

CHEMISTRY OF PHOSPHORUS YLIDES 20¹
NOVEL SYNTHESIS OF PHOSPHORANYLIDENE-CYCLOBUTYLIDENE
DERIVATIVES FROM THE REACTION OF N-PHENYLIMINOVINYLLIDENE -,
2-OXOVINYLLIDENE- AND 2-THIOXOVINYLLIDENE-
TRIPHENYLPHOSPHORANE WITH α -DIKETONES.

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ABSTRACT

Naphtho [2,1-b] furan -1,2-dione(1), isatin (8a), N-methylisatin (8b) and/or N-acetyl isatin (8c) can be converted by reaction with N-phenyliminovinylidene-(2a), 2-oxovinylidene-(2b) and/or 2-thioxovinylidene-triphenylphosphorane (2c) into the corresponding phosphoranylidenecyclobutylidene derivatives (5a-c) and (9a-i) respectively. The structure of the new cyclobutylidenes was confirmed on the bases of elemental analysis and spectral studies.

Key words : Phosphacumulenes, α -diketones, cyclobutylidenes

INTRODUCTION:

In the scope of enhanced reactivity and versatility of their nucleophilic reactions, phosphacumulenes (2a-c), are the most important phosphorus compounds were used recently, for the synthesis of heterocycles^{1,2}. Therefore, it was of interest to study the reaction of the active phosphacumulene ylides, namely, (N-phenyliminovinylidene)- 2a, (2-oxovinylidene)- 2b and/or (2-thioxovinylidene)-triphenylphosphorane (2c) with some α -diketones, such as, naphtho[2,1-b]furan-1,2-dione (1) and isatins (8a-c) and compare the reactivity of these active phosphacumulene ylides (2a-c) with the reactivity of the stabilized phosphonium ylides (6a,b), towards the above mentioned α -diketones.

RESULTS AND DISCUSSION:

When naphtho[2,1-b]furan-1,2-dione (1) was treated with two mole equivalents of active phosphacumulene ylides, namely, (N-phenyliminovinylidene)-2a, (2-oxovinylidene)-2b and/or (2-thioxovinylidene)-triphenylphosphorane (2c) in tetrahydrofuran at room temperature for six hrs in case of 2a, nine hrs with 2b and/ or twelve hrs with 2c, triphenylphosphine oxide together with the corresponding phosphoranylidenecyclobutylidene derivatives (5a-c), were obtained respectively. Structural support for 1-[2,4-bis(phenylimino)-3-(triphenylphosphoranylidenecyclobutylidene)naphtho[2,1-b]furan-2(1H)-one (5a) was based upon correct elemental analysis and spectroscopic data. The IR spectrum of 5a (in KBr, cm⁻¹) showed strong absorption bands at 1735 (C=O), 1640 (C=N), 1610 (C=P)³ and 1440 (P-phenyl)⁴. In the ¹³C-NMR spectrum of 5a, a signal was observed at δ 192.89 which is attributed to the carbonyl-lactone and there is no absorption band for the ketocarbonyl-function, which appeared in the starting material at δ 190.16⁵. A signal at δ 12.23 was observed in the ³¹P-NMR of 5a which fits with phosphorane in a four-membered ring.⁶

2-(2-Oxonaphtho[2,1-b]furan-1(2H)-ylidene)-4-(triphenylphosphoranylidenecyclobutylidene)-1,3-cyclobutanedione (5b) revealed the presence of strong absorption bands at 1720 (C=O, lactone), 1660 (C=O, cyclobutanedione),⁷ 1620 (C=P) and 1440 (P-phenyl), in its IR spectrum. In the ¹³C-NMR spectrum, it showed signals at δ 194.00 (C=O, cyclobutanedione). and 160.00 (C=O, lactone). Moreover, a signal at δ 8.13 was observed in its ³¹P-NMR.

In case of 1-[2,4-dithio-3-(triphenylphosphoranylidenecyclobutylidene)naphtho[2,1-b]furan-2(1H)-one (5c)

strong absorption bands at 1740 (C=O), 1660 (C=P), 1440 (P-phenyl) and 1200 (C=S)⁴ was found in its IR spectrum. The distinguishing features of ¹³C-NMR spectrum of **5c** were presence of signals at δ 197.02 (C=S) and 193.77 (C=O) and the ³¹P-NMR, shift was recorded at δ 10.01.

The reaction of active phosphacumulene ylides was studied with the bifunctional isatin **8a**, too. When two mole equivalents of (N-phenyliminovinylidene)triphenylphosphorane (**2a**) was allowed to react with one mole of isatin **8a** in tetrahydrofuran at ambient temperature for three hrs, the corresponding 1-hydro-3-[2,4-bis-(phenylimino)-3-(triphenylphosphoranylidene)cyclobutylidene]-2-indolinone (**9a**) and triphenylphosphine oxide were isolated. Carrying out the reaction using four moles of the phosphorane **2a** instead of two, led to the formation of the same phosphoranylidene-cyclobutylidene **9a**, together with triphenylphosphine oxide. The structure of compound **9a** was verified through elemental analysis and spectroscopic results. The IR spectrum showed bands at 3421 (NH), 1716 (C=O, lactam), 1620 (C=P) and 1440 (P-phenyl) cm⁻¹. The ¹H-NMR of **9a** showed signals at δ 4.4 (H, NH, s) exchangeable with D₂O and 7.7-7.5 (29H, aromatics, m). Its ³¹P-NMR shift recorded at δ 15.45.

When isatin **8a** was treated with (2-oxovinylidene)-**2b** or (2-thioxovinylidene)-triphenylphosphorane (**2c**), in dry boiling tetrahydrofuran for six hrs in case of **2b** and/or ten hrs with **2c**, orange and brown crystals of **9b** and **9c** were obtained respectively. The IR spectrum of 1-hydro-3-[2,4-dioxo-3-(triphenylphosphoranylidene)cyclobutylidene]-2-indolinone (**9b**) revealed the presence of strong absorption bands at 3400 (NH) 1720 (C=O, lactam), 1640 (C=O, cyclobutanedione),⁷ 1620 (C=P) and 1440 (P-phenyl). Presence of carbonyl groups in **9b** was also attested by signals at δ 198.5 (C=O, cyclobutanedione) and 179.4 (C=O, lactam), in its ¹³C-NMR spectrum. Moreover, ¹H-NMR showed signal at δ 4.25 (H, NH, s) exchangeable with D₂O and 7.7-7.4 (19H, aromatics, m). The ³¹P-NMR shift recorded for compound **9b** was δ 11.50. On the other hand, absorption bands were shown by the IR spectrum of 1-hydro-3-[2,4-dithioxo-3-(triphenylphosphoranylidene)-cyclobutylidene]-2-indolinone (**9c**) at 4321, 1718, 1440 and 1184 which were attributed to the N-H, C=O, P-phenyl and C=S groups respectively. The ¹H-NMR spectrum of **9c** disclosed the presence of signal at δ 4.8 (H, NH, s) exchangeable with D₂O.

The reaction of *N*-methyl isatin and *N*-acetyl isatin (**8b,c**) was also performed with the active ylides (**2a-c**). The reaction was stirred in THF at room temperature for three hrs in case of **2a**, six hr with **2b** and/or ten hr with **2c**. The phosphoranylidene-cyclobutylidene derivatives (**9d-i**) were isolated together with triphenylphosphine oxide. Analytical and spectroscopic data for these compounds are recorded in Tables (I) and (II).

CONCLUSION

It could be concluded that the reaction of active phosphacumulene ylides (**2a-c**), with α -diketones **1** and **8a-c** occurs by [2+2]-cycloaddition of the reactive carbonyl group, rather than the lactone^{5,8} in naphtho[2,1-b]furan-1,2-dione (**1**) or lactam⁹ in isatins **8a-c**. Initial nucleophilic attack by the carbanion centre in the active phosphacumulene ylides (**2a-c**) furnishes the oxaphosphetane **3**, as an intermediate.¹⁰ Expulsion of triphenylphosphine oxide from **3** affording the unstable ketene **4**,¹¹ which is followed immediately by [2+2]-cycloaddition to a second molecule of the active phosphacumulenes **2**, giving the four-membered ring phosphoranylidene-cyclobutylidenes **5a-c** and **9a-i** (scheme 1). Besides, the difference in the nucleophilic character of (N-phenyliminovinylidene)-**2a**, (2-oxovinylidene)-**2b** and/or (2-thioxovinylidene) triphenylphosphorane (**2c**) can be noticed, too (**2a**>**2b**>**2c**).¹² While (N-phenyliminovinylidene)triphenylphosphorane **2a** reacts smoothly with **1** and **8a-c**, the oxo- and thioxo-analogue react less rapidly, respectively. On the other hand, we have

previously reported¹³ that the reaction of the stabilized phosphonium ylides, namely, methoxy-6a and/or ethoxycarbonylmethylenetriphenylphosphorane (6b) with naphtho[2,1-b]furan-1,2-dione (1), afforded the α,β -unsaturated compounds 7a,b. Therefore, it could be concluded that the active and stabilized phosphonium ylides behave differently towards α -diketones. These reactions represents a convenient method for the preparation of the cyclobutylidene derivatives 5a-c, 9a-i, by one step process, and can be considered as a new trend supplements to the wide utilization of active phosphacumulenes in preparative work.¹³

EXPERIMENTAL

All melting points are uncorrected. The solvents were dried and distilled by usual techniques. Reactions were carried out under nitrogen atmosphere. Elemental analyses were carried out at the "Microanalysis Department", National Research Center. The IR spectra were measured in KBr, on a Perkin-Elmer infracord Spectrometer Model 157 (Crating). The ¹H- and ¹³C-NMR spectra were recorded on a Varian Spectrometer at 90 MHz, using TMS as an internal reference. ³¹P-NMR spectra were run, relative to external H₃PO₄ (85%), with a Varian FT-80 Spectrometer, Mass Spectra were obtained on a Varian MATCH-4B instrument.

The reaction of naphtho[2,1-b]furan-1,2-dione(1) with (N-phenyliminovinylidene)-2a, (2-oxovinylidene)-2b, and/or (2-thioxovinylidene)-triphenylphosphorane(2c). Preparation of the new phosphoranylidene-cyclobutylidene derivatives (5a-c).

To a solution of naphtho[2,1-b]furan-1,2-dione (1)¹⁴ (0.01 mol) in 20 ml of tetrahydrofuran was added dropwise, with stirring at room temperature, a solution of (N-phenyliminovinylidene)- 2a,¹⁵ (2-oxovinylidene)- 2b¹⁶ and/or (2-thioxovinylidene)-triphenylphosphorane (2c)¹⁶ (0.02 mol) in 30 ml THF. The reaction mixture was left for six hrs in case of 2a, nine hrs with 2b and/or twelve hrs with 2c, during which the colour was changed from orange to brown. After THF has been distilled off under reduced pressure, the residue that left behind was dissolved in 20 ml of chloroform followed by addition of 20 ml of n-hexane, and the new solution was left overnight in the refrigerator. The precipitate that formed was filtered off and crystallized from the appropriate solvent to give phosphoranylidene-cyclobutylidene derivatives (5a-c). The chloroform/n-hexane filtrate was chromatographed on alumina, affording triphenylphosphine oxide, m.p. and mixed m.p. 151°C¹⁷. Yields, analytical and physical data are shown in Table (I) and (II)

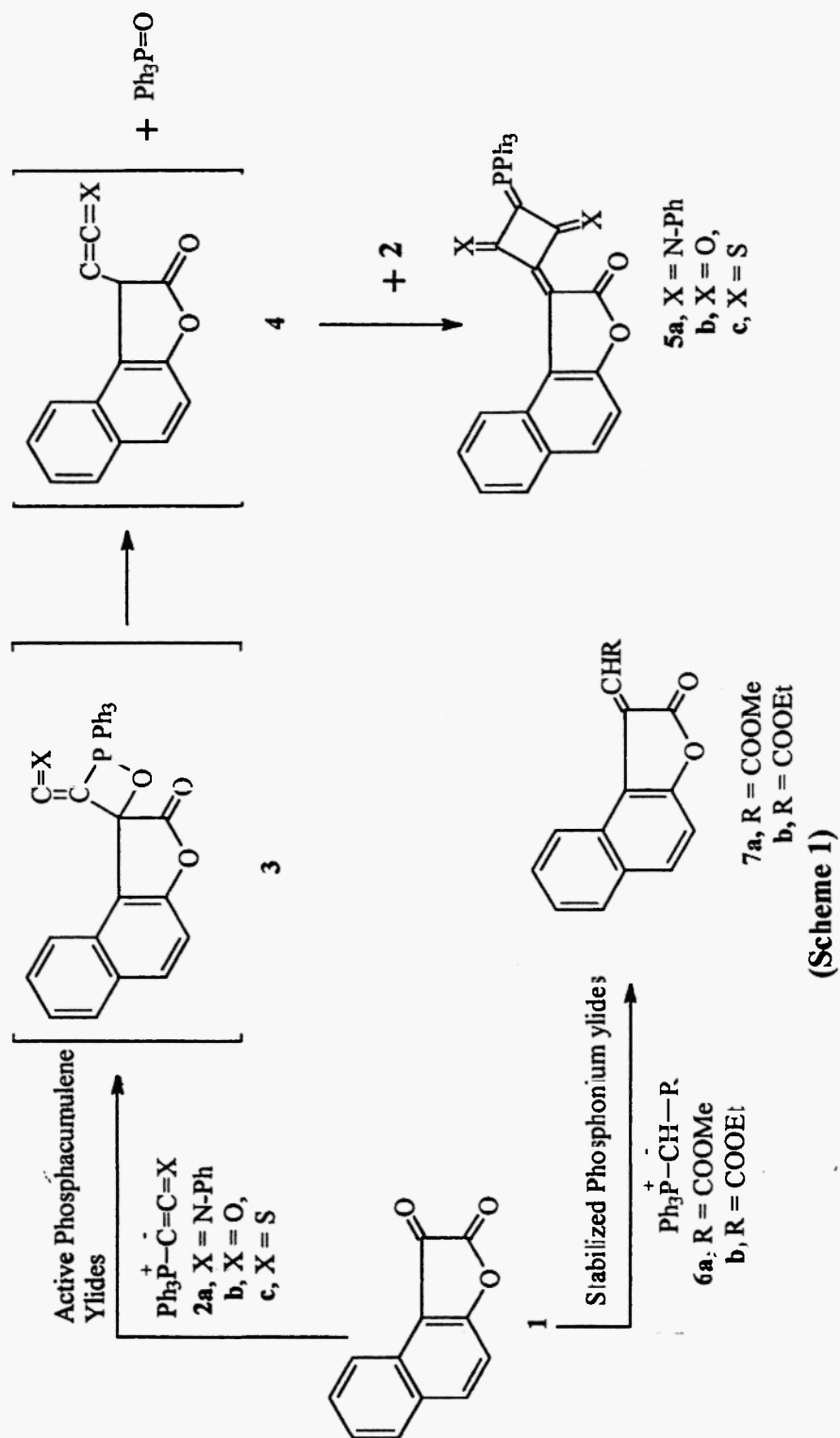
The reaction of isatin (8a) with (N-phenyliminovinylidene)-triphenylphosphorane (2a). Synthesis of 1-hydro-

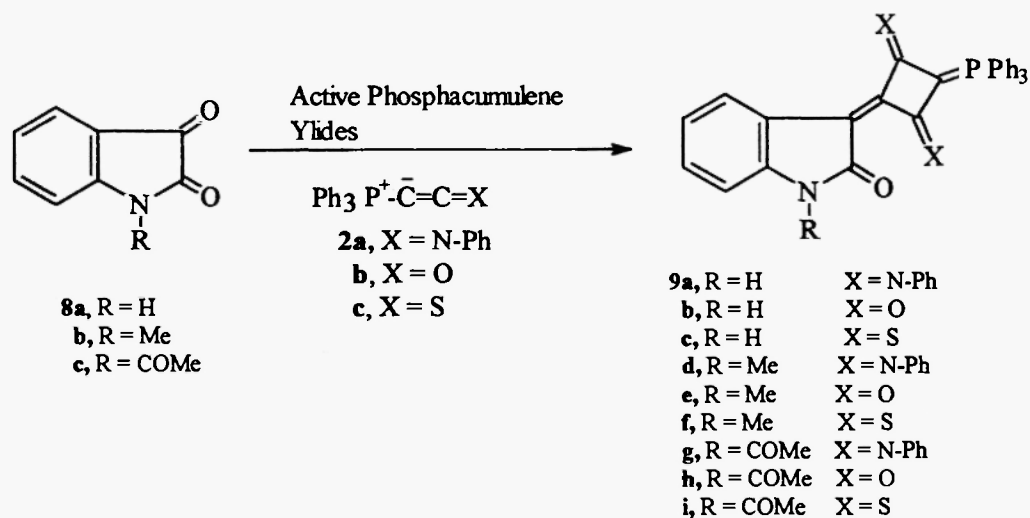
3-[2,4-bis-(phenylimino)-3-triphenylphosphoranylidene]cyclobutylidene]-2-indolinone (9a)

To a solution of isatin (8a) (0.01 mol) in 20 ml THF, was added dropwise at room temperature, a solution of (N-phenyl-iminovinylidene)triphenylphosphorane (2a) (0.02 mol) in 20 ml THF. The reaction mixture was stirred for three hrs, during which the colour changed from orange to brown. After the solvent was distilled off, The residue that left behind, was crystallized from benzene to give the phosphoranylidene-cyclobutylidene (9a). When the reaction was performed using one mole of the isatin (8a) and four moles of the phosphorane (2a). The same phosphoranylidene-cyclobutylidene 9a, together with triphenylphosphine oxide were obtained. Yields, analytical and physical data of compound (9a-i) are shown in Table (I) and (II).

Table (I) : Physical and Analytical data for Phosphoranylidene Cyclobutanediones (5a-c) and (9a-i)

No	Mol.wt	m.p°		Yield%	crystallization	Analyses Calc / Found				
		C				C	H	N	P	S
5a	674			80%		81.89	4.59	4.15	4.59	-
	C ₄₆ H ₃₁ N ₂ O ₂ P	194		Ethanol		81.75	4.62	4.05	4.62	-
5b	524			70%		77.86	4.00	-	5.91	-
	C ₃₄ H ₂₁ O ₄ P	160		Ethanol		77.75	4.13	-	5.80	-
5c	556			65%		73.38	3.77	-	5.57	11.51
	C ₃₄ H ₂₁ O ₂ PS ₂	232		Ethanol		73.53	3.80	-	5.62	11.70
9a	623			75%		80.89	4.82	6.74	4.98	-
	C ₄₂ H ₃₀ N ₃ OP	300		Ethanol		80.75	4.53	6.84	4.95	-
9b	473			80%		76.10	4.23	2.96	6.55	-
	C ₃₀ H ₂₀ NO ₃ P	190		chloroform/ Pet.ether		76.32	4.12	2.75	6.46	-
9c	505			75%		71.29	3.96	2.77	6.14	12.67
	C ₃₀ H ₂₀ NOPS ₂	175		Ethyl acetate/ Pet.ether		70.15	3.76	2.56	6.02	12.58
9d	637			72%		81.00	5.01	6.59	4.86	-
	C ₄₃ H ₃₂ N ₃ OP	210		chloroform/ Pet.ether		80.52	5.25	6.65	4.65	-
9e	487			75%		76.38	4.51	2.87	6.36	-
	C ₃₁ H ₂₂ NO ₃ P	145		chloroform/ Pet.ether		76.23	4.50	2.66	6.25	-
9f	519			80%		71.67	4.23	2.69	5.97	12.33
	C ₃₁ H ₂₂ NOPS ₂	190		Ethyl acetate /n-hexane		71.58	4.43	2.57	5.85	12.22
9g	665			75%		79.39	4.81	6.31	4.66	-
	C ₄₄ H ₃₂ N ₃ O ₂ P	190		Benzene/ Pet.ether		79.26	4.70	6.20	4.54	-
9h	515			79%		74.56	4.27	2.71	6.01	-
	C ₃₂ H ₂₂ NO ₄ P	280		Benzene/ Pet.ether		74.73	4.16	2.56	6.14	-
9i	547			65%		70.20	4.02	2.55	5.66	11.70
	C ₃₂ H ₂₂ N ₂ O ₅ PS ₂	165		Methylene chloride/ n-hexane		70.42	4.33	2.45	5.54	12.55





Scheme 2

Table (II) : NMR & IR Data for Phosphoranylidene Cyclobutanediones (9d-i)

Cpd No	I.R	NMR		
		¹ H-NMR	³¹ P-NMR	¹³ C-
9d	1716 (C=O), 1436 (P-phenyl)	2.8 (s, 1H, N-CH ₃) 7.2-7.7 (m, 29H, Ar)	δ 13.94	δ 179 (C=O)
9e	1704 (C=O), 1440 (P-phenyl)	3.2 (s, 3H, CH ₃) 7.3-7.9 (m, 19H, Ar)	δ 15.81	δ 193(C=O, lactone, 178.5 (C=O, cyclobutandione)
9f	1740 (C=O), 1440 (P-phenyl), 1335 (C=S)	3.7 (s, 3H, CH ₃) 7.3-8.3 (m, 19H, Ar)	δ 25.57	δ 198(C=S) δ 193(C=O)
9g	1718 (C=O), 1645 (C=N), 1438 (P-phenyl)	2.9 (s, 3H, COCH ₃) 7-7.8 (m, 29H, Ar)	δ 16.36	—
9h	1700 (C=O, lactone), 1633 (C=O, cyclo)	2.7 (s, 3H, COCH ₃)	δ 20.82	δ 165(C=O, cyclobutandione, 165 (C=O, lactone)
9i	1680 (C=O), 1436 (P-phenyl), 1160 (C=S)	3.7 (s, 3H, CH ₃) 7-7.4 (m, 19H, Ar)	—	δ 192(C=S), δ 168(C=O)

Reaction of (2-Oxovinylidene)- 2b and/or (2-Thioxovinylidene)-triphenylphosphorane (2c) with Isatin 8a. Synthesis of Phosphoranylidene-cyclobutyliedne Derivatives 9b and c.

A mixture of isatin (8a) (0.01 mol), (2-oxovinylidene)-2b and/or (2-thioxovinylidene)-triphenylphosphorane (2c) (0.02

mol) in THF (40 ml) was refluxed for six hrs in case of **2b** and/or ten hrs with **2c**. THF was distilled off and the residue was crystallized from benzene to give the cyclobutylidene derivatives **9b,c**, respectively. The benzene filtrate, afforded upon concentration and addition of n-hexane, triphenylphosphine oxide.

When the reaction was performed using four moles of the phosphorane (**2a**, **b** and **c**) and one mole of the isatin (**8a**) the phosphorane reacted with only one carbonyl group in isatin (**8a**) together with unchanged phosphorane (**2a**, **b** and **c**) were obtained.

The Reaction of N-Methyl Isatin **8b and/or N-Acetyl Isatin **8c** with Phosphacumulenes **2a-c**. Preparation of Phosphoranylidene-cyclobutylidenes **9d-i**.**

A solution of N-methyl isatin **8b** and/or N-acetyl isatin **8c** (0.01 mol) in 20 ml of tetrahydrofuran was added dropwise with stirring, to a solution of the active phosphacumulene ylides **2a-c** (0.02 mol) in 30 ml THF. The reaction mixture was kept at room temperature for three hr in case of **2a**, six hr with **2b** and/or ten hr with **2c**. After the solvent was distilled off, the residue was dissolved in 20 ml chloroform followed by addition of 30 ml n-hexane and the new solution was left overnight in the refrigerator. The precipitate that formed was filtered off and crystallized from the appropriate solvent.

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