Reductive Dearomative Arylcarboxylation of Indoles with CO_2 via Visible-Light Photoredox Catalysis

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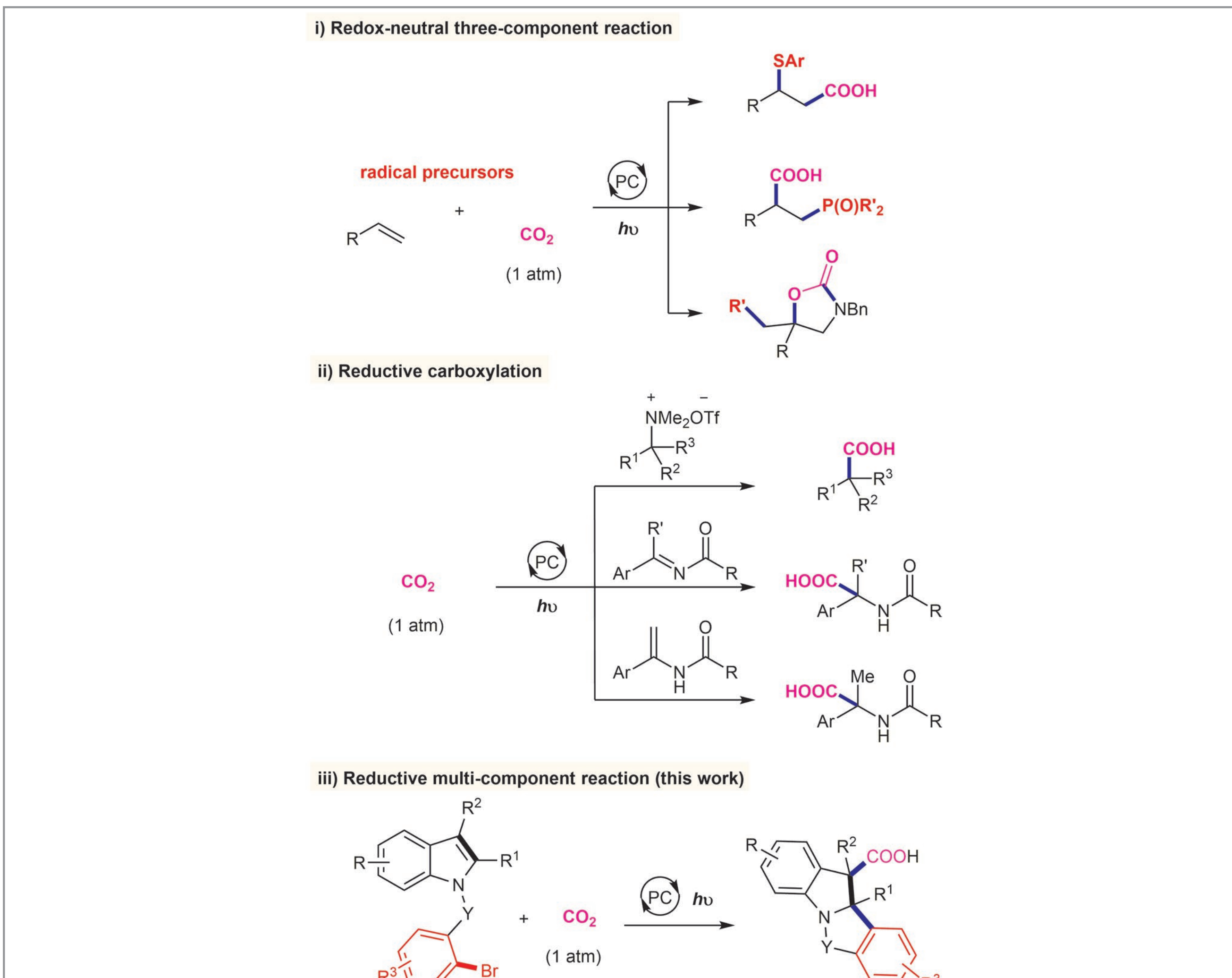
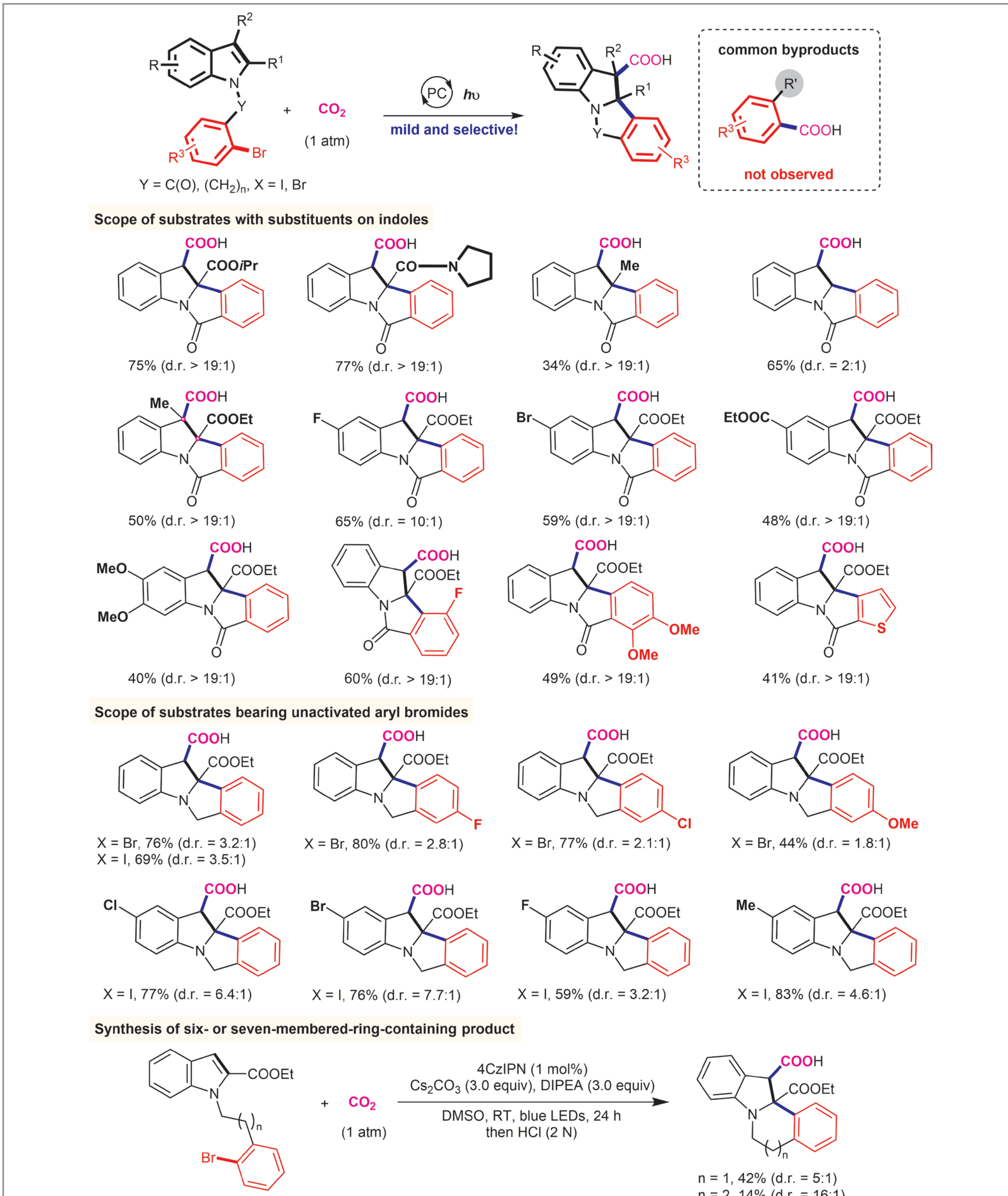
The catalytic reductive coupling of two electrophiles with one unsaturated bond represents an economic and efficient way to construct complex molecular skeletons, and is commonly achieved by transition-metal-catalyzed two-electron-transfer reactions. However, the latter almost invariably suffer from chemoselectivity issues, which are caused by side reactions of the in situ generated organometallic reagents, including β-H elimination and ipso direct coupling. Inspired by the merits of visible-light photoredox catalysis, the group of Professor Da-Gang Yu, from Sichuan University (Chengdu, P. R. China), has recently reported a novel strategy relying on visible-light photoredox-catalyzed successive single electron transfer (SSET), thus accomplishing the first example of dearomative arylcarboxylation of indoles with CO_2.



Scheme 1 Visible-light-driven CO_2 utilization in Yu's group; PC = photocatalyst.

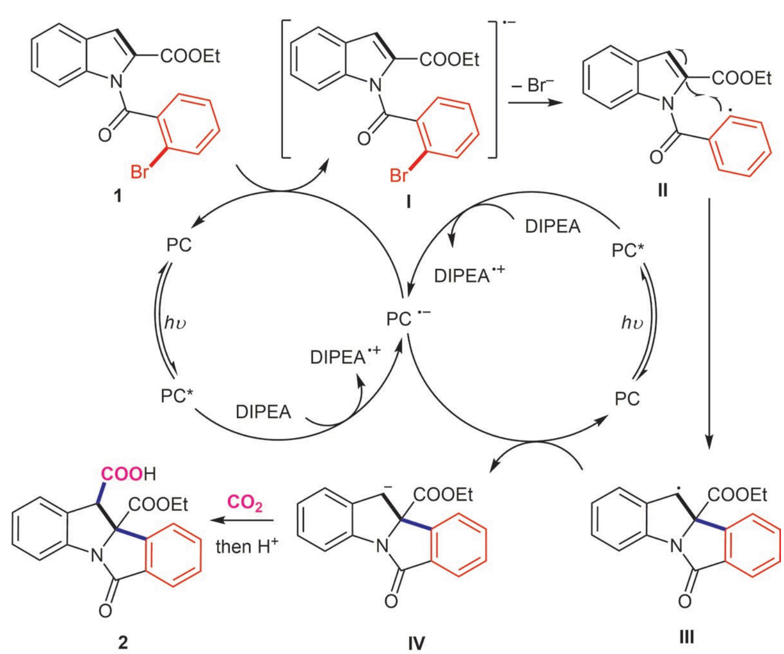


Scheme 2 Selected examples of the reductive dearomative arylcarboxylation

The focus of Professor Yu's group has been on searching for new strategies and useful chemistry in the field of CO_2 utilization and visible-light photoredox catalysis (Scheme 1). "By studying the intersection of these two areas, we wish to mimic nature to realize efficient visible-light-driven CO_2 utilization," explained Professor Yu. He continued: "Along with other great chemists in this field (for the full list of references see the original paper), in the last few years we designed and developed redox-neutral and regioselective three-component thiocarboxylation (*Angew. Chem. Int. Ed.* **2017**, *56*, 15416–15420), phosphonocarboxylation (*Nat. Commun.* **2019**, DOI: 10.1038/s41467-019-11528-8) and oxy-alkylation (*Org. Lett.* **2018**, *20*, 190–193; *Org. Lett.* **2018**, *20*, 3049–3052) of alkenes." Moreover, the group also discovered the reductive carboxylation with CO_2 of enamides/imines (*Angew. Chem. Int. Ed.* **2018**, *57*, 13897–13901) and C–N bonds in tetraalkyl ammonium salts (*J. Am. Chem. Soc.* **2018**, *140*, 17338–17342), in which the SSET strategy was successfully developed. Based on these two strands of work, Professor Yu's group further challenged themselves with the task of developing the multi-component reductive carboxylation with unsaturated bonds, especially those in aromatic rings (*ACS Catal.* **2017**, *7*, 8324–8330).

In their latest account, Professor Yu and his group have developed a novel reductive dearomative arylcarboxylation of indoles with CO_2 via visible-light photoredox catalysis, realizing the synthesis of valuable but difficult-to-access 3D cyclic skeletons of indoline-3-carboxylic acids. "This SSET process avoids possible side reactions via transition-metal catalysis, including ipso carboxylation of aryl halides and β-hydride elimination," explained Professor Yu. He continued: "These reactions feature mild reaction conditions (room temperature, 1 atm CO_2), good functional group tolerance, high chemoselectivity and low loading of photocatalyst. Besides the activated aryl halides bearing electron-withdrawing groups, unactivated aryl halides, which are more electron-rich and thus more challenging to engage in single-electron reduction via photocatalysis, are also reactive in these conditions (Scheme 2). Furthermore, the corresponding products bearing six- and seven-membered rings can also be obtained. With the benzylic anions as the possible intermediates (Scheme 3), D_2O and aldehyde could be used as alternative electrophiles – besides CO_2 – in such a process."

The authors believe that this SSET strategy might provide a new dimension for CO_2 utilization, visible-light photoredox catalysis and multi-component reductive couplings. "Other designs with different kinds of electrophiles and unsaturated bonds would be successful by using this strategy," noted Professor Yu, who concluded: "We would like to acknowledge that an elegant intermolecular arylcarboxylation of alkenes with CO_2 (*J. Am. Chem. Soc.* **2020**, *142*, 8122–8129)



Scheme 3 Possible mechanism of the reductive dearomative arylcarboxylation. PC = photocatalyst, i.e. 3,5-tetrakis(carbazol-9-yl)-4,6-dicyanobenzene (4CzIPN).

was achieved independently by Professor Gang Li from Fujian Institute of Research on the Structure of Matter (Fuzhou, P. R. China) at almost the same time.”

About the authors

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Wen-Jun Zhou was born in Sichuan province, P. R. of China, in 1984. He obtained his bachelor’s degree in 2006 at Northwest Normal University (P. R. of China) and Ph.D. under the guidance of Prof. Jin-Xian Wang in the same university, in 2011. He then worked independently at Neijiang Normal University (P. R. of China). Since 2015, Dr. Zhou has been carrying out his postdoctoral research in the group of Prof. Dr. Da-Gang Yu, Sichuan University (P. R. of China). His research focuses mainly on synthetic organometallic chemistry, photoredox chemistry and radical chemistry.

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Zhe-Hao Wang received his M.S. degree from Lanzhou University (P. R. of China) in 2018. He then moved to Sichuan University (P. R. of China) for his doctoral studies where he worked on the development of CO_2 transformation via visible-light photoredox catalysis under the supervision of Prof. Da-Gang Yu and Prof. Yiwen Li.

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Li-Li Liao obtained her B.S. degree in 2016 at Sichuan University (P. R. of China) under the supervision of Prof. Da-Gang Yu. She is currently a PhD student in the same research group. Her research interests include photoredox catalysis and CO_2 utilization.

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Ke-Gong Cao received his B.A. from College of Chemistry, Sichuan University (P. R. of China) in 2020. In the same year, he will continue his research in the group of Prof. Da-Gang Yu as a Master’s student in Sichuan University. His research interests focus on CO_2 utilization via photoredox catalysis.

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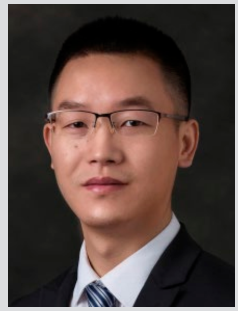

Prof. D.-G. Yu

Da-Gang Yu was born in Jiangxi province, P. R. of China, in 1986. He received his Ph.D. with Prof. Dr Zhang-Jie Shi from Peking University (P. R. of China) in 2012. He carried out postdoctoral research under a Humboldt fellowship in the group of Prof. Dr. Frank Glorius, Muenster University (Germany). Since 2015, he has been working independently at Sichuan University (P. R. of China) with support from "The Thousand Young Talents Plan" and National Natural Science Foundation of China–Outstanding Young Scholars. His research interests focus mainly on novel transformations of CO_2, radical chemistry and novel transition-metal catalysis. He has received many honors, including "Organic Chemistry Frontiers" Emerging Investigators in 2016, Thieme Chemistry Journals Award in 2017, Chinese Chemical Society Youth Award in 2018, "Science China Chemistry" Emerging Investigators and "Chemical Communications" Emerging Investigators in 2020.