417. *Optical Activity in Relation to Tautomeric Change. Part V. Kinetic Status of Ionic Intermediates in Prototropy.*

By Shing Kong Hsü, Christopher K. Ingold, and Christopher L. Wilson.

This paper deals with the intimate mechanism of prototropic change, the method of attack being a development of that initiated in Part II (Ingold and Wilson, J., 1934, 92). The enquiry is directed to determine whether or not catalysed prototropic change involves short-lived intermediates, and if so, whether they are of the nature of transition complexes or entities with some degree of kinetic stability and independence. These questions are fundamental to any consideration of the relation of the intermediates to the tautomerides, and the rôle of the former in the interconversion of the latter.

We shall show that the discussion of these matters is much assisted if we are able first to solve the following special problem. A tautomeride, A, possesses a single centre of asymmetry situated at the point of the attachment of the mobile atom. In the associated tautomeride, B, a double bond appears in this position so that during the change from A to B asymmetry is lost; thus optically active A yields inactive B. It is required to find whether the loss of optical activity may occur, either partly or wholly, in any intermediate state of the changing system, *i.e.*, in any state in which there is a finite probability of the reaction turning back without completion.*

A kinetic criterion to decide this question is easily devised. By methods which do not depend on optical activity, we can measure the rate of the conversion A ⟶ B, and of its reverse B ⟶ A. These rate constants determine the speed at which, starting from A, the system can traverse a complete cycle through B and return to A. Now, if in the change A ⟶ B no optical activity is lost in any intermediate state, then A will become racemised only through progressive dilution of the original substance with inactive material regenerated from B. Hence the rate of racemisation will always and in principle be equal to the independently determinate rate at which the system can traverse the cycle through B. On the other hand, if optical activity can be lost at all in any intermediate state, Z, then the shorter cycle *via* Z becomes available as a route of racemisation. In this case, therefore, racemisation will in general proceed more rapidly than would correspond to the determinable rate of traverse of the cycle *via* B. How much more rapidly will depend on the proportion in which state Z, when formed, passes back into A and forward into B. It is qualitatively obvious that, if the former sequel greatly predominated, the opening of the cycle through Z would add greatly to the speed. On the other hand, if the latter sequel predominated, the route through Z would contribute but little, and the observed speed would be only slightly greater than that calculated from the non-optical data. The recognition of this limiting case is important, because if the observed and the calculated rate agree it becomes necessary to take precautions against mistaking a coincidence of accident for one of principle.

The quantitative expression of these ideas is as follows. Let k_1 and k_2 be the non-optically observed rate constants and κ_1 . . . κ_4 the (unobservable) constants for the reactions connecting state Z with A and B:

$$\mathrm{A} \underset{k_2}{\overset{k_1}{\rightleftharpoons}} \mathrm{B} \qquad\qquad \mathrm{A} \underset{\kappa_3}{\overset{\kappa_1}{\rightleftharpoons}} \mathrm{Z} \underset{\kappa_4}{\overset{\kappa_2}{\leftrightarrows}} \mathrm{B}$$

The rate of racemisation in the absence of short-circuiting, *i.e.*, solely by means of the cycle which passes through B, is given by the function

$$\rho = (k_1 + k_2)/(k_2 e^{k_1 t} + k_1 e^{-k_2 t}) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (R)$$

where ρ is the fraction of the original optical activity retained in racemisation at time t. If, however, optical activity is lost at state Z, the rate is

$$\rho = (k_1 + k_2)/e^{k_1 t/\alpha}[k_2 + k_1 e^{-(k_1 + k_2)t}] \quad . \quad . \quad . \quad . \quad . \quad (R')$$

where α is the fraction of material which, having reached the state Z, passes forward into the tautomeride B. Evidently α, which is given by $\alpha = \kappa_4/(\kappa_3 + \kappa_4)$, may range from zero to unity. In the special case, $\alpha = 1$, *i.e.*, if $\kappa_4 \gg \kappa_3$, equation (R') reduces to (R). In the general case, $\alpha < 1$, that is, if $\kappa_4 \not\gg \kappa_3$, equation ($R'$) represents a greater rate of racemisation than equation (R).

We have applied the same principle in an alternative way by measuring, not the racemisation of A, but the mutarotation of the whole system A + B. The theory of this test

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* The correct term for what we here call " state " is extension of configuration. Under the term " intermediate state " we include not only intermediate compound (with energy minima in all normal co-ordinates) and intermediate complex (with energy maximum in one normal co-ordinate) but also the totality of configurations included in any bounded strip of potential " surface " extending across the reaction track in the configuration-space of the reacting system.

is even simpler. It is necessary first to measure by non-optical methods only the rate ot the direct reaction A ⟶ B. If no optical activity is lost at any intermediate state in which there is a finite probability that the system returns to its original condition without first forming B, then the rate of mutarotation will be equal to the rate at which B is formed from original molecules of A; that is, it will be equal to the non-optically measured rate of the forward reaction. If, however, optical activity is lost in an intermediate state, Z, then the rate of mutarotation will be that with which state Z is produced from original molecules of A. Since in general only a fraction of the material which reaches state Z passes forward into B, the rate of production of Z from original A must be greater than the rate of formation of B from original A. It follows that in this case the rate of mutarotation will in general be greater than the non-optically measured rate of the change A ⟶ B. How much greater will depend, as before, on the relative proportions in which material, having reached state Z, passes back into A and forward into B.

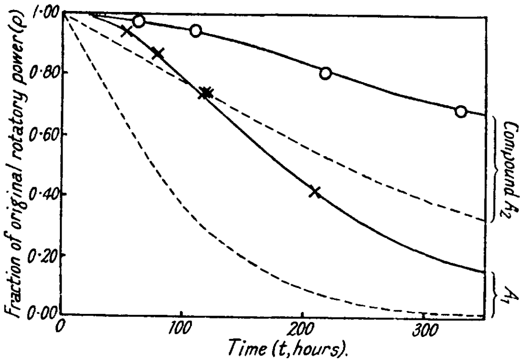
In symbols, this amounts to the following. If μ is the fraction of the original optical activity which is retained in mutarotation in time t, then, for the case in which optical activity is lost only at B and not intermediately, we have

$$\mu = e^{-k_1 t} \quad . \quad . \quad . \quad . \quad . \quad (M)$$

Thus the rate constant for the optical determination is the same as for the non-optical. If, however, optical activity is lost in an intermediate state Z, the formula becomes

$$\mu = e^{-\kappa_1 t} = e^{-k_1 t/\alpha} \quad . \quad . \quad (M')$$

where α has the significance already mentioned. Evidently formula (M') reduces to formula (M) if $\alpha = 1$, *i.e.*, if $\kappa_4 \gg \kappa_3$. In the general case, however, (M') represents a greater rate of mutarotation than (M).



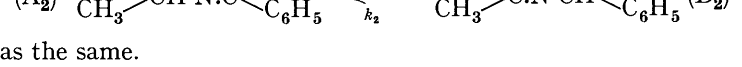
The tautomeric system chosen for study was the methyleneazomethine system, $\mathrm{CH{\cdot}N{:}C \rightleftharpoons C{:}N{\cdot}CH}$, which can be obtained in association with suitable asymmetry and convenient rates of interchange in either direction. Appropriate rates and sufficiently balanced equilibria are found when at least one aryl group is attached to each end of the triad system. The catalyst is sodium ethoxide, and the solvent alcohol or a mixture containing alcohol.

The first example to be studied was the following :

$$(\mathrm{A_1})\ {}^{\mathrm{C_6H_5}}_{\mathrm{CH_3}}\!>\overset{*}{\mathrm{C}}\mathrm{H{\cdot}N{:}C}<^{\mathrm{C_6H_4Cl}(p)}_{\mathrm{C_6H_5}} \rightleftharpoons {}^{\mathrm{C_6H_5}}_{\mathrm{CH_3}}\!>\mathrm{C{:}N{\cdot}CH}<^{\mathrm{C_6H_4Cl}(p)}_{\mathrm{C_6H_5}}\ (\mathrm{B_1})$$

In this case the non-optically measured rate constants, k_1 and k_2, were used to calculate the rates at which $\mathrm{A_1}$ should racemise if no optical activity is lost in any intermediate state. The observed rate of racemisation was exactly equal to the calculated.

It was then necessary to decide whether this coincidence was one of principle, or whether it arose through the accidental relationship $\alpha = 1$. Therefore a second example was similarly examined :



$$(\mathrm{A_2})\ {}^{\mathrm{C_6H_5}}_{\mathrm{CH_3}}\!>\overset{*}{\mathrm{C}}\mathrm{H{\cdot}N{:}C}<^{\mathrm{C_6H_5}}_{\mathrm{C_6H_5}} \underset{k_2}{\overset{k_1}{\rightleftharpoons}} {}^{\mathrm{C_6H_5}}_{\mathrm{CH_3}}\!>\mathrm{C{:}N{\cdot}CH}<^{\mathrm{C_6H_5}}_{\mathrm{C_6H_5}}\ (\mathrm{B_2})$$

The result was the same.

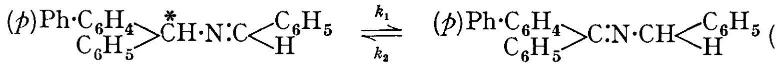
The diagram shows the racemisation–time curves (full line) calculated for $\mathrm{A_1}$ and $\mathrm{A_2}$ from non-optical data by means of formula (R). The crosses and circles represent the polarimetric observations. The broken curves illustrate the function (R') for the "average" case $\kappa_3 = \kappa_4$, *i.e.*, $\alpha = 0{\cdot}5$.

The possibility of a double accidental coincidence is not at once to be set aside, as the following considerations show. According to the ionic theory of tautomerism the intermediate state, Z, could be identified with ionisation products which are either simply solvated or combined with a catalyst. The proportion in which material in the intermediate state undergoes change to give A or B would then depend on the relative rates with which the mesomeric anion takes up a proton in the two possible positions :

$$\mathrm{CH{\cdot}N{:}C} \underset{\kappa_3}{\overset{\kappa_1}{\rightleftharpoons}} [\mathrm{H}]^+ + [\mathrm{C{-}N{-}C}]^- \underset{\kappa_4}{\overset{\kappa_2}{\leftrightharpoons}} \mathrm{C{:}N{\cdot}CH}$$

If it should be true that the up-take of a proton by the anion is for some reason more facile at a carbon atom to which two aryl groups are attached than at the alternative carbon atom if this bears only one, then for both the above examples we might find $\kappa_4 \gg \kappa_3$, *i.e.*, $\alpha \sim 1$. Because of this possibility we examined a third example in which the disposition of aryl groups with respect to the centre of asymmetry of A is reversed. If the previous results are affected by the cause mentioned, then in this case the rate of loss of optical activity should be enormously greater than that calculated on the assumption that none disappears intermediately.

The third case, which was studied by the mutarotation method, was the following :

(A₃)  (B₃)

$$(\mathrm{A_3})\ \begin{matrix}(p)\mathrm{Ph{\cdot}C_6H_4}\\ \mathrm{C_6H_5}\end{matrix}\!>\!\overset{*}{\mathrm{C}}\mathrm{H{\cdot}N{:}C}\!<\!\begin{matrix}\mathrm{C_6H_5}\\ \mathrm{H}\end{matrix} \underset{k_2}{\overset{k_1}{\rightleftharpoons}} \begin{matrix}(p)\mathrm{Ph{\cdot}C_6H_4}\\ \mathrm{C_6H_5}\end{matrix}\!>\!\mathrm{C{:}N{\cdot}CH}\!<\!\begin{matrix}\mathrm{C_6H_5}\\ \mathrm{H}\end{matrix}\ (\mathrm{B_3})$$

The non-optically measured rate constant of the forward reaction was 0·0128 hr.$^{-1}$ under the conditions of the comparison. It is derived from measurements of the rate of approach to equilibrium and of the equilibrium constant, and is subject to a possible error of about 5%. The constant for the rate of mutarotation was 0·0122 hr.$^{-1}$, which is equal to the non-optical rate constant to within the error of measurement of the latter (and certainly is not greater).

These three examples are considered to establish with a high degree of probability the conclusion that the mechanism of interchange in the tautomeric system studied is such as to preclude the possibility of losing optical activity in any reversibly formed intermediate state. It is necessary now to consider the significance of this conclusion in relation to the more general enquiry concerning the mechanism of tautomeric change.

As a basis, the ionic theory of prototropy may be adopted, according to which the mobile entity is not a hydrogen atom but a proton removed by the catalyst and returned from the solvent, the electron distribution in the tautomeric system adjusting itself to suit combination in either position. For the methyleneazomethine system we have proved (aside from a most improbable series of coincidences) that if the seat of dissociation is asymmetric the ionisation products retain enantiomeric identity. Until recently there appeared to be a considerable body of experimental evidence which, contrary to any accepted theory, favoured the conception of stable asymmetry in a kinetically free mesomeric system : the alleged optical activity of some diazo-compounds, and the retention of optical activity in the halogenation of a ketone and in the alkali salts of certain nitro-compounds, seemed to point in this direction. Most of this evidence has now, however, either been shown to be erroneous or explained in a different way, and doubt has been cast on the interpretation of what is outstanding. Contemporaneously, the quantum theory of the mesomeric effect has, thanks mainly to Pauling, been placed in the simpler cases on a firm basis of calculation, without the disclosure of any cause through which the retention of asymmetry in a kinetically free system could possibly be explained. Therefore we regard our results substantially as a demonstration that the ionisation products of our system do not at any period of the interchange become kinetically free; by which we mean that they do not at any moment become sufficiently separated from other molecules to permit the change of quantisation (mesomeric hybridisation of eigenfunctions) which, if it occurred, would destroy asymmetry.

This conclusion bears directly on a much-discussed question concerning the mechanism of tautomeric change in general. In the form in which Ingold, Shoppee, and Thorpe (J., 1926, 1477) advanced the ionisation theory of prototropy, the removal of the proton by a base and its return by an acid were regarded as consecutive bimolecular processes. A different picture was, however, given by Lowry (J., 1927, 2554), who regarded as simultaneous the extraction and restoration of the proton, the whole reaction being treated as a termolecular one involving the base, the substrate, and the acid. This conception is consistent with the known kinetics of prototropy because in basic catalysis the solvent, which is of constant active mass, can normally function as the auxiliary acid, whilst in acid catalysis it can likewise act as the complementary base. A number of authors have compared these theories in the light of experimental evidence, and all have decided in favour of the bimolecular hypothesis. For instance, Baker (J., 1928, 1583, 1979; 1929, 1205) studied the effect of polar substituents on the velocity of prototropic change in certain derivatives of glucose, and his results made it almost certain that only the bimolecular mechanism operates. Pedersen (*J. Physical Chem.*, 1934, **38**, 591) has used Dawson's experiments on the prototropy of acetone as basis for a simple and convincing proof that the bimolecular theory applies here also. On account of such demonstrations, and because the principal argument by which Lowry supported his termolecular hypothesis has been shown to be inconclusive (Baker, " Tautomerism," p. 191 *et seq.*), the bimolecular theory is now generally accepted. We regard the work described in this paper as the first substantial proof that for certain systems Lowry's theory is nevertheless correct, and that to the same extent the bimolecular hypothesis of Ingold, Shoppee, and Thorpe lacks generality. Obviously, if the ionisation products are to remain bound throughout the change, the restoration of the proton must be commenced before the dismemberment is completed.*

We may survey the whole position by considering prototropic systems arranged in series according to a scale of decreasing acidity, *i.e.*, decreasing relative stability in the anion. Such a series of triad systems, for instance, would range from carboxylic acids and thio-acids, through simple ketones such as acetone, to unsaturated hydrocarbons and azomethines :

[H]·O·C⁚O . . . . . [H]·O·C⁚C . . . . . [H]·C·C⁚C

It is a commonplace that the anions of the early members of such a series have kinetic independence, and Pedersen has shown that this remains true at least as far along the series as the simple ketones; this, then, is the range within which prototropy proceeds by the bimolecular mechanism. At the end of the series, however, as we have shown for azomethines, the anion does not attain kinetic freedom; this is the region of validity of the termolecular mechanism. The problem of exact delimitation remains.

EXPERIMENTAL.

dl-*Benzhydrylidene-α-phenylethylamine* (A_2).—Benzophenone dichloride, prepared according to Kekulé and Franchimont (*Ber.*, 1872, **5**, 908; cf. McKenzie, J., 1896, **69**, 987) from benzophenone and phosphorus pentachloride, had b. p. (uncorr.) 189—190°/21 mm. (yield, 85%). It was condensed with α-phenylethylamine by Ingold and Wilson's method (J., 1933, 1502). The product, crystallised twice from light petroleum below 0°, had m. p. 52—53° (yield, 63%) (Found: C, 88·4; H, 6·7; N, 5·3. Calc. for $C_{21}H_{19}N$: C, 88·4; H, 6·7; N, 4·9%). Hydrolysis by warming for 20 minutes with 20% hydrochloric acid gave benzophenone, identified as its 2 : 4-dinitrophenylhydrazone (m. p. 237—238°), and α-phenylethylamine, identified as its picrate (m. p. 187°).

d-*Benzhydrylidene-α-phenylethylamine* (A_2).—*l*-α-Phenylethylamine, α −13·26° (*l* 50 mm., *t* 21°, λ 5461), b. p. 184—185°/748 mm., was employed, and d-*benzhydrylidene-α-phenylethylamine*, b. p. 182°/3 mm., was obtained as a viscid liquid which could not be crystallised (Found: C, 88·1; H, 6·7; N, 4·3%). Hydrolysis with 20% aqueous hydrochloric acid gave α-phenylethylamine having α − 14·53° (*l* 50 mm., *t* 21°, λ 5461), which is a higher rotation than that of the base employed in the condensation (cf. Ingold and Wilson, *loc. cit.*, p. 1503).

2 : 4-*Dinitrophenylhydrazones of Acetophenone and Benzophenone.*—These were prepared

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* As elucidated in the well-known discussion of Trautz and Bodenstein, a termolecular process is a limit of rapidly consecutive bimolecular reactions. In adopting Lowry's mechanism, we generalise it slightly by refusing to imply that there is *no* separation in time between the proton transfers. Therefore it is only in rather a loose sense that the term termolecular can be applied to our version of the mechanism.

according to the existing literature (Brady, J., 1931, 757; Allen, *J. Amer. Chem. Soc.*, 1930, **52**, 2955; Purgatti, *Gazzetta*, 1894, **24**, I, 555). The former separated from alcohol in orange needles, m. p. 237—237·5° (Found: C, 55·3; H, 4·0; N, 18·7. Calc.: C, 56·0; H, 4·0; N, 18·7%), and from xylene in crimson prisms. The latter separated from alcohol in brownish-red plates, m. p. 237·5—238° (Found: C, 62·9; H, 3·9; N, 15·5. Calc.: C, 63·0; H, 3·9; N, 15·5%), and from xylene in microscopic orange crystals. The solubilities of the two compounds in ethyl alcohol at 25° were 0·0061 and 0·0074 g./100 c.c. respectively.

Fusion diagram of mixtures of the two 2 : 4-*dinitrophenylhydrazones.* Mixtures of the two compounds had the following m. p.'s, the temperatures being those at which the substance became perfectly clear:

X (%)	0	20	40	60	80	100
M. p.	237·5°	225·3°	213·0°	217·0°	227·1°	237·3°

(X = Acetophenone-2 : 4-dinitrophenylhydrazone.)

All m. p.'s were determined in the same apparatus and are therefore not corrected. The diagram representing these figures consists of two straight lines, showing a eutectic point for a mixture, m. p. 210°, containing 45·3% of X.

Isomerisation of dl-*Benzhydrylidene-α-phenylethylamine* (A_2).—In view of the difficulty of preparing the isomeric Schiff's base, α-phenylethylidene-benzhydrylamine, in a state of purity, the attainment of tautomeric equilibrium was followed beginning with benzhydrylidene-α-phenylethylamine. This (0·1 g.) was heated with 1·33*N*-sodium ethoxide solution (5 c.c.) for various periods of time in small sealed glass bulbs immersed in a thermostat at 85·0°. The dry alcohol for the catalyst solution was prepared by use of magnesium (Lund and Bjerrum, *Ber.*, 1931, **64**, 210). The product was isolated by pouring into water and extraction with ether. The extract, after being dried (sodium sulphate), was evaporated, and the dry solid residue was dissolved in alcohol and treated with slight excess of a solution of 2 : 4-dinitrophenylhydrazine in alcoholic sulphuric acid (cf. Brady, *loc. cit.*). After being boiled for 45 minutes, the mixture was kept for 12 hours, and the precipitated 2 : 4-dinitrophenylhydrazones were collected on a filter of sintered glass, washed with a small known volume of alcohol, dried at 110°, and weighed.

The composition of the mixed dinitrophenylhydrazones was determined from the m. p. under conditions already defined, and also by analysis, the carbon contents of the two dinitrophenylhydrazones being sufficiently separated for this purpose (53·3 and 62·9% for acetophenone and benzophenone derivatives respectively). The two methods gave results in good agreement, and the rate constants were calculated from the means of the compositions obtained by the two methods, an appropriate correction being applied for the solubility of the compounds in the ethyl alcohol used in their preparation. The data are recorded below:

	Conversion (%).				
	Uncorr. for solubility.			Corr.	
Time (hrs.).	M. p.	Analysis.	Mean.	Mean.	k (hr.$^{-1}$).
91·8	12·3	11·9	12·1	14·5	0·00657
167·0	19·9	18·5	19·2	20·8	0·00630
240·0	25·2	23·5	24·4	25·7	0·00678
317·0	27·4	26·4	26·9	28·0	0·00656
730·0	31·1	30·4	30·8	32·0	—
820·0	30·9	31·3	31·1	32·0	—

The velocity constants are those of the approach to equilibrium, $k = k_1 + k_2$, the equilibrium constant being given by the last two determinations of composition. Hence $k = k_1 + k_2 = 0{\cdot}00655$ hr.$^{-1}$, and $K = k_1/k_2 = 0{\cdot}47$; wherefore $k_1 = 0{\cdot}00209$ hr.$^{-1}$ and $k_2 = 0{\cdot}00446$ hr.$^{-1}$, the sense of k_1 and k_2 being as on p. 1780.

Racemisation of d-*Benzhydrylidene-α-phenylethylamine* (A_2).—The Schiff's base was heated for various periods of time under the conditions employed in the investigation of the tautomeric change. The mixture of the isomerides was isolated and hydrolysed as described above for the separate individuals, the ketones being removed from the acid solution by means of ether. The aqueous layer was basified with potassium hydroxide and extracted with ether, the extract dried over anhydrous potassium carbonate and distilled (water-bath) under reduced pressure (< 1 mm.). The α-phenylethylamine, which could thus be separated sharply from the benzhydrylamine, was collected with the neglect of small head and tail fractions, and examined polarimetrically. The results are in the following table, line 3 of which gives the temperature at which the observations of rotation in line 2 were made (*l* 50 mm., λ 5461). The last line contains the ratios ρ of the original activity retained after times *t*.

Time, *t* (hrs.)	0	63	111	218	330
Rotation (*a*)	14·53°	14·02°	13·70°	11·78°	9·98°
Temp.	21°	21°	20°	22°	21°
ρ	1·000	0·975	0·945	0·810	0·689

dl-p-*Phenylbenzhydrylamine.*—Condensation of benzoyl chloride with diphenyl in carbon disulphide solution in the presence of aluminium chloride (Montagne, *Rec. trav. chim.*, 1908, **27**, 357; Wolf, *Ber.*, 1881, **14**, 2031; Perrier, *Compt. rend.*, 1893, **116**, 1299) gave *p*-phenylbenzophenone in 60% yield, b. p. 413°/758 mm., m. p. 99°, and, after recrystallisation from ethyl alcohol, 102° (Montagne gives m. p. 102°, b. p. 419—420°/774 mm.; Perrier gives m. p. 106°). The oxime, prepared by Koller's method (*Monatsh.*, 1891, **12**, 502) and crystallised twice from alcohol, had m. p. 186—187° (Koller gives 193—194°). It was reduced in ethyl-alcoholic solution by means of 2·5% sodium amalgam (cf. Montagne, *loc. cit.*), the mixture being maintained slightly acid by occasional addition of acetic acid. (Amalgam prepared in an iron vessel was ineffective; our amalgam was prepared under paraffin in a porcelain dish.) After distillation of most of the alcohol, the acetate of the base was precipitated by addition of water, and the base was liberated by ammonia. Crystallised from dry ether, it formed needles, m. p. 77° (yield, about 50%); it gave an intense violet solution in concentrated sulphuric acid.

dl-*Benzylidene*-p-*phenylbenzhydrylamine* (A_3).—Benzaldehyde (1 mol.) and *p*-phenylbenzhydrylamine (1 mol.) reacted completely on being heated together at 100° for 5 minutes. The product, crystallised twice from ethyl alcohol, formed needles, m. p. 125—133° (Found: C, 89·6; H, 6·2; N, 4·4. $C_{26}H_{21}N$ requires C, 89·9; H, 6·1; N, 4·0%), and further crystallisation from light petroleum gave small prisms, m. p. 133—134° (Found: C, 89·9; H, 6·3; N, 4·3%). Hydrolysis, by warming with 2*N*-hydrochloric acid, resolved the Schiff's base into its components; benzaldehyde was identified as its 2 : 4-dinitrophenylhydrazone, m. p. 237—238°, and *p*-phenylbenzhydrylamine as its acetate, m. p. 161°.

p-*Phenylbenzhydrylidene-benzylamine* (B_3).—*p*-Phenylbenzophenone and benzylamine failed to react at 150°, even in the presence of anhydrous zinc chloride or fused sodium acetate. The Schiff's base was, however, obtained as follows: *p*-Phenylbenzophenone dichloride was prepared by heating the ketone (30 g.) with a slight excess of phosphorus pentachloride to 170—180° for 6 hours and distilling the product. The dichloride, b. p. 188—195°/1 mm., a liquid which subsequently solidified (yield 65%), was heated at 100° with freshly distilled benzylamine (3·5 mols.) for 5 minutes. The Schiff's base, isolated in the usual manner by addition of water, extraction with ether, and removal of excess benzylamine by repeated shaking of the ethereal extract with 2% aqueous acetic acid, separated from light petroleum as long colourless needles, m. p. 90—91° (Found: C, 89·7; H, 6·2; N, 4·1. $C_{26}H_{21}N$ requires C, 89·9; H, 6·1; N, 4·0%). Hydrolysis with 2*N*-aqueous hydrochloric acid gave *p*-phenylbenzophenone (2 : 4-dinitrophenylhydrazone, m. p. 217—217·5°) and benzylamine (benzoyl derivative, m. p. 105°).

Optical Resolution of p-*Phenylbenzhydrylamine.*—The resolution of the base proved unusually tedious. Many attempts by crystallising the *l*-quinate, *l*-malate, and hydrogen malate from ethyl or methyl alcohol were unsuccessful. Partial resolution was effected by fractional crystallisation of the *d*-camphor-10-sulphonate and *d*-bromocamphor-10-sulphonate from either methyl or ethyl alcohol. The latter salt was inconveniently soluble. Repeated crystallisation of the former gave a very small yield of a base having $[\alpha]_D^{20^\circ}$ + 10·0° (in ether). Better results were obtained by the use of *d*-tartaric acid. A solution of the base in 40 times its weight of cold 95% alcohol was mixed with an equivalent amount (for the formation of the hydrogen tartrate) of a solution of tartaric acid (1 part) in water (3 parts) and 95% alcohol (50 parts). After 12 hours, the separated salt was collected, the base liberated by treatment with ammonia, and used in a repetition of the above process. The separation of the salt became more rapid in successive cycles, and after four such operations the base was optically pure. It separated from dry ether in glistening leaflets, m. p. 78°, $[\alpha]_D^{20^\circ}$ + 22° (1 g. in 40 c.c. of ether), + 16·5° (1 g. in 52 c.c. of 1 : 4-dioxan); the yield of *d*-base was 15% of the weight of *dl*-base employed.

d-*Benzylidene*-p-*phenylbenzhydrylamine* (A_3).—The condensation was effected as before, and the product, twice crystallised from light petroleum, formed needles, m. p. 133°, $[\alpha]_D^{20^\circ}$ + 3·0° (0·5 g. in 32 c.c. dioxan) (Found: C, 89·6; H, 6·3; N, 4·1. $C_{26}H_{21}N$ requires C, 89·9; H, 6·1; N, 4·0%).

Analysis of Mixtures of (A_3) *and* (B_3).—The m. p.'s of mixtures of the compounds are as follows :

B_3 (%)	0	20	40	50	60	80	100
M. p.	90·5°	93·0°	108·3°	113·5°	118·5°	127·5°	134·0°

The fusion diagram is not of the usual type, and since the m.p.'s were somewhat ill-defined, recourse was had to the dinitrophenylhydrazone method already described (p. 1783). p-*Phenylbenzophenone*-2 : 4-*dinitrophenylhydrazone* formed microscopic orange prisms, m. p. 217—217·5° (crude) (Found : C, 68·2; H, 4·3; N, 12·6. $C_{25}H_{18}O_4N_4$ requires C, 68·5; H, 4·1; N, 12·8%). Benzaldehyde-2 : 4-dinitrophenylhydrazone formed minute orange crystals, m. p. 237—238° (crude) (Found : C, 54·3; H, 3·4; N, 19·3. Calc. : C, 54·5; H, 3·5; N, 19·6%). Mixtures of the two dinitrophenylhydrazones had the following m. p.'s :

X (%)	0	20	40	50	60	70	80	90	100
M. p.	237·8°	230·4°	220·1°	213·5°	204·8°	198·0°	205·8°	214·3°	217·3°

(X = *p*-phenylbenzophenone-2 : 4-dinitrophenylhydrazone.)

The graph of these figures is a two-branch curve giving a eutectic at the composition X = 68·0%, and m. p. 195·6°.

Isomerisation of dl-p-*Phenylbenzhydrylidene-benzylamine* (B_3).—The Schiff's base (0·2 g.) was maintained at 25° in a small, sealed, Monax-glass bulb with a 0·1*N*-solution (3 c.c.) of sodium ethoxide in a mixture of dry ethyl alcohol (57·4% by vol.) and sodium-dried 1 : 4-dioxan (42·6%). The reaction was arrested by adding water, and the mixed Schiff's bases were isolated and converted into the 2 : 4-dinitrophenylhydrazones in the manner described on p. 1783. Both thermal and ultimate analysis were applied as before. The solubility correction was determined from the thermally estimated change in composition which resulted when a mixture of the two hydrazones was treated with a known volume of alcohol until saturated with respect to each component. A number of such experiments led to the following results :

	Conversion (%).				
	Uncorr. for solubility.			Corr.	
Time (hrs.).	M. p.	Analysis.	Mean.	Mean.	k (hr.$^{-1}$).
15	13·4	12·6	13·0	13·7	0·0243
24	17·5	16·7	17·1	17·8	0·0222
40	25·3	24·6	25·0	25·9	0·0223
68	34·4	33·2	33·8	34·5	0·0224
144	42·0	42·9	42·5	43·8	—
150	42·0	42·9	42·5	43·8	—

From these data $k = k_1 + k_2 = 0·0228$, and $K = k_1/k_2 = 1·28$, wherefore $k_1 = 0·0128$ and $k_2 = 0·0100$, where these constants apply as on p. 1781.

Mutarotation of d-*Benzylidene*-p-*phenylbenzhydrylamine* (A_3).—The Schiff's base, $[\alpha]_D^{20°} + 3·0°$ (0·5 g. in 32 c.c. of dioxan), was dissolved in the catalyst solution (1 g. in 15 c.c.), and the mutarotation was followed in a 2-dm. jacketed tube maintained 25·0°. The results are given below, α being the rotation at $\lambda = 5893$.

t (hrs.) ...	0	1·0	3·0	6·5	9·0	18·0	23·5	27·5	31·0
α	0·53°	0·525°	0·515°	0·495°	0·485°	0·44°	0·40°	0·38°	0·37°
t (hrs.) ...	41·0	48·0	53·0	65·5	70·5	78·0	91·0	105·0	117
α	0·33°	0·31°	0·285°	0·24°	0·23°	0·20°	0·18°	0·14°	0·13°

The graph obtained by plotting $\log_{10} \alpha$ against t is a straight line, the slope of which, divided by $- 2·303$, gives the unimolecular velocity constant $k_m = 0·0122$ hr.$^{-1}$.

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UNIVERSITY COLLEGE, LONDON.

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