Electronic Supplementary Information

N-doped natural albite mineral as green solid catalyst for efficient isomerization of glucose into fructose in water

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1. Additional experimental section

kinetic data fitting:

The kinetic data (the first 10 min of reaction) were fitted with the Weibull model, and the activation energy (Ea) for CS/Ab-catalyzed glucose conversion in water was calculated using Arrhenius' equation, as shown in the following equations:

$$\frac{C_t}{C_0} = exp\left[-(kt)^n\right]$$

C_t and C_0 are the glucose concentration at time = t and 0 min，respectively; k is the reaction rate constant, and n is the shape constant.

$$k = k_0 exp\left(-\frac{E_a}{RT}\right)$$

Where k_0 is the frequency factor; R is the gas constant (8.314 J mol^{-1} K^{-1}); and T is the reaction temperature.

2. Additional results and discussion Section

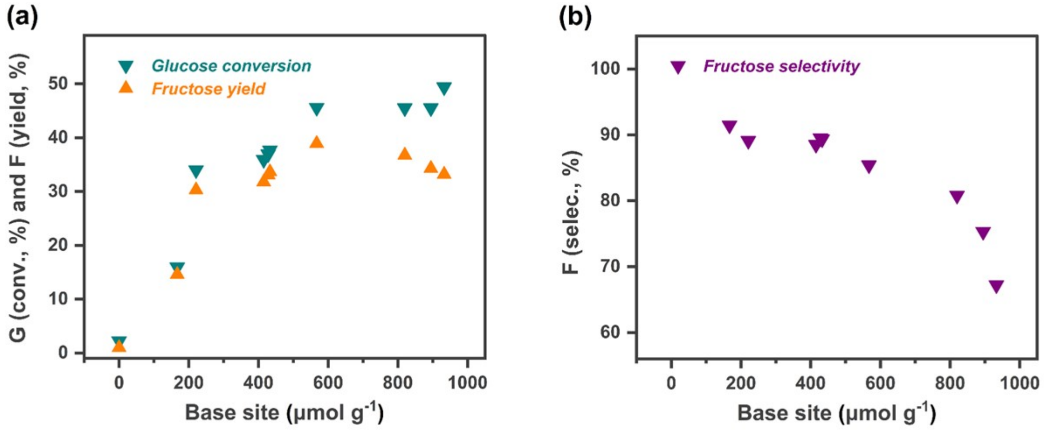

Figure S1. Correlation of basic sites with (a) glucose conversion and fructose yield and (b) fructose selectivity for all synthesized catalysts, including Ab-cal, CS/Ab with different N content[a], AR, Re1, Re2 and Re3. [a]N content (wt.%) was calculated from the theoretical nitrogen loading of the material. (Synthesis details: the N content of the material was 0, 0.5, 2.0, 4.13 and 5.8 wt.%. The process of catalyst preparation was the same as that of CS/Ab in the section 2.2)

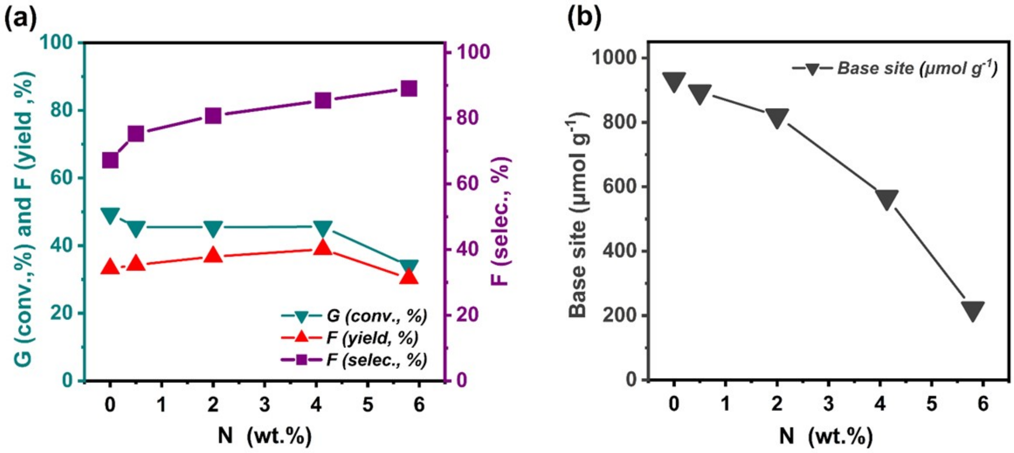

Figure S2. (a) Glucose conversion, fructose yield and fructose selectivity obtained over CS/Ab catalysts with different N content (wt.%)[a]. Reaction conditions: 3 mL of 0.1 mol L^{-1} glucose solution; 30 mg CS/Ab; 90 °C; 30 min; N_2 1 atm. (b) The effect of N content (wt.%) of CS/Ab catalysts to base site (μmol g^{-1}) [b].

[a]N content (wt.%) was calculated from the theoretical nitrogen loading of the material. (Synthesis details: the N content of the material was 0, 0.5, 2.0, 4.13 and 5.8 wt.%. The process of catalyst preparation was the same as that of CS/Ab in reference to section 2.2.)

[b]The base site was quantified via acid-base titration.

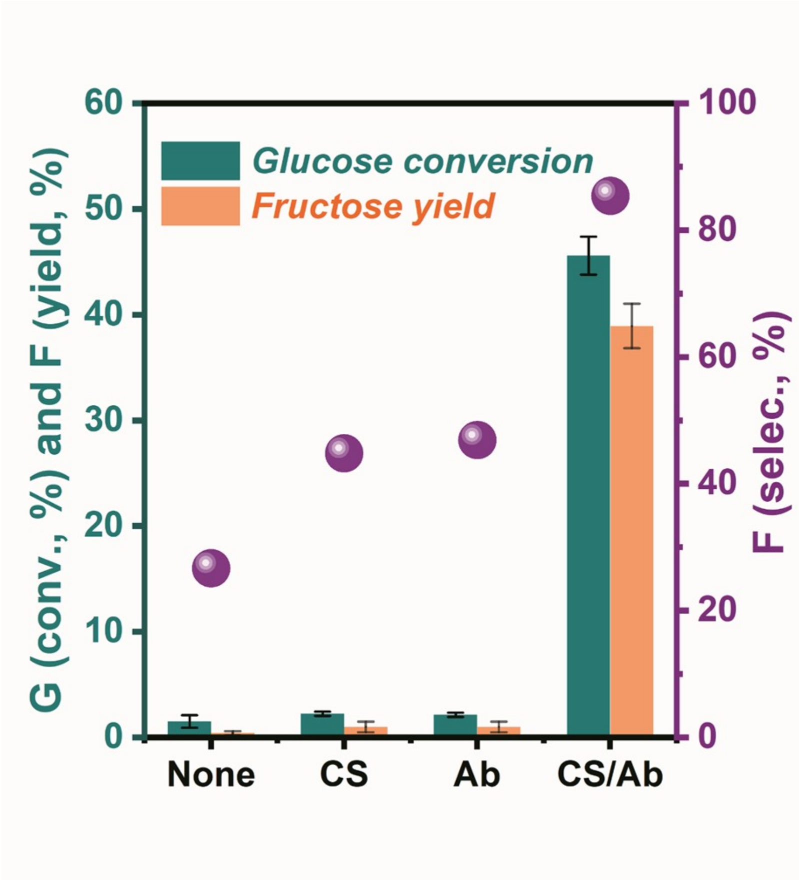

Figure S3. Glucose conversion, fructose yield and fructose selectivity obtained over various catalysts. Reaction conditions: 3 mL of 0.1 mol L^{-1} glucose solution; 30 mg CS/Ab; 90 °C; 30 min; N_2 1 atm.

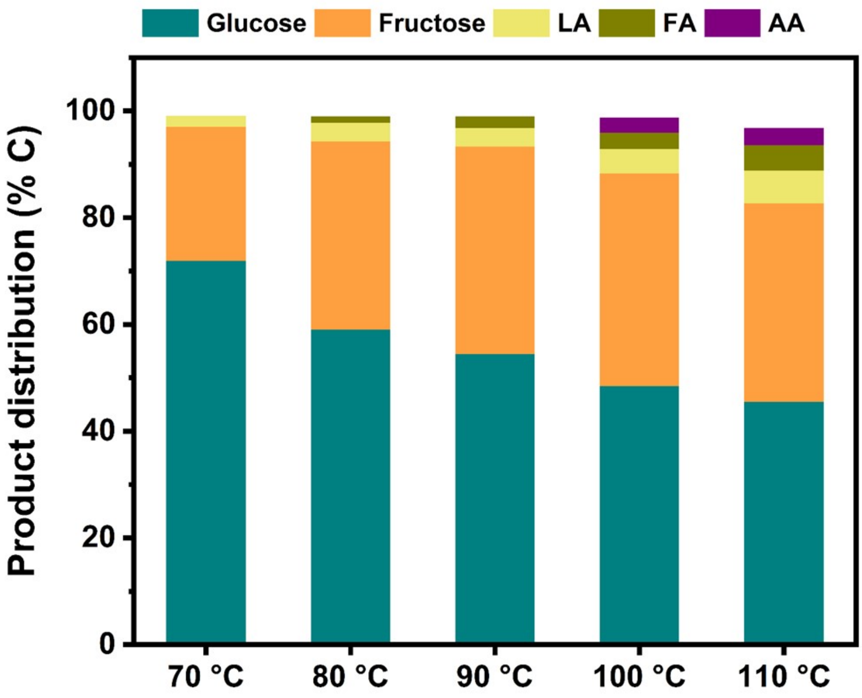

Figure S4. Product distributions evolved with the reaction temperature for glucose conversion with CS/Ab catalyst. Reaction conditions: 30 min; glucose 54 mg; catalyst loading 30 mg; water 3.0 mL; N_2 1 atm.

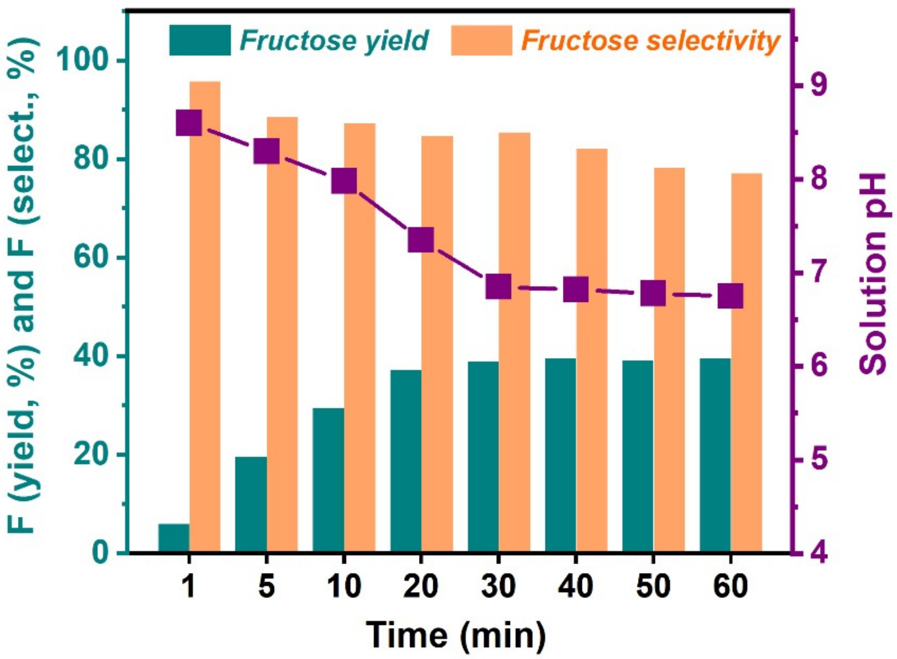

Figure S5. Fructose yield, selectivity and solution pH as a function of reaction time for glucose isomerization in the presence of CS/Ab. Reaction conditions: 90 °C, 3 mL of 0.1 mol L^{-1} glucose; catalyst loading 30 mg; N_2 1 atm.

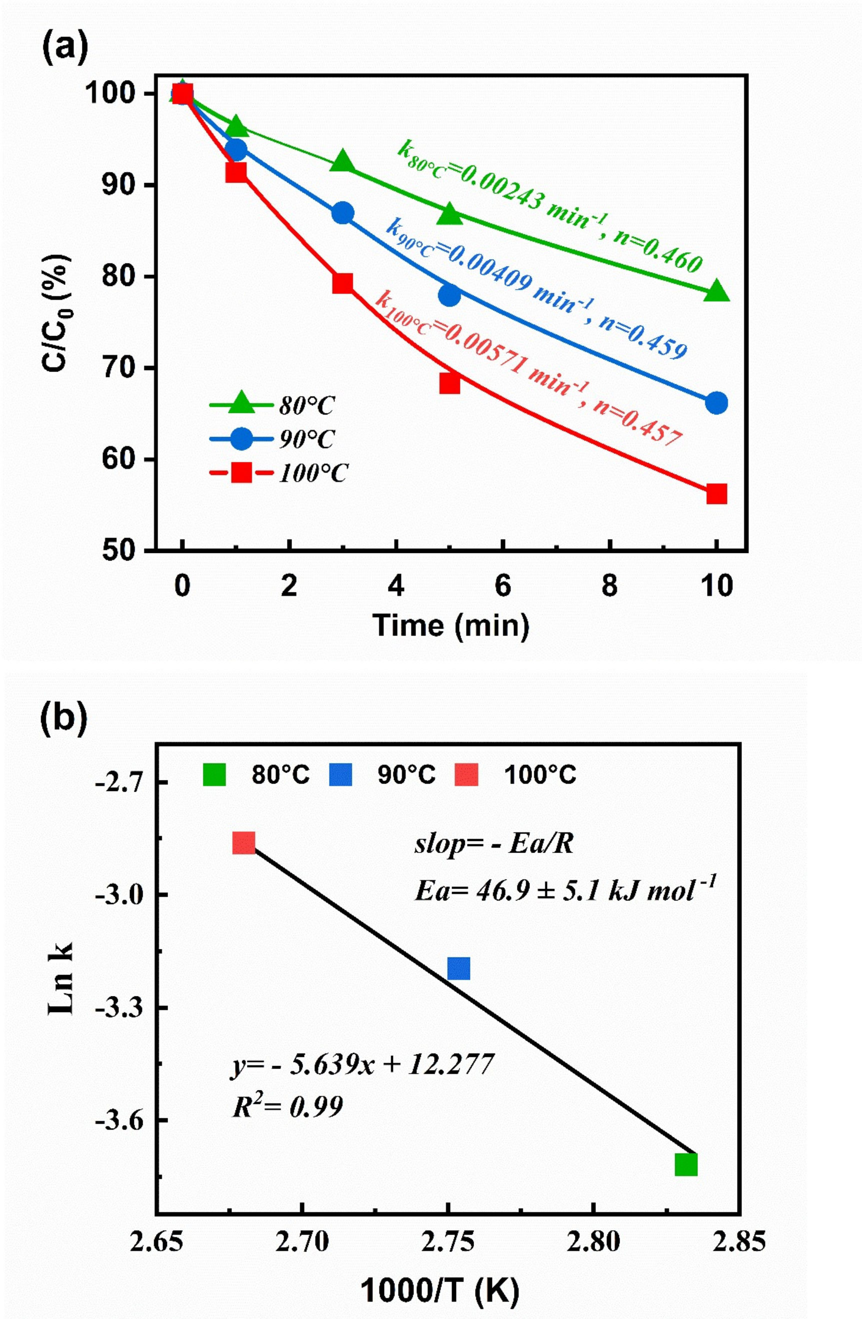

Figure S6. (a) Curve fittings using Weibull model for the kinetics of glucose isomerization over CS/Ab at 80, 90 and 100 °C. (b) Kinetics results (Ea = activation energy; R = gas constant (i.e., 8.314 J mol^{-1} K^{-1})) for catalytic isomerization over CS/Ab. Reaction conditions: glucose 0.1 mol L^{-1}; catalyst loading 30 mg; water 3 mL; N_2 1 atm.

Table S1 Chemical composition of raw albite mineral (Ab) as determined by XRF (in oxide wt.%)

Material	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	Fe_2O_3	BaO	Total
Ab	5.50	4.85	17.01	59.28	4.58	7.98	0.50	0.07	99.77

Table S2 Content of element detected by SEM-EDS over CS/Ab catalyst

Entry	Element	Weight (%)	Atomic (%)
1	C K	27.24	39.45
2	N K	4.58	5.69
3	O K	25.27	27.45
4	Al K	9.30	5.77
5	Si K	33.61	21.63

Table S3 Effect of glucose concentration on the isomerization

Entry	Glucose concentration (wt.%)	Catalyst loading (mg)	Reaction time (min)	Results[b]		
				X_{glu} (%)	Y_{Fru} (%)	S_{Fru} (%)
1	0.9	30	30	46.5	42.0	90.4
2	1.8	30	30	45.6	38.9	85.4
3	2.7	30	30	40.1	35.4	88.2
4	3.6	30	30	33.1	29.5	89.1
5	5.0	30	30	31.5	27.2	86.2
6	5.0	60	60	38.3	32.3	84.3

[a]Reaction conditions: glucose solution 3.0 mL; 90 °C; N_2 1 atm.

[b]Results include glucose conversion (X_{glu}), Fructose yield (Y_{Fru}), and fructose selectivity (S_{Fru}).

Table S4. Isomerization of glucose to fructose obtained in this work and the literature data.

Entry	Catalyst	Glucose concentration (wt.%)	T (°C)	t (min)	X_{glu} (%)	S_{fru} (%)	Y_{fru} (%)	Ref.
Homogeneous base catalysts								
1	NaOH	10	90	-	36	50	18	1
2	Triethylamine	10	100	30	57	54	31	2
3	Ethylenediamine	10	100	30	42	60	25	2
4	Piperidine	10	100	30	49	59	29	2
Heterogeneous base catalysts								
5	immobilized tertiary amines	10	100	48	30.7	75	23	3
6	N-enriched biochar catalyst	5	120	20	12	84	11	4
7	MCN-2-DH	1	90	40	37.4	84.6	31.6	5
8	CaO/C	5	80	40	41.9	69.7	29.2	6
9	ATP	-	100	120	26.4	77.9	20.6	7
10	MgO	4	90	45	44.1	75.8	33.5	8
11	$Mg-C_3N_4$	10	80	240	38	84	32	9
12	water hyacinth	5	120	45	35	89	31	10
13	**CS/Ab**	**1.8**	**90**	**30**	**45.6**	**85.4**	**38.9**	**This work**
14	**CS/Ab**	**5**	**90**	**60**	**38.3**	**84.3**	**32.3**	**This work**

Results include glucose conversion (X_{glu}), Fructose yield (Y_{Fru}), and fructose selectivity (S_{Fru}).

Table S5. Characterization of the Catalysts

Entry	Catalysts	Basic sites[a] (μmol g^{-1})	Composition[b] (wt.%)		
			N	C	H
1	Fresh catalyst (CS/Ab)	567	2.24	19.47	0.65
2	AR[c]	167	2.24	21.86	0.69
3	Re1[d]	433	2.12	20.76	0.63
4	Re2[d]	428	-	-	-
5	Re3[d]	416	-	-	-

[a]Basic sites of the materials. Calculated by the amount of p-toluenesulfonic acid (PTSA) (5 mmol L^{-1}) via acid-base titration of materials.

[b]Element Analysis of the materials.

[c]The CS/Ab catalyst was used for isomerization of glucose in water at 90 °C for 1 h.

[d]The AR catalyst was treated after regeneration via calcination, subsequent soaked with NaOH aqueous solution and rinsed with deionized water until neutral.

References

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