

ORIGINAL RESEARCH ARTICLE

**Enhanced adsorption desulfurization performance of
metal-modified Y zeolites**

Supplementary File

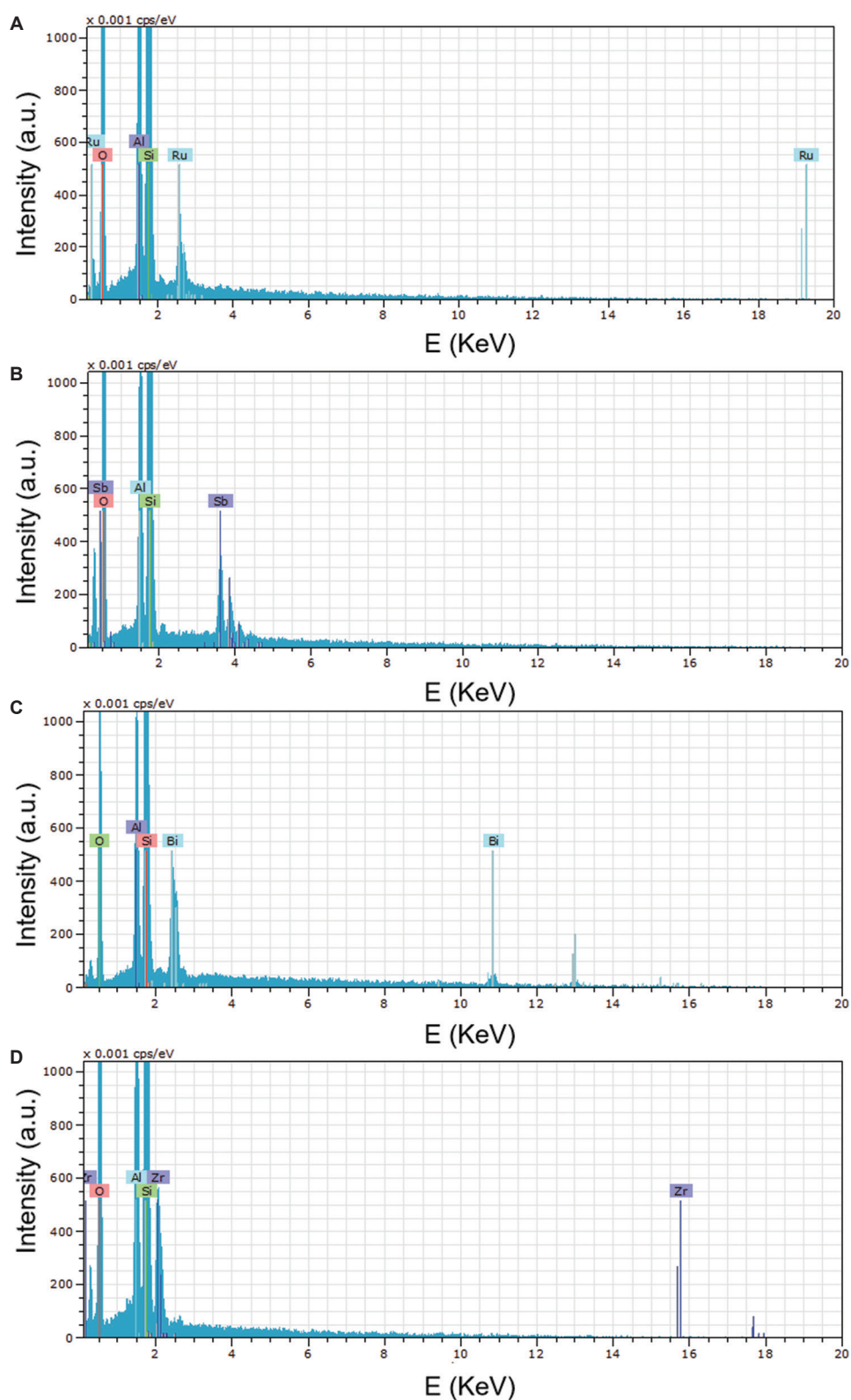


Figure S1. EDX spectra of MY-1 adsorbents. (A) RuY-1. (B) SbY-1. (C) BiY-1. (D) ZrY-1.

Abbreviations: BiY: Bismuth-modified Y-zeolite; EDX: Energy-dispersive X-ray spectroscopy; MY: Metal ion-modified Y-zeolite; RuY: Ruthenium-modified Y-zeolite; SbY: Antimony-modified Y-zeolite; ZrY: Zirconium-modified Y-zeolite.

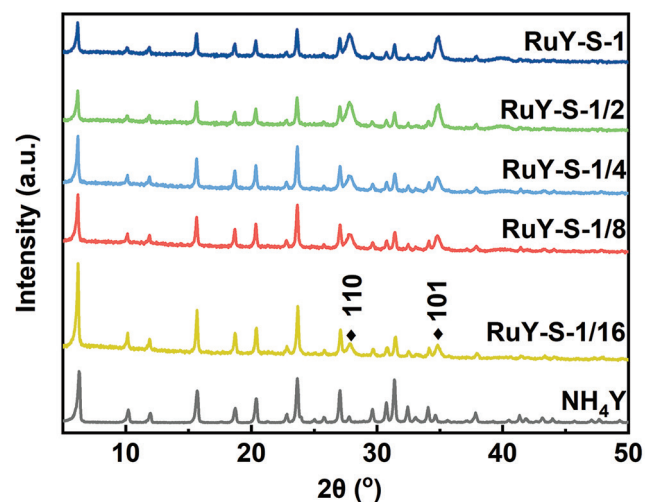


Figure S2. XRD patterns of RuY-X adsorbents calcined at 500°C.

Abbreviations: NH₄Y: Ammonium-form Y-zeolite; RuY: Ruthenium-modified Y-zeolite; XRD: X-ray diffraction.

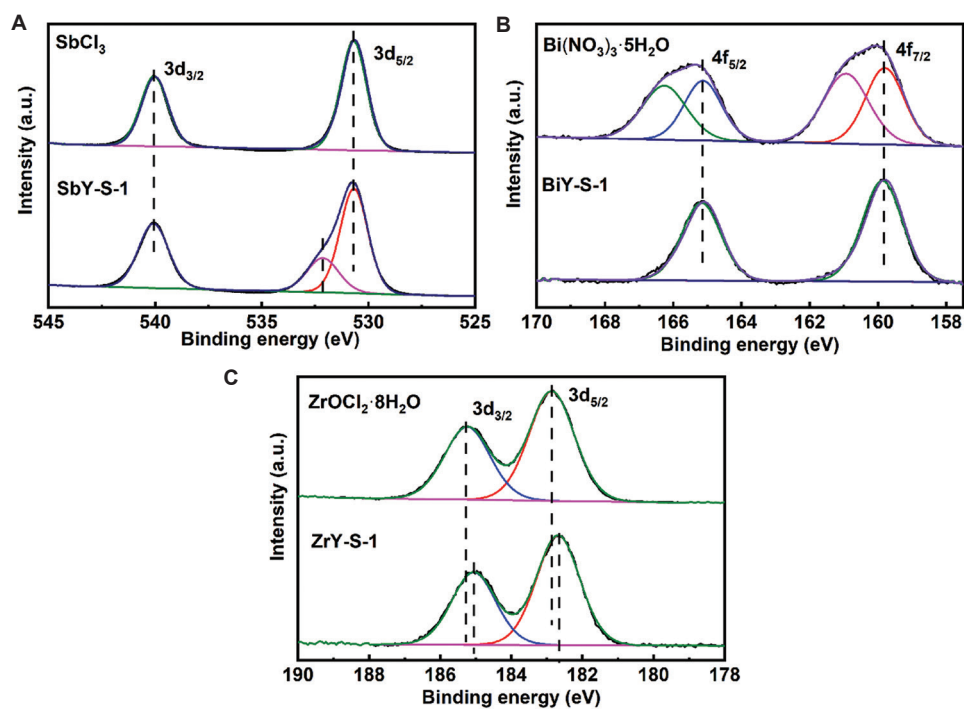


Figure S3. XPS spectra before and after the calcination of adsorbents. (A) SbY-1. (B) BiY-1. (C) ZrY-1.

Abbreviations: BiY: Bismuth-modified Y-zeolite; SbY: Antimony-modified Y-zeolite; XPS: X-ray photoelectron spectroscopy; ZrY: Zirconium-modified Y-zeolite.

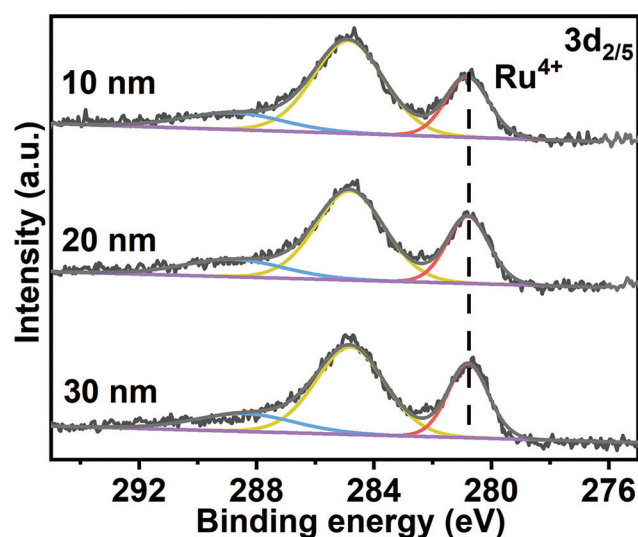


Figure S4. Depth-profiled XPS spectra of the RuY-1/2 sample after etching at 10 nm, 20 nm, and 30 nm. Abbreviations: RuY: Ruthenium-modified Y-zeolite; XPS: X-ray photoelectron spectroscopy.

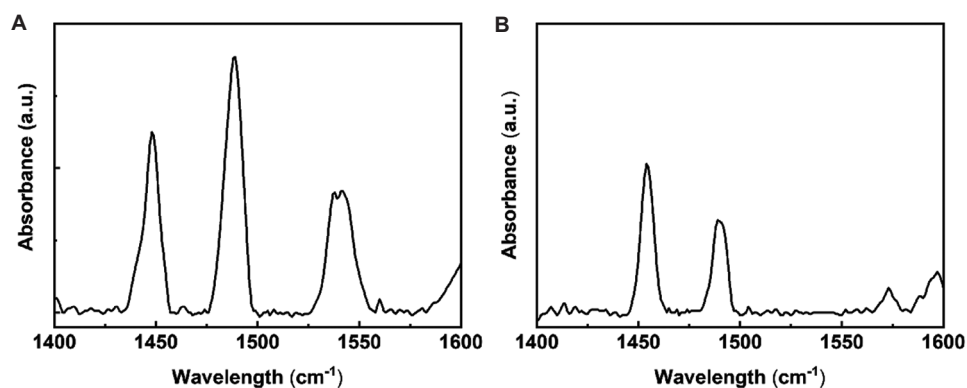


Figure S5. Py-FTIR spectra of RuY-1. Spectra of adsorbent after pyridine desorption at 150°C (A) and 450°C (B) are shown.

Abbreviations: PY-FTIR: Pyridine-Fourier-transform infrared spectroscopy; RuY: Ruthenium-modified Y-zeolite.

Table S1. EDX analysis of MY-1 adsorbents

Adsorbents	RuY-1	SbY-1	ZrY-1	BiY-1
Metal added (wt%)	11.30	13.60	23.4	10.20
Metal loaded (wt%)	Ru (5.02)	Sb (13.85)	Zr (10.28)	Bi (16.22)

Abbreviations: BiY: Bismuth-modified Y-zeolite; EDX: Energy-dispersive X-ray spectroscopy; MY: Metal ion-modified Y-zeolite; RuY: Ruthenium-modified Y-zeolite; SbY: Antimony-modified Y-zeolite; ZrY: Zirconium-modified Y-zeolite.

Table S2. Pore structure of MY-1 adsorbents

Adsorbents	Langmuir area (m ² /g)	External area (m ² /g)	Internal area (m ² /g)	Pore width (nm)	Pore volume (cm ³ /g)
NH ₄ Y	921.14	86.42	834.72	0.6232	0.3163
RuY-1	735.23	70.49	664.74	0.6552	0.2486
ZrY-1	593.06	50.93	488.13	0.6253	0.1951
SbY-1	476.42	44.42	432.00	0.6211	0.1438
BiY-1	462.27	28.16	434.11	0.6418	0.1546

Abbreviations: BiY: Bismuth-modified Y-zeolite; MY: Metal ion-modified Y-zeolite; NH₄Y: Ammonium Y-zeolite; RuY: Ruthenium-modified Y-zeolite; SbY: Antimony-modified Y-zeolite; ZrY: Zirconium-modified Y-zeolite.

Table S3. Comparison of sulfur removal performance by various adsorbents reported in the literature

Adsorbents	Sulfur compound (initial sulfur concentration)	Weight	Sulfur removal (%)	References
Ru-Y-1	TP (20 ppm)	0.1 g	68	This work
AC/MnO-10%	TP (50 ppm)	0.5 g	~27	1
HKUST-1@ γ -Al ₂ O ₃	DBT (35 ppm)	0.5 g	69	2
Eu-MOF	TP (1000 μ g/g)	Adsorbent: oil=1:100	64.7	3
CuCeY	TP (500 mg/L)	0.1 g	74.3	4
Ni/ZnO-SiO ₂ -Al ₂ O ₃	TP (500 mg/L)	-	86.33	5

Abbreviations: AC: Activated carbon; Al₂O₃: Aluminum oxide; CuCeY: Copper-cerium-exchanged Y zeolite; DBT: Dibenzothiophene; Eu-MOF: Europium metal-organic framework; HKUST-1: Hong Kong University of Science and Technology MOF-1; MnO: Manganese oxide; RuY-1: Ruthenium-exchanged Y zeolite; TP: Thiophene; ZnO: Zinc oxide; SiO₂: Silicon dioxide.

References

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