Efficiency and Selectivity of Microwave Reactors in Organic Chemistry

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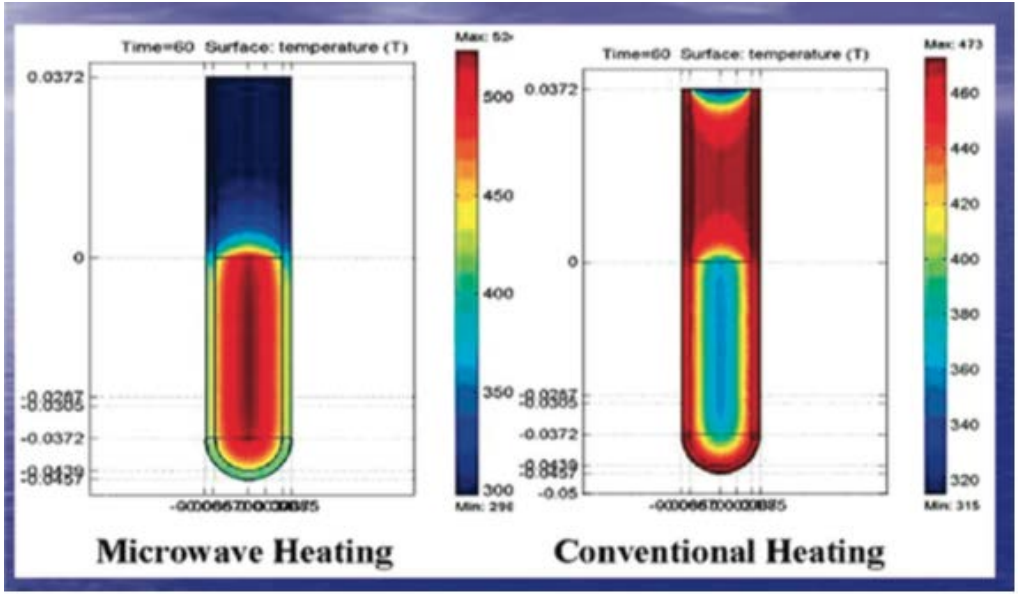
Two Main Principles of Microwave-Assisted Synthesis

Dipolar Mechanism

- Polar molecule follows electric field alignment

Electrical Conductor Mechanism

- Results in polarization
- Electrical resistance in solvent causes heating in sample



Acc. Chem. Res. **2011,** *44*, 469-478.
Acc. Chem. Res. **2005**, *38,* 653-661.

Motivation

- Green Chemistry Principles
  5. Safer solvents and auxiliaries
  6. Design for energy efficiency
  9. Catalysis
- Arrhenius Law

$$k = Ae^{-E_a/(RT)}$$

Green Chem. **2011**, *13*, 794-806.
Acc. Chem. Res. **2002,** *35*, 686.

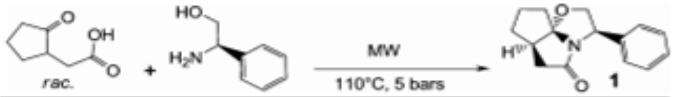
Solvent-free Accelerated Organic Syntheses Using Microwaves

Reactions once run in solvent to control reaction temperature can now be run without solvent using microwave assisted reactions.

- Produces higher yields
- Allows for faster reactions
- Cheaper because solvent isn't necessary
- Safer - don't have to worry about pressure increases
- Can operate at ambient pressure

Green Chem. **2010**, *12*, 961-964.

Table 1 Optimisation of irradiation for solvent-free reactions.

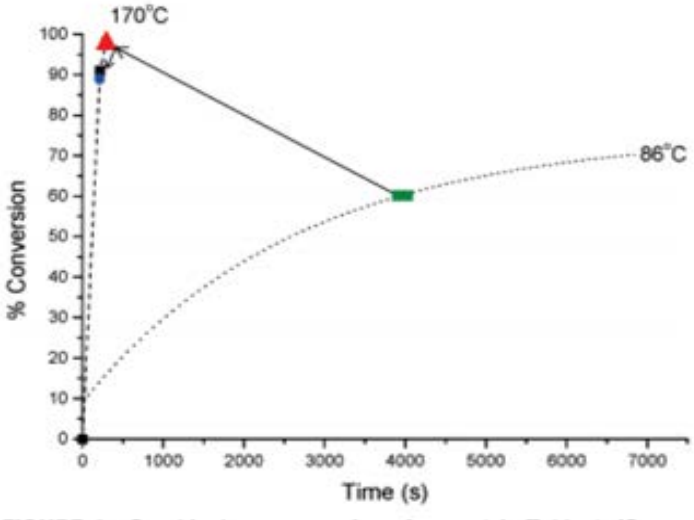


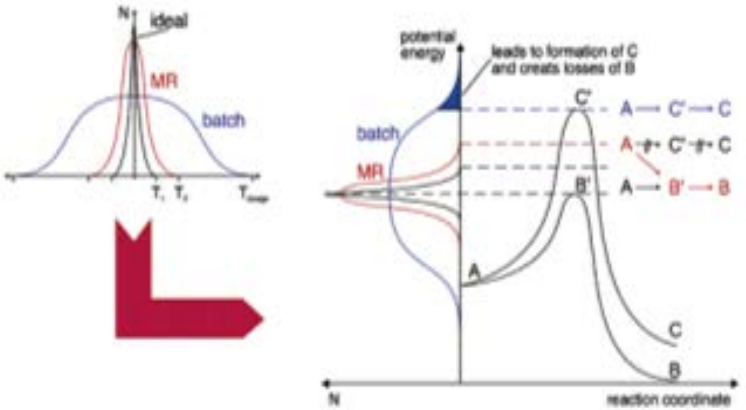
Eentry	Time/min	Power/W	Conversion (%)	Yield (%)
1	2	50	30	27
2	4	50	49	45
3	6	50	54	48
4	2	100	90	89
5	4	100	100	96
6	6	100	100	91
7	2	150	95	88
8	4	150	100	90
9	6	150	100	82
10[a]	5	100	18	—
11[a]	10	100	100	93
12[b]	12 h, toluene, Dean–Stark	94		

[a] In toluene 0.18 M. [b] See ref. 14.

Superior Heating Methods in Microwave Assisted Reactions

Rapid heating causes the reaction to reach a higher percent conversion and also causes an increase in the speed of the reaction.



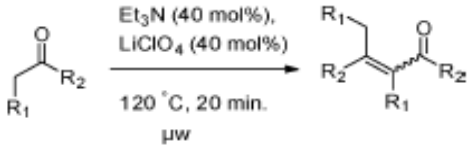


Chem. Rev. **2007**, *107,* 2300-2318.

Selectivity

- Solvent-free reactions
- High stereoselectivity
- High regioselectivity

Table 5 Self-condensation of acyclic aldehydes and ketones



Entry	R_1	R_2	Yield (%)[a]	$E:Z$[b]
1	C_5H_{11}	H	95	98 : 2
2	C_4H_9	H	93(0)[c]	97 : 3
3	C_3H_7	H	90	95 : 5
4	C_2H_5	H	90	98 : 2
5	$(CH_3)_2CHCH_2$	H	85	94 : 6
6	$PhCH_2$	H	92	98 : 2
7	$PhCH_2CH_2$	H	89	97 : 3
8	H	4-Me-C_6H_4	15	>99 : 1
9	H	4-Me-C_6H_4	42[d]	50 : 50

[a] Isolated yield. [b] Ratio based on the peak integration of ^{1}H NMR (500 MHz). [c] Reaction without $LiClO_4$. [d] Reaction was done at 200 °C for 4 h.

Acc. Chem. Res. **2005**, *38, 653-661*.

Selectivity

- Little or no loss of functional group tolerance

Table 5
Oxidation of substituted alcohols to aldehydes using cobalt aluminate (sample A) under the optimum conditions.

Substrate	Conversion (%)	Selectivity (%)
p-Methoxy benzyl alcohol	74.11	81.34
p-Nitro benzyl alcohol	63.09	79.12
1-Phenyl ethanol	63.45	83.25
1-Phenyl-1-propanol	58.34	80.94
Benzyl alcohol	80.91	98.68

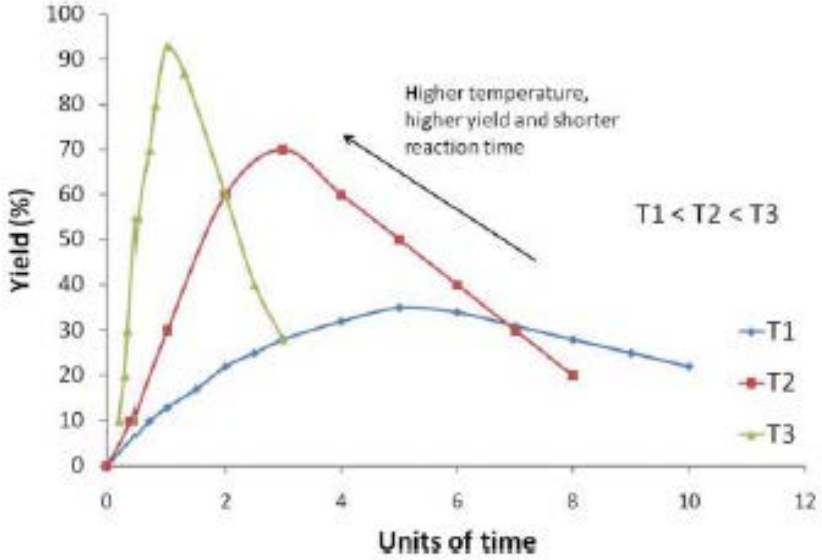
Table 6
Oxidation of substituted alcohols to aldehydes using cobalt aluminate (sample B) under the optimum conditions.

Substrate	Conversion (%)	Selectivity (%)
p-Methoxy benzyl alcohol	73.71	78.84
p-Nitro benzyl alcohol	58.07	74.89
1-Phenyl ethanol	78.54	85.43
1-Phenyl-1-propanol	71.23	81.87
Benzyl alcohol	95.98	98.90

Green Chem. **1999**, *1*, 43-55.; Ceramics International41(2015)2069–2080

Thermal vs MW Heating

- Rapid heating likely the cause of improvements in yield, selectivity, etc.
- Same improvements possible, but infeasible in conventional systems

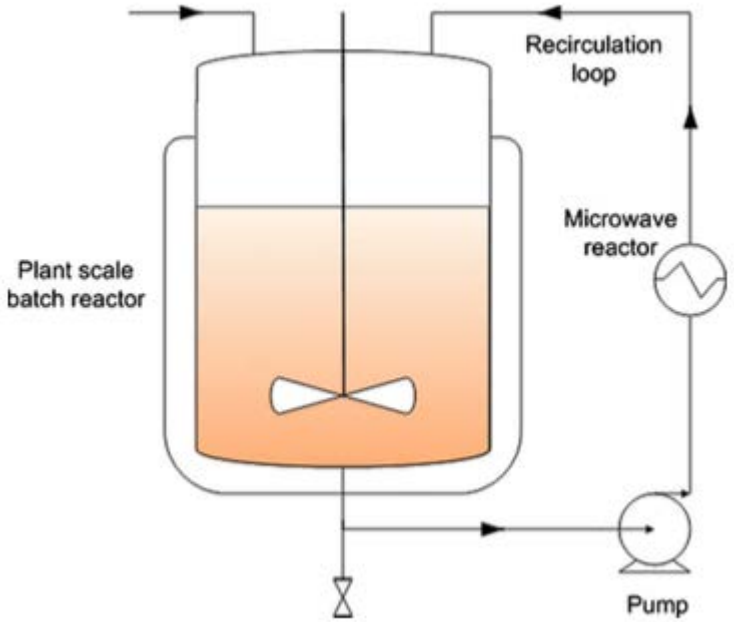


Green Chem. **2010,** *12,* 1340–1344.

Industrial Scale Microwave Reactors

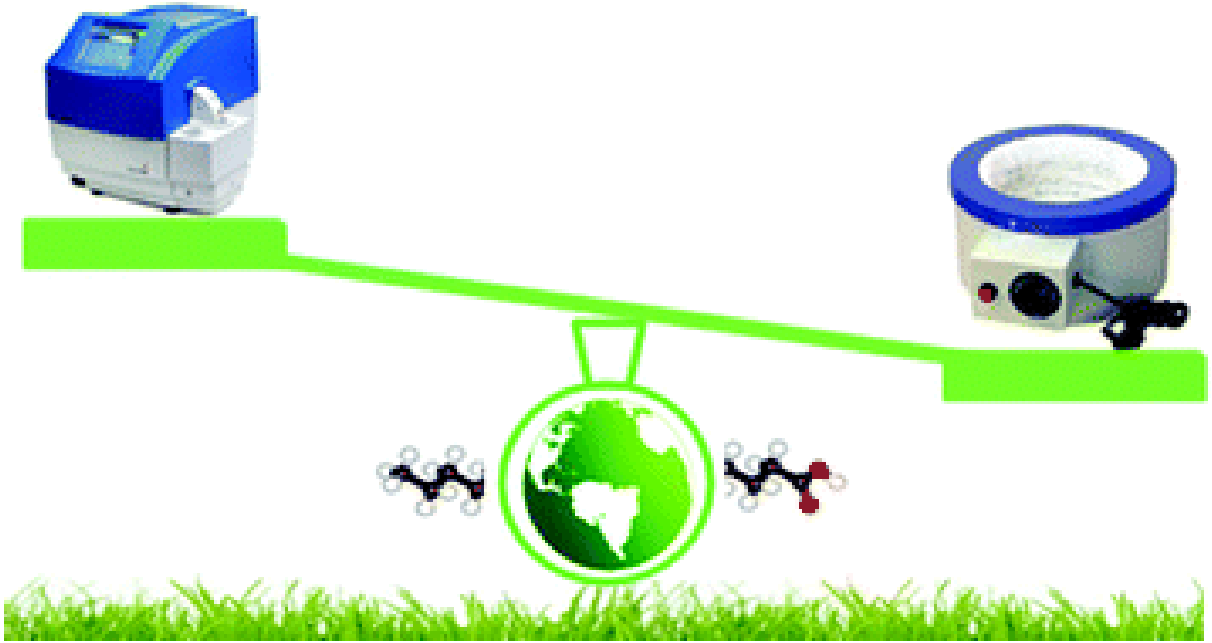
Large scale reactions

- Laboratory to industrial
  - mg scale to kg scale
- Single mode to multimode



Green Chem. **2011**, *13*, 794-806.

Conclusions



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