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$NiCo_2O_4$ nanoparticles: an efficient and magnetic catalyst for Knoevenagel condensation

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1.1 Introduction of reaction

- **Knoevenagel condensation:**

  Fine chemicals;

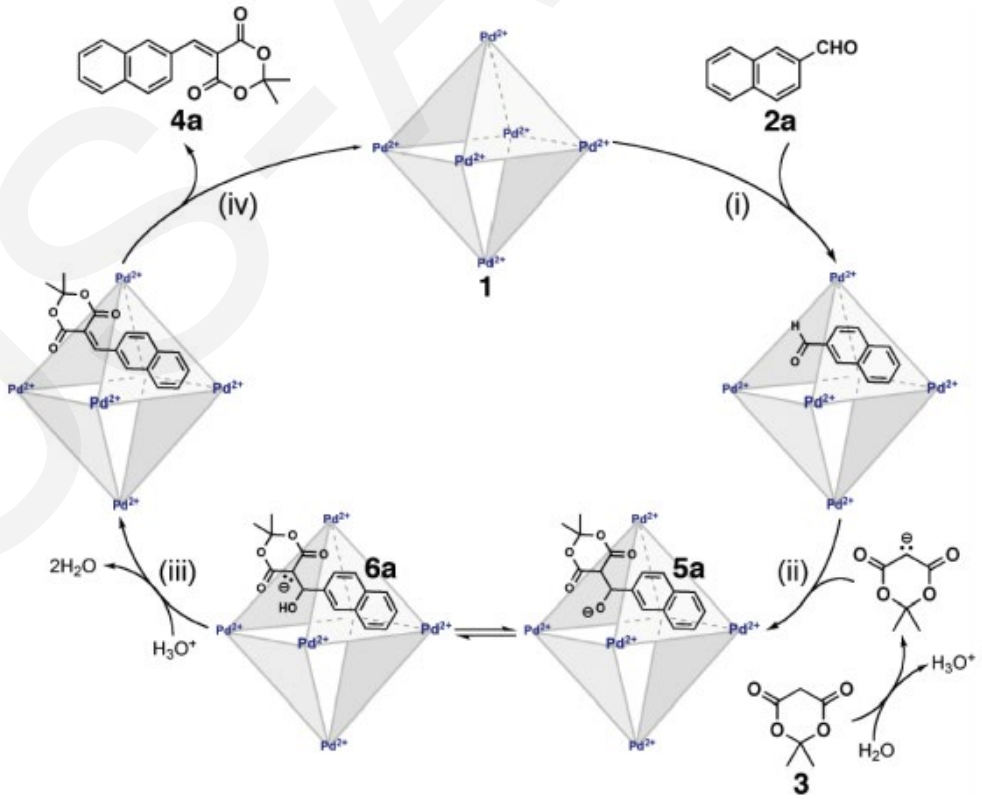
  Drugs;

  Perfumes and cosmetics.

Drugs

Cosmetics

Perfumes



Proposed mechanism for the catalytic Knoevenagel condensation of aldehyde 2a with 3 in the presence of cage 1

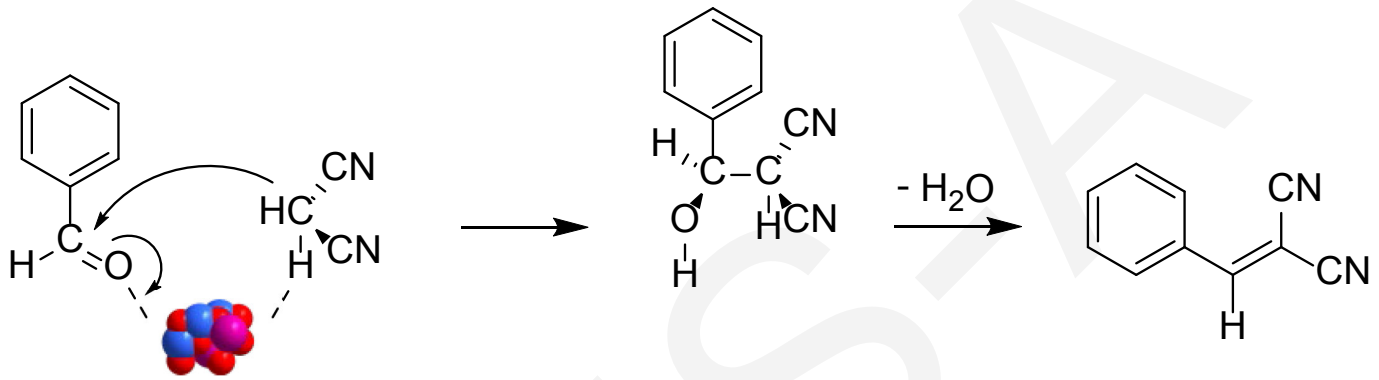


Figure 2.1 Possible mechanism for $NiCo_2O_4$ catalyzed Knoevenagel condensation

2.1 Highlights in this part:

- Advanced performance of $NiCo_2O_4$ catalyst with 99% yield for 20 runs;
- Easy recovery by an external magnet after the Knoevenagel condensation;
- Mild conditions and convenient process for industrial practice.

3.1 Characterization of the catalysts

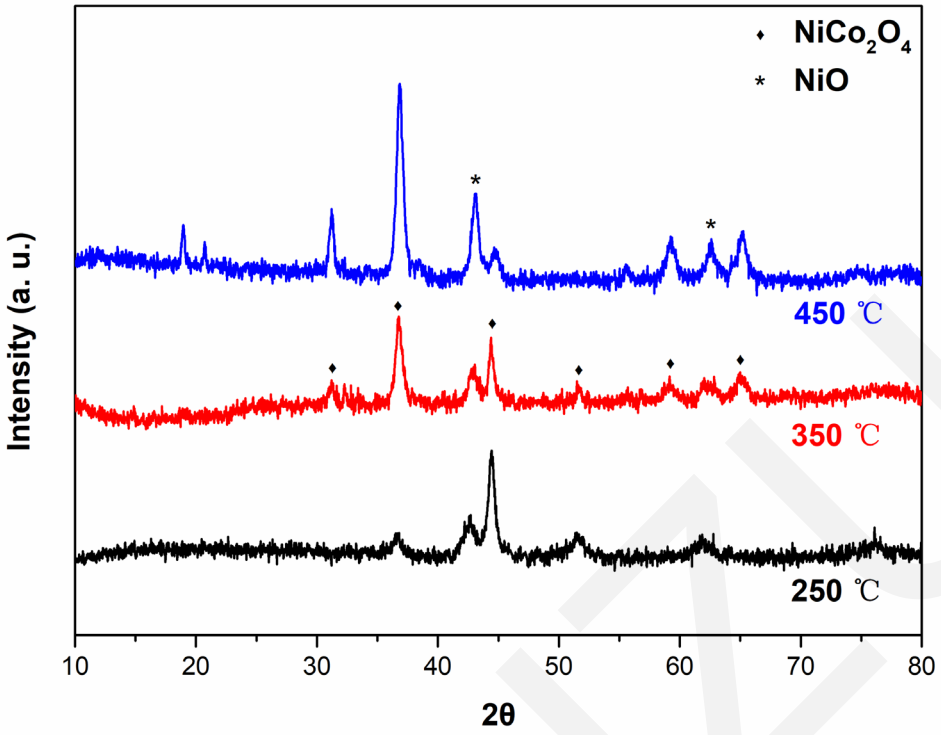


Figure 3.1 XRD patterns of the prepared catalysts.

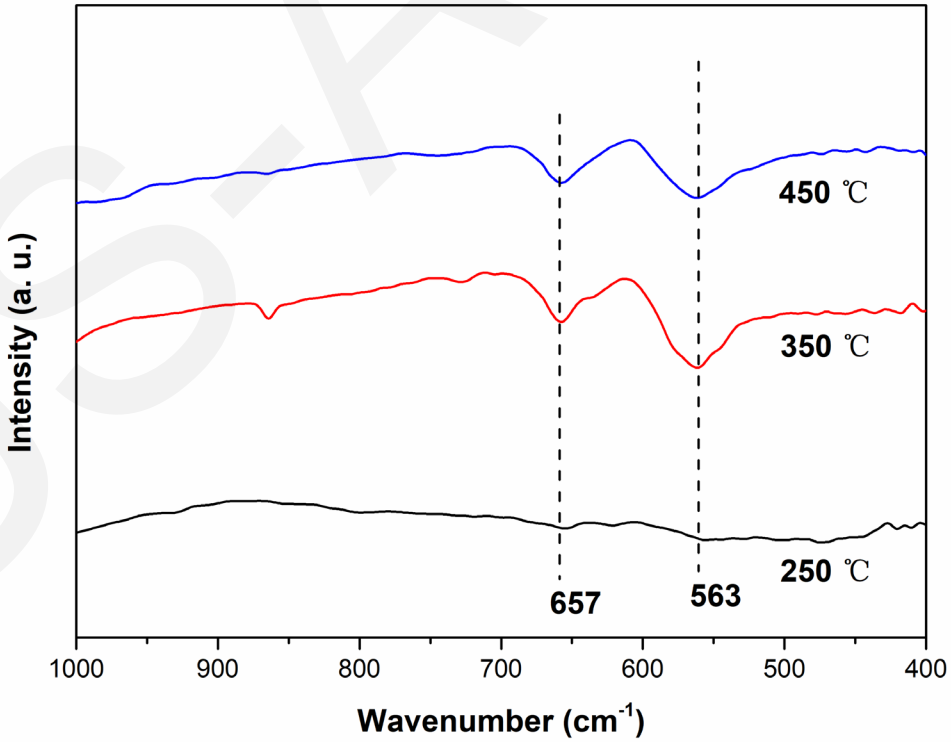


Figure 3.2 FT-IR patterns of the prepared catalysts.

- An appropriate calcination temperature;
- A balance between crystallinity and purity.

- The characteristic adsorption bands at 657 and 563 cm^{-1}.

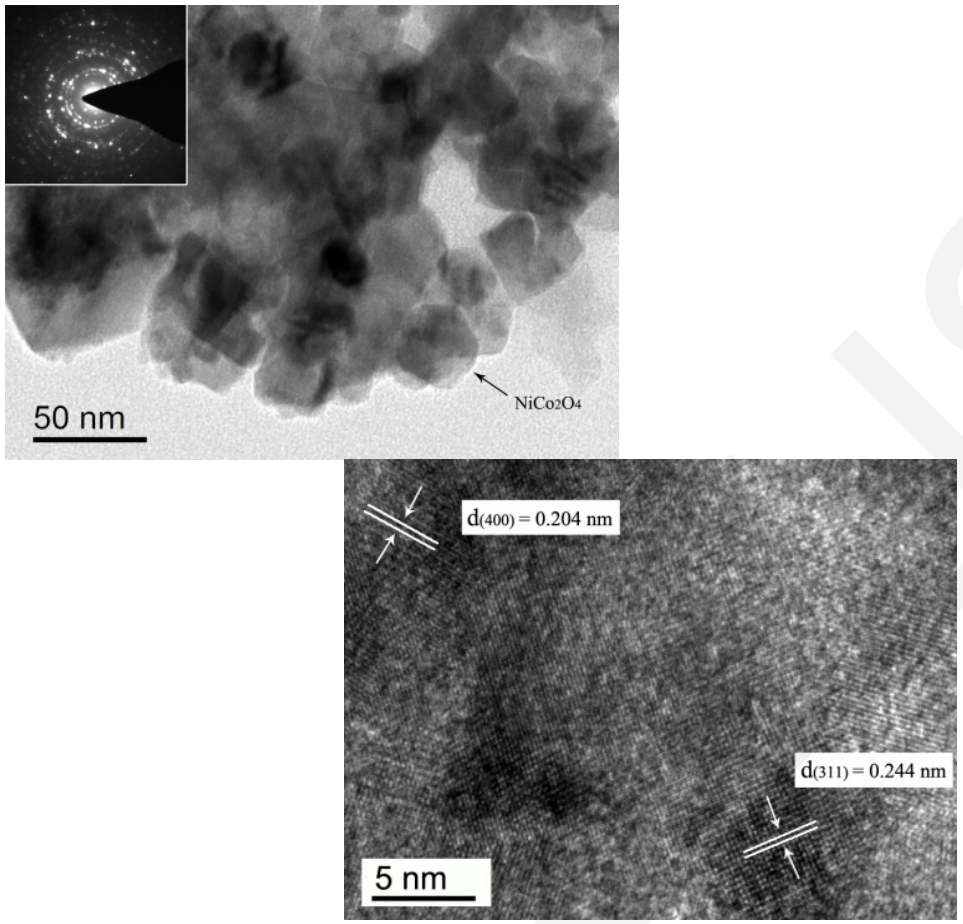


Figure 3.3 (a) TEM image and selected area electron diffraction (SAED) pattern of $NiCo_2O_4$ nanocatalyst; (b) HRTEM image of $NiCo_2O_4$ nanocatalyst

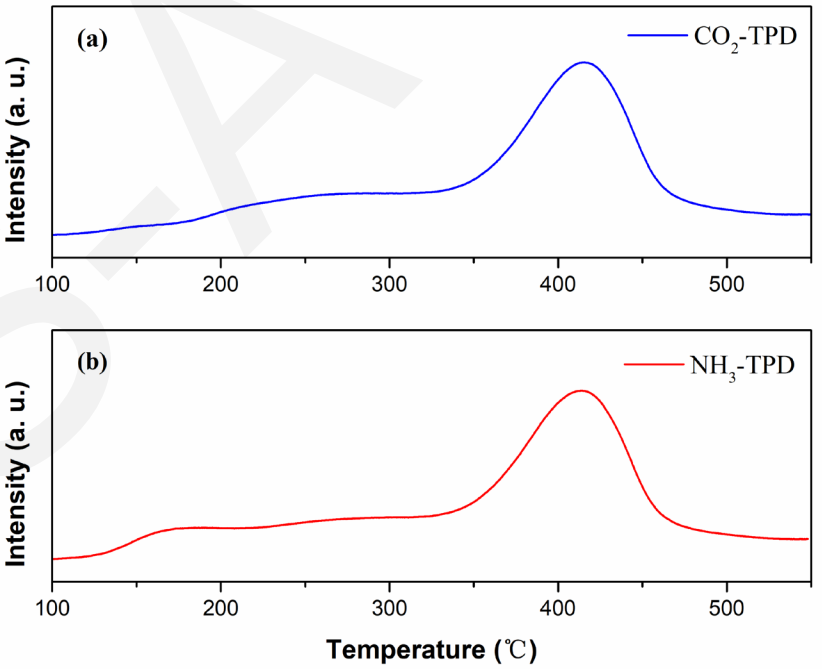


Figure 3.4 CO_2-TPD and NH_3-TPD of the $NiCo_2O_4$ sample.

Table 1 Characteristics of the prepared $NiCo_2O_4$ catalyst

Sample	S_{BET} (m^2/g)	Pore size (nm)	Pore volume (cm^3/g)
$NiCo_2O_4$	4.302	21.263	0.023

3.4 Conclusions

- In summary, a convenient and environmentally-friendly procedure is provided for the synthesis of 2-benzylidenemalononitrile by Knoevenagel condensation of benzaldehyde and malononitrile using nano-$NiCo_2O_4$ as a new, effective, stable and recyclable catalyst. In practice, this advanced catalyst can achieve not only superior catalytic performance, but also a favourable number of cycles. Thus, it has considerable potential for application to continuous Knoevenagel condensation reactions without significant loss of catalytic activity.