Electronic Supporting Information (ESI)

An environment friendly electrochemical synthesis of 1,1,4,4-tetramethyl-2-tetrazene energetic materials from undimethylhydrazine

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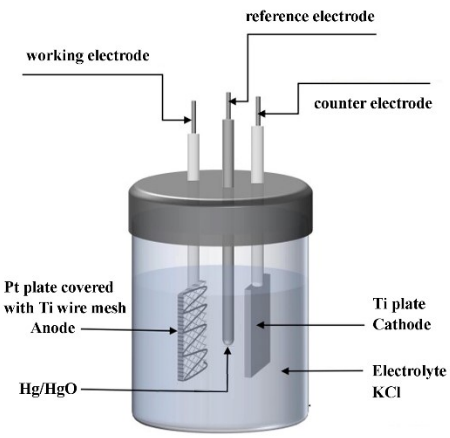
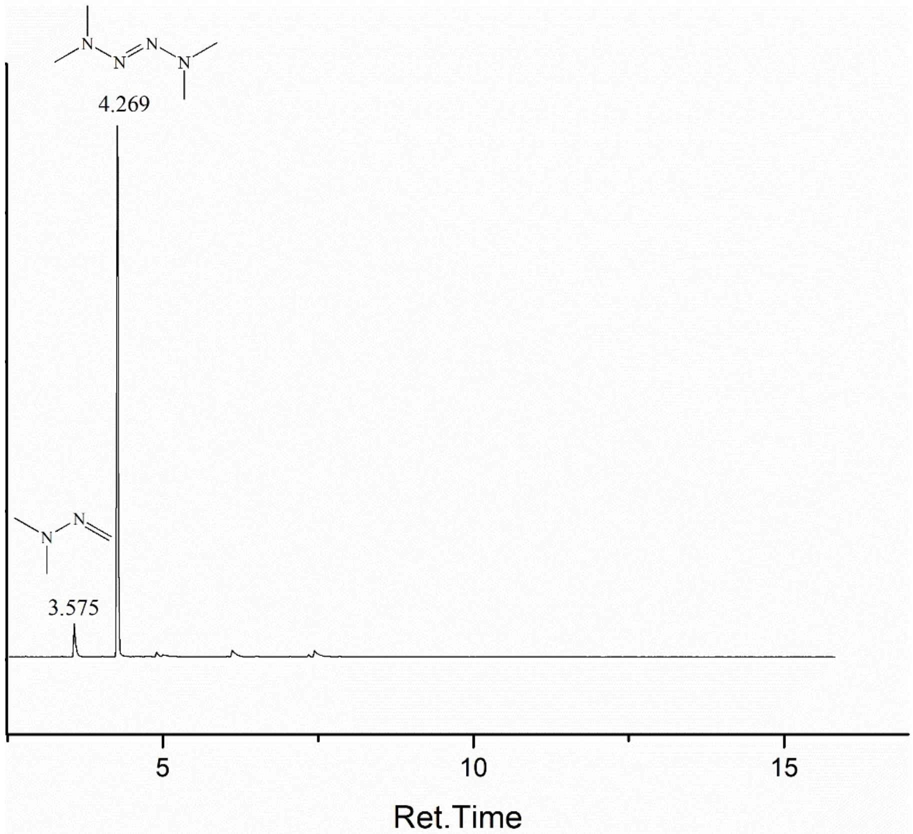


Fig. S1 The diagram of a representative three-electrodes electrochemical synthesis system.

GC-MS data were recorded on Shimadzu QC-MS 2010PLUS*. The temperature of the column box was set at 40 ℃, and the temperature of the injection port was 180 ℃. The temperature program is 10℃/min heating rate from 40℃ to 150℃ and 15℃/min heating rate from 150℃ to 200℃.



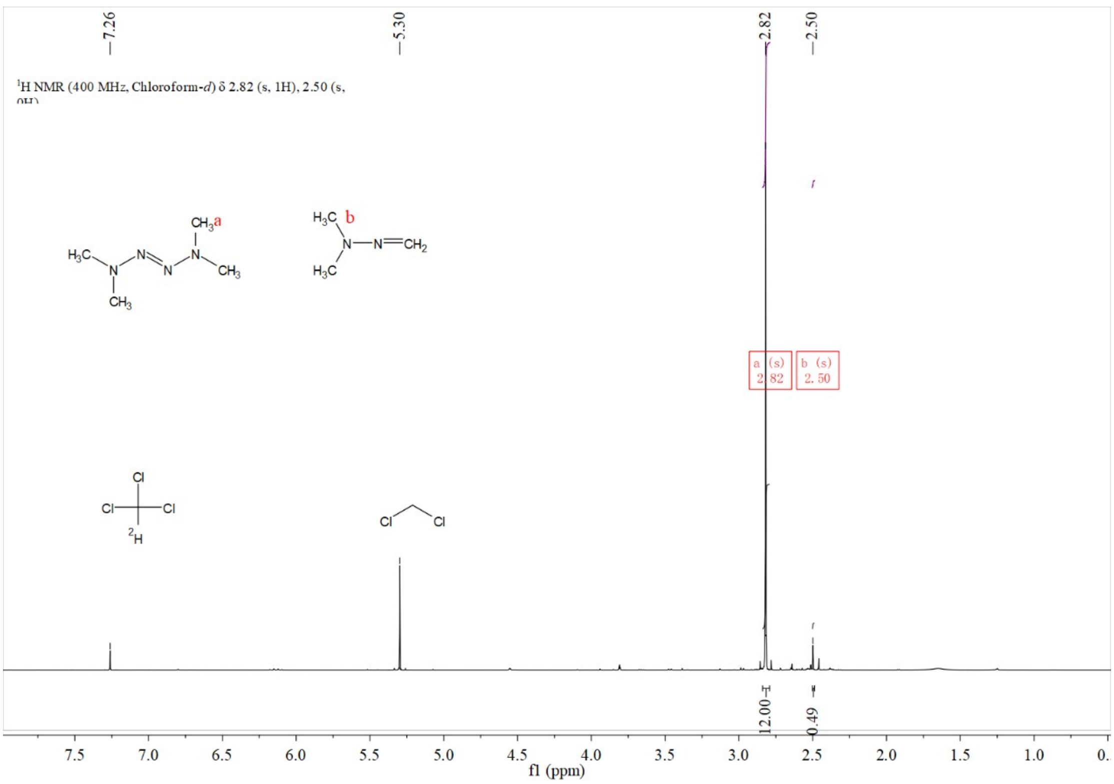


Fig. **S2** GC-MS (top) and ^{1}H NMR (bottom) of products in $CDCl_3$ at 293 K with the electrodes of

Pt anode and C cathode)

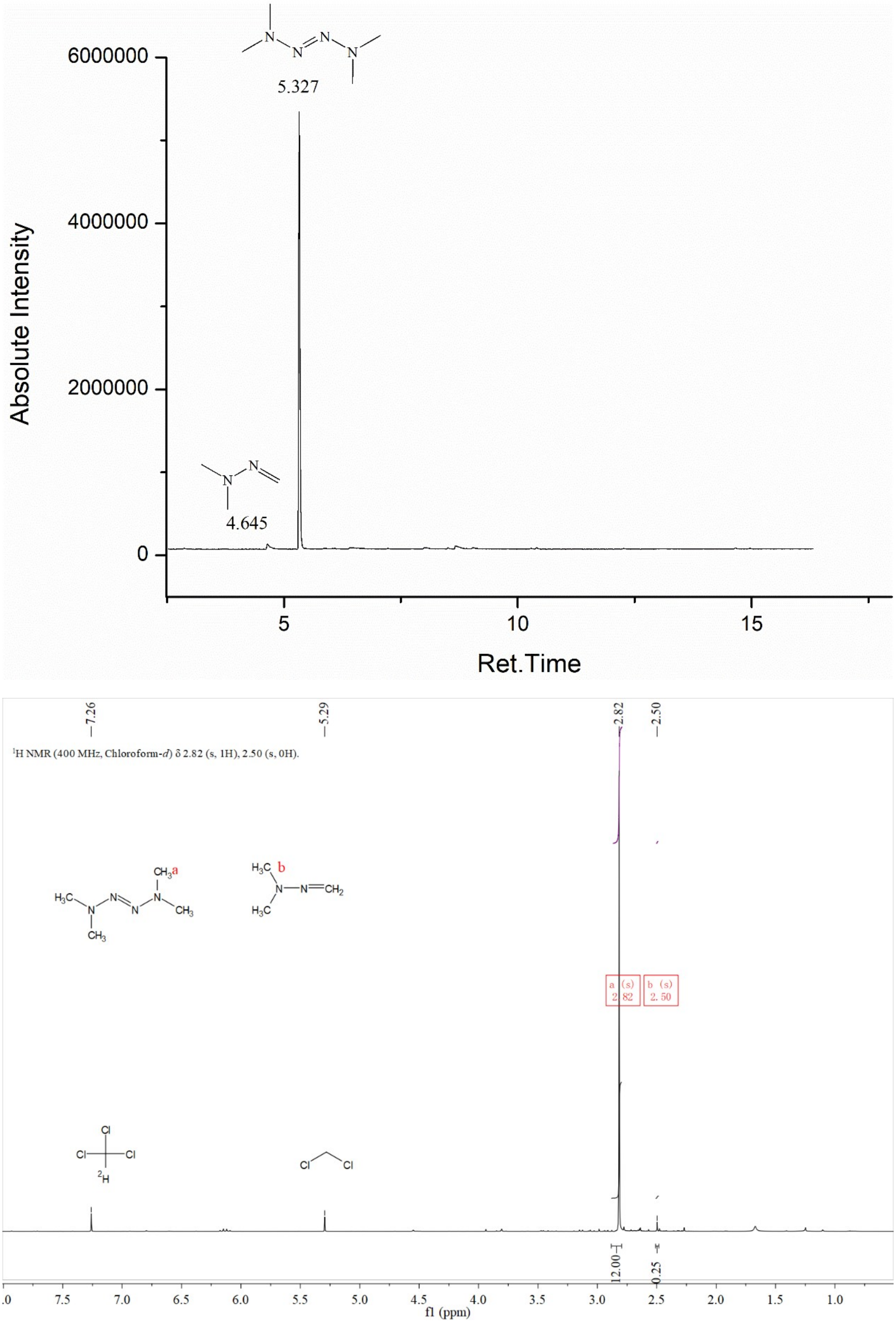


Fig. **S3** GC-MS (top) and ^{1}H NMR (bottom) of products in $CDCl_3$ at 293 K with the electrodes of Pt anode and Ti cathode)

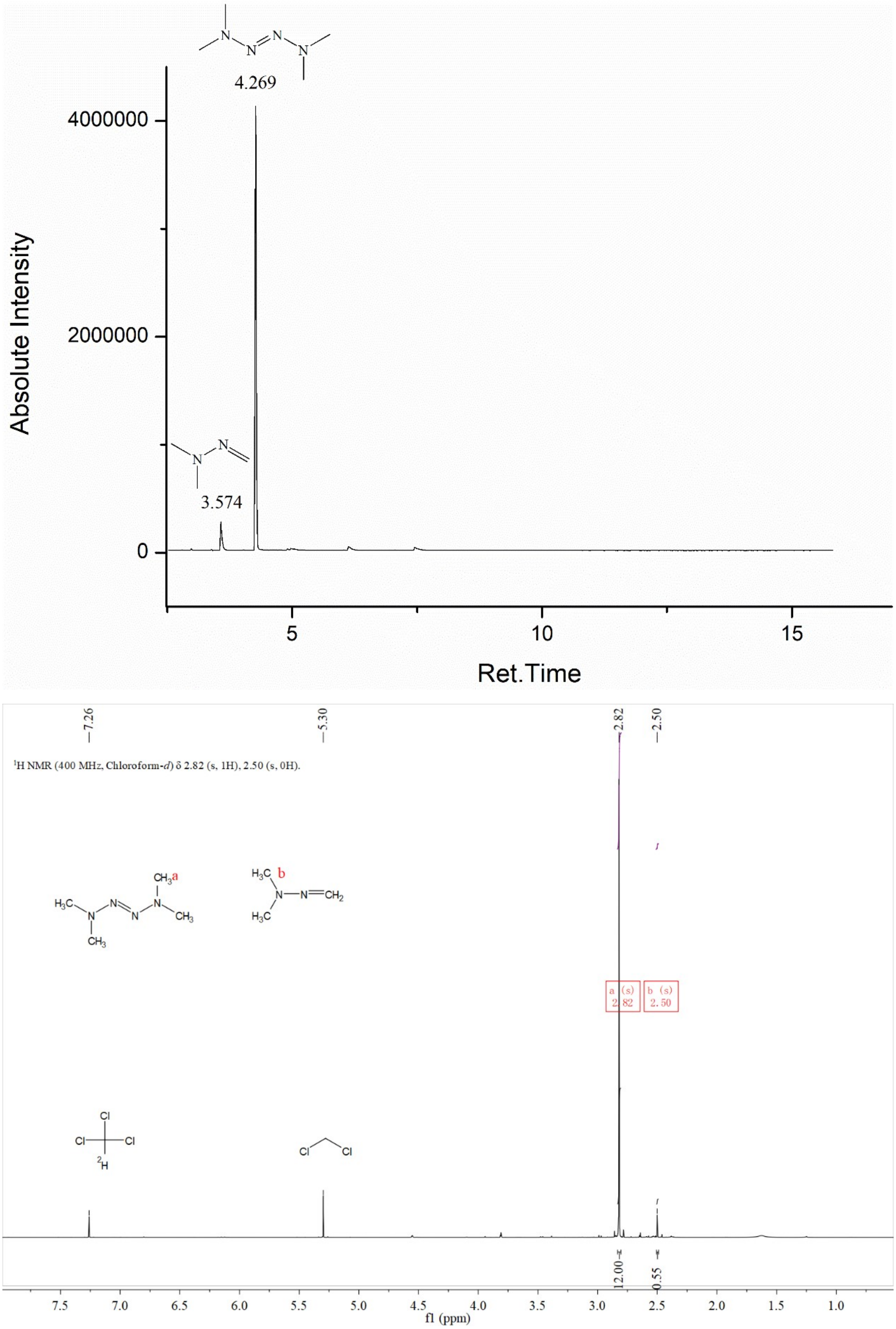
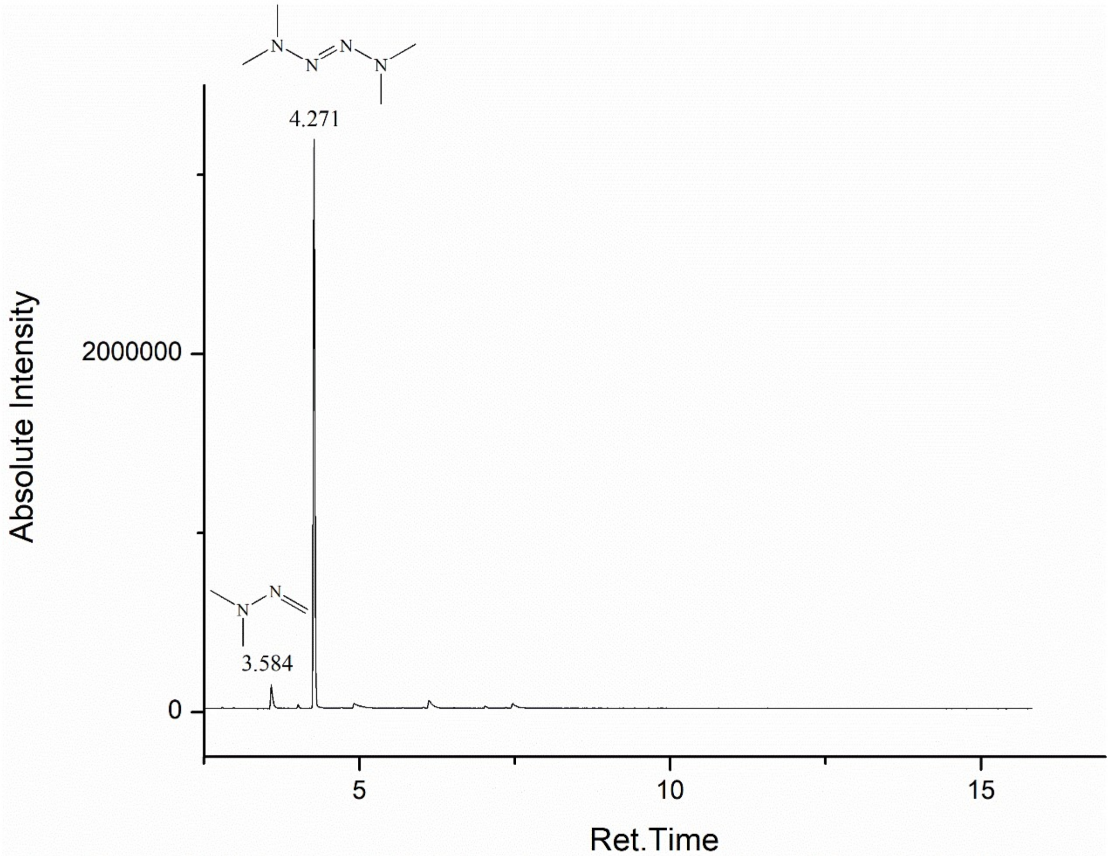


Fig. **S4** GC-MS (top) and ^{1}H NMR (bottom) of products in $CDCl_3$ at 293 K with the electrodes of Au anode and C cathode



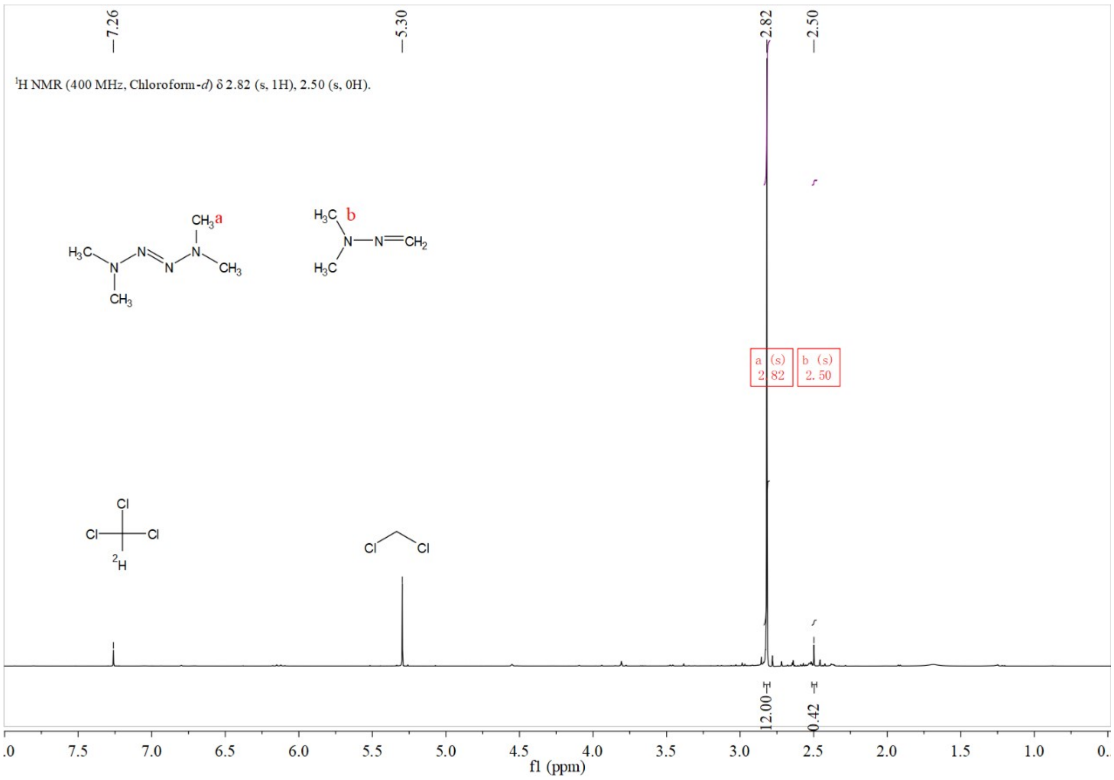
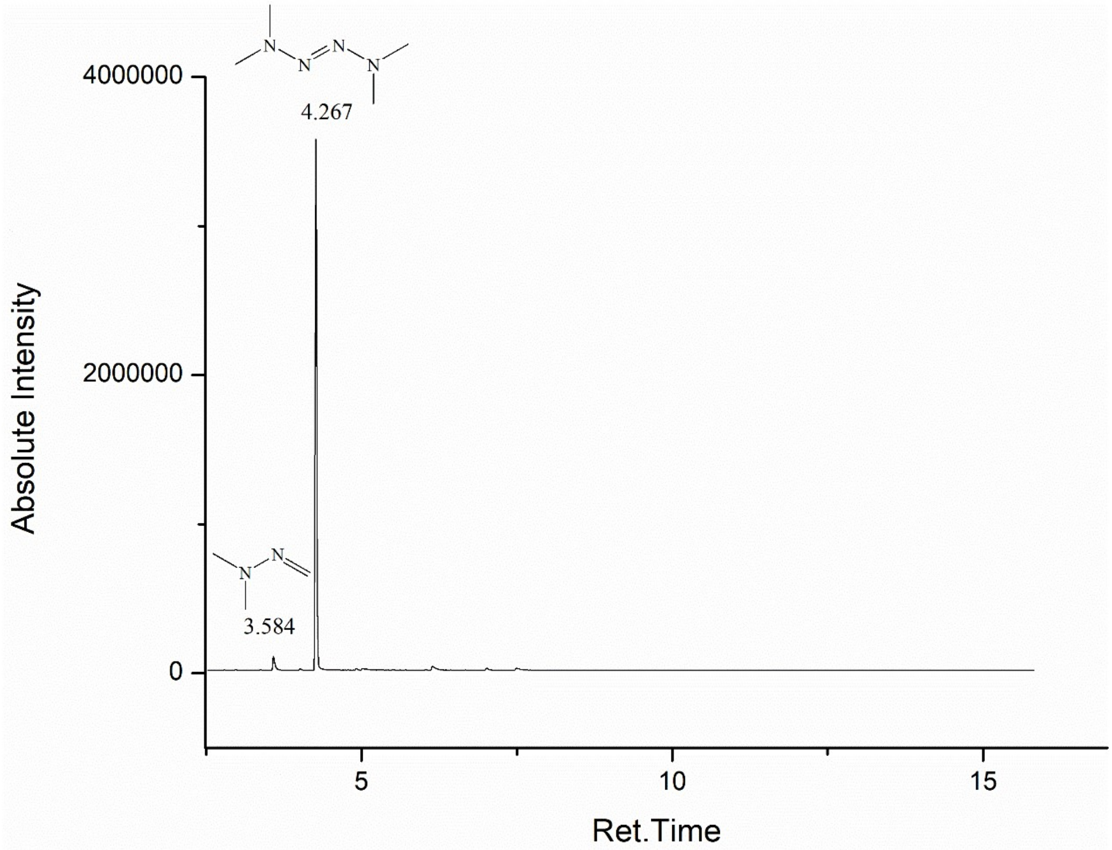


Fig. **S5** GC-MS (top) and ^{1}H NMR (bottom) of products in $CDCl_3$ at 293 K with the electrodes of RuIr@Ti anode and C cathode



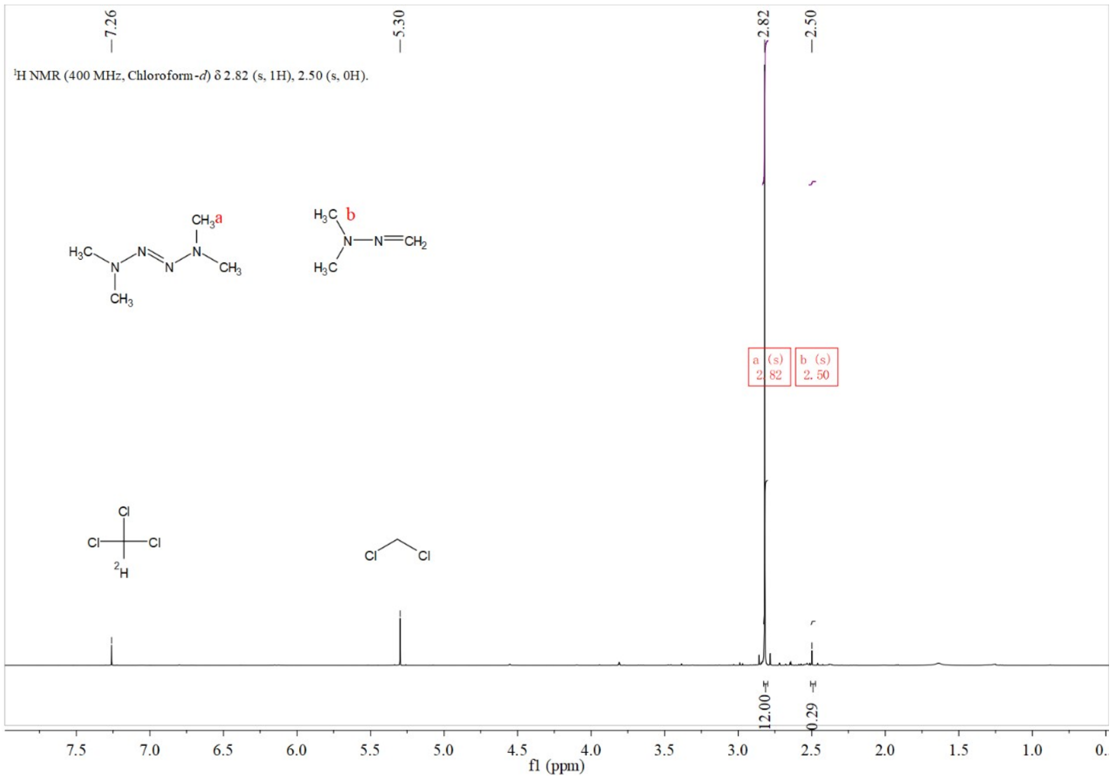
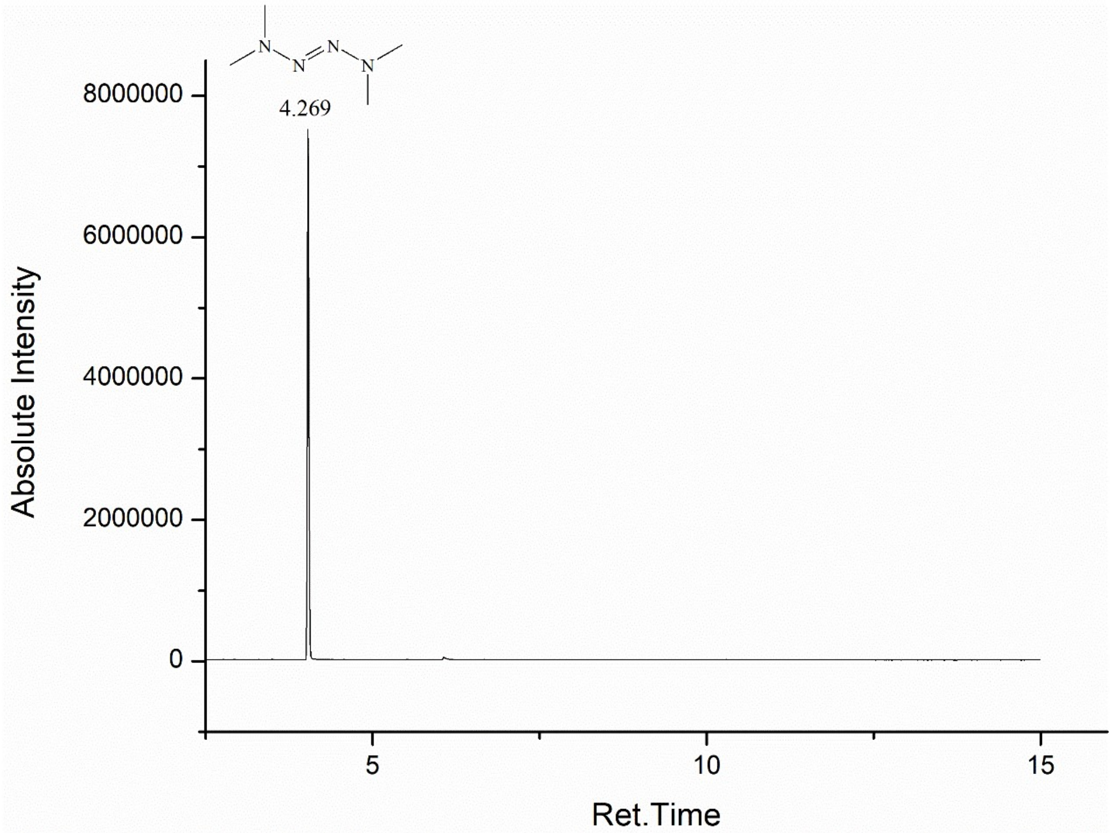


Fig. **S6** GC-MS (top) and ^{1}H NMR (bottom) of products in $CDCl_3$ at 293 K with the electrodes of RuIr@Ti anode and Ti cathode



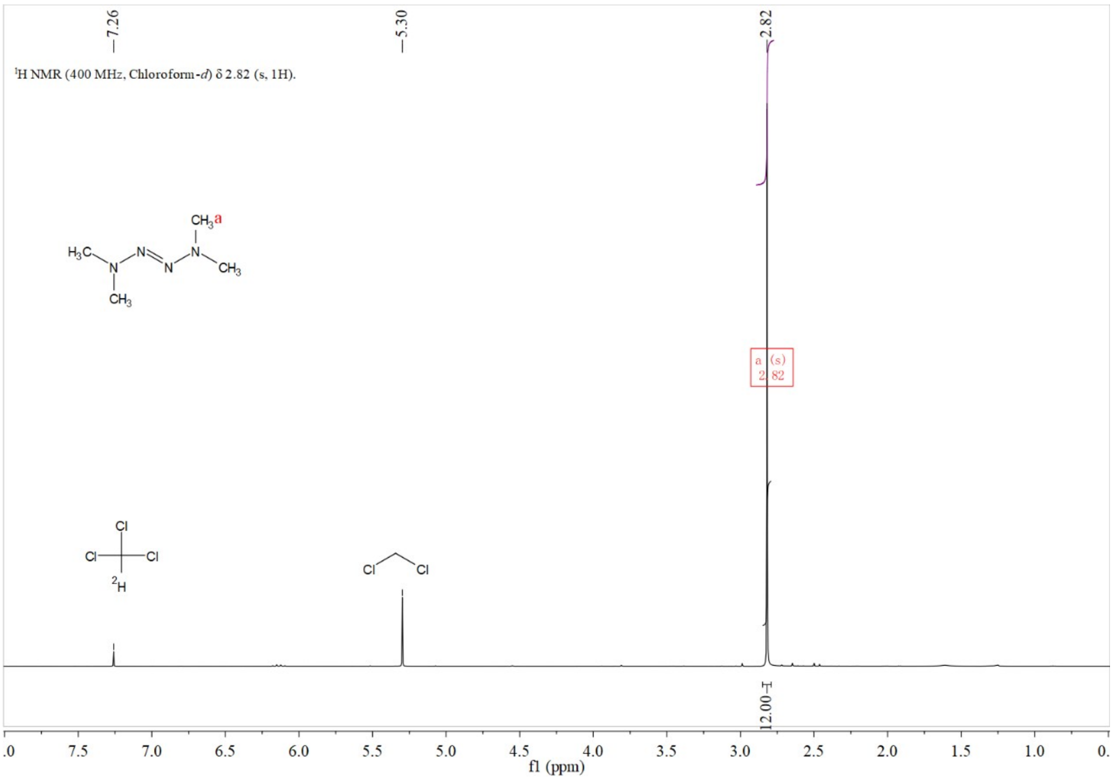


Fig. **S7** GC-MS (top) and ^{1}H NMR (bottom) of products in $CDCl_3$ at 293 K with the electrodes of Ti-WM/Pt anode and Ti cathode.

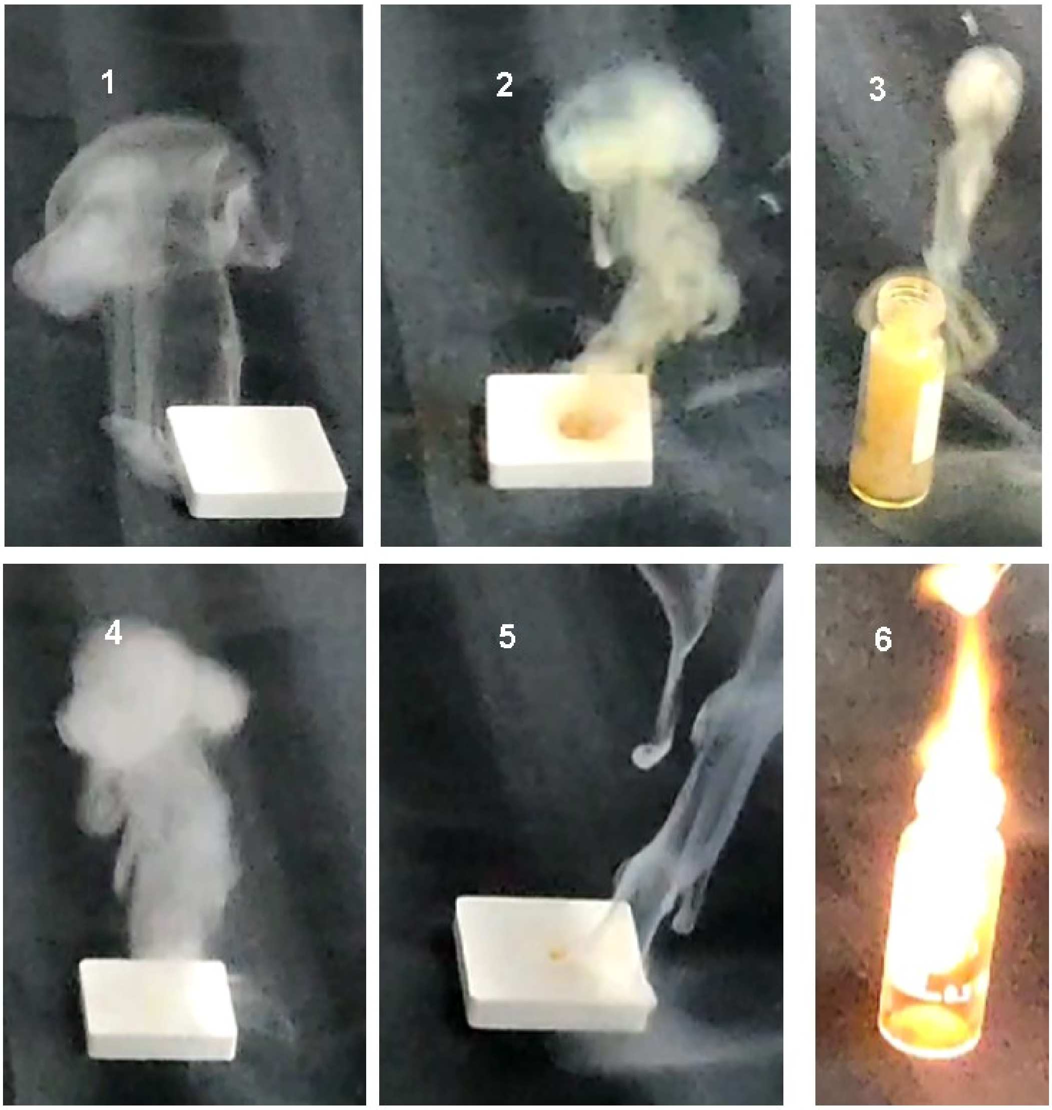


Fig. S8 Hypergolicity test of TMTZ and UDMH with oxidizers H_2O_2, HNO_3 and N_2O_4: (1) TMTZ/H_2O_2, (2) TMTZ/HNO_3, (3) TMTZ/N_2O_4, (4) UDMH/H_2O_2, (5) UDMH/HNO_3, (6) UDMH/N_2O_4.

Table S1. Hypergolicity data of TMTZ and UDMH with oxidizers H_2O_2, HNO_3 and N_2O_4.

Mixtures	Contact time (s)	Ignition time (s)	Ignition delay time (s)
TMTZ/H_2O_2	4.976	5.457	0.481
TMTZ/HNO_3	9.616	9.757	0.140
TMTZ/N_2O_4	3.091	3.151	0.060
UDMH/H_2O_2	22.744	22.962	0.218
UDMH/HNO_3	8.122	8.182	0.060
UDMH/N_2O_4	5.257	5.315	0.058

[1]. Hampton C, Ramesh K, Smith J, Importance of chemical delay time in understanding hypergolic ignition behaviors. 41st Aerospace Sciences Meeting and Exhibit, AIAA2003-1359, 2003

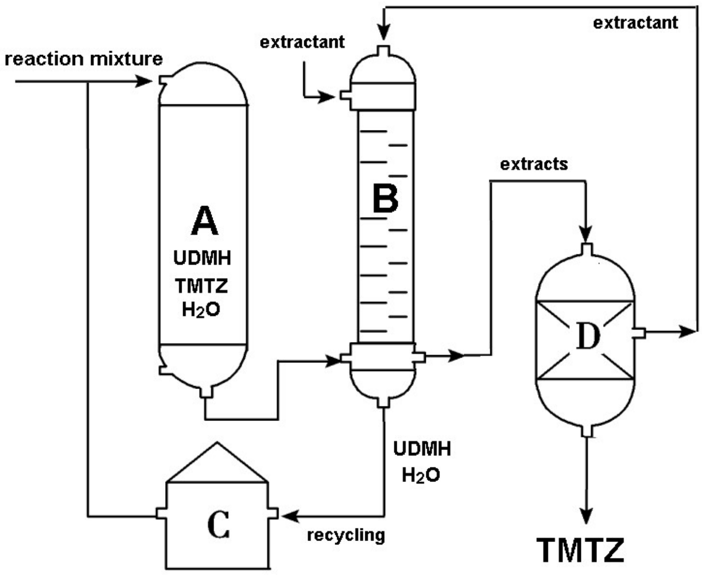


Fig. S9 Flowsheet of the continuous production process of TMTZ obtained from UDMH electrochemical oxidation: A electrochemical oxidation; B extraction; C pump; D rectification.