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Robust Route to Efficient Extraction of Cr from Different Cr-containing Hazardous Wastes by Capitalizing on a Reduction-chlorination-volatility Technique

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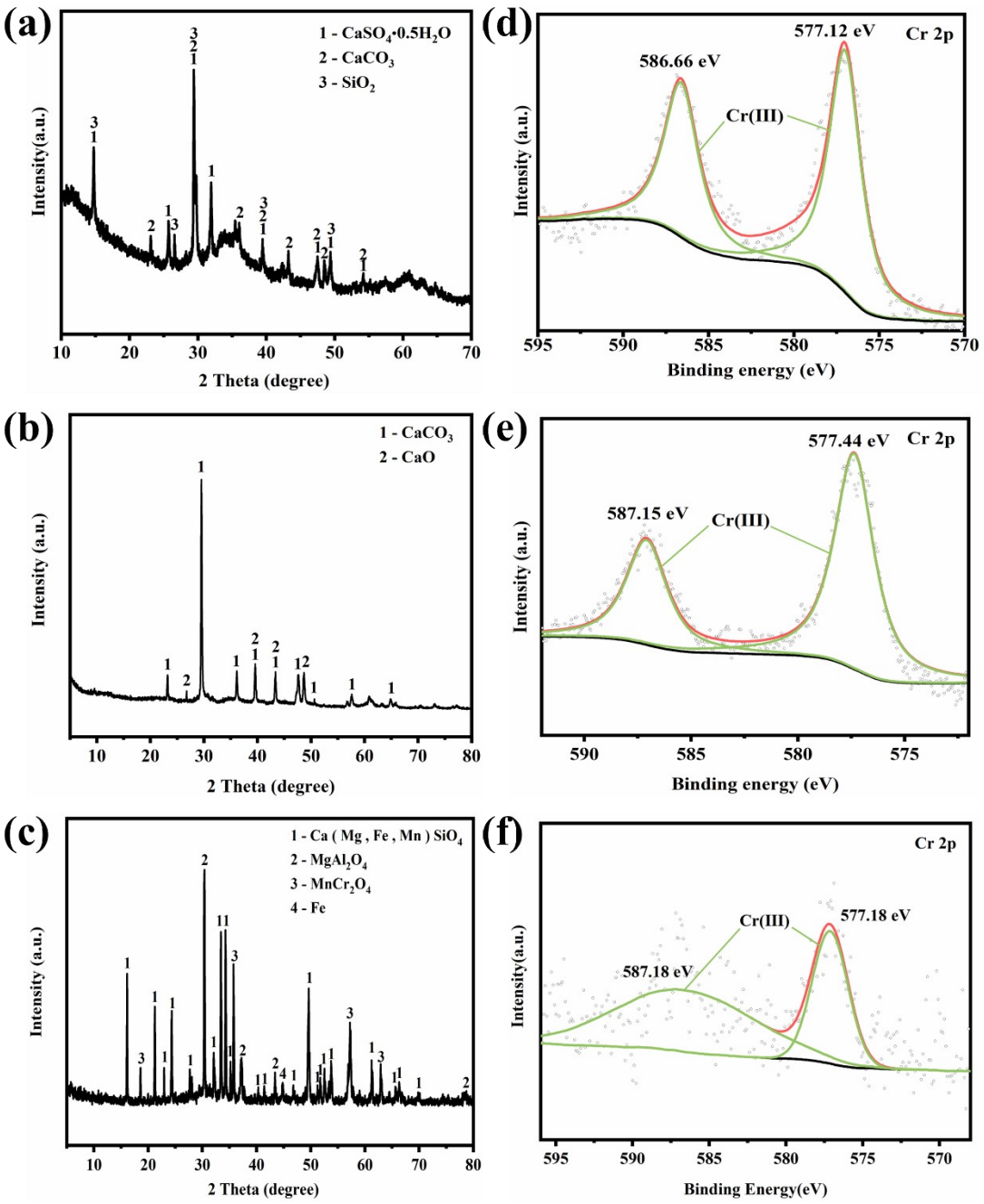

Fig. S1 XRD patterns of (a) ES; (b) TS and (c) SSS. High-resolution XPS spectra of Cr 2p in (d) ES, (e) TS and (f) SSS.

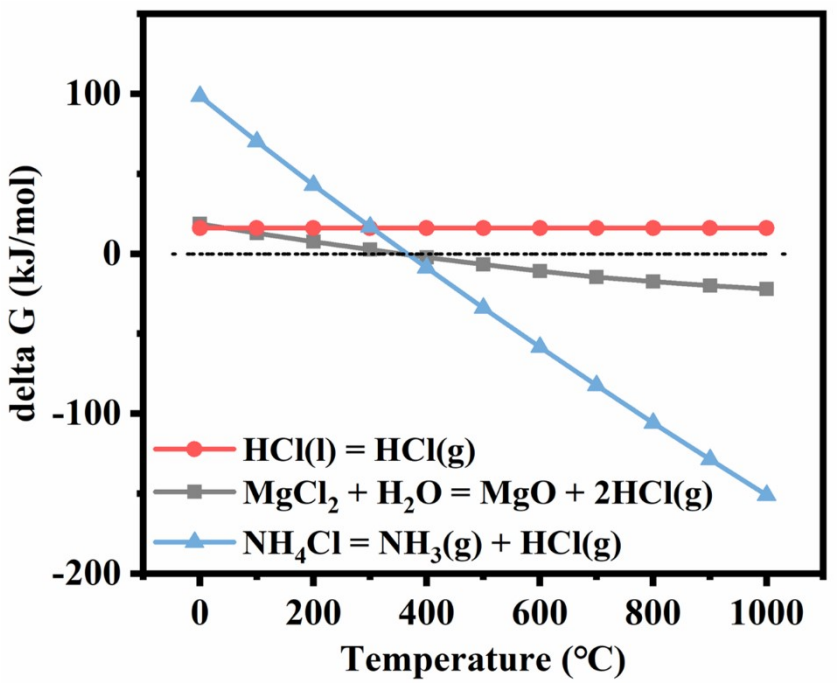

Fig. S2 Gibbs free energy of decomposition of the $MgCl_2 \cdot 6H_2O$, HCl and NH_4Cl at different temperatures.

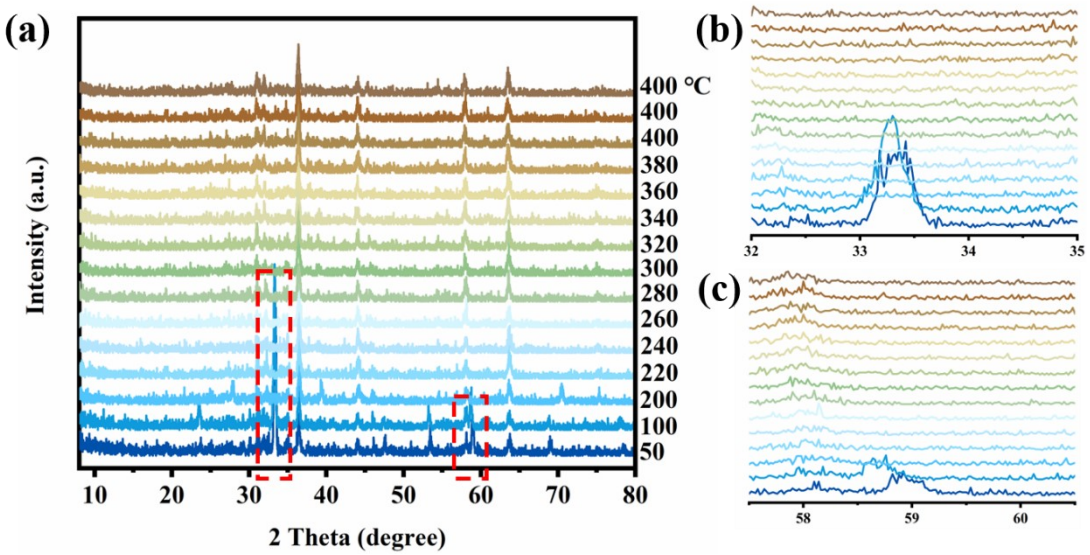

Fig. S3 (a) In situ XRD spectra of the mixed COPR and NH_4Cl at the temperature ranging from 50 to 400 °C. Enlarged spectra ranging from (b) 32°-35° and (c) 57.5°-60.5° part in (a).

Table S1. Activation energy of $CrCl_3 \cdot 6H_2O$ volatilization calculated by FWO method.

α	**R^2**	**E_a** (kJ/mol)
0.2	0.984	73.72
0.3	0.996	164.38
0.4	0.999	225.33
0.5	0.930	222.65
0.6	0.964	1696.43
0.7	0.419	278.48
0.8	0.889	255.12
0.9	0.939	205.36
Average	-	390.18

Table S2. Kinetic mechanism function and standard deviation.

No.	reaction model	standard deviation
1	Avrami-Erofeev, m=4	1.120
2	Avrami-Erofeev, m=3	1.679
3	Avrami-Erofeev, m=2	0.175
4	Avrami-Erofeev, m=1.5	2.206
5	Phase boundary reaction, n=1	0.187
6	Phase boundary reaction, n=2	2.834
7	Phase boundary reaction, n=3	2.002
8	One-dimensional diffusion	0.846
9	Two-dimensional diffusion	8.977
10	Three-dimensional diffusion	0.159
11	Jander' type diffusion	0.140
12	Power law, n=1/4	0.164
13	Power law, n=1/3	0.249
14	Power law, n=1/2	0.455
15	Power law, n=2/3	0.578
16	First order	1.028

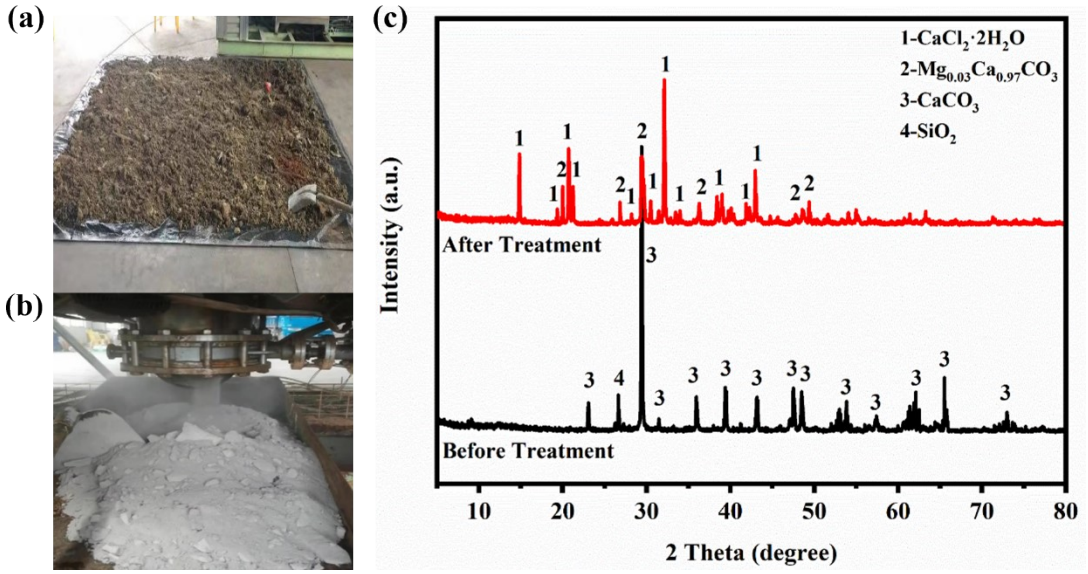

Fig. S4 Digital images (a) before and (b) after the pilot reaction. (c) XRD patterns of COPR before and after the pilot reaction.

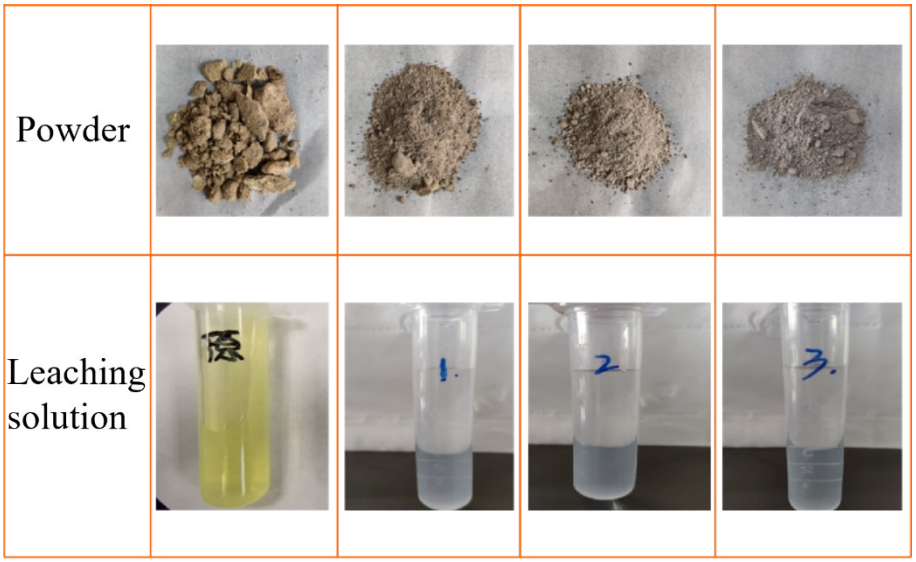

Fig. S5 Digital images of raw residues and leaching solution of powders after extracting Cr in three repeated pilot tests.

Table S3. Cr extraction rates of three Cr-containing wastes after the chlorination treatment.

Types	Treatment	Extraction rate of Cr
ES	Chlorination + acid leaching	82.1%
TS	Chlorination	85.3%
SSS	Chlorination + acid leaching	93.1%

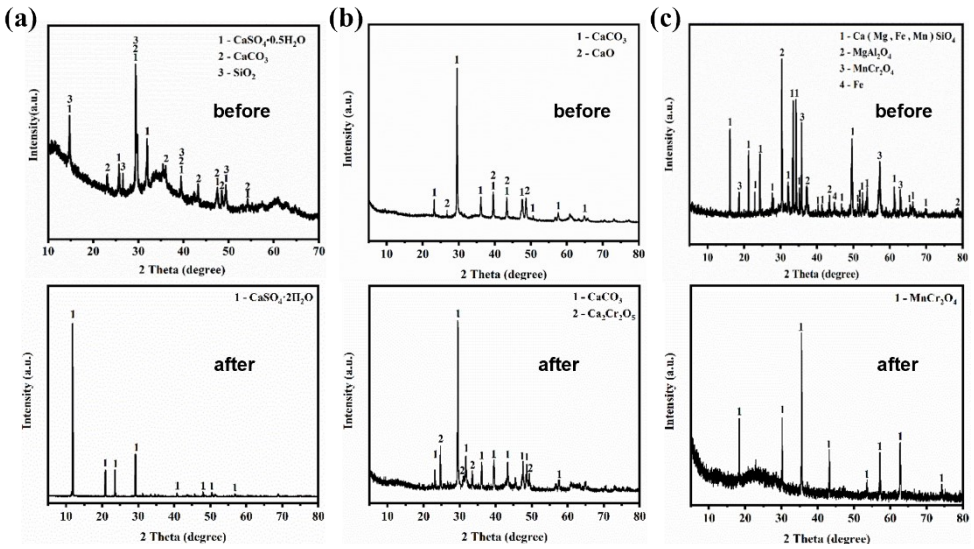

Fig. S6 XRD patterns of (a) ES, (b) TS and (c) SSS before and after the chlorination treatment.