Supplementary Information

New Magnetic Fe Oxide-Carbon Based Acid Catalyst Prepared from Bio-Oil for Esterification Reactions

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Figure S1. X-ray diffractograms of materials (B8Fe)₄₅₀, (B16Fe)₄₅₀ and (B24Fe)₄₅₀.

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Figure S2. X-ray diffractograms of samples (B8Fe)$_{400}$, (B8Fe)$_{450}$, (B8Fe)$_{500}$ and (B8Fe)$_{600}$.

Figure S3. Mössbauer spectra, at 30 K, of samples (B8Fe)$_{450}$, (B8Fe)$_{500}$ and (B8Fe)$_{600}$. 

Amorphous carbon
\(\gamma\text{-Fe}_2\text{O}_3/\text{Fe}_3\text{O}_4\)

Intensity / a.u.

20 / degree

30K

Relative transmission

Velocity (mm/s)
Table S1. Hyperfine parameters at 30 K of samples (B8Fe)$_{450}$, (B8Fe)$_{500}$, (B8Fe)$_{600}$, (B8Fe)$_{450}$S, (B8Fe)$_{500}$S and (B8Fe)$_{600}$S

<table>
<thead>
<tr>
<th>Sample</th>
<th>Oxidation state</th>
<th>$\delta \pm 0.05$ / (mm s$^{-1}$)</th>
<th>Deq/Δ $\pm 0.05$ / (mm s$^{-1}$)</th>
<th>H$_{HF}$ $\pm 0.5$ / Tesla</th>
<th>Area $\pm 1$ / %</th>
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<tbody>
<tr>
<td>(B8Fe)$_{450}$</td>
<td>Fe$^{3+}$</td>
<td>0.45</td>
<td>0.0</td>
<td>48.0</td>
<td>54</td>
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<td>0.40</td>
<td>0.0</td>
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<td>0.45</td>
<td>1.03</td>
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<td>(B8Fe)$_{450}$S</td>
<td>Fe$^{3+}$</td>
<td>0.43</td>
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<td>0.39</td>
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<td>(B8Fe)$_{500}$</td>
<td>Fe$^{3+}$</td>
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<td>0.0</td>
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<td>0.0</td>
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<td></td>
<td>0.44</td>
<td>0.98</td>
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<td>(B8Fe)$_{500}$S</td>
<td>Fe$^{3+}$</td>
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<td>(B8Fe)$_{600}$</td>
<td>Fe$^{3+}$</td>
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<td>(B8Fe)$_{600}$S</td>
<td>Fe$^{3+}$</td>
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<td>42.4</td>
<td>25</td>
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<td>0.46</td>
<td>0.98</td>
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</table>

$\delta$: isomer shift; Deq/Δ: quadrupole splitting; H$_{HF}$: hyperfine field; (B8Fe)$_{450}$, (B8Fe)$_{500}$, (B8Fe)$_{600}$: bio-oil impregnated with 8 wt.% of iron, thermally treated at 400, 450, 500 or 600 °C, respectively; (B8Fe)$_{450}$S, (B8Fe)$_{500}$S, (B8Fe)$_{600}$S: sulfonated (B8Fe)$_{450}$, (B8Fe)$_{500}$, (B8Fe)$_{600}$, respectively.
Figure S4. EDS analysis of iron materials before ((B8Fe)$_{400}$) and after sulfonation ((B8Fe)$_{400}$S).

Figure S5. TEM images of material (B8Fe)$_{400}$S.
Figure S6. FTIR-ATR spectra of sulfonated materials: (B8Fe)400S, (B8Fe)450S, (B8Fe)500S and (B8Fe)600S.

Figure S7. TG curves in air atmosphere of materials (B8Fe)400 and (B8Fe)400S.
Figure S8. TG curves in air atmosphere of materials (B8Fe)$_{450}$, (B8Fe)$_{450}$S, (B8Fe)$_{500}$, (B8Fe)$_{500}$S, (B8Fe)$_{600}$ and (B8Fe)$_{600}$S.

Figure S9. Potentiometric titration curves with n-butylamine of materials (B8Fe)$_{400}$S, (B8Fe)$_{450}$S, (B8Fe)$_{500}$S and B8Fe$_{500}$S.