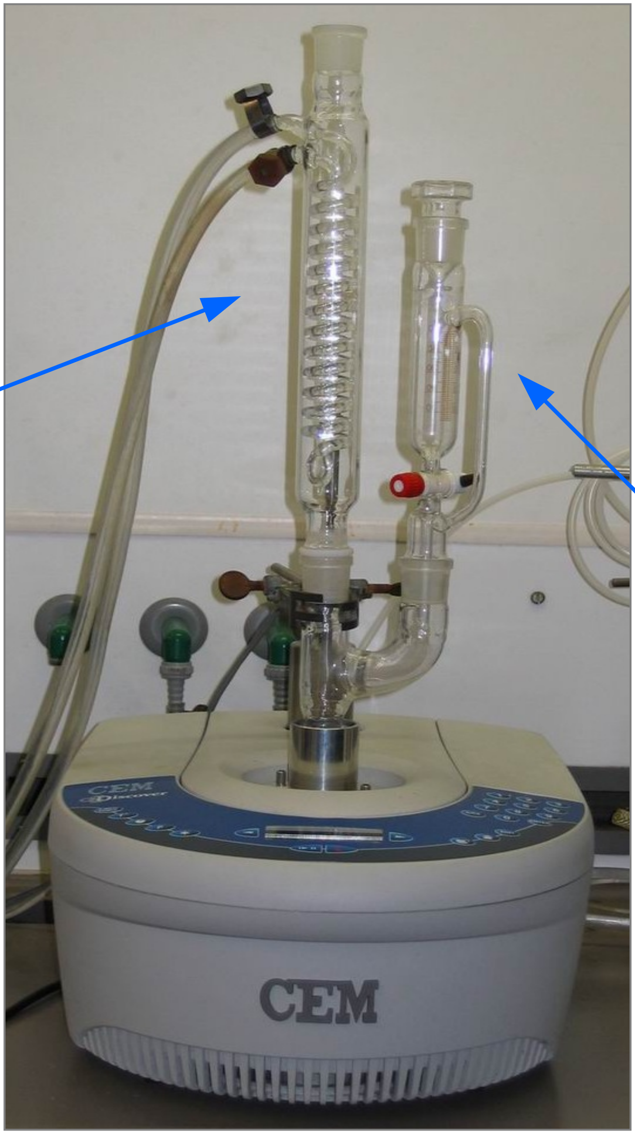
Microwave Assisted Organic Chemistry (MAOS) in Open Vessels

Mauro Iannelli

Open Vessels…Why?

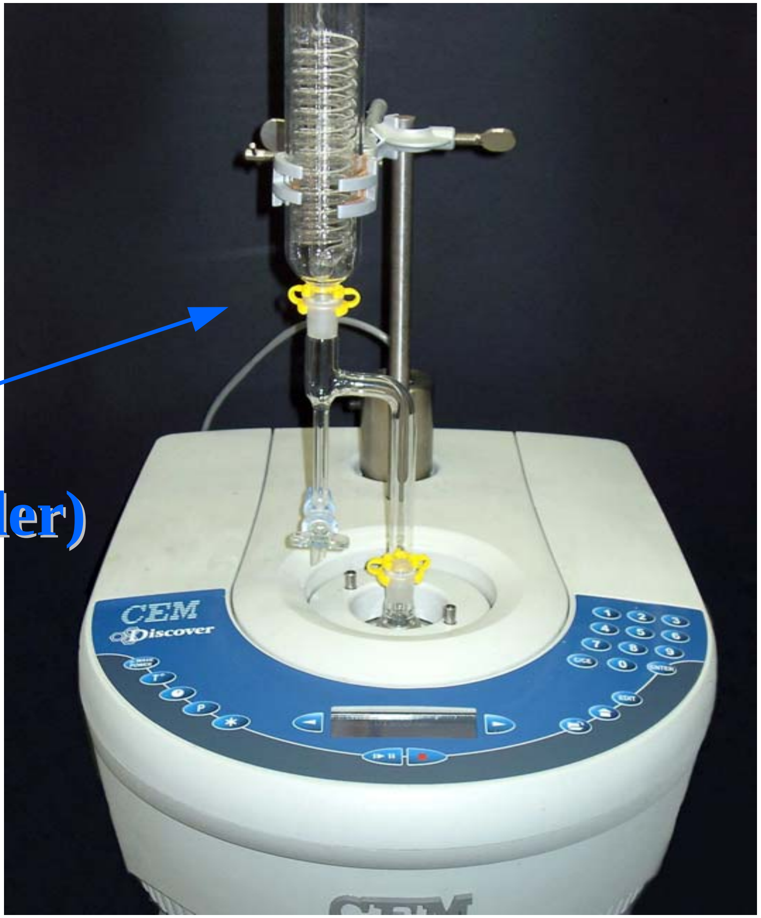
- **Possibility to use the same experimental setup normally used in traditional organic syntheses**

Condenser



Dropping funnel

Dean-Stark (Wasserabscheider)



Open Vessels…Why?

- **More accurate temperature control**
  - **Temperature limited to the boiling point of the solvent**
  - **Conditions easily reproducible in normal conditions (oil bath)**

Open Vessels…Why?

- **Higher operative safety**
  - **No danger of explosions due to increasing pressure**

Open Vessels…Why?

- **Extreme Use Easiness**

Choice of solvent

- **Function of Loss Factor (tanδ)**

tanδ > 0.5 : High MW absorbers

Solvent
ethylene glycol
ethanol
DMSO
2-propanol
formic acid
methanol
nitrobenzene
1-butanol

tanδ ↑

Homogeneous heating

Transfer of energy:

MW $\rightarrow$ solvent
solvent $\rightarrow$ molecular species

Low enhancement in reaction rate

Heinrich Heine Universität Düsseldorf

Choice of solvent

- **Function of Loss Factor (tanδ)**

$0.1 < \tan\delta < 0.5$: Medium MW absorber

tanδ

Solvent
2-butanol
1,2-dichlorobenzene
NMP
acetic acid
DMF
1,2-dichloroethane
water
chlorobenzene

Choice of solvent

- **Function of Loss Factor (tanδ)**

tanδ < 0.1 : Low MW absorbers

Solvent
chloroform
acetonitrile
ethyl acetate
acetone
tetrahydrofuran
dichloromethane
toluene
hexane

tanδ

Almost transparent to MW

Act as heat sink

Direct coupling: MW $\rightarrow$ molecular species

High enhancement in reaction rate

Choice of Microwave

Mono-Mode Reactor

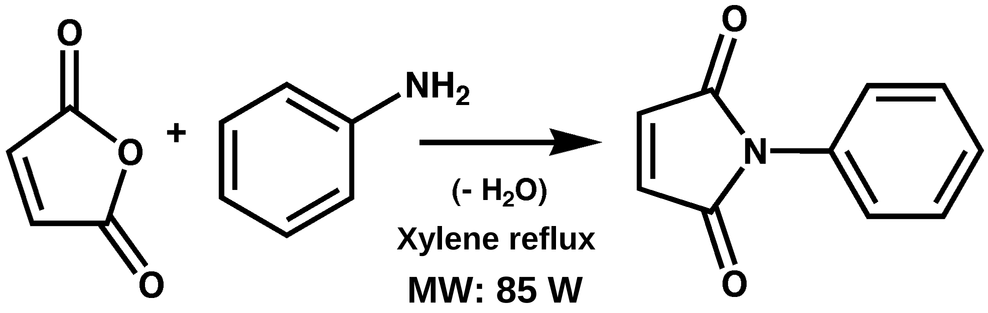
- High Field Homogeneity
- No Hot Spots
- Easy to control

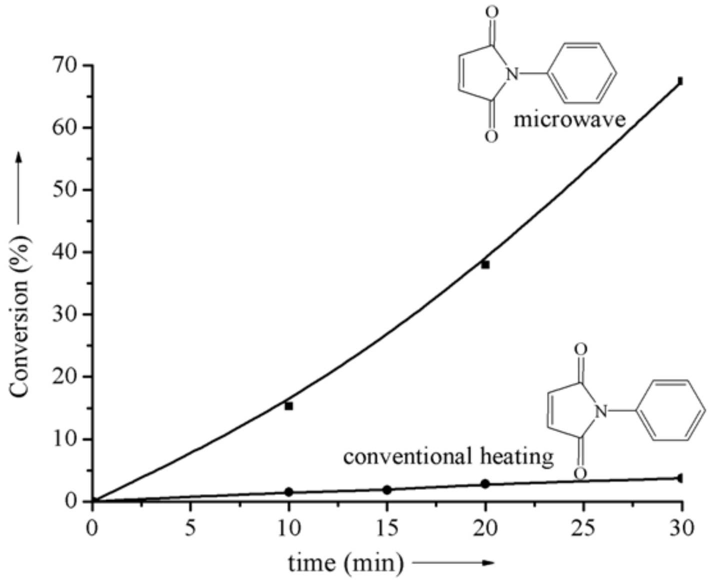
Multi-Mode Reactor

- Low Field Homogeneity
- Hot Spots
- Low Reproducibility

Synthetic Applications

Imide Synthesis



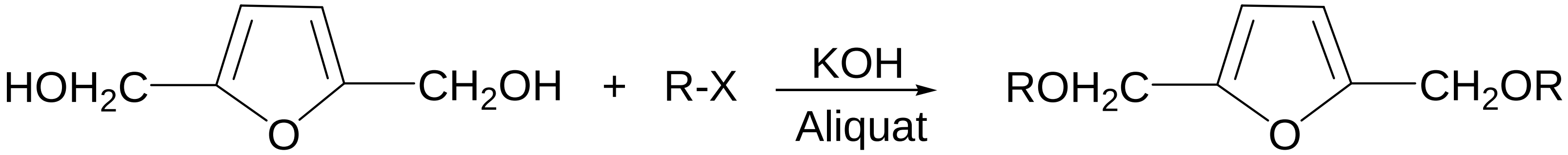


30 min, 70%

30 min, 5%

E. Bezdushna, H. Ritter, *Macrom. Rapid. Comm.*, **2005**, In Press

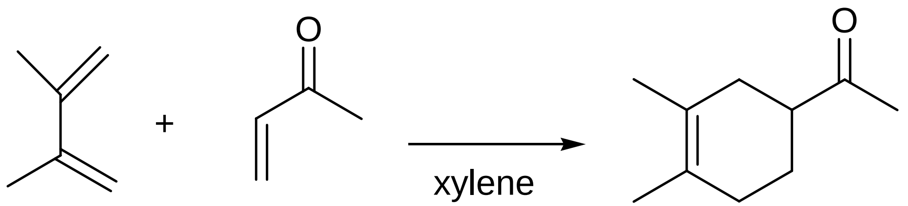
Ether Synthesis



MW (30 W, 180^oC, 5 min): 93%
Oil Bath (180^oC, 5 min): 41%

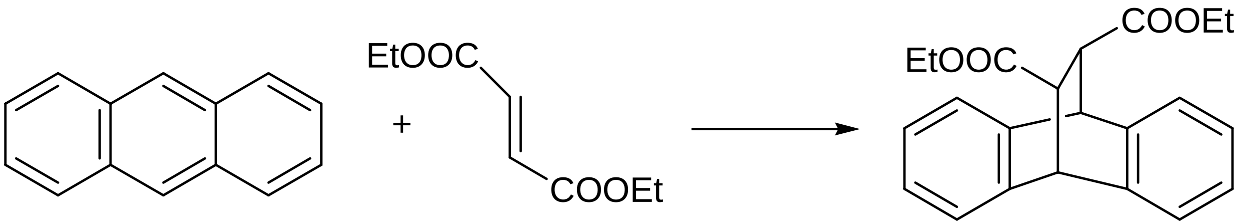
B. L. Hayes, Microwave Synthesis: Chemistry at the Speed of Light, CEM Publishing, Matthews NC, **2002**.

Diels-Alder Reaction



MW (95^{o}C, 7h): 92%
Oil Bath (95^{o}C, 7h): 47%

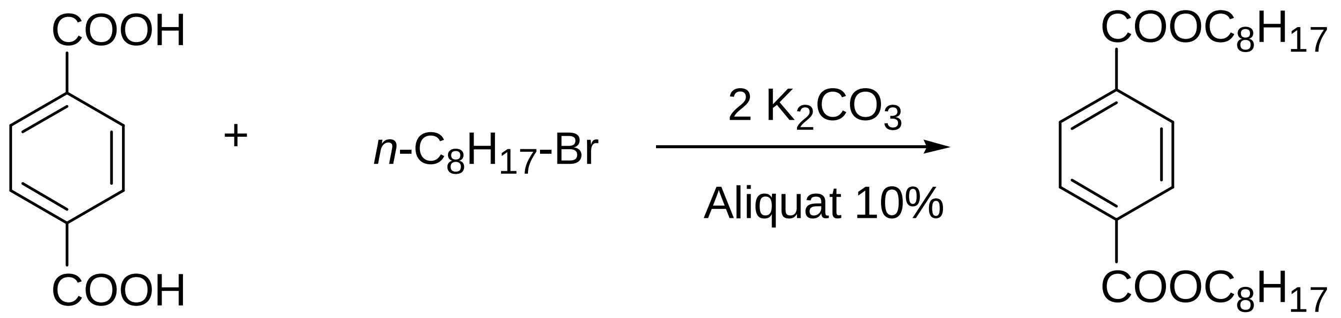
Berlan, P. Giboreau, S. Lefeuvre, C. Marchand, *Tetrahedron Lett.* **1991**, *32*, 2363-2366.



MW (120 W, 1 min, grafite): 92%
Oil Bath (reflux, 60h): 90-96%

B.Garrigues, C. Laporte, R. Laurent, A. Laporterie, J. Dubac, *Liebigs Ann.* **1996**, 739-741.

Esterification

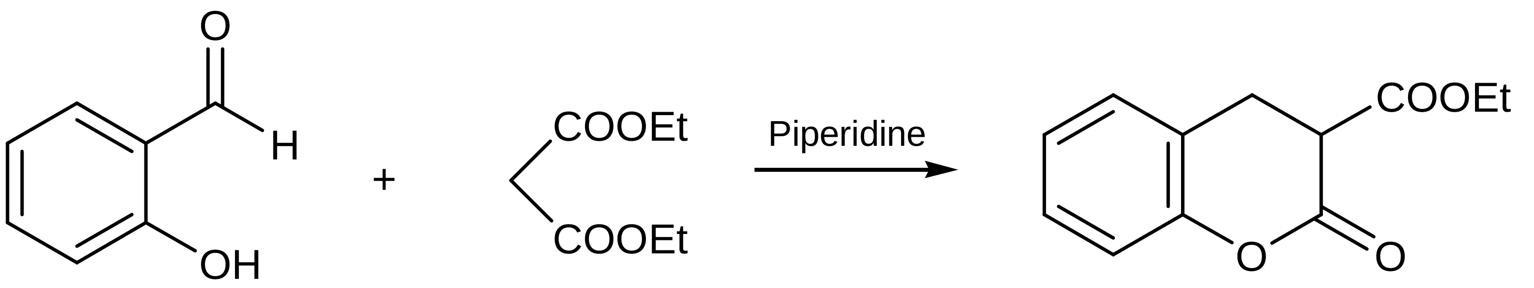


MW (600 W, 227^{o}C, 7 min): 87%

Oil Bath (227^{o}C, 7 min): 20%

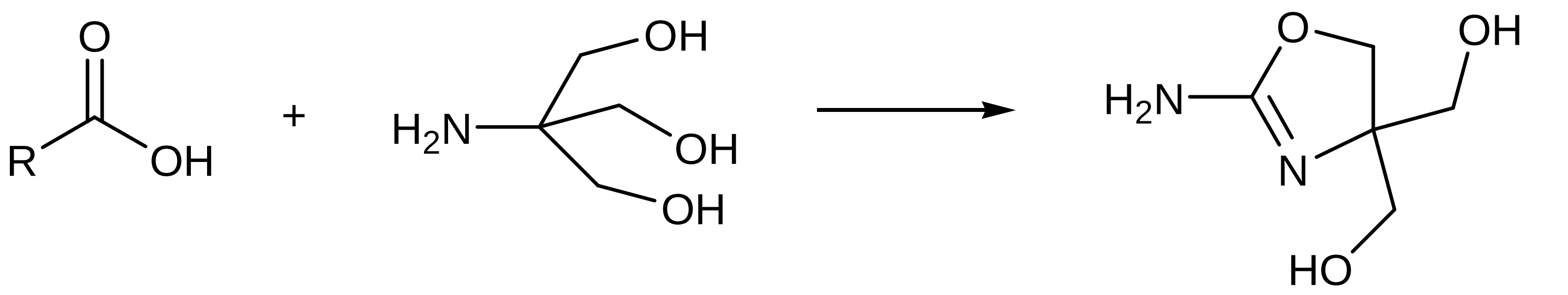
L. Perreux, A. Loupy, *Tetrahedron* **2001**, *57*, 9199-9223

Heterocycle Formation



MW (180 W, 3 min, reflux): 82%
Oil Bath (20 min, reflux): 73%

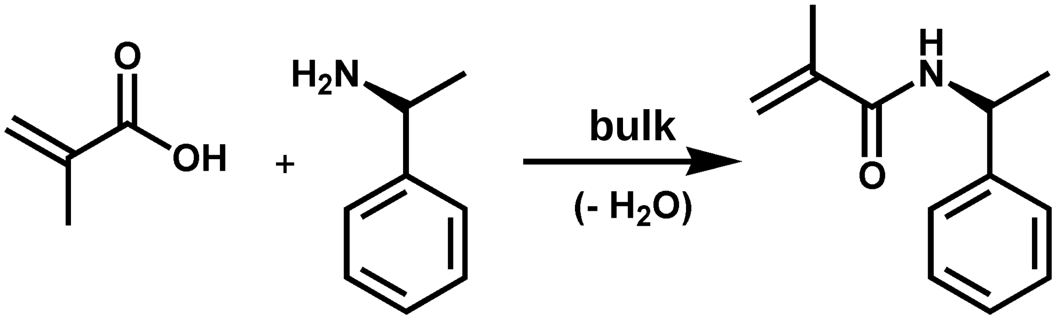
R. N. Gedye, J. B. Wei, Can. J. Chem. **1998**, 76, 525-532

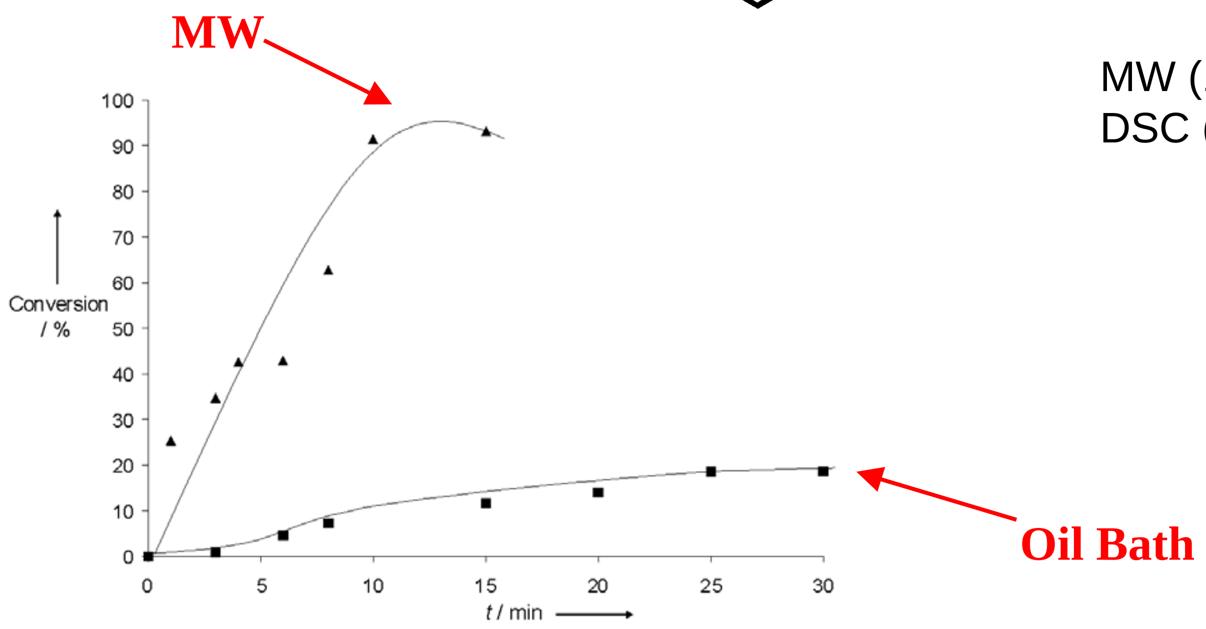


MW (200°C, 10 min): 80-95%
Oil Bath (200°C, 10 min): <5%

L. Perreux, A. Loupy, Tetrahedron **2001**, 57, 9199-9223

Amide Synthesis

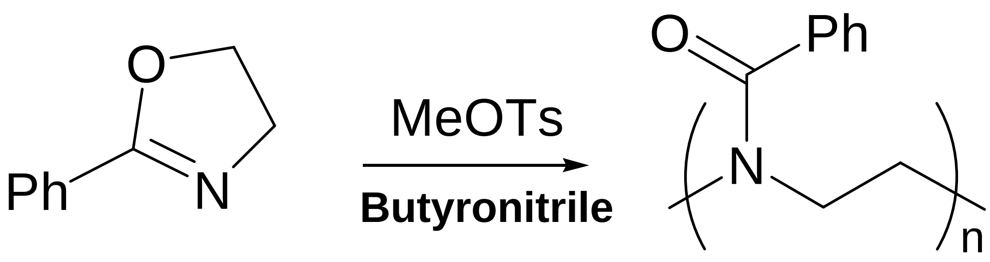


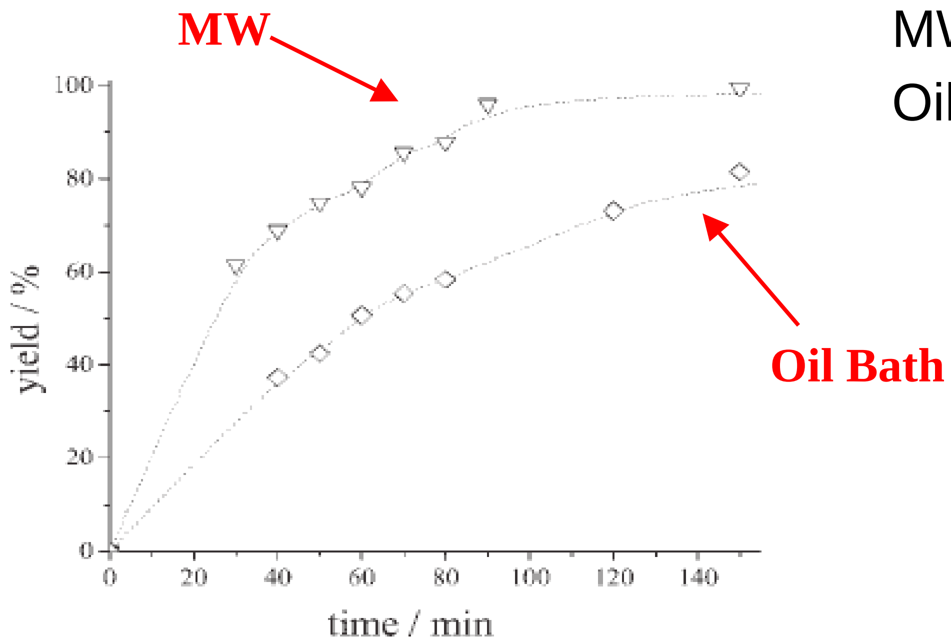


MW (140 W, 15 min,180ºC): 93%
DSC (200ºC, 15 min): 13%

M. Iannelli,V. Alupei, H. Ritter,*Tetrahedron*, **2005**, 1509–1515

Cationic Ring Opening Polymerization

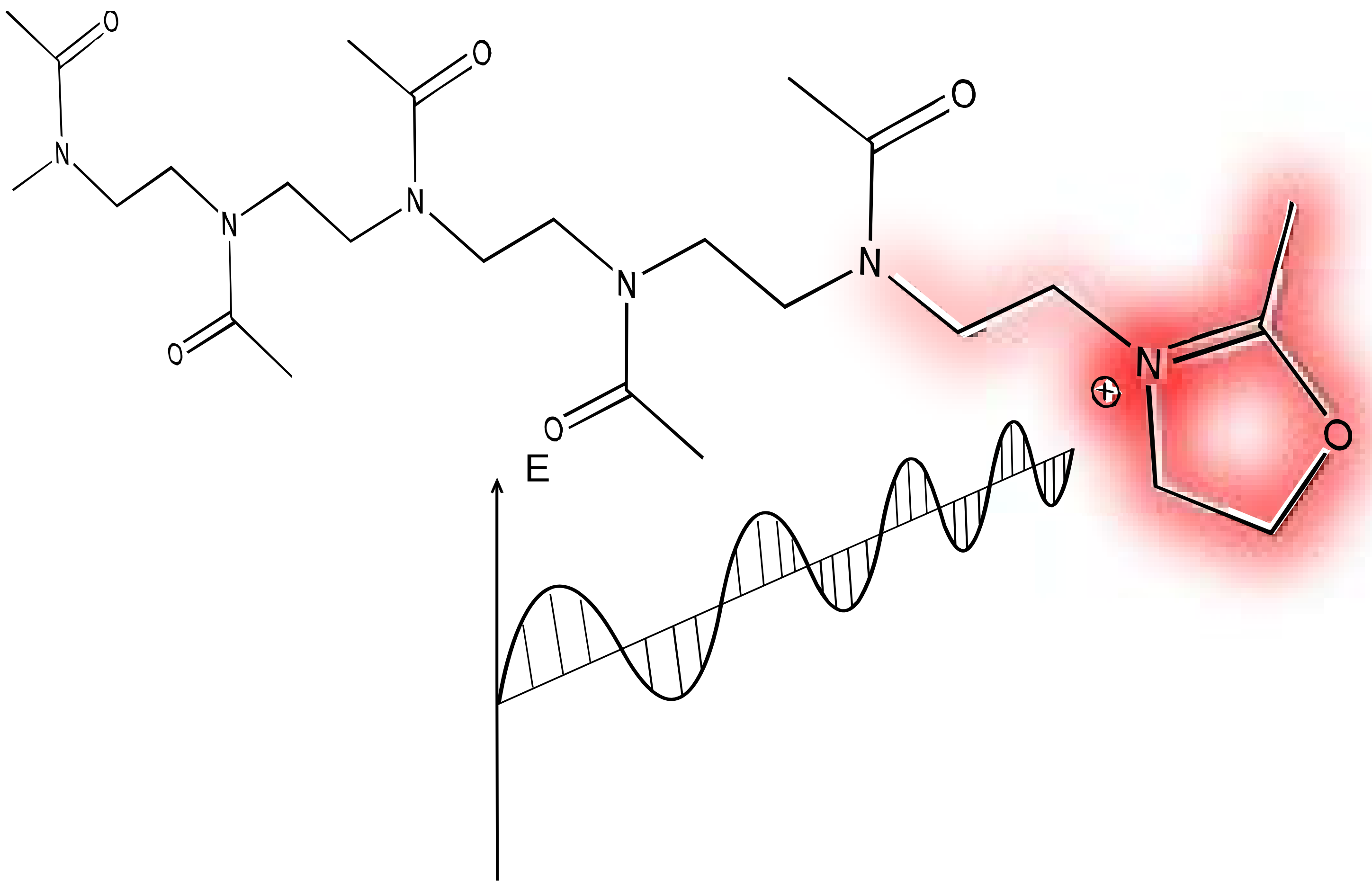




MW (90 W,125^{o}C, 60 min):80%

Oil Bath (125^{o}C, 60 min): 52%

S. Sinnwell, H. Ritter, *Macromol. Rapid Commun.* **2005**, 26, 160–163



S. Sinnwell, H. Ritter, *Macromol. Rapid Commun.* **2005**, 26, 160–163

Conclusions

- Microwave Assisted Organic Reactions performed in open vessels offer many advantages in terms of reaction time and improved yield compared with both reactions in close systems and normal conditions

- Right choice of solvent and technical devices are decisive for maximize these advantages