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Incorporation of molecular nitrogen into organic compounds

IV *. Novel lactam synthesis by nitrogenation of enol lactones

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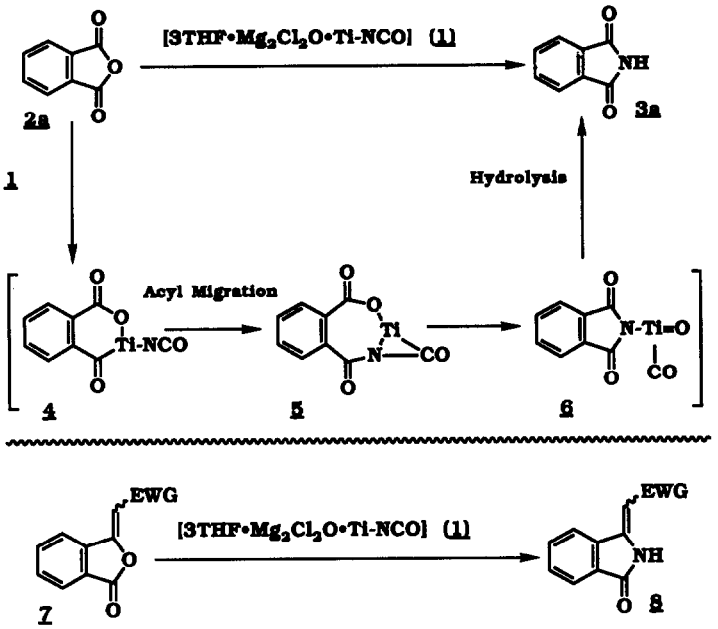
Abstract

Enol lactones **7**, which are readily prepared from *o*-haloacetophenone derivatives **15** by palladium-catalyzed carbonylation, react with the titanium–isocyanate complex [3THF·Mg_2Cl_2OTiNCO] (**1**) generated by fixation of CO_2 with titanium–nitrogen complex [TiNMg_2Cl_2·THF] to give the isoindolinone derivatives **8** in good yields.

Introduction

Incorporation of molecular nitrogen into organic compounds by use of transition metal complexes is an attractive process. We have already reported that acid anhydride reacts with the low-valent titanium–isocyanate complex **1** [2b] prepared from titanium–nitrogen complex [2a] and CO_2 to give phthalimide **3a** or quinazoline derivative in good yields [1]. The results showed that molecular nitrogen could be incorporated into organic compounds via titanium complex. We suggested that this reaction proceeded by the following pathway (Scheme 1): The acid anhydride **2a** adds to the low-valent titanium–nitrogen complex **1** to afford metalacycle **4**. Migration of the acyl group to nitrogen on titanium gives a seven-membered metalacycle **5** which is converted into five-membered titanium oxide complex **6**. Hydrolysis of **6** would afford cyclic imide **3a**. We expected that enol lactones **7** substituted with an electron-withdrawing group at the vinylic position may oxidatively add to the low-valent titanium complex to give the lactams **8**, which are useful compounds for the synthesis of alkaloids or biologically active substances. Now we report our novel procedure to prepare lactams from enol lactones by use of

* For Part III see ref. 1b.



Scheme 1

titanium–isocyanate complex **1**. The results indicate that molecular nitrogen can be used for the synthesis of lactams via titanium–nitrogen complex.

Results and discussion

Reaction of enol lactone with isocyanate complex

In order to examine the synthesis of the lactams **8** from enol lactones **7** by use of titanium–isocyanate complex **1**, compound **7a** was chosen as the starting material because it has an electron-withdrawing substituent at the vinylic position. Treatment of phthalide (**9**) with lithiated methyl *p*-tolyl sulfone followed by Jones oxidation afforded the hydroxylated compound **11a**. Dehydration of **11a** in benzene in the presence of TsOH upon heating gave the enol lactone **7a** in high yield. When a solution of enol lactone **7a** and isocyanate complex **1**, [2b], prepared from titanium–nitrogen complex [2a] and CO_2, was heated in NMP (*N*-methyl 2-pyrrolidinone) at 100 °C for 24 h, phthalimide **3a** and *p*-tolyl methyl sulfone **13** were obtained in 33% and 28% yields, respectively. Presumably, nitrogenation into **7a** occurred to produce the desired lactam **8a**, subsequent hydration gave **12a**. Then, a retro-aldol reaction occurred to provide imide **3a** and sulfone **13**. Treatment of compound **7a** with complex **1** at 70 °C for only 15 min afforded desired lactam as hydrate form **12a** in 31% yield along with **11a**. Conversion of **12a** into **8a** proceeded smoothly in benzene in the presence of TsOH (69% yield). The use of THF or CH_3CN as solvent for the reaction did not improve the yields of the desired lactams **12a** and **8a** (Table 1). Reaction of the corresponding *E*-isomer **7a'** under the same reaction conditions also gave **12a** (31% yield).

Hydration product **12a** was unstable because the retro-aldol reaction readily occurred to produce phthalimide **3a** and sulfone **11**. Treatment of **12a** with MeOH

Table 1

Nitrogenation of **7a** with **1**

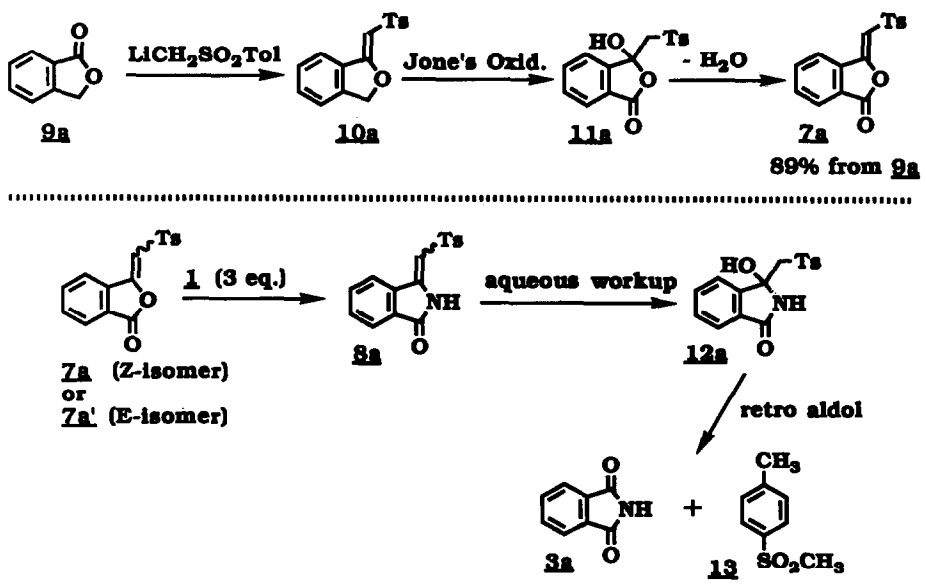
Run	Solvent	Temperature	Time	Yields (%)				
				8a	**12a**	**3a**	**13**	SM (as **11a**)
1	THF	reflux	24h	9	13	–	–	38
2	CH_3CN	reflux	24h	19	3	–	–	45
3	NMP	100 °C	24h	–	–	33	28	–
4	NMP	70 °C	15 min	–	31	–	–	32
5 [a]	NMP	70 °C	40 min	–	31	–	–	51

[a] *E*-isomer **7a'** was used as starting material

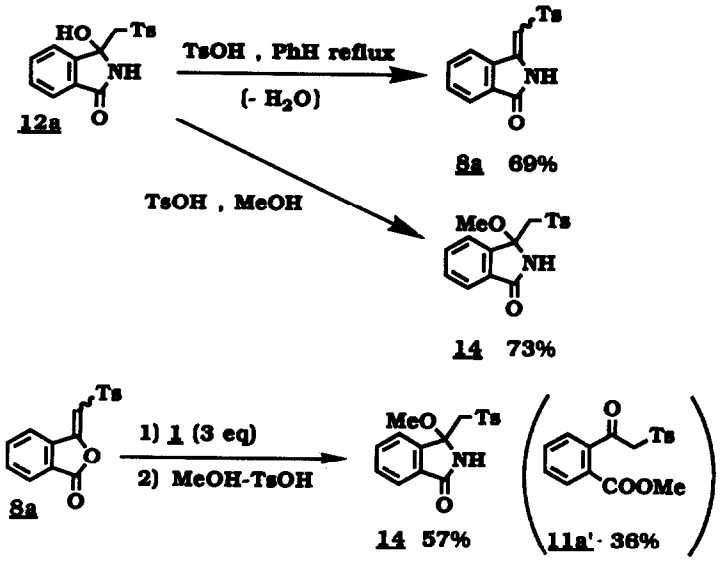
in the presence of TsOH afforded more of the stable methoxylated compound **14** (73% yield). The crude nitrogenation product was treated with MeOH in the presence of TsOH to give methoxylated lactam **14** in 57% yield along with compound **11** (which **11** was isolated as **11a'** by treatment with CH_2N_2 in 36% yield). These results exhibit that enol lactone **7** reacted with the low-valent titanium–isocyanate complex **1** and nitrogen on titanium–isocyanate complex was utilized for the synthesis of lactams.

New synthesis of enol lactone by palladium-catalyzed carbonylation

In order to develop the novel synthesis of lactam by use of titaniumisocyanate complex **1**, various enol lactones were required. It was thought that *o*-bromoacetophenone derivative **15** would afford acyl-palladium complex **17** by treatment with low-valent palladium catalyst under carbon monoxide, which reacts with internal ketone [3] to give metalacycle **19**. Reductive elimination of palladium(0) complex should afford enol lactone **7**. As expected, when *o*-bromoacetopheneone **15b** was



Scheme 2



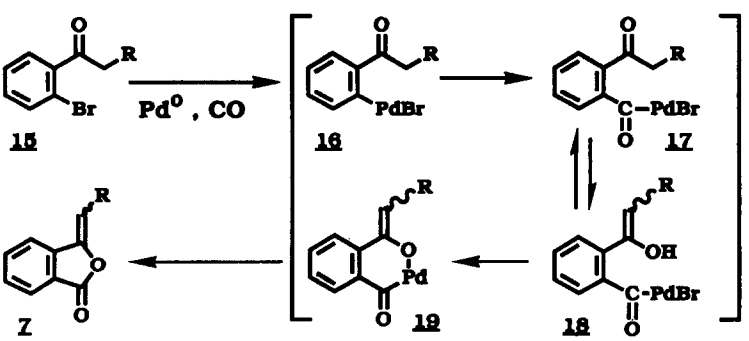
Scheme 3

treated with $Pd(PPh_3)_4$ in the presence of K_2CO_3 under carbon monoxide (1 atm) in toluene at 100 °C, the desired enol lactone **7b** was obtained in high yield. Representative results for the synthesis of enol lactones by palladium-catalyzed carbonylation are shown in Table 2.

Table 2

Enol–lactone formation by palladium-catalyzed carbonylation

Run	SM	R	Products	Yield
1	**15b**	H	**7b**	83%
2	**15c**	n-Pr	**7c**	87%
3	**15d**	Ph	**7d**	88%



Scheme 4

Table 3

Synthesis of lactams by nitrogenation

Run	SM	R	Temperature (°C)	Time	Products	Yield (%)
1	**7b**	H	100	24 h	**8b**	55
2	**7c**	n-Pr	120	24 h	**8c**	80
3	**7d**	Ph	120	24 h	**8d**	81.5
4	**7e**	CN	80	60 min	**12e**	53
5	**7a**	Ts	70	40 min	**14**	57 [a]

[a] After treatment with MeOH.

The present procedure for the synthesis of enol lactones **7** is useful because the starting material is readily available and is easily handled. Therefore, a large variety of enol lactones **7** should be obtained by use of this method.

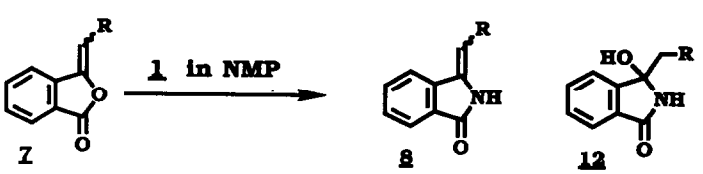
Novel lactam synthesis by use of titanium–isocyanate complex 1

The generality of new lactam synthesis was examined by treatment of complex **1** with various enol lactones **7**. A solution of enol lactone **7** and isocyanate complex **1** (3 equiv.) was heated in NMP under argon. The reaction was monitored by TLC until the disappearance of the starting material. The results are shown in Table 3. Methylene enol lactone **7b** prepared by palladium catalyzed carbonylation into *o*-bromoacetophenone (**15b**) afforded 3-methylene isoindolinone **8b** in 55% yield (run 1). As for the substituent, *n*-propyl or phenyl group gave the desired lactam **8c** or **8d** in high yield, respectively (runs 2 and 3). Although an electron-withdrawing group such as CN or Ts group was found to enhance the reaction rate, the yield was moderate owing to the instability of the starting material or the product.

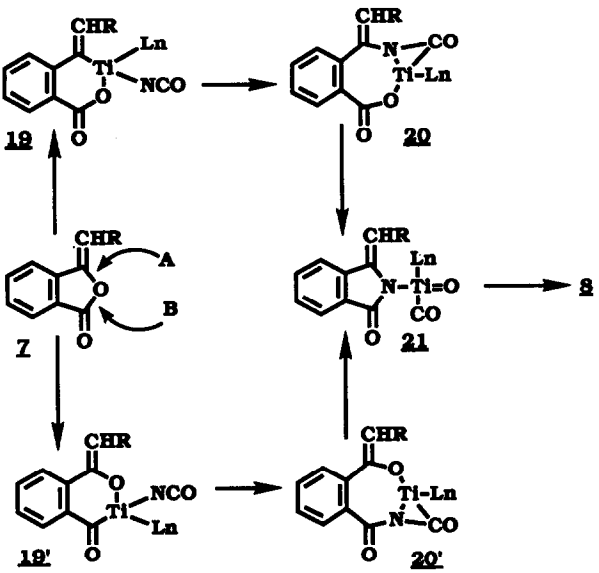
The reaction is thought to proceed through the following pathway. The initial step of this reaction would be oxidative addition of *O*-vinyl bond (arrow A) or *O*-acyl bond (arrow B) of enol lactone **7** to the low-valent titanium complex **1**. Migration of vinyl or acyl group of metalacycle **19** or **19′** to the nitrogen on the titanium affords the seven-membered metalacycle **20** or **20′** which is converted into the titanium oxide complex, **21**. Hydrolysis of this complex should afford lactam **8**.

Reaction of enol lactone with NH_3

We next examined whether isoindolinone **8** could be prepared from enol lactone **7** and NH_3 because phthalimide **3a** is obtained from phthalic anhydride and aqueous NH_3 upon heating (300 °C) [4]. A solution of enol lactone **7a** in aqueous NH_3 was heated in a sealed tube at 150 °C for 12 h. However, neither the desired lactam **8a** nor the hydrate product **12a** was obtained, phthalic acid **15** and methyl *p*-tolyl sulfone **13** were isolated in 41% and 24% yields, respectively. On the other



Scheme 5



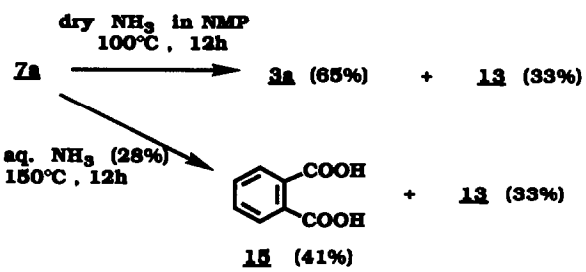
Scheme 6

hand, treatment of enol lactone **7a** with dry NH_3 in NMP in a sealed tube at 100 °C for 12 h afforded phthalimide **3a** and sulfone **13** in 65% and 33% yields, respectively. These results show that lactam **12a** or **8a** cannot be obtained by treatment of enol lactone **7a** with aqueous NH_3 or dry NH_3.

An important feature of the new nitrogenation reagent compared with NH_3 is its neutral character. Therefore, isoindolinone **8** could be obtained by one step without decomposition of the starting material and of the product. These results indicate that titanium–isocyanate complex **1** can be used as a N1 unit reagent, and new nitrogenation method provided a useful synthetic method for quinazoline [1] and isoindolinones **8** which are important intermediates for the synthesis of naturally occurring products or biologically active substances.

Experimental

All manipulations were performed under nitrogen by standard Schlenk techniques and all the reaction solutions were degassed by freeze–pump–thaw cycles.



Scheme 7

Solvents were dried by distillation under argon from sodium benzophenone (THF, Et_2O, dioxane), CaH_2(benzene, toluene, mesitylene, NMP, pyridine) or P_2O_5(CH_3CN). NMR spectra were recorded on either a JEOL JNM-FX90Q, JEOL JNM-FX100 or JEOL JNM-GX270. IR spectra were recorded on a JASCO A-300 spectrophotometer. Mass spectra were recorded with JEOL JMS DX303 or JEOL JMS-HX110 instruments. Melting points were determined by Yanagimoto Special No. 815 or Isii Melting Point Apparatus and are uncorrected.

Titanium nitrogen complex [THF · Mg_2Cl_2TiN] [2a], and titaniumisocyanate complex [3THF · $Mg_2Cl_2OTiNCO$] (**1**) [2b] were prepared by a standard procedure.

*3-(*p*-Toluenesulfonylomethylidene)phthalan (**10a**).* To a solution of methyl *p*-tolyl sulfone (**13**, 288 mg, 1.69 mmol) in 5 mL THF was added n-BuLi (1.69 mmol) at −78 °C under argon and the solution was stirred at this temperature for 25 min. A solution of phthalide (**9**, 227 mg, 1.69 mmol) was added to the solution and the reaction mixture was stirred for 25 min at −78 °C. A small amount of saturated NH_4Cl solution was added to the reaction mixture and the aqueous layer was extracted with Et_2O. The organic layer was dried over Na_2SO_4 and was concentrated. The residue was purified by column chromatography on silica gel with n-hexane-ethyl acetate (3/2) as eluent to give colorless crystals of **10a** (480 mg, 99%). IR ν_{max} ($CHCl_3$): 1640 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 2.41(s, 3 H), 5.53(s, 2 H), 6.05(s, 1 H), 7.22–8.05(m, 8 H); mass (*m/z*): 286(M^+, bp), 222, 179, 131, 91.

*3-Hydroxy-3-*p*-toluenesulfonylmethylidine phthalide (**7a**).* To a solution of **10a** (480 mg, 1.69 mmol) in acetone (5 mL) was added Jones reagent at 0 °C until the color of the solution was changed to red-brown and the solution was stirred at this temperature for 30 min. The reaction mixture was diluted with Et_2O and i-PrOH was added. The organic layer was extracted with saturated $NaHCO_3$ solution and the aqueous layer was acidified with 6 *N* HCl which was extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4 and evaporated to give the colorless oil of **11a**. IR ν_{max} ($CHCl_3$) 3400, 1790, 1718 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 2.47(s, 3 H), 3.60(d, *J* 14.4 Hz, 1 H), 3.98(d, *J* 14.4 Hz, 1 H), 6.5(brs, 1 H), 7.27–7.94(m, 8 H); mass 318(M^+), 300(bp), 236, 170, 149, 91.

A solution of the crude product (**11a**) in 70 mL benzene was refluxed in the presence of a catalytic amount of TsOH in a Dean–Stark apparatus for 24 h. The benzene solution was washed with saturated $NaHCO_3$ solution, dried over Na_2SO_4, and evaporated. The residue was purified by column chromatography on silica gel with n-hexane-ethyl acetate (2/1) as eluent to give the colorless oil of **7a** (455 mg, 90% from **10a**). IR ν_{max} ($CHCl_3$) 1817 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 2.44(s, 3 H), 6.52(s, 1 H), 7.26–8.06(m, 8 H); mass (*m/z*) 300(M^+), 236, 155, 91(bp). High resolution mass spectrum, found: 300.04490. $C_{16}H_{12}O_4S$, calcd: 300.04497.

Syntheses of enol lactone 7 by palladium-catalyzed carbonylation

General Procedure

A solution of *o*-bromoacetophenone derivative (**15**, 1 equiv.), $Pd(PPh_3)_4$ (5 mol %), K_2CO_3 (1 equiv.) in toluene was heated at 100 °C for 3 h under carbon monoxide. After cooling, ether was added and the solution was filtered through Celite. The filtrate was concentrated to give crude the product, which was purified by column chromatography on silica gel to give the desired enol lactone **7**.

Methylenephthalide (7b). The crude product, which was prepared from o-bromoacetophenone (**7b**, 40 mg, 0.2 mmol), $Pd(PPh_3)_4$ (12 mg, 0.01 mmol), and K_2CO_3 (28 mg, 0.2 mmol) in toluene (0.5 mL) under carbon monoxide, was purified by column chromatography on silica gel with n-hexane-ethyl acetate(4/1) as eluent to give **7b** (24.5 mg, 83%). IR ν_{max} ($CHCl_3$): 1770 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 5.24(s, 2 H), 7.50–7.97(m, 4 H); mass (*m/z*): 146(M^+), 118($M^+ - CO$), 104, 76(bp).

Butylidenephthalide (7c). The crude product, which was prepared from o-bromobutylophenone (**7c**, 96 mg, 0.4 mmol), $Pd(PPh_3)_4$ (24 mg, 0.02 mmol), and K_2CO_3 (56 mg, 0.4 mmol) in toluene (1.0 mL) under carbon monoxide, was purified by column chromatography on silica gel with n-hexane-ethyl acetate (4/1) as eluent to give **7c** (65 mg, 87%). IR ν_{max} ($CHCl_3$): 1780 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 0.99(t, *J* 7.2 Hz, 3 H), 1.45–1.67(m, 2 H), 2.46(dt, *J* 7.6, 8.0 Hz), 5.64(t, *J* 8.0 Hz, 1 H), 7.30–7.96(m, 4 H); Mass (*m/z*): 188(M^+), 159($M^+ - CO$), 131($M^+ - Bu$), 76(bp). High resolution mass spectrum found 188.0847. $C_{12}H_{12}O_2$ calcd; 188.0837.

Benzalphthalide (7d). A crude product which was prepared from benzyl *o*-bromophenylketone (**7d**, 55 mg, 0.2 mmol), $Pd(PPh_3)_4$ (12 mg, 0.01 mmol), and K_2CO_3 (28 mg, 0.2 mmol) in toluene (0.5 mL) under carbon monoxide was purified by column chromatography on silica gel with n-hexane-ethyl acetate (4/1) as eluent to give **7d** (39 mg, 88%); mp 107–109 °C (depression of melting point was not observed). IR ν_{max} ($CHCl_3$): 1780 cm^{-1}.

Z-3-Cyanomethylidenephthalide (7e). To a solution of CH_3CN (125 μL, 2.4 mmol) in THF (2.5 mL) was added n-BuLi (1.6 *N* hexane solution, 1.5 mL, 2.4 mmol) at −78 °C and the solution was stirred for 30 min. A solution of phthalide (**9**, 268 mg, 2 mmol) in THF (2 mL) was added to the solution at −78 °C and the solution was stirred for 25 min at the same temperature. Et_3N (404 mg, 4 mmol) and MsCl (344 mg, 3 mmol) was added to the solution and the solution was stirred for 5 min. Ether was added to the solution and the organic layer was washed with brine, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel with Et_2O as eluent to give a mixture of *E* and *Z*-3-cyanomethylidenephthalan (189 mg, 92%), which was dissolved in acetone (10 mL). A solution of Jones reagent was added to the acetone until the color of the solution changed to red-brown. After 1 h, i-PrOH was added and the solution was filtered through the Celite. The filtrate was concentrated and the residue was dissolved in CH_2Cl_2 (10 mL). To this solution was added Et_3N (404 mg, 4 mmol) and MsCl (344 mg, 3 mmol) at 0 °C and the solution was stirred for 5 min. The solution was diluted with Et_2O and the organic layer was washed with 5% HCl solution, saturated $NaHCO_3$ solution and brine, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel with n-hexane-ethyl acetate (3/1) as eluent to give the colorless oil of **7a** (300 mg, 88% from phthalide). IR ν_{max} ($CHCl_3$): 2249, 1815, 1665 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 5.37(s, 1 H), 7.18–7.88(m, 4 H); mass (*m/z*) 171(M^+), 143, 104, 76, 50(bp); High resolution mass spectrum $C_{10}H_5O_2N$ calcd: 171.0320. found 171.0315.

*Reaction of **1** with enol lactone **7***

General procedure

A solution of enol lactone **7**, titanium–isocyanate complex **1** (3 equiv.) in NMP was heated under argon at an appropriate temperature. After cooling, ethyl acetate

and then water were added to the solution. The solution was filtered through Celite and the organic layer was washed with saturated $NaHCO_3$ solution and brine, dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel to give the desired enol lactone **8** or **12**.

Reaction of **1** *with* Z-*3*-p-*toluenesulfonylmethylidene phthalide (7a).* A solution of **7a** (60 mg, 0.2 mmol) and **1** (264 mg, 0.6 mmol) in NMP (1 mL) was warmed at 70 °C under argon for 15 min. After usual workup, the residue was purified by column chromatography on silica gel eluted with ethyl acetate to give colorless oil of **12a** (19.5 mg, 31%) and **11a** (20.5 mg, 32%). **12a**: IR ν_{max} ($CHCl_3$): 3420, 1718 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 2.46(s, 3 H), 3.35(d, J 14.5 Hz, 1 H), 4.08(d, J 14.5 Hz, 1 H), 7.33–7.91(m, 9 H); mass (m/z): 317(M^+), 299($M^+ - H_2O$), 170(TsMe), 140, 91(bp); High resolution mass spectrum found 317.0722. $C_{16}H_{15}NO_4S$ calcd: 317.0727.

Conversion of **12a** *to 3-*p-*toluenesulfonylmethylidene-isoindole-1-one (8a).* A solution of **12a** (9.8 mg, 0.031 mmol) in benzene was refluxed in the presence of a catalytic amount of TsOH in a Dean–Stark apparatus for 15 h. The organic layer was washed with saturated $NaHCO_3$ solution and brine, dried over Na_2SO_4, and evaporated. The residue was purified by column chromatography on silica gel with n-hexane-ethyl acetate (3/1) as eluent to give the colorless oil of **7a** (5.7 mg, 69%). IR ν_{max} ($CHCl_3$) 3400, 1730 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 2.44(s, 3 H), 6.07(s, 1 H), 7.31–7.94(m, 8 H), 9.30–9.75(brs, 1 H); mass (m/z 299 (M^+, bp), 235($M^+ - SO_2$). High resolution mass spectrum found 299.0599. $C_{16}H_{13}NO_3S$ calcd: 299.0616.

*3-*p-*Toluenesulfonylmethyl-3-methoxy-isoindole-1-one (14).* A solution of the crude product in MeOH prepared from **1** (264 mg, 0.6 mmol) and **7a** (60 mg, 0.2 mmol), was stirred with a catalytic amount of TsOH for 15 h. After the usual workup, the residue was purified by column chromatography on silica gel with ethyl acetate as eluent to give colorless oil of **14** (38 mg, 57%) and **10a'** (24 mg, 36%). IR ν_{max} (neat) 3420, 1730, 1718, 1600 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.45(s, 3 H), 2.88(s, 3 H), 3.37 (d, J 14.4 Hz, 1 H), 4.08(d, J 14.4 Hz, 1 H), 7.31–7.88(m, 9 H); mass (m/z): 300(M^+ – MeO), 162($M^+ - TsCH_2$), 155(Ts), 91.

Reaction of **1** *with* E-*3*-p-*toluenesulfonylmethylidene phthalide (7a').* A solution of **7a'** (28 mg, 0.09 mmol) and **1** (124 mg, 0.28 mmol) in NMP (1 mL) was warmed at 70 °C for 15 min. After usual workup, the residue was purified by column chromatography on silica gel with ethyl acetate as eluent to give colorless oil of **12a** (8.7 mg, 31%) and **10a** (15 mg, 51%).

Reaction of **1** *with 3-methylenephthalide (7b).* A solution of **7b** (29 mg, 0.2 mmol) and **1** (264 mg, 0.6 mmol) in NMP (1 mL) was warmed at 100 °C for 24 h under argon. After usual workup, the residue was purified by column chromatography on silica gel eluted with ethyl acetate to give colorless oil of **8b** (16 mg, 55%). IR ν_{max} ($CHCl_3$): 3450, 1710 1655 cm^{-1}; ^1H NMR ($CDCl_3$) δ 4.98(d, J 2.2 Hz, 1 H), 5.21(d, J 2.0 Hz), 7.49–7.93(m, 4 H), 8.25(brs, 1 H); mass (m/z): 145(M^+, bp) 117(M^+ – CO), 103, 90; High resolution mass spectrum found 145.0540. C_9H_7NO calcd: 1450.0527.

Reaction of **1** *with 3-butylidenephthalide (7c).* A solution of **7c** (37 mg, 0.2 mmol) and **1** (264 mg, 0.6 mmol) in NMP (1 mL) was warmed at 120 °C for 24 h under argon. after the usual workup, the residue was purified by column chromatography on silica gel with ethyl acetate as eluent to give the colorless oil of **8c** (29.5 mg, 80%). IR ν_{max} ($CHCl_3$): 3450, 1700 1655 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 0.94(t, J 7.3 Hz, 3

H), 1.45–1.64(m, 4 H), 2.29(dt, *J* 7.3, 7.9 Hz) 5.57(t, *J* 7.9 Hz, 1 H), 7.35–7.82(m, 4 H), 8.70(brs, 1 H); mass (m/z): 187(M^+) 158(bp), 130(M^+ – Bu); High resolution mass spectrum found 187.0999. $C_{12}H_{13}NO$ calcd: 187.0998.

Reaction of 1 with 3-benzylidenephthalide (7d). A solution of **7d** (50 mg, 0.225 mmol) and **1** (298 mg, 0.675 mmol) in DMF (1 mL) was warmed at 120 °C for 24 h under argon. After the usual workup, the residue was purified by column chromatography on silica gel with ethyl acetate as eluent to give the colorless oil of **8d** (40.5 mg, 81%): IR ν_{max} ($CHCl_3$): 3450, 1700 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 6.56(s, 1 H), 7.29–7.93(m, 9 H), 8.17(brs, 1 H); mass (*m/z*) 221(M^+, bp) 193(M^+ – CO), 165; High resolution mass spectrum found 221.0825. $C_{15}H_{10}NO$ calcd: 221.0841.

Reaction of 1 with Z-3-cyanomethylidenephthalide (7e). A solution of **7e** (34 mg, 0.2 mmol) and **1** (264 mg, 0.6 mmol) in NMP (1 mL) was warmed at 80 °C for 60 min under argon. After the usual workup, the residue was dissolved in benzene containing a catalytic amount of TsOH. The solution was refluxed overnight in a Dean–Stark apparatus. The solvent was evaporated and the residue was purified by column chromatography on silica gel with ethyl acetate as eluent to give the colorless oil of **8e** (18 mg, 53%). IR ν_{max} ($CHCl_3$) 3440, 2210, 1740, 1650 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 5.24(s, 1 H), 7.62–7.97(m, 9 H), 8.20(brs, 1 H); mass (*m/z*): 170(M^+, bp) 130($M^+ - CH_2CN$), 76; High resolution mass spectrum found 170.0483. $C_{10}H_6N_2O$ calcd: 170.0480.

Reaction of 7a with NH_3. A solution of **7a** (30 mg, 0.1 mmol) in NMP (2 mL) containing dry NH_3 (3%) was placed in a stainless tube which was then sealed and heated at 100 °C for 12 h. After cooling, the solution was neutralized with dilute HCl and extracted with ethyl acetate. The organic layer was dried over Na_2SO_4, and concentrated. The residue was purified by column chromatography on silica gel with ethyl acetate/n-hexane (1/1) as eluent to give a mixture (15.2 mg, the ratio was determined by nmr spectrum) of phthalimide (**3a**, 65%) and methyl *p*-tolyl sulfone (**13**, 33%).

Reaction of 7a with NH_3. A solution of **7a** (30 mg, 0.1 mL) in 28% NH_4OH (1 mL) was placed in stainless tube which was then sealed and heated at 150 °C for 12 h. After the usual workup, phthalic acid (**15**, 7 mg) and methyl *p*-tolyl sulfone (**13**, 4 mg, 24%) were obtained. The conversion of phthalic acid to dimethyl phthalate (8 mg, 41%) by treatment with CH_2N_2 confirmed the structure.

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