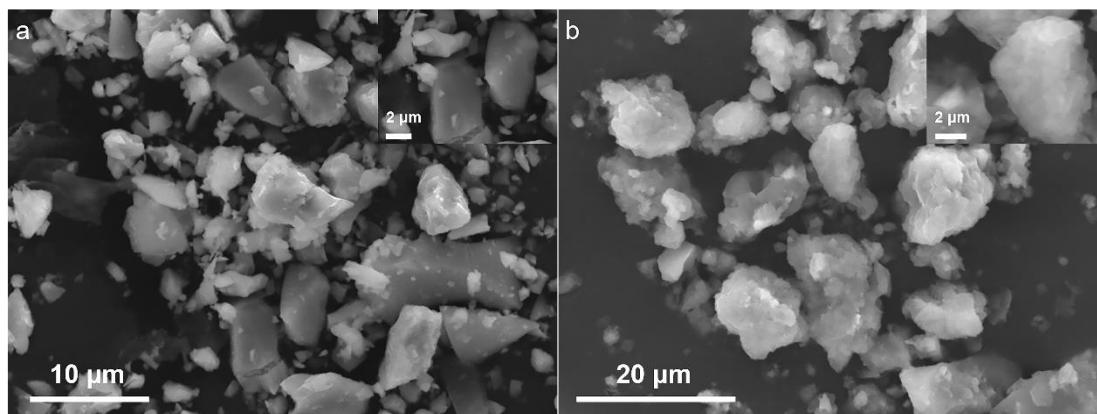
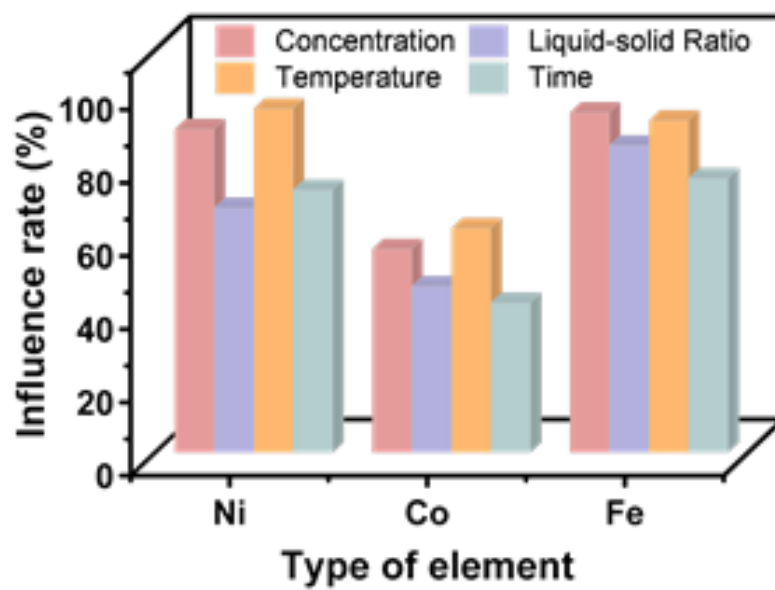


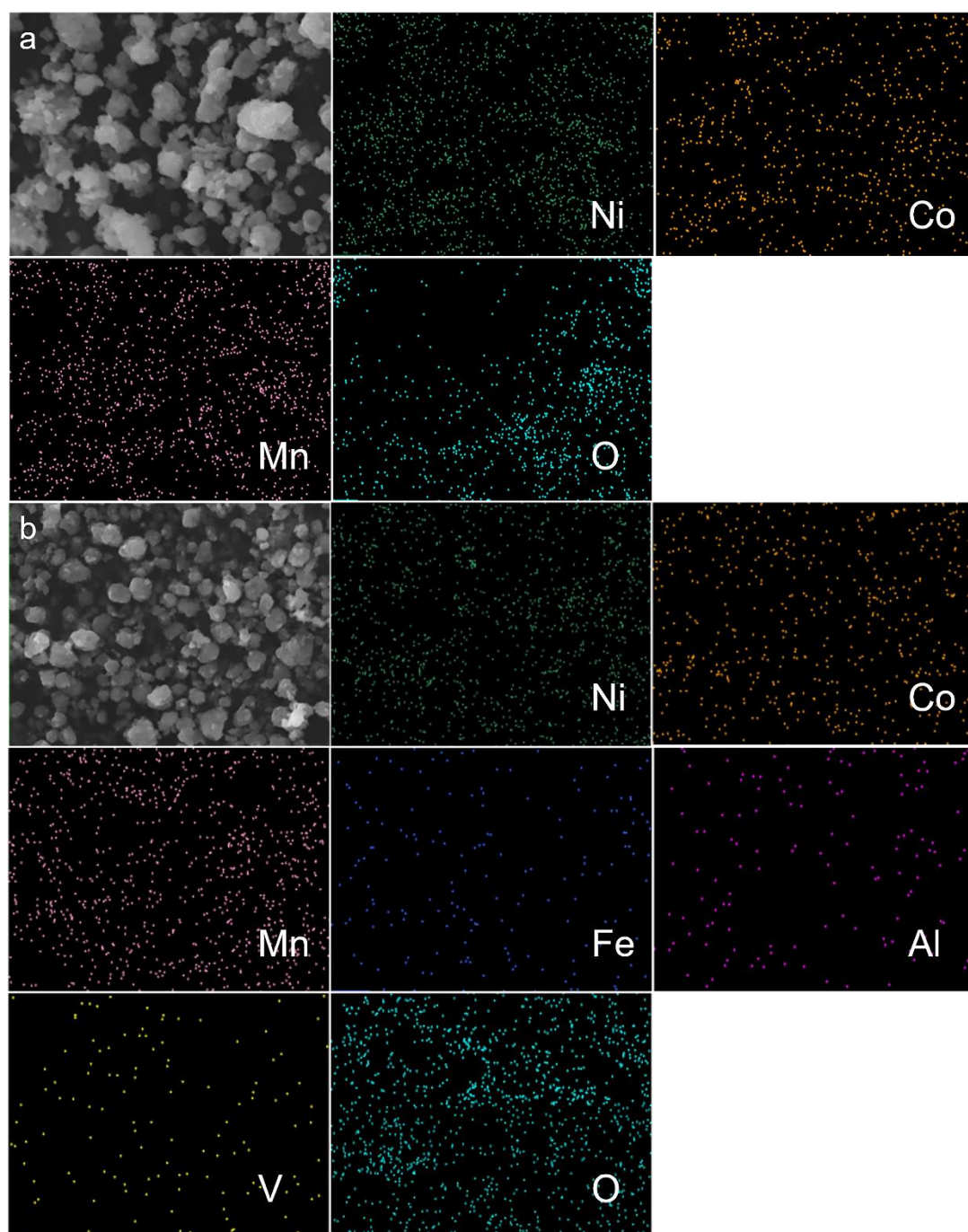
## Supplementary Information



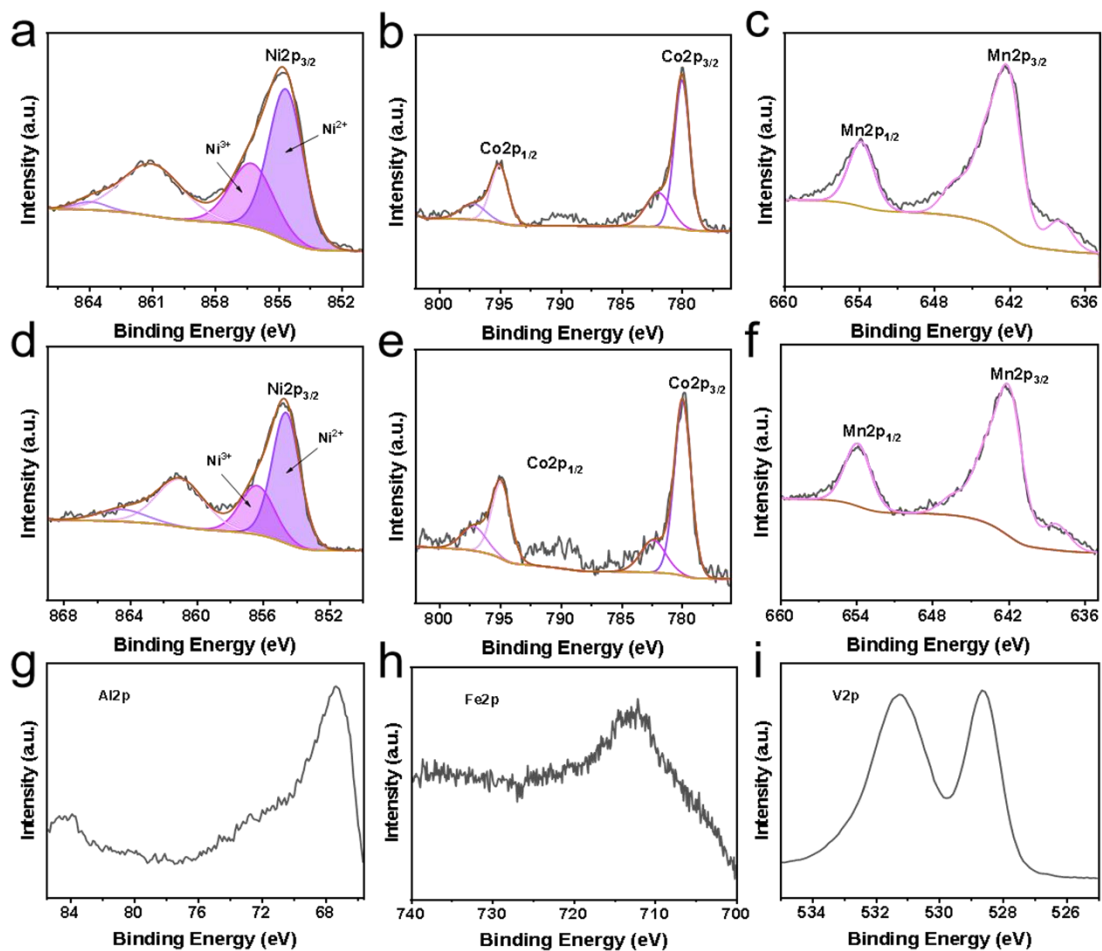
**Figure S1.** SEM images of (a) waste catalyst powder and (b) roasting product.



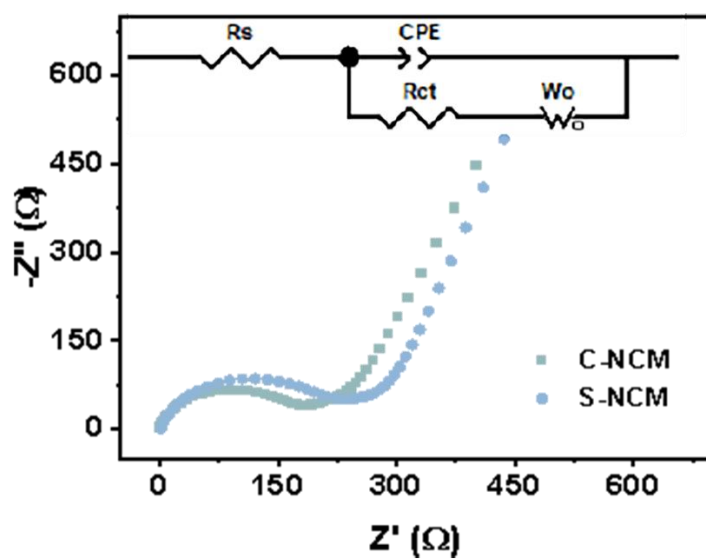
**Figure S2.** The influence rate of roasting conditions on leaching efficiency of metal element.



**Figure S3.** EDS mapping of (a) S—NCM and (b) C—NCM.

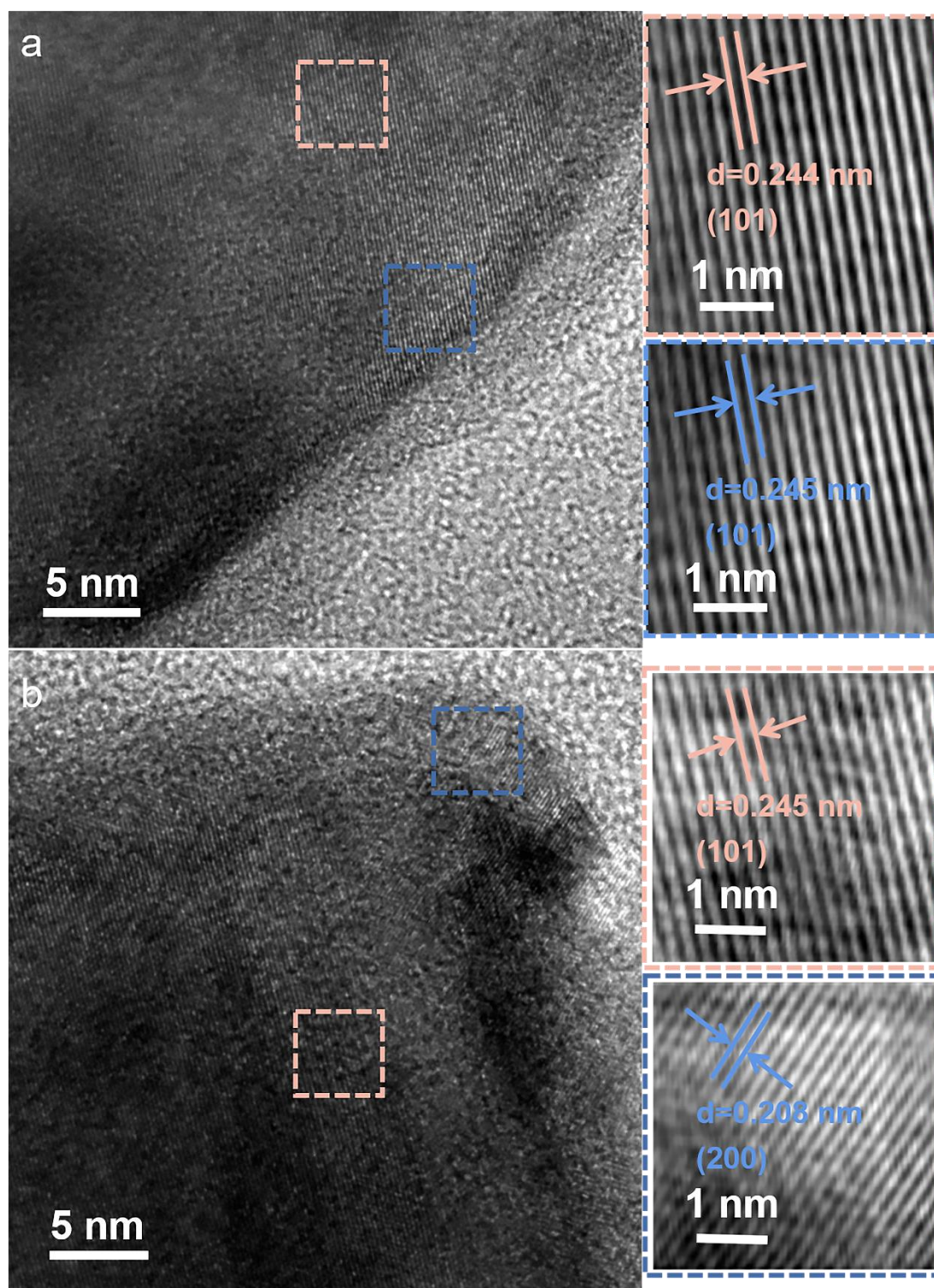


**Figure S4.** XPS spectra of Ni 2p for S-NCM (a), C-NCM (d), Co 2p for S-NCM (b), C-NCM (e), Mn 2p for S-NCM (c), C-NCM (f). And Al 2p (g), Fe 2p (h), V 2p (i) for C-NCM.

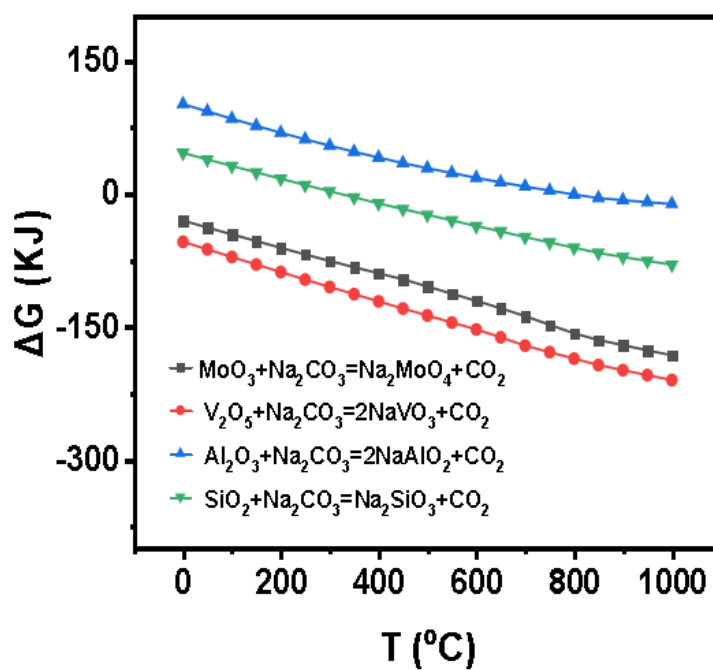


**Figure S5.** Comparison of C-NCM and S-NCM of Nyquist plots.





**Figure S6.** TEM images of (a) C-NCM and (b) S-NCM after 300 cycles at 1 C.



**Figure S7.** Relationship between  $\Delta G$  and temperature for reaction equations as calculated by HSC 6.0 software.

**Table S1.** Leaching efficiency of metal elements in waste HDS catalyst during roasting process control stage.

Roasting condition		Leaching efficiency (%)		
		Co	Ni	Fe
Temperature ( $^{\circ}\text{C}$ )	500	0.6	0.1	0.0
	550	0.0	0.0	0.0
	600	0.2	0.0	0.5
	650	0.0	0.0	1.5
	700	0.0	0.1	0.1
Time (h)	1.0	0.1	0.0	0.0
	1.5	0.0	0.0	0.0
	2.0	0.0	0.0	0.0
	2.5	0.0	0.0	1.5
	3.0	0.0	0.0	0.0

	80	0.0	0.0	0.0
	90	0.0	0.0	0.0
Na/WC (wt%)	100	0.0	0.0	0.0
	110	0.0	0.0	1.5
	120	0.0	0.0	1.5

**Table S2.** Leaching efficiency of metal elements under optimal acidolysis condition.

Element	Co	Ni	Fe
Leaching efficiency (%)	100.0	93.9	92.2

**Table S3.** Solubility product and precipitated pH of main metal elements in acid leaching solution.

Equilibrium Reaction	$K_{sp}$	pH	
		Precipitation	Disappearance
$Ni^{2+} + 2OH^- = Ni(OH)_2$	$5.48 \times 10^{-16}$	6.37	8.87
$Co^{2+} + 2OH^- = Co(OH)_2$	$5.92 \times 10^{-15}$	6.89	9.39
$Mn^{2+} + 2OH^- = Mn(OH)_2$	$1.90 \times 10^{-13}$	7.64	10.14
$Fe^{3+} + 2OH^- = Fe(OH)_3$	$2.79 \times 10^{-39}$	1.15	2.82

**Table S4.** Rietveld refinement results of S—NCM and C—NCM.

Specimen	a (Å)	c (Å)	c/a	$R_{wp}$ (%)	$I_{(003)}/I_{(104)}$
S-NCM	2.86921	14.23438	4.96108	2.61	1.49
C-NCM	2.86854	14.23259	4.96161	2.18	1.09

**Table S5.** The calculation results of  $R_s$ ,  $R_{ct}$  and  $R_{total}$  for the electrodes before testing.

Sample	$R_s$ ( $\Omega$ )	$R_{ct}$ ( $\Omega$ )	$R_{total}$ ( $\Omega$ )
C—NCM	0.817	156.600	157.417
S—NCM	1.089	203.100	204.189

**Table S6.** Impurity element content in water immersion experiment (WIE) and acidolysis experiment (AE).

Element	Ni	Co	Mo	V	Fe	Al	Mn
Impurity content of WIE (mg/L)	0	1.5	2362.4	546.8	0	13.0	0
Impurity content of AE (mg/L)	2506.0	1036.0	8.0	78.5	894.5	16.0	1.0