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Chemistry

Special Topic: Chemistry Boosts Carbon Neutrality

Chemistry boosts carbon neutrality

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The large-scale use of fossil fuels has brought about rapid development of human social productivity. However, it has also led to a sharp rise in greenhouse gas emissions, which intensifies global warming and increases extreme weather events. Therefore, controlling carbon emissions has become a critical concern worldwide. In September 2020, Chinese president Xi Jinping pledged to the United Nations General Assembly: "We aim to have carbon dioxide (CO_2) emissions peak before 2030 and achieve carbon neutrality before 2060." This not only demonstrates China's responsibility as a great power, but also contributes to the achievement of global climate goals.

Carbon neutrality means that the net emissions of greenhouse gases such as CO_2 and methane (CH_4) are zero. Since CO_2 accounts for the highest proportion of greenhouse gases, decreasing CO_2 has become the key to carbon neutrality. However, since China is currently the world's largest emitter of CO_2, we must rely firmly on scientific and technological innovation to realize the net zero carbon footprint in just 40 years. There are mainly two ways to achieve carbon neutrality. One is to reduce CO_2 emissions via consuming less fossil fuels and exploiting more clean energy. The other is to increase the consumption of CO_2 that has already existed in the atmosphere by capture, utilization, and sequestration, and then convert CO_2 into high value-added chemicals or store it in plants, soils, and oceans. Chemistry, as a science that studies the relation and transformation of matter and energy, is expected to play an important role in the realization of the above two pathways through developing high-performance catalysts, designing novel reaction processes and energy conversion paths, etc.

Here we organize a special topic on "Chemistry Boosts Carbon Neutrality", which includes seven high-quality papers covering the latest research, reviews and perspectives related to both the reduction of CO_2 emissions and the enhancement of CO_2 consumption.

In the section of reducing CO_2 emissions, several catalysts are designed for clean energy utilization. An idea on using ammonia as an energy carrier to diminish CO_2 emissions is also proposed. Wang *et al*. [1] reported a defect and interface engineering strategy to develop a broadband photocatalyst that enables to extend the visible light absorption to 590 nm and boosts the solar hydrogen evolution rate by approximately 20 times compared with the base system. Yan *et al*. [2] developed polyxometalates supported single-atom Rh catalysts, which can increase the catalytic activity in hydroformylation while maintaining the stereo-selectivity of the product. It helps decrease the energy consumption of this thermally catalytic reaction, thus reducing the usage of fossil fuels and CO_2 emissions. Lin *et al*. [3] summarized recent advances in carbon-supported non-precious metal single-atom catalysts for energy conversion electrocatalysis. The application, challenges, and future opportunities of such catalysts in the electrochemical reactions, including CO_2 reduction, hydrogen evolution, oxygen evolution, and nitrogen reduction have also been comprehensively discussed. Finally, Jiang *et al*. [4] provided a novel perspective of constructing an artificial nitrogen cycle to thoroughly realize energy decarbonization. In this cycle, ammonia serves as a clean energy carrier, which can be synthesized from atmospheric dinitrogen and green hydrogen from water electrolysis by renewable energies. The energy can be released when converting ammonia back to dinitrogen and water.

In the section of enhancing CO_2 consumption, several novel catalysts that increase the conversion efficiency of CO_2 to useful chemicals are discussed. Gao *et al*. [5] reported a perovskite oxide-derived Cu catalyst with abundant grain boundaries, which can effectively convert CO_2 into valuable multicarbon (C_{2+}) compounds. Grain boundaries were found to enhance the adsorption of CO, thus promoting C–C coupling kinetics. Yu *et al*. [6] systematically reviewed the progress and challenges in decarboxylation with CO_2. They also pointed out that applying CO_2 in low concentration/purity as the carboxyl source in the decarboxylation reaction, developing greener solvents and conducting research that combines theory and experiments could be future focus to solve practical industrial problems. Xie *et al*. [7] summarized the progress of using two-dimensional materials as photocatalysts to convert a variety of inert small molecules in the air including CO_2 into chemicals. They proposed the concept of functional customization, which optimizes the electronic structure, active sites, charge carrier separation and mobility of two-dimensional materials by regulating their thickness, vacancies, doping, etc. for catalytic activity improvement.

To sum up, this special topic discusses how chemistry can contribute to carbon neutrality via two pathways, reducing CO_2 emissions and enhancing CO_2 consumption. In the first path, a variety of single-atom and composite-structured catalysts in photocatalytic, electrocatalytic and thermocatalytic reactions are developed, which promote the utilization efficiency of clean energy and reduce the consumption of fossil fuels. In the second path, several novel catalysts such as perovskite oxide derivatives and two-dimensional materials are designed to improve the conversion rate of CO_2 to high value-added chemical compounds in the electrochemical reduction and dicarboxylation reactions. We would like to thank all the authors who have contributed the high-quality peer-reviewed articles to this special topic. We are also grateful to the deputy editors in chemistry who invited these papers, as well as the editorial and production staff of *National Science Open* for their high-quality assistance. We sincerely hope that this special topic can provide scientific inspiration for the achievement of China's carbon neutrality goal from the perspective of chemistry.

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