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Press release **For immediate release**

HKU Chemist and Collaborators Unveil Eco-Friendly Method to Efficiently Convert Methane to Ethanol

March 17, 2025

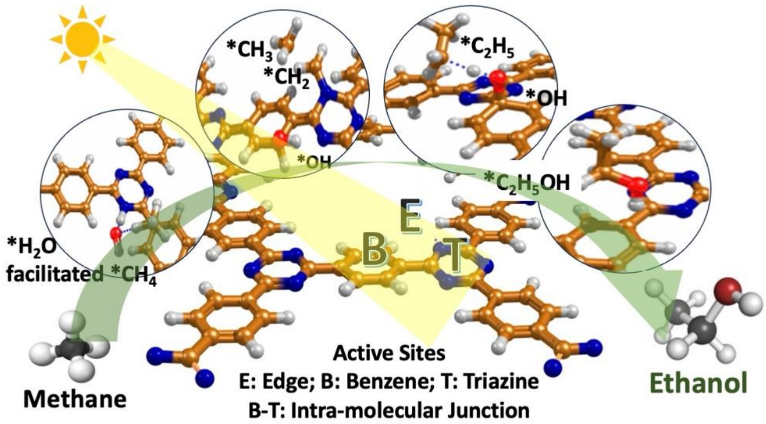

Figure 1. Mechanism for photocatalytic conversion of methane to ethanol.
Image adapted from Xie, J. et al., *Nature* (2025), https://doi.org/10.1038/s41586-025-08630-x.

In advancing sustainable energy solutions, an international collaborative team of scientists has achieved a significant milestone in low-carbon chemical conversion. In their recent publication in *Nature*, the team, led by Professors Zhengxiao GUO of Department of Chemistry at The University of Hong Kong (HKU), Weixin HUANG of University of Science and Technology of China, Richard CATLOW of University College London and Junwang TANG of Tsinghua University, have discovered a photocatalytic approach to converting methane to ethanol with high selectivity of around 80% and a methane conversion rate of 2.3% in a single run using a packed-bed flow reactor. The system achieves an impressive apparent quantum efficiency (AQE) of 9.4%, which measures how effectively it converts incident photons into electrons that participate in the reaction under specific wavelength conditions.

Background

Ethanol is well known to spirit up many celebratory occasions, but more significantly, it serves as an ideal liquid hydrogen carrier and a chemical feedstock for a wide range of applications towards carbon neutrality. The global market for ethanol exceeds USD 100 billion, with a current compound annual growth rate (CAGR) of approximately 7%. Methane, the primary constituent of natural and shale gas, is often flared for heating. Despite its potential as a carbon source for chemical synthesis, its inherent chemical inertness poses substantial hurdles to its efficient conversion.

Traditional industrial methane conversion is typically conducted via syngas under high temperatures and pressures, a process that is energy-intensive and exhibits poor product selectivity. Efforts to directly convert methane into ethanol often encounter challenges in controlling highly selective carbon-carbon (C-C) coupling to produce a specific C_{2+} chemical, such as ethanol.

Innovative Catalytic Conversion

The efficient conversion is achieved through a unique intra-molecular junction formed between alternate benzene and triazine units within a covalent triazine framework (CTF-1) polymer. The intra-molecular junction enhances the life-time and the efficient separation of photo-generated charges while enabling preferential adsorption of O_2 and H_2O to the benzene and triazine units, respectively, to facilitate C-C coupling. Moreover, this intrinsically asymmetric dual-site feature effectively delineates the C-C coupling sites from the hydroxyl radical formation sites, thereby mitigating the risk of overoxidation of the intermediate into CO_2 and water. When further enhanced by the addition of Pt, the intramolecular junction photocatalyst demonstrates a very promising ethanol production rate, as stated above.

'This is a step-change advancement in the photocatalytic conversion of methane into value-added green chemicals – not only in terms of a newly identified metal-free "intramolecular junction" for effective C-C coupling; but also by turning methane into a much more desirable liquid chemical, relatively efficiently at ambient conditions,' Professor Guo, one of the corresponding authors of the paper, remarked.

Comparison to Traditional Methods

Conventionally, as in the Fischer−Tropsch synthesis, methane conversion to liquid chemicals requires high temperature (> 700 °C) and pressure (~ 20 bar) to activate its C−H bond, involving high energy input and multiple steps. Previous attempts in the photocatalytic conversion of methane to a C_{2+} product often encounter either low selectivity and/or low efficiency, due to the limited capabilities of the specific catalysts. The newly developed CTF-1 catalyst demonstrates over 20 times higher quantum efficiency along with a very high selectivity.

Potential Applications and Broader Impacts

Methane is an abundant yet climate-potent gas. Its one-step photocatalytic conversion represents a highly desirable approach to decarbonising the chemical and fuel industries. Particularly in liquid form, ethanol is much easier to store, transport and distribute, compared to gaseous hydrogen. It can be directly reformed onboard of low-carbon vehicles - on land, at sea or in the air, offering great potential for applications in urban transport, shipping and the upcoming low-altitude economy, thereby paving the way towards carbon neutrality.

Future Research and Development

Led by Professor Guo, the HKU research team will continue to explore innovative options in tailoring the catalyst and intensifying the conversion process, as part of a consortium effort under the UGC Theme-Based Research Scheme and the RGC-EU Collaborative Innovation Scheme.
The full paper can be accessed at: https://www.nature.com/articles/s41586-025-08630-x

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