

957. Chalcones and Related Compounds. Part IX.* Preparation and Rearrangement of Some 1,3-Diphenylprop-2-en-1-ols ("Chalcols").

By W. DAVEY and J. A. HEARNE.

Various preparative methods for "chalcols" have been studied and their relative merits assessed. Attempts to resolve chalcol by chemical methods are outlined. Rearrangement of chalcols in alkaline media has been investigated qualitatively and that of chalcol quantitatively.

"CHALCOL" 1,3-diphenylprop-2-en-1-ol, and chalcols substituted in the benzene rings have been prepared by catalytic hydrogenation of the acetylenic alcohol,¹ reduction of the chalcone,² or through the Grignard reaction.^{1,3-6} By Burton and Ingold's method⁴ we obtained a 70% yield of chalcol, together with diphenyl and dichalcol ether (probably owing to the acid conditions used during isolation of the chalcol).⁵ It was essential to remove all traces of diphenyl to prevent decomposition of the chalcol.

Attempts to prepare 4'-methoxy- and 4'-dimethylamino-chalcol by Willstaedt's method^{7,8} gave the chalcones.

Reduction of chalcone by lithium aluminium hydride was not investigated since saturated ketone and alcohol were possible by-products.⁹⁻¹⁴ Modified reduction of chalcone

* Part VIII, *J.*, 1963, 4386.

¹ K. N. Campbell, B. K. Campbell, and M. J. McGuire, *Proc. Indiana Acad. Sci.*, 1940, **50**, 87.

² H. G. Kuivila and O. F. Beumel, *J. Amer. Chem. Soc.*, 1958, **80**, 3798.

³ H. Nomura, *Bull. Soc. chim.*, 1925, **37**, 1245.

⁴ H. Burton and C. K. Ingold, *J.*, 1928, 904.

⁵ C. W. Shoppee, *J.*, 1928, 2569.

⁶ H. Burton, *Proc. Leeds Phil. Lit. Soc.*, 1930, **61**, 2 (*Chem. Abs.*, 1930, 4284).

⁷ H. Willstaedt, *Ber.*, 1931, **64**, B, 2693.

⁸ H. Willstaedt, *Svensk Kem. Tidskr.*, 1941, **53**, 416.

⁹ F. A. Hockstein and W. G. Brown, *J. Amer. Chem. Soc.*, 1948, **70**, 3484.

¹⁰ W. G. Brown, *Org. Reactions*, 1948, p. 482.

¹¹ H. H. Wasserman and N. E. Aubrey, *J. Amer. Chem. Soc.*, 1955, **77**, 590.

¹² R. E. Lutz and J. O. Weiss, *J. Amer. Chem. Soc.*, 1955, **77**, 1814.

¹³ H. O. House, *J. Amer. Chem. Soc.*, 1956, **78**, 2298.

¹⁴ R. S. Rondestvedt, *J. Amer. Chem. Soc.*, 1951, **73**, 4509.

and of 4- and 4'-nitrochalcones with aluminium isopropoxide¹⁵⁻¹⁷ gave almost theoretical yields of chalcals. The chalcals were pure after recrystallisation and did not decompose on standing (4 years) as did the product from the Grignard reaction (few days). Attempts to prepare 4-dimethylaminochalcocal by the procedure of Lutz *et al.*¹⁸ gave the isopropyl ether of the required chalcocal, and similarly reduction of 4-methoxy-, 4'-methoxy-, and 4-methyl-chalcones gave oils which distilled undecomposed under reduced pressure to give the isopropyl ethers of the chalcals. Although 4'-dimethylaminochalcone gave an uncrystallisable oil, 4'-bromochalcone gave the chalcocal whose ultraviolet spectrum in ethanol was like that of chalcocal itself. Oxidation of the isopropyl ethers from the reduction of 4- and 4'-methoxychalcones with cold potassium permanganate in acetone gave only anisic acid in the water-soluble fraction and the spectra of these ethers were identical (rearrangement of the 4'-isomer had occurred even under the neutral conditions of preparation).

Lund¹⁹ has described the formation of ethers in the alkoxide reduction of conjugated ketones, *e.g.*, dibenzylideneacetone and dicinnamoylacetone; the reduction was formulated as proceeding *via* a cyclic intermediate²⁰ although recently²¹ an additional mechanism involving the donation of hydride ion from a second alkoxide molecule to the ketone alkoxide complex has been suggested. In the present reductions ether formation appeared to be correlated with the presence of aromatic substituents capable of providing increased electron accession at the point of reaction (*i.e.*, $-\text{N}(\text{CH}_3)_2$; $-\text{OCH}_3$; $-\text{CH}_3$ groups) and in the case of the methoxy-compound (and possibly with the others) accompanied by anionotropic rearrangement. For nitro-, bromo-, and unsubstituted chalcones neither etherification nor rearrangement occurred, even on prolonged boiling.

Potassium borohydride reduction of chalcone and of its *p*-methyl and *p*-bromo-derivatives in hot aqueous methanol, by the method of Huls and Simon,²² gave the required chalcals quantitatively. 4'-Methylchalcone is known⁴ and 4-methylchalcocal was characterised in several ways. Its spectrum at 210—310 $\text{m}\mu$ was similar to that of chalcocal, but the *K* band was more intense and at a longer wavelength, whilst that of the 4'-isomer was almost identical with chalcocal, presumably owing to the styryl system. Reduction of nitrochalcones by this method gave dark amorphous products. 4-Methoxychalcone on reduction yielded the chalcocal as an unstable solid, whilst the 4'-isomer yielded an oil which decomposed with an odour of benzaldehyde, rapidly decolourised bromine solution, and contained "active hydrogen." The chalcocal obtained by reduction of 4-dimethylaminochalcone could only be isolated by extraction and evaporation under nitrogen as white needles which rapidly became a yellow oil on exposure to the air, and a solution in petrol deposited yellow oil. Treatment with methyl iodide gave the quaternary methiodide as a stable white solid. The chalcals obtained showed some correlation between instability and the presence of substituents leading to increased electron accession in the allylic system, *e.g.*, comparison of 4-dimethylaminochalcocal and its quaternary salt. Potassium borohydride reduction of chalcones represented the most convenient route to substituted chalcals in that reaction was rapid, quantitative, the end point was visible and the products were easily isolated.

Attempted resolution of chalcocal *via* hydrogen phthalate or succinate; (+)-camphor-10-sulphonate or (—)-menthoxyacetyl derivative failed and the behaviour of chalcocal on

¹⁵ H. Meerwein and R. Schmidt, *Annalen*, 1925, **444**, 227.

¹⁶ W. L. Truett and W. N. Moulton, *J. Amer. Chem. Soc.*, 1951, **73**, 5913.

¹⁷ E. A. Braude and E. S. Waight, *J.*, 1953, 419.

¹⁸ R. E. Lutz, T. A. Martin, J. F. Codrington, T. M. Amaker, R. K. Allison, N. K. Leake, R. J. Rowlett, J. D. Smith, and J. W. Wilson, *J. Org. Chem.*, 1949, **14**, 982.

¹⁹ H. Lund, *Ber.*, 1937, **70**, 1520; *Kem Maanedstlat*, 1936, **17**, 169.

²⁰ R. B. Woodward, N. L. Wendler, and F. J. Brutschy, *J. Amer. Chem. Soc.*, 1945, **67**, 1425; R. E. Lutz and J. S. Gillespie, jun., *ibid.*, 1950, **72**, 344; L. M. Jackman and J. A. Mills, *Nature*, 1949, **164**, 789.

²¹ W. N. Moulton, R. E. van Atta, and R. R. Ruch, *J. Org. Chem.*, 1961, **26**, 290.

²² R. Huls and T. Simon, *Bull. Soc. Roy. Sci. Liège*, 1956, **25**, 89.

attempted esterification may be correlated with its dehydration¹ with hot acid to a hydrocarbon. 4-Nitrochalcol gave the diester with succinic anhydride in chloroform-triethylamine; this esterification may have been due to the nitro-group's increasing the tendency to oxygen-hydrogen heterolysis in comparison with unsubstituted chalcol. The half-ester obtained was evidently unstable and disproportionated into the diester and free acid, possibly by alkyl-oxygen heterolysis and recombination of the allylic carbonium ion with another molecule of half-ester.²³ Chalcols appeared to be too reactive for chemical resolution to be effective.

The rearrangement of chalcol to 1,3-diphenylpropan-1-one (hydrochalcone) caused by sodium ethoxide or ethanolic potassium hydroxide was first described by Nomura,³ Burton and Ingold⁴ recorded the rearrangement of 4- and 4'-chloro- and -methyl-chalcols to the corresponding ketones, the rearrangement being almost quantitative. Repetition of the rearrangement of chalcol showed that another material (A) (m. p. 145°) was produced by the reaction of the hydrochalcone with the alkaline reagent and this further reaction was faster when the reagent was sodium ethoxide in dry ethanol or potassium hydroxide in absolute ethanol. Water retarded this reaction and use of 20% potassium hydroxide solution in 60% aqueous ethanol gave high yields of hydrochalcone, free from product A. In an aqueous medium and heterogeneous conditions only hydrochalcone was obtained. Although chalcol gave a soluble sodium compound on heating with sodium in dry benzene, no rearrangement product was isolated on decomposition of the sodium salt with water.

Material A was isolated but not successfully investigated. Its ultraviolet spectrum at 230–250 m μ showed only weak absorption ($[\epsilon]_{230}^{1\%} = 25.0$) compared with the strong absorption due to benzoyl or styryl groups exhibited by chalcol ($[\epsilon]_{230}^{1\%} = 1041$) and hydrochalcone ($[\epsilon]_{230}^{1\%} = 632.5$). Infrared spectra of chalcol, hydrochalcone, and A showed a common aromatic character. Very strong absorption at 1732 cm.⁻¹ indicated a carbonyl group, the enhanced frequency and intensity suggesting an ester linkage. Strong absorption at 1249 cm.⁻¹ with a shoulder at 1265 cm.⁻¹ and grouped with bands at 1228 and 1066 cm.⁻¹ could possibly have been due to C-O-C stretching.

From the evidence, A is probably a lactone, being converted into the sodium salt of the acid in strong alkali. Elemental analysis indicated a formula C₁₉H₂₀O₂, but a structural formulation was not possible. The only similar case reported²⁴ was the dimerisation of 2-methylallyl alcohol by alkali to glycol, followed by oxidation to lactone and dibasic acid, but in our case, dimerisation did not appear to have occurred.

4'-Bromo-, 4-methyl-, and 4-methoxy-chalcol were converted into the corresponding hydrochalcones by 20% potassium hydroxide in absolute ethanol, reaction time being kept to a minimum. 4-Dimethylaminochalcol and 4-nitrochalcol gave tars, and attempted rearrangement of isopropyl 4-methoxychalcol ether to the enol ether with subsequent acid hydrolysis was not successful.

Attempts to rearrange chalcol with triethylamine were unsuccessful, but 4-nitrochalcol yielded an isomer, m. p. 99.5–100.5°, whose spectra were consistent with its being 4-nitrohydrochalcone.

The rearrangement of 4-nitrochalcol by triethylamine, unlike that of the unsubstituted compound, was consistent with the deactivating effect of the nitro-group rendering protropy easier.

Quantitative Study of the Rearrangement.—Kinetics were studied using potassium hydroxide in aqueous ethanol and methanol. Ethylene glycol and dioxan were unsuitable owing to decomposition. The use of aqueous solvents reduced secondary reaction of hydrochalcone to a small fraction during the times used.

The reaction was followed by measuring the optical density of neutralised samples of the reaction mixture at 253.25 m μ and comparing it with those of standard solutions of chalcol and hydrochalcone in the same solvent.

²³ A. G. Davies and J. Kenyon, *Quart. Rev.*, 1955, **9**, 203.

²⁴ A. Striegler, *Chem. Tech.*, 1958, **10**, 78 (*Chem. Abs.*, 1958, **52**, 16,183).

Both compounds obeyed Beer's law and did not mutually interfere. The rearrangement was of the first order.

Variation in solvent. The effects of variation in the water content of the medium are in Table 1.

TABLE 1.

Variation in solvent composition and first-order rate constant for the rearrangement of chalcol.

[KOH] = 2.523M. Temp. 80°. [Chalcol] = 0.002M.

Mole % H ₂ O in solvent	H ₂ O	D _{solvent}	10 ⁵ k (sec. ⁻¹)	10 ⁵ lnk	Run No.
57.0	16.0	29.2	11.0 ± 0.6	2.40	15
67.3	21.6	34.0	6.82 ± 0.05	1.92	16
75.4	27.1	38.5	5.40 ± 0.36	1.69	12, 13, 14
82.0	32.5	43.0	3.97 ± 0.15	1.38	17

k was a logarithmic function of the water concentration and of the dielectric constant, since the latter is almost a linear function of water concentration. By extrapolation of the former to zero water and alcohol concentrations, catalytic constants *k*_{OH⁻} and *k*_{OC₂H₅⁻} were found to be 0.68 × 10⁻⁵ and 12.4 × 10⁻⁵ l. mole⁻¹ sec.⁻¹, respectively.

From data by Caldin and Long²⁵ for sodium hydroxide in aqueous ethanol at 25°, we estimated the relative amounts of ethoxide and hydroxide ions in the mixtures. There being no datum on the effect of temperature on the equilibrium, the values so calculated (Table 2) can only be approximate.

TABLE 2.

Catalyst concentration calculated from the data of Caldin and Long.²⁵

10 ⁵ k	[H ₂ O]	[OH ⁻]/b	[OC ₂ H ₅ ⁻]/b	[OC ₂ H ₅ ⁻]	10 ⁵ k	[H ₂ O]	[OH ⁻]/b	[OC ₂ H ₅ ⁻]/b	[OC ₂ H ₅ ⁻]
11.0	16.0	0.699	0.301	0.758	5.40	27.1	0.885	0.115	0.290
6.82	21.6	0.807	0.193	0.486	3.97	32.5	0.926	0.074	0.187

b = Total base concentration.

k was linear with ethoxide ion concentration, and extrapolation of *k* versus [OC₂H₅⁻]/*b*, gave 12.3 × 10⁻⁵ and 0.72 × 10⁻⁵ l. mole⁻¹ sec.⁻¹ for *k*_{OC₂H₅⁻} and *k*_{OH⁻} in agreement with the former values.

The catalytic constant *k*_{CH₃O⁻} was estimated as 2.6 × 10⁻⁵ l. mole⁻¹ sec.⁻¹ from runs 6 and 7 (Table 6), by use of *k*_{OH⁻} = 0.7 × 10⁻⁵ and data from Koskikallio²⁶ on the equilibrium [HO⁻][CH₃OH]/[CH₃O⁻][H₂O] to estimate methoxide ion concentration in the aqueous methanol used as solvent.

The effect of variation in the catalyst concentration is shown in Table 3.

TABLE 3.

	Run no.	[KOH]	10 ⁵ k (sec. ⁻¹)
A	Solvent 57—59 mole %	10, 11	1.083
	H ₂ O—C ₂ H ₅ OH	4, 5	2.373
	Chalcol 0.002M	15	2.523
	Temp. 80°	—	—
B	Chalcol 0.01M	2	1.083
	1, 3	2.373
	21	0.388
C	Solvent 76.5—74.4 mole %	21	0.388
	H ₂ O—C ₂ H ₅ OH	20	0.776
	Chalcol 0.002M	19	1.941
	Temp. 80°	12, 13, 14	2.523
	18, 22	3.882
D	Solvent 30% v/v	9	1.083
	H ₂ O—CH ₃ OH	8	2.523
	Chalcol 0.002M	—	—
	Temp. 70°	—	—

²⁵ E. F. Caldin and G. Long, *J.*, 1954, 3737.

²⁶ J. Koskikallio, *Suomen Kemistilehti*, 1950, 30, B, 111; R. G. Burns and B. D. England, *Tetrahedron Letters*, 1960, No. 241.

For groups *A* and *C* the relative amounts of ethoxide and hydroxide ions can be estimated as above from the data of Caldin and Long.²⁵

From these data, and $k_{\text{OH}^-} = 0.7 \times 10^{-5}$ l. mole⁻¹ sec.⁻¹, a plot of $(k - k_{\text{OH}^-} - k_{\text{OCH}_3^-})$ against $[\text{OC}_2\text{H}_5^-]$ is straight, with slope $k_{\text{OOC}_2\text{H}_5^-} = 12.3 \times 10^{-5}$ l. mole⁻¹ sec.⁻¹, as previously obtained.

The values of the catalytic constants obtained were: $k_{\text{OH}^-} = 0.7 \times 10^{-5}$; $k_{\text{OCH}_3^-} = 2.6 \times 10^{-5}$; $k_{\text{OOC}_2\text{H}_5^-} = 12.3 \times 10^{-5}$ l. mole⁻¹ sec.⁻¹. These can be compared with those of Bender and Glasson²⁷ for hydrolysis and alcoholysis of esters. Their observed nucleophilicities of hydroxide, methoxide, and ethoxide ions were a linear function of our catalytic

TABLE 4.

10^5k	$[\text{H}_2\text{O}]$	$[\text{OH}^-]/b$	$[\text{OH}^-]$	$[\text{OC}_2\text{H}_5^-]$	10^5k	$[\text{H}_2\text{O}]$	$[\text{OH}^-]/b$	$[\text{OH}^-]$	$[\text{OC}_2\text{H}_5^-]$
3.34	17.4	0.729	0.790	0.290	1.36	28.7	0.895	0.695	0.081
9.84	16.0	0.699	1.66	0.710	3.66	27.6	0.887	1.72	0.220
11.00	16.0	0.699	1.76	0.760	5.40	27.1	0.882	2.22	0.300
0.513	28.8	0.896	0.348	0.040	9.64	25.7	0.867	3.37	0.510

constants, which however do not parallel their basicities. These authors explained the reversal in order of nucleophilicity and basicity as being due to the greater polarisability of the methoxide ion.

The effects of temperature on the reaction in aqueous ethanol and methanol are in Table 5.

TABLE 5.

KOH 3.882M.		Solvent 74.4 mole % $\text{H}_2\text{O}-\text{C}_2\text{H}_5\text{OH}$.		Chalcol 0.002M.	
10^5k	Temp.	— luk	$10^3/T^\circ\text{K}$	Run no.	
9.64 ± 0.15	80°	9.25	2.83	18, 22	
3.59 ± 0.03	70	10.2	2.91	23	
1.11 ± 0.01	60	11.4	3.00	24	
KOH 2.523M.		Solvent 30% v/v $\text{H}_2\text{O}-\text{CH}_3\text{OH}$.		Chalcol 0.002M.	
6.05 ± 0.91	80°	9.71	2.83	6, 7	
2.66 ± 0.13	70	10.5	2.91	8	

These results gave 25.3 kcal. deg.⁻¹ mole⁻¹ for the Arrhenius activation energy, and frequency factor $A = 4.3 \times 10^{11}$, for the reaction in ethanol. In methanol $E_a = 19.9$ kcal. deg.⁻¹ mole⁻¹. Variation in initial chalcol molarity between 0.013 and 0.002M shows no general trend within experimental error. We conclude that the rate of rearrangement follows the order of proton affinity of the catalyst, and ease of rearrangement is correlated with the presence of electron-attracting substituents on the chalcol.

From the many examples of base-catalysed prototropy in triad systems investigated (see C. K. Ingild, "Structure and Mechanism in Inorganic Chemistry," (Bell, London, 1953) it seems likely that rearrangement here involves removal of α -hydrogen followed by conversion into an enol which is unstable with respect to the saturated ketone. Whether the mechanism is "unimolecular" (consecutive) or "bimolecular" (concerted) cannot be determined.

EXPERIMENTAL

Synthesis via the Grignard Reaction.—Chalcol was obtained in 70% yield by Burton and Ingold's method⁴ and Willstaedt's method⁷ gave 4'-methoxychalcol (10% yield) (confirmed by analysis, mol. wt., mixed m. p.s of compound and its dibromide) and not the expected 4'-methoxychalcol. Similarly ω -bromostyrene, magnesium, and 4-dimethylaminobenzaldehyde gave 4'-dimethylaminochalcone (16% yield) and not the expected chalcol.

²⁷ M. J. Bender and W. A. Glasson, *J. Amer. Chem. Soc.*, 1959, **81**, 1590.

Reduction of Chalcones.—Aluminium isopropoxide–isopropyl alcohol reduction of chalcone yielded chalcol in 96% yield and 4-nitrochalcol was similarly obtained.²⁸ 4'-Bromochalcol was also obtained by this method as white needles, m. p. 57.5–58° (Found: C, 62.1; H, 4.52; Br, 25.8%; *M* 260. Calc. for C₁₅H₁₃BrO requires C, 62.32; H, 4.53; Br, 27.6%; *M* 289) (Willstaedt⁷ gave m. p. 100°) [ultraviolet spectrum: λ_{max.} 255 (ε 24,200), 293; λ_{min.} 226 (ε 12,600); 290 mμ (ε 1050)].

Reduction of 4-methoxy or 4'-methoxychalcone gave *isopropyl 4-methoxychalcol ether* (Found: C, 80.74; H, 7.86. C₁₉H₂₂O₂ requires C, 80.81; H, 7.85%) [λ_{max.} 258 mμ (ε 20,000); λ_{min.} 230 mμ (ε 9080)].

Similarly 4-dimethylaminochalcone gave 70% yield of *4-dimethylaminochalcol isopropyl ether*, m. p. 100–100.5° (Found: C, 81.55; H, 8.44; N, 4.63%; *M*, 290. C₂₀H₂₀NO requires C, 81.32; H, 8.53; N, 4.53%; *M* 295.4) and 4-methylchalcone gave *isopropyl 4-methylchalcol ether* as a yellow oil, b. p. 126–128°/0.7 mm. (Found: C, 85.2; H, 8.4. C₁₉H₂₂O requires C, 85.5; H, 8.27%).

*Potassium borohydride reduction.*²² To a solution of 0.04 mole ketone in the minimum of hot methanol, was slowly added a saturated aqueous solution of 0.02 mole borohydride, with agitation. The mixture was boiled until the colour of the chalcone had disappeared, poured into saturated sodium chloride solution, ether extracted, and the product isolated.

Chalcone gave an almost quantitative yield of chalcol. The following chalcols were obtained: *4-methoxychalcol*, white needles, m. p. 52.5°, decomposing to a yellow oil, with an odour of benzaldehyde, in a few days (Found: C, 79.77; H, 6.79%; *M*, 235. C₁₆H₁₆O₂ requires C, 79.98; H, 6.71%; *M*, 240.3) (Bromine uptake 1.95 mol./mol. for C₁₆H₁₆O₂; vigorous reaction occurred with methyl magnesium iodide, with evolution of methane). 4'-Methoxychalcol was uncrystallisable. *4-Dimethylaminochalcol* gave white needles (m. p. 54.5°) from light petroleum (b. p. 40–60°) under nitrogen, which decomposed to a yellow oil in a few hours. Treatment with excess of methyl iodide under reflux for 15 min. gave a stable white solid, crystallising from ethanol as a microcrystalline powder, m. p. 166.5° (decomp.) (Found: C, 54.30; H, 5.98; I, 31.9; N, 3.34. C₁₈H₂₂INO requires C, 54.70; H, 5.61; I, 32.1; N, 3.54%). For comparison *4-dimethylaminochalcone methiodide* was prepared as a pale yellow microcrystalline powder, m. p. 194.5° decomp. from ethanol (Found: C, 55.19; H, 5.08; I, 32.6; N, 3.78. C₁₈H₂₀INO requires C, 54.98; H, 5.13; I, 32.3; N, 3.56%). *4-Methylchalcol* was obtained as fine, white needles, m. p. 62–62.5° (80% yield) (Found: C, 85.78; H, 7.33%; *M*, 227. C₁₆H₁₆O requires C, 85.69; H, 7.19%; *M*, 224) [λ_{max.} 258 mμ (ε 24,600); λ_{min.} 229 mμ (ε 5570)]. Bromine uptake was rapid and methane was readily liberated with methylmagnesium iodide.

4-Methylchalcol was obtained in white needles, m. p. and mixed m. p. with compound prepared by Burton and Ingold's method,⁴ 77–78° [λ_{max.} 254 mμ (ε 22,800) λ_{min.} 228 mμ (ε 8750)]. *4'-Bromochalcol* gave needles, m. p. and mixed m. p. with material from Meerwein–Pondorff reduction, 56.5°.

4-Nitrochalcol (1 g.) and succinic anhydride (0.4 g.) were mixed in boiling chloroform (50 ml.) and dry triethylamine (5 ml.) added, resulting in the immediate solution of the reactants. After refluxing for 2 hr. the solvent was removed and crystallisation from light petroleum (b. p. 40–60°) gave *di-(4-nitrochalcyl) succinate* as yellow needles, m. p. 95–96° (Found: C, 69.36; H, 5.21; N, 4.87%; *M*, 580. C₃₄H₂₈N₂O₈ requires C, 69.92; H, 4.76; N, 4.73%; *M*, 592.6).

Rearrangement of Chalcol.—Chalcol (1 g.) was heated under reflux to 100° with ethanolic potassium hydroxide (25 ml. 20% w/v KOH in 60% v/v aqueous ethanol) for 3 hr. Acidification with dilute hydrochloric acid and ether extraction gave hydrochalcone in plates from 70% v/v aqueous ethanol (80% yield, m. p. 70.5–71.5°; Nomura³ gave m. p. 72° [λ_{max.} 234 mμ (ε 13,300)]).

Chalcol (10 g.) was refluxed with ethanolic potassium hydroxide (400 ml. 20% KOH) for 10 hr. The dark mixture was acidified with 2N-HCl, extracted with benzene, the extract was washed and dried and the solvent removed under reduced pressure. Distillation under reduced pressure gave two fractions, an oil, b. p. 136–138°/0.5 mm. solidifying on seeding with hydrochalcone, crystallised in plates, m. p. and mixed m. p. 70.5–71.5° and a viscous oil b. p. 160–200°/0.5 mm. (50% yield), solidifying on standing. Recrystallisation from light petroleum (b. p. 60–80°) or 70% aqueous ethanol gave *Compound A* in needles, m. p. 145.5–146.5°, from

²⁸ R. E. Lutz and E. H. Rinker, *J. Amer. Chem. Soc.*, 1955, **77**, 366.

acetone large colourless cubes, m. p. 145° (Found: C, 81.49; H, 7.26%; *M*, 220. C₁₉H₂₀O₂ requires C, 81.37; H, 7.19%; *M*, 280) [λ_{\max} , 258.5 m μ (ϵ 701)].

TABLE 6.

Run	[KOH] (N)	[Chalcol] (M)	Solvent (mole % H ₂ O)	Temp. (°C)	Solvent	<i>E</i> ₀	<i>E</i> _∞	Time (min.)	<i>E</i>	10 ⁵ <i>k</i>
1	2.373	0.0124	56.9	80	Ethanol	0.523	0.200	30.5	0.475	8.80
								59.75	0.432	9.23
								90.0	0.397	9.15
								120.0	0.365	9.33
								150.0	0.337	9.53
								184.7	0.316	9.24
								243.0	0.281	9.49
								281.8	0.261	9.86
								298.5	0.258	9.59
										Mean
2	1.083	0.0125	59.0	80	Methanol	0.529	0.201	30.25	0.510	3.29
								61.0	0.494	3.08
								121.8	0.462	3.13
								179.8	0.428	3.41
								250.3	0.407	3.10
		Mean	3.21 ± 0.12							
6	2.523	0.00193	44.4 *	80	Methanol	0.409	0.172	63.5	0.369	4.85
								181.0	0.324	4.09
								217.7	0.274	6.45
		Mean	5.13 ± 0.88							
7	2.523	0.00248	44.4 *	80	Methanol	0.525	0.222	59.83	0.465	6.14
								121.2	0.409	6.64
								184.0	0.364	6.86
								245.0	0.325	7.34
		Mean	6.75 ± 0.36							
8	2.523	0.00278	44.4 *	70	Methanol	0.591	0.252	61.33	0.561	2.51
								122.8	0.532	2.60
								179.4	0.508	2.69
								240.5	0.474	2.93
		Mean	2.66 ± 0.13							
12	2.523	0.00226	75.4	80	Ethanol	0.402	0.173	52.0	0.362	6.15
								120.0	0.333	4.98
								188.0	0.290	5.95
								215.3	0.268	5.83
								301.0	0.251	5.96
		Mean	5.77 ± 0.32							
23	3.882	0.00195	74.4	70	Ethanol	0.415	0.184	60.0	0.387	3.59
								120.0	0.362	3.62
								180.0	0.340	3.63
								210.0	0.332	3.53
		Mean	3.59 ± 0.03							
24	3.882	0.00224	74.4	60	Ethanol	0.476	0.212	180.5	0.446	1.12
								241.0	0.437	1.11
								270.0	0.433	1.10
		Mean	1.11 ± 0.01							

* 30 ml. standard KOH in water diluted with AnalaR methanol to 100 ml.

Chalcol (1 g.) agitated with a hot melt of potassium hydroxide (10 g.) and water (2 ml.) for 5 min. gave 70% yield of hydrochalcone and some dark fragrant tar.

Chalcol (0.8 g.), refluxed with sodium (2 g.) in ethanol (30 ml.) for 3 hr. gave a dark solution

which was poured into saturated sodium chloride solution, extracted with ether and the white precipitate in the aqueous phase filtered off, acidified and extracted with benzene and the product recovered from the benzene to give compound A, m. p. 145°.

Chalcol (1 g.) refluxed with sodium (0.5 g.) in benzene (100 ml.) gave a benzene-soluble sodium compound. No rearrangement product was obtained on acidification.

Heating hydrochalcone with ethanolic potassium hydroxide or sodium ethoxide gave Compound A and a small amount of tar. Refluxing of hydrochalcone in aqueous ethanol (30%) with potassium hydroxide (20%) led to decomposition as evidenced by the slow decrease in optical density of the solution at 243 m μ .

Rearrangement of 4'-bromochalcol by refluxing with ethanolic potassium hydroxide (20%) gave 4'-bromohydrochalcone, m. p. 98—99° (lit.,²⁹ 98—99°) (70% yield). [λ_{\max} . 255.5 m μ (ϵ 16,300); λ_{\min} . 226.5 m μ (2890)]. Its oxime had m. p. 120° (lit.,²⁹ 115—125°). Similarly were obtained 4-methylhydrochalcone, m. p. 15° [oxime, m. p. 85.5° (lit.,⁴ 85—86°), and 4-methoxyhydrochalcone, m. p. 67—68° (lit.,³⁰ 68°) [λ_{\max} . 227.5 m μ (ϵ 14,400), 241.5 (ϵ 14,400), 277.5 (ϵ 3010); λ_{\min} . 215.0 (ϵ 9870), 234.0 (ϵ 12,900), 266.0 (ϵ 2580)].

4-Nitrochalcol (1 g.) was refluxed with triethylamine (20 ml.), water (2 ml.), and methanol (4 ml.) for 8 hr. gave 4-nitrohydrochalcone as yellow needles from light petroleum (b. p. 40—60°), m. p. 99.5—100.5° [Found: C, 71.35; H, 5.49; N, 5.38%; *M*, 247. C₁₅H₁₃NO₃ requires C, 70.60; H, 5.13; N, 5.49%; *M*, 255] [λ_{\max} . 245.0 m μ (ϵ 15,900), 275.0 (ϵ 12,800); λ_{\min} . 226.0 (ϵ 8480), 262.0 (ϵ 11,400)].

Quantitative Study of the Rearrangement of Chalcol.—Reactions were carried out in a 3-necked 100 ml. Pyrex flask fitted with a double-surface reflux condenser connected to a soda-lime tube by narrow bore tubing. The flask was also fitted with a stoppered straight inlet tube dipping under the surface of the contents, and was thermostatted to $\pm 0.02^\circ$.

For each run the vessel was flushed out with nitrogen, 50 ml. aqueous alcoholic KOH pipetted in and the whole allowed to attain thermal equilibrium. The reaction medium was made up by dilution of a known volume of standard KOH in distilled water, to 100 ml. with 95.6% w/w spectroscopic ethanol.

The weighed sample of chalcol in a micro-beaker was dropped into the reaction vessel and the whole vigorously shaken for 15 sec. The initial sample was then taken with a 1 ml. calibrated pipette inserted down the inlet tube, suction being applied by a rubber bulb. This was neutralised, the resulting KCl dissolved, and the whole made up to 10 ml. with 95.6% spectroscopic ethanol.

The optical density of this solution at 253.23 m μ was compared, using 1 mm. quartz cells, with (a) 1 ml. reagent similarly neutralised and diluted, (b) (c) the same with the separate addition of a measured volume of standard chalcol or hydrochalcone in 95.6% spectroscopic ethanol before dilution to 10 ml.

First-order rate constants were calculated from $(2.303/t) \log_{10} (E_0 - E)/(E_t - E)$ when t = time (sec.), E = calculated final O.D., E_0 = initial O.D., E_t = O.D. at time t . Some typical results are in Table 6.

THE POLYTECHNIC, 309 REGENT ST., LONDON W.1.

[Present address (W. D.): COLLEGE OF TECHNOLOGY,
PORTSMOUTH, HANTS.]

[Received, January 28th, 1964.]

²⁹ J. R. Johnson, T. L. Jacobs, and A. M. Schwartz, *J. Amer. Chem. Soc.*, 1938, **60**, 1885.

³⁰ A. Schiavello and C. Sebastiano, *Gazzetta*, 1949, **79**, 909.