Supplementary Materials

Tuning the catalytic activity of recyclable heterogeneous catalysts for the direct etherification reaction of glycerol using antagonistic additives

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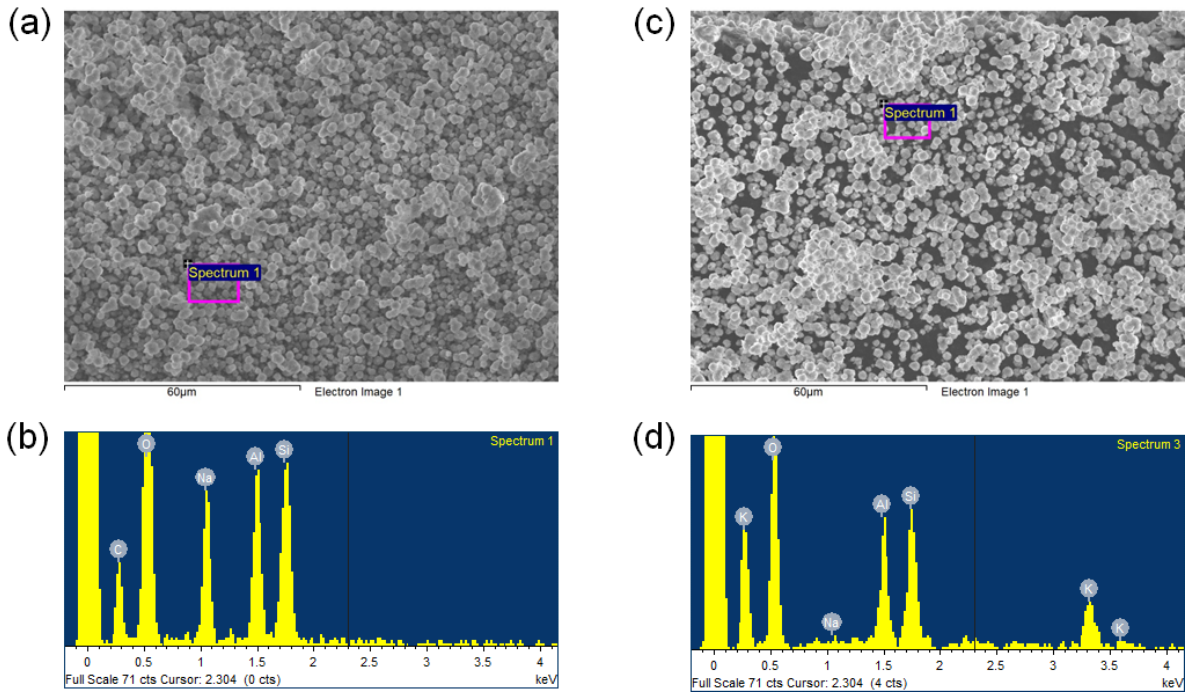

Figure S1. SEM images and EDX data of zeolite (a) and (b) Na-zeolite, (c) and (d) K-zeolite, respectively.

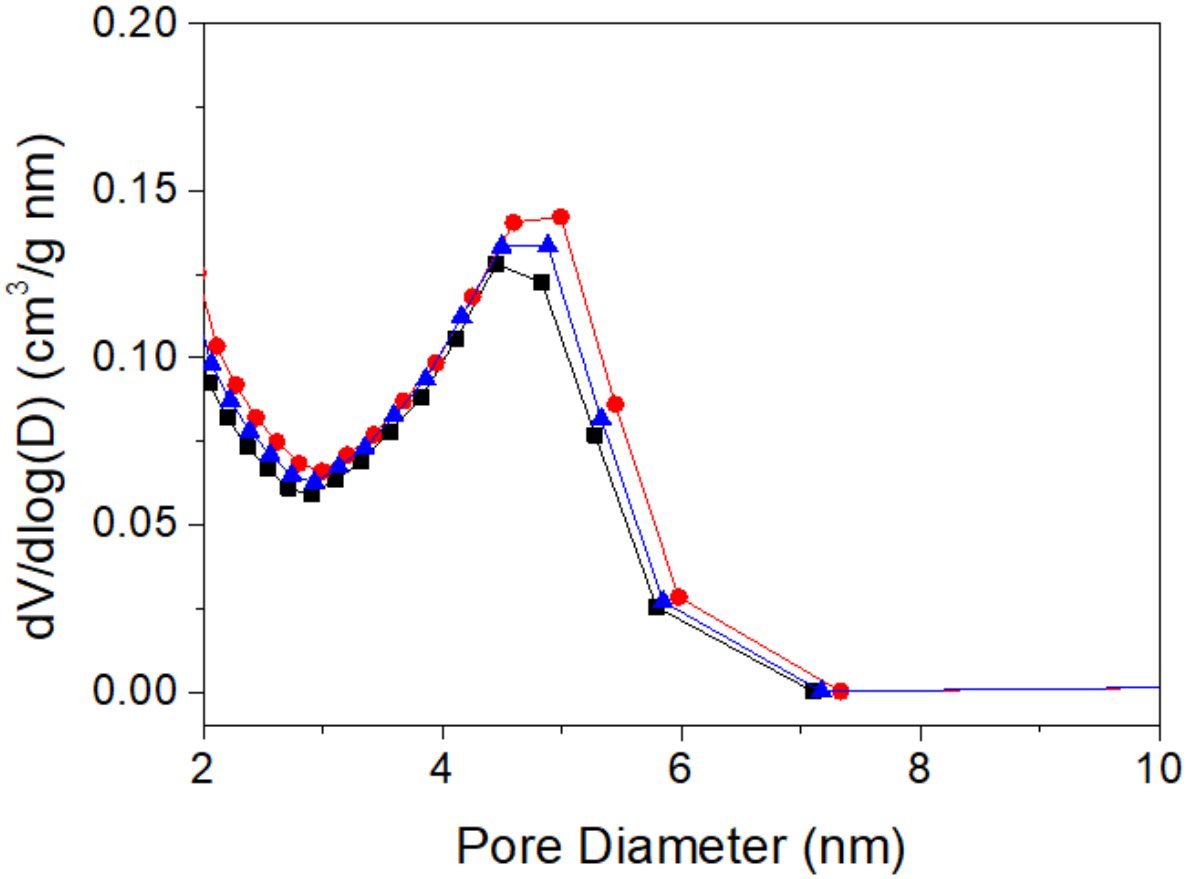

Figure S2. BJH pore size distribution plot of XZ-K: (-■-) pristine zeolite, (-●-) after 5 recycles, (-▲-) after 10 recycles.

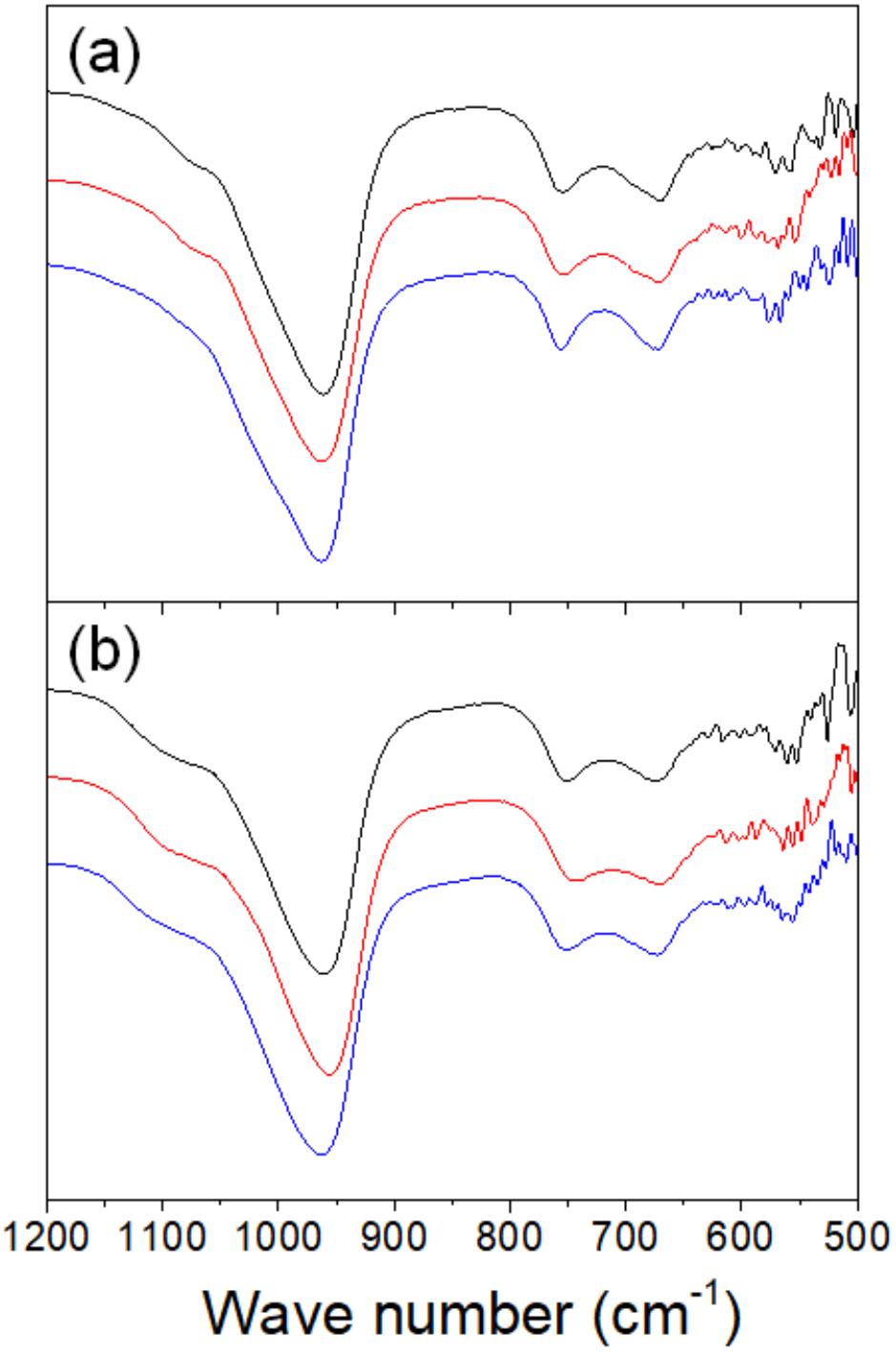

Figure S3. FT-IR spectra of (a) XZ-Na and (b) XZ-K: (—) pristine zeolite, (—) after 5 recycles, (—) after 10 recycles.

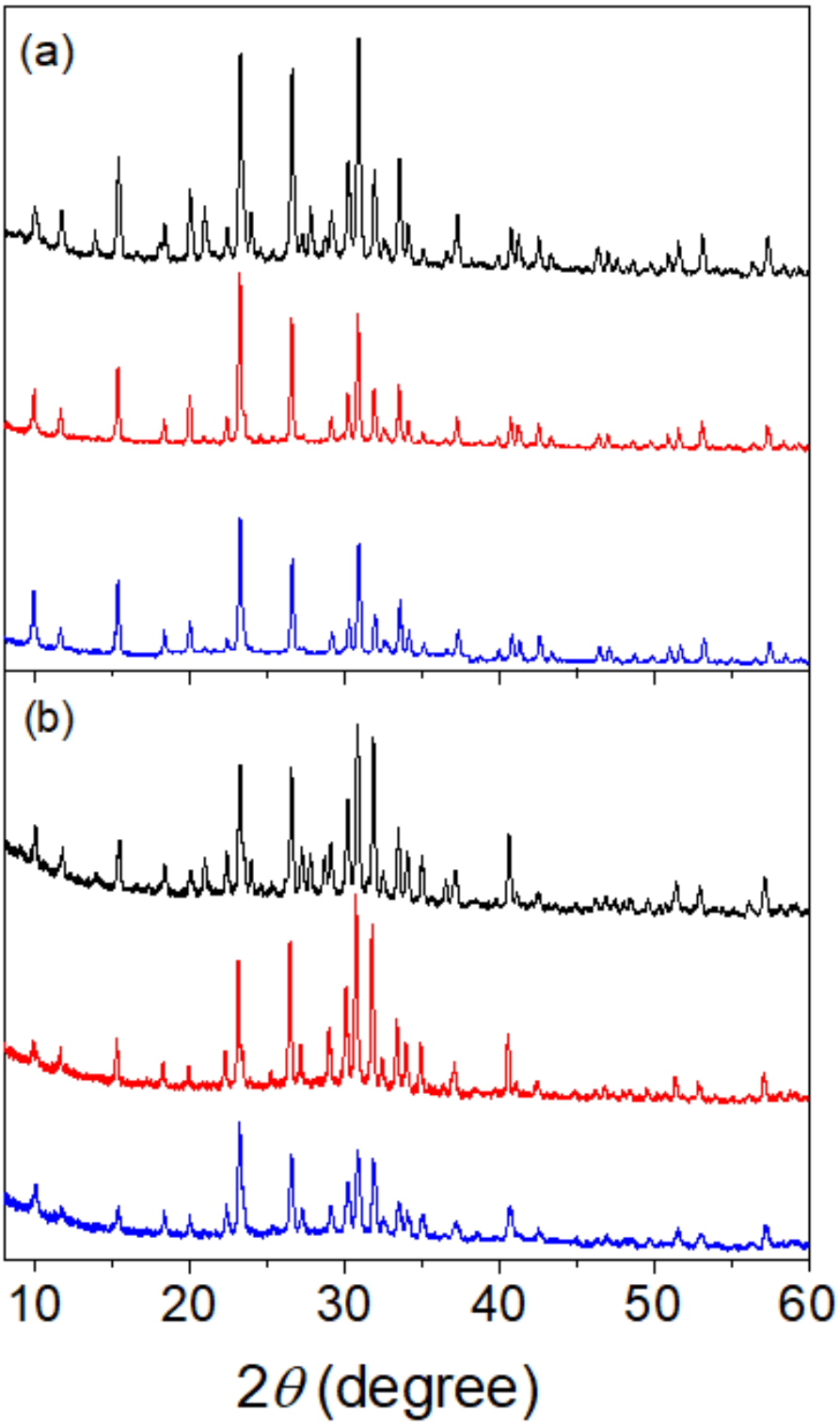

Figure S4. XRD patterns of (a) XZ-Na and (b) XZ-K: (—) pristine zeolite, (—) after 5 recycles, (—) after 10 recycles.

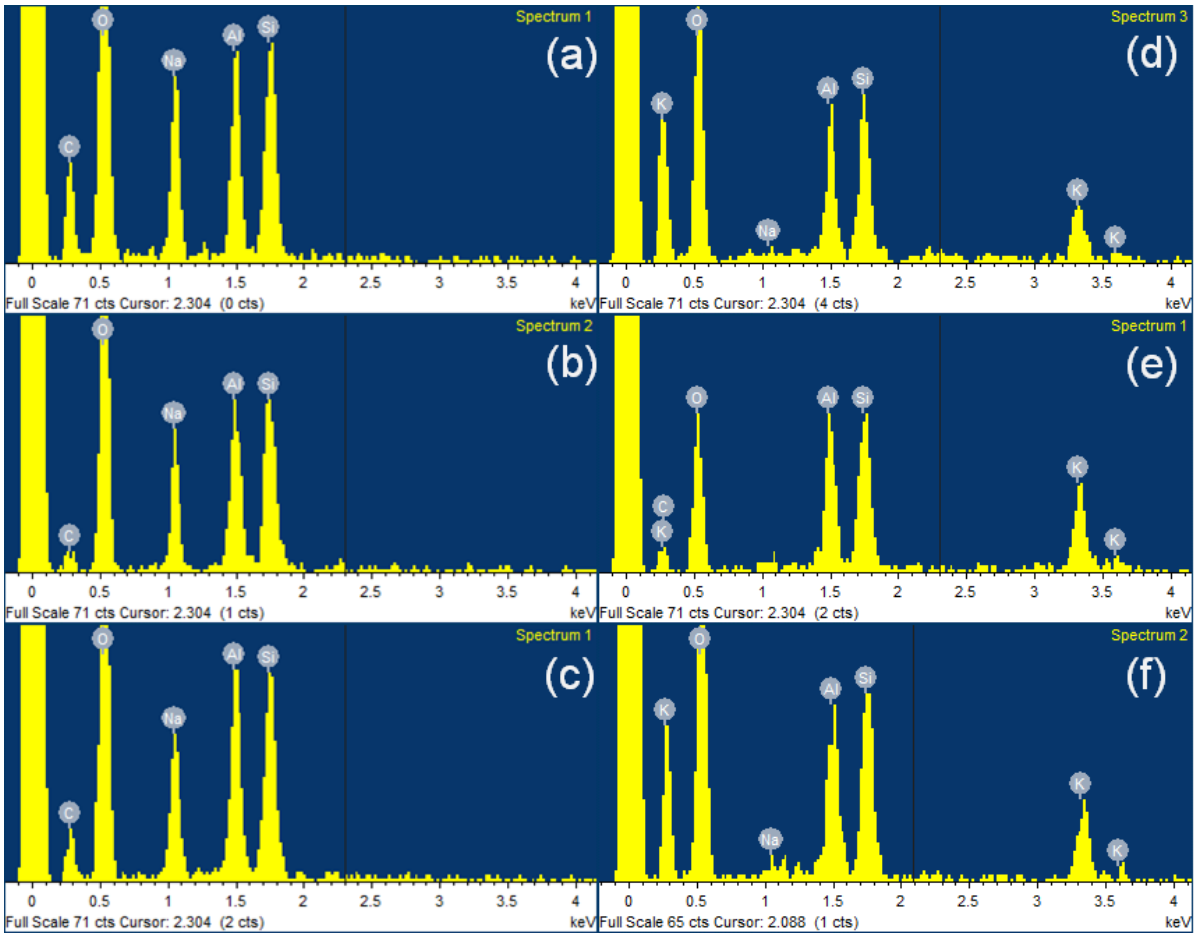

Figure S5. EDX data of XZ-Na (a) pristine, (b) after 5th recycle, (c) after 10th recycle and XZ-K (d) pristine, (e) after 5th recycle, (f) after 10th recycle, respectively.

Table S1. Structural characterization of zeolites

	Recycle	Atomic ratio (%)					Surface area (m^2 g^{-1})	Pore volume (cm^3 g^{-1})
		O	Na	Al	Si	K		
XZ-Na	0^{th}	64.65	10.26	10.47	14.62	-	541	0.27
	5^{th}	64.76	10.15	10.51	14.58	-	528	0.26
	10^{th}	64.87	10.03	10.56	14.54	-	498	0.25
XZ-K	0^{th}	61.11	-	11.56	16.23	11.10	465	0.26
	5^{th}	61.00	-	11.52	16.14	11.34	433	0.25
	10^{th}	61.07	0.01	11.54	16.25	11.13	407	0.23

Table S2. Recycling of XZ-M for the direct etherification of glycerol

Cycle No.		1	2	3	4	5	6	7	8	9	10
XZ-Na	Conv. of glycerol	76.3	77.4	76.1	75.4	76.8	75.3	74.2	75.3	72.1	70.2
	Yield of DG	50.8	51.2	50.3	51.1	50.3	50.6	51.2	50.3	50.2	51.2
	Yield of TG	20.4	21.2	21.3	20.2	20.6	20.2	19.4	20.1	22.2	21.2
XZ-K	Conv. of glycerol	85.4	85.1	84.8	85.9	86.2	84.4	85.3	84.6	84.2	83.5
	Yield of DG	54.1	55	54.3	54.5	53.8	53.6	55.1	53.9	54.2	55.2
	Yield of TG	21.3	20.2	20.8	21.2	20.1	19.6	20.2	21.1	20.4	19.9