Contents

2 RESEARCH THAT MAKES A DIFFERENCE

4 A BANNER YEAR OF RESEARCH CAPS A DECADE OF ACHIEVEMENT

8 RESEARCH AND INDUSTRY: FOSTERING SYNERGY

11 RESEARCH SPOTLIGHTS

14 RECRUITMENT TO SUPPORT NEW TALENT AND BUILD CAPACITY

17 TECHNICAL SERVICES AND CONTINUING EDUCATION: SHARING EXPERTISE WITH THE LOCAL COMMUNITY

18 GRADUATE STUDIES

21 A YEAR OF SUCCESS

22 PEER-REVIEWED SELECTED RESEARCH PAPERS PUBLISHED DURING 2011–2012
Texas A&M University at Qatar Research Yearbook 2012

RESEARCH THAT MAKES A DIFFERENCE

February

Texas A&M University at Qatar Awards: Faculty Excellence Award recipient was Dr. Haitham Abu-Rub, professor, electrical and computer engineering. The award recognizes significant scholarly accomplishments and research contributions. Research Fellow Excellence Award recipients were Dr. Dong Suk Han, assistant research scientist, chemical engineering, and Dr. Mohammad Shaqfeh, associate research scientist, electrical engineering. The award recognizes contributions to advancing research capabilities at Texas A&M University at Qatar, and team work skills. Research Team Excellence Award recipient was Dr. Ahmed Abdel-Wahab, associate professor, chemical engineering, and his team. The award promotes and recognizes scholarly and research contributions of the team members at Texas A&M at Qatar. Richard E. Ewing Award for Excellence in Student Research recipients were graduate student Marwa Qaraqe, and undergraduate student Hussein Zahreddine. The award honors those students who have excelled in academics and research.

March


April


May

Texas A&M University at Qatar received $39 million in research funding for 39 projects from Qatar National Research Fund at its announcement of the National Priorities Research Program cycle-5 awards. The university success rate for proposals was 36 percent, compared to a 25 percent success rate for all institutions. Funded projects span the university’s degree programs in chemical, mechanical, electrical and petroleum engineering, and science program.

Texas A&M University at Qatar and Qatar Petrochemical Company (QAPCO) signed an agreement in which the corporation endowed a fund for the University to bring a Nobel Laureate to Qatar, as the QAPCO Chair of Polymer Science. Nobel Laureate chemist Dr. Robert H. Grubbs holds an adjunct faculty position at Texas A&M University at Qatar, where he is collaborating with Dr. Hassan S. Bazzi, associate professor of science and chair of science program.

Dr. Haitham Abu-Rub

Dr. Dong Suk Han

Dr. Mohammad Shaqfeh

Marwa Qaraqe

Dr. Troy Bickham

Dr. Robert H. Grubbs

Dr. Dragomir Bukur, professor of chemical engineering, Dr. Patrick Linke, professor of chemical engineering, and Dr. Nimir Elbashir, associate professor of chemical engineering, were recognized in its Academy eBriefing by the New York Academy of Sciences (NYAS) for their research activities as presented at the Qatar Foundation Annual Research Forum 2011.
**Dr. Ahmed Abdel-Wahab** and **Dr. Syed Hussain**, electrical & computer engineering, were awarded research grants in the third cycle of the Junior Scientists Research Experience Program (JSREP).

**Dr. Khalid Qaraqe** and **Dr. Kamel Tourki** received the award for Best Poster Award in the IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN 2012). This is a leading international symposium dedicated to the advancement of cutting-edge wireless technologies and associated regulatory policies.

**Dr. Nesrin Ozalp**, associate professor of mechanical engineering, and research associate **Mr. Shameem Usman** received the Best Paper Award in the session on “Renewable Energy 3” at the 9th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT2012). The paper title is “Numerical and Optical Analysis of Weather Adaptable Solar Reactor.”

**Dr. Patrick Linke**, professor, managing director for Qatar Sustainable Water and Energy Utilization (QWE), and **Dr. Ahmed Abdel-Wahab**, associate professor of chemical engineering and technical director for QWE, were awarded Construction Week’s sustainability initiative award for their work on the QWE Initiative.

**Dr. Dr. Nimir Elbashir** and his exceptional team received the award for Best Energy and Environment Research Program of the Year, presented at the Joint Qatar Foundation Annual Research Forum and Arab Expatriate Scientists Network Symposium. Dr. Elbashir’s work highlighted multi-scale investigations of fuels leading to the design of a novel Fischer-Tropsch reactor for gas-to-liquid processes.

QNRF recognized two new merit awards: “Best Research Team of the Year”, which went to the research team led by **Dr. Milivoj Belic**, professor of physics, and "Research Office of the Year.”

**Dr. Patrick Linke** and **Dr. Ahmed Abdel-Wahab**

**Dr. Nesrin Ozalp**

**Dr. Khalid Qaraqe**

**Dr. Patrick Linke**

**Dr. Ahmed Abdel-Wahab**

**Dr. Syed Hussain**

**Dr. Nimir Elbashir**

**Dr. Milivoj Belic**
Matching the pillars of Qatar National Vision 2030 with the skills of first-rank scientists, engineers, academics and industry experts, 2012 was a powerhouse year for research at Texas A&M University at Qatar.

Over the past year, Texas A&M at Qatar marked its tenth anniversary not only as an institution, but also as a front-rank member of the scientific community. With a unique-to-Qatar vision, the University has gained recognition in the region and worldwide as a leading destination for engineering education and research. In addition, the institution builds Qatar’s human capacity while also establishing and enhancing the research infrastructure envisioned by the Qatar Foundation.

“At the heart of Texas A&M at Qatar’s successful partnerships and recent successes in research is a set of core values that it has long held as an originating member of the Texas A&M University System,” says Dr. Mark H. Weichold, dean and CEO. “The translation of those values into a unique-to-Qatar vision and mission has been gaining recognition for Texas A&M at Qatar, not only in Qatar and the region but also worldwide, as a leading destination of choice for engineering, education and research.” Texas A&M at Qatar partners in business, industry and government are stakeholders in research. Similarly, the University itself is a stakeholder in its partners’ economic success. These partnerships build bridges of opportunity and progress for all, driving Qatar’s economy and culture towards global leadership, not only into the next decade, but into the next century.

The University’s research is a two-pronged attack. It addresses current, specific needs of Qatar’s industry and organizations, especially with regard to energy,
The focus of the University’s research certainly needs to be on addressing current, specific needs of Qatar’s industry and organizations, especially with regard to energy, the environment and advances in computing. However, the focus of its research also needs to address more fundamental, curiosity-driven ‘research for the future’ that may give rise to a new industry or direction for the country.

DR. MARK WEICHOLD
DEAN AND CEO

The graduate program not only provides a source of researchers but it enables Texas A&M at Qatar to hire and retain top quality faculty. The State of Qatar desires a knowledge-based economy, so we must have people trained to create knowledge. That is what these programs do.

DR. KENNETH HALL
ASSOCIATE DEAN FOR RESEARCH AND GRADUATE STUDIES
the environment, and advances in computing. At the same time, research also addresses more fundamental, curiosity-driven ideas for the future that can give rise to a new industry or opportunity for the country.

Dr. Weichold adds, “The focus of the University’s research certainly needs to be on addressing current, specific needs of Qatar’s industry and organizations, especially with regard to energy, the environment and advances in computing. However, the focus of its research also needs to address more fundamental, curiosity-driven ‘research for the future’ that may give rise to a new industry or direction for the country.”

Dr. Kenneth Hall’s attitude toward the quality of that work reflects that of the University itself, “One of the reasons I have had a relatively strong research career is that whenever someone said, That’s impossible, I said, Watch me.” As associate dean of research and graduate studies and the director of the division of Texas A&M Engineering Experiment Station (TEES) at Texas A&M at Qatar, Hall has helped create a groundbreaking department that takes on both academic and research challenges. “The main reason I decided to come here was that with resources becoming available, graduate and research budgets appeared sufficient to enable real impact,” he adds. To quantify and propagate this kind of excellence, the University has created an overarching standard called Responsive Research. A project that meets the Responsive Research standard will have the potential for high global impact, support the themes of the Qatar National Research Strategy and reflect the efforts and expertise of our researchers plus industry consortia. Projects may be pure, applied or policy-driven investigations, and must be focused on clearly defined engineering and scientific questions. “The strategic vision has been to turn Texas A&M University at Qatar into a top-quality academic research institution. We have come a long way towards achieving that vision as our departments have responded to both academic and research challenges,” says Hall.

He also credits the institution’s success to its expansion of graduate studies programs. “Sustainable academic research usually requires graduate studies,” adds Hall. “Now that Texas A&M at Qatar faculty members have begun developing graduate programs, they have come to realize that having Ph.D. students engaged in research ensures robust research programs.”

He continues, “It’s our number one short-term goal. The graduate program not only provides a source of researchers but it enables Texas A&M at Qatar to hire and retain top quality faculty. The State of Qatar desires a knowledge-based economy, so we must have people trained to create knowledge. That is what these programs do.”

“Excellence is the principal assessment criterion for research conducted at Texas A&M at Qatar” said Dr. Eyad Masad, assistant dean of research and graduate studies. “Excellence in research for engineering and science does not fit a single definition, but is recognizable by its potential for long-lasting impact locally and globally.”
PARTNERS FOR PROGRESS

Pure and applied science are intertwined commercially and intellectually. Each gains value by its relationship with the other. Today, universities, businesses and other entities make these relationships possible, and those relationships are often key elements of the program’s research.

On 21 May 2012, Texas A&M at Qatar hosted its first research/industry partnership showcase, “Research and Industry: Fostering Synergy,” at the Qatar National Convention Center. The event promoted dialogue among University researchers and industry representatives on collaboration and opportunities for advancing the State of Qatar’s National Vision 2030 and strategic development goals through research. The showcase also highlighted some of the University’s research achievements and provided an opportunity for industry to discuss ways that Texas A&M at Qatar research can better support Qatar’s industrial sector.

The daylong showcase included about 30 presentations highlighting successful collaboration in four areas: energy, water and environment; petroleum technologies; materials processes and applications; and information and communication technology. Examples of showcased:

- advances in new energy sources;
- systems to enhance energy efficiency;
- an environmental impact assessment of cooling water discharge into seawater;
- petroleum industry technologies including subsurface processes, sonic stimulation, ultra-trace gas detection and improved methods of oil and gas recovery from carbonate reservoirs;
- characterization of infrastructure and advanced material;
- new methods for increasing speed and reliability of wireless networks.

A partnership with any given entity can produce research advances across multiple disciplines. One of the most successful partnerships for Texas A&M University at Qatar has been its relationship with energy producer RasGas, which Dr. Kenneth Hall describes as “one of the University’s strongest and most enthusiastic research partners.”

Through this partnership, RasGas generously sponsors several Texas A&M at Qatar students, who get to apply their educational and research experience on live RasGas projects. The company also helps fund and support research projects that explore and create cutting-edge technology to improve the overall efficiency of the oil and gas industry. Some of these projects include clearer well communications, better well-logging technology, enhancing gas condensate deliverability, improving visualization technology and detection of water in gas flow lines. Other projects currently in development are 3D LiDAR (light detection and ranging) visualization and interpretation software. Six years into the partnership, RasGas and the University continue to strengthen the bonds between industry and education, which will add significant value to Qatar’s future prosperity and growth.
Texas A&M at Qatar promotes unrestricted and innovative thinking, where proposed research can be pure, applied or policy driven, and seeks to address or provide the means to address clearly defined engineering and scientific questions, through Responsive Research, Texas A&M at Qatar is actively leading and participating in research that is innovative, technology-led and collaborative.

DR. EYAD MASAD
ASSISTANT DEAN OF RESEARCH AND GRADUATE STUDIES
RESEARCH SPOTLIGHTS

RESEARCH BOTH BROAD AND DEEP
Qatar and the Gulf region as a whole are experiencing unprecedented growth in economies, infrastructure and population. Naturally, this has led to the need for rapid expansion in the wireless and telecommunications industries. Dr. Khalid Qaraqe, professor of electrical engineering, and his team are rising to the challenge. A professor in the electrical and computer-engineering program, Qaraqe and his team have secured more than $6 million in research funding, and with impressive results: They have produced advances in communications that make vital and practical improvements in voice and data transmission for cellular devices. These advances include technical breakthroughs that improve the reliability of transmissions and the transmission and reception capacities of wireless devices; superior processing of the multiple “fingers” of a wireless signal that arrives at your phone; and more reliable “handoffs” as a phone or other device moves from one cell zone to another.

This research was made possible by Texas A&M at Qatar’s new Wireless Research Laboratory. Enabling researchers to conduct both fundamental and applied research, the state-of-the-art lab allows scientists and engineers to continue to deployment after research and development.

Qaraqe’s team has helped to enhance worldwide visibility of Texas A&M at Qatar by establishing partnerships with Qtel, RasGas and the Ministry of Interior; securing external funds and successfully completing projects supported by the Qatar National Research Fund and by industry; facilitating a research culture within the electrical and computer engineering program; involving undergraduates in research; recruiting graduate students; and promoting Texas A&M at Qatar through its administrative and leadership efforts, all of which are of vital importance to the academic and industrial growth of Qatar.

In addition, the team has been heavily involved in industry consultations, by serving as conscientious reviewers and chairs for tutorials, technical committee members in scientific journals and international IEEE conferences. Recent achievements have included publication of more than 40 journal papers, at least 90 conference papers and chapters in eight books, as well as the mentoring of 12 post-doctoral researchers, nine Ph.D. students, four M.S. students, 22 undergraduate students, and by producing one (in-process) patent.

Dr. Hussein Al-Nuweiri, program chair of electrical and computer engineering, and Dr. Mohammad Shaqleh, an associate research scientist in electrical engineering at Texas A&M at Qatar, have also been conducting research in significant areas of wireless technology, including finding ways to utilize scarce radio spectrum resources efficiently. International telecommunication standards have kept the door wide open for service providers to innovate and apply their specific implementations of scheduling and resource allocation. The team has co-authored many technical papers in top-tier IEEE journals and at flagship conferences. Their research contributions have been in three main areas: 1) cooperating/relaying technologies, 2) multilayer transmission schemes, and 3) channel-aware dynamic user scheduling.

INTERNATIONAL COLLABORATION IN FUNDAMENTAL SCIENCE
Just as one partnership can produce benefits across many disciplines, simply beginning a project with a cross-disciplinary approach has its benefits, as well. Dr. Milovoj Belic, a professor
of physics at Texas A&M at Qatar. Belic guides his team to combine expertise in frontier fields such as nonlinear optics, nonlinear dynamics of deterministic and chaotic systems, and large-scale computational physics and math.

Belic’s research addresses problems in their fields of expertise and has produced significant contributions, such as obtaining exact solutions to multidimensional, nonlinear evolution and partial differential equations – theoretical work that quickly translates into practical impact in the marketplace. Their contributions also include mathematical analysis of chaotic systems in partial differential equations, nonlinear computational mechanics, molecular quantum mechanics, quantum computing, synchronization of chaotic systems, neural networks and applications, as well as complex networks and their applications.

Since 2005, the team has published 129 publications with Texas A&M at Qatar affiliation in refereed journals in math and physics. They have presented their results at 66 international conferences, seminars and colloquia and their papers have been cited 985 times in scientific literature. In addition, former student Anas Al Bastami has won outstanding undergraduate research awards from Texas A&M at Qatar and been admitted for graduate studies, along with others, to prestigious graduate programs. The team is also proud to collaborate with internationally renowned scientists at premier centers for math and physics around the world.

RESEARCH IS EDUCATION
Dr. Mashhad Fahes, assistant professor in the petroleum engineering program, knows that a vital career in research begins with vital habits. This kind of practical and real-world education – true preparation for the future – is a foundational idea at the University.

“Students should be exposed to research methodologies at this early stage of their professional development, so that research values become an integral part of their work habits,” she says. “These methodologies include critical thinking, the ability to design projects and experiments to prove or disprove hypotheses, and the ability to work in a large team for an extended period of time.” Undergraduates are involved in the research team under either the National Priorities Research Program (NPRP) or Qatar National Research Fund’s (QNRF) Undergraduate Research Experience Program (UREP). “Their contributions to our research work are very valuable,” Fahes added.

Her team’s latest UREP project, conducted in collaboration with international energy firm Total, S.A., involves four faculty members, three industry mentors and 12 undergraduate students, aided by four full-time research assistants. Over the summer of 2012, some students were able to serve in internships at the Total Research Center at Qatar Science and Technology Park (QSTP), where they worked on their research projects with actual data from Qatar oil wells.

In one part of this project, students divided into groups to conduct a comprehensive study of water-oil flow in horizontal pipes, to be able to model water-oil emulsions. Some students have been conducting experimental work by measuring the various properties of water-oil emulsions with water and oil produced from Qatar wells. Other students have been performing simulations by trying to relate rates of production with pressures along the long surface of production pipes.

To enhance the students’ research experience, each was assigned a specific task, to take ownership and follow up by reporting on it. Faculty and research assistants were there to guide and supervise the students.

Fahes’ research shows students how industry and academia work together to solve real life problems and that research is not done in a closed box. This inspires those students who are interested in academia to consider applying for a graduate degree and to pursue a career path that will lead to their becoming faculty members. Students more interested in a career in industry enter the workforce with research experience that exposed them to engineering in the making.
Since 2005, the team has published **129 publications** with Texas A&M at Qatar affiliation in refereed journals in math and physics. They have presented their results at **66 international conferences**, seminars and colloquia and their papers have been cited **985 times** in scientific literature.

---

Students should be exposed to **research methodologies** at this early stage of their professional development, so that **research values** become an **integral part** of their work habits.

**DR. MASHHAD FAHES**
ASSISTANT PROFESSOR OF PETROLEUM ENGINEERING

---

**Since 2005, the team has published 129 publications** with Texas A&M at Qatar affiliation in refereed journals in math and physics. They have presented their results at **66 international conferences**, seminars and colloquia and their papers have been cited **985 times** in scientific literature.

**DR. MILIVOJ BELIC**
PROFESSOR OF PHYSICS
RECRUITMENT TO SUPPORT NEW TALENT AND BUILD CAPACITY

Commitment to innovative, technology-led and collaborative research makes the University such an appealing destination to researchers.

SUPPORTING NEW TALENT

A key aspect of Texas A&M University at Qatar’s research projects is its emphasis on human-capacity building. By recruiting highly qualified researchers, graduate students and undergraduate students, Texas A&M at Qatar’s research focuses on the development of a sustainable, unique research infrastructure that positions the institution, Qatar Foundation for Education, Science and Community Development and the State of Qatar among the worldwide leaders in research and discovery.

“Texas A&M at Qatar promotes unrestricted and innovative thinking, where proposed research can be pure, applied or policy driven, and seeks to address or provide the means to address clearly defined engineering and scientific questions,” says Masad. “Through Responsive Research, Texas A&M at Qatar is actively leading and participating in research that is innovative, technology-led and collaborative.”

It is this commitment to innovative, technology-led and collaborative research that makes the University such an appealing destination to current and future researchers. Those who come here know they will play key roles in research that is groundbreaking and high risk; that challenges current conventions from a position of intellectual strength while exploring new boundaries or adapting current techniques to an entirely different field. Conducting this research in an environment that insists on the exchange of ideas across and within disciplines leads to major advancements that have long-term impact on both the scientific community and society.

“Young students and researchers gain the opportunity to develop their careers, together with support for cutting edge areas of engineering and science,” adds Masad. “Responsive research is a key component of delivering the Texas A&M University at Qatar strategy and is intended to facilitate the identification of the next generation of strategic priorities. It plays a crucial role in sustaining the University’s recognition as a world contributor to engineering and scientific research.”
A NEW MEANING FOR “THINK GLOBALLY, ACT LOCALLY”

Officially inaugurated in February of 2012, Technical Services at Texas A&M at Qatar provides services and expertise to local industry and organizations. By working with the advanced facilities of participating laboratories, Technical Services caters to the research needs of multiple scientific disciplines by offering University partners access to facilities, equipment and faculty advice for their use. This benefits Qatar in its progress towards a knowledge-based society by supporting the research and testing needs of multiple, industry-oriented disciplines, including electronics, machinery, materials, fuel characterization, water/environmental research, chemistry and research computing.

Local partners who have utilized the facility include Carnegie Mellon University in Qatar, Dolphin Energy, Energoprojekt-Entel, Metito, Qatar Fertilizer Company (QAFCO), Qatar Shell LLC, Qatar University Wireless Innovations Center, Total E&P Qatar, URS, Virginia Commonwealth University-Qatar and Worley Parsons.

Technical Services also offers research initiatives that include hosting and training workshops, such as the two-day Rapid Prototyping Workshop presented by Texas A&M at Qatar and the United Nations Economic and Social Commission for Western Asia (ESCWA) and ESCWA Technology Centre (ETC) in June of 2012. The event attracted technology managers from across the region involved in engineering design and prototyping. The workshop included sessions and live demonstrations on electronic prototyping, preparing prototyping jobs, metal printing, integrated manufacturing systems, plastic printing and rapid-prototyping capabilities.

Texas A&M at Qatar’s Continuing Education Services (CES) is dedicated to becoming the premier provider of lifelong engineering education in the region, helping clients maintain excellence in their engineering disciplines. They accomplish this by providing exemplary technical short courses, certification programs and training opportunities to enhance safety behaviors, impart innovative engineering skills and enhance business acumen of its participants. In addition, they support the University’s Quality Enhancement theme “Aggies Commit to Learning for a Lifetime” by ensuring the short course body of knowledge is innovative in delivery and at the forefront of engineering practice, research and development. This allows them to serve the needs of Qatar and the region through knowledge transfer and local support of companies and institutions.

The CES initiative is a direct response to requirements from local professionals and industries for training and education services. CES thus pursues two goals at once, promoting the vision of a knowledge-based economy for Qatar, while ensuring the education quality equips graduates and professionals to create cutting-edge technology and solve modern, real-world challenges.
HELPING TO BUILD

For several years, the University has hosted master’s degree and doctoral-level students from its main campus in College Station, Texas. Texas A&M at Qatar welcomed its inaugural class of chemical engineering master’s students in the fall 2011 semester. These students, who attend a rigorous set of core courses, contribute significant intellectual resources to Texas A&M at Qatar’s research activities. They seek to tackle the most complex of chemical engineering problems in a creative and efficient way, utilizing effective logic-based approaches to problem solving.

Research involvement focuses on topics such as gas-to-liquids, environmental remediation and water treatment, and safety and process engineering. Texas A&M at Qatar chemical engineering graduate students are committed to research that is expanding conventional wisdom and changing lives. After graduation, they will be well equipped to begin careers in industry or to pursue their Ph.D. studies.

The University has now enrolled its second group of master’s students into its chemical-engineering program, bringing the graduate student population to more than 40 young men and women from Qatar and other countries. They add to the creation of a vibrant community for collaboration and scientific discovery.

One of those students, Mary Anna Katebah, is researching new ways to remove kinetic hydrate inhibitors from produced water and is working with ConocoPhillips while pursuing her graduate studies. Her reasons for enrolling in the graduate program were clear. “After having studies in Texas A&M at Qatar’s undergraduate chemical engineering program for four years, and also working as an undergraduate researcher for two, I was familiar with the level of education that the University could offer. I was confident that a graduate degree from Texas A&M at Qatar would enable me to be even more successful in meeting my career goals.”

Planting homegrown teams capable of great research requires a long period of cultivation. Qatar Foundation and Texas A&M at Qatar have chosen this path by creating exciting centers for high-quality, team-oriented research and by establishing attractive research awards. The spotlight is on Qatar Foundation and Texas A&M at Qatar, as well as its hard-working teams that strive to achieve excellence in research and education while encouraging others to do the same.
The future looks bright. Through contributions of new pure and applied science, the University’s researchers and partners are moving Qatar closer to its goal of a knowledge-based economy, and growing the reputation of the University as a worldwide source for cutting-edge research.
PEER-REVIEWED SELECTED RESEARCH PAPERS PUBLISHED DURING 2011–2012

CHEMICAL ENGINEERING


Han, D. S., B. Batchelor, and A. Abdel-Wahab. “Sorption of Selenium (IV) and Selenium (VI) onto Synthetic Pyrite (Fe52): Spectroscopic and Microscopic Analyses.” Journal of Colloid and Interface Science, vol. 368, pp. 496-504 (2012).


Han, D.S., B. Batchelor, and A. Abdel-Wahab. “XPS Analysis of Sorption of Selenium (IV) and Selenium (VI) to Mackinawite (FeS).” Environmental Progress & Sustainable Energy DOI 10.1002/ep.10609 (2011).


ELECTRICAL AND COMPUTER ENGINEERING


MECHANICAL ENGINEERING


PETROLEUM ENGINEERING


Kyran, S.J., S. Muhammad, M. Knestrick, A.A. Bengali, and D.J. Darensbourg. “Photochemically Generated Transients from k\(^{-1}\) and k\(^{1}\). Triphos Derivatives of Group 6 Metal Carbonyls and Their Reactivity with Olefins.” Organometallics, 31, 3163 (2012).


