Supplementary Information for

Conversion of glucose to levulinic acid and upgrade into γ-valerolactone on Ru based catalysts

Yubo Liu[a,b], Guoqiang Ding[c], Guoping Zhao[d], Haohao She[a,b], Yulei Zhu*[,a,c], and Yong Yang[a,c]

[a] State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences, Taiyuan 030001, PR China.

[b] University of Chinese Academy of Sciences, Beijing, 100049, PR China.

[c] Synfuels China Co. Ltd., Beijing, PR China.

[d]Key Laboratory of Precision Nutrition and Food Quality, Department of Nutrition and Health, China Agricultural University, Beijing 100083.

*Corresponding author. E-mail: zhuyulei@sxicc.ac.cn

Table of contents

1. Catalyst characterizations Methods

X-ray diffraction (XRD) measurements. Powder X-ray diffraction (XRD) patterns were collected on a Bruker D8 ADVANCE A25 X-ray diffractometer (Germany), with Cu Kα radiation at 40 kV and 40 mA. The X ray patterns were recorded in 2θ values ranging from 10° to 80° with a scanning speed of 4 °/min.

IR spectra of adsorbed pyridine (Py-IR). For each run, the samples were pressed into self-supporting wafers and degassed in vacuum at 350 °C for 1 h followed by exposure to pyridine vapor. Subsequently, the Py-IR spectra were measured at the set temperature after applying vacuum for 30 min. Next, saturated adsorption of pyridine vapor on the samples was performed until an equilibrium was achieved. The quantification of Brønsted and Lewis acid sites was estimated from the integrated area of adsorption bands at ca. 1540 and 1450 cm^{-1}, respectively. The concentrations of acid sites of different strengths in terms of temperature can be quantitatively determined from the amounts of pyridine desorbed at corresponding temperatures.

NH_3-TPD. The acid amounts of zeolites were measured with thermal programmed desorption (TPD) of NH_3 on Auto Chem. Ⅱ 2920 equipment (Micromeritics, USA) with a mass spectra. The samples (150 mg) were firstly placed in a U-shaped quartz tubular reactor and pretreated at 350 ºC in helium (20 mL/min) for 1 h. Then the sample was adsorbed with NH_3 until saturation. Then, the zeolite was flushed with helium at 100 °C for 0.5 h to remove the physisorbed NH_3. TPD was conducted from 100 °C to 800 °C at a heat rate of 10 °C / min.

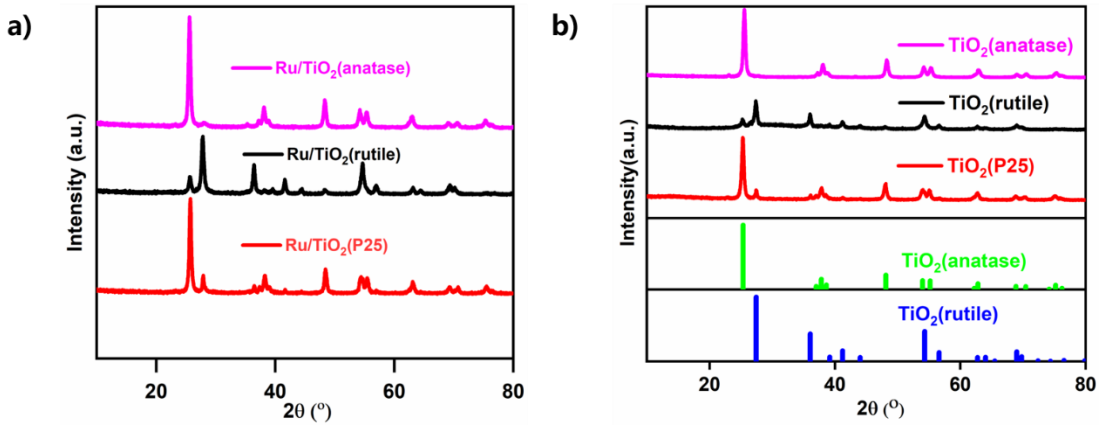

Fig. S1 XRD patterns of the (a) fresh Ru/TiO_2 catalysts and (b) the supports.

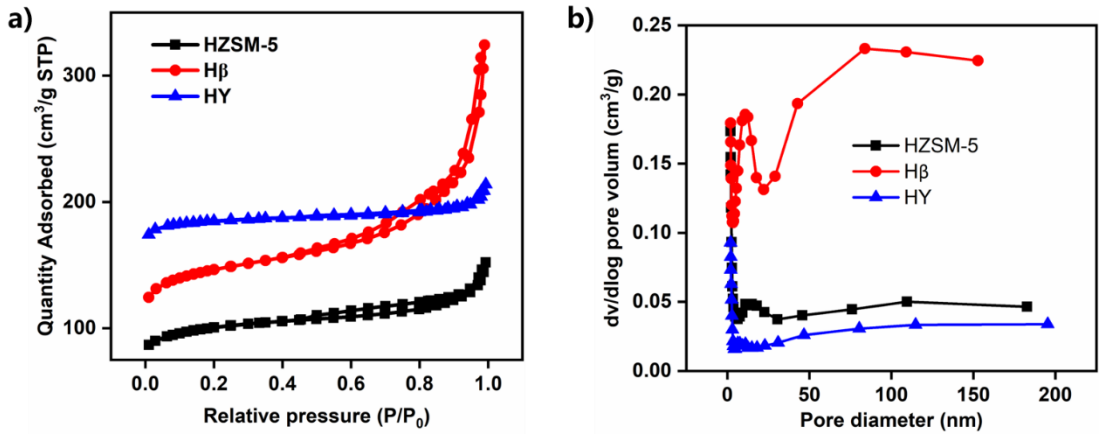

Fig. S2 The N_2 adsorption-desorption isotherms (a) and BJH pore size distribution (b) of different zeolites.

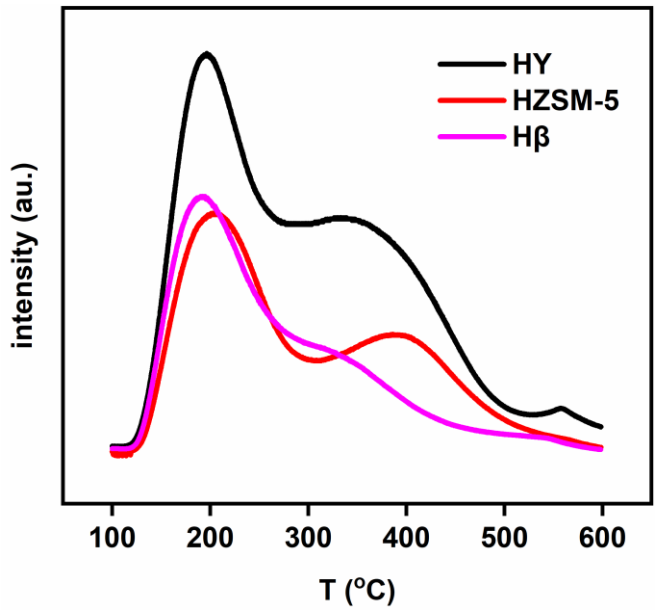

Fig. S3 The NH_3-TPD profiles of HZSM-5, Hβ, and HY zeolite.

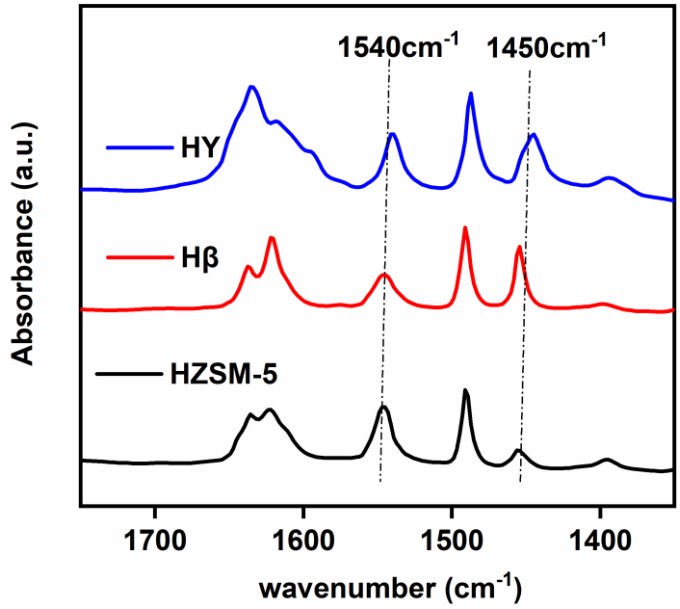

Fig. S4 The Py-IR spectra of HZSM-5, Hβ, and HY zeolite.

Table S1 The textural data of various zeolites.

Sample	Surface area ($m^2 \cdot g^{-1}$)			Pore volume ($cm^3 \cdot g^{-1}$)		
	Total	Micropore	External	Total	Micropore	Mesopore
HZSM-5	328	229	98	0.22	0.11	0.11
Hβ	479	333	146	0.49	0.16	0.33
HY	588	536	52	0.32	0.26	0.06

Table S2 The different type of acid distribution over the zeolites.

catalysts	100 ºC ($mmol \cdot g^{-1}$)		100 ºC ~ 200 ºC weak acid ($mmol \cdot g^{-1}$)		200 ºC ($mmol \cdot g^{-1}$)		200 ºC ~ 350 ºC moderate strong acid ($mmol \cdot g^{-1}$)		350 ºC strong acid ($mmol \cdot g^{-1}$)	
	L	B	L	B	L	B	L	B	L	B
HZSM-5	0.078	0.138	0.046	0.042	0.032	0.096	0.017	0.022	0.015	0.074
Hβ	0.153	0.185	0.141	0.142	0.012	0.043	0.0011	0.032	0.0107	0.0112
HY	0.297	0.410	0.270	0.019	0.031	0.391	0.0195	0.123	0.012	0.268