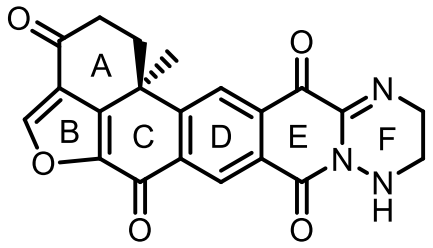
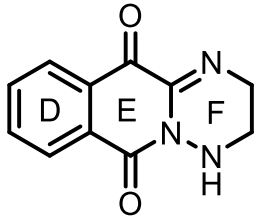
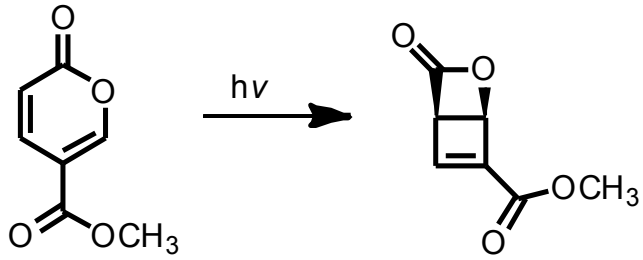
Synthesis of the DEF Ring System of Noelaquinone by Staudinger *aza*-Wittig reaction
&
Reactions Involving Methyl 3-Oxo-2-Oxabicyclo[2.2.0]Hexane-6-Carboxylate

1. 

noelaquinone



model system

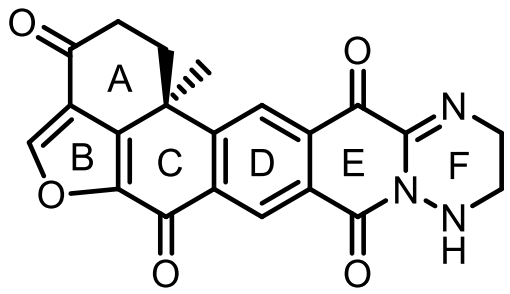
2. 

9/8/2012

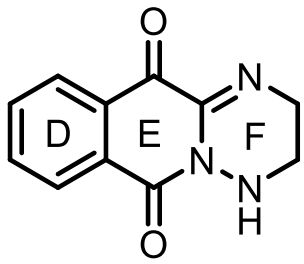
Liming Cao

Wipf Group Research Topic Seminar

1. Synthesis of the DEF Ring System of Noelaquinone by Staudinger aza-Wittig reaction



noelaquinone

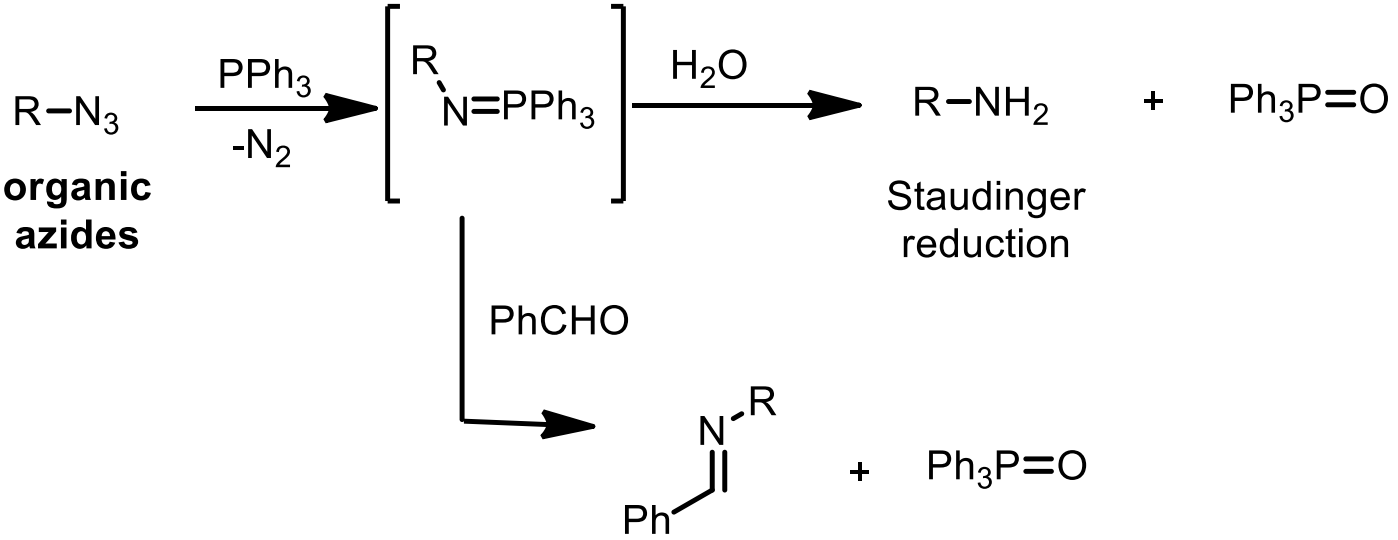


model system

Liming Cao

Wipf Group Research Topic Seminar

Staudinger/*aza*-Wittig (SAW) Reaction



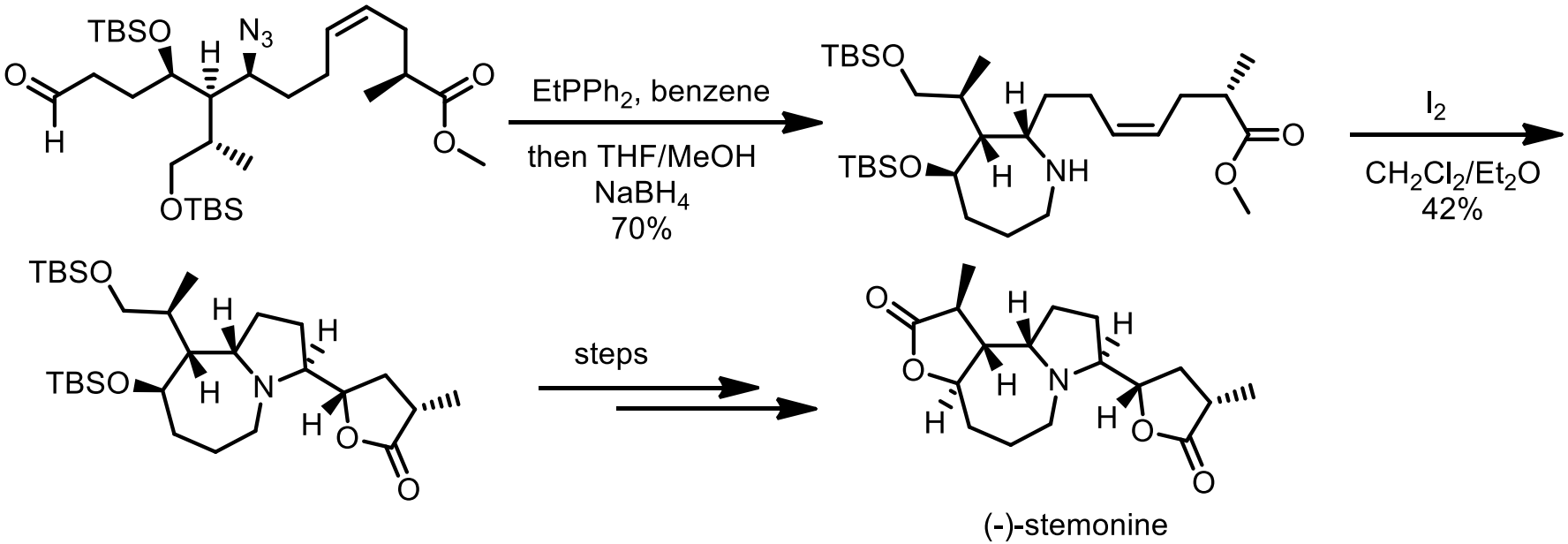
Intermolecular: aldehydes, ketone, acid halide, heterocumulene

Intramolecular: imide, ester, amide

Scriven, E. F. V.; Turnbull, K. *Chem. Rev.* **1988**, *88*, 297-368.
Brase, S.; Gil, C.; Knepper, K.; Zimmermann, V. *Angew. Chem. Int. Ed.* **2005**, *44*, 5188-5240.

Application of the SAW Reaction in Natural Product Synthesis

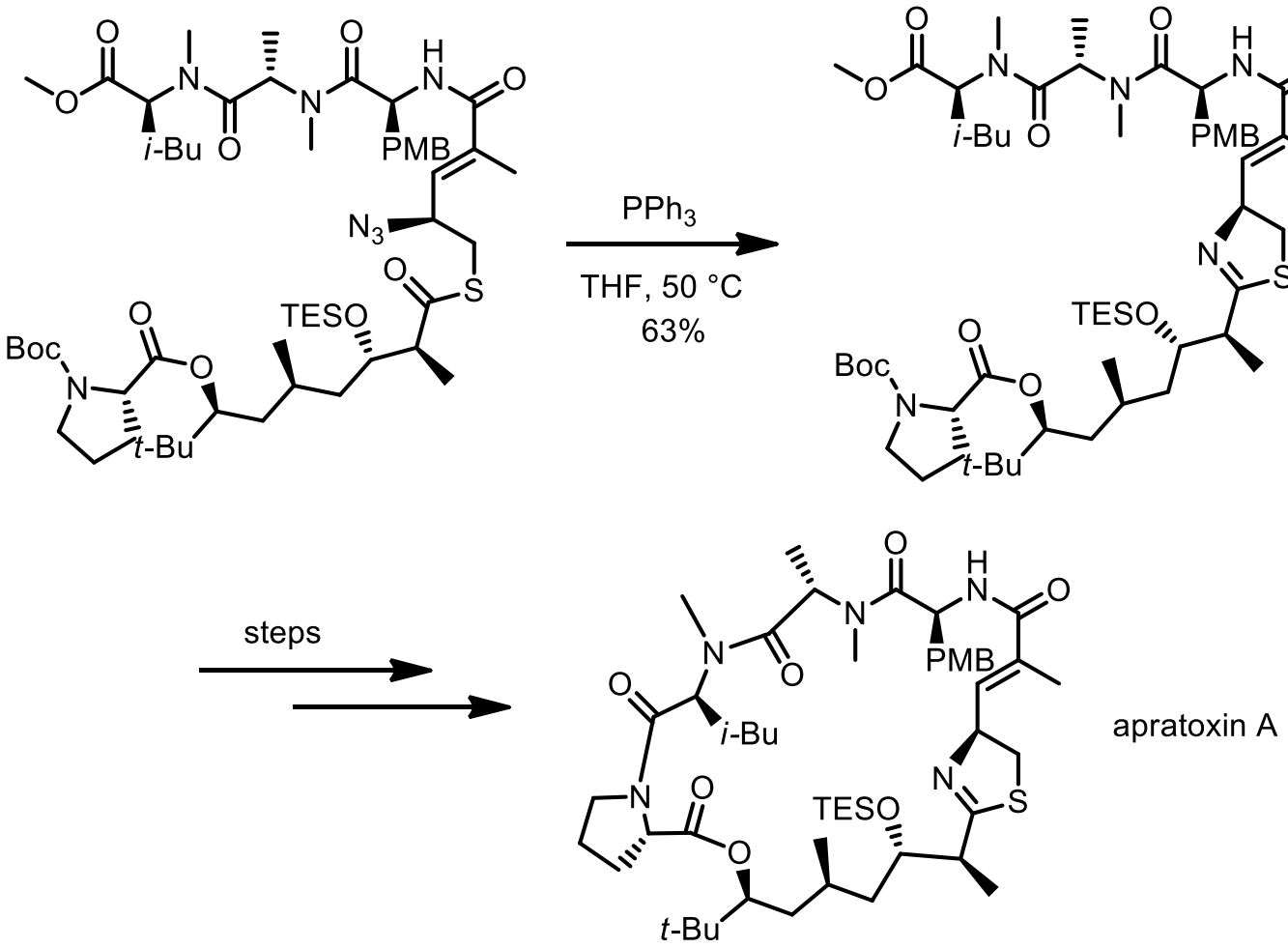
- Williams's preparation of (-)-stemonine



Williams, D. R.; Shamim, K.; Reddy, J. P.; Amato, G. S.; Shaw, S. M. *Org. Lett.* **2003**, *5*, 3361-3364.
Williams, D. R.; Fromhold, M. G.; Earley, J. D. *Org. Lett.* **2001**, *3*, 2721-2724.

Application of the SAW Reaction in Natural Product Synthesis

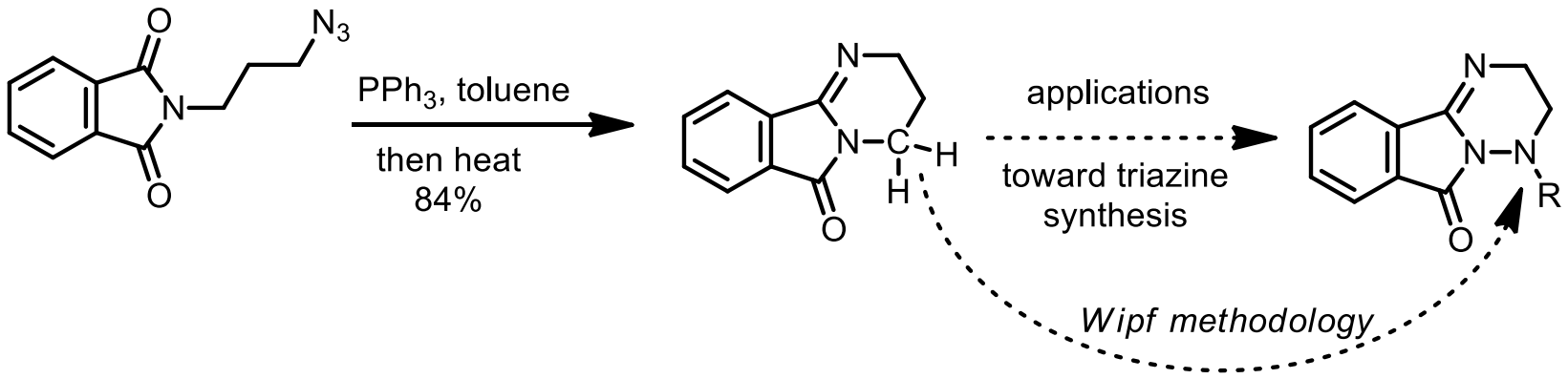
- Forsyth and Chen's preparation of apratoxin A



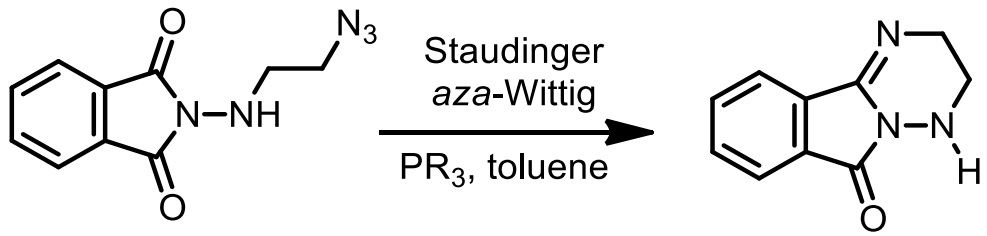
Chen, J.; Forsyth, C. J. *J. Am. Chem. Soc.* **2003**, *125*, 8734-8735.

Wipf group Methodology: 1,2,4-Triazine Synthesis

Eguchi and Takeuchi:

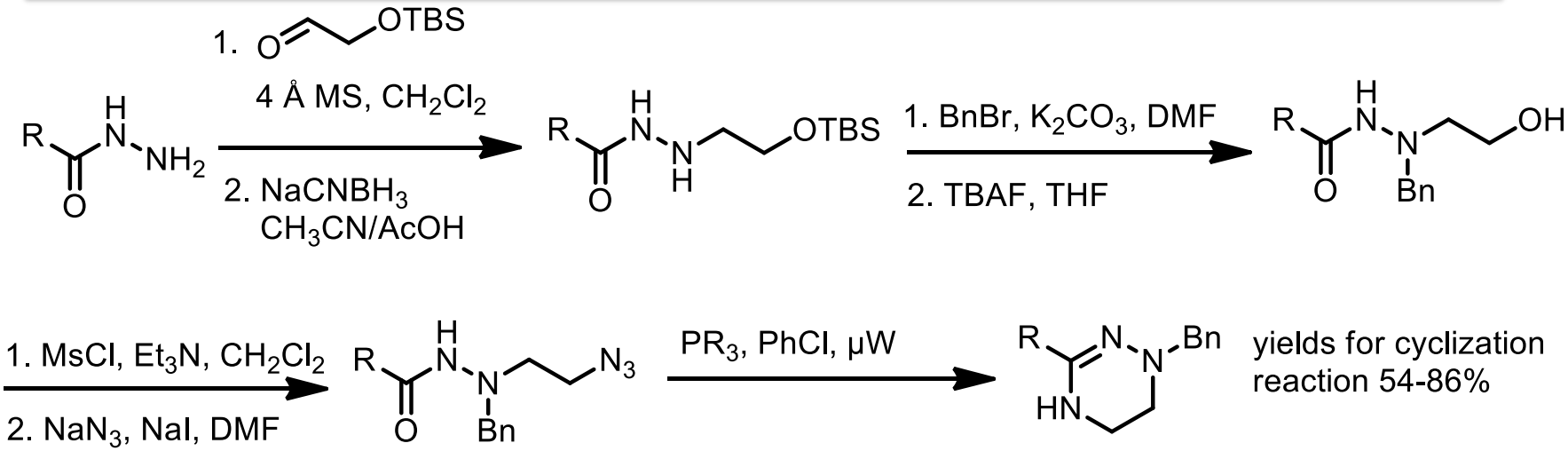


Amantini, Elzner and Fu:

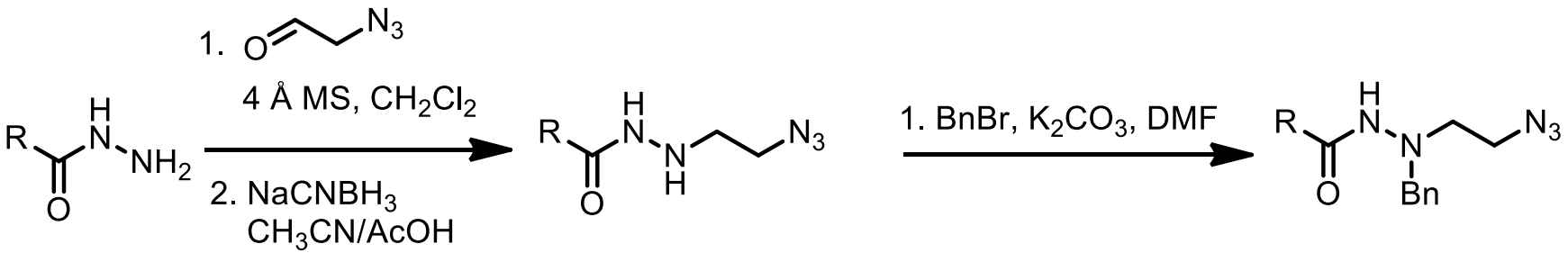


Eguchi, S.; Takeuchi, H. *J. Chem. Soc., Chem. Commun* **1989**, 602-603.
Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

Wipf group Methodology: 1,2,4-Triazine Synthesis

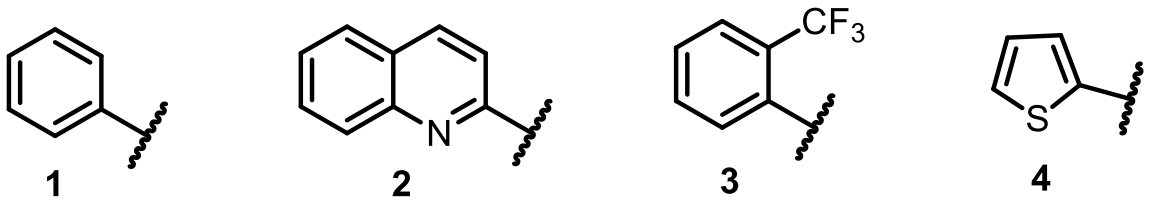


R= **1**, **2**, **3**, **4**



R= **2**, **3**

R =

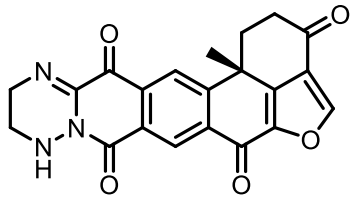


1 **2** **3** **4**

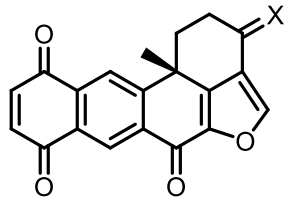
Isolation and Characterization of Noelaquinone

- First isolated in 1996 from an unidentified *Xestospongia* sp. (Indonesia) by Paul Scheuer. 67.2 g Sponge yielded 6 mg natural product
- Structure determination based upon NMR-analysis
- Structurally related to a class of marine metabolites isolated from the same *Xestospongia* sp.
  - (+)-halenaquinone and (+)-xestoquinone
- The thermodynamically stable naphthoquinone is replaced by a tetrahydro-1,2,4 – triazine moiety
- potential to be biologically active; structurally similar to halenaquinone(antibiotic, cytotoxic and antifungal activity)

Xestospongia sp.
(California Academhy of Sciences
www.calacademy.org)



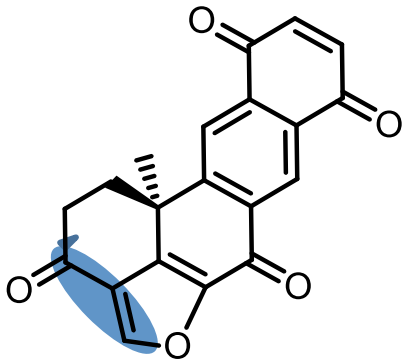
Noelaquinone



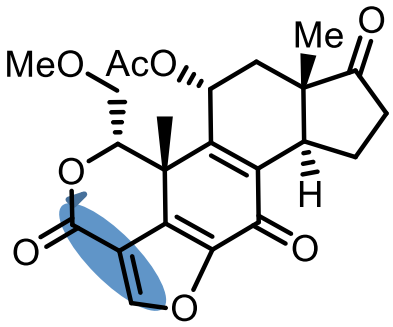
X = O: Halenaquinone
X = H_2: Xesoquinone

Y. Zhu, W. Y. Yoshida, M. Kelly-Borges, P. J. Scheuer, *Heterocycles* **1998**, *49*, 355-360
Wipf et al., *Org. Biomol. Chem*. **2004**, *2*, 1911-1920
N. Ihle et al. *Mol. Cancel Therap*. **2004**, *3*, 763-772
Nakamura, M.; et al. *Biosci. Biotechnol. Biochem.* **2005**, *69*, 1749-1752
Laurent, D. ; et al.*Bioorg. Med. Chem.* **2006**, *14*, 4477-4482.

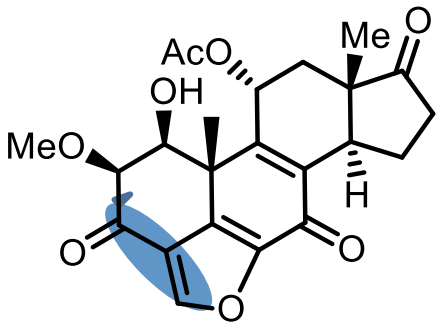
Wortmannin and Halenaquinone Analogs



halenoquinone



wortmannin



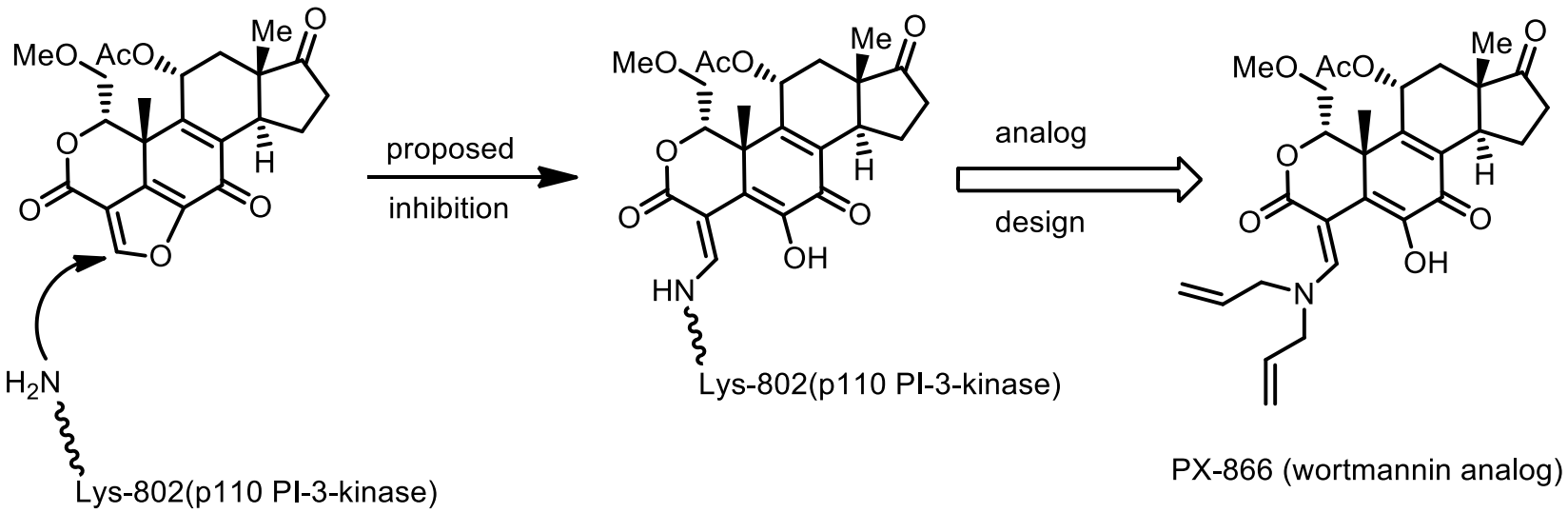
viridin

wortmannin and viridin:

- Viridin family-tricyclic furan group
- Potent nonselective inhibitors, poor candidates for therapeutics

Hanson, J. R. *Nat. Prod. Rep.* **1995**, 381-384.
Wipf, P.; Halter, R. J. *Org. Biomol. Chem.* **2005**, *3*, 2053-2061.
Lee, R. H.; Slate, D. L.; Moretti, R.; Alvi, K. A.; Crews, P. *Biochem. Biophys. Res.Commun.* **1992**, *184*, 765-772.
Fujiwara, H.; et al. *Eur. J. Pharmacol.* **2001**, *413*, 37-45.
Foster, F. M.; Traer, C. J.; Abraham, S. M.; Fry, M. J. *J. Cell Sci.* **2003**, *116*, 3037-3040.

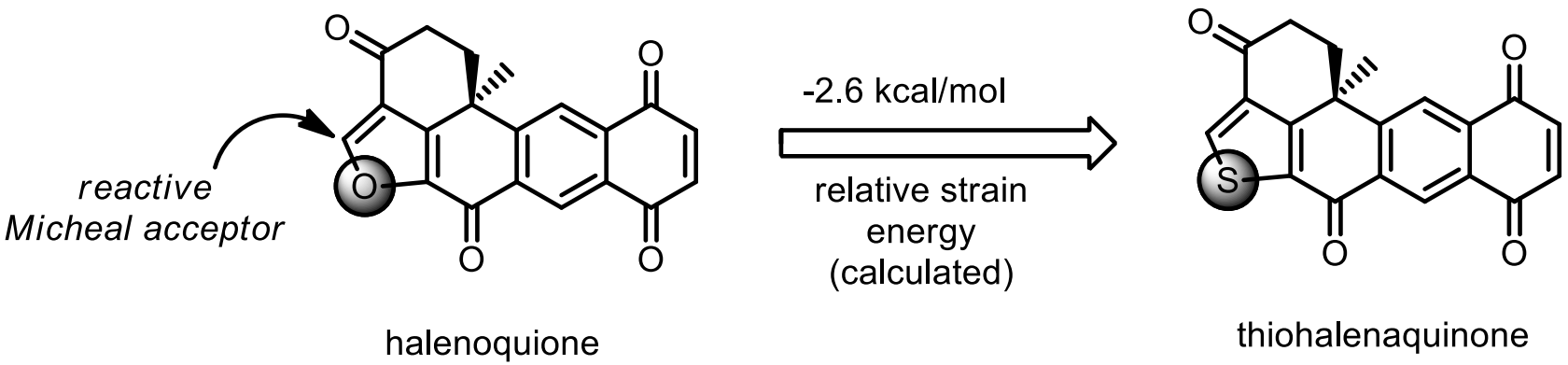
The Proposed Biological Activity



- The addition of a kinase residue to the reactive Michael acceptor of wortmannin, forming a covalent adduct that inhibits the protein function.
- Analog PX-866 is a potent is a potent phosphoinositide (PtdIns)- 3-kinase inhibitor (IC_{50} = 0.1 nM).

Wipf, P.; Minion, D. J.; et al. *Org. Biomol. Chem.* **2004**, *2*, 1911-1920.
Norman, B. H.; Paschal, J.; Vlahos, C. J. *Bioorg. Med. Chem. Lett.* **1995**, *5*, 1183-1186.
Ihle, N. T.; et al. *Mol. Cancer Ther.* **2004**, *3*, 763-772.

Thiohalenaquione

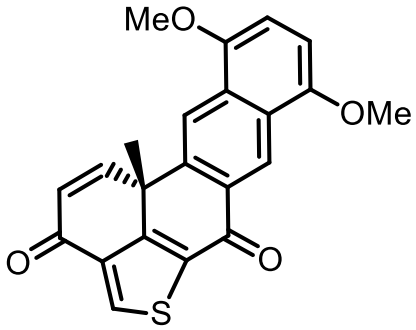


- Pfnek-1 kinase in *Plasmodium falciparum*, the parasite responsible for malaria
- Malaria- research focus of US army, WRAIR' s new treatment
- Thiophene-containing analog of halenaquinone, thiohalenaquinone: attenuate the reactivity of the Michael acceptor by replacing the furan ring with thiophene; increase the selectivity profile of the molecule for the targeted kinase

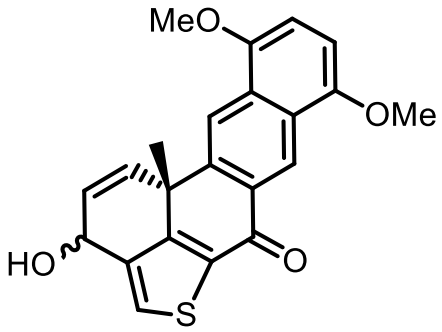
Wakefield, B.; Halter, R. J.; Wipf, P. *Org. Lett.* **2007**, *9*, 3121-3124.
Wakefield, B. Synthetic Studies on (E)-Alkene Peptide Isosteres and Thiophene-containing Furanosteroids. Doctoral Dissertation, University of Pittsburgh, 2008.
Ward, P.; Equinet, L.; Packer, J.; Doerig, C. *Bmc Genomics* **2004**, *5-5*.
Walter Reed Army Institute of Research (WRAIR): http://wrair-www.army.mil. 2012.

IC_{50} values of thiohalenaquinone analogs

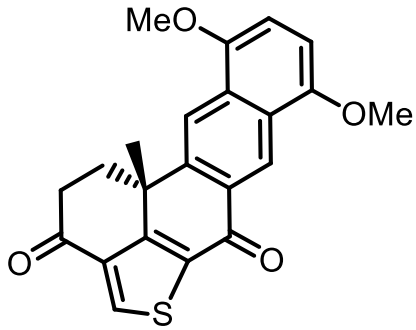
Wakefield:



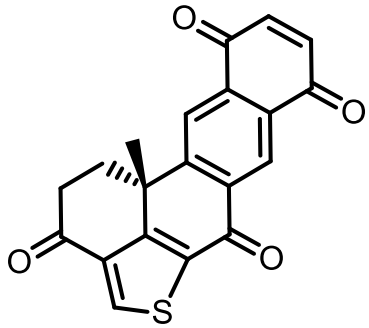
1



2



3



4

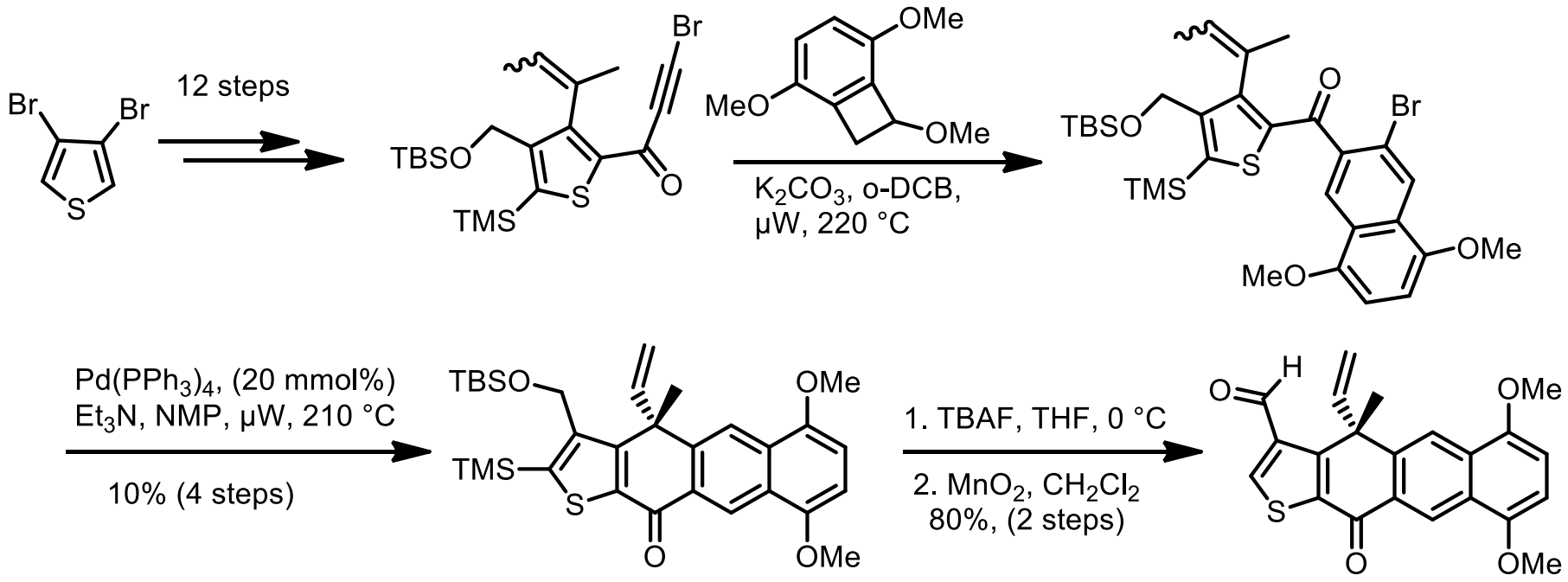
In collaboration with the Dow group at the Walter Reed Army Institute of Research (against Pfnek-1.):

Thiohalenaquinone analog	IC_{50} (μM)
1	2.8-3.9
2	>2500
3	>2500
4	4.6-6.7

Wakefield, B. Synthetic Studies on (E)-Alkene Peptide Isosteres and Thiophene-containing Furanosteroids. Doctoral Dissertation, University of Pittsburgh, 2008.

The synthesis of thiohalenaquione

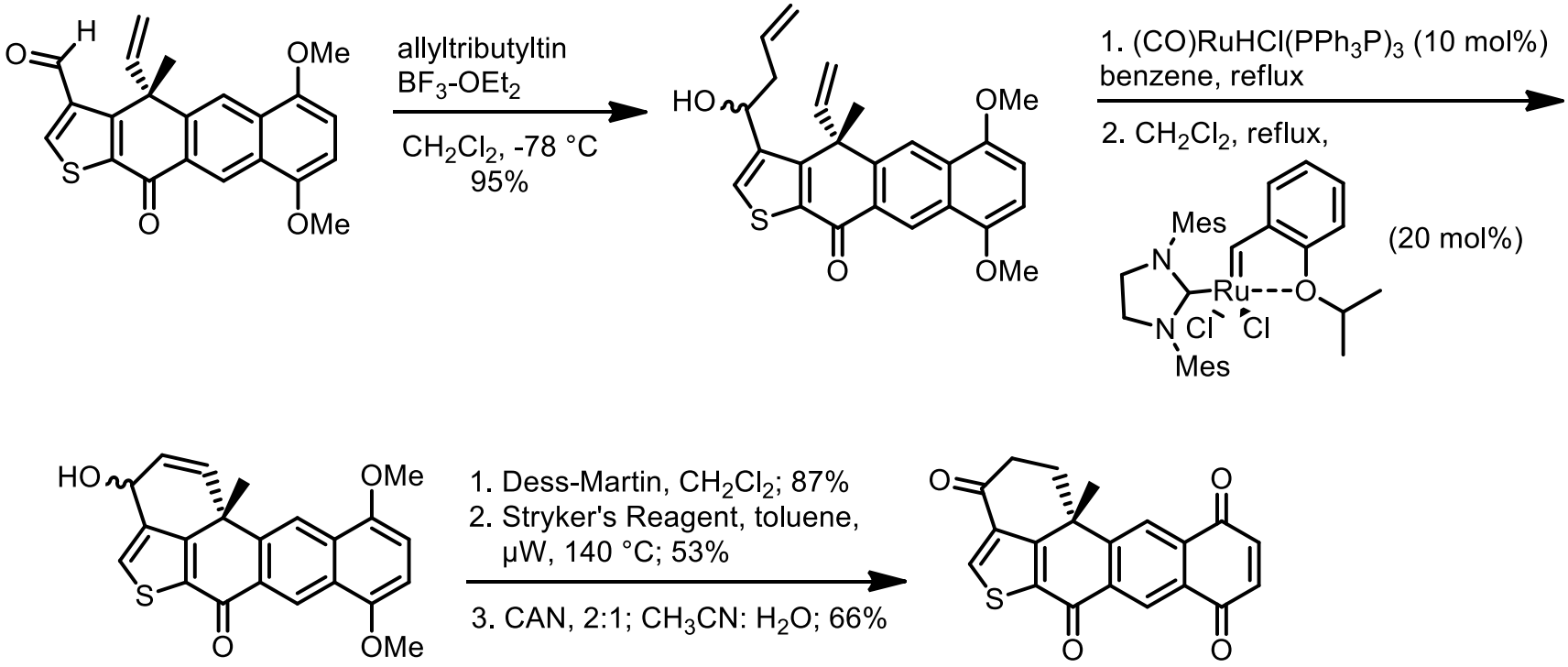
Wakefield:



Wakefield, B.; Halter, R. J.; Wipf, P. *Org. Lett.* **2007**, *9*, 3121-3124.
Wakefield, B. Synthetic Studies on (E)-Alkene Peptide Isosteres and Thiophene-containing Furanosteroids. Doctoral Dissertation, University of Pittsburgh, 2008.

The synthesis of thiohalenaquione

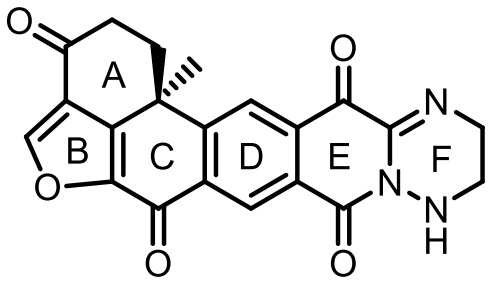
Wakefield:



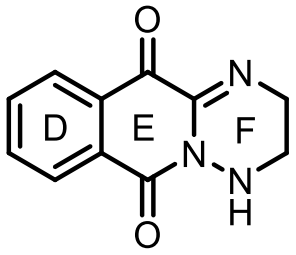
Wakefield, B.; Halter, R. J.; Wipf, P. *Org. Lett.* **2007**, *9*, 3121-3124.

Wakefield, B. Synthetic Studies on (E)-Alkene Peptide Isosteres and Thiophene-containing Furanosteroids. Doctoral Dissertation, University of Pittsburgh, 2008.

Model System Studies for the DEF Rings of Noelaquinone

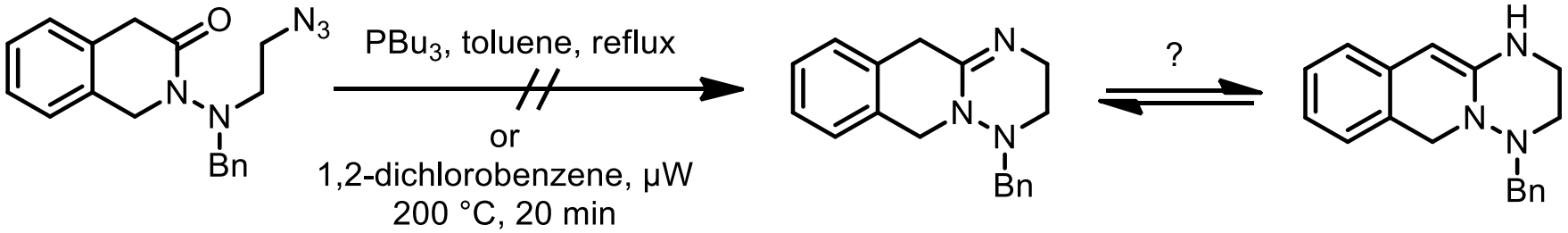


noelaquinone



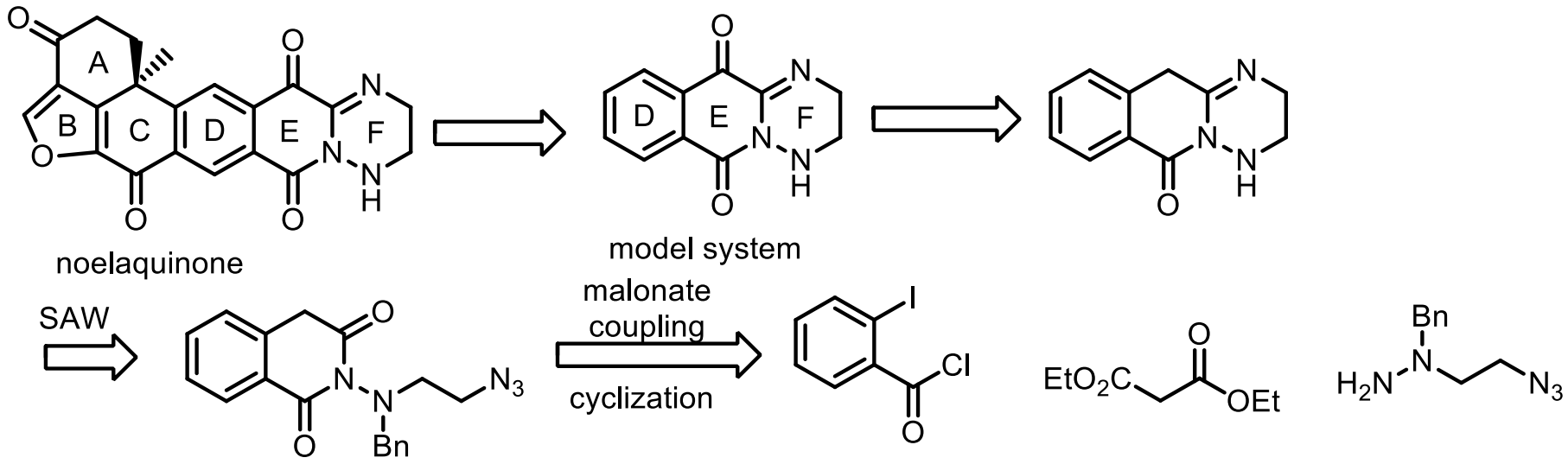
model system

Amantini, Elzner and Fu:



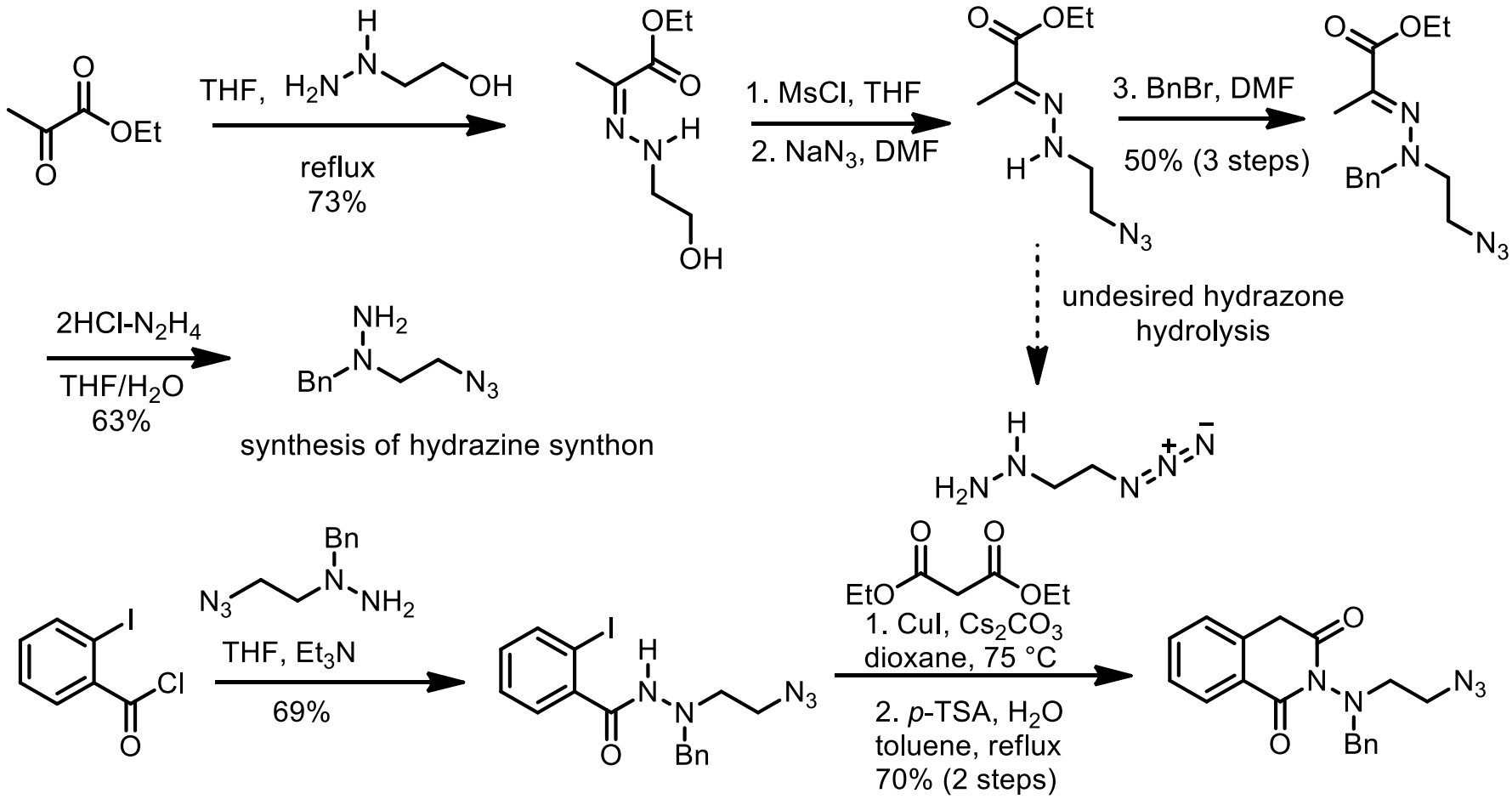
Maciejewski, J. P. New Methods for Heterocycle Preparation. Doctoral Dissertation, University of Pittsburgh, 2010.

General Retrosynthetic Analysis



Maciejewski, J. P. New Methods for Heterocycle Preparation. Doctoral Dissertation, University of Pittsburgh, 2010.
Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

Model System Studies for the DEF Rings of Noelaquinone



Maciejewski, J. P. New Methods for Heterocycle Preparation. Doctoral Dissertation, University of Pittsburgh, 2010.

Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

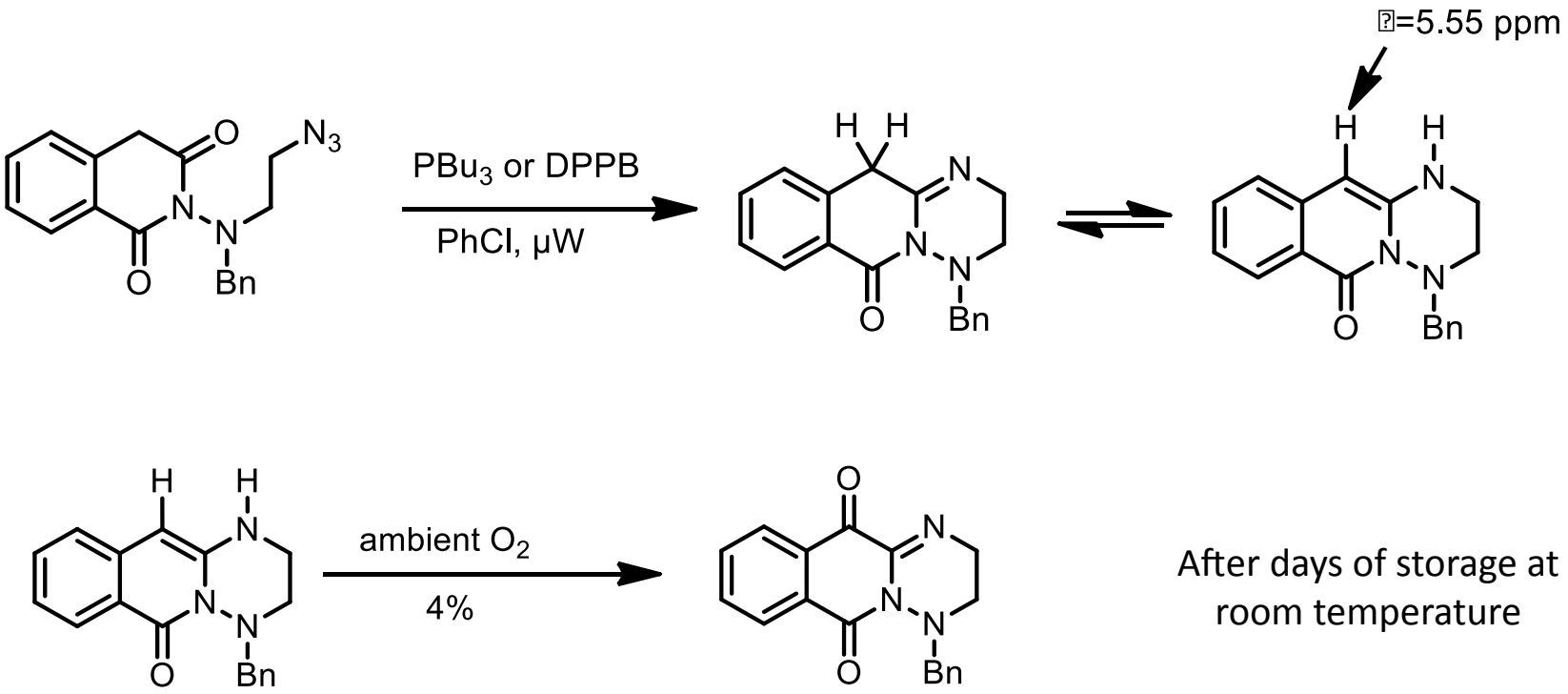
Brase, S.; Gil, C.; Knepper, K.; Zimmermann, V. *Angew. Chem. Int. Ed. Engl.* **2005**, *44*, 5188-5240.

Fischer, M.; Kloiber, K.; Hausler, J.; Ledolter, K.; Konrat, R.; Schmid, W. *ChemBioChem* **2007**, *8*, 610-612.

Xie, X. A.; Cai, G. R.; Ma, D. W. *Org. Lett.* **2005**, *7*, 4693-4695.

Yip, S. F.; Cheung, H. Y.; Zhou, Z. Y.; Kwong, F. Y. *Org. Lett.* **2007**, *9*, 3469-3472.

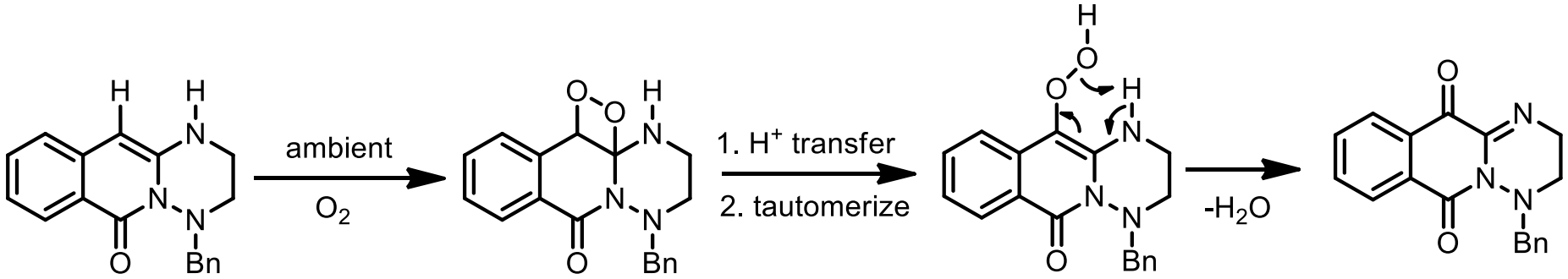
Model System Studies for the DEF Rings of Noelaquinone



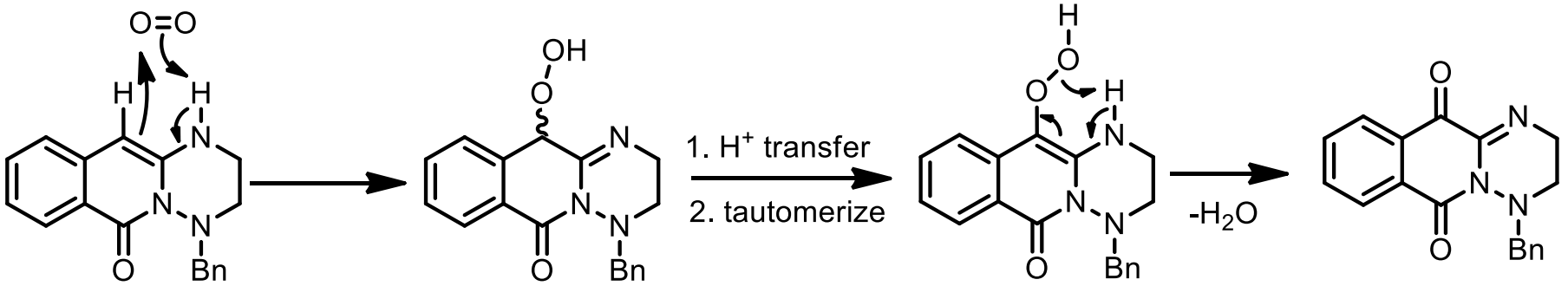
Maciejewski, J. P. New Methods for Heterocycle Preparation. Doctoral Dissertation, University of Pittsburgh, 2010.
Milas, N. A. *Chem Rev* **1932**, *10*, 295-364.

Model System Studies for the DEF Rings of Noelaquinone

Proposed mechamism:



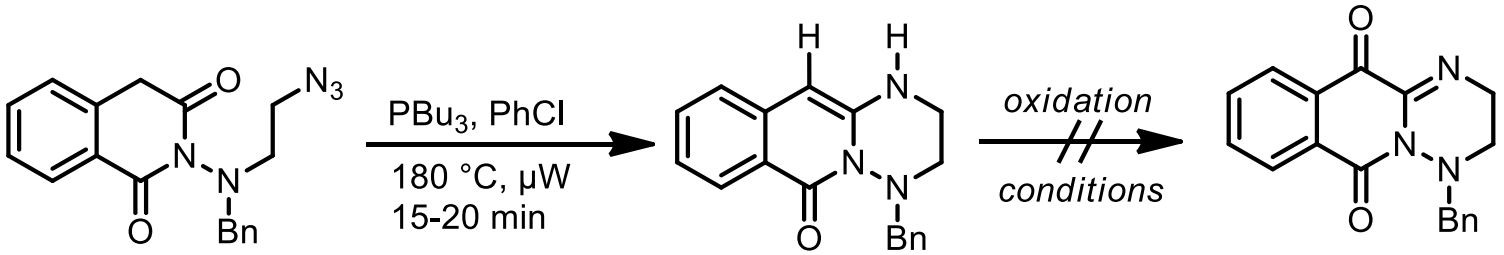
Or ene mechanism:



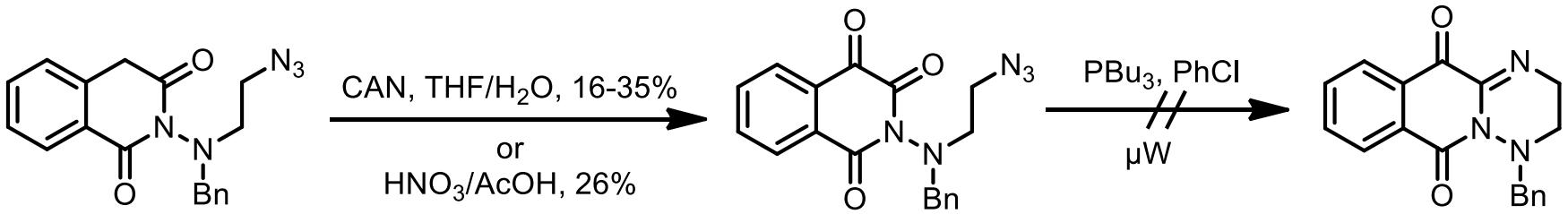
Model System Studies for the DEF Rings of Noelaquinone

Failed attempt to access the triazine model system:

Oxidation after the SAW reaction



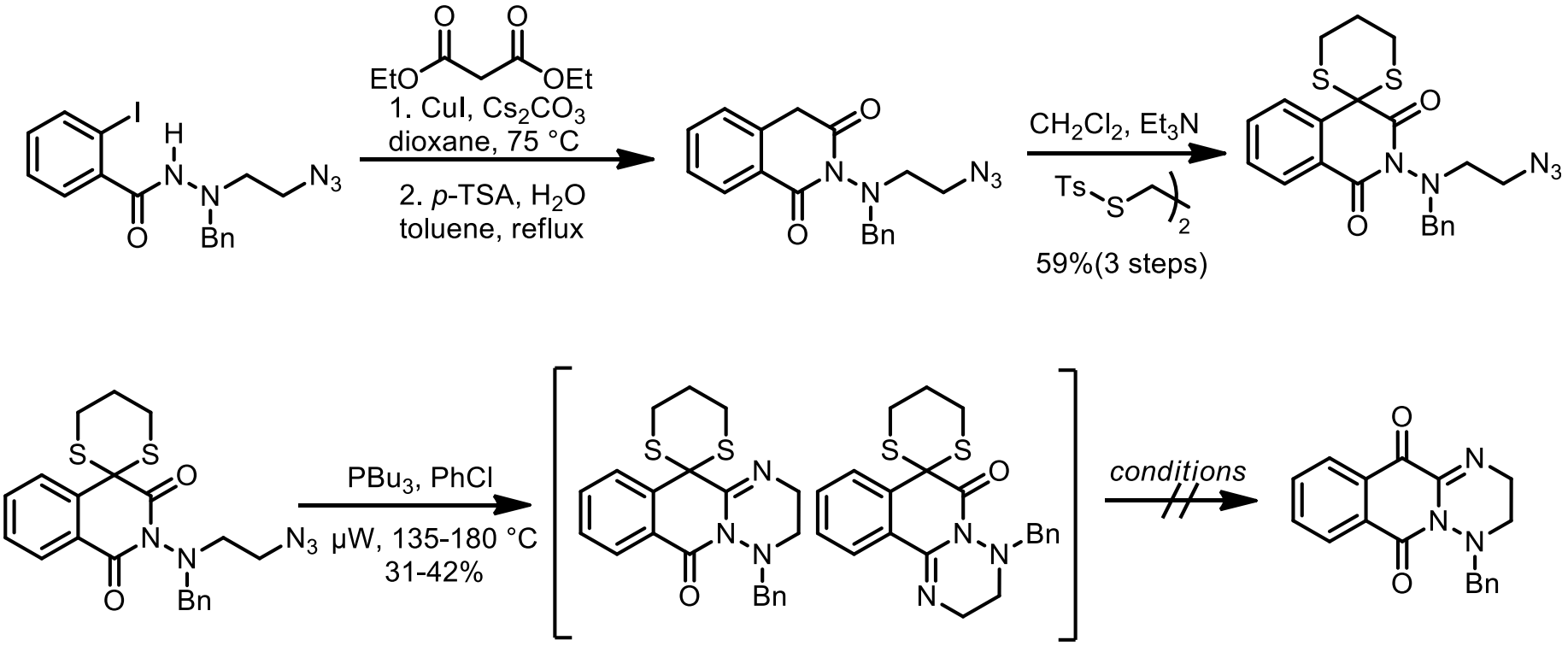
Oxidation before the SAW reaction



Maciejewski, J. P. New Methods for Heterocycle Preparation. Doctoral Dissertation, University of Pittsburgh, 2010.

Model System Studies for the DEF Rings of Noelaquinone

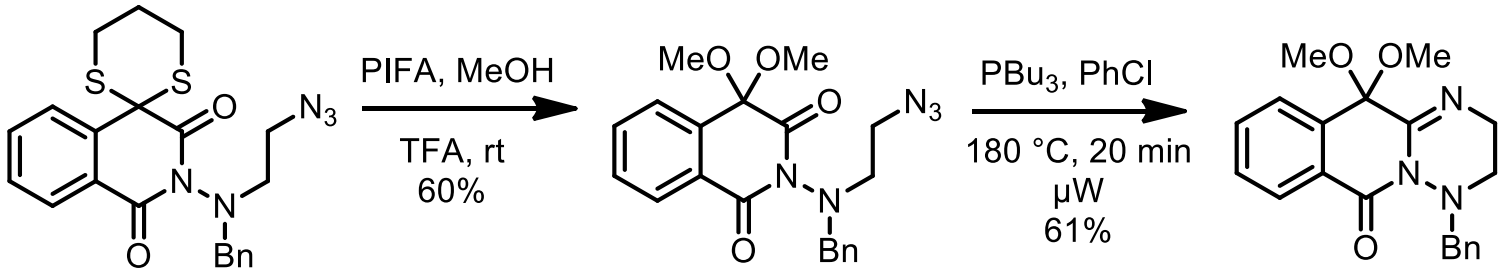
Oxidation/SAW reaction sequence:

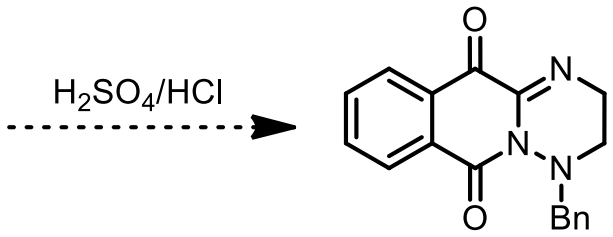


Maciejewski, J. P. New Methods for Heterocycle Preparation. Doctoral Dissertation, University of Pittsburgh, 2010.
Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.
Woodward, R. B.; Pachter, I. J.; Scheinbaum, M. L. *Org. Synth.* **1988**, *50-9*, 1016-1019.

Model System Studies for the DEF Rings of Noelaquinone

Desulfurization/SAW sequence to arrive at dimethoxyketal:

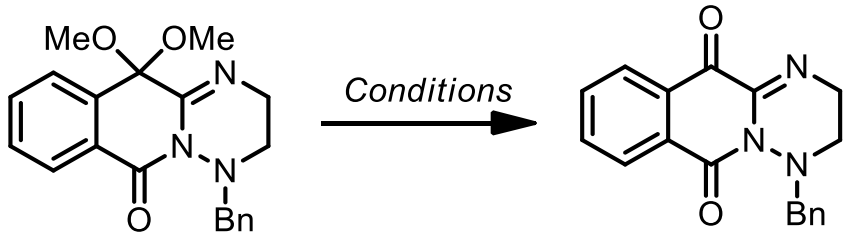




- Spectrum superimposable to that of auto-oxidation product
- Messy spectrum
- Product not isolated and irreproducible

Maciejewski, J. P. New Methods for Heterocycle Preparation. Doctoral Dissertation, University of Pittsburgh, 2010.
Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.
Fleming, F. F.; Funk, L.; Altundas, R.; Tu, Y. *J. Org. Chem.* **2001**, *66*, 6502-6504.

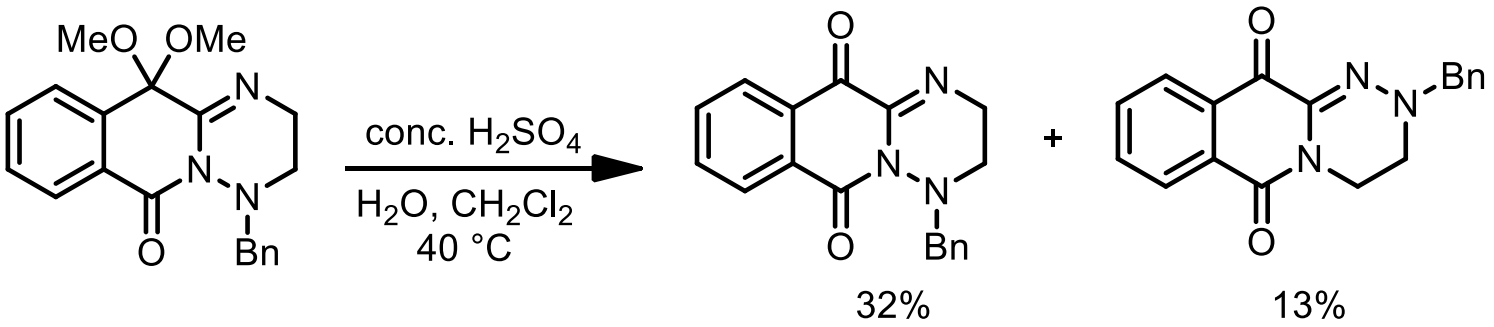
Model System Studies for the DEF Rings of Noelaquinone

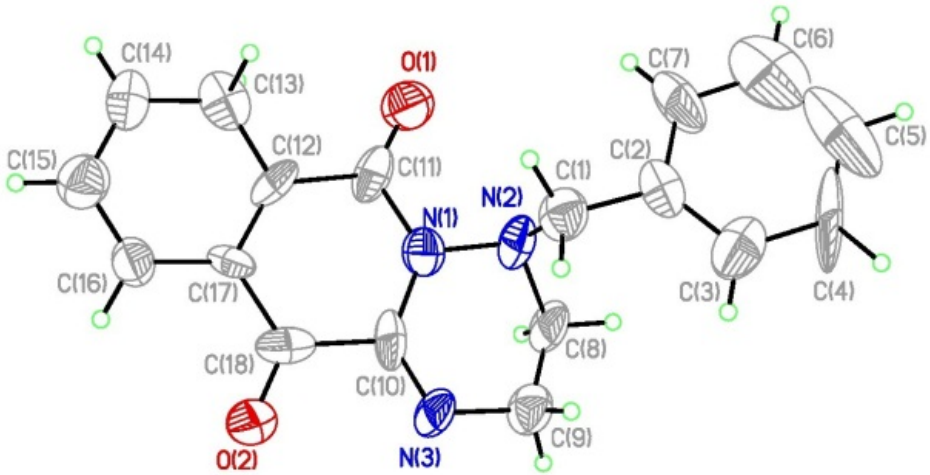


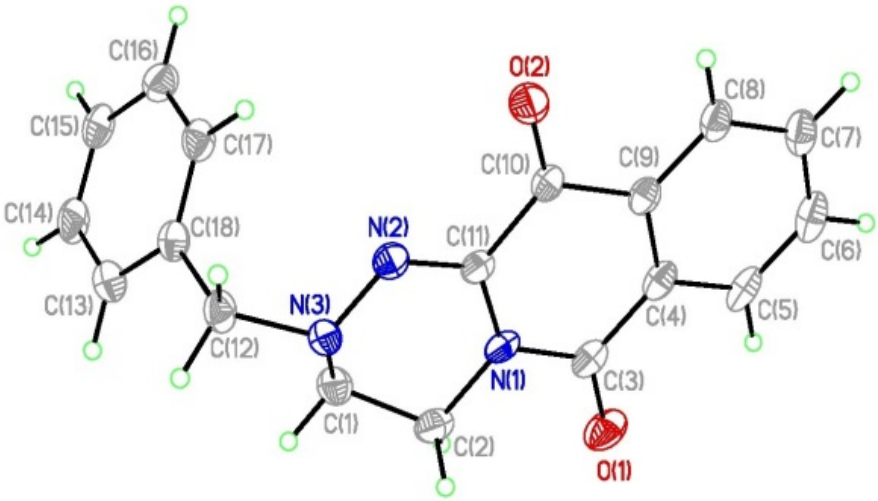
entry	conditions	result
1	HCl, Acetone, 50 °C , 12 h	decompose
2	I_2, acetone, rt 12 h	no reaction
3	p-TSA monohydrate, rt 24 h	no reaction
4	HCl, glacial acetic acid, rt 24 h	decompose
5	$Bi(NO_3)_3 \cdot 5H_2O$, CH_2Cl_2, 40 °C 12h	no reaction
6	$BiBr_3$, H_2O, rt 24 h; reflux 2h	unknown product

Sun, J. W.; Dong, Y. M.; Cao, L. Y.; Wang, X. Y.; Wang, S. Z.; Hu, Y. F. *J. Org. Chem.* **2004**, *69*, 8932-8934
Colvin, E. W.; Raphael, R. A.; Roberts, J. A. *J. Chem. Soc. D, Chem. Commun.* **1971**, 858.
Eash, K. J.; Pulia, M. S.; Wieland, L. C.; Mohan, R. S. *J. Org. Chem.* **2000**, *65*, 8399-8401.

Model System Studies for the DEF Rings of Noelaquinone



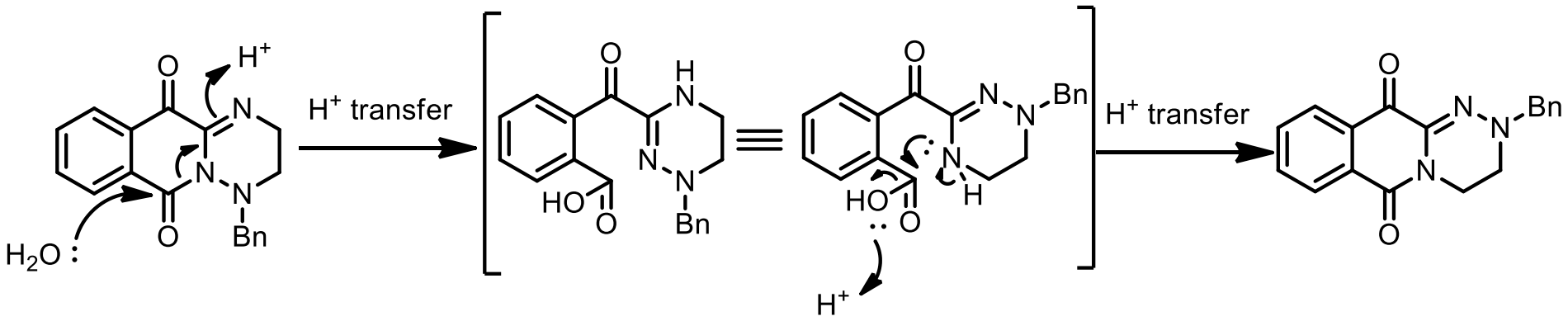




Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

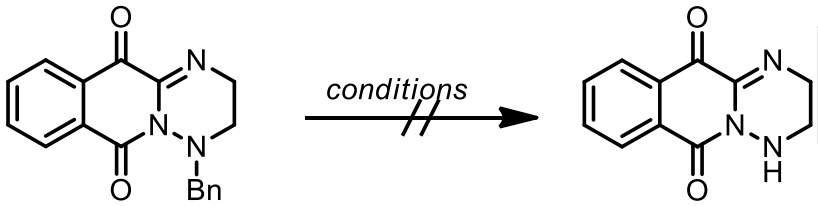
Model System Studies for the DEF Rings of Noelaquinone

Proposed mechanism: **A**ddition of the **N**ucleophile, **R**ing **O**pening, and **R**ing **C**losure (ANRORC mechanism)



H.C. van der Plas, Adv. Heterocyl. Chem., **1999**, *74*, 1.

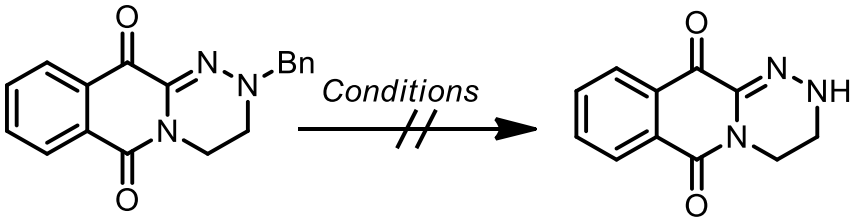
Model System Studies for the DEF Rings of Noelaquinone



entry	conditions	yield (%)
1	5% Pd/C, H_2, MeOH, 12 h rt	decompose
2	5% Pd/C, HCOOH, MeOH 12 h, rt	unknown product
3	5% Pd/C, 1,4-cyclohexadiene, MeOH, rt 12 h	decompose + SM
4	0.2 eq 5% Pd/C, HCOOH, MeOH, rt 12 h	isomerization (56%)
5	2 eq 5% Pd/C, HCOOH, MeOH, rt 12 h	decompose
6	Zn, ammonium formate, MeOH, rt 12 h	decompose
7	$FeCl_3$, CH_3CN, rt 12 h	decompose
8	CAN, CH_3CN, H_2O, rt 12 h	unknown product
9	NIS, CH_2Cl_2, rt 12 h	SM
10	$NaNO_2$, TFA, H_2O, CH_2Cl_2, rt 12h	decompose + SM

Paliakov, E.; et.al. *Tetrahedron Lett.* **2004**, *45*, 4093-4095.
Cheng, C. J.; et. al. *J. Org. Chem.* **2009**, *74*, 5671-5674.
Bernotas, R. C.; et. al. *Synth. Commun.* **1990**, *20*, 1209-1212.
Kanai, M.; et. al. *Org. Lett.* **2003**, *5*, 1007-1010.
Kanai, M.; et. al. *Chem. Lett.* **2004**, *33*, 1424-1425.
Gray, B. D.; Jeffs, P. W. *Chem. Commun.* **1987**, 1329-1330.
Elamin, B.; et. al. *J. Org. Chem.* **1979**, *44*, 3442-3444.

Model System Studies for the DEF Rings of Noelaquinone

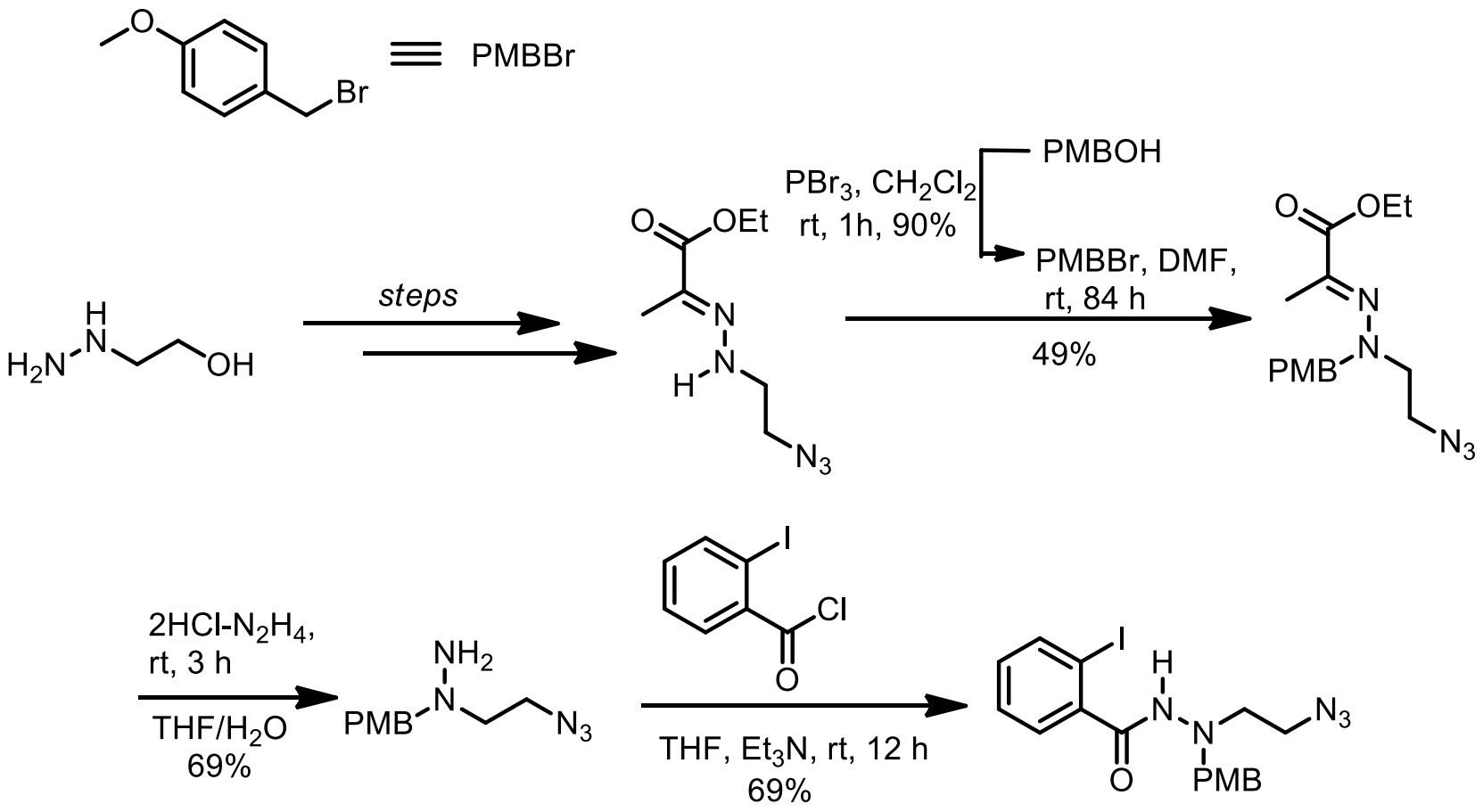


Removal of benyl group: problematic

entry	conditions	result
1	BBr_3, CH_2Cl_2, rt 12 h	decompose
2	5% Pd/C, H_2, 1,1-dichloroethane, MeOH, rt 12 h	unknown product
3	TrocCl, $NaHCO_3$, CH_3CN, rt 12 h	no reaction
4	$Pd(OH)_2$, PMHS, Boc_2O, EtOH, rt 12 h	decompose
5	$Pd(OH)_2$, H_2, MeOH, rt 12 h	unknown product
6	5% Pd/C, H_2, 1,1,2-trichloroethane, rt 5 h	unknown product & decompose material

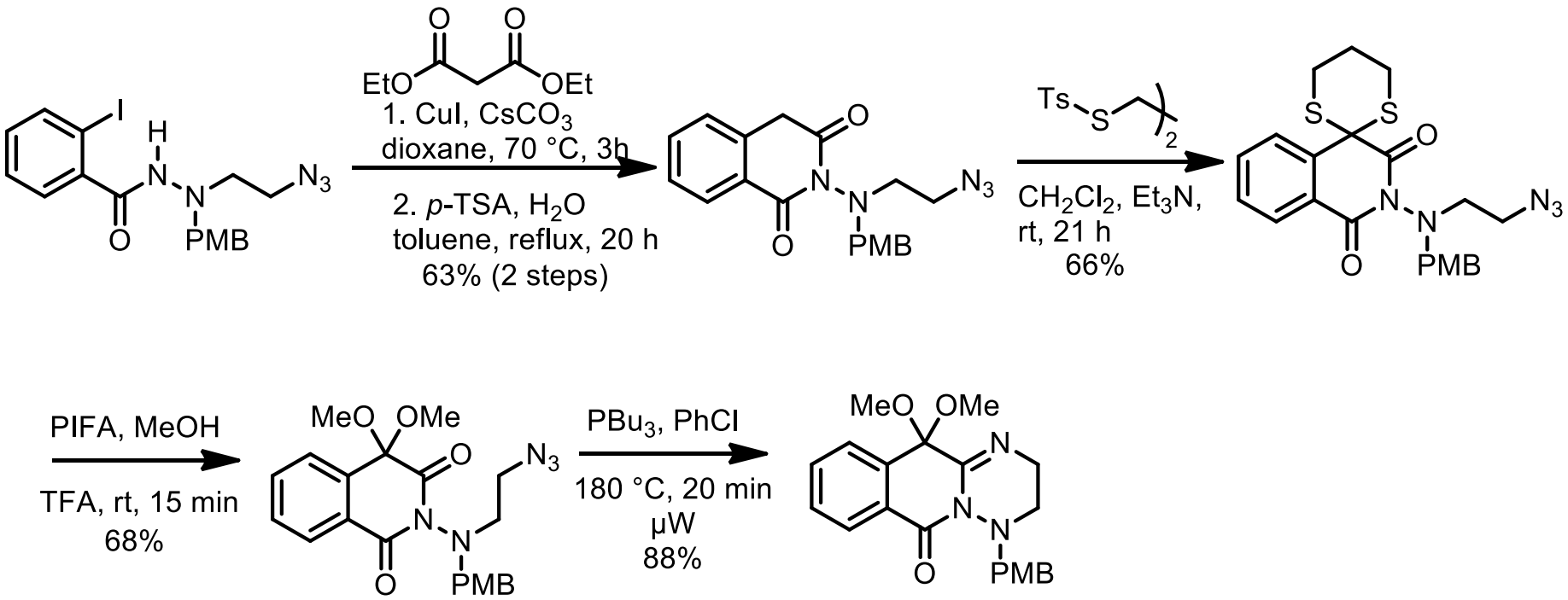
Bajwa, J. S.; et. al. *Tetrahedron Lett.* **2000**, *41*, 6025-6028.
Srinivasa, G. R.; et. al. *Synth. Commun.* **2004**, *34*, 1831-1837.
Rodebaugh, R.; et. al *Tetrahedron Lett.* **1996**, *37*, 5477-5478.
Bull, S. D.; et. al. *J. Chem. Soc., Perkin Trans. 1* **2001**, 3106-3111.
Grayson, E. J.; Davis, B. G. *Org. Lett.* **2005**, *7*, 2361-2364.
Rawal, V. H.; et. al. *J. Org. Chem.* **1987**, *52*, 19-28.
Shirai, M.; et. al. *Tetrahedron Lett.* **1999**, *40*, 5331-5332.
Chandrasekhar, S.; et. al. *Tetrahedron Lett.* **2003**, *44*, 2057-2059.

Model System Studies for the DEF Rings of Noelaquinone



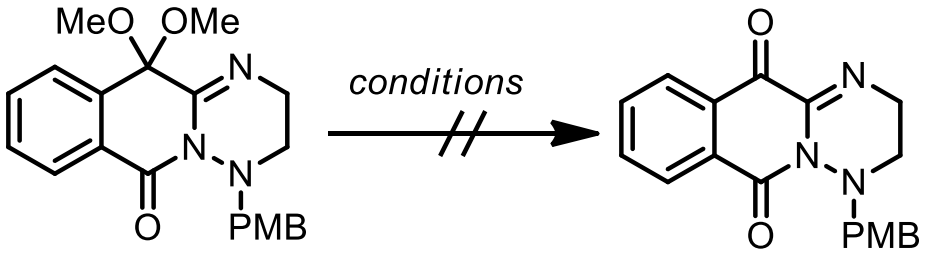
Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

Model System Studies for the DEF Rings of Noelaquinone



Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

Model System Studies for the DEF Rings of Noelaquinone

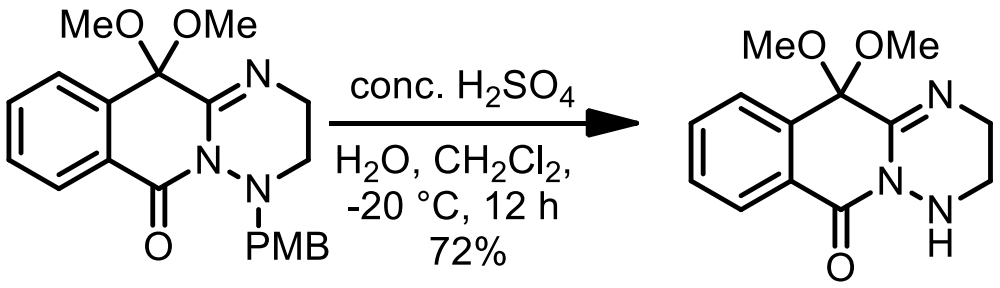


entry	conditions	result
1	conc. H_2SO_4, CH_2Cl_2, H_2O, 40 °C 12 h	decompose
2	$LiBF_4$, CH_3CN, H_2O, rt 8h, then 55 °C 1h	SM
3	Amberlyst-15, acetone, H_2O, rt 40 h	SM
4	PPTS, acetone, H_2O, reflux, 18 h	SM

Lipshutz, B. H.; Harvey, D. F. *Synth. Commun.* **1982**, *12*, 267-277.
Bonin, M.; et. al. *Tetrahedron Lett.* **1986**, *27*, 1569-1572.
Roush, W. R.; Sciotti, R. J. *J. Am. Chem. Soc.* **1994**, *116*, 6457-6458.
Coppola, G. M. *Synthesis* **1984**, 1021-1021.
Hagiwara, H.; Uda, H. *Chem. Commun.* **1987**, 1351-1353.

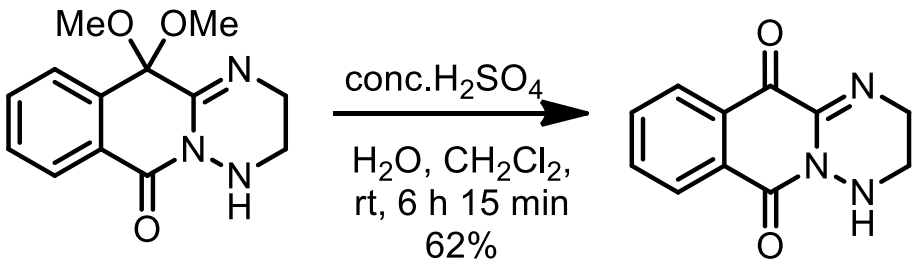
Model System Studies for the DEF Rings of Noelaquinone

Unexpectedly:



Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

Model System Studies for the DEF Rings of Noelaquinone

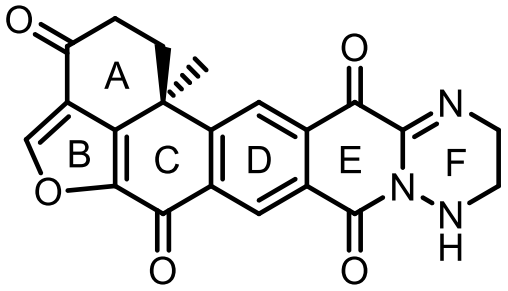


No Isomerization:
Oxocarbenium ion stablized by smaller lipophilicity , which helps its solvation in the aqueous solution

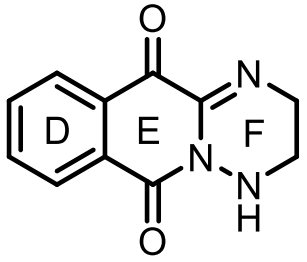
entry	conditions	result
1	TFA, H_2O, CH_2Cl_2, rt 12 h	SM
2	HCl, H_2O MeOH, rt 12 h	unknown product
3	H_2SO_4, H_2O, MeOH, rt 12 h	SM
4	DDQ, CH_3CN, H_2O, rt 18 h	SM
5	conc. H_2SO_4, THF, H_2O, 4 °C 12 h	SM
6	conc. H_2SO_4, THF, H_2O, rt 12 h	SM
7	conc. H_2SO_4, CH_2Cl_2, H_2O, 4 °C 12 h	SM
8	conc. H_2SO_4, CH_2Cl_2, H_2O, 35 °C 12 h	decompose
9	conc. H_2SO_4, CH_2Cl_2, H_2O, rt 6 h 15 min	62%

Ellison, R. A.;et. al. *Tetrahedron Lett.* **1975**, 499-502.
Tanemura, K.; et. al. *Chem. Commun.* **1992**, 979-980.
Cao, L. M.; et. al. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

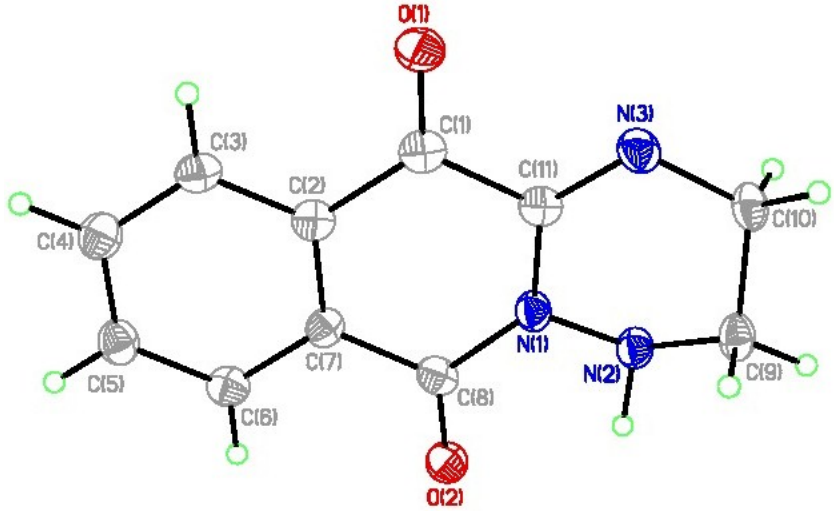
Model System Studies for the DEF Rings of Noelaquinone



noelaquinone



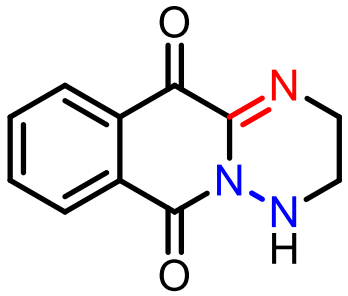
model system



Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

Bond Lenghth

entry	Bond (Å)	*d*	*m*	*σ*	*n*
1	C_{ar}-**C=N**-$C_{sp3(C,\ H)}$	1.279	1.279	0.008	75
2	$N_{pyramidal}$-N_{planar}	1.420	1.420	0.015	68



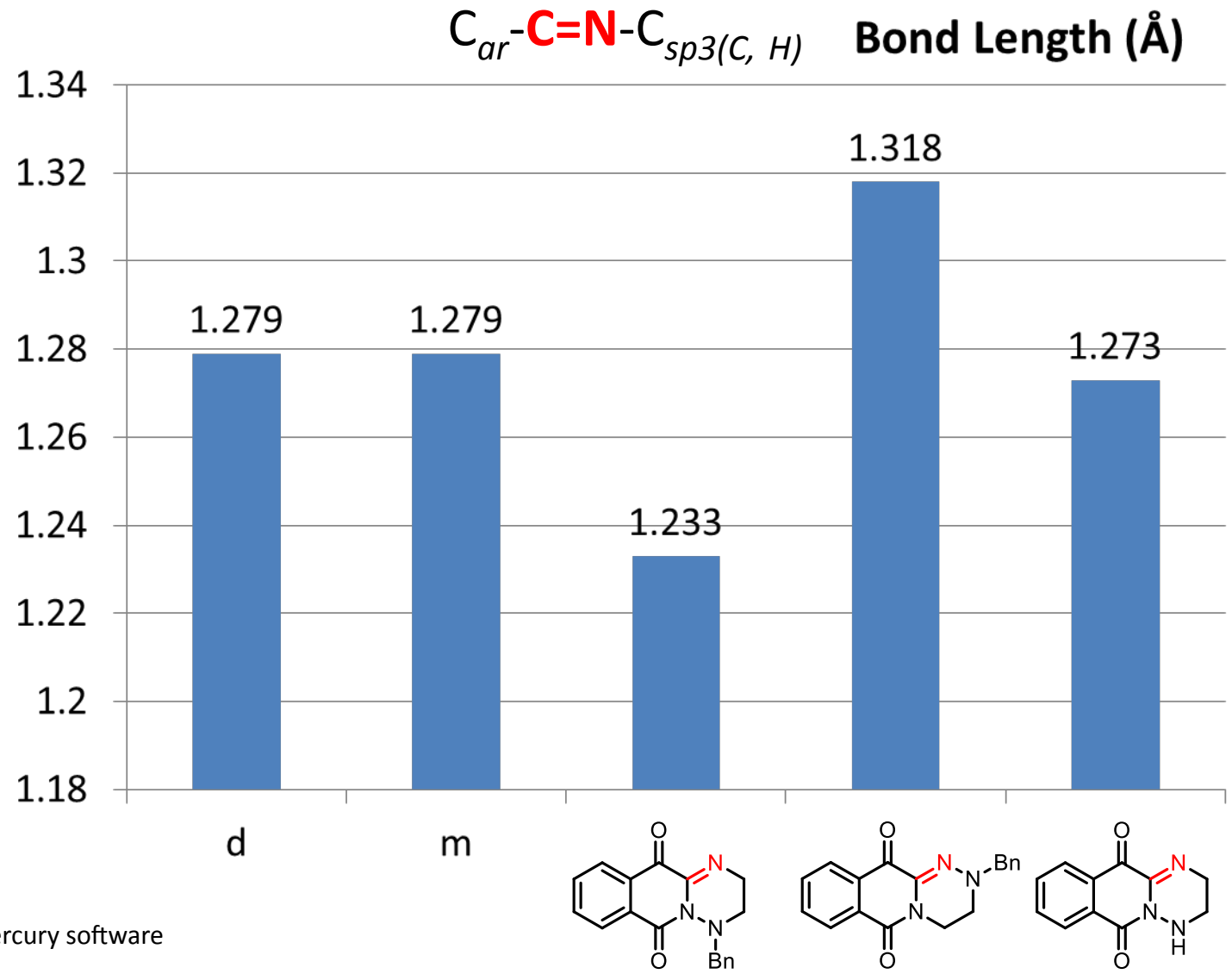
d: the unweighted sample mean, where the equation holds $d = \sum_{i=1}^{n} d_i/n$,
and d_i is the *i*th observation of the bond length in a total sample of n observations.

m: the sample median, which has the property that half of the observations in the sample exceed *m*, and half fall short of it.

σ: the sample standard deviation: $\sigma = \sum_{i=1}^{n} [(di - d)^2/(n-1)]^{\frac{1}{2}}$

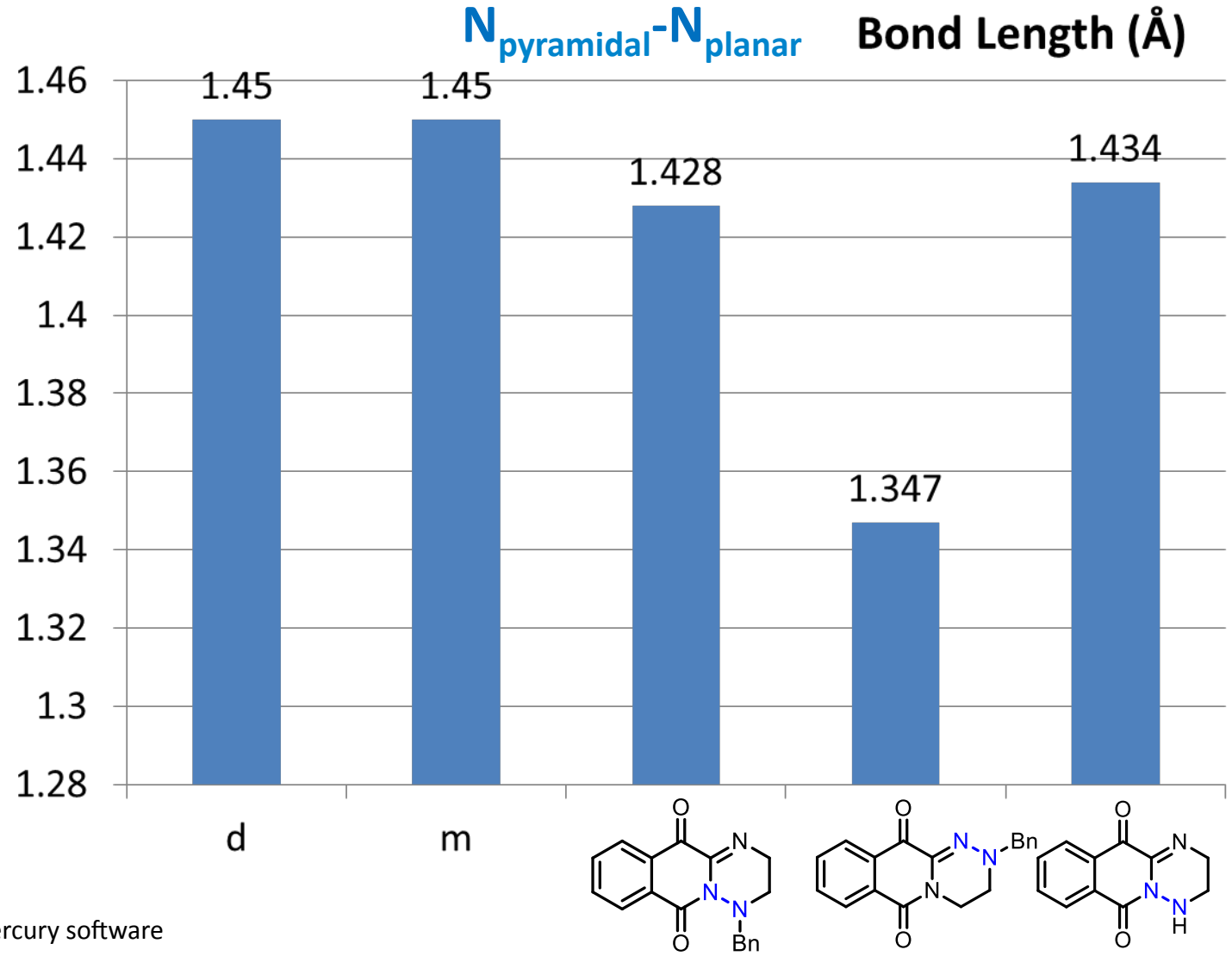
Allen, F. H.; Kennard, O.; Watson, D. G.; Brammer, L.; Orpen, A. G.; Taylor, R. *J. Chem. Soc. Perk. T. 2.,* **1987**, S1-S19.

Bond Lenghth



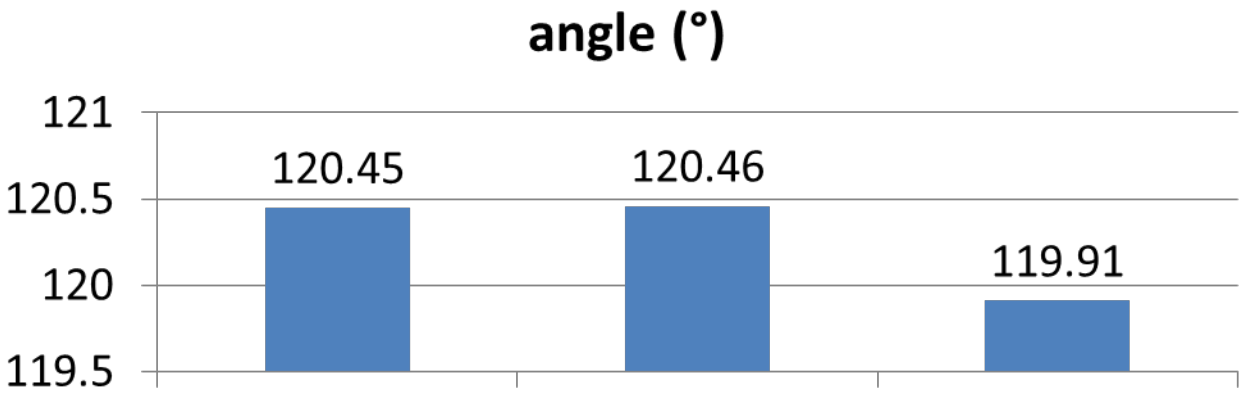
Mercury software

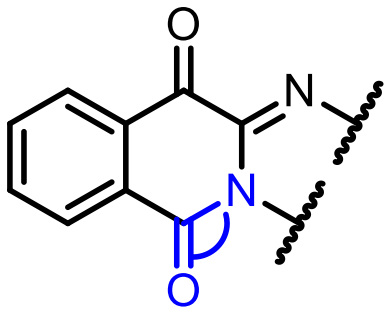
Bond Lenghth

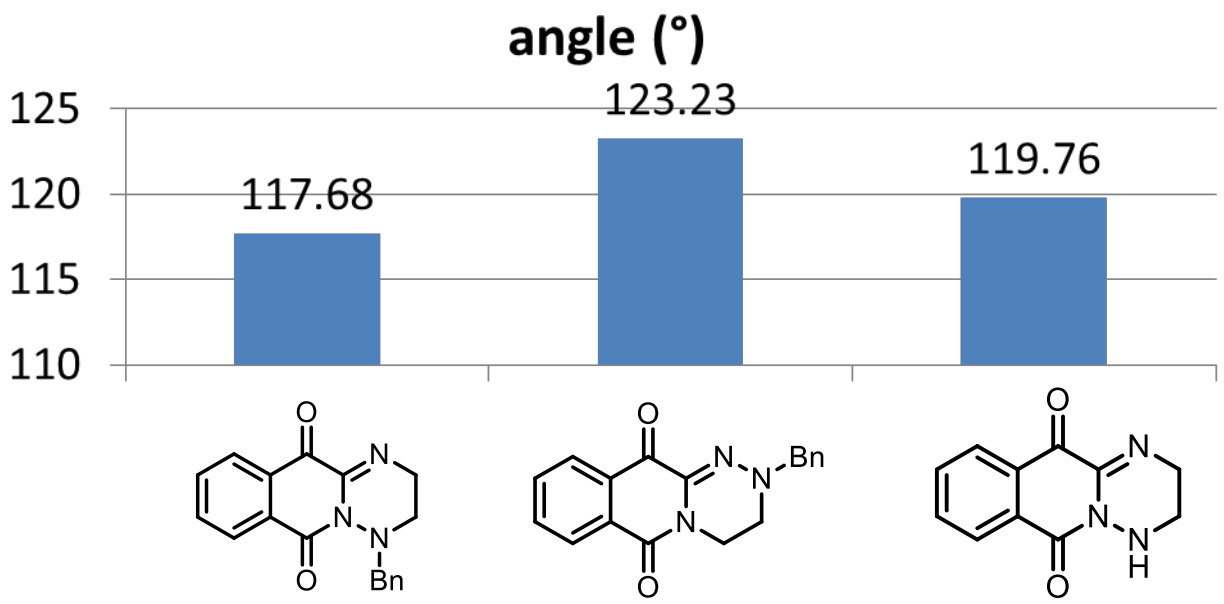


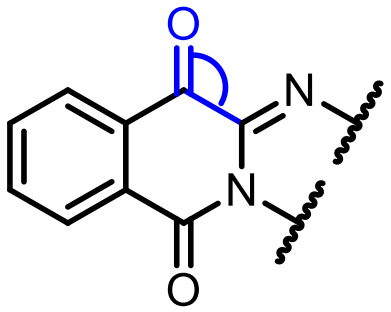
Mercury software

Bond Angle



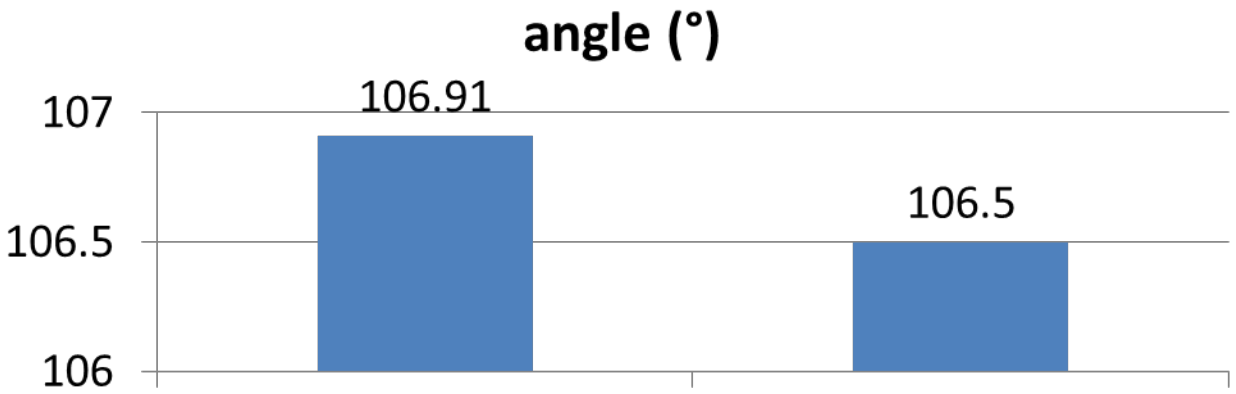


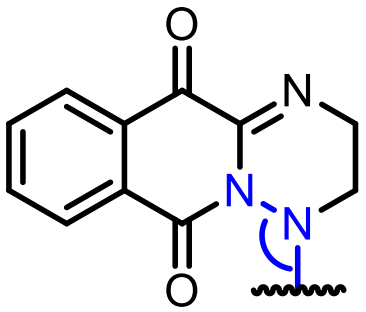


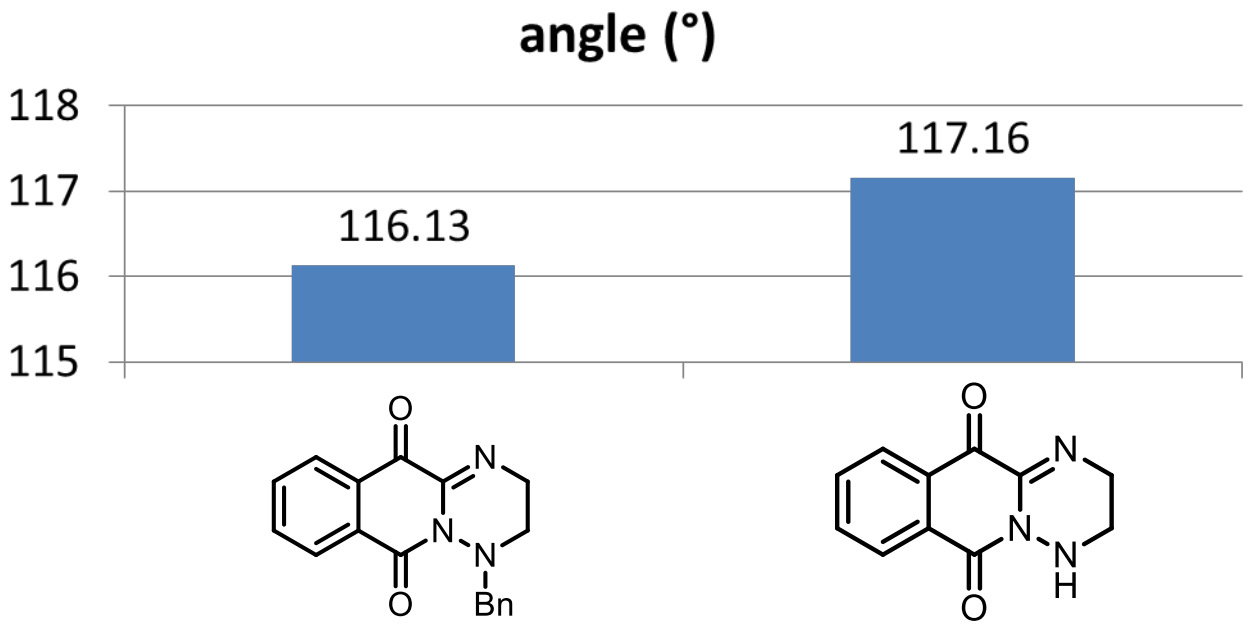


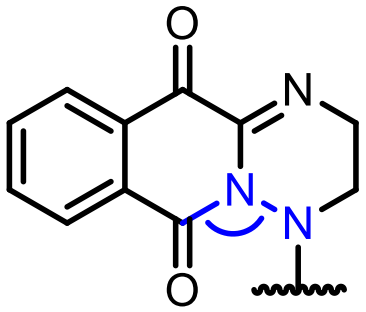
Mercury software

Bond Angle



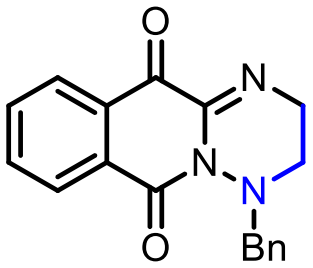


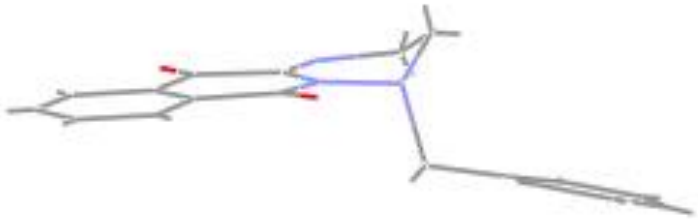


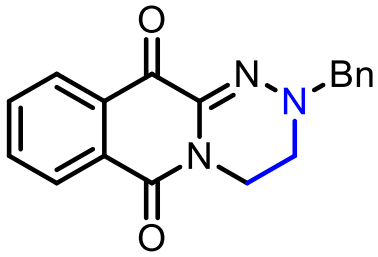


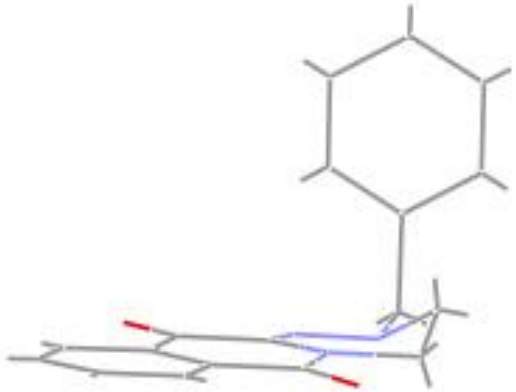
Mercury software

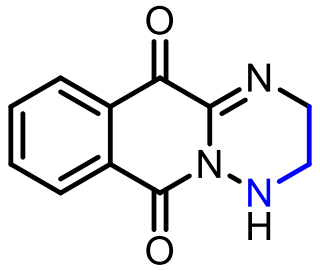
Conformation: Envelope





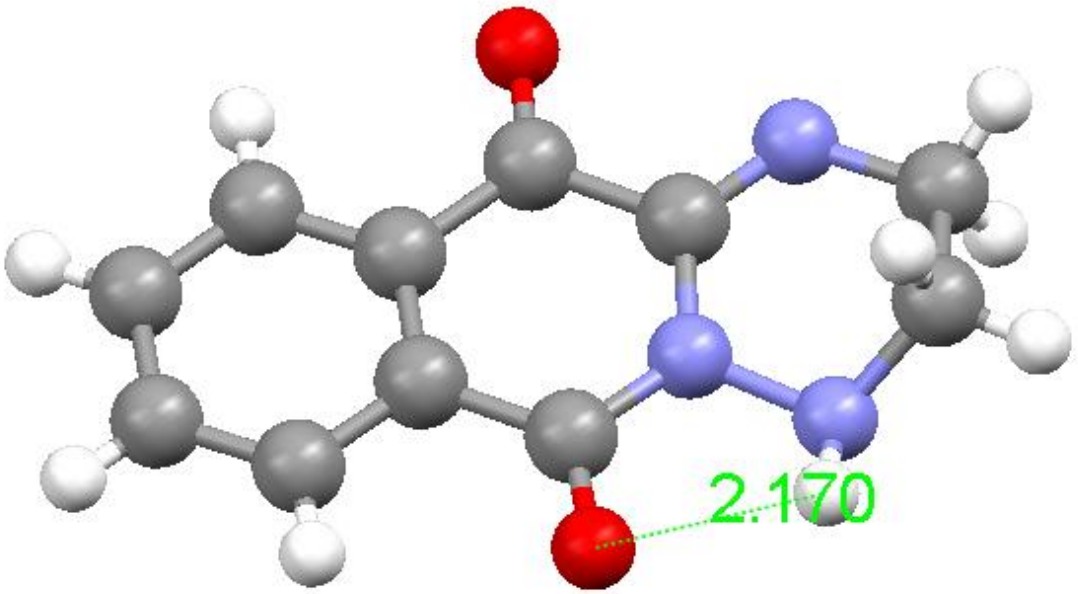


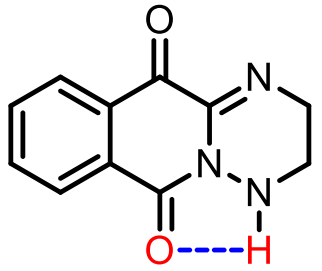




Mercury software

Hydrogen Bonding





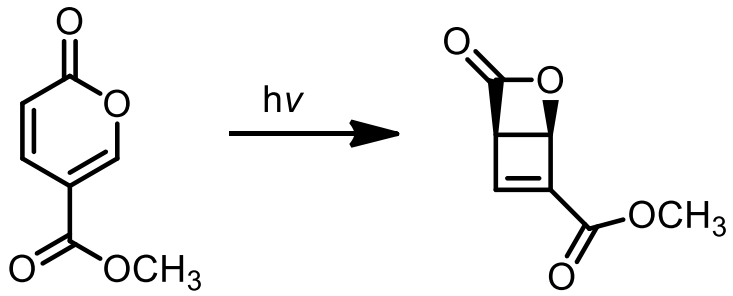
2.17 Å

Conclusion

- A model system for the DEF rings of the natural product noelaquinone was synthesized in 13 steps with an overall yield of 2%.
- A method to prepare an advanced hydrazine intermediate has been developed. This intermediate can be readily transformed into the homophthalimide via the Cu(I)-catalyzed C-arylation of diethyl malonate.
- An intramolecular Staudinger/*aza*-Wittig reaction served as a key step for the formation of the triazine moiety.

Cao, L. M.; Maciejewski, J. P. ; Elzner, S.; Amantini, D.; Wipf, P. *Org.Biomol. Chem.*, **2012**, *10*, 5811-5814.

2. Reactions Involving Methyl 3-Oxo-2-Oxabicyclo[2.2.0] Hexane-6-Carboxylate

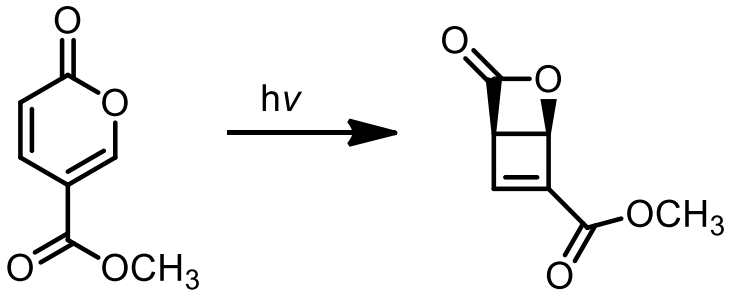


Photochemical 4π Electrocyclization

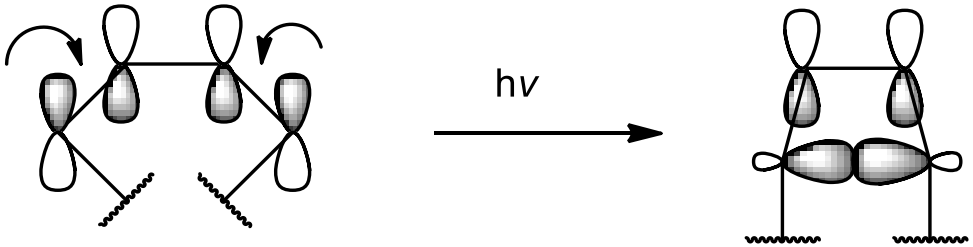
Liming Cao

Wipf Group Research Topic Seminar

Photochemical 4π Electrocyclization Reaction



Photochemical 4π Electrocyclization



HOMO of butadiene moiety

- Disrotatory rotation gives in-phase interactions .
- The product adopts a syn geometry .

Frontier molecular orbital analysis of photochemical 4π electrocyclization

Javaheripour, H.; Neckers, D. C. *J. Org. Chem.* **1977**, *42*, 1844-1850.
Gutekunst, W. R.; Baran, P. S. *J. Am. Chem. Soc.* **2011**, *133*, 19076-19079.
Fukui, K.; Yonezawa, T.; Shingu, H. *J. Chem. Phys.* **1952**, *20*, 722-725.

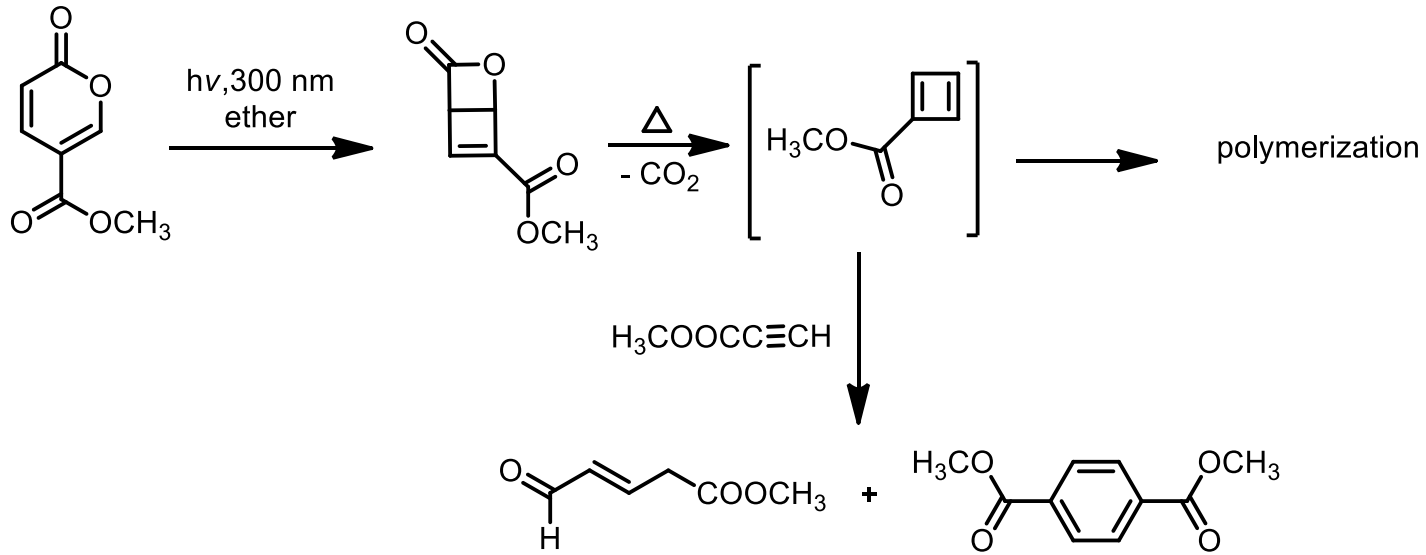
Previous Work

Corey:

2-pyrone

N-Methyl-2-pyridone

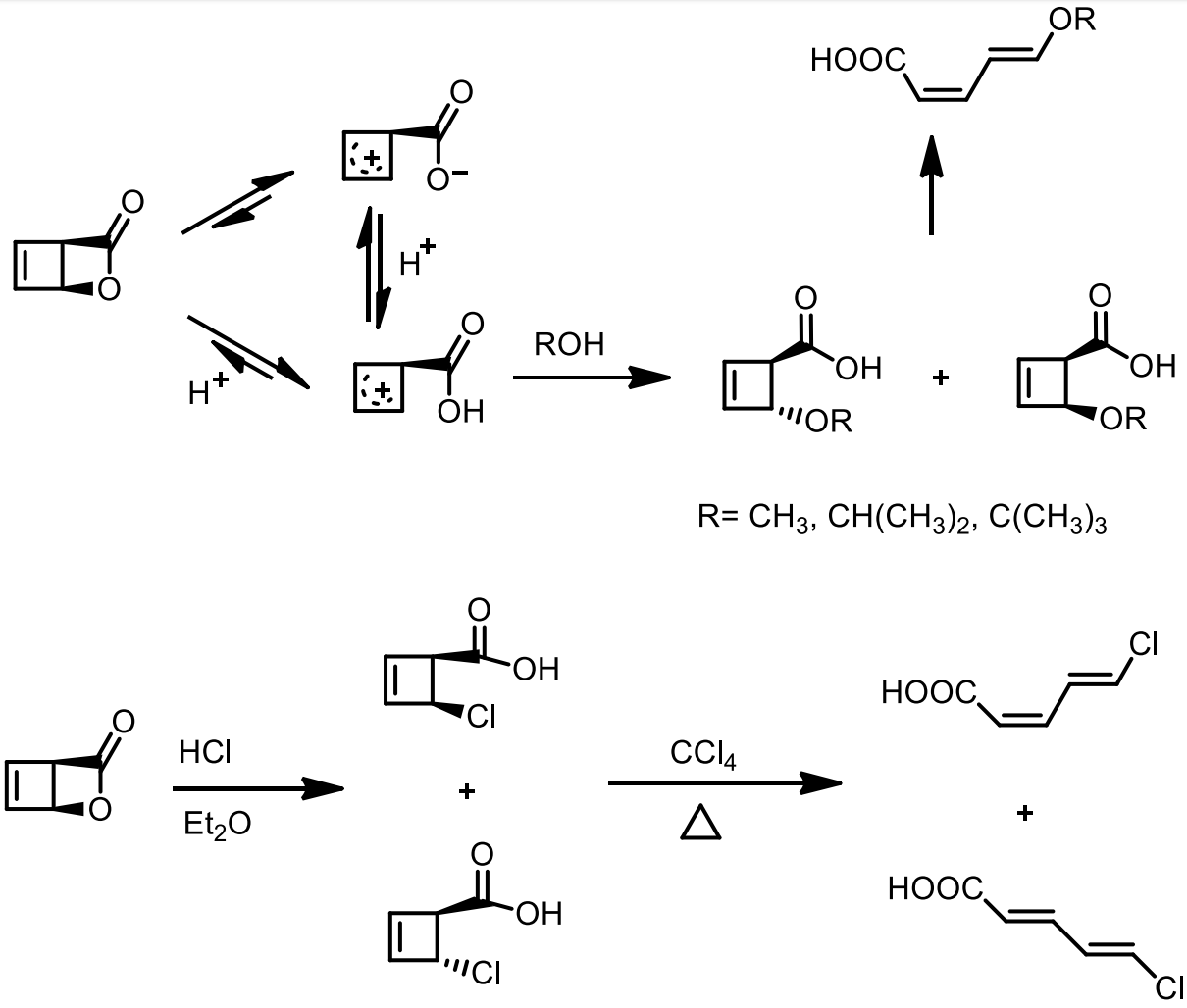
Neckers:



Corey, E. J.; Streith, J. *J. Am. Chem. Soc.* **1964**, *86*, 950.
Javaheripour, H.; Neckers, D. C. *J. Org. Chem.* **1977**, *42*, 1844-1850.

Previous Work

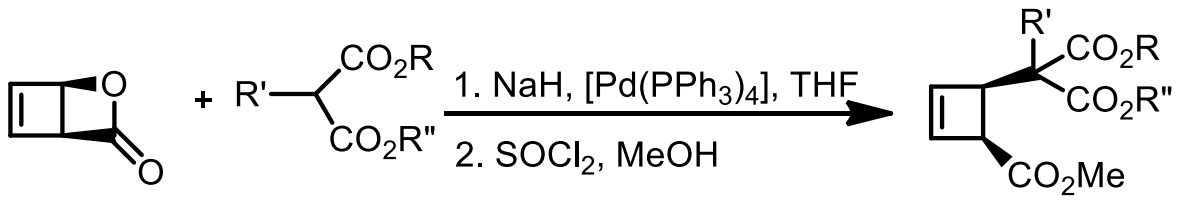
Mckendry:



Pirkle, W. H.; Mckendry, L. H. *J. Am. Chem. Soc.* **1969**, *91*, 1179.

Previous Work

Maulide: a Tsuji-Trost reaction catalyzed by $Pd(PPh_3)_4$

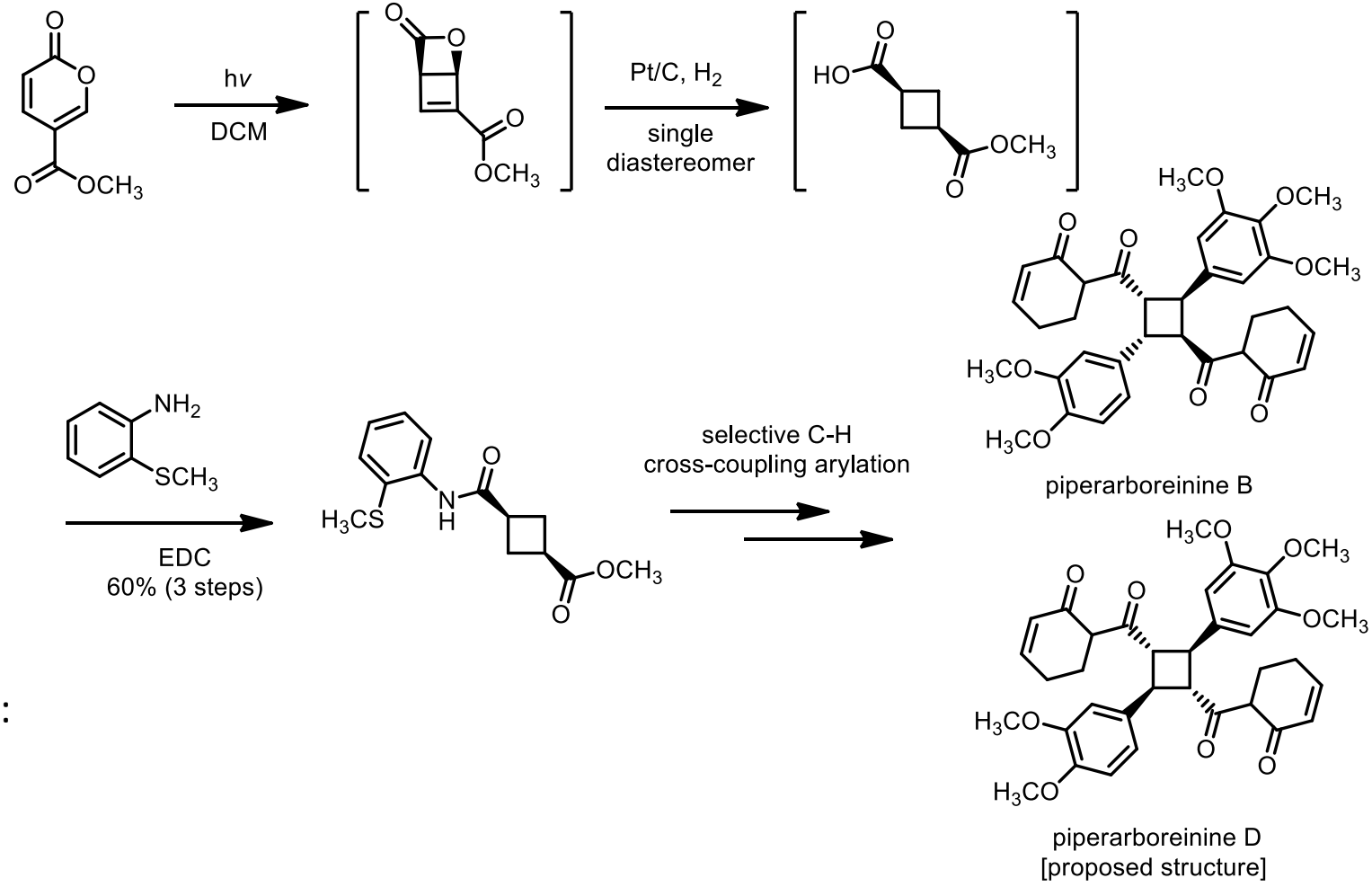


R, R" = alkyl groups

R' = alkyl, benzyl, acetate, allyl, and homopropargyl groups

Frebault, F.; Luparia, M.; Oliveira, M. T.; Goddard, R.; Maulide, N. *Angew. Chem. Int. Ed. Engl.* **2010**, *49*, 5672-5676.

Previous Work



Baran:

Gutekunst, W. R.; Baran, P. S. *J. Am. Chem. Soc.* **2011**, *133*, 19076-19079.

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