

A One-Slide Summary of Quantum Mechanics

Fundamental Postulate:

$$O \Psi = a \Psi$$

operator wave function (scalar) observable

What is Ψ ? *Ψ is an oracle!*

Where does Ψ come from? *Ψ is refined*

Variational Process

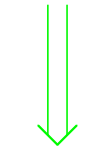
$$\mathcal{H}\Psi = E \Psi$$

Hamiltonian operator (systematically improvable)

Energy (cannot go lower than "true" energy)

electronic road map: systematically improvable by going to higher resolution

convergence of E

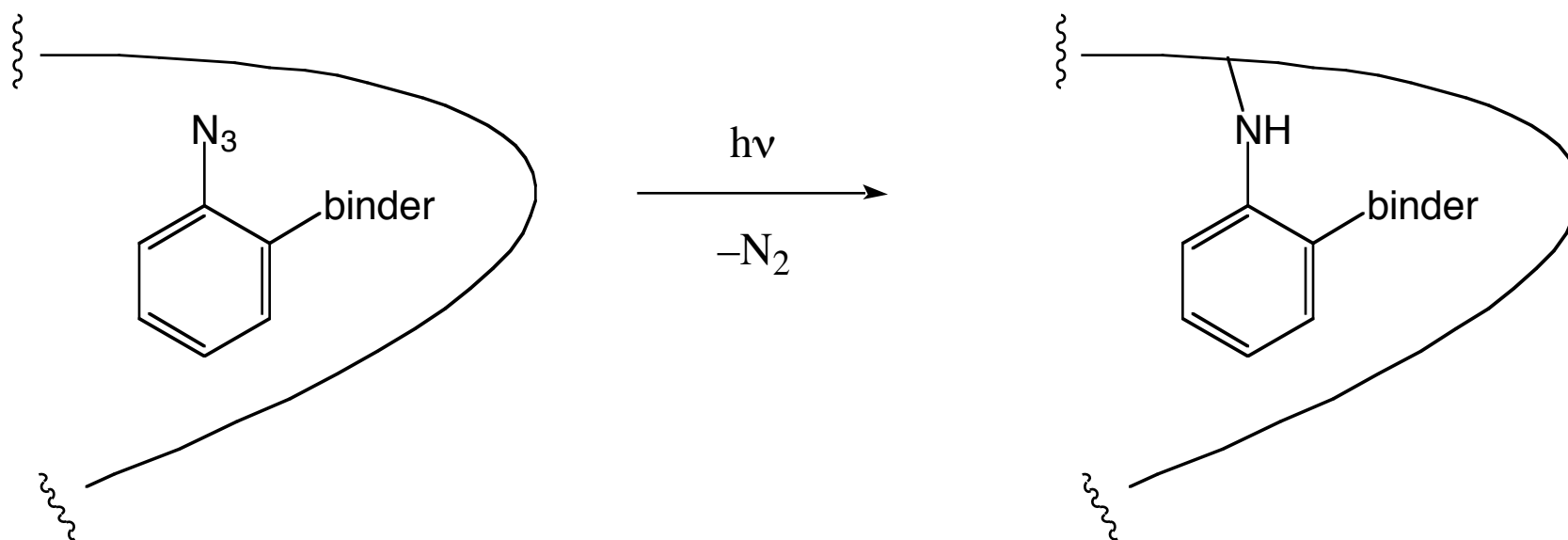


truth

What if I can't converge E ?

Test your oracle with a question to which you already know the right answer...

Photoaffinity Labeling 1



ligand with attached photoaffinity label in enzyme active site

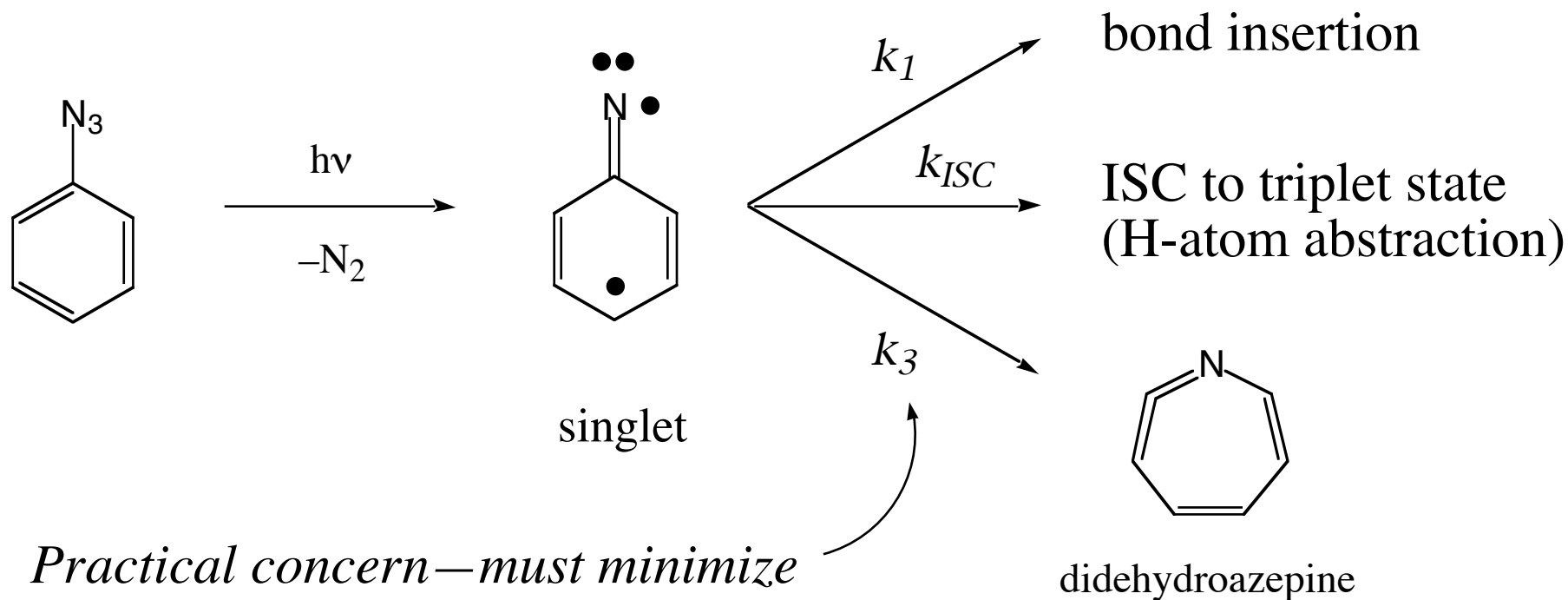
singlet nitrene covalently modifies enzyme – active site can be identified by sequencing of protein

Photoaffinity Labeling 2

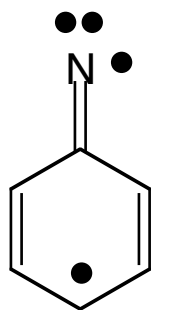
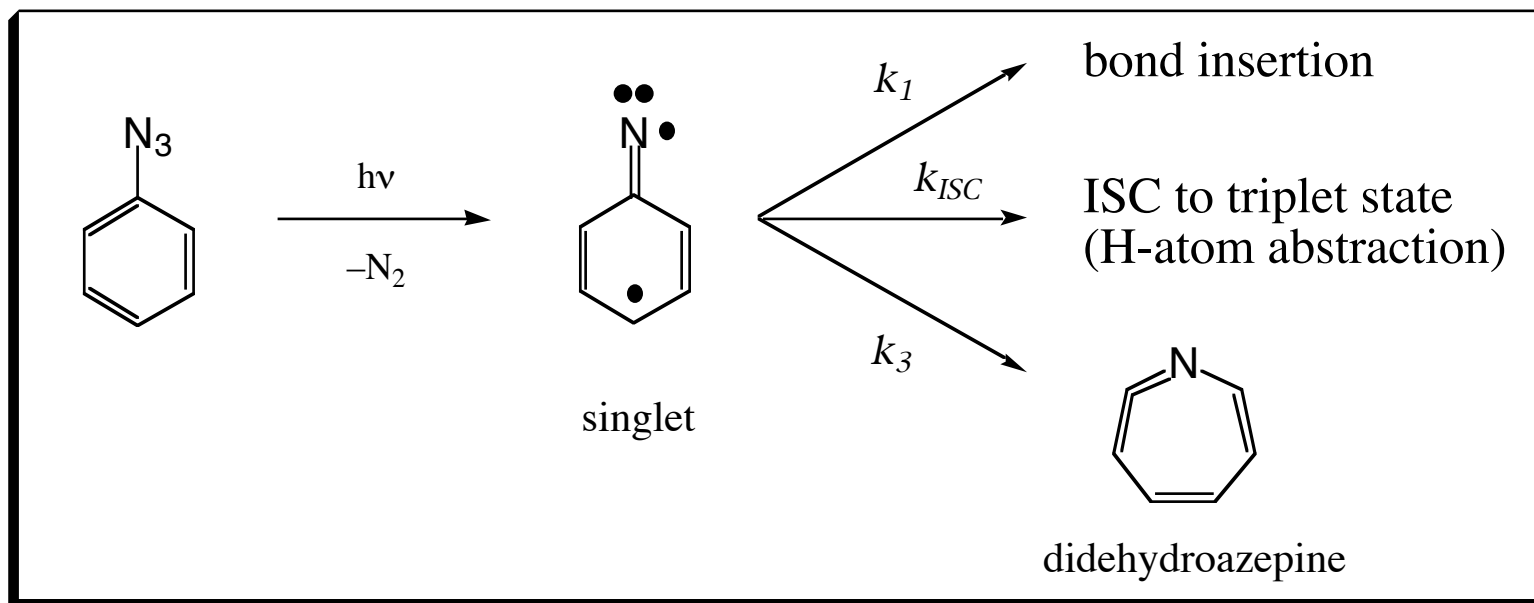
Attractive features of aromatic nitrenes as photoaffinity labels:

- 1) Generated with light outside of protein absorption bands*
- 2) Highly reactive singlets*
- 3) N_2 is an innocuous byproduct of activation*

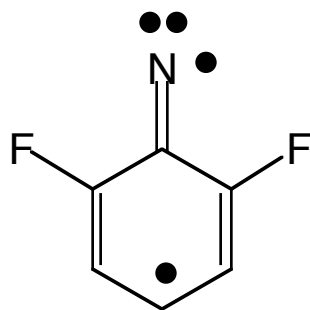
But:



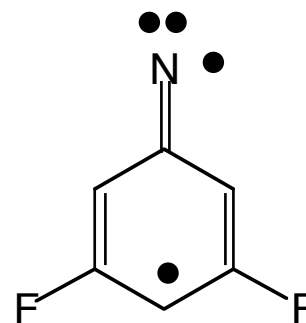
Photoaffinity Labeling 3



$$k_3 > k_1$$



$$k_1 > k_3$$



$$k_3 > k_1$$

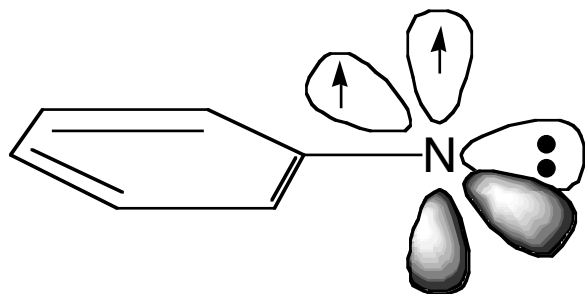
Platz et al.

A Plea for Help from Quantum Mechanics

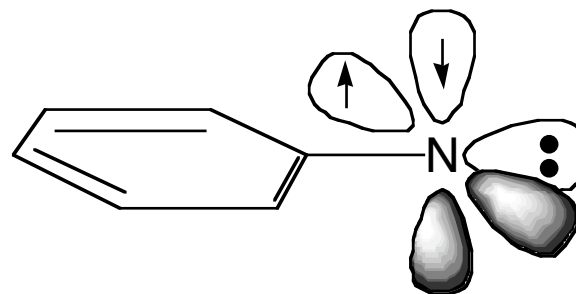
High level ab initio calculations of 2,6-difluorophenyl-nitrene and 3,7-difluoro-[1,2]-didehydroazepine (and their 3,5-disubstituted isomers, where there is no fluorine effect) would be most welcome and instructive!

M. S. Platz, *Accounts of Chemical Research*, **1995**, 28, 487.

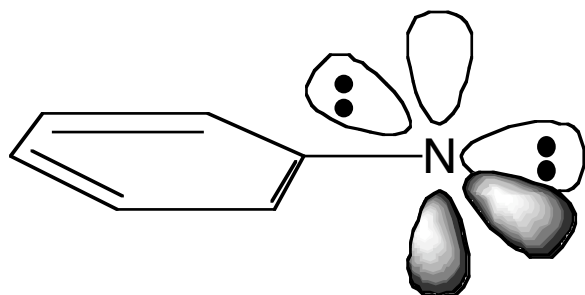
Configuration Cartoons



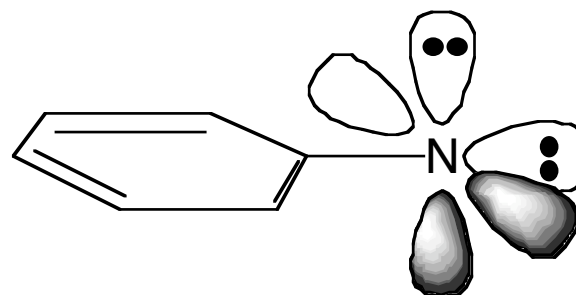
3A_2 (T0)



1A_2 (S1)

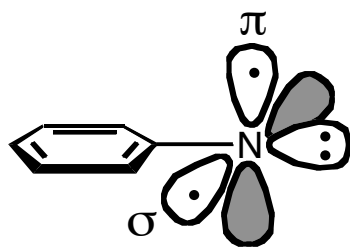


1^1A_1 (S2)



2^1A_1 (S3)

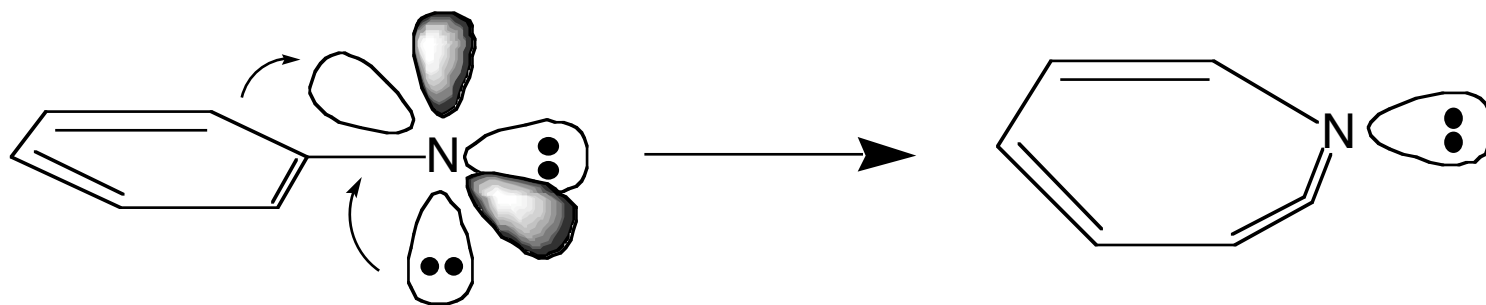
Relative E (kcal/mol) for PhN



	3A_2	1A_2	1^1A_1	2^1A_1
MRCISD/DZP	0.0	21.0	39.8	(52)
CASPT2N(8,8)/TZP	0.0	19.3	34.8	54.5
CCSD(T)/DZP	0.0	—	35.2	(47.2)
BLYP/TZP	0.0	(14.3)	29.5	(41.0)
Expt.	0.0	18	30	?

Kim, S.-J.; Hamilton, T. P.; Schaefer, H. F. *J. Am. Chem. Soc.* **1992**, *114*, 5349;
 Hrovat, D. A.; Waali, E. E.; Borden, W. T. *ibid.* **1992**, *114*, 8698; Smith, B. A.;
 Cramer, C. J. *ibid.* **1996**, *118*, 5490; Travers, M. J.; Cowles, D. C.; Clifford, E. P.;
 Ellison, G. B. *ibid.* **1992**, *114*, 8699.

Ring Expansion Mechanism

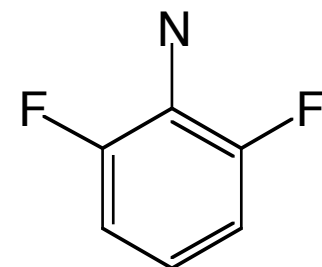
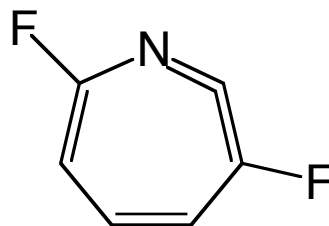
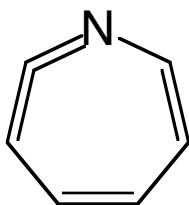
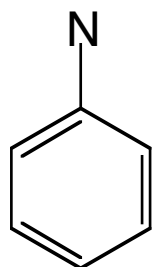
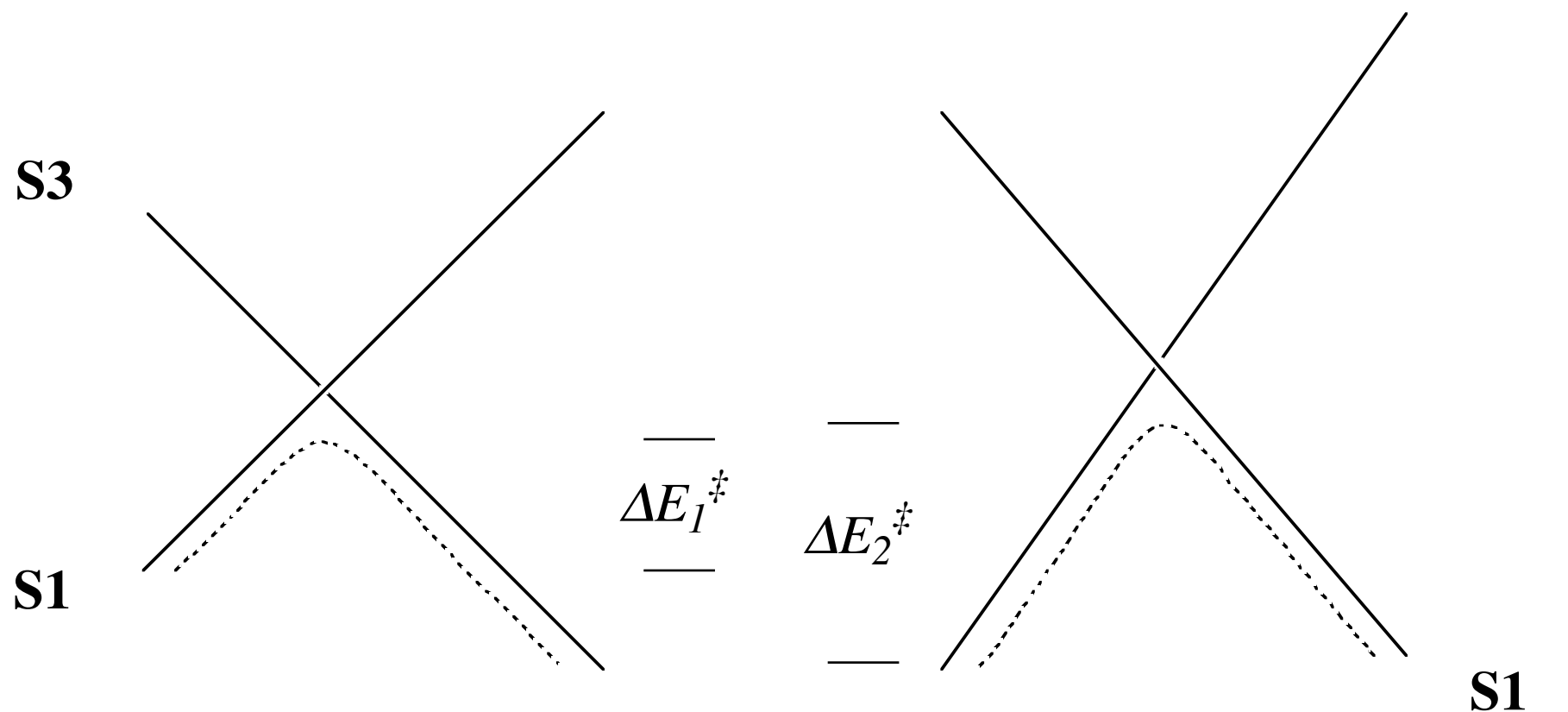


Wagner-Meerwein shift of
CH to aligned in-plane
(empty) N p orbital

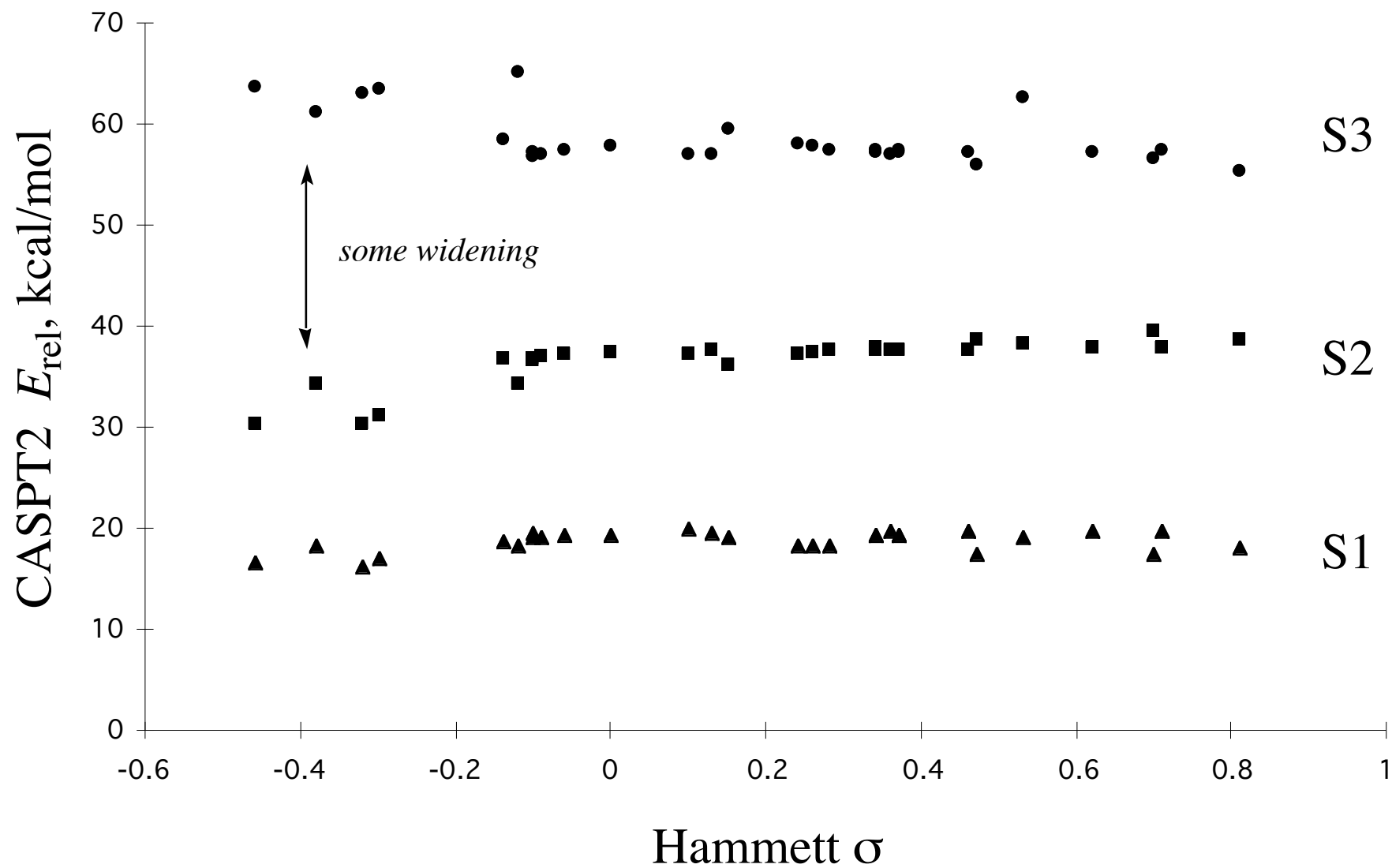
The electronic configuration
of the didehydroazepine
correlates with the S3 nitrene

Avoided Crossing

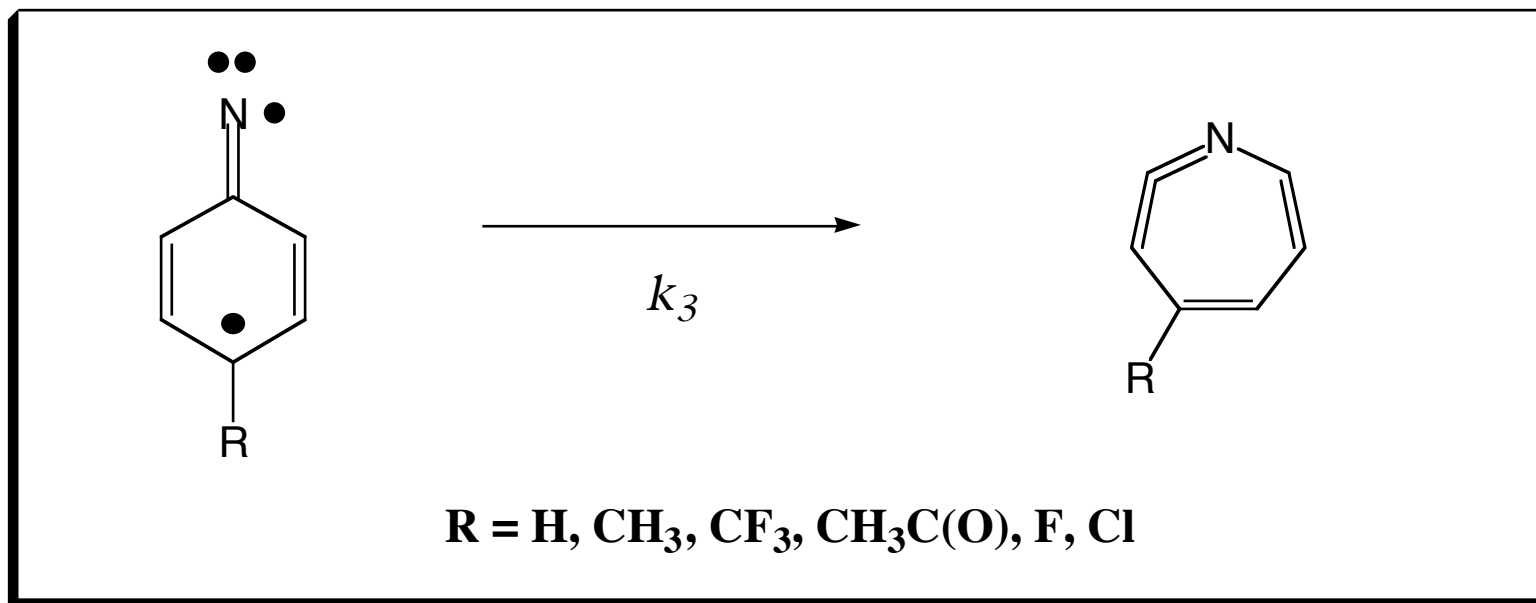
π -Electron-donating groups should slow ring expansion **S3**



Phenylnitrene Energies With 32 Different *meta* and *para* Substituents



Photoaffinity Labeling 5

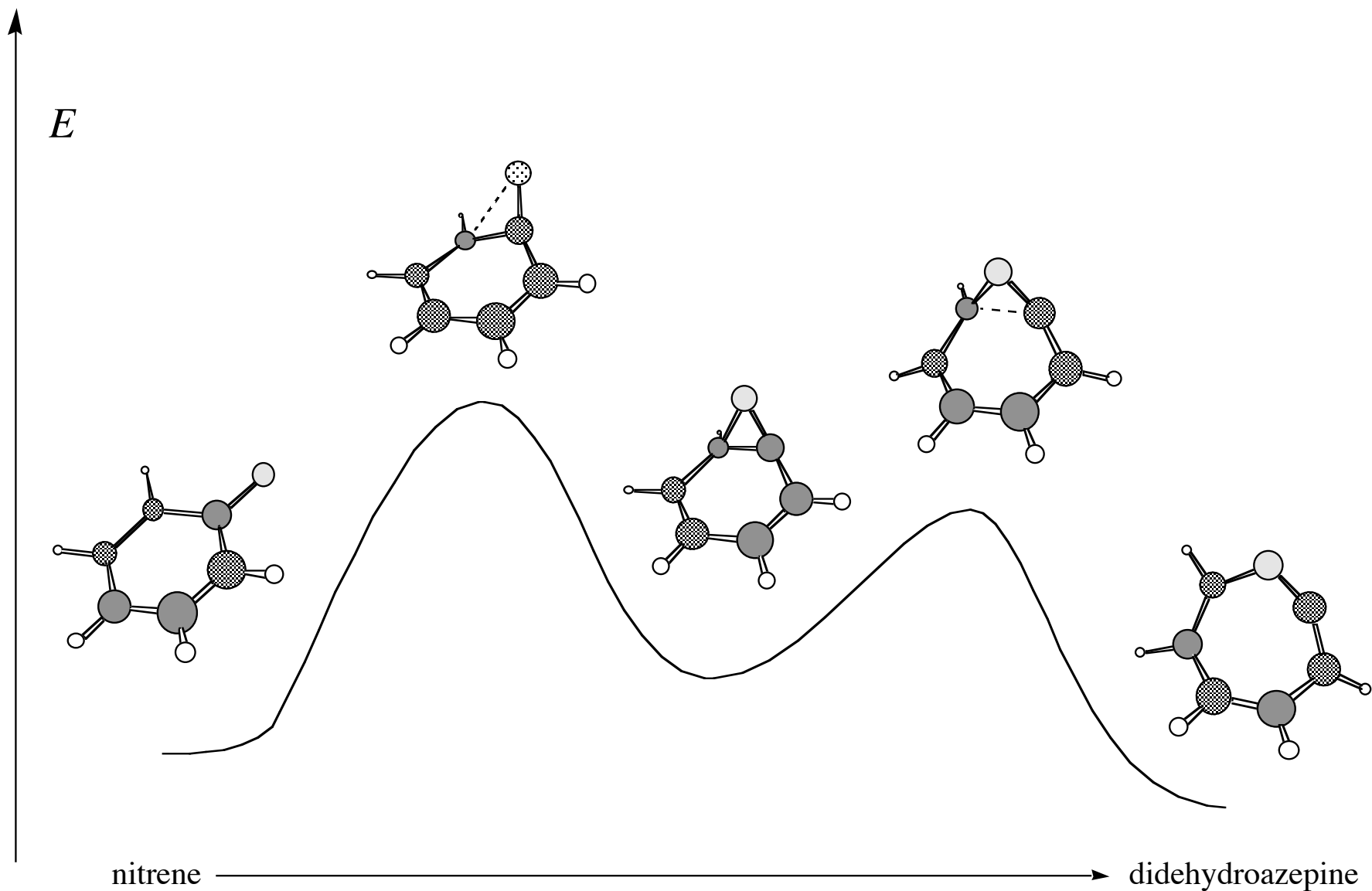


"Measured" $E_a = 5.7 \pm 0.4$ kcal/mol in every case

For $R = \text{I}, \text{OCH}_3, \text{N}(\text{CH}_3)_2$, ISC too fast to measure k_3

Gritsan, N. P.; Tigelaar, D.; Platz, M. S. *J. Phys. Chem. A* **1999**, *103*, 4465.

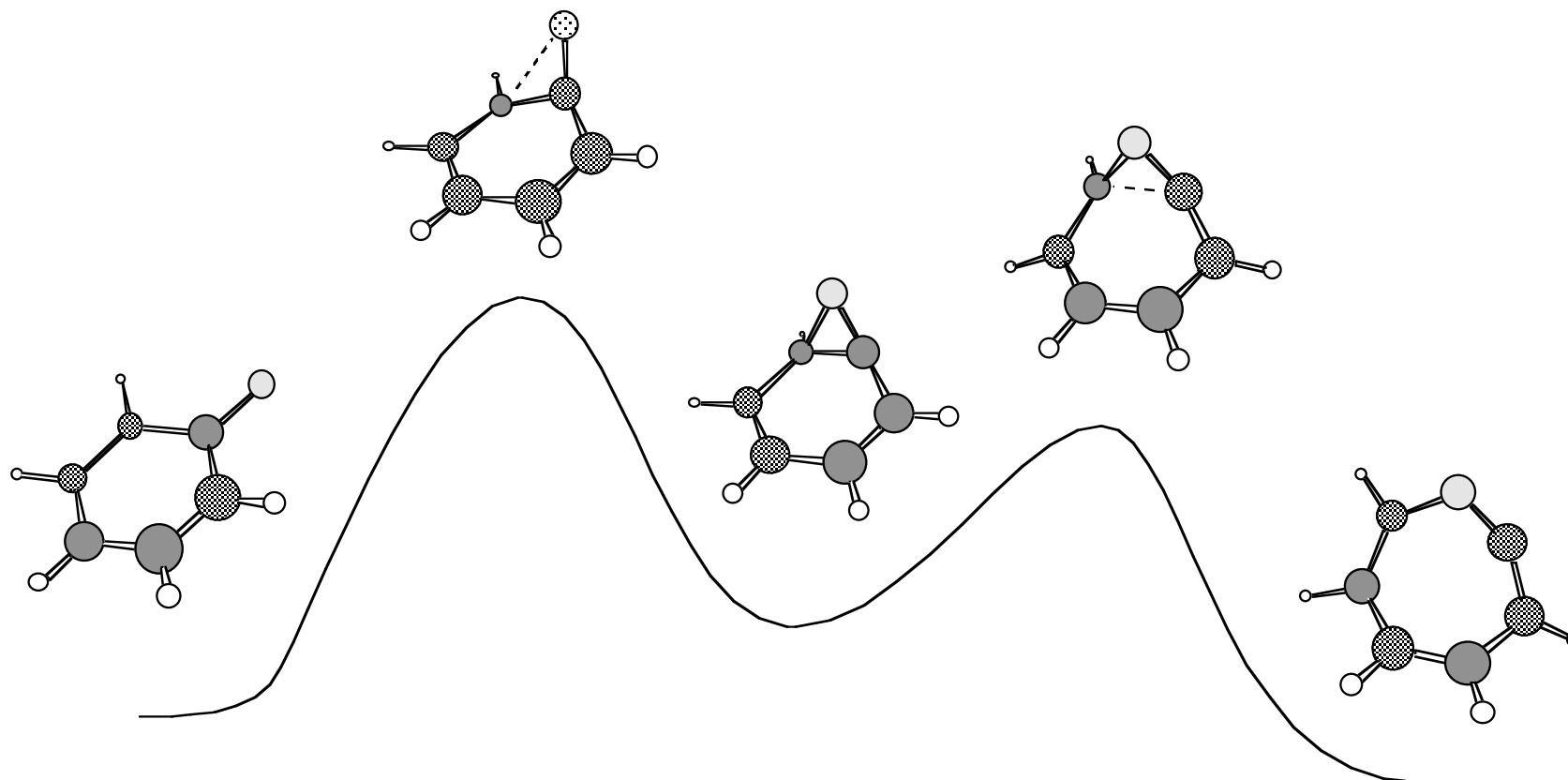
Actual Ring Expansion Reaction Coordinate



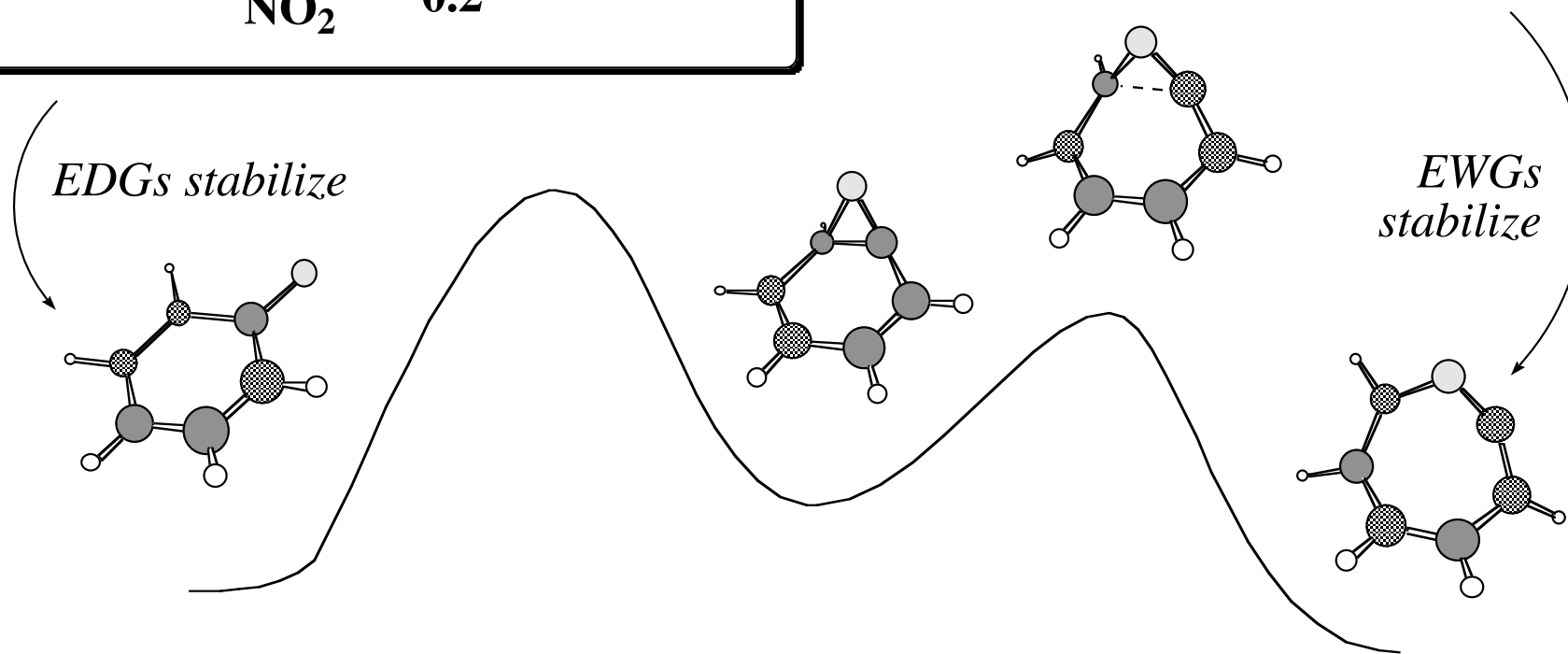
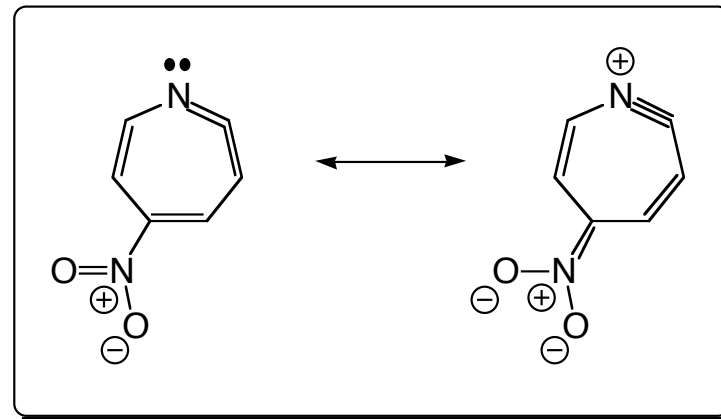
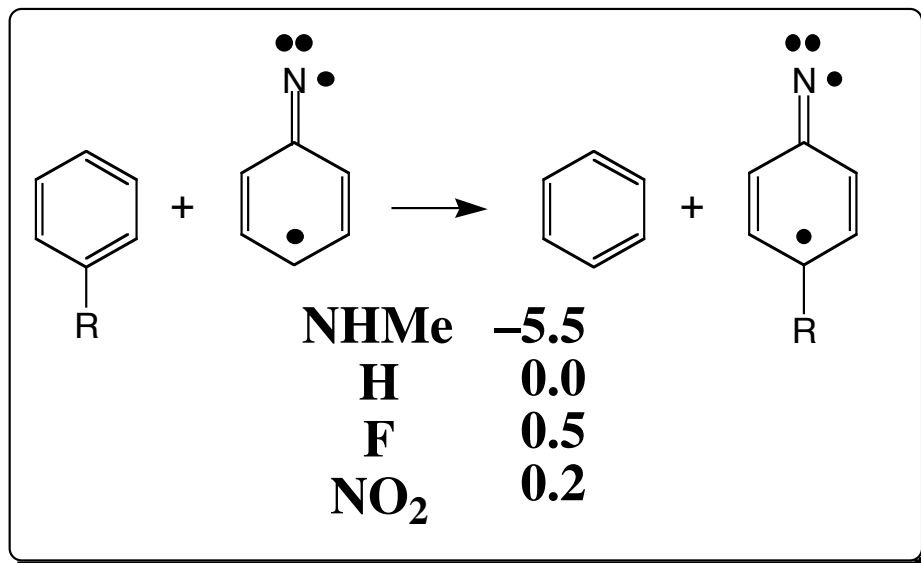
Substituent Effects on Ring Expansion Coordinate

Relative 298 K enthalpies in kcal/mol

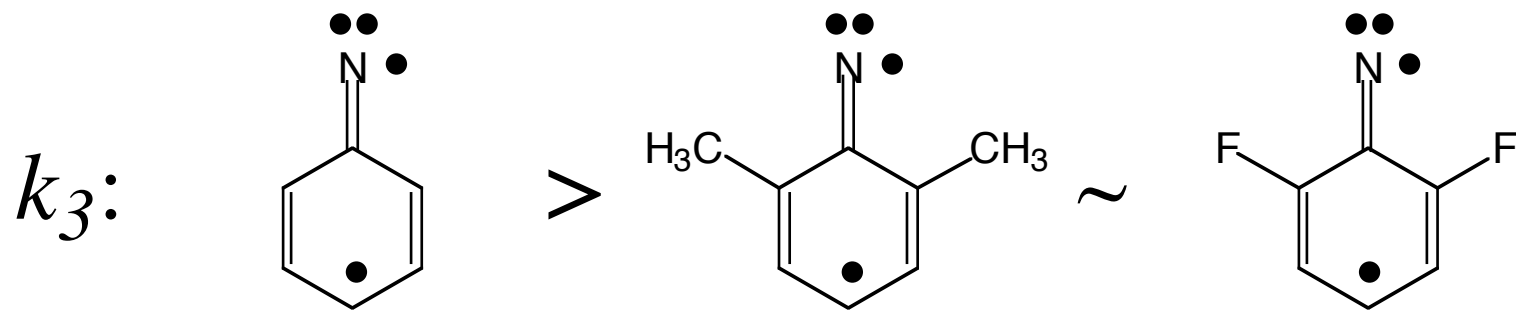
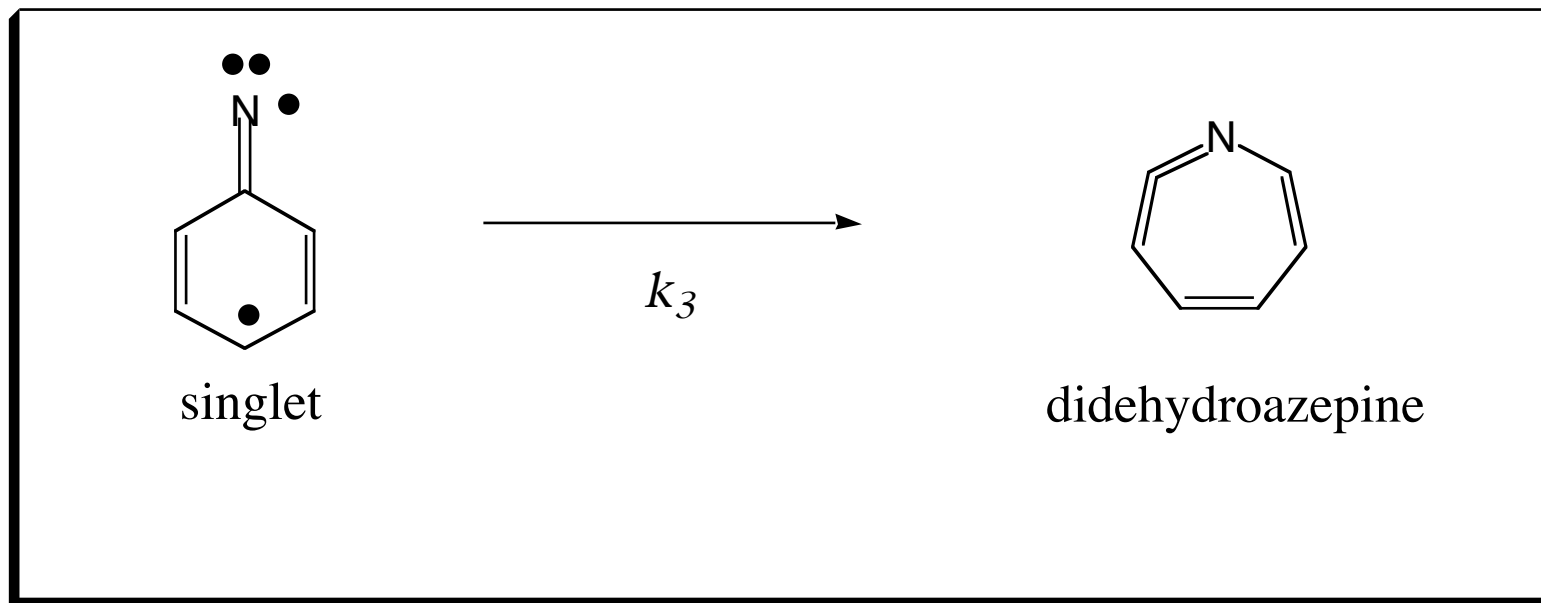
NHMe	12.3	8.5	13.3	1.7
H	8.5	2.7	5.8	-1.9
F	8.9	3.0	7.3	-1.6
NO₂	9.5	3.7	4.8	-0.7



Substituent Effects Rationalized



Photoaffinity Labeling 4

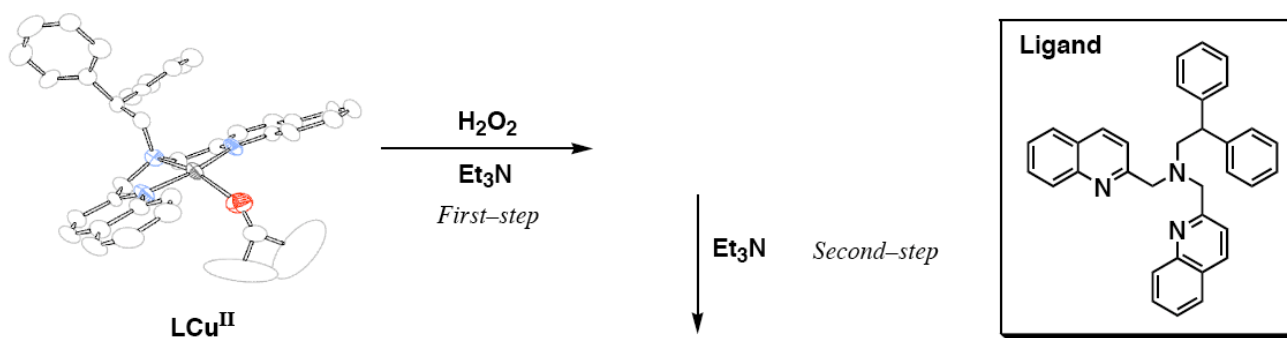


Karney, W. L.; Borden, W. T. *J. Am. Chem. Soc.* **1997**, *119*, 3347.

Theoretical Recommendation

Optimal photoaffinity labels will be aromatic azides combining steric bulk at *ortho* positions with strong electron-donating group at *para* position

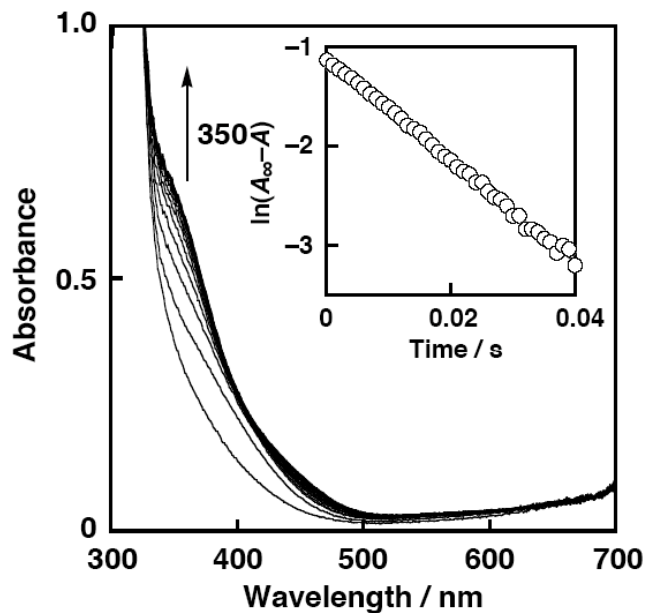
Activation of O₂ by Cu^{II}?



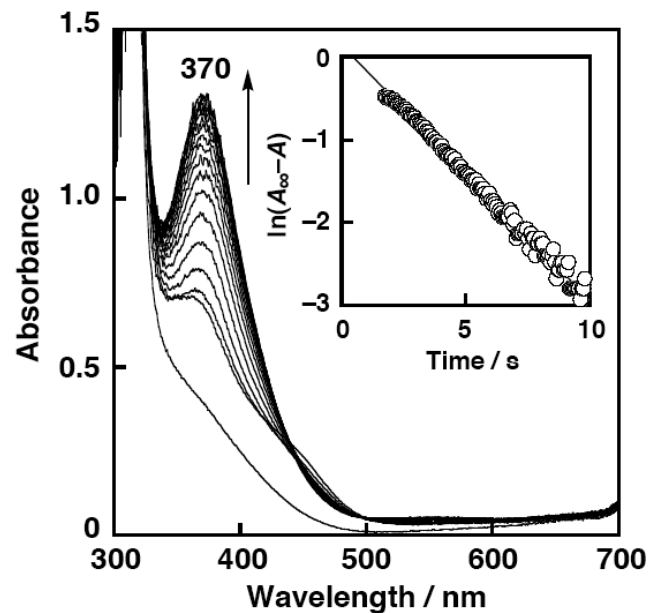
Shinobu Itoh

UV-vis

First-step ($t = 0 \sim 0.04$ s)



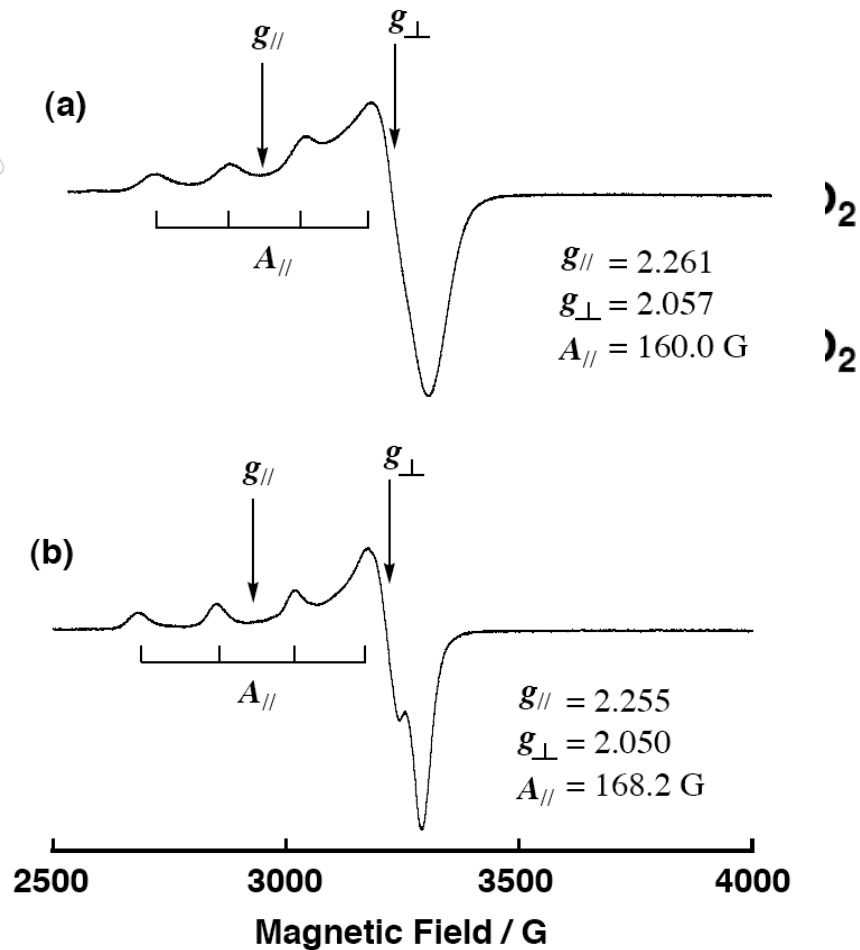
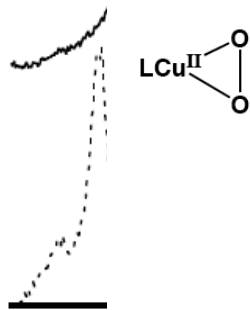
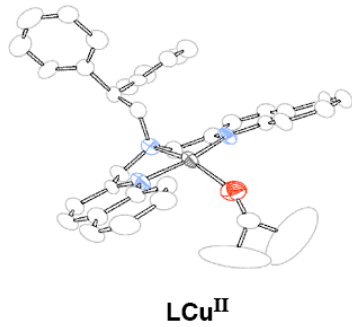
Second-step ($t = 0.04 \sim 10$ s)



Are the Spectral Data Consistent?

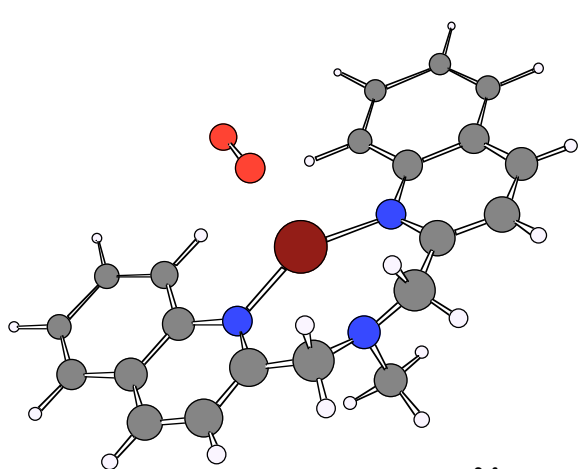
ESR

Resonance Rai



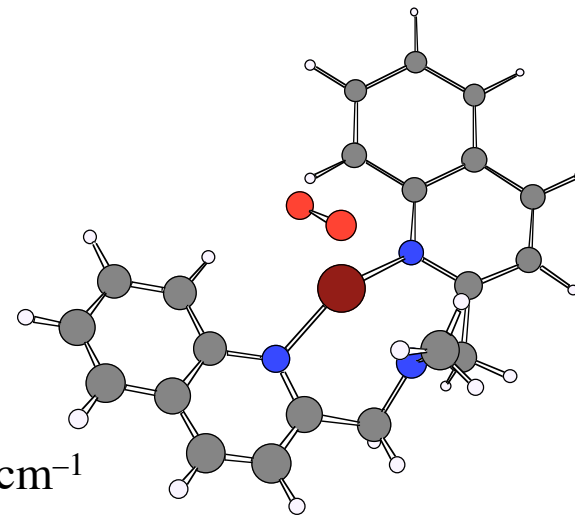
?

What Does Theory Have to Say?



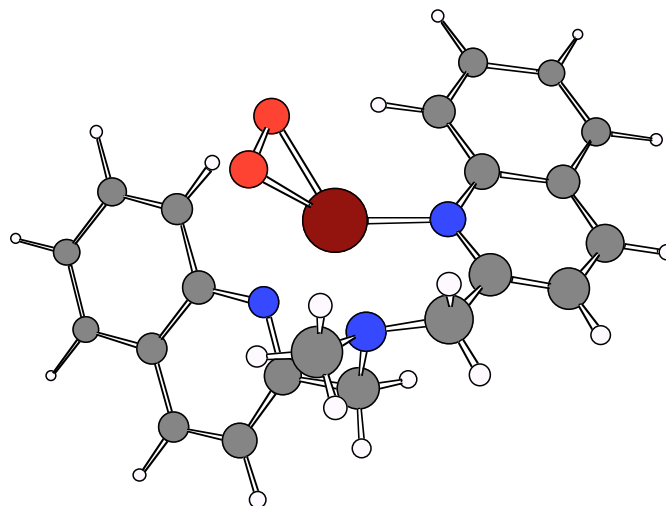
$$\nu_{\text{OO}} = 1158 \text{ cm}^{-1}$$

minima



$$\nu_{\text{OO}} = 1019 \text{ cm}^{-1}$$

*ESR spectral predictions
for all 3 cases
are consistent with most
spin being on oxygen
(which is inconsistent
with the experimental
spectrum)*



$$\nu_{\text{OO}} = 953 \text{ cm}^{-1}$$

(but blank in 500-
600 cm^{-1} range)

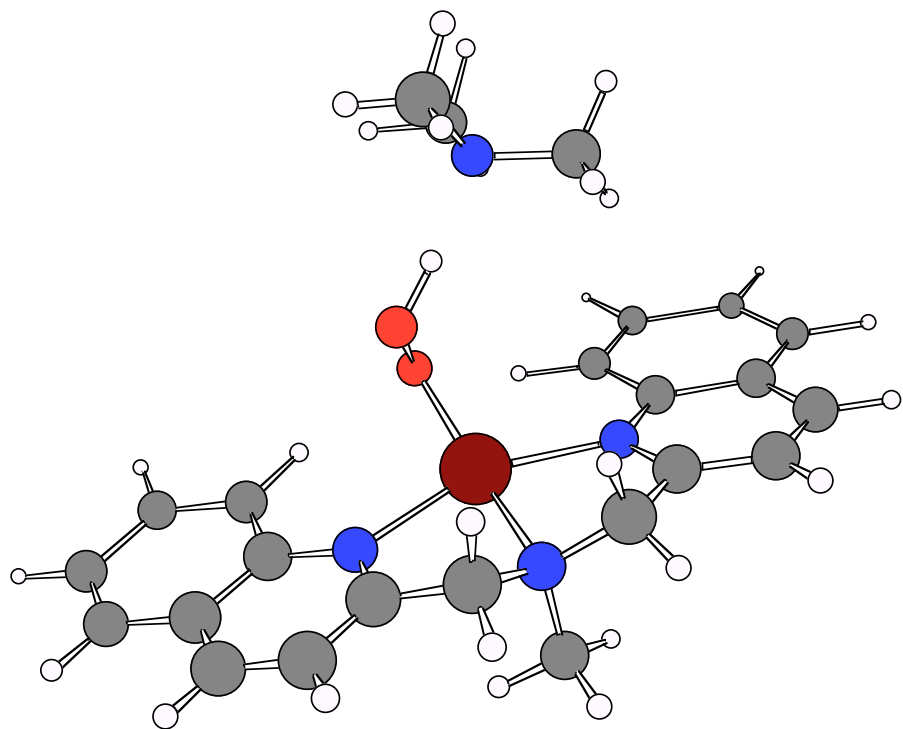
Time to Make Some *Predictions*

Experiment

$$\nu_{\text{OO}} = 900 \text{ cm}^{-1} \quad ({}^{18}\Delta\nu = 51)$$

$$\nu_{\text{CuO}} = 582 \text{ cm}^{-1} \quad ({}^{18}\Delta\nu = 23)$$

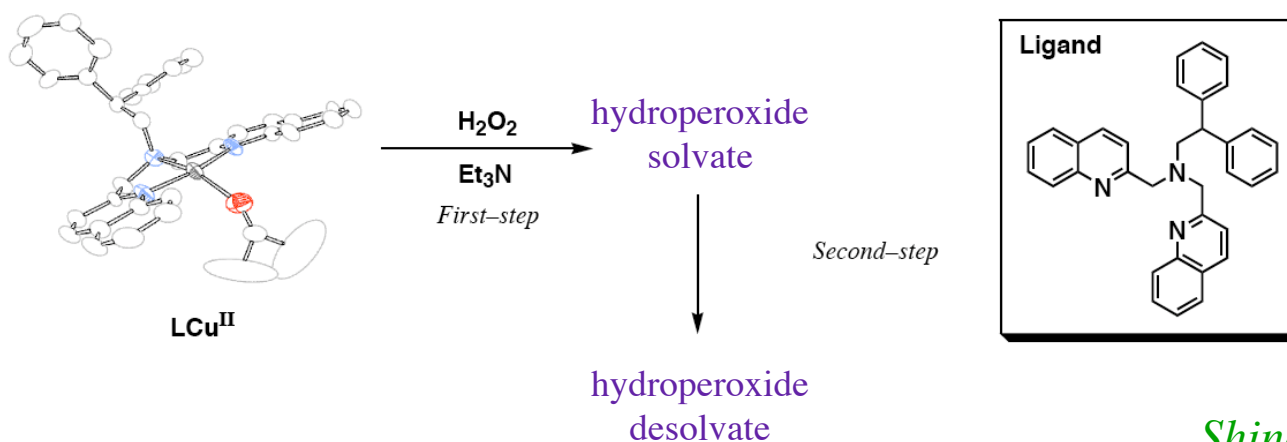
$$A_{\parallel} = 168.2 \text{ G}$$



Is that sufficient proof?

Theory predicts a shift in ν_{OO} of 5 cm^{-1} for the $-\text{OOD}$ isotopomer. A straightforward experiment (in progress) to run the stop-flow with DOOD instead of HOOH and check this *prediction*.

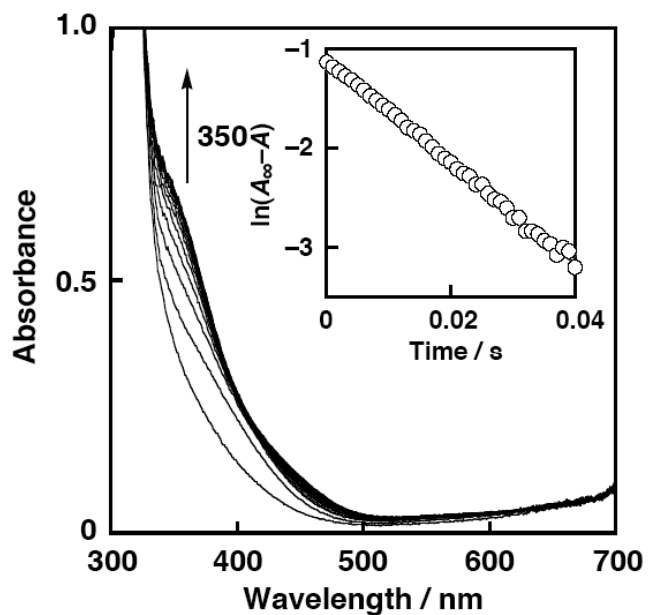
What About Cu^{II}?



Shinobu Itoh

UV-vis

First-step ($t = 0 \sim 0.04$ s)



Second-step ($t = 0.04 \sim 10$ s)

