

Table S1. Lattice parameter and cell volume of CoMnO_x-T and CuCoMnO_x-T catalyst

| Catalyst | Space group | Lattice Parameter (Å) | | | Cell volume (Å ³) |
|---------------------------|-------------|-----------------------|-------|-------|-------------------------------|
| | | a | b | c | |
| CoMnO _x -200 | I41/amd | 8.097 | 8.097 | 9.266 | 607.5 |
| CoMnO _x -300 | I41/amd | 8.096 | 8.096 | 9.242 | 605.7 |
| CoMnO _x -400 | I41/amd | 8.096 | 8.096 | 9.243 | 605.9 |
| CoMnO _x -500 | I41/amd | 8.097 | 8.097 | 9.254 | 606.7 |
| CuCoMnO _x -200 | Fd-3m | 8.169 | -- | -- | 545.2 |
| CuCoMnO _x -300 | Fd-3m | 8.160 | -- | -- | 543.5 |
| CuCoMnO _x -400 | Fd-3m | 8.176 | -- | -- | 546.7 |
| CuCoMnO _x -500 | Fd-3m | 8.189 | -- | -- | 549.3 |

Table S2. Grain size of CoMnO_x-T and CuCoMnO_x-T calculated by XRD

| Catalyst | θ | hkl | FWHM | D/Å |
|--------------------------------|----------------------------|------------|--------------|------------|
| CoMnO_x-200 | 36.23 | 311 | 0.934 | 89 |
| CuCoMnO_x-200 | 36.47 | 311 | 0.957 | 86 |
| CoMnO_x-300 | 36.43 | 311 | 1.035 | 80 |
| CuCoMnO_x-300 | 36.39 | 311 | 1.111 | 74 |
| CoMnO_x-400 | 36.36 | 311 | 0.952 | 87 |
| CuCoMnO_x-400 | 36.34 | 311 | 0.959 | 86 |
| CoMnO_x-500 | 36.39 | 311 | 0.411 | 201 |
| CuCoMnO_x-500 | 36.34 | 311 | 0.464 | 178 |

Table S3. Specific surface area and pore volume of CoMnO_x-T and CuCoMnO_x-T catalysts

| Catalyst | S_{BET} (m²g⁻¹) | V_{Pore} (cm³g⁻¹) |
|--------------------------------|--|--|
| CoMnO_x-200 | 75 | 0.246 |
| CoMnO_x-300 | 109 | 0.267 |
| CoMnO_x-400 | 63 | 0.186 |
| CoMnO_x-500 | 30 | 0.210 |
| CuCoMnO_x-200 | 49 | 0.109 |
| CuCoMnO_x-300 | 79 | 0.157 |
| CuCoMnO_x-400 | 53 | 0.157 |
| CuCoMnO_x-500 | 12 | 0.090 |

Table S4. The H₂ consumption of CoMnO_x-T and CuCoMnO_x-T catalyst calculated by H₂-TPR

| Catalyst | Total H₂ cons. (mmol/g_{cat}) |
|--------------------------------|---|
| CoMnO_x-200 | 7.83 |
| CoMnO_x-300 | 11.05 |
| CoMnO_x-400 | 11.26 |
| CoMnO_x-500 | 8.94 |
| CuCoMnO_x-200 | 11.03 |
| CuCoMnO_x-300 | 11.64 |
| CuCoMnO_x-400 | 11.42 |
| CuCoMnO_x-500 | 10.94 |

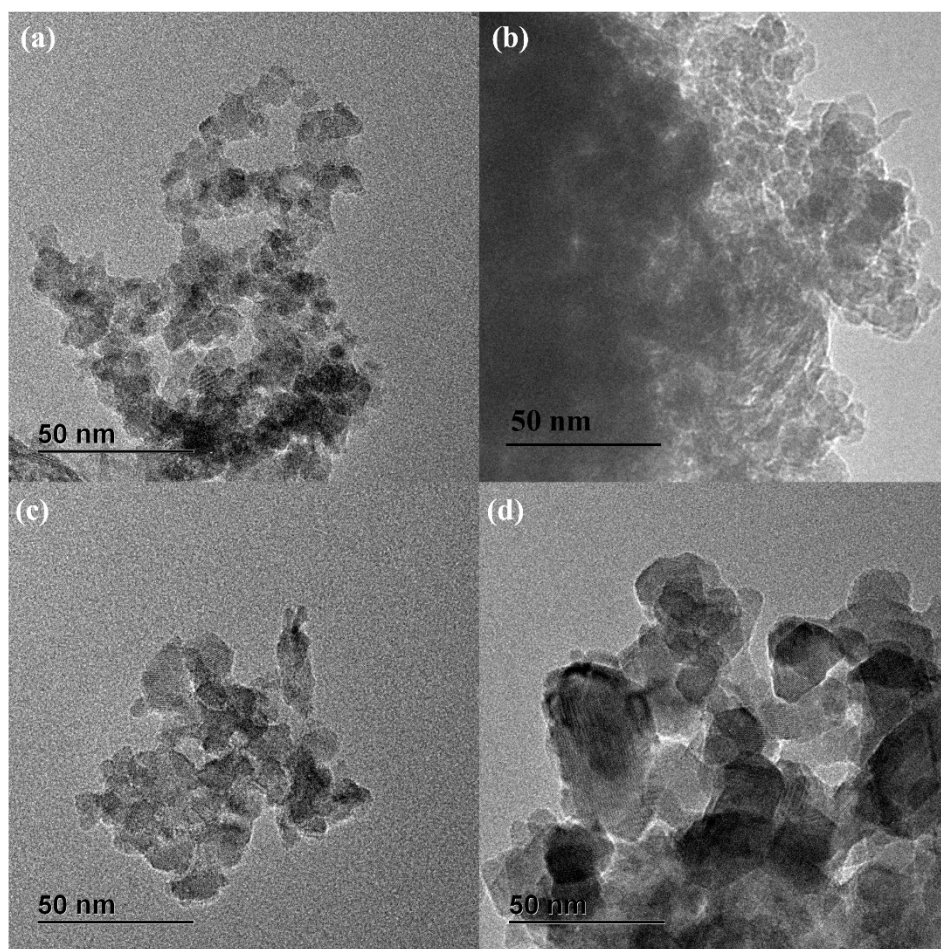


Figure S1 TEM images of CuCoMnO_x -200 (a), CuCoMnO_x -300 (b), CuCoMnO_x -400 (c) and CuCoMnO_x -500 (d)

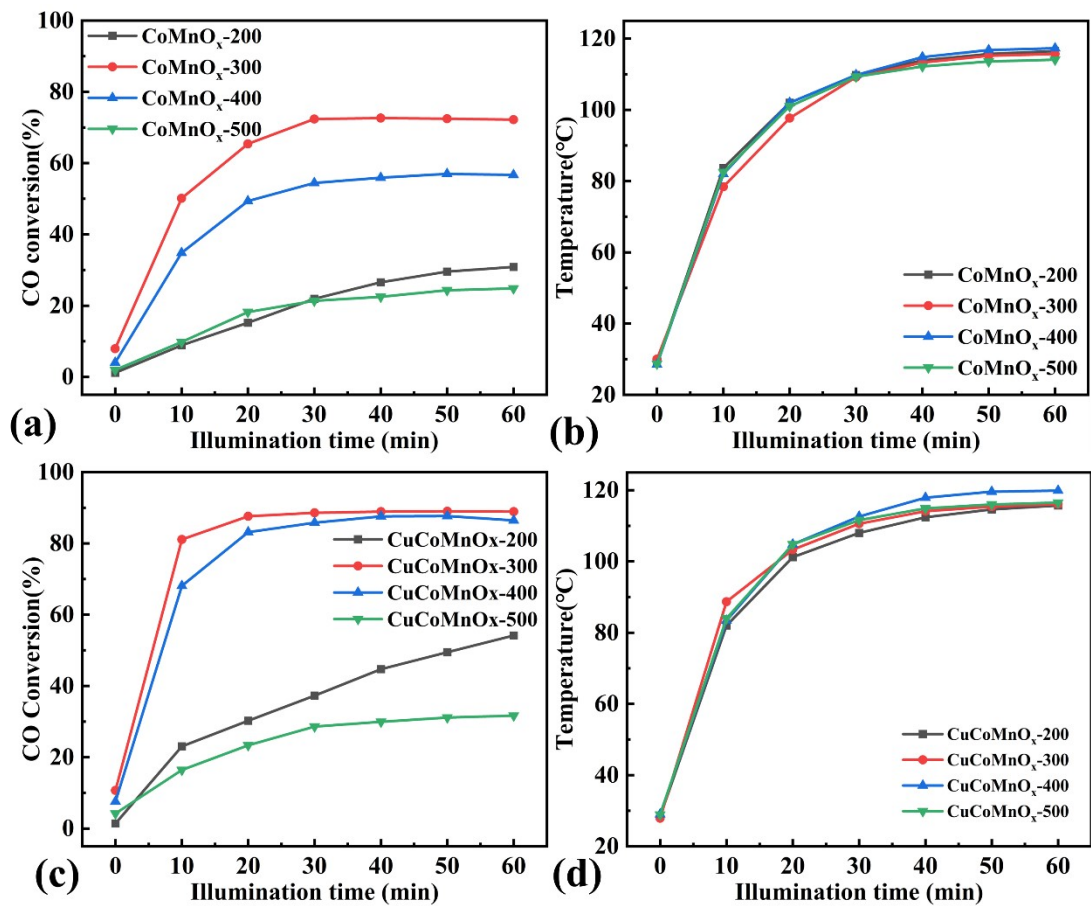


Figure S2. CO conversion (a,c) and temperature (b,d) curves of CoMnO_x-T and CuCoMnO_x-T in CO-PROX at 250 mW/cm²

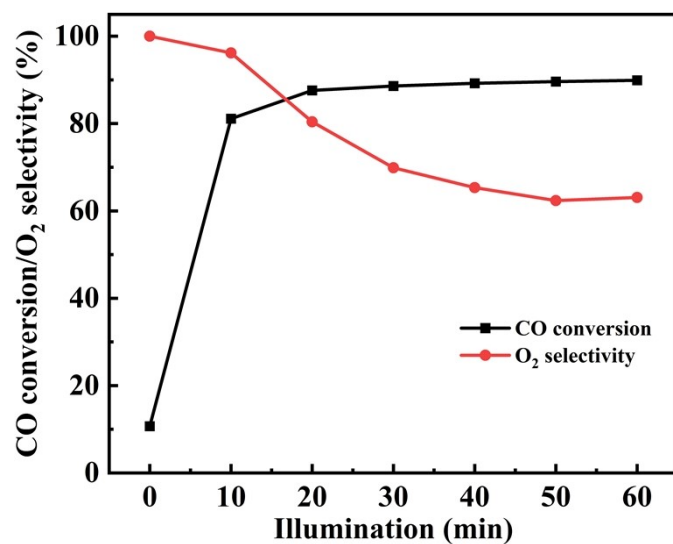


Figure S3 CO conversion and O₂ selectivity of CuCoMnO_x-300 for photothermal CO-PROX

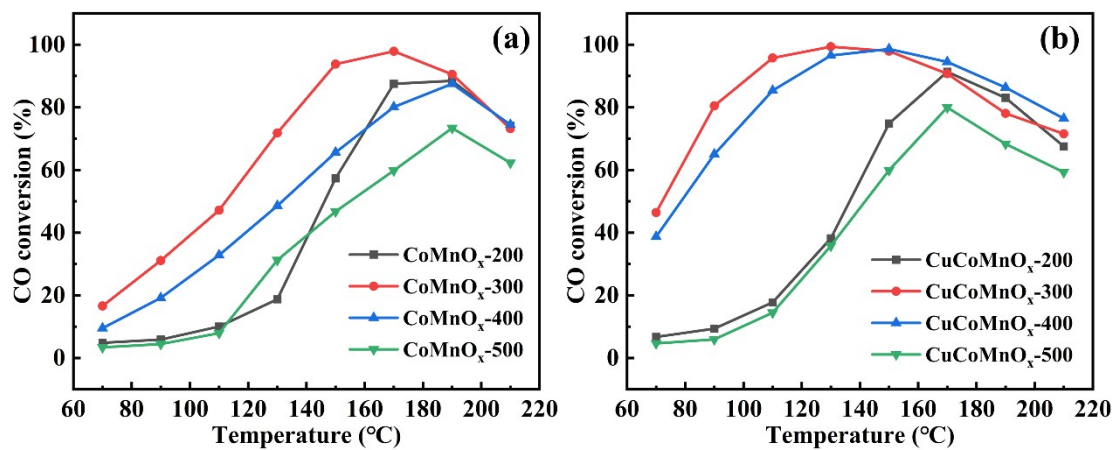


Figure S4. CO conversion of thermal catalysis over CoMnO_x-T (a) and CuCoMnO_x-T (b)

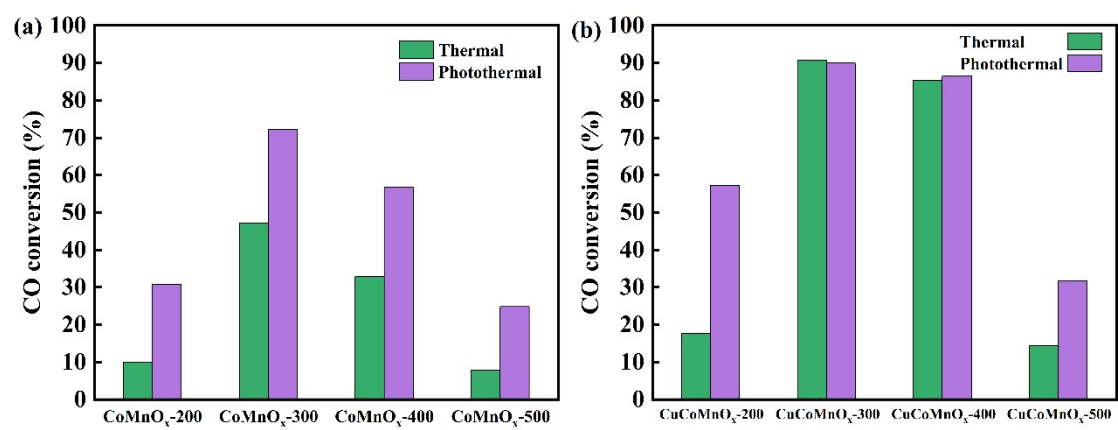


Figure S5. comparison of CO conversion of the CoMnO_x and CuCoMnO_x catalysts for thermal and photothermal CO-PROX

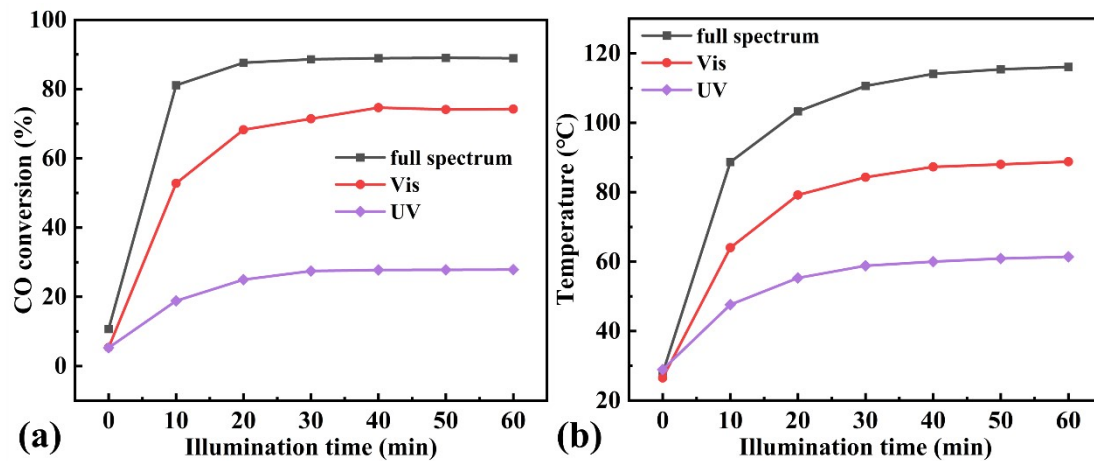


Figure S6. CO conversion and temperature curve of CuCoMnO_x-300 in CO-PROX at 250W/cm² illuminated under different optical composition

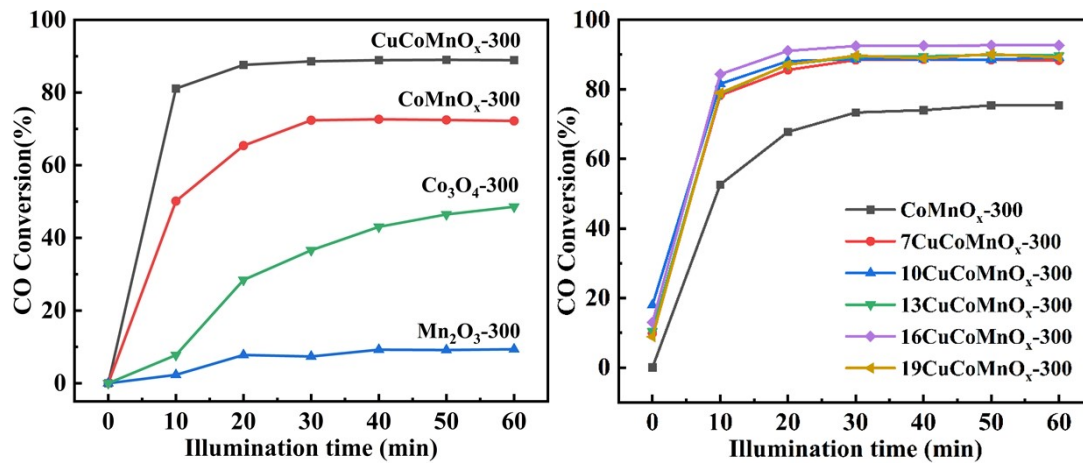


Figure S7. CO conversions of pure Co_3O_4 and Mn_2O_3 , binary CoMnO_x and ternary CuCoMnO_x calcined at 300 °C (a) and CO conversions of CuCoMnO_x -300 with different copper amount in photothermal CO-PROX at 250mW/cm²

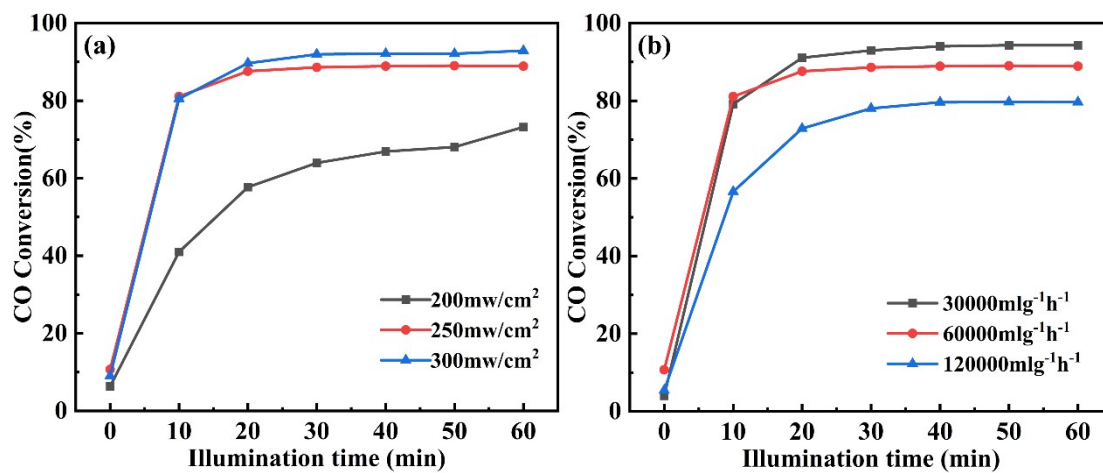


Figure S8. CO conversion of CuCoMnO_x-300 in CO-PROX at different illumination power densities (a) and at different weight hourly space velocity (b) at 250 mW/cm² (b)

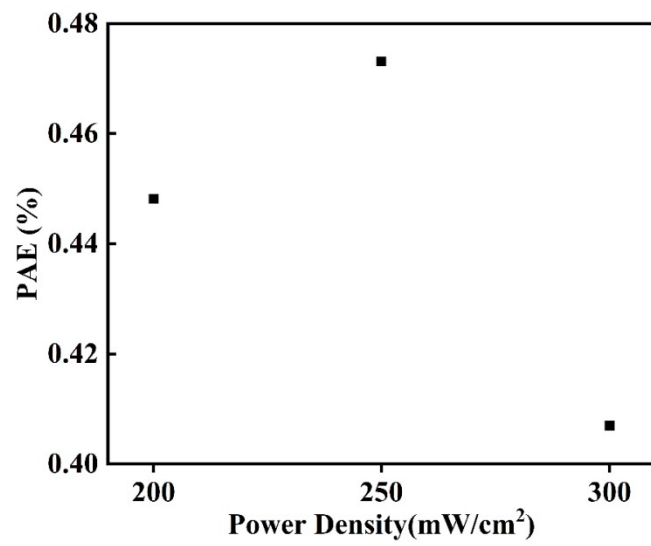


Figure S9. PAE values of CuCoMnO_x-300 catalyst under different illumination densities.

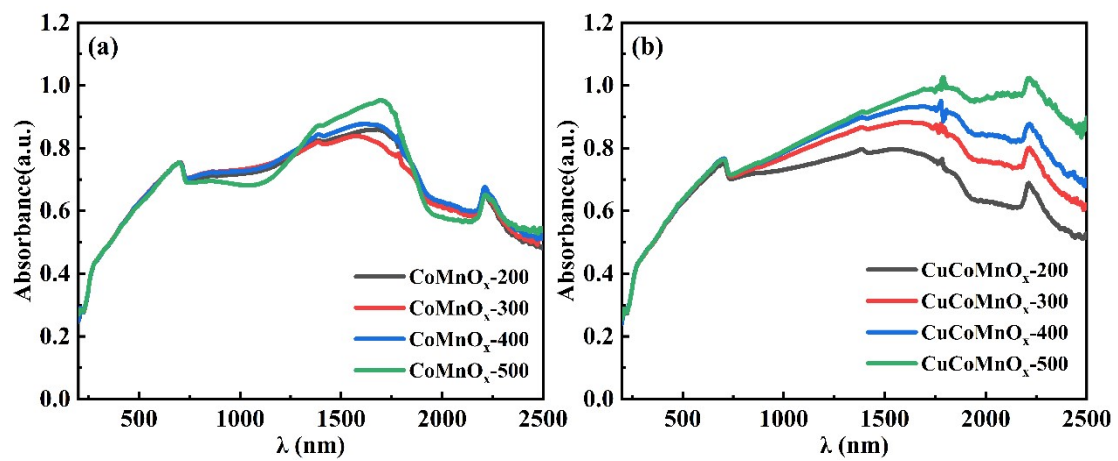


Figure S10. UV-Vis-IR absorption spectra of (a) CoMnO_x-T, (b) CuCoMnO_x-T.

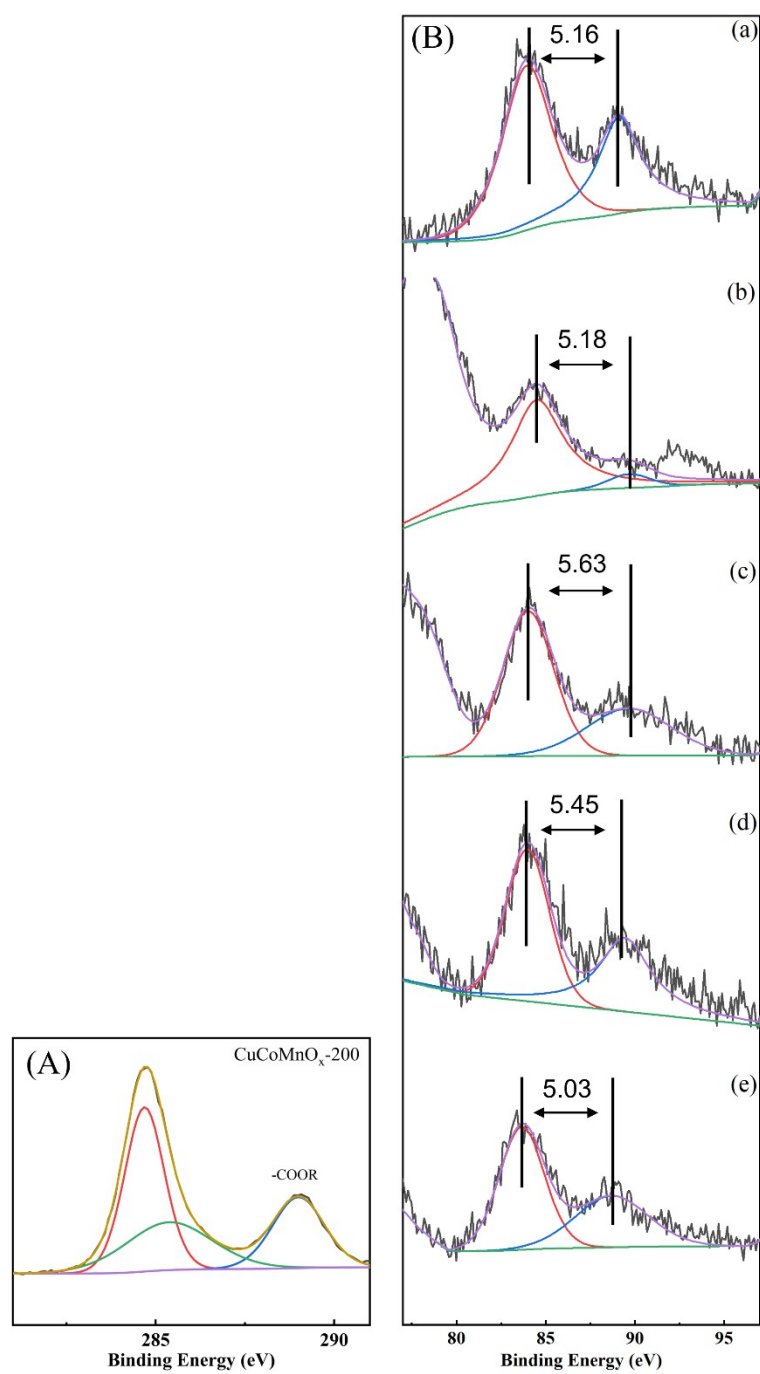


Figure S11. XPS spectra of C 1s (A) and Mn 3s (B) of CoMnO_x-300 (a), CuCoMnO_x-200 (b), CuCoMnO_x-300 (c), CuCoMnO_x-400 (d) and CuCoMnO_x-500 (e).

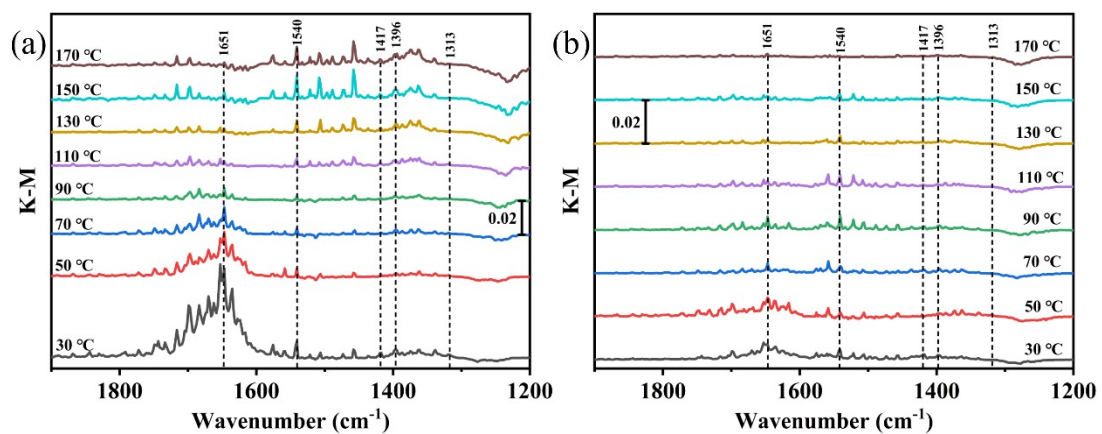


Figure S12. DRIFTS spectra (1900-1200 cm⁻¹) of CoMnO_x-300 (a) and CuCoMnO_x-300 (b) under the reaction stream at different temperature.

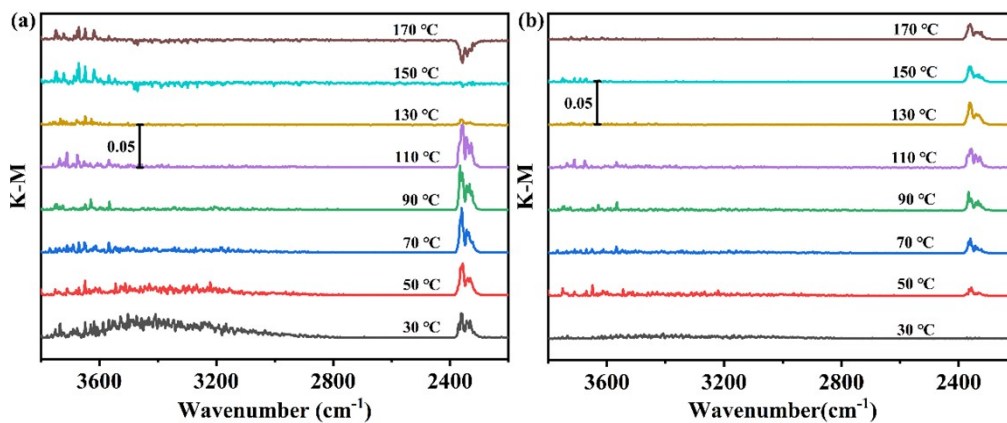


Figure S13. DRIFTS spectra (3800-2200 cm^{-1}) of CoMnO_x-300 (a) and CuCoMnO_x-300 (b).