Chemical and X-Ray Crystallographic Characterization of the Reaction Products in the 1,3-Dipolar Cycloaddition of Diazomethane to *p*-Toluquinone

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The product **2** in the 1,3-dipolar cycloaddition of one equivalent of diazomethane to *p*-toluquinone (**1**) was determined by 250 MHz nmr spectra to be approximately 85% 6-methyl-1-*H*-indazole-4,7-dione (**2b**). X-ray crystallographic analysis was employed in the characterization of 1,6-dimethyl-1-*H*-indazole-4,7-dione (**4a**), which was the major 1-*N*-methyl regioisomer in the methylation of the cycloaddition mixture **2** with diazomethane. Methylation of the cycloaddition product **2** with diazomethane also provided a regioisomeric mixture of the 2-*N*-methyl derivatives **5**. This mixture was synthesized for characterization by an independent method which utilized the cycloaddition of 3-methylsydnone (**10**) to toluquinone (**1**). 1,5,6-Trimethyl-1-*H*-indazole-4,7-dione (**9**) was found to be a minor product in the reaction of diazomethane with the cycloaddition product **2**.

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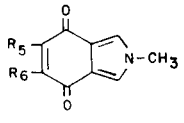
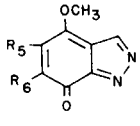
The cycloaddition of 1,3-dipolar species to 1,4-quinones provides a useful one step synthesis of a variety of heterocyclic quinones. The major 1,3-dipoles that have been used with 1,4-quinone dipolarophiles are the diazoalkanes, the azides, the nitrilimines and the nitrile oxides [2]. The 1,3-dipolar cycloaddition of diazomethane to *p*-toluquinone (**1**) [3-5] (Scheme I) was investigated in our laboratories as a rapid method for the synthesisis of 5- and/or 6-methyl-1-*H*-indazole-4,7-dione (**2a** and/or **2b**). This cycloaddition mixture of **2a** and **2b** was then *N*-methylated with another equivalent of diazomethane yielding mainly the isomers **4a** and **4b** which were to be used for further derivatization. In order to utilize this synthetic scheme, it was necessary to purify and characterize these isomers carefully.



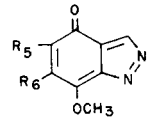
5a, R_5 = H, R_6 = CH_3

5b, R_5 = CH_3, R_6 = H



6a, R_5 = H, R_6 = CH_3

6b, R_5 = CH_3, R_6 = H



7a, R_5 = H, R_6 = CH_3

7b, R_5 = CH_3, R_6 = H

With monosubstituted benzoquinones such as *p*-toluquinone [1], there are two possible regioisomeric products in the 1,3-dipolar cycloaddition with diazomethane [2]. Previous literature [3-5] did not adequately clarify the composition of the cycloaddition product **2a** and/or **2b** due to the lack of sophisticated nmr spectrometers at the time of publication. For example, several earlier investigators had described the cycloaddition product as solely 6-methyl-1-*H*-indazole-4,7-dione (**2a**) [3,4]. Another research group made no attempt to ascertain the regioisomeric composition of the cycloaddition product **2** [5].

Results and Discussion.

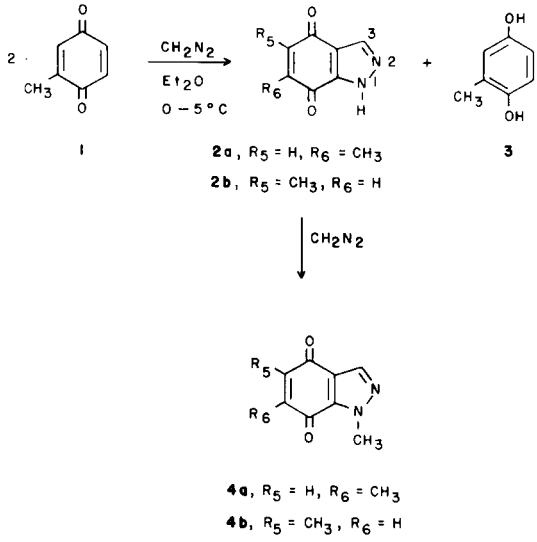
In our laboratories, the 1,3-dipolar cycloaddition of *p*-toluquinone (**1**) and 0.3 *M* ethereal diazomethane [6] at 0-5° provided a yellow product (30% total yield) composed of both regioisomers **2a** and **2b** as evidenced by the 250 MHz proton nmr spectrum. Based upon the integration of the protons at the 3-position, the product is an 85:15 mixture of isomers, not distinguished as to identity by nmr.

Budzikiewicz and coworkers [4] had synthesized 6-methyl-1-*H*-indazole-4,7-dione (**2a**) by an independent method and found the infrared spectrum of compound **2a** and the cycloaddition product **2** to be identical. Their results suggested that the major isomer in the cycloaddition product was 6-methyl-1-*H*-indazole-4,7-dione (**2a**); however, it seemed unlikely that the cycloaddition product **2**, which was 85 percent one isomer, would have an infrared spectrum identical to that of compound **2a**. Therefore, the independent synthesis of 6-methyl-1-*H*-indazole-4,7-dione (**2a**) described by Budzikiewicz was duplicated in our laboratories in order to utilize the 250 MHz proton nmr spectrometer to assign the structure of the major regioisomer unequivocally. The infrared spectra of 6-methyl-1-*H*-indazole-4,7-dione (**2a**) and the cycloaddition product **2** were indeed identical! Comparison of the 250 MHz nmr spectra clearly indicated that 6-methyl-1-*H*-indazole-4,7-dione (**2a**) is the predominant isomer in the cycloaddition product. The regioisomeric mixture **2** could not be separated by tlc or column chromatography on silica gel.

Further methylation of the cycloaddition mixture **2** with diazomethane could theoretically yield four sets of regioisomeric mixtures, **4a** + **4b**, **5a** + **5b**, **6a** + **6b** and **7a** + **7b**, based upon the position of methylation at N-1, N-2, O-4 or O-7. However, the methylation of 1-*H*-indazole-4,7-diones by diazomethane generally occurs at the basic nitrogen positions [6-8] (*i.e.*, mixtures **4** and **5** would be predicted products, rather than *O*-methyl ethers **6** and **7**).

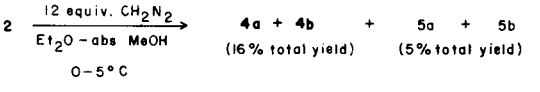
Treatment of cycloaddition mixture **2** in absolute methanol with 12 equivalents of 0.6 *M* ethereal diazomethane [9] at 0-5° provided a mixture of methylated products in 21

SCHEME I



percent total yield (Scheme II). Column chromatography of the reaction residue on silica gel separated two regioisomeric mixture **4** and **5**. Both mixtures appeared to contain

SCHEME II



a 75:25 ratio of regioisomers as evidenced by their proton nmr spectra. Since the starting material for the methylation reaction **2** was predominantly 6-methyl-1-*H*-indazole-4,7-dione (**2a**), the major constituents of mixtures **4** and **5** were suspected to be the 6-methyl regioisomers. In order to verify this assumption, mixture **4** was separated by preparative thick layer chromatography, providing the major regioisomer in pure form. An X-ray crystallographic analysis of the major constituent of **4** proved unequivocally that this compound is 1,6-dimethyl-1-*H*-indazole-4,7-dione (**4a**) (Figure 1) [10]. Additional details of the X-ray crystallographic study are included at the end of the Experimental of this paper.

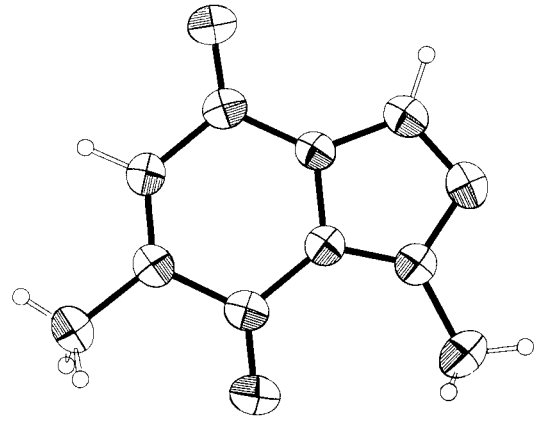
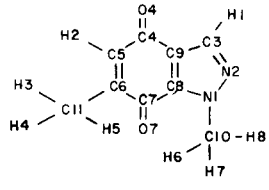


Figure 1. An ORTEP [10,11] Drawing of the Crystalline Structure of 1,6-Dimethyl-1-*H*-indazole-4,7-dione (**4a**).

Table I

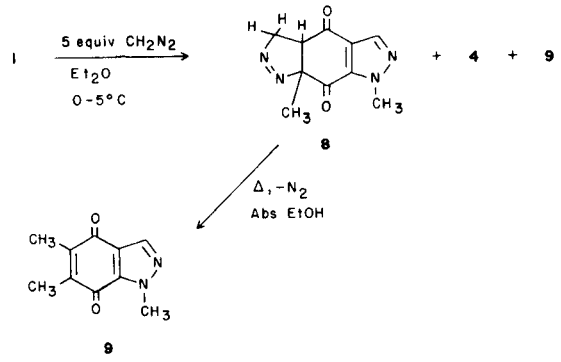
Intramolecular Distances (Å) in 1,6-Dimethyl-1-*H*-indazole-4,7-dione (**4a**)



Atoms	Distances (e.s.d.)	Atoms	Distances (e.s.d.)
O4-C4	1.225(1)	O7-C7	1.222(1)
N1-N2	1.353(1)	N1-C8	1.343(1)
N1-C10	1.459(1)	N2-C3	1.327(1)
C3-C9	1.399(1)	C4-C5	1.481(1)
C4-C9	1.456(1)	C5-C6	1.335(1)
C6-C7	1.494(1)	C6-C11	1.497(1)
C7-C8	1.470(1)	C8-C9	1.381(1)
C3-H1	0.94(1)	C5-H2	0.96(1)
C11-H3	1.07(1)	C11-H4	1.05(1)
C11-H5	0.90(1)	C10-H6	0.91(1)
C10-H7	0.88(2)	C10-H8	0.83(2)

The minor regioisomer contained an impurity after preparative thick layer chromatography which also appeared to be a methylated 1-*H*-indazole-4,7-dione. This impurity was isolated in pure form in the reaction of *p*-toluquinone (**1**) with 5 equivalents of diazomethane at 0-5° (Scheme III). Column chromatography of the reaction residue provided not only the expected mixture **4** but also a slower eluting yellow solid. This compound was immediately recrystallized from absolute ethanol converting it to a different yellow solid compound as evidenced by tlc. This recrystallized product, 1,5,6-trimethyl-1-*H*-indazole-4,7-dione (**9**), was the impurity which co-developed with the 1,5-dimethyl derivative **4b** in the preparative thick layer chromatograph. It is assumed that the cycloadduct **8** [12] had been isolated by column chromatography of the reaction residue (Scheme III), and that upon heating in a protic solvent, compound **8** lost nitrogen yielding the 1,5,6-trimethyl-1-*H*-indazole-4,7-dione (**9**). Similar reactions have been reported, such as the one involving the 1,3-dipolar cycloaddition of diazomethane to 2-methyl-1,4-naphthoquinone, followed by pyrolysis of the cycloadduct, to yield 2,3-dimethyl-1,4-naphthoquinone [13,14]. Evidently, small amounts of cycloadduct **8** decompose to the 1,5,6-trimethyl derivative **9** during either the reaction or the purification, causing contamination of the 1,5-dimethyl-1-*H*-indazole-4,7-dione (**4b**). Also, the addition of only two equivalents of 0.3 *M* ethereal diazomethane to toluquinone (**1**) provided the regioisomeric mixture **4** in one step (19% total yield); however, a small amount of the 1,5,6-trimethyl drivative **9** was still detected in the proton nmr spectrum

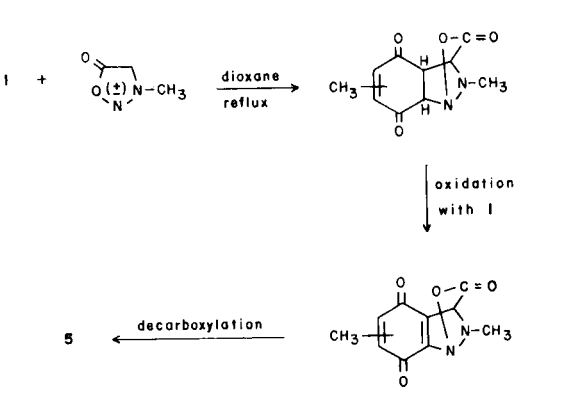
SCHEME III



of compound **4b** after chromatographic separation.

The presence of the 2-*N*-methyl ring structure in the regioisomeric mixture **5** (Scheme II) was verified by an independent synthesis of this mixture. This utilized the cycloaddition of 3-methylsydnone to toluquinone (Scheme IV).

SCHEME IV



The mesoionic 3-methylsydnone (**10**) [15] served as a 1,3-dipole in the cycloaddition with *p*-toluquinone (**1**) yielding the 2-*N*-methyl regioisomeric mixture **5** after *in situ* oxidation and decarboxylation [7,16]. No regioselectivity was observed in this cycloaddition since equimolar amounts of regioisomers were isolated. However, the proton nmr spectrum of this mixture is identical in chemical shifts to that of the regioisomeric mixture isolated in the reaction of the cycloaddition product **2** with diazomethane (Scheme II).

By the characterization of the major products in the reaction of diazomethane with *p*-toluquinone, the structures and properties of both 1,6-dimethyl-1-*H*-indazole-4,7-dione (**4a**) and 1,5-dimethyl-1-*H*-indazole-4,7-dione (**4b**) can be assigned unequivocally. This now clarifies confusion in the literature and allows the utilization of the easily obtainable mixture **4**, albeit in low yield, for synthetic purposes after separation.

Table II

Intramoleculalr Angles (°) in 1,6-Dimethyl-1-*H*-indazole-4,7-dione (**4a**)

Atoms	Angle	Atoms	Angle
N2-N1-C8	111.2(1)	N2-N1-C10	119.4(1)
C8-N1-C10	129.4(1)	N1-N2-C3	105.8(1)
N2-C3-C9	111.0(1)	O4-C4-C5	121.1(1)
O4-C4-C9	123.6(1)	C5-C4-C9	115.3(1)
C4-C5-C6	124.7(1)	C4-C5-H2	116.5(5)
C6-C5-H2	118.8(5)	C5-C6-C7	120.7(1)
C5-C6-C11	123.3(1)	C7-C6-C11	116.0(1)
O7-C7-C6	121.8(1)	O7-C7-C8	123.4(1)
C6-C7-C8	114.8(1)	N1-C8-C7	128.9(1)
N1-C8-C9	107.4(1)	C7-C8-C9	123.7(1)
C3-C9-C4	134.6(1)	C3-C9-C8	104.6(1)
C4-C9-C8	121.0(1)	N1-C10-H6	109.9(9)
N1-C10-H7	112.0(10)	N1-C10-H8	112.0(10)
C6-C11-H3	108.2(7)	C6-C11-H4	112.7(7)
C6-C11-H5	110.0(8)	N2-C3-H1	120.4(6)
C9-C3-H1	128.6(6)		

EXPERIMENTAL

Melting points were determined with a Thomas-Hoover capillary melting point apparatus and are uncorrected. Precoated tlc plates (5 × 10 cm) of silica gel 60 F-254 (layer thickness 0.25 mm) from E. M. Reagents were used for tlc analysis and spots were detected with a Mineralight (uv-shortwave). The preparative tlc plates used for separations were Analtech Uniplates precoated with silica gel GF (1000 microns thick). Column chromatography was accomplished using silica gel 60 (Mesh 70-230 ASTM) from E. M. Reagents. Elemental analyses were performed by Atlantic Microlab, Inc., Atlanta, Georgia, and were within ±0.4 percent of the theoretical values. Mass spectra were obtained from the Research Triangle Institute Mass Spectrometry Laboratory, Research Triangle Park, NC, using electron impact for ionization. X-ray crystallographic studies were performed by Hodgson and Eggleston of the UNC-CH Department of Chemistry, Chapel Hill, NC [10]. ORTEP drawings [11] were used to depict the molecular structures. Infrared spectra were obtained from a Perkin-Elmer Model 297 infrared spectrophotometer. The uv absorption spectra were determined with a Cary 15 spectrophotometer. Routine proton nuclear magnetic resonance (nmr) spectra were obtained on a JEOL JNM-FX60 spectrometer (59.75 MHz) unless otherwise indicated. A Bruker Wm-250 spectrospin spectrometer (250.137 MHz for proton nmr spectra and 62.89 MHz for C-13 nmr spectra) at the UNC-CH Department of Chemistry was utilized for better separation of Chemical shifts were indicated. In all nmr spectra tetramethylsilane was used as an internal reference for determining chemical shifts on the δ scale. Chemical shifts quoted in the case of multiplet are measured from the apporoximate center unless otherwise indicated, and the abbreviations used in the descriptions of the nmr spectra are as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet. All solvents used were reagent grade and all starting materials were used as obtained from the suppliers unless otherwise indicated.

6-Methyl-1-*H*-indazole-4,7-dione (**2a**) and 5-Methyl-1-*H*-indazole-4,7-dione (**2b**). (Cycloaddition Product **2**).

The procedure was adapted from the method of Awad *et al.* [5]. A solution of diazomethane (0.35 *M*) in ethyl ether [17] (210 ml, 0.075 mole diazomethane) was added dropwise to a cold stirred solution of methyl-*p*-benzoquinone (**1**) (8.3 g, 0.067 mole). A yellow precipitate formed upon addition of the diazomethane solution. The yellow precipitate was transformed into a purple solid in the brown reaction solution 30 minutes after the diazomethane solution had been completely added. The suspension was stirred for 2 hours at 0-5° then for 1 day at room temperature

Table III

Positional and Thermal Parameters and Their Estimated Standard Deviations
(1,6-Dimethyl-1-*H*-indazole-4,7-dione **4a**)

Atom	X	Y	Z	B(1,1)	B(2,2)	B(3,3)	B(1,2)	B(1,3)	B(2,3)
O4	0.2932(2)	0.65393(8)	0.6536(1)	0.0464(4)	0.00372(5)	0.0144(2)	-0.0010(3)	0.0188(4)	-0.0033(2)
O7	0.2369(2)	0.44155(8)	0.1126(1)	0.0462(4)	0.00450(6)	0.0129(2)	-0.0027(3)	0.0181(4)	-0.0031(2)
N1	0.2129(2)	0.37501(8)	0.4549(2)	0.0266(4)	0.00318(6)	0.0132(2)	-0.0009(2)	0.0126(4)	-0.0003(2)
N2	0.2061(2)	0.37221(9)	0.6210(2)	0.0291(4)	0.00383(6)	0.0141(2)	-0.0005(3)	0.0148(5)	0.0021(2)
C3	0.2292(3)	0.4539(1)	0.6761(2)	0.0245(4)	0.00400(8)	0.0121(2)	0.0006(3)	0.0124(5)	0.0004(2)
C4	0.2799(3)	0.6037(1)	0.5334(2)	0.0226(4)	0.00329(7)	0.0134(3)	0.0009(3)	0.0103(5)	-0.0012(2)
C5	0.2925(3)	0.6355(1)	0.3631(2)	0.0273(4)	0.00286(7)	0.0138(3)	0.0004(3)	0.0130(5)	0.0008(2)
C6	0.2805(3)	0.5849(1)	0.2265(2)	0.0241(4)	0.00357(7)	0.0119(3)	0.0005(3)	0.0099(5)	0.0013(2)
C7	0.2517(3)	0.4888(1)	0.2368(2)	0.0216(4)	0.00365(7)	0.0117(2)	0.002(3)	0.0100(5)	-0.0006(2)
C8	0.2396(2)	0.4568(1)	0.4058(2)	0.0199(4)	0.00294(6)	0.0123(2)	0.0003(3)	0.0096(5)	0.0001(2)
C9	0.2513(2)	0.5102(1)	0.5456(2)	0.0194(4)	0.00328(7)	0.0104(2)	0.0007(3)	0.0092(4)	0.0003(2)
C10	0.1942(3)	0.2943(1)	0.3569(2)	0.0414(6)	0.00306(8)	0.0211(4)	-0.0021(4)	0.0195(7)	-0.0028(3)
C11	0.2942(4)	0.6194(1)	0.0561(2)	0.0452(6)	0.00418(9)	0.0133(3)	-0.0019(4)	0.0174(7)	0.0021(3)
H1	0.231(2)	0.467(1)	0.790(2)	4.5(4)					
H2	0.307(2)	0.697(1)	0.351(2)	3.4(3)					
H3	0.156(3)	0.607(1)	-0.033(3)	8.3(6)					
H4	0.407(3)	0.589(1)	0.010(2)	7.5(6)					
H5	0.319(3)	0.677(1)	0.063(2)	6.9(5)					
H6	0.213(3)	0.248(1)	0.428(3)	7.7(6)					
H7	0.291(3)	0.288(1)	0.305(3)	8.0(6)					
H8	0.084(3)	0.289(1)	0.291(3)	11.1(7)					

The Form of the Anisotropic Thermal Parmater is: EXP[-(B(1,1)*H*H + B(2,2)*K*K + B(3,3)*L*L + B(1,2)*H*K + B(1,3)*H*L + B(2,3)*K*L)].

and filtered. The solid was washed with ethyl ether and air dried. Recrystallization of the purple compound from absolute methanol yielded the desired yellow product (3.3 g, 30% total yield), mp with slow decomposition from 205° to >285°; mp in an evacuated sealed capillary tube 215° dec (lit [5] mp 205°); tlc R_f = 0.38 (chloroform:methanol/10:1); uv (absolute methanol): λ max = 217, 252, 297 nm; ir (potassium bromide): 3250 medium (N-H), 1660 broad, strong (conj C=O), 1600 cm^{-1}, medium (conj C=C); ^{1}H-nmr (250.137 MHz, perdeuteriomethanol): δ 2.12 (d, side peak, 5-CH_3 of compound **2b**, 2.13 (d, 3, J = 1.7 Hz, 6-CH_3 of compound **2a**), 6.66 (q, 1, J = 1.7 Hz, 5-H of compound **2a**), 6.69 (q, side peak, 6-H of compound **2b**), 8.15 (s, 1, 3-H of compound **2a**), 8.19 ppm (s, side peak, 3-H of compound **2b**).

Anal. Calcd. for $C_8H_6N_2O_2$: C, 59.26; H, 3.73; N, 17.28. Found: C, 59.17; H, 3.75; N, 17.28.

1,6-Dimethyl-1-*H*-indazole-4,7-dione (**4a**), 1,5-Dimethyl-1-*H*-indazole-4,7-dione (**4b**), the 2,5-Dimethyl-2-*H*-indazole-4,7-dione and 2,6-Dimethyl-2-*H*-indazole-4,7-dione Mixture (**5**) and 1,5,6-Trimethyl-1-*H*-indazole-4,7-dione (**9**) as an Impurity (Diazomethane Methylated Derivatives of the Cycloaddition Products **2a** and **2b**).

A stirred suspension of the cycloaddition product **2** (compounds **2a** and **2b**/5.5:1, respectively, 0.35 g, 2.0 mmoles) in absolute methanol (125 ml) was cooled to 10° and a solution of 0.6 *M* cold ethereal diazomethane [20] (40 ml, 24 mmoles) was added dropwise. Nitrogen gas was liberated during addition of th diazomethane solution. The brown reaction solution was stirred overnight at room temperature, then allowed to evaporate slowly in the hood to a brown solid. The solid was boiled in chloroform, and the solution was filtered hot to remove insoluble starting material. The filtrate was evaporated *in vacuo*, leaving a brown residue. This residue was chromatographed on a silica gel column (18 g of silica gel, chloroform as the eluent). The first band eluted was a yellow solid (0.12 g, 31% total yield of regioisomers **4a** and **4b**/3:1, respectively). After two recrystallizations from absolute methanol, a crop from the second recrystallization filtrate yielded a yellow soid (13 mg), mp 125-129.5°, which was a single isomer (1,6-dimethyl-1-*H*-indazole-4,7-dione **4a**); tlc: R_f = 0.50 (benzene:ethyl acetate/20:1, developed 7 times); uv (absolute methanol): λ max = 257, 262 (shoulder), 303 nm; ir (potassium bromide): 1685 (shoulder), 1665-1650 broad, strong (conj C=O), 1608 cm^{-1}, medium (conj C=C); ^{1}H-nmr (250.137 MHz, deuteriochloroform): δ 2.14 (d, 3, J = 1.7 Hz, 6-CH_3), 4.24 (s, 3, CH_3-N), 6.57 (q, 1, J = 1.7 Hz, 5-H), 7.86 ppm (s, 1, 3-H); ms: m/e 176.

The first recrystallization filtrate (60 mg) of the yellow solid was chromatographed on a preparative tlc plate (benzene:ethyl acetate/20:1, developed 7 times). Two bands separated with ΔR_f = 0.1 (R_f = 0.6 and R_f = 0.7). The top ptlc band (R_f = 0.7) was removed from the plate, washed with acetone, and filtered. Rotary evaporation of the filtrate yielded a yellow solid (12 mg of **1**, 5-dimethyl-1-*H*-indazole-4,7-dione (**4b**) containing a small amount of impurity **9**, tlc R_f = 0.58 (benzene:ethyl acetate/20:1, developed 7 times); uv (absolute methanol): λ max = 217, 256, 262 (shoulder), 303 nm; ir (potassium bromide): 1665-1650 broad, strong (conj C=O), 1605 cm^{-1}, medium (conj C=C); ^{1}H-nmr (250.137 MHz, deuteriochloroform): δ 2.11 (3, 5-CH_3 and 6-CH_3 of the impurity, 1,5,6-trimethyl-1-*H*-indazole-4,7-dione (**9**), 2.15 (d, 3, J = 1.5 Hz, 5-CH_3), 4.22 (s, 3, CH_3-N), 6.56 (q, 1, J = 1.5 Hz, 6-H), 7.86 (s, 3-H of the impurity, compound **9**), 7.88 ppm (s, 1, 3-H); ^{13}C-nmr (62.89 MHz, decoupled, deuteriochloroform): δ 16.8 (5-CH_3), 39.6 (CH_3-N), 134.4 (3-C), 137.1, 137.5 (3a, 5 and 6 quinone ring carbons), 149.8 (7a-C), 178.8, 182.4 ppm (4-C=O and 7-C=O); ms: m/e 176.

The second ptlc band (R_f = 0.6) was removed from the plate, washed with acetone, filtered and the filtrate was rotary evaporated to a yellow solid (10 mg), mp 126-129°. The ^{1}H-nmr spectrum indicated it was 1,6-dimethyl-1-*H*-indazole-4,7-dione (**4a**). An X-ray crystallographic analysis [10] of this yellow solid (compound **4a**) proved its structure unequivocally.

Continued elution of the chromatographic column (of the orginal reaction mixture) afforded another light yellow solid (20 mg, 5% yield). Recrystallization from absolute ethanol yielded 10 mg of solid, mp 218-230°. This solid is a regioisomeric mixture of 2,6-dimethyl-2-*H*-indazole-4,7-dione **5a** and 2,5-dimethyl-2-*H*-indazole-4,7-dione (**5b**) (ratio of 3 to 1, respectively); tlc R_f = 0.20 (chloroform:ethyl acetate/85:15); uv (absolute methanol): λ max = 223, 253, 305 nm; ir (potassium bromide): 1685-1645 broad, strong (conj C=O, 1602 cm^{-1}, medium (conj C=C); ^{1}H-nmr (59.75 MHz, deuteriochloroform): δ 2.12 (s, side peak, part of doublet from the 5-CH_3 of the 2,5-dimethyl isomer **5b**), 2.16 (d, 3, J = 1.5 Hz, 6-CH_3 of the 2,6-dimethyl isomer **5a**), 4.07 (s, 3, CH_3N), 6.63 (q, 1, J = 1.5 Hz, 5-H and 6-H of the 2,6-dimethyl and 2,5-dimethyl isomer, respectively), 7.85 (s, 1, 3-H of the 2,6-dimethyl isomer), 7.89 ppm (s, side peak, 3-H of the 2,5-dimethyl isomer; ms: m/e 176.

2,6-Dimethyl-2-*H*-indazole-4,7-dione (**5a**) and 2,5-Dimethyl-2-*H*-indazole-4,7-dione (**5b**) Regioisomeric Mixture (**5**) *via*3-Methylsydnone Cycloaddition.

A modification of the method of Brockman and Reschke [7] was used in this procedure. A solution of methyl *p*-benzoquinone (4.6 g, 0.04 mole) and 3-methylsydnone [20,21] (4.0 g, 0.04 mole) in dioxane [23] (70 ml) was refluxed for 3 days. Evaporation of solvent and column chromatography (220 g of silica gel, chloroform eluent) eluted the starting material first, followed by a yellow solid (1:1 mixture of the 2,5-dimethyl and 2,6-dimethyl isomers). Recrystallization from absolute ethanol afforded 1.39 g (20% total yield), mp 205-208°; tlc R_f = 0.21 (chloroform:ethyl acetate/85/15); ir (potassium bromide): 1680-1646 broad, strong (conj C=O), 1603 cm^{-1}, medium (conj C=C); ^{1}H-nmr (59.75 MHz deuteriochloroform): δ 2.15 (t, 3, J = 1.5 Hz, 5-CH_3 and 6-CH_3 of isomeric mixture **5**, 4.08 (s, 3, CH_3N), 6.64 (sextet, 1, J = 1.5 Hz, 5-H and 6-H of isomeric mixture **5**, 7.87, 7.90 (two singlets, 1, 3-H of the 2,6-dimethyl isomer and the 2,5-dimethyl isomer, respectively.

Anal. Calcd. for $C_9H_8N_2O_2$: C, 61.35; H, 4.58; N, 15.90. Found: C, 61.31; H, 4.61; N, 15.86.

1,6-Dimethyl-1-*H*-indazole-4,7-dione (**4a**), 1,5-Dimethyl-1-*H*-indazole-4,7-dione (**4b**). (Diazomethane-Methylated Derivatives of the Cycloaddition Product (**2**) Formed *in Situ*).

A solution of 0.38 *M* ethereal diazomethane [17] (210 ml, 0.08 mole) was added slowly in a continuous stream to a cold (0°) stirred solution of methyl-*p*-benzoquinone (**1**) (3.6 g, 0.03 mole) in anhydrous ethyl ether (60 ml). As the diazomethane solution was added, the reaction solution darkened and the temperature increased to 10°. The brown solution was stirred for 3 hours at 5° and then at room temperature overnight. Slow evaporation of the solvent yielded a black tar which was chromatographed on a 150 g silica gel column eluted with chloroform. The first band eluted was a yellow solid (1.0 g, 19% yiled), mp 71-78°. Recrystallization (absolute ethanol) gave a mp of 78-92° and C, H and N analyses were obtained for this isomeric mixture of 1,6-dimethyl-1-*H*-indazole-4,7-dione (**4a**) and 1,5-dimethyl-1-*H*-indazole-4,7-dione (**4b**).

Anal. Calcd. for $C_9H_8N_2O_2$: C, 61.35; H, 4.58; N, 15.90. Found: C, 61.25; H, 4.60; N, 15.85.

A small amount of pink solid eluted from the chromatographic column after the yellow mixture and a complex mixture of compounds. This pink solid (0.1 g) was methyl-1,4-hydroquinone (**3**), mp 123-124° (lit [16] mp 126-127°); ^{1}H-nmr (d_6-acetone): δ 2.13 (s, 3, CH_3), 6.60 (m, 3, aromatic-H), 7.55 ppm (s, 2, OH, disappears upon deuterium oxide addition).

1,5,6-Trimethyl-1-*H*-indazole-4,7-dione (**9**).

A solution of 0.5 *m* ethereal diazomethane [19] was added dropwise to a solution of methyl-*p*-benzoquinone (**1**) (0.5 g, 4.0 mmoles) in a 35 ml mixture of ethyl ether:absolute methanol/6:1 at 0° until all of the intermediate 6-methyl-1-*H*-indazole-4,7-dione (**2a**) and 5-methyl-1-*H*-indazole-4,7-dione (**2b**) was methylated (as judged by tlc). This required 40 ml of 0.5 *M* ethereal diazomethane (20 mmole). The solvent was allowed to evaporate in the hood, yielding a brown tar which was chromatographed on a silica gel column (30 g of silica gel, chloroform eluent). The first yellow band eluted was a mixture of 1, 6-dimethyl-1-*H*-indazole-4,7-dione (**4a**), 1,5-dimethyl-1-*H*-indazole-4,7-dione (**4b**), and 1,5,6-trimethyl-1-*H*-indazole-4,7-dione (**9**), as previously described. The second yellow band eluted from the column was evaporated to a yellow solid (R_f = 0.24, chloroform:ethyl acetate/85:15). Recrystallization (absolute ethanol) yielded a yellow crystalline solid upon standing several months. This solid was 1,5,6-trimethyl-1-*H*-indazole-4,7-dione (**9**) (17 mg, 2% yield), mp 137-139°; tlc R_f = 0.53 (chloroform:ethyl acetate/85:15); uv (absolute methanol): λ max = 217, 263 (shoulder), 269, 305 nm; ir (potassium bromide): 1655 broad, strong (conj C=O), 1600 cm^{-1}, medium (conj C=C); ^{1}H-nmr (59.75 MHz, deuteriochloroform): δ 2.09 (s, 6, 5-CH_3 and 6-CH_3), 4.21 (s, 3, CH_3-N), 7.85 ppm (s, 1, 3-H); ms: m/e 190.

Analyses

Cycloaddition Product (**2**)		C	H	N
Calcd.	for $C_9H_6N_2O_2$:	59.26	3.73	17.28
Found:		59.17	3.75	17.28
1-*N*-Methyl Regioisomeric Mixture (**4**)				
Calcd.	for $C_9H_8N_2O_2$:	61.35	4.58	15.90
Found:		61.25	4.60	15.85
2-*N*-Methyl Regioisomeric Mixture (**5**)				
Calcd.	for $C_9H_8N_2O_2$:	61.35	4.58	15.90
Found:		61.31	4.61	15.86

X-Ray Crystallographic Studies — Eggleston and Hodgson [10].

A yellow crystal of 1,6-dimethyl-1-*H*-indazole-4,7-dione (**4a**), submitted as sample 5-67F, was found to be monoclinic, space group $P2_1/c$ (*vide infra*), a = 6.9751(27), b = 15.3412(32), c = 8.0603(27) Å, ° = 103.64(3)°, Volume = 838.17 Å, Z = 4, Dc = 1.39, Dm = 1.38 Mgm^{-3} (flotation in ethylene glycol/aqueous potassium iodide solution). A fragment of approximate dimensions 0.60 × 0.60 × 1.0 mm was cleaved from a larger crystal and used in the analysis. Peliminary cell constants were obtained on the Enraf Nonius CAD4 diffractomer using MoKα radiation and a graphite monochromator. Final cell constants were determined after careful centering of 25 reflections with 35° ≥ 2θ ≥ 30°. Intensity data were collected in a θ-ω scan mode out to 2θ(Mo) = 55°. Intensity standards, monitored at regular intervals, showed no sign of crystal deterioration. The data were corrected for Lorentz-polarization effects, but not for absorption (μ = 1.095 cm^{-1} for these atoms). Excluding 465 "unobserved" data, 1399 unique reflections with I ≥ 3σ (I) were measured and used in the subsequent analysis.

Solution and Refinement.

The data were inverted to E-values and the structure was discovered by MULTAN using 110 reflections for which E ≥ 1.90. An E map calculated from that set of phases having the highest combined figure of merit provided positions for all 13 non-hydrogen atoms. Isotropic least-squares refinement of these positions led to values of the agreement factors $R_1 = \Sigma||Fo| - |Fc||/\Sigma|Fo|$ and $R_2 = [\Sigma w(|Fo| - |Fc|)^2/\Sigma w|Fo|^2]^{1/2}$ of 0.239 and 0.217, respectively. Initially, the weights w were assigned as unity, but in the final stages of refinement a weighting scheme of the type $w = 4Fo^2/\sigma^2(Fo^2)$ was used, where $\sigma(Fo^2)$ is given by the expression $\sigma(Fo^2) = [\sigma^2(I) + (0.01)^2I^2]^{1/2}$. Following the inclusion of anisotropic libration parameters for the nonhydrogen atoms and three cycles of least-squares refinement R_1 = 0.08, R_2 = 0.11 and a difference Fourier map revealed positions for all eight hydrogen atoms. In all subsequent least-squares calculations the hydrogen atoms positions were refined isotropically while refinement of the non-hydrogen atom positions included anisotropic librational parameters. A corection for secondary extinction was in-

cluded and least squares refinement converged to values of 0.043 and 0.047 for R_1 and R_2, respectively. The value of the extinction coefficent was $4.29(2) \times 10^{-6}$. A final difference Fourier map showed a peak of hieght 0.114 $e\text{Å}^{-3}$ in the center of the six membered ring but was otherwise featureless.

Description of the Structure.

A view of the structure is given in Figure 1. Tables of bond lengths (Table I) and angles (Table II) as well as atomic positions and thermal parameters (Table III) are provided.

The methyl groups are bound to N1 and C6 of the indazole ring. All bond lengths and angles are within the range expected for the indazole structure. A least squares plane calculated for all atoms in the indazole ring (including O4 and O7) shows the ring to be virtually planar with the largest deviation 0.015(2)Å at C8. The methyl carbon atom C11 is coplanar with the ring while the methyl carbon atom C10 sits below the least-squares plane by 0.037(2)Å.

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