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## Cinnoline Chemistry. XI. The Ultraviolet Spectra of Halogen Substituted 4-Hydroxy- and 4-Mercaptocinnolines

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The ultraviolet spectra of a series of 4-hydroxy- and 4-mercaptocinnolines substituted with fluorine, chlorine or bromine in the 5-, 6-, 7- and 8-position have been obtained in absolute methanol solution between 200 and 500  $m\mu$ . The spectra were used to make structural assignments for the products of cyclization from mesoxalyl chloride, *m*-fluoro- and *m*-bromophenylhydrazones.

The halogenated 4-hydroxy and 4-mercaptocinnolines whose ultraviolet spectra are recorded in this paper were prepared by the method of Barber *et al.*, (1) described in our previous paper of this series (2). This method involves the cyclization of halogen substituted mesoxalyl chloride phenylhydrazones to 4-hydroxycinnoline-3-carboxylic acids. When the mesoxalyl chloride phenylhydrazones are substituted with halogen in the *meta* position, the cyclization may proceed in two directions to give the isomeric 5- and 7-halo-4-hydroxycinnoline-3-carboxylic acids. These halogenated 4-hydroxycinnoline-3-carboxylic acids were converted into the halogenated hydroxycinnolines by decarboxylation.

7-Chloro-4-hydroxycinnoline (m.p. 276-277°) was prepared by Atkinson and Simpson (3) by an unambiguous method from 2-amino-4-chloroacetophenone, therefore its structure is known with certainty. Barber, *et al.*, (1) obtained a chlorohydroxycinnoline (m.p. 330-332°) from the cyclization of mesoxalyl chloride *m*-chlorophenylhydrazone followed by decarboxylation to which they assigned the structure 5-chloro-4-hydroxycinnoline since it differed in melting point from the product described by Atkinson and Simpson (3). In our hands the method of Barber, *et al.*, (1) gave a mixture of 5-chloro-4-hydroxy- and 7-chloro-4-hydroxycinnoline. Likewise the mesoxalyl chloride *m*-bromophenylhydrazone gave a mixture of 5-bromo-4-hydroxy- (m.p. 325-327°) and 7-bromo-4-hydroxycinnoline (285-286°). However, we obtained only the 7-fluoro-4-hydroxycinnoline (m.p. 226-227°) from the mesoxalyl chloride *m*-fluorophenylhydrazone.

We were able to assign the structures of the products obtained from the cyclization of the mesoxalyl chloride *m*-bromo and *m*-fluorophenylhydrazones from their ultraviolet spectra. The assignments were based upon the similarity of the spectra of 4-hydroxycinnolines when these were substituted with halogen in the same position. These similarities in the spectra are clearly illustrated in the instances of the 6- and 8-halo-4-hydroxycinnolines shown in Figures 2 and 4 respectively. The structures of the 6- and 8-isomers were known with certainty.

We have assigned the structure of 7-fluoro-4-hydroxycinnoline (m.p. 226-227°) and 7-bromo-4-hydroxycinnoline (m.p. 285-286°) based upon the close similarity of the spectrum of these compounds

compared with the spectra of 7-chloro-4-hydroxycinnoline, as shown in Figure 3. Likewise we have assigned the structure 5-bromo-4-hydroxycinnoline to the other bromo isomer (m.p. 325-327°) because of the similarity of the spectrum of this compound compared with that of 5-chloro-4-hydroxycinnoline as shown in Figure 1.

The same spectral similarities exist in the corresponding 4-mercaptocinnolines (2) substituted with halogen in the same position. These spectra are shown in Figures 5, 6, 7 and 8. The spectra were recorded in absolute methanol.

When 95% ethanol was used as the solvent, the mercapto group of several 4-mercaptocinnolines was replaced by a hydroxyl group upon standing for a few days at room temperature. The spectral evidence for this exchange is demonstrated in the instance of 8-bromo-4-mercaptocinnoline and is recorded in Figure 9.

The spectra of the 4-hydroxy- and 4-mercaptocinnolines consist of four bands between 200 and 400  $m\mu$ . The longest wavelength high-intensity band appears at  $\sim 380 m\mu$  for the 4-hydroxycinnolines and at  $\sim 420 m\mu$  for the 4-mercaptocinnolines in methanol solution. Obviously this band is associated with the carbonyl or thiocarbonyl group since it does not appear in the spectra of cinnolines without this type of substituent (4). The band probably should be assigned to a  $\pi \rightarrow \pi^*$  transition because of its high intensity ( $\epsilon > 10,000$ ).

The three bands of shorter wavelengths are the three  $\pi \rightarrow \pi^*$  bands usually observed in naphthalene type systems (5). The differences in the spectra caused by change of the position of the halogen substituent mainly appears in the two lower intensity bands at 280-300 and 250-260  $m\mu$  respectively. These bands correspond to the  ${}^1L_b$  and  ${}^1L_a$  bands of the Platt notation for aromatic hydrocarbons (6) and corresponding bands are observed in cinnolines without carbonyl or thiocarbonyl groups in the 4- position. Osborn and Schofield (4) investigated the behavior of these two bands as a function of the position of the substituent in a series of chlorocinnolines and found that the overall effect on the intensities of the two bands was in agreement with the concept that the transition moment of the  ${}^1L_b$  band is directed mainly along the long axis of the cinnoline ring and that the transition moment of the shorter wavelength of the  ${}^1L_a$  band is directed along the short axis.

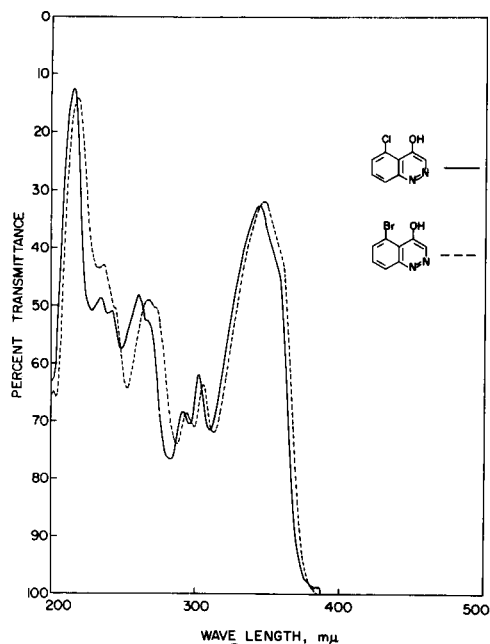


Figure 1. 5-Chloro-4-hydroxycinnoline,  $\lambda$  max  $m\mu$  (log  $\epsilon$ ); 214 (4.36); 232 (3.90); 241 (3.86); 259 (3.90); 266 (3.84); 289 (3.62); 301 (3.72); 342 (4.09). 5-Bromo-4-hydroxycinnoline, 216 (4.33); 234 (3.96); 265 (3.89); 270 (3.86); 292 (3.61); 304 (3.69); 346 (4.09).

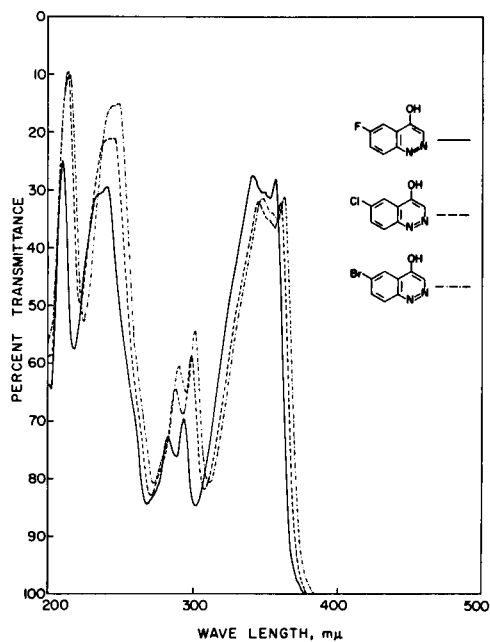


Figure 2. 6-Fluoro-4-hydroxycinnoline,  $\lambda$  max  $m\mu$  (log  $\epsilon$ ); 210 (4.17); 234 (4.11); 241 (4.12); 283 (3.54); 294 (3.60); 342 (4.15); 357 (4.14). 6-Chloro-4-hydroxycinnoline, 214 (4.41); 240 (4.23); 245 (4.23); 288 (3.68); 299 (3.77); 345 (4.09); 360 (4.09). 6-Bromo-4-hydroxycinnoline, 215 (4.40); 243 (4.31); 249 (4.31); 290 (3.74); 301 (3.81); 348 (4.10); 363 (4.10).

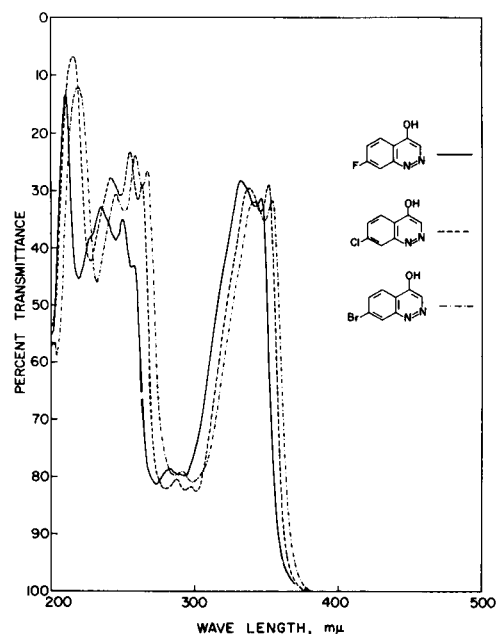


Figure 3. 7-Fluoro-4-hydroxycinnoline,  $\lambda$  max  $m\mu$  (log  $\epsilon$ ); 208 (4.34); 225 (4.02); 235 (4.08); 248 (4.06); 256 (3.96); 280 (3.42); 288 (3.39); 331 (4.14); 345 (4.11). 7-Chloro-4-hydroxycinnoline, 214 (4.47); 240 (4.14); 253 (4.20); 262 (4.13); 285 (3.38); 295 (3.34); 336 (4.12); 350 (4.13). 7-Bromo-4-hydroxycinnoline, 217 (4.36); 243 (4.11); 257 (4.19); 265 (4.16); 289 (3.41); 339 (4.09); 352 (4.10).

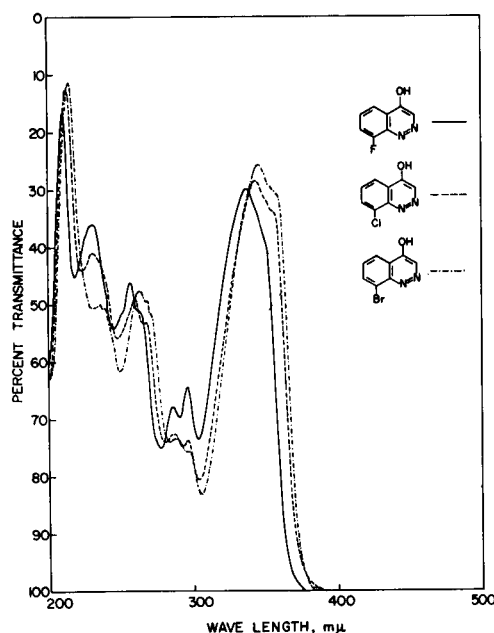


Figure 4. 8-Fluoro-4-hydroxycinnoline,  $\lambda$  max  $m\mu$  (log  $\epsilon$ ); 209 (4.29); 228 (4.05); 255 (3.93); 284 (3.63); 294 (3.68); 336 (4.12). 8-Chloro-4-hydroxycinnoline, 212 (4.35); 229 (3.99); 258 (3.89); 266 (3.84); 285 (3.55); 294 (3.52); 342 (4.14). 8-Bromo-4-hydroxycinnoline, 213 (4.38); 234 (3.84); 261 (3.91); 267 (3.84); 286 (3.53); 294 (3.49); 344 (4.17).

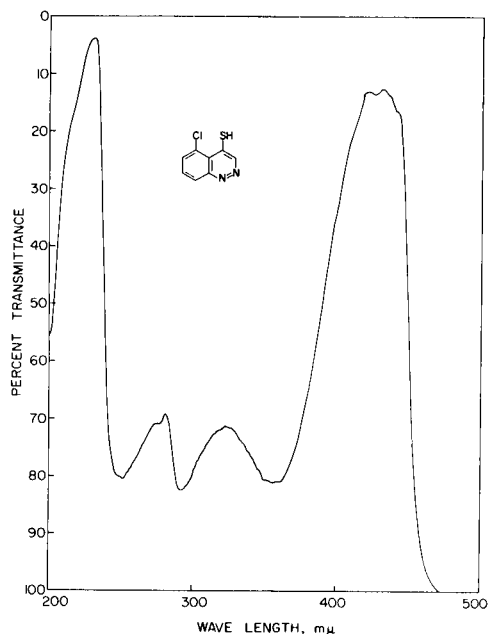


Figure 5. 5-Chloro-4-mercaptocinnoline,  $\lambda$  max  $m\mu$  (log  $\epsilon$ ); 231 (4.48); 272 (3.53); 281 (3.53); 328 (3.51); 421 (4.28); 430 (4.26).

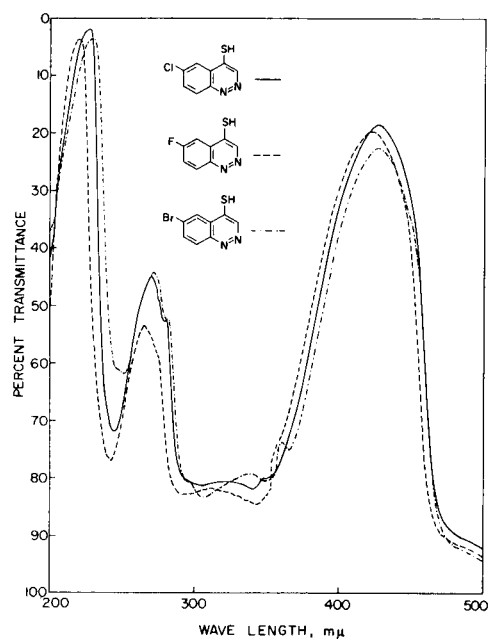


Figure 6. 6-Fluoro-4-mercaptocinnoline,  $\lambda$  max  $m\mu$  (log  $\epsilon$ ); 221 (4.55); 267 (3.83); 313 (3.33); 424 (4.25). 6-Chloro-4-mercaptocinnoline, 229 (4.63); 271 (3.94); 281 (3.85); 322 (3.37); 430 (4.26). 6-Bromo-4-mercaptocinnoline, 231 (4.56); 273 (3.95); 284 (3.85); 299 (3.38); 340 (3.41); 361 (3.53); 429 (4.28).

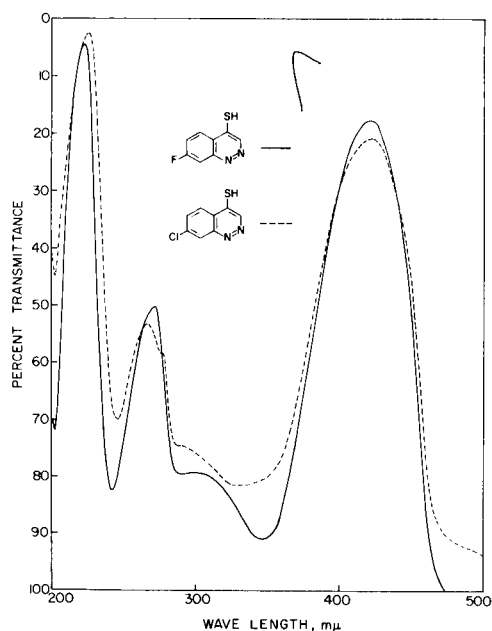


Figure 7. 7-Fluoro-4-mercaptocinnoline,  $\lambda$  max  $m\mu$  (log  $\epsilon$ ); 221 (4.53); 270 (3.87); 306 (3.41); 420 (4.28). 7-Chloro-4-mercaptocinnoline, 227 (4.60); 267 (3.84); 278 (3.77); 296 (3.50); 427 (4.23).

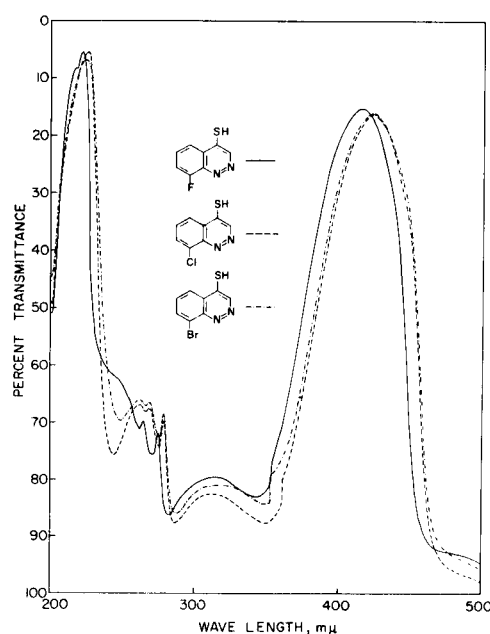


Figure 8. 8-Fluoro-4-mercaptocinnoline,  $\lambda$  max  $m\mu$  (log  $\epsilon$ ); 220 (4.50); 266 (3.59); 276 (3.56); 316 (3.40); 417 (4.31). 8-Chloro-4-mercaptocinnoline, 227 (4.50); 262 (3.64); 269 (3.63); 279 (3.60); 315 (3.32); 425 (4.30). 8-Bromo-4-mercaptocinnoline, 227 (4.46); 263 (3.66); 271 (3.65); 281 (3.61); 320 (3.36); 426 (4.27).

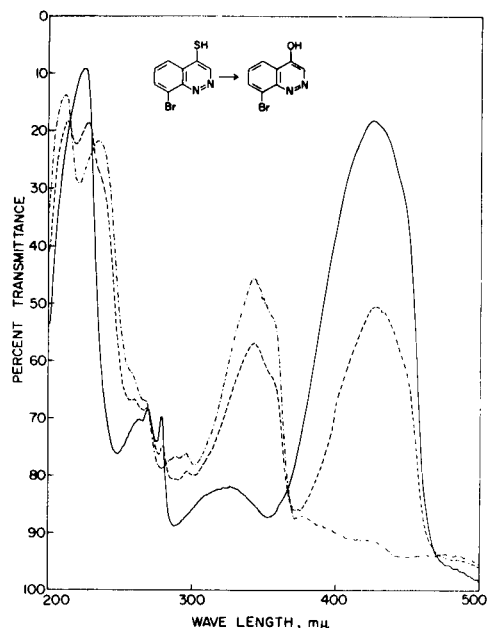


Figure 9. The solid line (—) represents the spectrum of 8-bromo-4-mercaptocinnoline taken immediately after solution in 95% ethanol. The dashed line (-----) represents the spectrum of this compound after the solution had been allowed to stand approximately 24 hours at room temperature.

The dot-dashed line (-.-.-) represents the spectrum of this compound after the solution had been allowed to stand for five days at room temperature.

A similar simple picture cannot be deduced from the spectra of the 4-hydroxy- and 4-mercaptocinnolines. Possibly the substitution of the carbonyl or thiocarbonyl group into the cinnoline system changes the direction of the transition moments, so that these two bands cannot be associated with transitions along the major axes in the molecule.

#### EXPERIMENTAL

The spectra were recorded on a Bausch and Lomb Spectrophotometer Model No. 505 between 200 and 500  $m\mu$  in 10 mm. quartz cells. The solvent was absolute methanol, dried over magnesium and distilled immediately before use. The concentrations were  $4.0 \times 10^{-5}$  M.

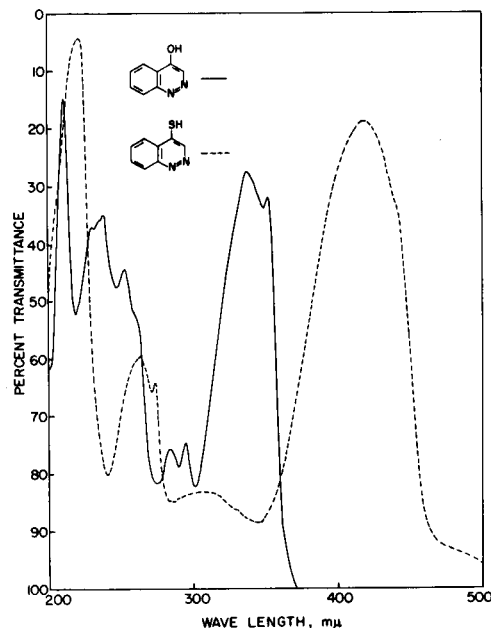


Figure 10. 4-Hydroxycinnoline,  $\lambda$  max  $m\mu$  ( $\log \epsilon$ ): 211 (4.32); 231 (4.03); 238 (4.06); 253 (3.94); 283 (3.48); 294 (3.50); 338 (4.15); 352 (4.09). 4-Mercaptocinnoline, 224 (4.58); 264 (3.82); 275 (3.75); 308 (3.39); 422 (4.30).

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