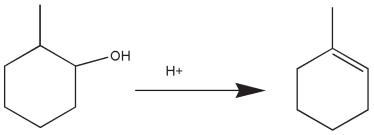
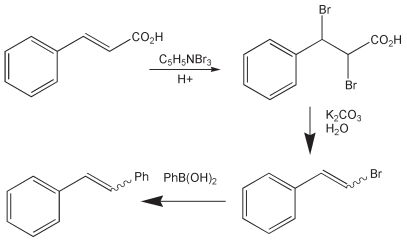
Clean, Fast Organic Chemistry:
Microwave-assisted laboratory experiments

By Nicholas E. Leadbeater, PhD & Cynthia B. McGowan, PhD

Take your students from the chemistries of yesterday's hot plate ...



to the microwave-assisted reactions they'll be using tomorrow quickly and easily!



Give your students more! The speed of microwave-assisted synthesis allows more time to learn.

● Purification and analysis ● More complex chemistries ● Varied research techniques

Transform your undergraduate organic laboratory into a state-of-the-art learning experience!

Expose your students to the most modern methods and the complex chemistries that they will be using after graduation, including multi-step and multi-component reactions that you currently cannot teach due to time restrictions. Reactions typically covered in academic organic laboratories require lengthy reflux times and leave little time for characterization, purification or repetition. The authors of Clean, Fast Organic Chemistry have taken many of these experiments and converted them to utilize microwave-assisted heating techniques.

Microwave energy has become the method of choice for both industrial and academic chemists, as it offers the safest, most effective way to increase reaction rates and improve product yields, while promoting green chemistry. Reactions that previously took hours, or even days, to complete can now be performed in minutes.

Microwave vs. Conventional Reflux Heating for Organic Experiments

Experiment Type	Reflux conditions	Microwave conditions
Diels-Alder	90 minutes in DMF	10 minutes in H_2O
Williamson Ether Synthesis	60 minutes in H_2O	10 minutes in H_2O
Aldol Condensation	23 hours in H_2O	15 minutes in H_2O
Bromination	45 minutes in HOAc	8 minutes in HOAc
Nucleophilic Aromatic Substitution	60-90 mins in Toluene	10 minutes in EtOH / H_2O
Hydrolysis	34 hours in MeOH / H_2O	9-15 minutes in MeOH / H_2O

Decreasing reaction times offers new teaching opportunities: students have more time for design, optimization, characterization, and analysis of reaction processes and products. Additionally, microwave-assisted reactions are often performed in aqueous solutions or neat, minimizing the need for organic solvents, simplifying the work-up process, and providing "green" reaction conditions.

Go Green!

It's time to think about the environment and our impact on it. Microwave energy is an inherently efficient way to transfer energy to a reaction, as it is transferred directly to the reaction solution. Because of this quality, it is the ideal energy source for driving reactions.

- Use water, ethanol or other environmentally benign solvents
- Neat reactions/high conversions help eliminate waste
- Non-hazardous reagents help students design safer syntheses
- Use catalysts, not stoichiometric reagents

Safe!

Not only is microwave-assisted chemistry good for the environment, it is also safer for chemists. Microwave synthesis systems designed for the laboratory offer an unmatched level of safety.

- Eliminate hot plate burns
- Reactions return to room temperature before removing from microwave
- Reactions are completely contained

About the Authors

Cynthia B. McGowan, PhD, is Senior Vice Provost for Academic Affairs at Merrimack College, (Massachusetts). She is also an 2013-2014 American Council on Education (ACE) fellow at the University of Massachusetts - Lowell. Prior to Merrimack, Dr. McGowan was a faculty member at Wellesley College for 10 years and was previously an industrial chemist. Dr. McGowan graduated from Russell Sage College (New York) and completed her doctorate in organic chemistry at Brandeis University (Massachusetts). In 1993, she joined Merrimack College as an Associate Professor. A committed and popular undergraduate teacher, she was recognized by her peers in 1999 with the Edward G. Roddy Jr. Outstanding Teacher of the Year Award. She has served on a number of college committees and was the President of the Faculty Senate for the 2011-2012 academic year. Dr. McGowan has served on committees for the Northeastern Section of the American Chemical Society, and is a member of Sigma Xi, American Women in Science, and the Project Kaleidoscope Faculty 21st Century Network.

Dr. McGowan's research incorporates microwave energy in the promotion of organic chemical reactions, with a principal emphasis on environmentally sustainable chemistry. In collaboration with Dr. Nicholas Leadbeater of the University of Connecticut, she has published two laboratory manuals, one for organic chemistry entitled "Clean, Fast Chemistry," and "Laboratory Experiments with Microwave Heating" that utilizes microwave chemistry techniques across several chemistry disciplines. She also incorporated microwave experiments into the 5th edition of "Microscale Organic Laboratory" by Mayo, Pike and Forbes, as well as co-authored a number of chapters in books on sustainable chemistry.

Nicholas E. Leadbeater, PhD, is an Associate Professor of Chemistry at the University of Connecticut. Dr. Leadbeater, a native of the United Kingdom, graduated from the University of Nottingham, completed his doctorate in inorganic chemistry at the University of Cambridge and stayed there as a research fellow for three years before joining the faculty of King's College London. In 2003, he was awarded the Royal Society of Chemistry's Harrison Medal. In 2004, he joined the faculty at the University of Connecticut and in 2010, was awarded the UCONN Excellence in Teaching Award for the Physical Sciences. He was awarded a Faculty Development Abroad grant. In 2011, Dr. Leadbeater is also the Interim Director of the Chemical Innovations Institute, established by the Connecticut legislature in June 2010. In addition, Dr. Leadbeater has contributed a number of "Academic Minutes" on a local National Public Radio station, talking about topics as diverse as green chemistry, chirality, biofuels, why the sky is blue, and the chemistry behind crusty bread.

Dr. Leadbeater's research interests are focused around development of new synthetic methodology, the use of microwaves in synthetic chemistry; organic synthesis in water; metal-mediated organic synthesis; clean synthesis; preparation of biofuels; physical organic chemistry; study of kinetics and mechanisms of organic reactions. He is a strong advocate of incorporating undergraduate students into research and of promoting clean chemistry and modern technology in education.

All reactions in this lab manual were performed in affordable, benchtop systems. Grants are available to assist in the implementation of laboratory courses on microwave-assisted organic synthesis. For more information on grants or equipment, contact CEM Corporation.

(800) 726-3331 • www.cem.com
For a sample of the lab manual or to order, please contact info@cem.com.