<td>$b_2 + L_3$</td>
<td></td>
</tr>
<tr>
<td>$vw, s$</td>
<td>21997</td>
<td>22010</td>
<td>$M_2$</td>
<td>$M_0 + 2v_1$'</td>
</tr>
<tr>
<td>$w, b$</td>
<td>22049</td>
<td>2023</td>
<td>$b_3$</td>
<td>$b_0 + 3v_1$'</td>
</tr>
<tr>
<td>$vw, s$</td>
<td>22117</td>
<td>2090</td>
<td>$b_3$</td>
<td>$b_0 + 3v_1$'</td>
</tr>
<tr>
<td>$w, d$</td>
<td>22136</td>
<td>2110</td>
<td>$b_3$</td>
<td>$b_0 + 3v_1$'</td>
</tr>
<tr>
<td>$w, d$</td>
<td>22144</td>
<td>2117</td>
<td>$b_3$</td>
<td>$b_0 + 3v_1$'</td>
</tr>
<tr>
<td>$w, d$</td>
<td>22213</td>
<td>2196</td>
<td>$b_3 + L_3$</td>
<td></td>
</tr>
<tr>
<td>$w, b$</td>
<td>22266</td>
<td>2238</td>
<td>$b_3 + L_3$</td>
<td></td>
</tr>
<tr>
<td>$vw, d$</td>
<td>22339</td>
<td>2312</td>
<td>$b_3 + L_3$</td>
<td></td>
</tr>
<tr>
<td>$w, d$</td>
<td>22468</td>
<td>2456</td>
<td>$b_3 + L_3$</td>
<td></td>
</tr>
<tr>
<td>$S, b &amp; d$</td>
<td>22591</td>
<td>2554</td>
<td>$M_2'$</td>
<td>$M_0' + 2v_1$'</td>
</tr>
<tr>
<td>$m, d$</td>
<td>22787</td>
<td>2760</td>
<td>$M_2'$</td>
<td>$M_0' + 2v_1$'</td>
</tr>
<tr>
<td>$m, b$</td>
<td>22715</td>
<td>2688</td>
<td>$M_2'$</td>
<td>$M_0' + 2v_1$'</td>
</tr>
<tr>
<td>$m, b$</td>
<td>22734</td>
<td>2707</td>
<td>$M_2'$</td>
<td>$M_0' + 2v_1$'</td>
</tr>
<tr>
<td>$m, d$</td>
<td>22831</td>
<td>2795</td>
<td>$M_2'$</td>
<td>$M_0' + 2v_1$'</td>
</tr>
<tr>
<td>$S, b$</td>
<td>22841</td>
<td>2814</td>
<td>$M_2'$</td>
<td>$M_0' + 2v_1$'</td>
</tr>
<tr>
<td>Red edge</td>
<td>..</td>
<td>22888</td>
<td>$D_0'$</td>
<td>Diffuse series</td>
</tr>
<tr>
<td>$S, vb &amp; d$</td>
<td>22925</td>
<td>2898</td>
<td>$D_0'$</td>
<td>Diffuse series</td>
</tr>
<tr>
<td>Violet edge</td>
<td>..</td>
<td>22977</td>
<td>$D_0'$</td>
<td>Diffuse series</td>
</tr>
<tr>
<td>$m, b$</td>
<td>23076</td>
<td>3049</td>
<td>$D_1$</td>
<td>$D_0 + v_1$'</td>
</tr>
<tr>
<td>$m, b$</td>
<td>23150</td>
<td>3123</td>
<td>$D_1$</td>
<td>$D_0 + v_1$'</td>
</tr>
<tr>
<td>$m, b$</td>
<td>23119</td>
<td>3165</td>
<td>$D_1$</td>
<td>$D_0 + v_1$'</td>
</tr>
<tr>
<td>$m, d$</td>
<td>23291</td>
<td>3264</td>
<td>$D_1$</td>
<td>$D_0 + v_1$'</td>
</tr>
<tr>
<td>$S, b &amp; d$</td>
<td>23392</td>
<td>3365</td>
<td>$D_1$</td>
<td>$D_0 + v_1$'</td>
</tr>
<tr>
<td>$m, b$</td>
<td>22338</td>
<td>3311</td>
<td>$D_1$</td>
<td>$D_0 + v_1$'</td>
</tr>
<tr>
<td>$w, d$</td>
<td>23392</td>
<td>3365</td>
<td>$D_1$</td>
<td>$D_0 + v_1$'</td>
</tr>
<tr>
<td>$w, d$</td>
<td>23403</td>
<td>3376</td>
<td>$D_1$</td>
<td>$D_0 + v_1$'</td>
</tr>
<tr>
<td>$w, d$</td>
<td>23455</td>
<td>3428</td>
<td>$D_1$</td>
<td>$D_0 + v_1$'</td>
</tr>
<tr>
<td>$w, b$</td>
<td>23557</td>
<td>3530</td>
<td>$M_2'$</td>
<td></td>
</tr>
<tr>
<td>Red edge</td>
<td>..</td>
<td>23493</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td>$vs$</td>
<td>..</td>
<td>3466</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td>Violet edge</td>
<td>..</td>
<td>23638</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td>$vs$</td>
<td>..</td>
<td>3611</td>
<td>3542</td>
<td>..</td>
</tr>
<tr>
<td>Red edge</td>
<td>..</td>
<td>23611</td>
<td>3584</td>
<td>..</td>
</tr>
</tbody>
</table>
## Spectral Studies on Some Organic Complexes of Uranyl Ion—I

### Table II—Contd.

<table>
<thead>
<tr>
<th>Nature</th>
<th>Pyridine uranyl chloride</th>
<th>Deuteropyridine uranyl chloride</th>
<th>Desig-</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Position in cm.⁻¹</td>
<td>ΔP</td>
<td>Position in cm.⁻¹</td>
<td>ΔP</td>
</tr>
<tr>
<td>Violet edge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w, b</td>
<td>23786</td>
<td>3769</td>
<td>23691</td>
<td>3664</td>
</tr>
<tr>
<td>w, b</td>
<td>23820</td>
<td>3793</td>
<td>23786</td>
<td>3759</td>
</tr>
<tr>
<td>w, b</td>
<td>23858</td>
<td>3831</td>
<td>23849</td>
<td>3822</td>
</tr>
<tr>
<td>w, b</td>
<td>23893</td>
<td>3866</td>
<td>23865</td>
<td>3838</td>
</tr>
<tr>
<td>w, b</td>
<td>23926</td>
<td>3899</td>
<td>23908</td>
<td>3881</td>
</tr>
<tr>
<td>S, b &amp; d</td>
<td>24013</td>
<td>3986</td>
<td>24001</td>
<td>3974</td>
</tr>
<tr>
<td>w, d</td>
<td>24190</td>
<td>4163</td>
<td>24194</td>
<td>4167</td>
</tr>
<tr>
<td>w, b</td>
<td>24220</td>
<td>4193</td>
<td>24228</td>
<td>4201</td>
</tr>
<tr>
<td>red edge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>νS, b &amp; d</td>
<td>24337</td>
<td>4310</td>
<td>24391</td>
<td>4364</td>
</tr>
<tr>
<td>violet edge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w, d</td>
<td>24600</td>
<td>4573</td>
<td>24612</td>
<td>4585</td>
</tr>
<tr>
<td>s, b</td>
<td>24698</td>
<td>4671</td>
<td>24704</td>
<td>4677</td>
</tr>
<tr>
<td>s, b</td>
<td>24966</td>
<td>4939</td>
<td>24984</td>
<td>4957</td>
</tr>
<tr>
<td>w, d</td>
<td>25016</td>
<td>4989</td>
<td>25005</td>
<td>4978</td>
</tr>
<tr>
<td>s, b</td>
<td>25037</td>
<td>5010</td>
<td>25052</td>
<td>5025</td>
</tr>
<tr>
<td>S, b</td>
<td>25061</td>
<td>5034</td>
<td>25075</td>
<td>5048</td>
</tr>
<tr>
<td>m, b</td>
<td>25392</td>
<td>5365</td>
<td>25404</td>
<td>5377</td>
</tr>
<tr>
<td>vw, b</td>
<td>25596</td>
<td>5569</td>
<td>25596</td>
<td>5569</td>
</tr>
<tr>
<td>vw, d</td>
<td>25639</td>
<td>5612</td>
<td>25625</td>
<td>5598</td>
</tr>
<tr>
<td>w, b</td>
<td>25670</td>
<td>5643</td>
<td>25688</td>
<td>5661</td>
</tr>
<tr>
<td>S, b</td>
<td>25720</td>
<td>5693</td>
<td>25730</td>
<td>5703</td>
</tr>
<tr>
<td>m, b</td>
<td>25733</td>
<td>5706</td>
<td>25750</td>
<td>5723</td>
</tr>
<tr>
<td>vw, s</td>
<td>26163</td>
<td>6136</td>
<td>26167</td>
<td>6140</td>
</tr>
<tr>
<td>vw, s</td>
<td>26189</td>
<td>6162</td>
<td>26178</td>
<td>6151</td>
</tr>
<tr>
<td>m, b</td>
<td>26285</td>
<td>6258</td>
<td>26255</td>
<td>6228</td>
</tr>
<tr>
<td>w, s</td>
<td>26298</td>
<td>6271</td>
<td>26305</td>
<td>6278</td>
</tr>
<tr>
<td>S, b</td>
<td>26425</td>
<td>6398</td>
<td>26448</td>
<td>6421</td>
</tr>
<tr>
<td>w, s</td>
<td>26880</td>
<td>6853</td>
<td>26885</td>
<td>6858</td>
</tr>
<tr>
<td>w, s</td>
<td>26903</td>
<td>6876</td>
<td>26901</td>
<td>6874</td>
</tr>
<tr>
<td>S, b</td>
<td>27010</td>
<td>6983</td>
<td>27025</td>
<td>6998</td>
</tr>
<tr>
<td>w, b</td>
<td>27136</td>
<td>7109</td>
<td>27126</td>
<td>7099</td>
</tr>
<tr>
<td>u, b</td>
<td>27712</td>
<td>7685</td>
<td>27695</td>
<td>7668</td>
</tr>
<tr>
<td>m, d</td>
<td>27806</td>
<td>7779</td>
<td>27833</td>
<td>7806</td>
</tr>
<tr>
<td>S, d</td>
<td>27900</td>
<td>7873</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S, d</td>
<td>27936</td>
<td>7909</td>
<td>27965</td>
<td>7938</td>
</tr>
</tbody>
</table>

Heavy absorption: 28281 28300 ...
a suitable thickness for greater details of absorption to be investigated. A number of vibrations, other than uranyl frequencies, were thus found associated with the fluorescence series. The spectrum is classified in four series. The absorption beyond U series could not be studied because thin single crystal could not be obtained of an adequate size. On making a thin film with powder the crystalline modification was found to get converted partly to Form I, thus making the spectrum very complicated.

(ii) Acetate.—The spectrum is shown in Fig. 3 and the observed bands are given in Table III with assignments. The fluorescence series starts with $b_0$ at ca. 20974 cm.$^{-1}$. A series of strong bands, M series, starts at ca. 773 cm.$^{-1}$ above $b_0$ and can be followed up to its fourth member with repetition frequency of ca. 690 cm.$^{-1}$ and consists of doublets with $\Delta\nu = 300$ cm.$^{-1}$. The doublet nature of D series, which starts at about 1660 cm.$^{-1}$ above $b_0$, is evident after its second member ($\Delta\nu = 355$ cm.$^{-1}$). The frequency interval between successive members of this series is about 715 cm.$^{-1}$. A series of comparatively sharper bands starts at about 6040 cm.$^{-1}$ above fluorescence series and is designated as U series in conformity with the general usage. From ca. 7990 cm.$^{-1}$ above $b_0$ the absorption seems to become continuous.

**DISCUSSION**

The identification of various electronic transitions in the pyridine complexes has been made through vibrational analysis, structure of bands and intensity considerations. In the case of diffuse bands with multiplet structure the vibrational analysis becomes unreliable, however, the second criterion is helpful that the intensity in the second group is higher than the first group and falls again after the second or the third group. It is an experimental generalisation that in almost all cases M, D and U series are doublets with separations varying from 150 cm.$^{-1}$ to 400 cm.$^{-1}$, the violet member being in general weaker. In uranyl sulphate a doublet separation of this order has also been observed in fluorescence series.$^{5,6,11}$ It is again a general observation that in going from a single salt to a double salt M series becomes more intense than D or F series. The solutions also accord with this conclusion where anionic complexing enhances M series and with hydrolysis D series becomes intense. In solid hydrolysed samples also M series is known to get weaker than in normal salt. The spectrum of pyridine uranyl acetate resembles that of double acetates, the M series bands are rather broad and have highest intensity. Pyridine complexes with uranyl
### TABLE III

Absorption bands of pyridine uranyl acetate at liquid air temperature

<table>
<thead>
<tr>
<th>Nature</th>
<th>Position in cm$^{-1}$</th>
<th>$\Delta \nu$</th>
<th>Designation</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w, s$</td>
<td>20974</td>
<td>..</td>
<td>$b_0$</td>
<td>Resonance band</td>
</tr>
<tr>
<td>$vw, d$</td>
<td>2104</td>
<td>130</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$w, b$</td>
<td>21149</td>
<td>175</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$w, b$</td>
<td>21209</td>
<td>235</td>
<td>..</td>
<td>$b_0 + v_2^\prime$</td>
</tr>
<tr>
<td>$w, b$</td>
<td>21237</td>
<td>263</td>
<td>L</td>
<td>Ligand</td>
</tr>
<tr>
<td>$w, b$</td>
<td>21665</td>
<td>691</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$S, b$</td>
<td>21704</td>
<td>730</td>
<td>$b_1$</td>
<td>$b_0 + v_3^\prime$</td>
</tr>
<tr>
<td>$VS, vb$</td>
<td>21747</td>
<td>773</td>
<td>$M_0$</td>
<td>Magnetic series</td>
</tr>
<tr>
<td>$VS, vb$</td>
<td>21831</td>
<td>857</td>
<td>$M_{0'}$</td>
<td>Magnetic series</td>
</tr>
<tr>
<td>$vw, b$</td>
<td>21922</td>
<td>948</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$vw, b$</td>
<td>21983</td>
<td>1009</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$S, b &amp; d$</td>
<td>22049</td>
<td>1075</td>
<td>$M_0$</td>
<td>..</td>
</tr>
<tr>
<td>$vw, b$</td>
<td>22341</td>
<td>1367</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$vw, b$</td>
<td>22384</td>
<td>1310</td>
<td>$b_4$</td>
<td>$b_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$VS, vb$</td>
<td>22423</td>
<td>1459</td>
<td>$M_4$</td>
<td>$M_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$VS, vb$</td>
<td>22551</td>
<td>1577</td>
<td>$D_0$</td>
<td>Diffuse series</td>
</tr>
<tr>
<td>$S, vd$</td>
<td>22635</td>
<td>1661</td>
<td>$D_{0'}$</td>
<td>$M_0 + 2v_4^\prime$</td>
</tr>
<tr>
<td>$S, b &amp; d$</td>
<td>22749</td>
<td>1775</td>
<td>$M_2$</td>
<td>..</td>
</tr>
<tr>
<td>$vw, b$</td>
<td>22821</td>
<td>1847</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$VS, vb$</td>
<td>23108</td>
<td>2134</td>
<td>$M_2$</td>
<td>$M_0 + 2v_4^\prime$</td>
</tr>
<tr>
<td>$VS, vb$</td>
<td>23246</td>
<td>2272</td>
<td>$D_2$</td>
<td>$D_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$S, d$</td>
<td>23305</td>
<td>2331</td>
<td>$D_1$</td>
<td>$D_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$S, d$</td>
<td>23350</td>
<td>2376</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$S, b &amp; d$</td>
<td>23457</td>
<td>2501</td>
<td>$M_3$</td>
<td>$M_0 + 2v_4^\prime$</td>
</tr>
<tr>
<td>$S, b &amp; d$</td>
<td>23704</td>
<td>2730</td>
<td>$D_1'$</td>
<td>Diffuse series</td>
</tr>
<tr>
<td>$S, d$</td>
<td>23793</td>
<td>2819</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$VS, vb$</td>
<td>23840</td>
<td>2866</td>
<td>$M_3$</td>
<td>$M_0 + 3v_4^\prime$</td>
</tr>
<tr>
<td>$VS, vb$</td>
<td>23959</td>
<td>2985</td>
<td>$D_2'$</td>
<td>$D_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$S, d$</td>
<td>24018</td>
<td>3044</td>
<td>$D_2$</td>
<td>$D_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$S, vb &amp; d$</td>
<td>24160</td>
<td>3186</td>
<td>$D_2$</td>
<td>$D_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$S, vb &amp; d$</td>
<td>24404</td>
<td>3430</td>
<td>$D_3$</td>
<td>$D_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$S, vb &amp; d$</td>
<td>24586</td>
<td>3612</td>
<td>$D_3'$</td>
<td>$D_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$S, b &amp; d$</td>
<td>25085</td>
<td>4111</td>
<td>$D_3'$</td>
<td>$D_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$w, b$</td>
<td>25564</td>
<td>4590</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$vw, b$</td>
<td>25817</td>
<td>4843</td>
<td>$D_4$</td>
<td>$D_0 + v_4^\prime$</td>
</tr>
<tr>
<td>$S, s$</td>
<td>27016</td>
<td>6042</td>
<td>$U_0$</td>
<td>Ultraviolet series</td>
</tr>
<tr>
<td>$S, d$</td>
<td>27666</td>
<td>6692</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$w, b$</td>
<td>27746</td>
<td>6742</td>
<td>$U_1$</td>
<td>$U_0 + v_1^\prime$</td>
</tr>
<tr>
<td>$w, b$</td>
<td>27840</td>
<td>6865</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>$S, vb &amp; d$</td>
<td>28478</td>
<td>7504</td>
<td>$SU_0$</td>
<td>New series starts</td>
</tr>
<tr>
<td>Heavy absorption</td>
<td>28969</td>
<td>7995</td>
<td>..</td>
<td>..</td>
</tr>
</tbody>
</table>

$v$—very, $w$—weak, $S$—strong, $m$—moderate, $s$—sharp, $b$—broad and $d$—diffuse.
chloride partly resemble the double chlorides and partly the unhydrolysed single chlorides. The spectra are red shifted with respect to the single salt and violet shifted compared to double salt (caesium uranyl chloride). The red shift seems to originate due to basic nature of pyridine in the first co-ordination sphere. Red shift is also observed in spectra of pyridine solutions with respect to the corresponding aqueous solutions. The resemblance of spectra, with single salts in that D and M series are almost equally intense and also with the double salts so far as red shift is concerned, indicates both anionic and nitrogen complexing in the equatorial plane of uranyl ion. The intimate structure and positions of various bands are not altered in the analogous compound with deutero-pyridine. An interesting feature of the spectra of pyridine uranyl chloride complexes is the extra sharpness of bands. The multiplet structure of D series could thus be observed. Each member of D series (red component) is found to consist of four bands, the interval of stronger central components is ca 20 cm.\(^{-1}\) and that of wings on either side ca 25 cm.\(^{-1}\). The members of D' series consist of three bands each, the separation being 23 cm.\(^{-1}\). There have been indications regarding a new transition to start after U series in a number of solids as well as solutions. In pyridine uranyl chloride Form I this transition is brought forth very clearly. It is not to be confused with U series which is weak. The bands of U series are clearly recognised by their sharp character among the broad bands of diffuse series.

**ACKNOWLEDGEMENT**

We are thankful to the Ministry of Education, Govt. of India, and C.S.I.R. for financial assistance and to Dr. S. D. Sinhval for permission to work on the microphotometer at U.P. State Observatory, Nainital. We are also grateful to Dr. R. K. Asundi for valuable comments and suggestions.

**REFERENCES**

1. Nichols, E. L. and Howes, H. L.  

2. Dieke, G. H. and Duncan, A. B. F.  

3. Rabinowitch, E. and Belford, R. L.  

4. Jozowska-Trzebiatowska, B. et al.  
Fig. 1. Absorption spectrum of pyridine uranyl chloride from I at liquid air temperatures along with complete micro-photometer tracings.
Fig. 2. Absorption spectrum of pyridine uranyl chloride form II at liquid air temperature.

Fig. 3. Absorption spectrum of pyridine uranyl acetate at liquid air temperature and room temperature.