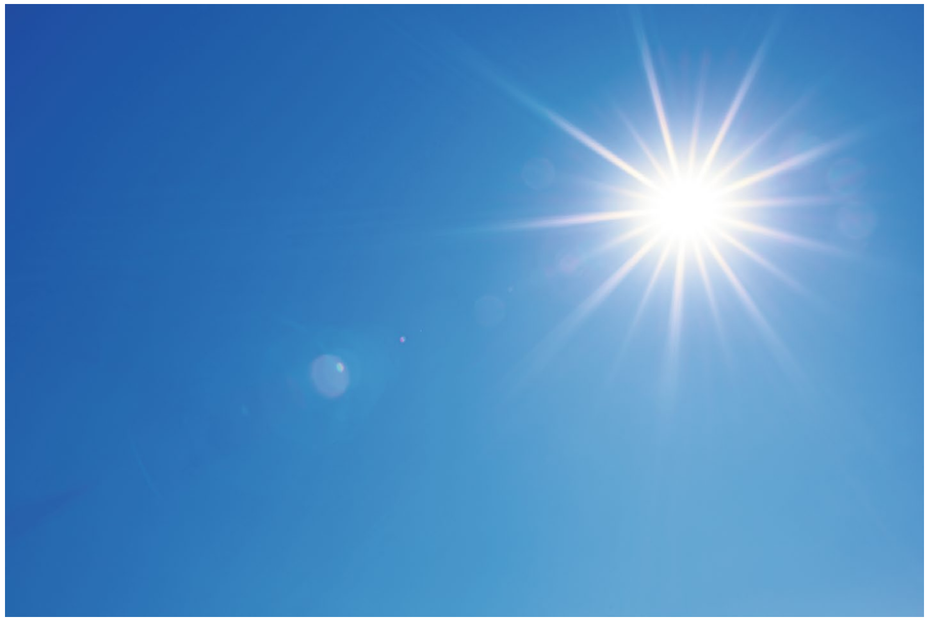
The solar generation

Solar-to-chemical conversion is key for the sustainable production of small molecules.

A future powered by solar energy is a future with hope. With photosynthesis at the fundamental core of converting solar energy into useful products in nature, scientists have been attempting, for some time, to harness solar energy in a similar way, using light-absorbing synthetic agents. But merely mimicking photosynthesis is not a viable route and instead, scientists have taken inspiration from the active components with key roles in photosynthesis and the two main stages of the process involving light-harvesting and the production of chemicals.

From this thinking, the field of artificial photosynthesis was established and diverse ways to convert solar energy to chemical energy were explored. Converting solar energy into stored chemical energy within bonds, to be released at a time when needed, or to be used to make value-added chemicals has been achieved within research laboratories but the scale-up of these methods to achieve efficient and cost-effective sustainable alternatives is more challenging.



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Initial interest focussed on water splitting using catalysts, producing hydrogen as the fuel and oxygen as the by-product. However, this concept has drawbacks associated with the storage of gaseous hydrogen and the need for expensive metal catalysts to carry out the reactions. Other solar fuels have also attracted interest including ammonia and aqueous hydrogen peroxide.

Featured on the cover of this issue, and reported in an Article by Kim et al., hydrogen peroxide is produced using only water and oxygen as reagents and lignin as a photocatalyst under visible light. Hydrogen peroxide is generated by reduction of oxygen, as well as the oxidation of water and therefore is more efficient than if low-value oxygen is the output from the oxidative half-reaction. Moreover, by teaming up this production of hydrogen peroxide with enzymes, Kim et al. describe a semi-artificial photosynthetic process which can enantioselectively oxyfunctionalize hydrocarbons.

As noted in a News & Views article by Han Sen Soo, artificial photosynthesis routes typically use expensive catalysts or use sacrificial reagents. By contrast, in the report by Kim et al., a waste product from the paper and pulp industry that would otherwise be combusted or disposed of, is used. Not only is lignin in plentiful supply but it acts as a photocatalyst and a hydroxyl radical scavenger, with the latter feature ensuring that the enzymes remain active throughout the reaction.

The enzymes in question — unspecific peroxygenases — result in highly enantioselective epoxidation of styrene, and hydroxylation of benzylic and aliphatic substrates. This production of small chiral molecules from solar energy and bio-based resources is a useful and sustainable approach for the synthesis of bioactive molecules with potential applications in pharmaceutics and agrochemicals.

Alongside solar energy, the use of other bio-based waste products from different industrial settings should be explored. Lignin is structurally and chemically well-matched for this particular process but other bio-based by-products may show the same kind of attributes to enable a sustainable approach to fine chemical production. In addition, the efficiency of generating hydrogen peroxide as the fuel is notable, with both half reactions yielding the product. Looking forward, the scalability of the process and the purity of water needed in the reaction are crucial considerations.

The production of fine chemicals has been interconnected with the petrochemical industry for some time, but as this industry changes, chemists must look to other resources to produce vital starting materials. As such, using renewable energy and bio-based by-products are natural changes that need to be made to achieve this goal. ❐

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