[Contribution from the School of Chemistry of the University of Minnesota]

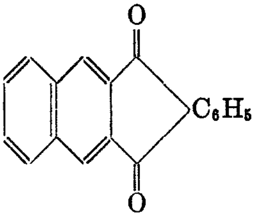
THE REACTIONS AND ENOLIZATION OF CYCLIC DIKETONES. VIII. THE 4,5- AND 5,6-BENZO DERIVATIVES OF 2-PHENYLINDANDIONE-1,3

C. F. KOELSCH

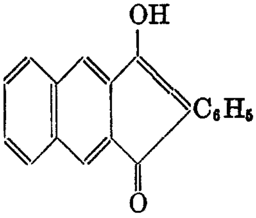
Received April 23, 1945

Probably the most important factor in determining whether a diketone derived from cyclopentane will exist in the solid state in its enolic or its ketonic form, is the lattice energy of the corresponding crystal. But it has not yet been possible to determine the difference in lattice energies of the keto and enol forms of such a pair of tautomers, for usually only one of the solid forms is available. In the few cases where two solid tautomers have been obtained, 2-*p*-iodophenylindandione-1,3 and 2-phenyl-5-bromoindandione-1,3 (1), the usual criteria of lattice energy have not been applicable since immediate keto-enol equilibration takes place when the substances are melted or dissolved.

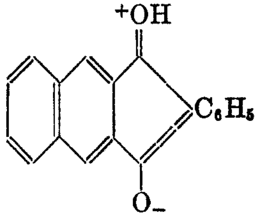
If the factor of lattice energy is disregarded, it nevertheless still appears possible to reach some fairly general conclusions as to the tendency of chemical factors to influence the crystallization of such a diketone in one or the other of its



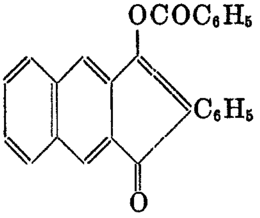
I



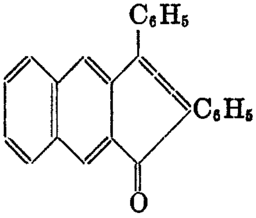
II



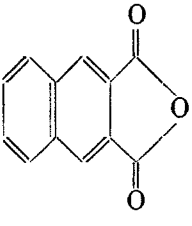
III



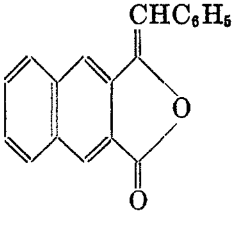
IV



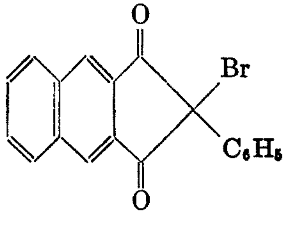
V



VI



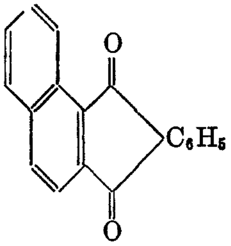
VII



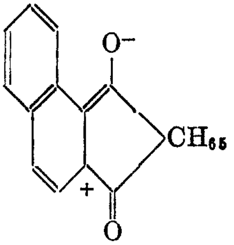
VIII

forms. Attempts in this direction have been described in some of the previous papers of this series (2), and some further observations on this aspect of the chemistry of cyclic diketones are made in the present paper.

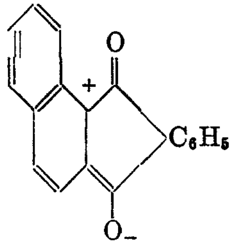
2-Phenyl-5,6-benzoindandione-1,3 (I) cannot give rise to any excited structures that do not involve extensive disturbance of its aromatic system. Such disturbance would be analogous to that necessary for the formation of 2,3-naphthoquinone, and evidence has been obtained (3) that this hypothetical compound cannot exist. The enol, 3-hydroxy-2-phenyl-5,6-benzoindone (II), however, can resonate through a separation of charge, forming a dipole (III). Since



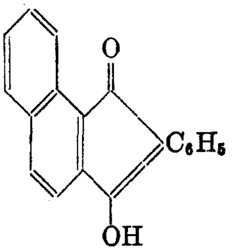
IX



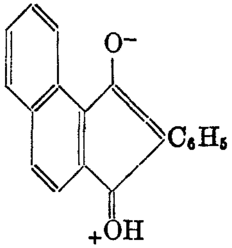
X



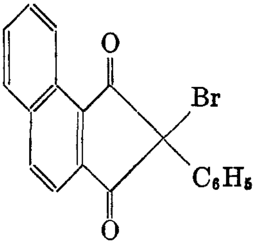
XI



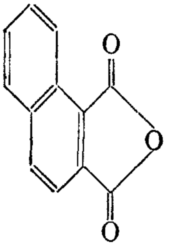
XII



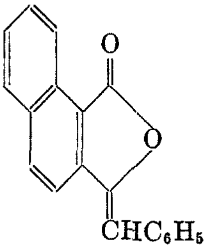
XIII



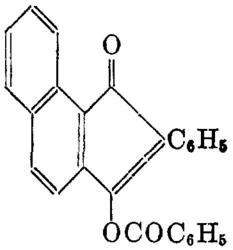
XIV



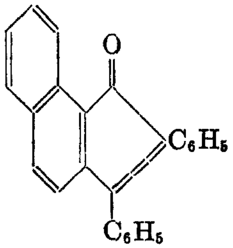
XV



XVI



XVII



XVIII

the resonance would increase the stability of the compound and the dipolar structure would contribute to the lattice energy of the crystal, it might be expected that the enolic form would tend to exist in preference to the ketonic form. This appears to be the case; the compound forms orange-red crystals similar in color to IV, V, and to a solution of its sodium salt, and different from the colorless crystals of VI, VII, and VIII.

Separation of charge in the ketonic form of 2-phenyl-4,5-benzoindandione-1,3 (IX) can take place with no more disturbance of the aromatic system than that involved in β-naphthoquinone; two resonance forms (X and XI) are thus possible. The enol,[1] however, can give rise to only one excited structure (XIII), and it might therefore be expected that the ketonic form would tend to exist in preference to the enolic form. Here again the expectation appears to be borne out; the compound forms pale yellow crystals similar in color to XIV, XV, and XVI, and different from XVII (red), XVIII (crimson), and a solution of its sodium salt (purple).

EXPERIMENTAL

Naphthalene-1,2-dicarboxylic anhydride (XV) was prepared by the method of Fieser and Hershberg (4). Naphthalene-2,3-dicarboxylic anhydride (VI) was prepared through the reactions studied by Dutta (5) and by Waldemann (6).

The benzalbenzophthalides (VII and XVI). A mixture of 7 g. of naphthalene-1,2-dicarboxylic anhydride, 0.5 g. of potassium acetate, and 5 g. of phenylacetic acid was heated at 250° for fifteen minutes. Crystallization of the product from acetic acid gave 3-benzal-6,7-benzophthalide (XVI),[2] yellow plates, m.p. 201–204° (4 g.).

Anal. Calc'd for $C_{19}H_{12}O_2$: C, 83.8; H, 4.4.
Found: C, 83.2; H, 4.5.

Naphthalene-2,3-dicarboxylic anhydride (7 g.) heated with phenylacetic acid and potassium acetate, gave only one product, *3-benzal-5,6-benzophthalide* (*VII*), flat yellow needles from acetic acid (5.8 g.), m.p. 191–193°.

Anal. Calc'd for $C_{19}H_{12}O_2$: C, 83.8; H, 4.4.
Found: C, 83.7; H, 4.5.

Rearrangement of the benzalphthalides to IX and II. 3-Benzal-6,7-benzophthalide(XVI, 3.5 g.) or 3-benzal-4,5-benzophthalide (m.p. 130–150°) was boiled for ten minutes with a solution of 0.5 g. of sodium in 30 ml. of methanol. The solution was diluted with water, filtered, and acidified. The resulting *2-phenyl-4,5-benzoindandione-1,3* (*IX*) was crystallized from acetic acid, giving yellow needles (3.0 g.), m.p. 175–176.5°. The diketone formed a yellow solution in acetic acid, a red solution in pyridine, a purple solution in aqueous sodium hydroxide, and a yellow-orange solution in conc'd sulfuric acid.

Anal. Calc'd for $C_{19}H_{12}O_2$: C, 83.8; H, 4.4.
Found: C, 83.5; H, 4.4.

3-Benzal-5,6-benzophthalide (VII) treated with sodium methoxide similarly, gave *3-hydroxy-2-phenyl-5,6-benzoindone* (*II*), red needles from acetic acid or better from ethyl

---

[1] Either XII or the isomer formed by migration of hydrogen to the ketonic oxygen.

[2] The structure indicated and not the isomeric one, 3-benzal-4,5-benzophthalide, follows if it is assumed that the more exposed β-carbonyl in XV is more reactive than the hindered α-carbonyl. The latter does react to a minor extent, however, for from the mother liquors there was obtained 3.7 g. of a mixture, yellow needles, m.p. 130–150°, not obtained analytically pure, of XVI with another substance, presumably the 4,5-benzo compound. Treatment of the mixture with sodium methoxide gave IX in a yield as good as that obtained from pure XVI.

acetoacetate, m.p. 285° with previous sintering. The sodium salt formed orange needles, difficultly soluble in cold water.

Anal. Calc'd for $C_{19}H_{12}O_2$: C, 83.8; H, 4.4.
Found: C, 83.3; H, 4.6.

Bromination. 2-Phenyl-4,5-benzoindandione-1,3 (IX) reacted slowly with one equivalent of bromine in acetic acid, even when it was warmed. The resulting *2-bromo-2-phenyl-4,5-benzoindandione-1,3* (*XIV*) crystallized from acetic acid in the form of yellow needles, m.p. 152–153°.

Anal. Calc'd for $C_{19}H_{11}BrO_2$: C, 65.0; H, 3.1.
Found: C, 64.8; H, 3.2.

3-Hydroxy-2-phenyl-5,6-benzoindanone (II) suspended in cold acetic acid reacted immediately with one equivalent of bromine, dissolving and losing its color. The resulting *2-bromo-2-phenyl-5,6-benzoindandione-1,3* (*VIII*) formed colorless plates from acetic acid, m.p. 157–158°.

Anal. Calc'd for $C_{19}H_{11}BrO_2$: C, 65.0; H, 3.1.
Found: C, 65.0; H, 3.3.

Benzoylation. 2-Phenyl-4,5-benzoindandione-1,3 (IX) treated with benzoyl chloride and dry pyridine or with benzoyl chloride in aqueous sodium hydroxide yielded *3-benzoyloxy-2-phenyl-6,7-benzoindone* (*XVII*), red needles from acetic acid, m.p. 187–189°. The benzoate was not affected when it was boiled for five minutes with alcohol containing 5% sulfuric acid, but it was rapidly hydrolyzed by warm alcoholic sodium hydroxide. It formed a red solution in acetic acid and in ether, and an orange-yellow solution in conc'd sulfuric acid.

Anal. Calc'd for $C_{26}H_{16}O_3$: C, 83.0; H, 4.2.
Found: C, 83.0; H, 4.5.

3-Hydroxy-2-phenyl-5,6-benzoindone (II), shaken with benzoyl chloride in 5% aqueous sodium hydroxide, yielded *3-benzoyloxy-2-phenyl-5,6-benzoindone* (*IV*), orange-yellow needles from acetic acid, m.p. 181–182°. Like its isomer, it was rapidly hydrolyzed by alcoholic sodium hydroxide.

Anal. Calc'd for $C_{26}H_{16}O_3$: C, 83.0; H, 4.2.
Found: C, 83.0; H, 4.1.

Reaction with phenylmagnesium bromide. A solution of 2-phenyl-4,5-benzoindandione-1,3 (IX) in toluene was treated with an excess of phenylmagnesium bromide and boiled until its purple color was discharged. The product was distilled at 15 mm., but it formed a red-purple glass that could not be obtained crystalline. Accordingly its solution in alcohol was boiled for three hours with semicarbazide hydrochloride and sodium acetate. The resulting *semicarbazone* was crystallized from ether-ligroin and then from alcohol, when it formed orange-red needles, m.p. 213–215°.

Anal. Calc'd for $C_{26}H_{19}N_3O$: C, 80.2; H, 4.9.
Found: C, 80.0; H, 5.1.

The purified semicarbazone was hydrolyzed by boiling it for five minutes with 1% alcoholic hydrochloric acid, and the resulting *2,3-diphenyl-6,7* (*4, 5?*)*-benzoindone* (*XVIII*) was crystallized from alcohol. It formed crimson needles, m.p. 167–168°.

Anal. Calc'd for $C_{25}H_{16}O$: C, 90.3; H, 4.8.
Found: C, 89.8; H, 5.0.

3-Hydroxy-2-phenyl-5,6-benzoindone (II) suspended in toluene was treated with an excess of phenylmagnesium bromide, and the solution was boiled for one hour. The resulting *2,3-diphenyl-5,6-benzoindone* (*V*) was distilled at 15 mm. and then crystallized from acetic acid, giving orange prisms, m.p. 193–194°.

Anal. Calc'd for $C_{25}H_{16}O$: C, 90.3; H, 4.8.
Found: C, 89.9; H, 5.2.

SUMMARY

The color of the 4,5-benzo derivative of 2-phenylindandione-1,3 indicates that the substance exists in the solid state as a diketone, whereas the color of the

isomeric 5,6-benzo derivative indicates that this substance crystallizes in its enolic form.

It is pointed out that these phenomena may be related to the relative abilities of the ketonic and the enolic forms to resonate with the development of dipolar structures.

Minneapolis, Minn.

REFERENCES

(1) Koelsch, *J. Am. Chem. Soc.*, **58**, 1328 (1936).
(2) Koelsch and Co-workers, *J. Org. Chem.*, **3**, 480, 489 (1938); **6**, 684 (1941); *J. Am. Chem. Soc.*, **65**, 1640 (1943).
(3) Fieser, *J. Am. Chem. Soc.*, **52**, 5219 (1930).
(4) Fieser and Hershberg, *J. Am. Chem. Soc.*, **57**, 1851 (1935).
(5) Dutta, *Ber.*, **67**, 1319 (1934).
(6) Waldemann, *J. prakt. Chem.*, **128**, 150 (1930).