

Solvent Free Oxidation of Primary Alcohols and Diols Using Thymine Iron(III) Catalyst

Afnan Al-Hunaiti^a, Teemu Niemi^a, Ahlam Sibaouih^a, Petri Pihko^b, Markku Leskelä^a and Timo Repo^{a*}

^a Department of Chemistry, Laboratory of Inorganic Chemistry, P.O. Box 55, FI-00014 University of Helsinki, Finland.

Fax: (+) 358 9 19150198; e-mail: timo.repo@helsinki.fi

^b Department of Chemistry, University of Jyväskylä, P.O. Box 35, FI-40014 University of Jyväskylä, Finland.

LIST OF SUPPORTING INFORMATION

1. Experimental Section (1 page).
2. Figure List (7 pages).
3. ESI-MS Data (4 pages).

General remarks: All chemicals purchased from sigma Aldrich and used as received. Caution should be taken while using high concentration of TBHP. It could undergo homolytic decomposition to afford tert-butoxy and tert-butyl peroxy radicals which have a low flash point and its vapors are highly flammable.

General Procedure for solvent free catalytic oxidation of alcohol: Commercially available anhydrous FeCl₃ (7 mg, 1.8 mol%) was added to thymine-1- acetate (17.6 mg, 0.096 mmol, 3.6mol%) and first 3 mmol of TBHP (322 μL) with a pump system (syringe pump equipped with a glass syringe and PTFE 1/16 in. tubing into the reaction) was added slowly, and the mixture was allowed to stand for 1 h. After this 2-octanol (250 mg, 2.6 mmol) was added. Further aliquot (344 μl, 3.2 mmol) of TBHP was added to have total 6.2 mmol of the oxidant, and the reaction was stirred at 80 °C for 16 hr. Acetophenone was added as internal standard and the reaction was quenched by using Na₂S₂O₃ 100 mg. in 1.5 mL acidified water, the solids were filtered off and the water phase was extracted with diethyl ether (3x3ml). The organic layer was collected and dried using Na₂SO₄, concentrated and its composition was analyzed via GC-MS and/ or NMR. The isolated yield of 2-octanone was 91.5% while for benzoic acid the isolated yield was 89.7 using flash chromatography (n-pentane/diethyl ether) (8:1) to afford the product.

General procedure for the oxidation of 1,2-phenylethandiol: The mixture of thymine-1-acetate(17mg,0.096mmol,4 mol%) and anhydrous iron chloride (7mg,0.048 mmol, 2 mol%) and first 3 mmol of TBHP (322 μL) with a pump system (syringe pump equipped with a glass syringe and PTFE1/16 in. tubing into the reaction) was added slowly, and the mixture was allowed to stir at room temperature in (5mL) acetonitrile solution. After this 1,4-Benzenedimethanol (331mg,2.4 mmol) was added to the mixture and stirred at 80oC for 6hr. Further aliquot 322 μl,3.0 mmol of TBHP was added to have total 6.0mmol of the oxidant. Acetophenone was added as internal standard and the reaction was quenched using Na₂S₂O₃ 100 mg in 1.5 mL acidified water the solids were filtered off and the water phase was extracted with diethyl ether (3x3ml). The organic layer was collected and dried using Na₂SO₄, concentrated and its composition was analyzed by GC-MS.

Chromatographic Analyses

Reaction products were isolated and analyzed quantitatively by GC (Agilent 6890 chromatograph, Agilent 19091 J-413 capillary column 0.32 mm-30 m-0.25 mm, FID detector) using acetophenone as internal standards. Products were identified by GC-MS analyses (Agilent 6890N equipped with Agilent 5973 mass selective detector, DB-innowax 19091 L-102 capillary columns, 200 mm-24 m-0.31 mm).

In situ complex preparation and catalysis

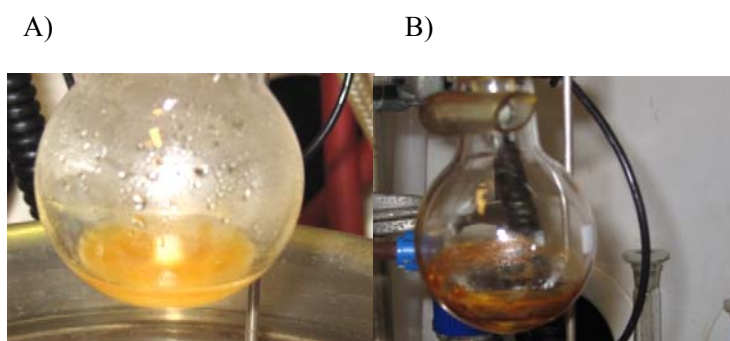


Figure S1. Preparation of the in situ catalyst and the solution after oxidation reaction: A) After mixing of reagents (FeCl_3 +THA+TBHP) and addition of MeCN. B) After the oxidation reaction.

Solvent effect:

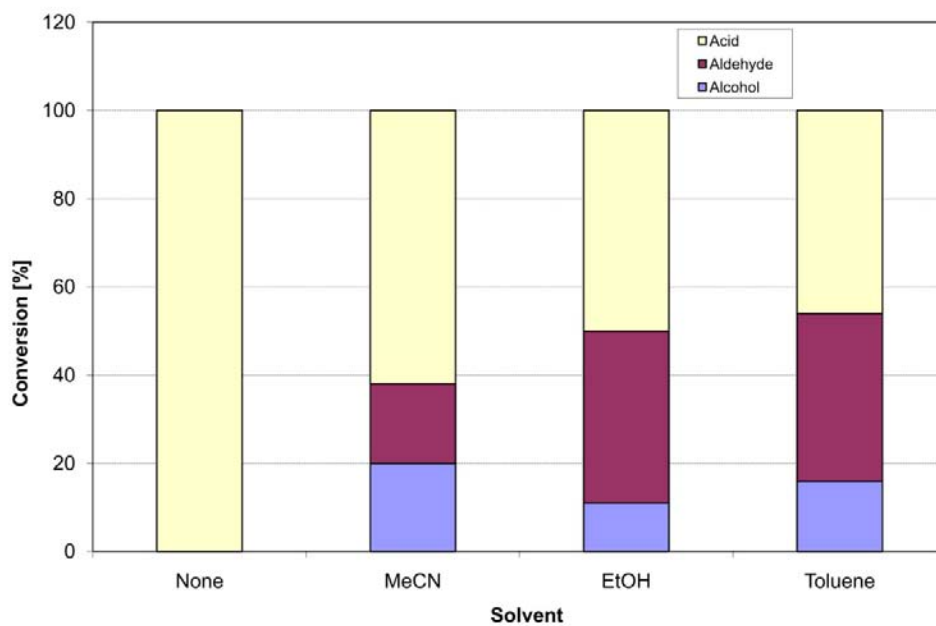


Figure S2. Solvent effect on the conversion of 2-octanol. Conditions: 3mmol of 2-octanol, 3.6mol% of THA, 1.8mol% of FeCl₃, 80°C, 2.5 eq. TBHP, 16hr.

Metal effect:

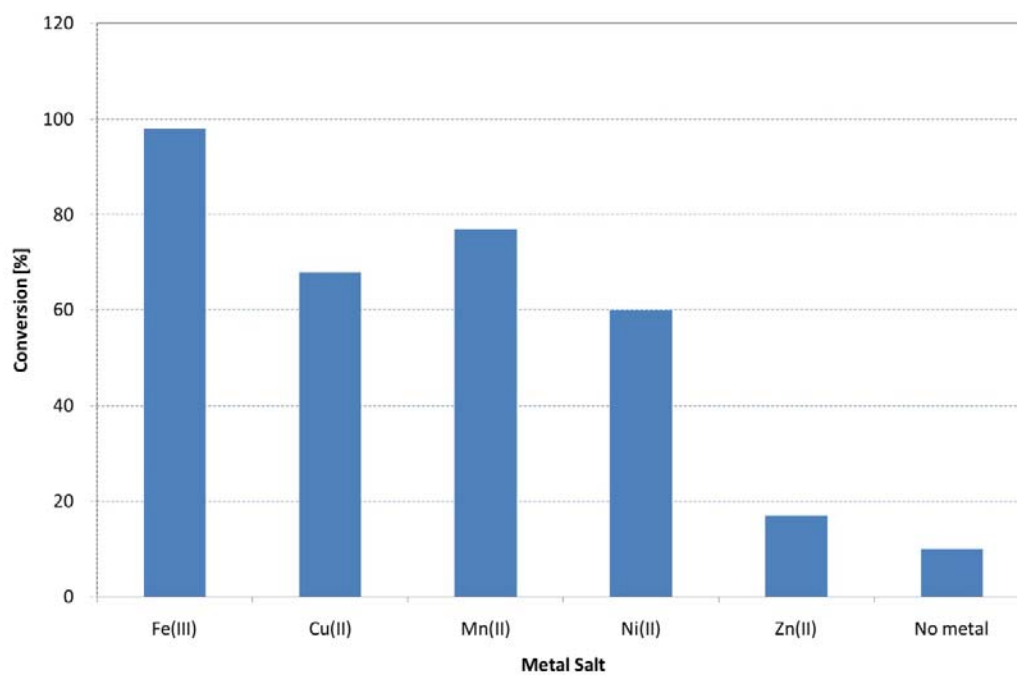


Figure S3. Metal effect on the conversion of 2-octanol. Conditions: 3mmol of 2-octanol, 3.6mol% of THA, 1.8mol% of Metal salt, 80°C, 2.5 eq. TBHP, 16hr.

The effect of L/Fe ratio on the benzyl alcohol conversion:

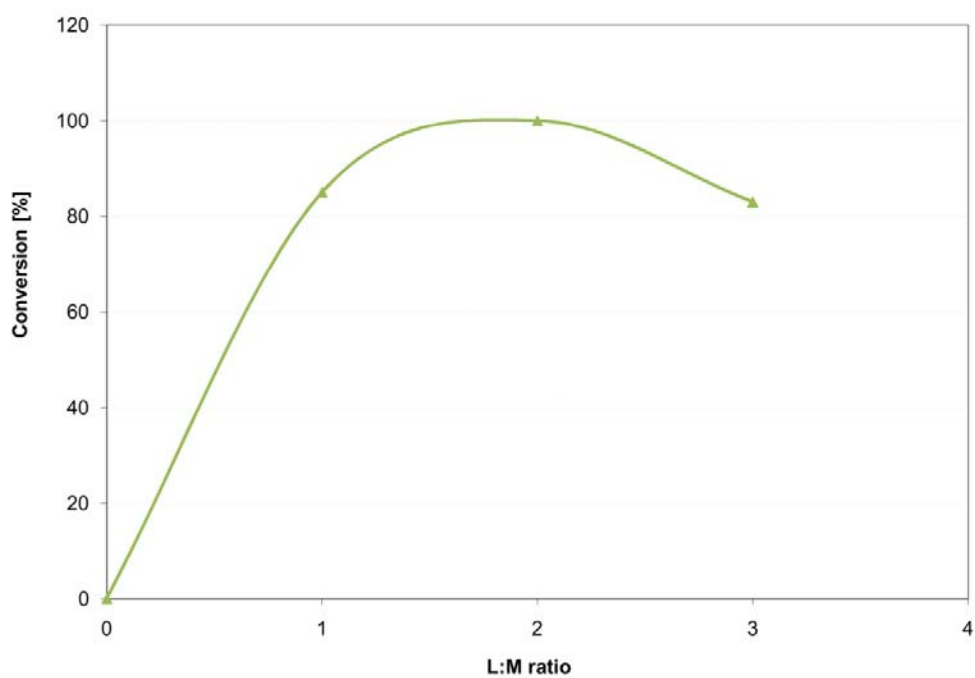


Figure S4. The effect of THA/Fe ratio on the benzyl alcohol conversion. Conditions: 3mmol of benzyl alcohol, 1.8mol% of Fe-THA Complex, 80°C, 2.5 equiv. TBHP, 3hr.

The effect of oxidant amount on the conversion of 2-octanol:

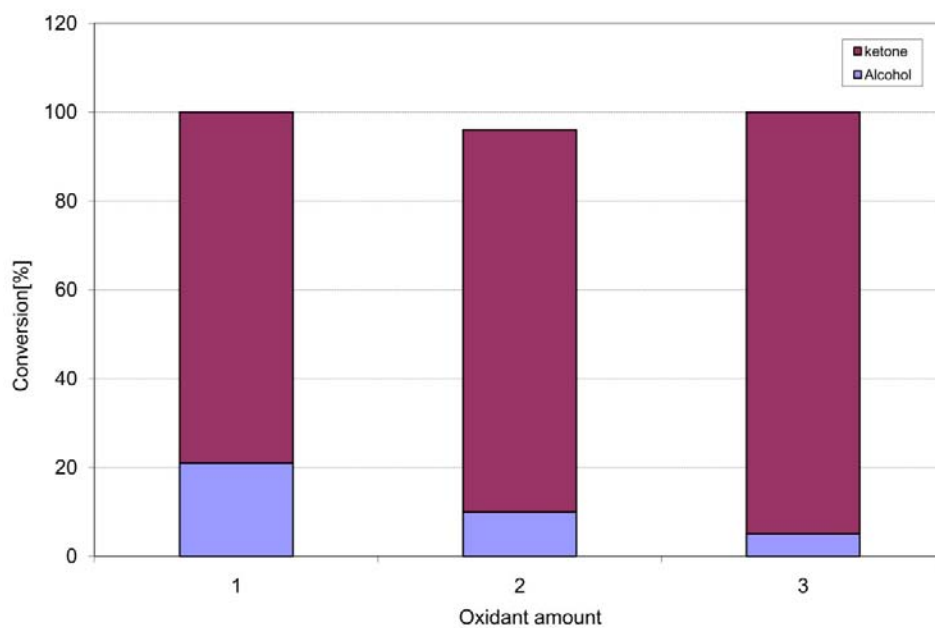


Figure S5. The oxidant amount effect on the conversion of 2-octanol. Conditions: 3mmol of 2-octanol, 3.6mol% of THA, 1.8mol% of FeCl₃, 80°C, 1,2 or 3equiv.TBHP,16h.

Different oxidant effect:

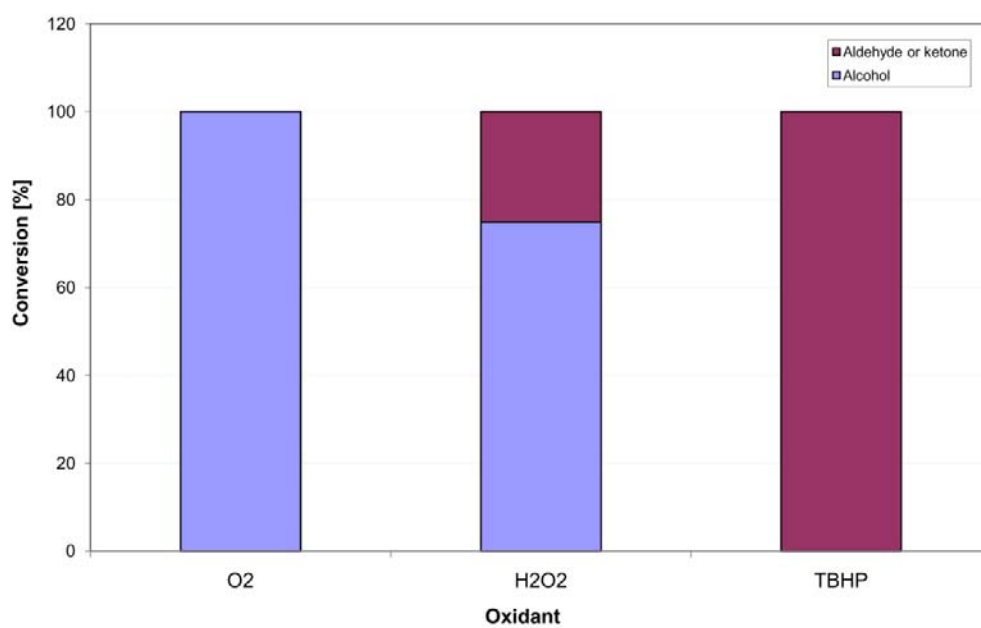


Figure S6. The oxidant effect on the conversion of 2-octanol. Conditions: 3mmol of 2-octanol, 3.6mol% of THA, 1.8mol% of FeCl₃, 80°C, 16hr, oxidant either 1 atm O₂, 3eqH₂O₂, 2.5 eq. TBHP.

Time effect:

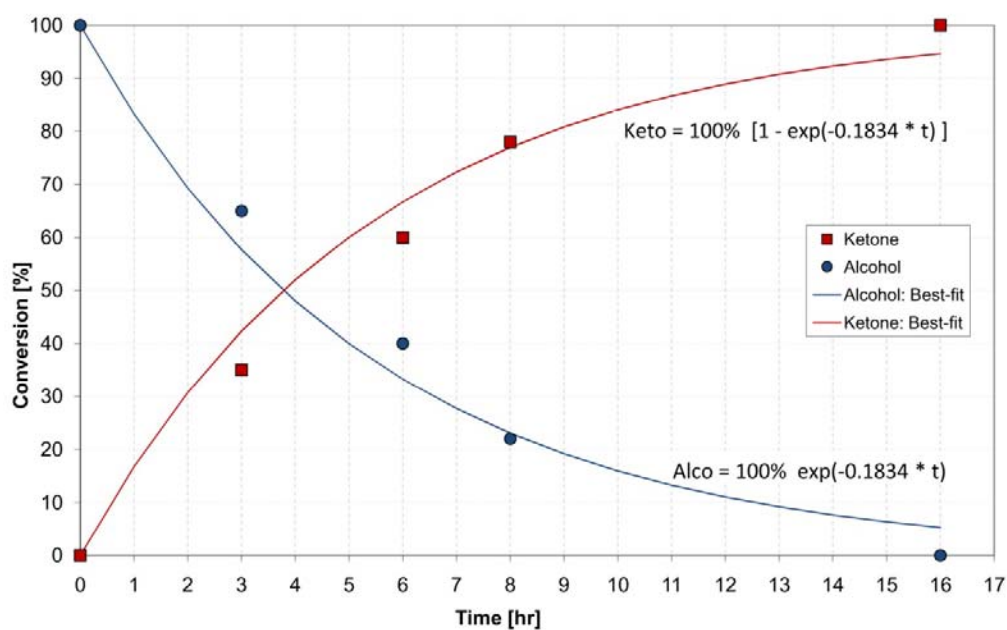


Figure S7. Time effect on the conversion of 2-octanol. Conditions: 3mmol of 2-octanol, 3.6mol% of THA, 1.8mol% of FeCl₃, 80°C, 2.5 eq. TBHP.

Catalyst amount effect:

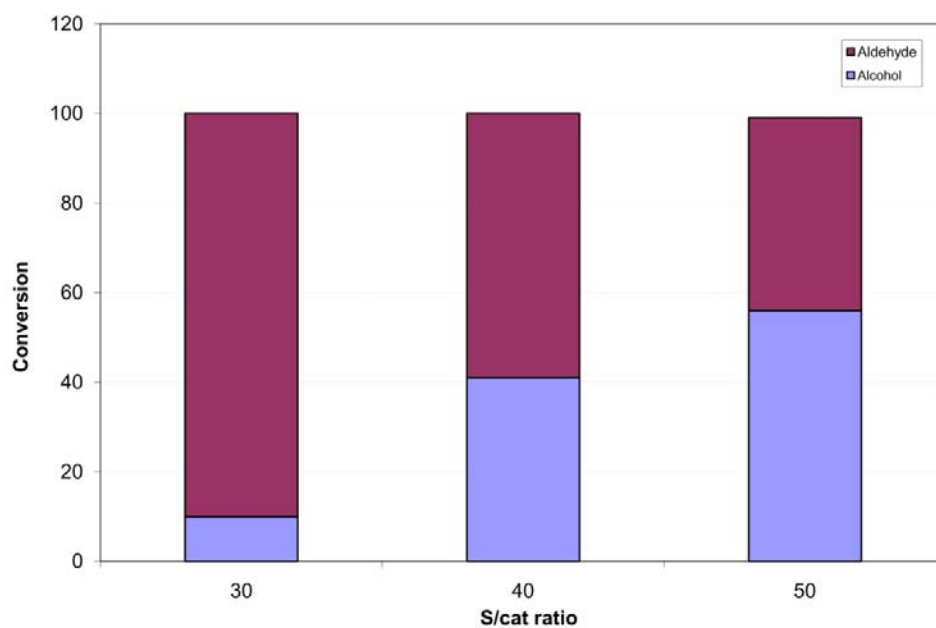


Figure S8. The effect of catalyst amount on the 2-octanol conversion. Conditions: 2-octanol as substrate, 1.8mol% of Fe-THA complex, 80°C, 2.5 eq. TBHP, 16hr.

The high resolution ESI-MS measurement.

Mass spectrometry analyses were performed using a time-of flight mass spectrometer equipped with an electrospray ion source (Bruker microTOF). All analyses were carried out in a negative ion mode. The sample solutions were introduced by continuous infusion with the aid of a syringe pump at a flow-rate of 180 $\mu\text{L}/\text{min}$. The instrument was operated at end plate offset -500 V and capillary -4500 V. Nebulizer pressure was 0.8 bar (N_2) and the drying gas (N_2) flow 7 L/min. Capillary exit and skimmer 1 were 90 and 30 V, respectively. Sodium formate was used for mass calibration for a calibration range of m/z 100-2000. Drying gas temperature was set at 220°C. The software used for the simulations is Bruker Daltonics Data Analysis (version 3.3). A measurement was taken from the reaction mixture of a thymine-acetate/ FeCl_3 complex and TBHP in methanol solution which was diluted with MeCN. Two related species to the iron thymine-1-acetate complex were found in spectrum (FigS9-S11).

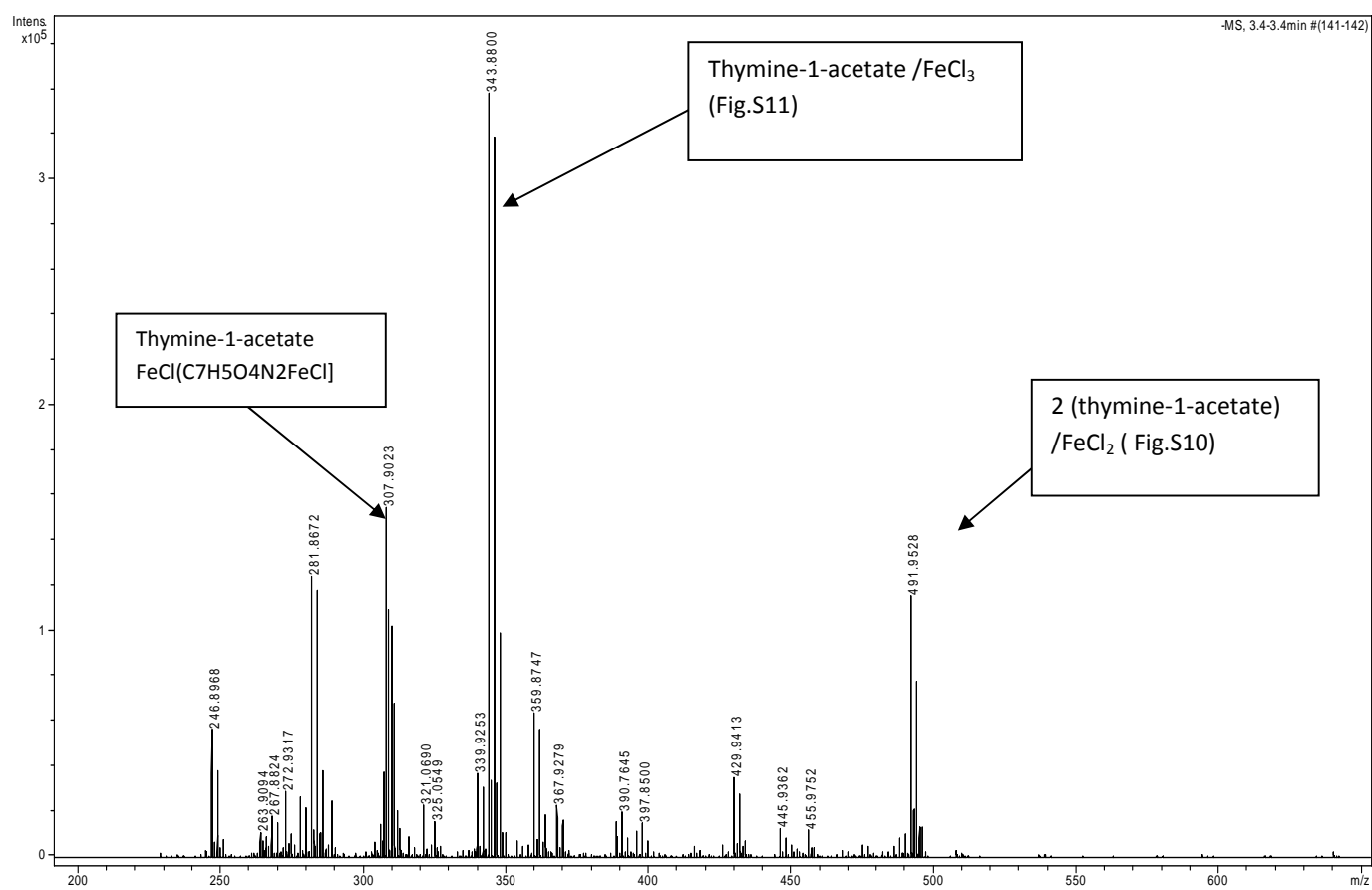


Figure S9. Full spectra of the insitu catalyst samples. The main two peaks are analyzed in the below figures.

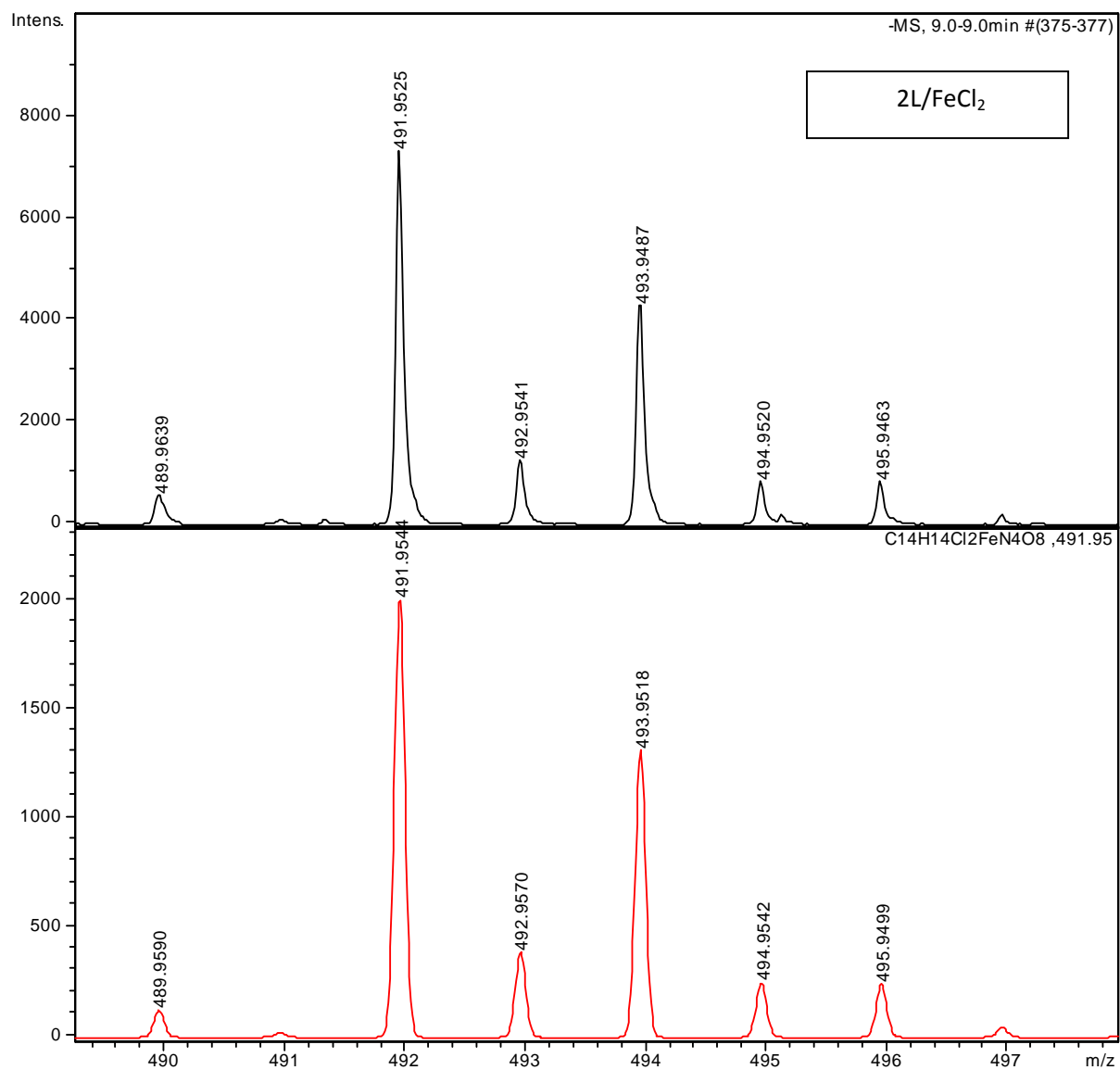


Figure S10. Experimental (black line) and simulated (red line) HRMS(-) spectra of $[C_{14}H_{14}N_4O_8FeCl_2]$: calc. m/z 491.9544 while the observed one is 491.9525 m/z . The error between simulated and found isotopic patterns is 3.735 ppm.

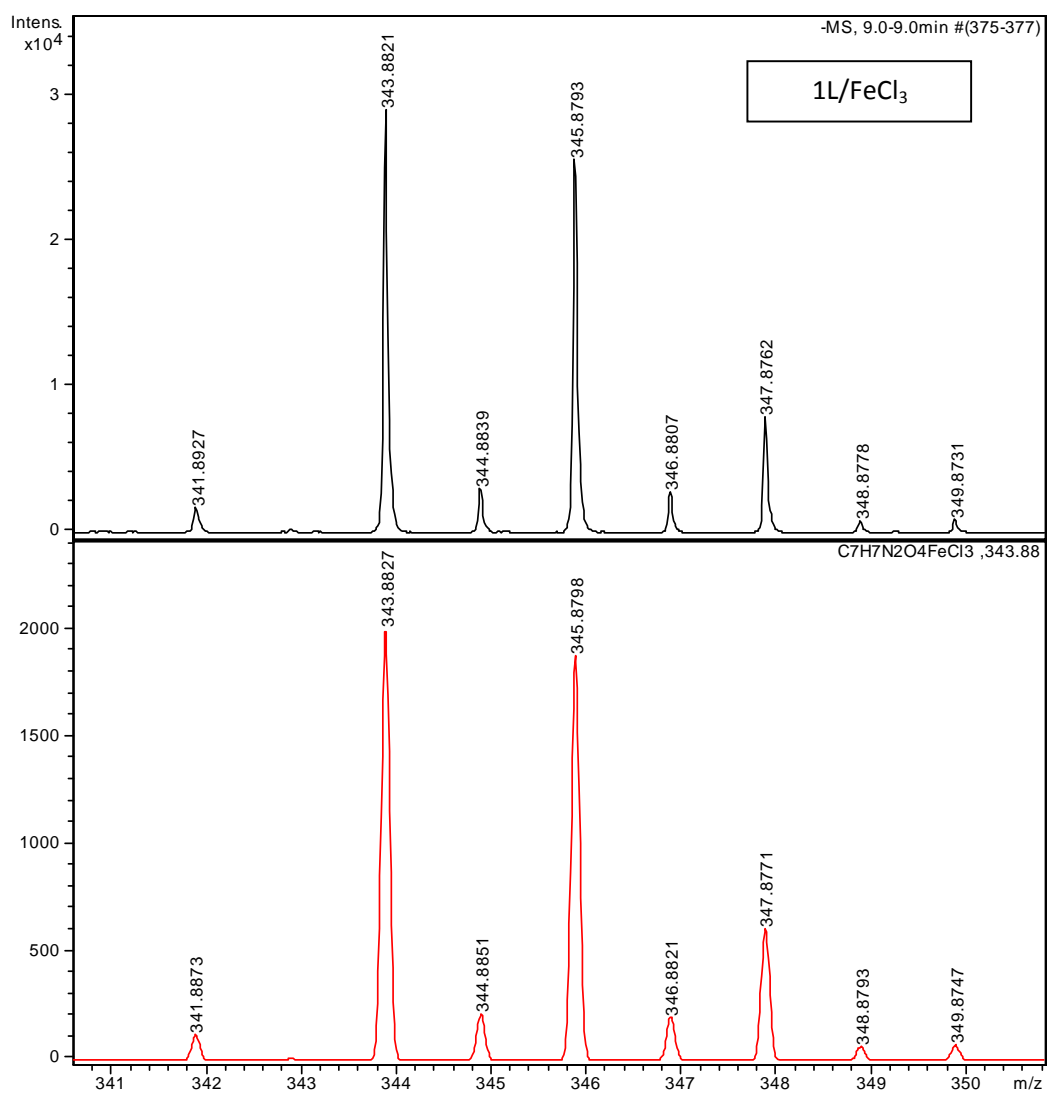


Figure S11. Experimental (black line) and simulated (red line) HRMS(-) spectra of Thymine -1-acetate/
FeCl₃. [C₇H₇N₂O₄FeCl₃] (calculated mass = 343.8826 m/z) while the observed one is (343.8821 m/z) The
error between simulated and observed isotopic patterns is 1.56501 ppm.