Spectral Properties of Mono- and Dihydroxychromones

G. Romussi and G. Ciarallo

Istituto di Chimica Farmaceutica e Tossicologica and Istituto di Tecnica Farmaceutica, University of Genoa, Genoa, Italy

Received July 14, 1975

The uv, ir, and nmr spectra of a number of hydroxy- and methoxychromones, substituted only in the benzene ring, were studied. The results are particularly useful in determining the position of the hydroxyl groups. Chromatographic data on paper are also given.

J. Heterocyclic Chem., 13, 211 (1976).

It has become evident that derivatives of chromone not substituted in the 2- and/or 3-positions, are more abundant in nature than was previously thought (1-4). Since uv, ir and nmr spectrometric data of these compounds may be very useful in determining the attachment site of oxygen substituents in natural chromones (2-4), the spectral behaviour of 23 chromones substituted in the benzene ring only, were studied.

Uv Spectra

Synthesized chromone derivatives exhibit high intensity absorption in the 290-360 (Band I) and 240-260 (Band II) nm regions (5) (Table 1). Comparison with chromone, which exhibits two major absorption peaks at 240 and 298 nm (6), shows a consistent bathochromic shift of one or both bands from the introduction of electron-donating groups.

Methylation of the 5-hydroxyl group, which prevents hydrogen-bonding with the pyrone carbonyl group, produces a hypsochromic shift of Band I (6-22 nm) and Band II (3-12 nm) (**2** → **1**, **11** → **9**, **13** → **12**). Methylation of a 6-hydroxyl group results in a hypsochromic shift (7-10 nm) of Band I and does not have any appreciable effect on Band II (**4** → **3**, **18** → **17**, **20** → **19**). Methylation of a 7-hydroxyl group has little effect on both bands (**6** → **5**, **23** → **22**). Methylation of a 8-hydroxyl group produces a small hypsochromic shift (3-8 nm) of one or both bands (**8** → **7**, **22** → **21**). Since uv spectral data in the identification and structural analysis of flavonoids has been amplified by the use of reagents such as sodium methylate, aluminium chloride, fused sodium acetate and boric acid-sodium acetate (7), the spectral shifts in the presence of these reagents were recorded.

Effects of Sodium Methoxide (Table 1).

Sodium methylate ionizes all phenolic groups and both bands in the hydroxychromone spectra undergo bathochromic shifts. It is consequently difficult to correlate these shifts with the phenolic groups location. No chromone showed signs of decomposition (8).

Effects of Aluminium Chloride and Aluminium Chloride-Hydrochloric Acid (Table 2).

The presence of *ortho*-dihydroxyl groups at positions 6,7 and 7,8 is detectable by means of the aluminium chloride uv spectrum, which has bathochromic shifts of either or both bands compared with methanol and aluminium chloride/hydrochloric acid spectra (**18**, **23**). Free 5-hydroxyl groups are detected by the formation of an acid stable complex with aluminium chloride, which exhibits a strong bathochromic shift (about 60-70 nm) of Band I and a smaller one (8-14 nm) of Band II (**2**, **11**, **13**, **14**, **16**).

Effects of Sodium Acetate (Table 2).

This reagent either has no bathochromic shift or a slight one (6-9 nm) in Band I of 6-hydroxychromones (**4**, **9**, **11**) and greater bathochromic effect (20-60 nm) on 7- and 8-hydroxychromones. A useful diagnostic shift (4-18 nm) of Band II is observed only when the 7- or 8-hydroxyl group is free (**6**, **8**, **14**, **16**, **18**, **20**, **22**, **23**). No chromone showed signs of decomposition.

Effects of Boric Acid-Sodium Acetate (Table 2).

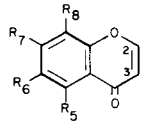
With this reagent *ortho*-dihydroxyl groups are detectable by a bathochromic shift (8-35 nm) of Band I (**11**, **18**, **23**).

Ir Spectra.

For solubility reasons it was not possible to obtain complete solution data. In Table 3a are listed principal absorptions in the 1580-1670 cm^{-1} region. The CO stretching band is at the highest frequency (at 1660 ± 4 cm^{-1} in carbon tetrachloride, at 1649 ± 9 cm^{-1} in chloroform and in the 1620-1670 cm^{-1} region in potassium bromide). Like similar 5-hydroxychromones (9) the

Table 1

Ultraviolet Absorptions of Chromone Derivatives



Compound No.	R_5	R_6	R_7	R_8	λ max, nm (log ε) (methanol)	λ max, nm (sodium methoxide)
1	OMe	H	H	H	220 (4.32), 252 (b) (4.08), 315 (c) (3.68)	--
2	OH	H	H	H	223 (4.30), 255 (b) (4.09), 329 (c) (3.56)	259 (b), 364 (c)
3	H	OMe	H	H	226 (4.23), 235 (a) (4.17), 246 (a), (b) (3.90), 327 (c) (3.78)	--
4	H	OH	H	H	228 (4.34), 237 (a) (4.24), 248 (a), (b) (4.01), 334 (c) (3.80)	243, 264 (a), (b), 378 (c)
5	H	H	OMe	H	236 (a) (4.16), 240 (4.24), 246 (b) (4.26), 281 (a) (3.89), 297 (c) (4.00), 303 (a) (3.99)	--
6	H	H	OH	H	236 (a) (4.14), 241 (4.22), 248 (b) (4.26), 287 (a) (3.91), 300 (c) (3.99)	256 (b), 338 (c)
7	H	H	H	OMe	222 (4.37), 253 (b) (4.11), 312 (c) (3.72)	--
8	H	H	H	OH	224 (4.24), 255 (b) (4.10), 315 (c) (3.63)	234, 268 (b), 300 (a), 356 (c)
9	OMe	OH	H	H	232 (4.27), 250 (a), (b) (4.00), 338 (c) (3.71)	246, 260 (a), (b), 287 (a), 385 (c)
10	OMe	OMe	H	H	232 (4.36), 251 (a), (b) (4.02), 335 (c) (3.69)	--
11	OH	OH	H	H	233 (4.21), 262 (b) (4.08), 360 (c) (3.54)	251, 271 (a), (b), 300 (a), 409 (c)
12	OMe	H	OMe	H	227 (4.16), 247 (4.25), 254 (b) (4.25), 287 (c) (3.91)	--
13	OH	H	OMe	H	227 (4.10), 252 (a) (4.24), 257 (b) (4.26), 293 (c) (3.85), 310 (a) (3.68)	246 (a), 260 (b), 266 (a), 285 (a), 347 (c)
14	OH	H	OH	H	224 (a) (4.15), 253 (a) (4.26), 258 (b) (4.28), 296 (c) (3.88), 320 (a) (3.67)	267 (b), 333 (c)
15	OMe	H	H	OMe	221 (4.35), 256 (b) (4.12), 338 (c) (3.62)	--
16	OH	H	H	OH	223 (4.16), 259 (b) (4.12), 306 (3.33), 360 (c) (3.47)	240, 267 (b), 332, 402 (c)
17	H	OMe	OMe	H	235 (4.27), 246 (a), (b) (3.98), 277 (3.78), 318 (c) (4.02)	--
18	H	OH	OH	H	227 (a) (4.19), 245 (a), (b) (3.90), 282 (3.69), 327 (c) (3.94)	234 (a), 250 (a), (b), 352 (c)
19	H	OMe	H	OMe	228 (a) (4.20), 237 (4.20), 258 (b) (4.03), 332 (c) (3.71)	--
20	H	OH	H	OH	229 (a) (4.08), 239 (4.09), 261 (b) (4.01), 342 (c) (3.60)	230 (a), 290 (b), 379 (c)
21	H	H	OMe	OMe	219 (4.26), 245 (a) (4.29), 250 (b) (4.34), 298 (c) (3.99)	--
22	H	H	OMe	OH	220 (4.13), 253 (a) (4.30), 258 (b) (4.36), 303 (c) (3.76)	245, 273 (b), 299 (a), 369 (c)
23	H	H	OH	OH	252 (a) (4.31), 258 (b) (4.37), 305 (c) (3.81)	272 (b), 309 (a), 363 (c)

(a) Shoulder. (b) Band II. (c) Band I.

Table 2

Utraviolet Absorptions of Chromone Derivatives

Compound No.	λ max, nm (aluminum chloride)	Δ λ (b)	Δ λ (c)	λ max, nm (aluminum chloride/hydrochloric acid)	Δ λ (b)	Δ λ (c)
2	229, 246, 264 (b), 284 (a), 387 (c)	9	58	230, 247, 264 (b), 281 (a), 388 (c)	9	59
11	253, 276 (b), 295 (a), 423 (c)	14	63	250, 276 (b), 296 (a), 424 (c)	14	64
13	223 (a), 253 (a), 266 (b), 310, 370 (c)	9	77	223 (a), 254 (a), 267 (b), 307, 370 (c)	10	77
14	266 (b), 311, 368 (c)	8	72	267 (b), 310, 370 (c)	9	74
16	250, 268 (b), 325, 433 (c)	9	73	249, 267 (b), 323, 436 (c)	8	76
18	227, 375 (c)	--	48	228 (a), 246 (a), (b), 287, 328 (c)	--	--
23	270 (b), 313, 340 (c)	12	35	252 (a), 258 (b), 304 (c)	--	--

Compound No.	λ max, nm (sodium acetate)	Δ λ (b)	Δ λ (c)	λ max, nm (sodium acetate/boric acid)	Δ λ (b)	Δ λ (c)
4	336 (c), 380 (a)	--	--	333 (c)	--	--
6	255 (b), 307 (a), 337 (c)	7	37	248 (a), (b), 285 (a), 302 (c)	--	--
8	266 (b), 303 (a), 355 (c)	11	40	254 (b), 314 (c)	--	--
9	247 (a), (b), 300 (a), 344 (c), 373 (a)	--	6	250 (a), (b), 338 (c)	--	--
11	260 (a), (b), 369 (c)	--	9	263 (b), 375 (c)	--	15
14	267 (b), 333 (c)	9	37	254 (a), 258 (b), 299 (c)	--	--
16	263 (b), 336, 380 (c)	4	20	260 (b), 295 (a), 362 (c)	--	--
18	251 (a), (b), 351 (c)	6	24	289 (a), 335 (c)	--	8
20	279 (b), 366 (c)	18	24	260 (b), 343 (c)	--	--
22	264 (a), 273 (b), 299 (a), 368 (c)	15	65	252 (a), 258 (b), 303 (c)	--	--
23	273 (b), 305 (a), 362 (c)	15	57	264 (b), 310, 340 (c)	6	35

(a) Shoulder. (b) Band II. (c) Band I.

Table 3a

Ir Absorptions of Chromones in the 1580-1670 cm^{-1} Region

Compound No.	Carbon Tetrachloride	Chloroform	Potassium Bromide	Compound No.	Carbon Tetrachloride	Chloroform	Potassium Bromide
1	1664	1654	1638	**13**	1657	1658	1657
	1606	1609	1600		1630	1625	1610
2	1656	1653	1656	**14**	--	--	1640
	1625	1620	1615				1610
	1595	1596		**15**	1664	1656	1662
3	1659	1648	1618			1606	1599
	1619	1619	1581			1588	1581
4	--	--	1627	**16**	--	1659	1655
			1612			1624	1610
			1582			1599	1583
5	1663	1648	1620	**17**	1655	1640	1638
	1625	1625	1590		1624	1625	1620
	1610	1599			1608	1601	1597
6	--	--	1625	**18**	--	--	1623
							1580
7	1661	1649	1658	**19**	1659	1640	1640
	1606	1604	1600		1612	1610	1604
					1580	1580	1572
8	--	--	1624				
9	1660	1648	1636	**20**	--	--	1636
	1621		1597				1587
10	1661	1649	1648	**21**	1659	1649	1640
	1619	1600			1619	1618	1618
					1599	1597	1595
11	1656	1655	1659	**22**	--	1655	1620
	1628	1625	1619			1631	1587
		1595				1605	
12	1659	1650	1645	**23**	--	--	1624
	1625	1624	1631				
	1609	1608	1585				

stretching band of the strongly chelated CO in compounds **2**, **11**, **13**, is unaffected by change of solvent, whereas the corresponding 5-methoxychromones **1**, **9**, **12**, show a solvent shift of the CO band ($\Delta\nu \sim 10$ cm^{-1}). The intense band at 1628 ± 3 cm^{-1} in carbon tetrachloride solution of **2**, **11**, **13**, could be probably the second band of a doublet CO absorption arising from a Fermi resonance (10).

The ir spectra of the hydroxychromones in potassium bromide are complex in the 2400-3600 cm^{-1} region and the O-H bands can be overlapped by C-H bands (Table 3b). All spectra contain one band, generally distinct, in the 3060-3090 cm^{-1} region; since the same band is present in the corresponding methoxychromones, this absorption was associated with aromatic and pyronic C-H vibration. All methoxyhydroxy- and methoxychromone spectra contain a weak band at 2830-2840 cm^{-1}, which is associated with the C-H stretching of the methoxyl group. 5-Hydroxychromone (**2**) and 5-hydroxy-7-methoxychromone (**13**) show a weak absorption envelope, which extends from 2400 to 3300 cm^{-1} underlying the C-H stretching frequencies at 3060 and 3079, 3010, 2975, 2840 cm^{-1} respectively. This spectral behaviour parallels that of similar 5-hydroxychromones (9). The ir spectra of the other hydroxychromones show an absorption envelope in the 2400-3600 cm^{-1} region, generally underlying the C-H stretching frequencies and other bands, which could be associated with the stretching modes of the OH group. The 5,6-(**11**); 6,7-(**18**); 6,8-(**20**); 7,8-dihydroxychromone (**23**) and 7-methoxy-8-hydroxychromone (**22**) spectra show O-H stretching bands at sufficiently high frequencies (at 3190; 3490 and

Table 3b

Ir Absorption of Hydroxychromones in the 2400-3560 cm^{-1} Region

Compound No.	Carbon Tetrachloride	Chloroform	Potassium Bromide
2	3300-2400 (a)	3300-2400 (a)	3300-2400 (a) 3060
4	--	--	3300-2400 (a) 3060
6	--	--	3300-2400 (a) ~ 3090 ~ 2920 2800 2690 2590
8	-	--	3300-2400 (a) 3060 2956 2850 2758 2670 2610 2570
9	3505 2923 2830	3502	3300-2400 (a) 3070 2985 2931 2840
11	3540 3200-2500 (a)	3530	3500-2400 (a) ~ 3190 3070 2725
13	3300-2400 (a) 3000 2960 2930 2840	--	3300-2400 (a) 3079 3010 2975 ~ 2840
14	--	--	3300-2400 (a) ~ 3060 ~ 2720 2610
16	--	3560	3300-2400 (a) ~ 3070 ~ 2950 ~ 2860

Table 3b (Continued)

Ir Absorption of Hydroxychromones in the 2400-2560 cm^{-1} Region

Compound	Carbon Tetrachloride	Chloroform	Potassium Bromide
18	--	--	3600-2400 (a) 3490 3310 3070 2800 ~ 2720 ~ 2590
20	--	--	3510 3400-2400 (a) 3210 3060 2970 2610
22	--	3520 2838	3500-2400 (a) ~ 3300 ~ 3080 2961 2930 2838 2730
23	--	--	3600-2500 (a) 3510 3330 3070 ~ 2880 ~ 2730

(a) Absorption envelope.

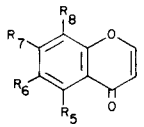
3310; 3510 and 3210; 3510 and 3330; ~ 3300 cm^{-1} respectively) so that they can be recognized. The solution data of the less soluble compounds are incomplete in the hydroxyl region owing to the weakness of the band.

Nmr spectra.

Proton signals of chromones generally occur in a number of well separated groups (Table 4). Methoxyl proton signals appear as singlets in the region 6.0-6.3 τ. The C-2 and C-3 protons occur as doublets (J = 6 Hz) in the ranges 1.6-2.2 and 3.6-4.0 τ respectively (11). It is difficult to determine the effect of the substituents in the aromatic ring on C-2 and C-3 protons. However, it is evident that the strong CO chelation in the 5-hydroxychromones produces a resonance of the pyronic protons at a lower field. A lesser similar effect is present in the 8-hydroxychromones; this confirms the possibility of weak chelation of heterocyclic oxygen with the 8-hydroxyl group (12). The aromatic ring protons appear in the region 2.0-3.8 τ. The C-5 proton, which is deshielded by the pyrone carbonyl group, generally

Table 4

Nmr Data at 60 MHz; Coupling Constants in Hz



No.	Compound R_5	R_6	R_7	R_8	Solvent	H-2	H-3	Assignment of Signals (a) R_5	R_6	R_7	R_8
1	OMe	H	H	H	DMSO-d_6	1.93, d $J_{2,3}$ = 6	3.82, d $J_{3,2}$ = 6	6.11, s	3.03, dd $J_{6,7}$ = 8; $J_{6,8}$ = 1	2.34, t $J_{7,6}$ = 8; $J_{7,8}$ = 8	2.92, dd $J_{8,7}$ = 8; $J_{8,6}$ = 1
2	OH	H	H	H	DMSO-d_6	1.68, d $J_{2,3}$ = 6	3.59, d $J_{3,2}$ = 6	-2.61, s	3.23, dd $J_{6,7}$ = 8; $J_{6,8}$ = 1	2.36, t $J_{7,6}$ = 8; $J_{7,8}$ = 8	2.98, dd $J_{8,7}$ = 8; $J_{8,6}$ = 1
3	H	OMe	H	H	$CDCl_3$	2.17, d $J_{2,3}$ = 6	3.67, d $J_{3,2}$ = 6	2.43, d $J_{5,7}$ = 3	6.09, s	2.73, dd $J_{7,8}$ = 9; $J_{7,5}$ = 3	2.62,d $J_{8,7}$ = 9
					DMSO-d_6	1.72, d $J_{2,3}$ = 6	3.66, d $J_{3,2}$ = 6	2.13-2.88	6.11, s	2.13-2.88	2.13-2.88
4	H	OH	H	H	DMSO-d_6	1.85, d $J_{2,3}$ = 6	3.79,d $J_{3,2}$ = 6	2.71, m	0.06, s	2.83, dd $J_{7,8}$ = 8; $J_{7,5}$ = 3	2.54,dd $J_{8,7}$ = 8; $J_{8,5}$ = 1
5	H	H	OMe	H	DMSO-d_6	1.77, d $J_{2,3}$ = 6	3.70, d $J_{3,2}$ = 6	2.02, d $J_{5,6}$ = 9.3	2.92, dd $J_{6,5}$ = 9.3; $J_{6,8}$ = 2	6.06, s	2.90, d $J_{8,6}$ = 2
6	H	H	OH	H	DMSO-d_6	1.83, d $J_{2,3}$ = 6	3.71, d $J_{3,2}$ = 6	2.03, dd $J_{5,6}$ = 8; $J_{5,8}$ = 1	3.00, dd $J_{6,5}$ = 8; $J_{6,8}$ = 2.5	-0.86, s	3.07, m
7	H	H	H	OMe	$CDCl_3$	2.08, d $J_{2,3}$ = 6	3.64, d $J_{3,2}$ = 6	2.23, dd $J_{5,6}$ = 8; $J_{5,7}$ = 2.5	2.67, t $J_{6,5}$ = 8; $J_{6,7}$ = 8	2.85, dd $J_{7,5}$ = 2.5; $J_{7,6}$ = 8	5.98, s
					DMSO-d_6	1.67, d $J_{2,3}$ = 6	3.61, d $J_{3,2}$ = 6	2.25-2.70	2.25-2.70	2.25-2.70	6.01, s
8	H	H	H	OH	DMSO-d_6	1.75, d $J_{2,3}$ = 6	3.70, d $J_{3,2}$ = 6	2.39-2.99	2.39-2.99	2.39-2.99	-0.54, s
9	OMe	OH	H	H	DMSO-d_6	1.97, d $J_{2,3}$ = 6	3.92, d $J_{3,2}$ = 6	6.28, s	0.59, bs	2.76 or 2.81, d $J_{7,8}$ = 9	2.76 or 2.81, d $J_{8,7}$ = 9
10	OMe	OMe	H	H	DMSO-d_6	1.89, d $J_{2,3}$ = 6	3.84, d $J_{3,2}$ = 6	6.10 or 6.21, s	6.10 or 6.21, s	2.44 or 2.64, d $J_{7,8}$ = 9	2.44 or 2.64, d $J_{8,7}$ = 9
11	OH	OH	H	H	DMSO-d_6	1.69, d $J_{2,3}$ = 6	3.65, d $J_{3,2}$ = 6	-2.50, bs	0.59, bs	2.71 or 3.02, d $J_{7,8}$ = 9	2.71 or 3.02, d $J_{8,7}$ = 9
12	OMe	H	OMe	H	DMSO-d_6	2.01, d $J_{2,3}$ = 6	3.89, d $J_{3,2}$ = 6	6.11 or 6.14, s	3.40 or 3.52, d $J_{6,8}$ = 2	6.11 or 6.14, s	3.40 or 3.52, d $J_{8,6}$ = 2
13	OH	H	OMe	H	DMSO-d_6	1.75, d $J_{2,3}$ = 6	3.68, d $J_{3,2}$ = 6	-2.75, bs	3.63, d $J_{6,8}$ = 2	6.13, s	3.41, d $J_{8,6}$ = 2
14	OH	H	OH	H	DMSO-d_6	1.83, d $J_{2,3}$ = 6	3.71, d $J_{3,2}$ = 6	-2.76, s	3.77 or 3.62, d $J_{6,8}$ = 2.5	-0.91, s	3.62 or 3.77, d $J_{8,6}$ = 2.5
15	OMe	H	H	OMe	DMSO-d_6	1.83, d $J_{2,3}$ = 6	3.76, d $J_{3,2}$ = 6	6.09 or 6.16, s	2.65 or 3.11, d $J_{6,7}$ = 8.4	2.65 or 3.11, d $J_{7,6}$ = 8.4	6.09 or 6.16, s

Table 4 (Continued)

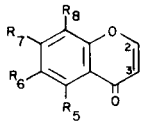
Nmr Data at 60 MHz; Coupling Constants in Hz

No.	Compound R_5	R_6	R_7	R_8		Assignment of Signals (a) H-2	H-3	R_5	R_6	R_7	R_8
16	OH	H	H	OH	DMSO-d_6	1.67, d $J_{2,3}$ = 6	3.63, d $J_{3,2}$ = 6	-1.82, s	2.83 or 3.37, d $J_{6,7}$ = 8.4	2.83 or 3.37, d $J_{7,6}$ = 8.4	0.38, s
17	H	OMe	OMe	H	DMSO-d_6	1.80, d $J_{2,3}$ = 6	3.72, d $J_{3,2}$ = 6	2.65, s	6.05 or 6.11, s	6.05 or 6.11, s	2.87, s
18	H	OH	OH	H	DMSO-d_6	2.15, d $J_{2,3}$ = 6	4.02, d $J_{3,2}$ = 6	2.91, s	-0.10, bs	-0.10, bs	3.32, s
19	H	OMe	H	OMe	$CDCl_3$	2.12, d $J_{2,3}$ = 6	3.68, d $J_{3,2}$ = 6	2.90, d $J_{5,7}$ = 3	6.06 or 6.14, s	3.25, d $J_{7,5}$ = 3	6.06 or 6.14, s
					DMSO-d_6	1.75, d $J_{2,3}$ = 6	3.67, d $J_{3,2}$ = 6	3.04, ns	6.06 or 6.14, s	3.04, ns	6.06 or 6.14, s
20	H	OH	H	OH	DMSO-d_6	1.81, d $J_{2,3}$ = 6	3.76, d $J_{3,2}$ = 6	3.23, ns	-0.33 or 0.26, s	3.23, ns	-0.33 or 0.26, s
21	H	H	OMe	OMe	DMSO-d_6	1.71, d $J_{2,3}$ = 6	3.70, d $J_{3,2}$ = 6	2.21, d $J_{5,6}$ = 8.4	2.72, d $J_{6,5}$ = 8.4	5.99 or 6.09, s	5.99 or 6.09, s
22	H	H	OMe	OH	DMSO-d_6	1.83, d $J_{2,3}$ = 6	3.81, d $J_{3,2}$ = 6	2.55, d $J_{5,6}$ = 8.4	2.86, d $J_{6,5}$ = 8.4	6.08, s	0.30, bs
23	H	H	OH	OH	DMSO-d_6	1.76, d $J_{2,3}$ = 6	3.75, d $J_{3,2}$ =6	2.53, d $J_{5,6}$ = 8.4	2.99, d $J_{6,5}$ = 8.4	0.10, bs	0.10, bs

(a) The positions of the signals have, wherever possible, been given in τ values. In the case of complex multiplets the limits of intervals in which the signals appear are given. Multiplicity is after τ values.

Table 5

Rf Data of Chromone Derivatives



No.	Compound R_5	R_6	R_7	R_8	Solvent System A (a)	B (b)	Fluorescence (c)
1	OMe	H	H	H	0.83	0.82	light blue
2	OH	H	H	H	0.78 (d)	0.90 (d)	--
3	H	OMe	H	H	0.81	0.87	bluish
4	H	OH	H	H	0.74	0.87	pale violet
5	H	H	OMe	H	0.80	0.87	yellowish
6	H	H	OH	H	0.75	0.88	yellowish green
7	H	H	H	OMe	0.81	0.85	bright blue
8	H	H	H	OH	0.70 (d)	0.84 (d)	--
9	OMe	OH	H	H	0.84	0.85	yellowish green
10	OMe	OMe	H	H	0.87	0.85	yellowish green
11	OH	OH	H	H	0.69	0.82	dark absorbing
12	OMe	H	OMe	H	0.80	0.81	light blue
13	OH	H	OMe	H	0.68	0.89	dark absorbing
14	OH	H	OH	H	0.63	0.89	dark absorbing
15	OMe	H	H	OMe	0.82	0.80	yellowish green
16	OH	H	H	OH	0.69	0.83	dark absorbing
17	H	OMe	OMe	H	0.79	0.83	blue violet
18	H	OH	OH	H	0.64	0.78	mauve
19	H	OMe	H	OMe	0.79	0.87	bluish
20	H	OH	H	OH	0.65	0.77	blue
21	H	H	OMe	OMe	0.85	0.86	yellowish green
22	H	H	OMe	OH	0.70 (d)	0.79 (d)	--
23	H	H	OH	OH	0.63 (d)	0.74 (d)	--

(a) Acetic acid:water = 15:85 (Rutin: Rf = 0.55). (b) *t*-Butyl alcohol:acetic acid:water = 3:1:1 (Rutin: Rf = 0.45). Commercial Rutin was used, whose properties (m.p., uv, Rf) are in agreement with those given by T. A. Geisman (5) and T. J. Mabry, *et al.*, (7). (c) Spots were located by irradiation at 254 nm. (d) Spots were located by spraying with a solution of diazotized sulphanilic acid.

absorbs at a lower field than the other aromatic protons, but in the 6-hydroxychromone (4) the C-5 proton, which is also shielded by the C-6 hydroxyl, occurs at a higher field than the C-8 proton. The strongly chelated 5-hydroxyl group shows a consistent absorption at a lower field than the other hydroxyl protons.

EXPERIMENTAL

The uv spectra were measured on an Optica CF 4 spectrophotometer with Mabry's procedure (7); the ir spectra were determined with a Perkin Elmer Model 257 spectrophotometer; the nmr spectra were recorded with a Perkin Elmer Model R 12 spectrometer using TMS as the internal reference. The chromatograms were performed on No. 1 Whatman paper with descending technique (Table 5).

Synthesis and Characterization of the Chromones.

The chromones were prepared by condensation of the appropriate *o*-hydroxyacetophenone derivatives with dry ethyl formate in the presence of sodium. The methyl ethers were demethylated with hydriodic acid or with anhydrous aluminium chloride.

The following compounds were prepared as described previously: 5-methoxychromone (**1**) (13); 5-hydroxychromone (**2**) (14); 6-methoxychromone (**3**) (15); 6-hydroxychromone (**4**) (16); 7-methoxychromone (**5**) (15); 7-hydroxychromone (**6**) (17); 5,6-dimethoxychromone (**10**) (20); 5,7-dimethoxychromone (**12**) (21); 5-hydroxy-7-methoxychromone (**13**) (21); 5,7-dihydroxychromone (**14**) (21); 6,7-dimethoxychromone (**17**) (22); 7,8-dimethoxychromone (**21**) (24); 7-methoxy-8-hydroxychromone (**22**) (12); 7,8-dihydroxychromone (**23**) (25).

8-Methoxychromone (**7**).

This chromone was synthesized from 2-hydroxy-3-methoxyacetophenone (18) by the procedure adopted for **5** (yield 60%) and purified by crystallization as needles from water, m.p. 133-135°.

Anal. Calcd. for $C_{10}H_8O_3$: C, 68.18; H, 4.58. Found: C, 68.22; H, 4.74.

8-Hydroxychromone (**8**).

The chromone **7** (0.8 g., 0.005 mole) was refluxed with 57% hydriodic acid (7 ml.) for 3 hours and cooled. Water (5 ml.) was added and the precipitate (0.7 g., 90%) purified by crystallization from dimethylformamide-water, m.p. at about 285° dec.

Anal. Calcd. for $C_9H_6O_3$: C, 66.67; H, 3.73. Found: C, 66.72; H, 3.74.

5-Methoxy-6-hydroxychromone (**9**).

A mixture of 2,5-dihydroxy-6-methoxyacetophenone (19) (1.8 g., 0.01 mole), ethyl formate (30 ml.) and powdered sodium (1.15 g., 0.05 mole) was maintained with stirring at 0° for 3 hours and overnight at room temperature. Water (25 ml.) was added and the excess ethyl formate was removed by evaporation. The solution was acidified with concentrated hydrochloric acid, heated on a water bath for 15 minutes, evaporated and the residue chromatographed on silica gel. Elution with chloroform-diethyl ether (1:1) gave **9** (0.4 g., 20%) which was purified by ethanol-light petroleum crystallization, m.p. 180-182°.

Anal. Calcd. for $C_{10}H_8O_4$: C, 62.50; H, 4.20. Found: C, 62.68; H, 4.20.

5,6-Dihydroxychromone (**11**).

This chromone was derived from **10** and **15** (57% hydriodic acid, refluxing) by the procedure adopted for **8** (yield 78 and 90%) and purified by crystallization as yellow needles from ethanol-water, m.p. 192-193°.

Anal. Calcd. for $C_9H_6O_4$: C, 60.68; H, 3.39. Found: C, 60.57; H, 3.47.

S. Raychaudhuri (20) only reports a m.p. 170° for 5,6-dihydroxychromone derived from 5,8-dimethoxychromone by demethylation and Wessely-Moser rearrangement with hydriodic acid, but in our case **11** was completely methylated (dimethylsulphate, anhydrous potassium carbonate, refluxing acetone) and purified by chromatography on silica gel (ether) and the methyl ether crystallized from carbon tetrachloride was identical (m.p., m. m. p., ir) with **10**.

5,8-Dimethoxychromone (**15**).

2-Hydroxy-3,6-dimethoxyacetophenone (18) and ethyl formate in the usual manner (21) gave 2-hydroxy-5,8-dimethoxychroman-4-one (yield 75%), which was purified by crystallization as needles from ethanol-water, m.p. 143°; ir (potassium bromide): 3375, 3235, 1665 cm^{-1}; nmr (DMSO-d_6): τ 2.43 (d, J = 5 Hz, 1H) 2-OH, τ 2.83 (d, J = 9 Hz, 1H) and 3.47 (d, J = 9 Hz, 1H) aromatic protons, τ 4.22 (m, 1H) 2-H, τ 6.26 (s, 6H) 5-OCH_3 and 8-OCH_3, τ 7.23 (m, 2H) >CH_2.

Anal. Calcd. for $C_{11}H_{12}O_5$: C, 58.93; H, 5.39. Found: C, 59.26; H, 5.52.

This chroman-4-one (1.1 g., 0.005 mole) in ethanol (10 ml.) and concentrated hydrochloric acid (0.5 ml.) was refluxed for 15 minutes After removal of the solvent, the crude 5,8-dimethoxychromone was crystallized from carbon tetrachloride (0.4 g., 40%) m.p. 129-130° (26).

Anal. Calcd. for $C_{11}H_{10}O_4$: C, 64.07; H, 4.89. Found: C, 64.30; H, 5.24.

5,8-Dihydroxychromone (**16**).

5,8-Dimethoxychromone (0.25 g., 0.0012 mole) in dry benzene (20 ml.) was refluxed for 2 hours in the presence of anhydrous aluminium chloride (1 g.). After removal of the solvent, cracked ice (10 g.) and concentrated hydrochloric acid (5 ml.) were added. It was left overnight, the precipitate filtered and purified by crystallization as yellow needles from ethanol-water (0.11 g., 50%), m.p. 242-243°.

Anal. Calcd. for $C_9H_6O_4$: C, 60.68; H, 3.39. Found: C, 60.99; H, 3.62.

Lack of Wessely-Moser rearrangement resulted from methylation of this product by the method adopted for **11**, which gave 5,8-dimethoxychromone.

6,7-Dihydroxychromone (**18**).

This compound was derived from **17** by the procedure adopted for **8** (yield 70%) and purified by crystallization as needles from ethanol-water, m.p. about 255° dec.

Anal. Calcd. for $C_9H_6O_4$: C, 60.68; H, 3.39. Found: C, 60.62; H, 3.78.

6,8-Dimethoxychromone (**19**).

This chromone was synthesized from 2-hydroxy-3,5-dimethoxyacetophenone (23) by the procedure adopted for **5** (yield 80%) and purified by crystallization from water, m.p. 143-145°.

Anal. Calcd. for $C_{11}H_{10}O_4$: C, 64.07; H, 4.89. Found: C, 63.83; H, 4.97.

68-Dihydroxychromone (**20**).

This compound was derived from **19** by the procedure adopted for **8** (yield 50%) and purified by crystallization as needles from ethanol-water, m.p. about 260° dec.

Anal. Calcd. for $C_9H_6O_4$: C, 60.68; H, 3.39. Found: C, 60.90; H, 3.57.

Acknowledgements.

We should like to thank Dr. M. Canepa Villa for the microanalyses and Dr. S. Morasso and A. Panaro for running the ir and nmr spectra.

REFERENCES AND NOTES

(1) S. Fukushima, T. Noro, Y. Saiki, A. Ueno and Y. Akahori, *J. Pharm. Soc.* Japan, **88**, 1135 (1968).

(2) Ratna Pendse, A. V. Rama Rao and K. Venkataraman, *Phytochemistry*, **12**, 2033 (1973).

(3) D. Bourwieg, B. Janistyn, M. Stocker and R. Pohl, *Arch. Pharm.*, **307**, 131 (1974).

(4) G. Romussi and G. Ciarallo, *Phytochemistry*, **13**, 2890 (1974).

(5) These bands are similar to those for flavonoids, T. A. Geissman, "The Chemistry of Flavonoid Compounds," Pergamon Press, Inc., (1962).

(6) I. Degani, R. Fochi and G. Spunta, *Boll. Sci. Fac. Chim. Ind. Bologna*, **26**, 6 (1968).

(7) T. J. Mabry, K. R. Markham and M. B. Thomas, "The Systematic Identification of Flavonoids," Springer, Heidelberg (1970).

(8) Sodium methoxide spectra were recorded immediately after the addition of three drops of the reagent solution. Since the spectra of compounds, which have no free hydroxyl groups show no change and the spectra of chromones with free hydroxyl groups exhibit shifts of Band I and II without changes in the shapes of spectral curves, it may be inferred that this procedure produces ionization only.

(9) R. D. H. Murray and P. H. McCabe, *Tetrahedron*, **25**, 5819 (1969).

(10) R. D. H. Murray, P. H. McCabe and T. C. Hogg, *ibid.*, **25**, 5839 (1969).

(11) C. T. Mathis and J. H. Goldstein, *Spectrochim. Acta*, **20**, 871 (1964).

(12) Iswar-Dass, N. Narasimhachari and T. R. Seshadri, *Proc. Indian Acad. Sci.*, **37A**, 599 (1953).

(13) A. A. Shamshurin and M. A. Yampol'skaya, *Zh. Obshch. Khim.*, **34**, 535 (1964).

(14) A. Murata, T. Suzuki and T. Ito, *Bunseki Kagaku*, **14**, 630 (1965).

(15) P. P. Joshi, R. T. Ingle and B. V. Bhide, *J. Indian Chem. Soc.*, **36**, 59 (1959).

(16) E. David and St. v. Kostanecki, *Ber.*, **35**, 2547 (1902).

(17) St. v. Kostanecki, L. Paul and J. Tambor, *ibid.*, **34**, 2475 (1901).

(18) W. Baker, N. C. Brown and J. A. Scott, *J. Chem. Soc.*, 1922 (1939).

(19) W. Baker, *ibid.*, 956 (1939).

(20) S. Raychauduri, T. R. Seshadri and S. K. Mukerjee, *Indian J. Chem.*, **11**, 1228 (1973).

(21) N. Narasimhachari, D. Rajagopalan and T. R. Seshadri, *J. Sci. Ind. Research (India)*, **12**, 287 (1953).

(22) G. H. Jones, J. B. D. Mackenzie, A. Robertson and W. B. Whalley, *J. Chem. Soc.*, 562 (1949).

(23) T. H. Simpson, *J. Org. Chem.*, **28**, 2107 (1963).

(24) N. Narasimhachari, D. Rajagopalan and T. R. Seshadri, *J. Sci. Ind. Research (India)*, **11B**, 347 (1952).

(25) E. David and St. v. Kostanecki, *Ber.*, **36**, 125 (1903).

(26) S. Raychauduri (20) gives for 5,6- and 5,8-dimethoxychromone the same m.p. 124-125°.