

## Electronic Supporting Information

### Magnetically Induced Localized Heating Enabling Rapid and Efficient Synthesis of Metal-Organic Frameworks

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## Experimental

### **Materials and Methods**

All reagents and solvents were purchased from commercial sources and used as received.

**Characterization:** Powder X-ray diffraction (PXRD) data was collected at room temperature using a Rigaku SmartLab diffractometer with copper radiation (Cu K $\alpha$ ,  $\lambda = 1.5406 \text{ \AA}$ ) and a secondary monochromator operating at 40 kV and 30 mA; whereby samples were measured between 5° and 50° at a scan speed of 4 s/min and step size of 0.01°. Infrared spectra measurements from 4000-400 cm<sup>-1</sup> were taken on a Thermo Scientific Nicolet i550 ATR-IR with 4 cm<sup>-1</sup> resolution. BET surface area measurements were performed on a Micromeritics ASAP2020Plus analyzer using N<sub>2</sub> sorption isotherms at 77 K. Scanning electron microscope (SEM) images were collected using JEOL JSM-IT200 benchtop electron microscope at a 15kV accelerating voltage whereby dry samples of HKUST-1, MOF-235 and MOF-5 were put on carbon tape. Dynamic light scattering (DLS) measurements were carried out using a Zetasizer Nano ZSP (Malvern Instruments) and disposable low volume cuvette. PEG-1000@IONPs dispersion in water (1 mg/mL) was measured at 25°C. The resulting data was averaged to get a mean size distribution profile. The change in mass magnetization (M) in response to the applied magnetic field (H) for PEG-1000@IONPs powders was measured using Lakeshore 8600 series Vibrating sample magnetometer (VSM). The magnetic properties were measured with an applied field range of  $\pm 3$  Tesla at a rate of 50 Oe/sec. Magnetic heating experiments were carried using a 4.2 kW Ambrell Easy heat instrument under different magnetic field strength (H) values and constant frequency of 224 kHz. A 8 turn coil (dimensions of 8 turn coil: internal diameter of 25 mm and length of 43mm) was used to perform the heating experiments.

**Synthesis of PEG -1000@IONPs:** PEG-1000 coated nanoparticles were synthesized by co-precipitation method using a reported procedure<sup>1</sup> with slight modifications. Initially 1.054 g (0.00039 mmol) of FeCl<sub>3</sub>.6H<sub>2</sub>O and 0.387 g (0.000195 mmol) of FeCl<sub>2</sub>.4H<sub>2</sub>O (Fe<sup>+3</sup>: Fe<sup>+2</sup> in ratio 2:1) were dissolved in 75 mL Millipore water and then mechanically stirred for 1 h constantly at temperature of 70 °C. Black colored precipitate formed on addition of 45 mL 25% NH<sub>4</sub>OH to above solution. Simultaneously, 3 g PEG -1000 already dissolved in 7.5mL Millipore water was also added to the black precipitate solution of iron oxide followed by constant stirring for another 1 h at 90 °C. The entire reaction was carried out under an inert atmosphere. Finally, the precipitates of the PEG-1000@IONPs obtained were separated using magnetic separation and washed using Millipore water to remove any excess salts or surfactant.

**Magnetic Induction Heating (MIH) Synthesis of HKUST-1:** HKUST-1 was synthesized using Magnetic induction heating based on a solvothermal synthesis procedure reported in literature.<sup>2</sup> Firstly, 0.2082 mmol of 1,3,5-benzenetricarboxylic acid and 0.3125 mmol of Cu (NO<sub>3</sub>)<sub>2</sub>.2.5H<sub>2</sub>O were dissolved in 5 mL

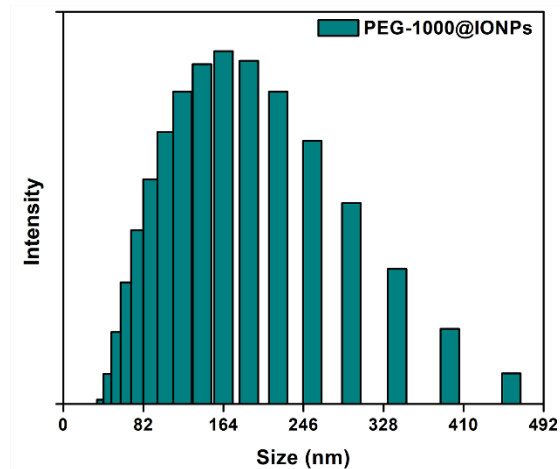
ethanol:H<sub>2</sub>O (1:1) mixture. The metal salt and ligand were allowed to dissolve completely to make a homogenous solution, and then 5 mg/mL PEG 1000@IONPs were added to the former solution. The solution was then sonicated for 20 min and transferred into a 10 mL glass vial. Finally, the solution was exposed to an alternating magnetic field of 35.32 kA/m magnetic field strength and 224kHz frequency for different time periods (10 min, 20 min, 30 min, 1 h, 1.5 h, 2 h and 2.5 h). The resultant MOF was separated from PEG 1000@IONPs using magnetic separation and washed using ethanol 3-4 times over a period of 2 days. The obtained material was then collected and dried. For the BET surface area measurements, the material was activated at 120 °C under dynamic vacuum for 12 h.

**Conventional solvothermal synthesis of HKUST-1 MOF:** HKUST-1 was synthesized using conventional solvothermal heating from the procedure same as above except that no magnetic PEG-1000@IONPS were used. The solution containing the precursors was transferred into a Teflon lined autoclave (20 mL) and put into a preheated oven at 65 °C for 2.5 h. The resultant MOF was separated from PEG 1000@IONPs using magnetic separation and washed using ethanol 3-4 times over a period of 2 days. The obtained material was then collected and dried.

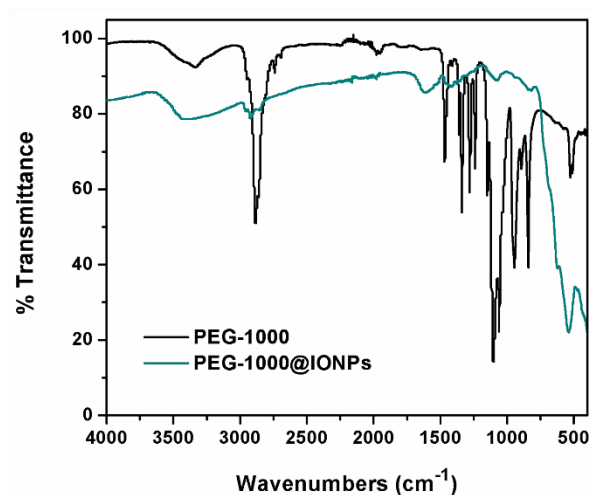
**Magnetic induction heating synthesis of MOF-235:** MOF-235 was synthesized using magnetic induction heating based on solvothermal synthesis method reported in literature.<sup>3</sup> Terephthalic acid (0.615 mmol) and FeCl<sub>3</sub>.6H<sub>2</sub>O (0.820 mmol) were dissolved in a 5mL solvent mixture of DMF:ethanol (3:1). Thereafter, PEG 1000@IONPs (5 mg/mL) were added to the former solution. The resultant mixture was then sonicated for 20 min and transferred into a 10 mL glass vial. Finally, the solution was exposed to an alternating magnetic field of 31.23 kA/m magnetic field strength and 224kHz frequency for 2.5 h. The resultant MOF was separated from PEG 1000@IONPs using magnetic separation and washed using first with DMF for 1-2 times followed by ethanol washing for 3-4 times over a period of 2 days. It was then collected and dried under vacuum to yield pure MOF-235 in 47.3% yield (based on ligand).

**Magnetic induction heating synthesis of MOF-5:** MOF-5 was synthesized using magnetic induction heating based on solvothermal synthesis method reported in the literature with slight modifications.<sup>4</sup> Terephthalic acid (0.270 mmol) and Zn(NO<sub>3</sub>)<sub>2</sub>.6H<sub>2</sub>O (1.512 mmol) were dissolved in 5mL DMF followed by the addition of 270 μL of Millipore water. Finally, 7.5 mg/mL PEG 1000@IONPs were added to the former solution which was then sonicated for 20 min and transferred into a 10 mL glass vial. This solution was then exposed to an alternating magnetic field of 60.92kA/m magnetic field strength and 224kHz frequency for 2.5 h. The resultant MOF was separated from PEG 1000@IONPs using magnetic separation and washed using first with DMF for 1-2 times followed by chloroform washing for 3-4 times over a period of 2 days.

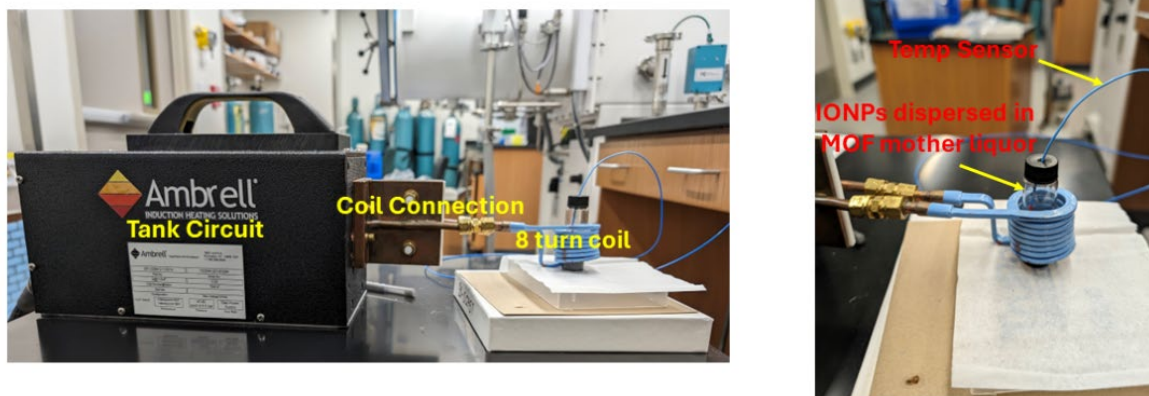
The obtained material was then vacuum dried to yield MOF-5 (based on ligand) in 52.1% yield and stored in an inert atmosphere.



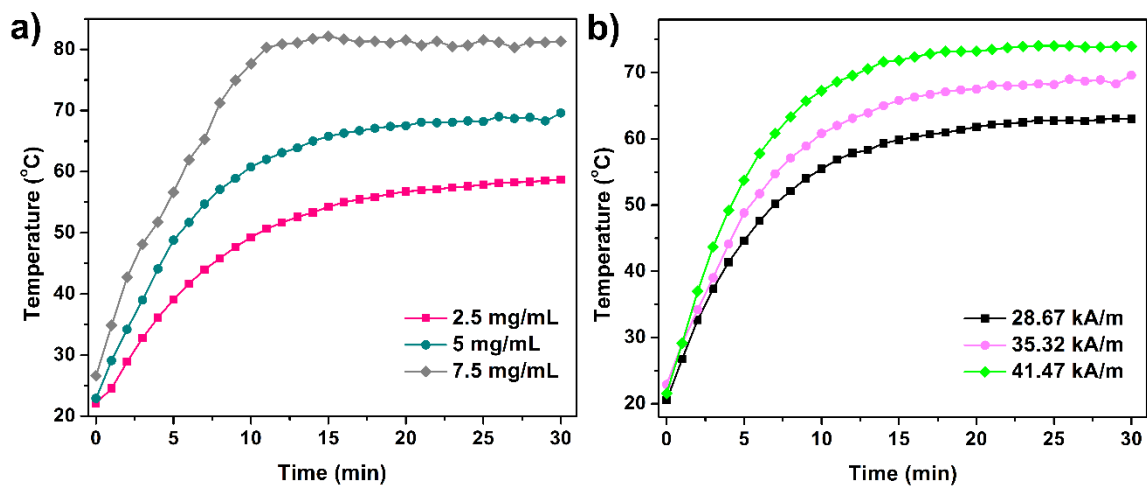
**Fig. S1.** The hydrodynamic size distribution of PEG-1000@IONPs measured using DLS.



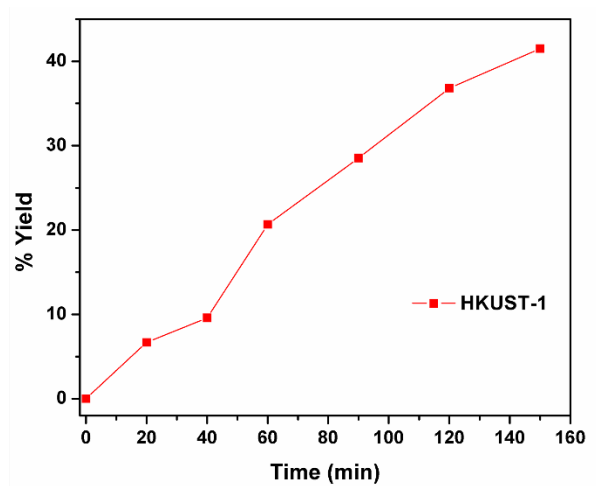
**Fig. S2.** Comparison of the FTIR spectra of PEG-1000 (black) and PEG-1000@IONPs (dark cyan).



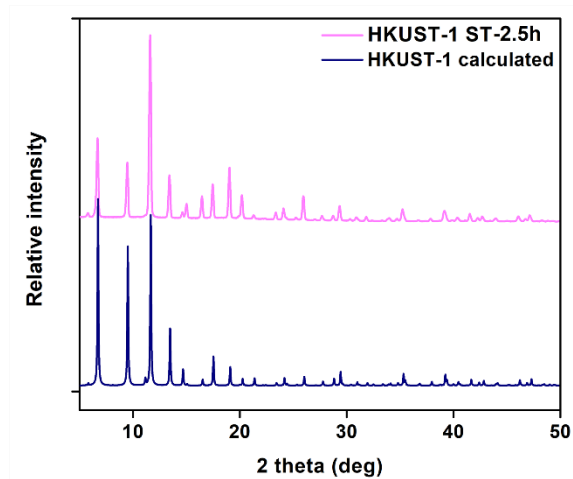
**Fig. S3.** The experimental setup for carrying out the MIH synthesis of MOFs using the Ambrell EasyHeat magnetotherm instrument under varying magnetic field strength (H) and a constant frequency of 224 kHz.



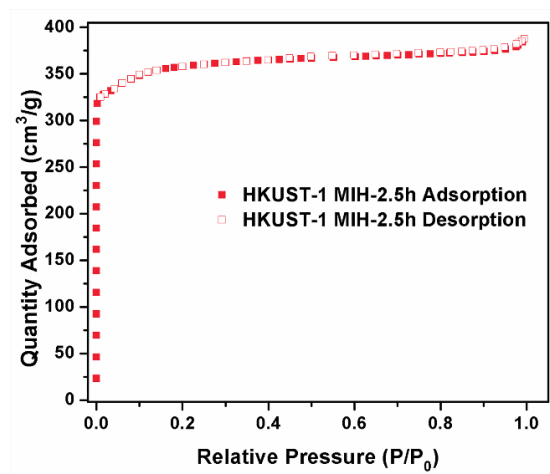
**Fig. S4.** The effect of (a) concentration, and (b) magnetic field strength on the heating properties of the PEG-1000@IONPs in the EtOH:water (1:1) solvent system.



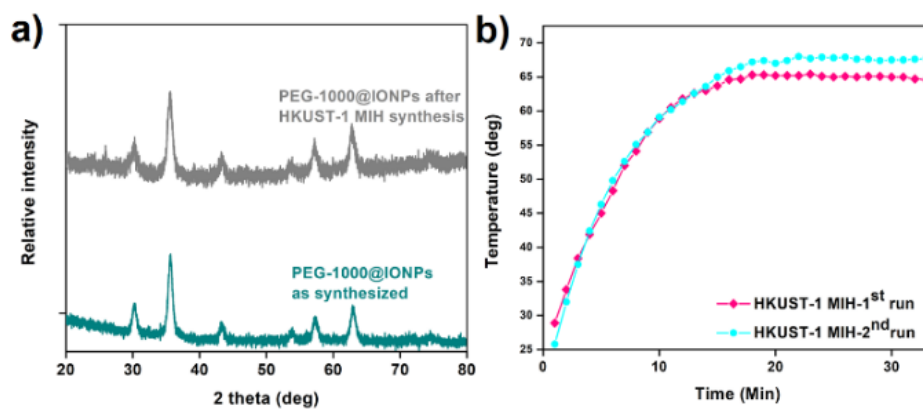
**Fig. S5.** The increase in yield over time for the MIH synthesis of HKUST-1.



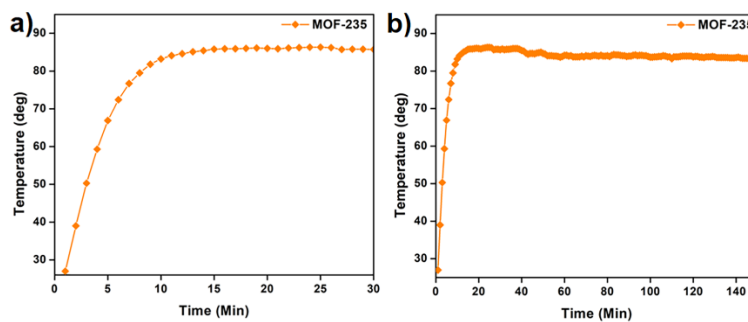
**Fig. S6.** The PXRD pattern of the product obtained from the conventional solvothermal synthesis carried out at 65 °C for 2.5 h (HKUST-1 ST-2.5h).



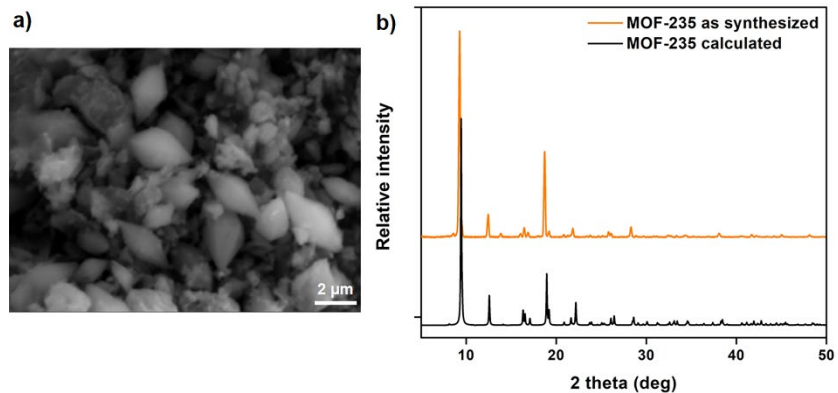
**Fig. S7.** The N<sub>2</sub> adsorption-desorption isotherms at 77K for **HKUST-1 MIH-2.5h** obtained from magnetothermal synthesis at 65 °C for 2.5 h.



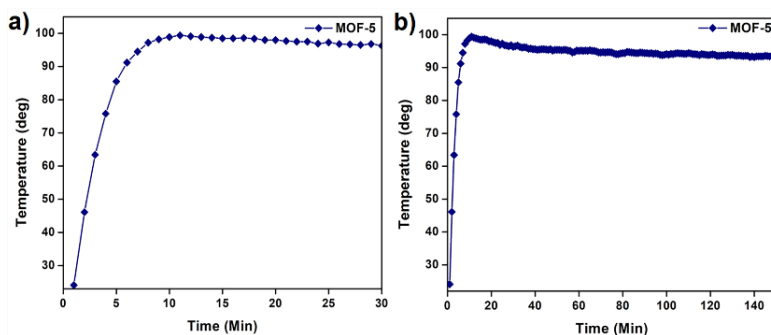
**Fig. S8.** The a) PXRD of the **PEG-1000@IONPs** before and after the **HKUST-1 MIH** synthesis, and b) heating profile of the **PEG-1000@IONPs** during reusability tests.



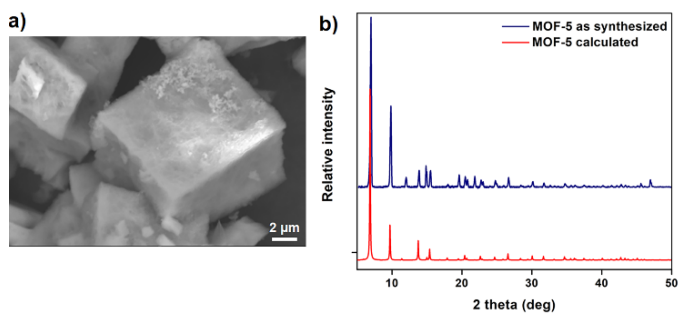
**Fig. S9.** The heating profile of **PEG-1000@IONPs** for (a) 30 min, and (b) 2.5 h synthesis of **MOF-235**.



**Fig. S10.** The a) SEM image, and b) PXRD pattern for MOF-235 obtained from MIH synthesis indicating high crystallinity.



**Fig. S11.** The heating profile of PEG-1000@IONPs for (a) 30 min, and (b) 2.5 h synthesis of MOF-5.



**Fig. S12.** The a) SEM image, and b) PXRD pattern for MOF-5 obtained from MIH synthesis.



**Table S1. A comparison of the efficiency of magnetic induction heating and the conventional solvothermal convection ovens for MOF synthesis.**

	Convection Oven	Magnetic Induction Heating <sup>2</sup>
Power rating	1680 W	191 W (at 65 °C)
Heat-up time <sup>1</sup>	25 min (for set temperature of 150 °C)	15 min (for set temperature of 65 °C)
Heat dissipation to the environment <sup>1</sup>	261 W (at set temperature of 150 °C)	Negligible
Temperature deviation from set value <sup>1</sup>	± 4.5 °C	± 1 °C

<sup>1</sup>Typical values for a set temperature of 150 °C. Source: [https://us.vwr.com/assetsvc/asset/en\\_US/id/12244825/contents/at-vwr-collection-oven-operation-manual.pdf](https://us.vwr.com/assetsvc/asset/en_US/id/12244825/contents/at-vwr-collection-oven-operation-manual.pdf)

<sup>2</sup> Values for synthesis of HKUST-1 using MIH.

### References

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