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Introduction to integrated approaches for methane activation

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Human have utilized a wide variety of chemical resources in their lives. In the early days, solid resources such as wood and coal were used for a long time, and then petroleum in liquid form was gradually used, leading to an explosive expansion of resource use. Today, we are moving into the age of natural gas, and beyond that, we are beginning to prepare to move into a resource system based on carbon dioxide and hydrogen. This is the direction of the age of gaseous resources. The transition of these chemical resources has been characterized by an increase in the hydrogen/carbon ratio of the resources. Methane is the most stable organic compound with the highest hydrogen/carbon ratio and will play a leading role in the gas age.

During the above-mentioned transition of chemical resources, a wide variety of chemical substances have been produced and have contributed to human life, and catalysts, needless to say, were indispensable in the production of these substances. In the gas age, the role of catalysts is also important, even more so than ever before, in the production of materials for chemical substrates and energy. This is because catalysts intrinsically have the potential to maximize energy and material efficiency in chemical substrate production processes and in energy production. However, while the development of catalysts for chemical conversion with higher energy and material efficiency than ever before is always mandatory, catalysts should be more advanced with regard to their functions, due to the fact that the reactivity of chemical resources declines as they age. The difficulty of catalytic reactions of methane, for example, is obvious. The next step, the use of carbon dioxide, will require not only catalysts but also the integration of a variety of technologies, making it even more difficult.

Against this background, the achievement of catalytic science and technology for methane utilization should be a major milestone in the history of human utilization of chemical resources. To reach this milestone, catalysis scientists and engineers must continue to work from various angles in a cross-sectoral manner. In recent years, research projects on catalytic science and technology for chemical conversion of methane have been conducted in various fields (*e.g.*, the JST-CREST project), and new results far beyond the conventional methane catalytic science have been produced one after another using metal–organic complex catalysts, biomimetic catalysts and solid catalysts, and computational and informatics methodologies have been applied to the development of methane catalytic technology. On this occasion, this themed collection of *Catalysis Science & Technology* features these achievements. At the time of this themed collection, we have not yet reached the stage where we can clearly say that we have reached a milestone, but the seeds for the next breakthrough are surely hidden in many papers. So, we would like to encourage our readers to take a look, extract the elemental science of catalysis required for methane reaction from various aspects, realize a breakthrough, and bring methane utilization technology in the gas age into the hands of the people.

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