Supporting Information
Taming the Transition Between ZIF-L-(Zn, Co) and ZIF-(8, 67) Using a Multi-Inlet Vortex Mixer (MIVM)

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1 Experimental Section

The concentration of metal ions was kept constant through all the experiments $[Zn^{2+}] = [Co^{2+}] = 0.05$ M.

1.1 Transition to ZIF-L

For the transition as function of Zn:Hmim ratio, solutions with [Hmim] = 0.5 M, 0.75 M, 1, 1.25 M, 1.5 M, 1.75 M were prepared. As such the Zn:Hmim ratios were as follow: 1:10, 1:15, 1:20, 1:25, 1:30, and 1:35, respectively. The precursor solutions were fed to four syringes (two for metal ions, and two for Hmim) to be pumped into MIVM. The flow rate of all syringes was fixed at 10 mL/min.

As for the transition as function of Zn:Hmim flow rate, the organic linker concentration was fixed at [Hmim] = 0.75 M for a Metal:Hmim ratio of 1:15. Two syringes were filled with Zn^{2+} and the other two with Hmim. The flow rate for the Zn ions was fixed at 10 mL/min while that for Hmim was varied as follows: 10 mL/min, 15 mL/min, 20 mL/min, 25 mL/min and 30 mL/min. The same procedure was followed for ZIF-L-Co to ZIF-67 transition. All solutions were prepared using double distilled water. The collected ZIF samples were aged for 12 hours followed by centrifugation at 5700 rpm for 15 min. The samples were washed four times with ethanol (EtOH) and freeze-dried overnight in order to remove all traces of methanol and adsorbed water for characterization.

1.2 Two-Syringe System

An aqueous solution of 2-Methylimidazole [Hmim = 3.5 M] was prepared in double distilled water, for a Metal:Hmim ratio of 1:70. For bimetallic ZnCo-ZIF-8 three atomic Zn:Co ratios were used as follows: 75:25, 50:50, and 25:75. Each precursor solution is fed into two separate syringes. The synthesis of all ZIFs is done at three flow rates: 6 mL/min, 20 mL/min, and 59 mL/min. The samples are then centrifuged at 5700 rpm for 20 minutes to remove excess solvent, then washed four times in ethanol, and dried overnight for further characterization.

1.3 Four-Syringe System

The four syringes system study was done only for ZIF-8. The same concentrations of the precursor solutions were used ([Zn^{2+}] = 0.05 M and [Hmim] = 3.5 M). However, the total number of used syringes was four where each of the metal and organic linker solutions were fed into two syringes. The synthesis of ZIF-8 was done at the following flow rates: 0.625 mL/min, 10 mL/min, 20 mL/min, 30 mL/min, 40 mL/min, 50 mL/min, and 60 mL/min.

Please note that the two-syringe system experiments in section 3.1 are concerned with the transition from ZIF-L to ZIF-8/67. The experiments that used the four-syringe system in section 3.2 dealt with the control the particle size of the ZIF particles.

1.4 Batch Synthesis of ZIF-8

The synthesis of ZIF-8 was done by adding 6 mL of Hmim solution ([Hmim] = 3.5 M) to a 50 mL beaker containing 6 mL of Zn^{2+} solution ([Zn^{2+} = 0.05 M]). The reaction was left to proceed for 30 min at a stirring rate of 500 rpm at room temperature.

1.5 Sample Calculation of the Reynolds Number Re

The Reynolds number (Re) was calculated using Eq. (1) in the main manuscript. The dynamic viscosity (μ) of Hmim at a concentration of 3.5 M and 25 °C is measured and found to be equal to 2.6 cP, which is higher than that of the metal precursor solution (0.89 cP). The measured density (ρ) of the Hmim solution is 1003 kg/m^3, slightly higher than that of the metal solution (997 kg/m^3). The velocity of the streams is calculated at the inlets; the mixing chamber diameter is L = 0.6 cm. The velocity of the inlet streams was calculated using the following equation:

$$V = \frac{Q}{A}$$

where V is the flow velocity in (m/s), Q is the flow rate in (l/min), A is the cross-sectional circular area of the inlet leading to the main mixing chamber (see Fig. 2 in the main manuscript).
Due to the significant difference in viscosity between the solutions of the organic linker precursor (2.6 cP) and the metal ion precursor (0.891 cP), Re for each solution was calculated at the inlet, and the reported Re is the sum of the Re's for each stream.

Here is a representative calculation of Re for a two-syringe system operating at 20 ml/min which corresponds to $Re = 3170$:

The velocities of both organic linker and metal ion solutions at the inlet have the same value $V = Q/A = 20$ cm^3/min/0.009503 cm^2 = 0.35075 m/s.

Re for the metal ion solution is then calculated as:
$Re = 997$ kg/m^3 x 0.35075 m/s x 0.006 m/0.00089 kg/m.s = 2358.

Re for the organic linker solution is then calculated as:
$Re = 1003$ kg/m^3 x 0.35075 m/s x 0.006/0.0026 kg/m.s = 811.7.

The total reported is then Re = 2358 + 811.7 = 3170.

Here is a table for the full calculations:

Two-Syringe System			
Flow rate (ml/min)	*Re* Metal Solution	*Re* Organic Solution	*Re* Total
6	707	244	951
20	2358	812	3170
59	6950	2395	9345

Four-Syringe System			
Flow rate (ml/min)	*Re* Metal Solution	*Re* Organic Solution	*Re* Total
0.625	147.34	50.74	198
10	2353	810	3163
20	4705	1624	6329
30	7057	2430	9487
40	9410	3241	12651
50	11762	4051	15813
60	14142	4870	19012

2 X-Ray Diffraction Profiles, Scanning Electron Microscopy, and Particle Size Distributions

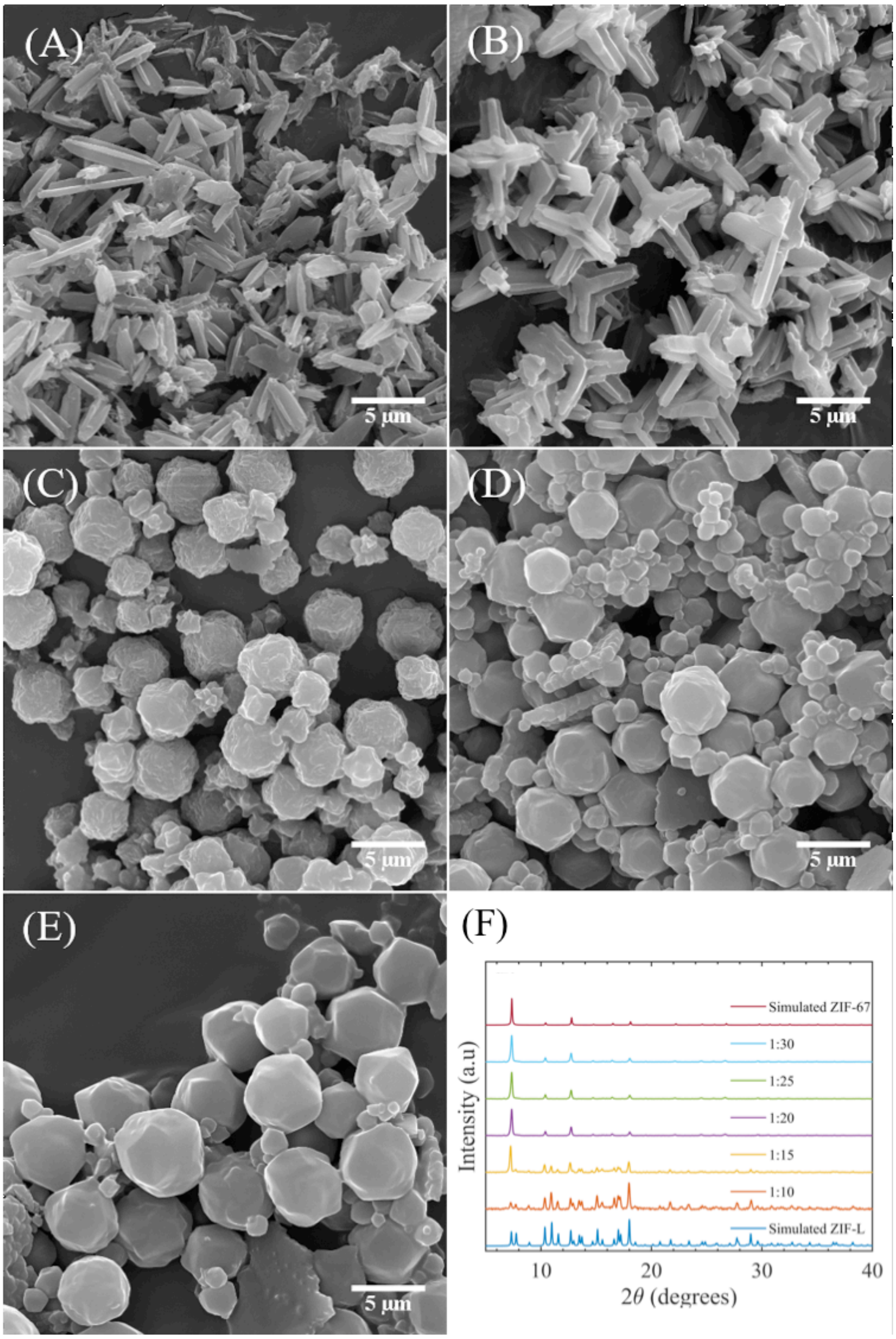

Fig. S1: SEM images of ZIF samples at different Co:Hmim ratios: (A) 1:10, (B) 1:15, (C) 1:20,(D) 1:25, and (E) 1:30. And (F) PXRD comparison between as synthesized ZIF samples at different Zn:Hmim ratios and the simulated ZIF-67 and ZIF-L.

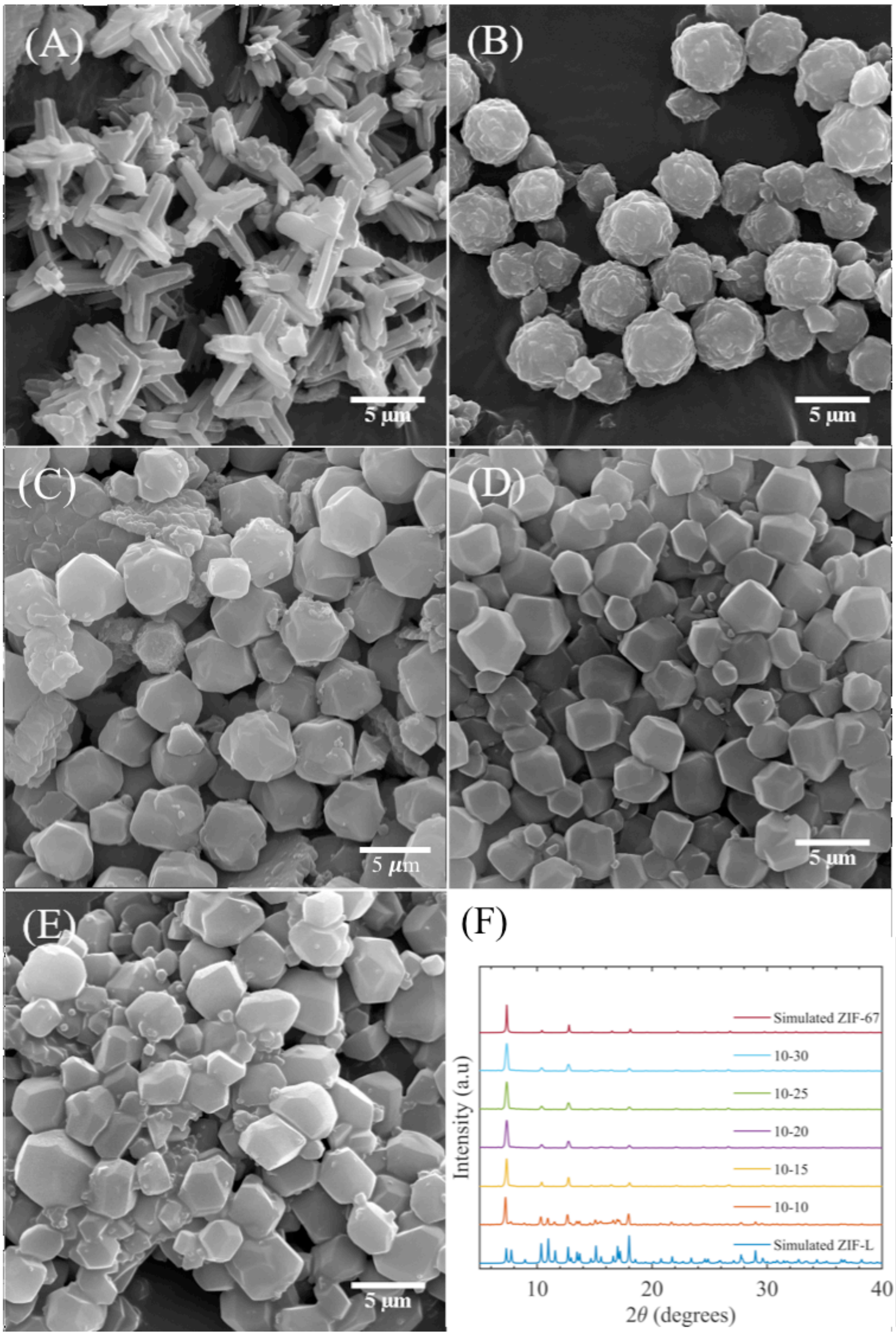

Fig. S2: SEM images of ZIF samples at different Co-Hmim flow rates: (A) 10-10 mL/min, (B) 10-15 mL/min, (C) 10-20 mL/min, (D) 10-25 mL/min, and (E) 10-30 mL/min. And (F) PXRD comparison between as synthesized ZIF samples at different Co-Hmim flow rates and the simulated ZIF-67 and ZIF-L.

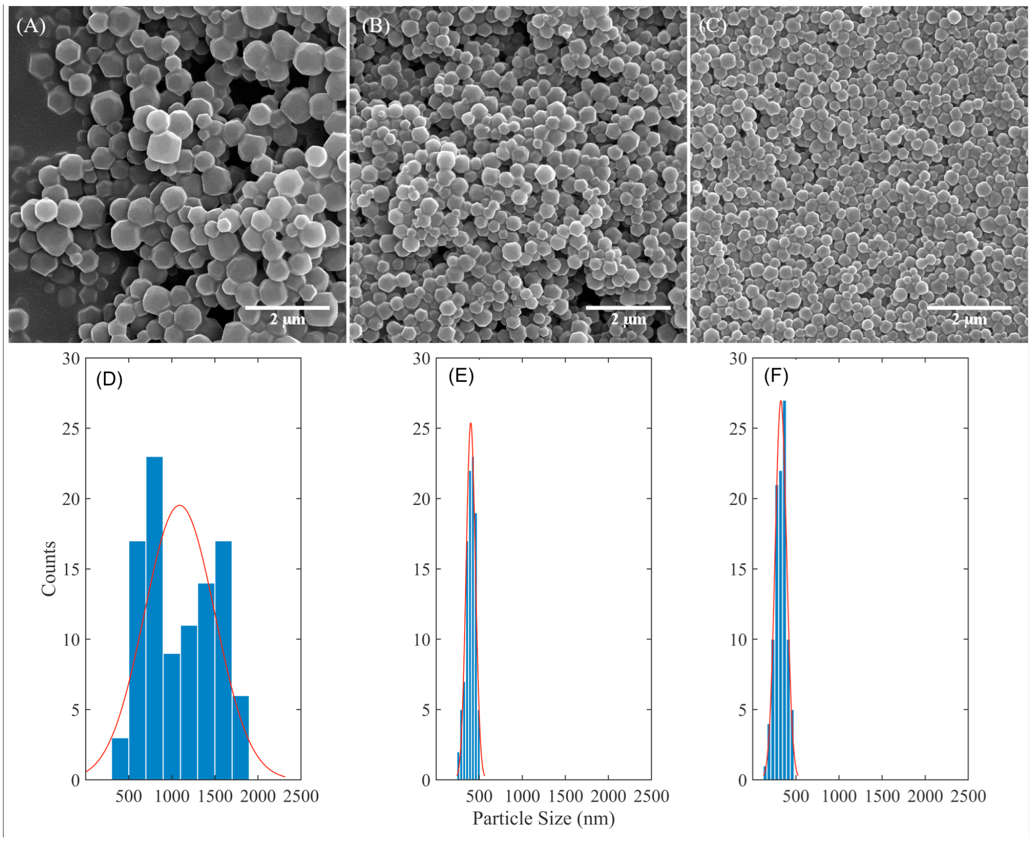

Fig. S3: SEM images of as synthesized ZIF-67 at (A) Re = 951, (B) Re = 3170, and (C) Re = 9345 showing the decrease in particle size. And the normal distribution of particle size showing a standard deviation of (D) 406 nm at Re = 951, (E) 53 nm at Re = 3170, and (F) 65 nm at Re = 9345.

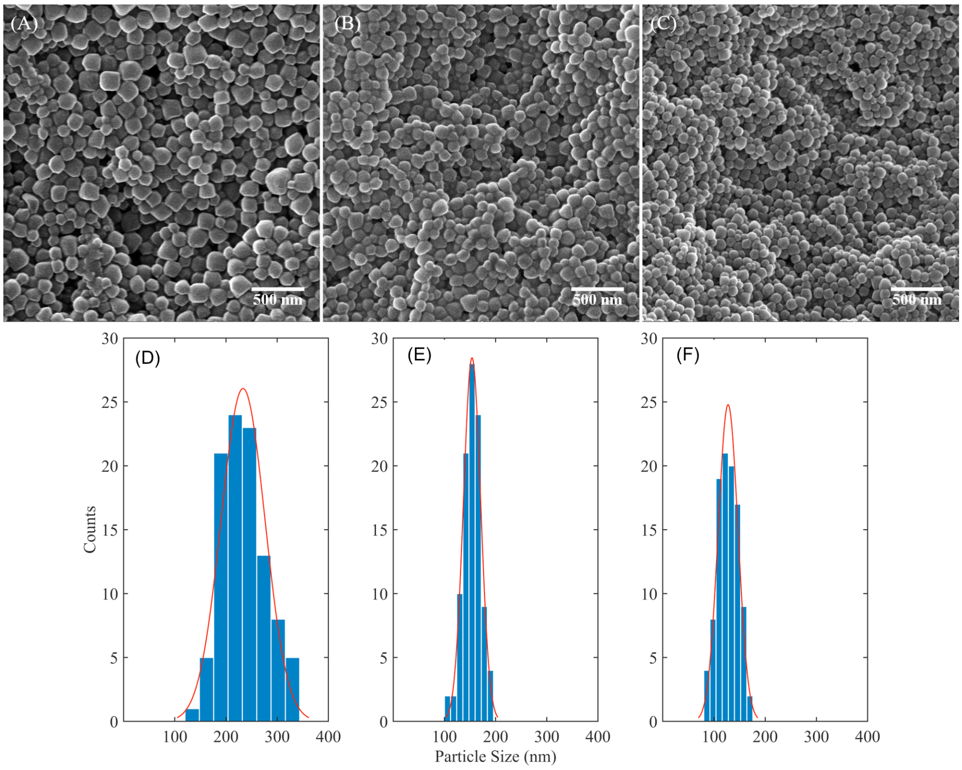

Fig. S4: SEM images of as synthesized Zn:Co 75:25 ZIF samples at (A) Re = 951, (B) Re = 3170, and (C) Re = 9345. And the normal distribution of particle size showing a standard deviation of (D) 36 nm, (E) 16 nm , and (F) 18 nm, respectively.

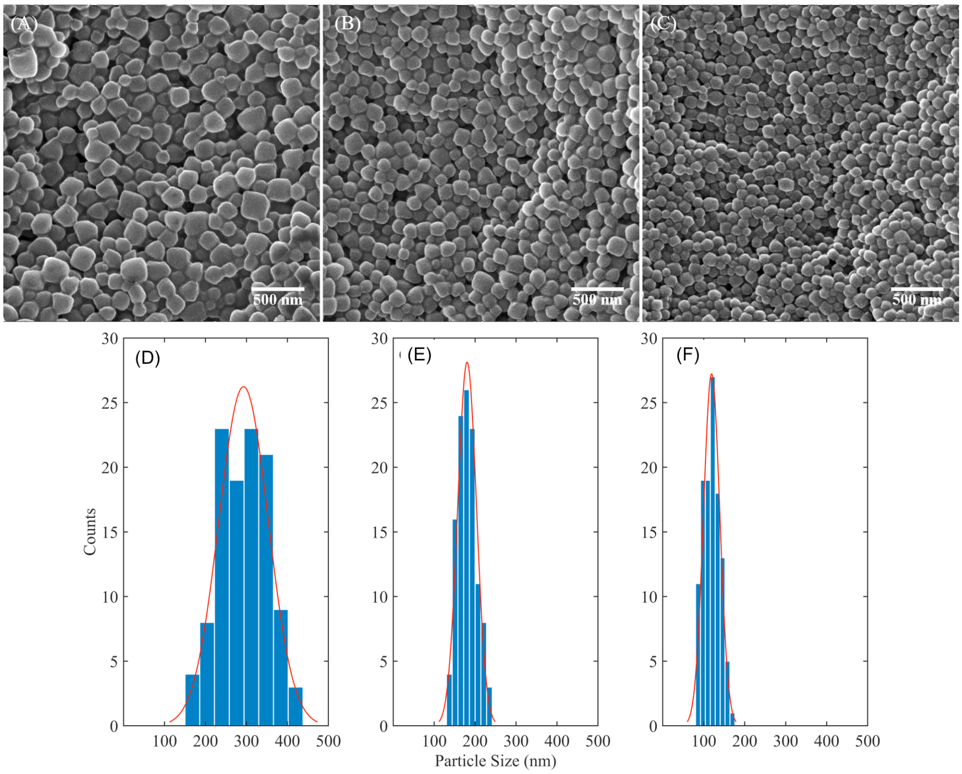

Fig. S5: SEM images of as synthesized Zn:Co 50:50 ZIF samples at (A) Re = 951, (B) Re = 3170, and (C) Re = 9345. And the normal distribution of particle size showing a standard deviation of (D) 57 nm, (E) 21 nm, and (F) 18 nm, respectively.

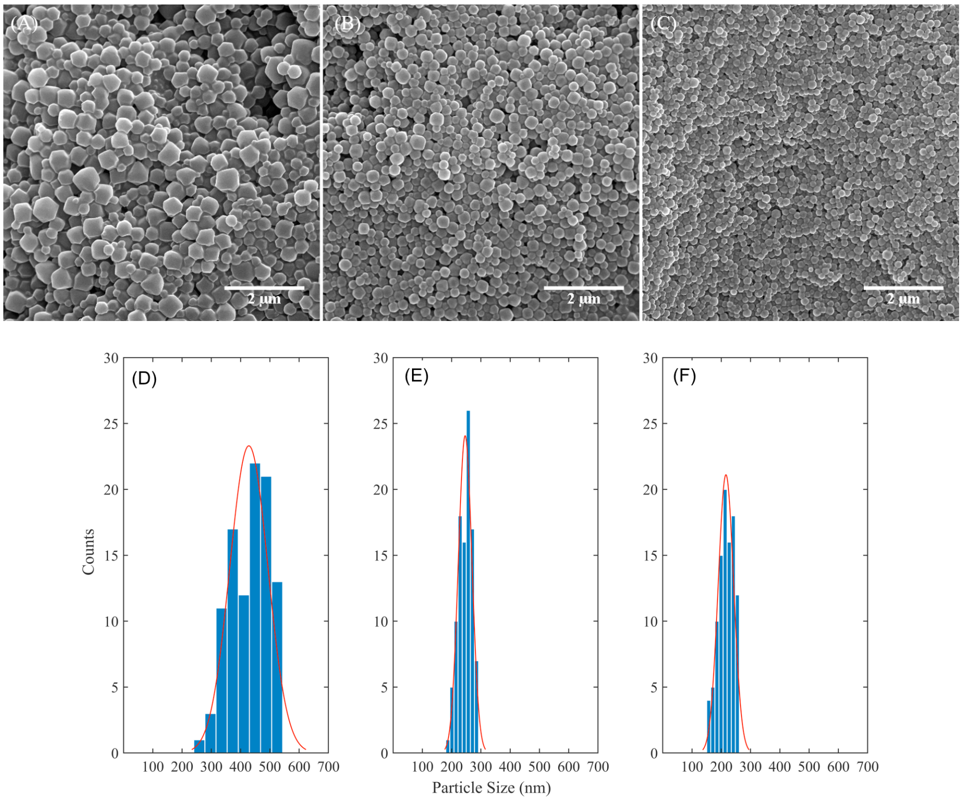

Fig. S6: SEM images of as synthesized Zn:Co 25:75 ZIF samples at (A) $Re = 951$, (B) $Re = 3170$, and (C) $Re = 9345$. And the normal distribution of particle size showing a standard deviation of (D) 60 nm, (E) 28 nm, and (F) 28 nm, respectively.

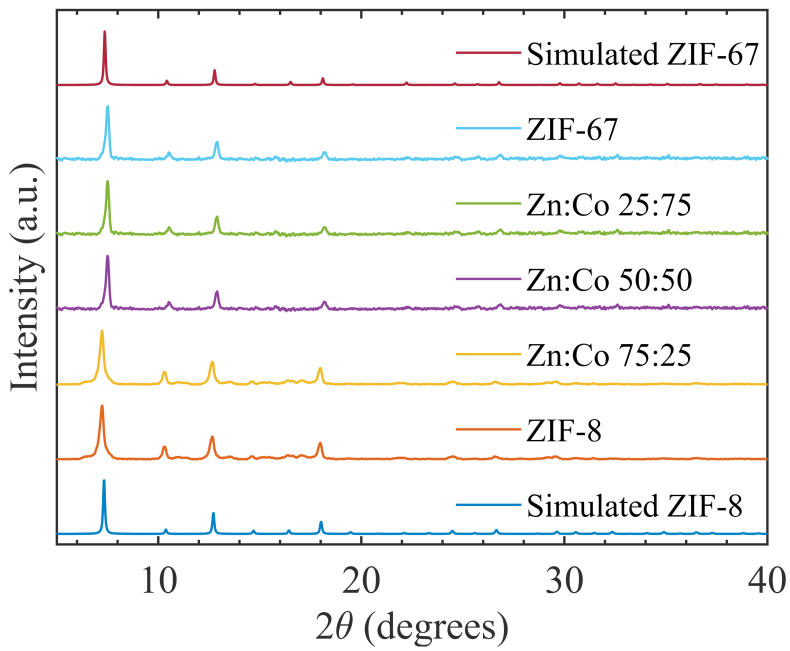

Fig. S7: PXRD comparison of the synthesized ZIF samples and the simulated ZIF-8 and ZIF-67, and their mixed metal derivatives at initial Zn:Co ratios of 75:25, 50:50, and 25:75.

3 Thermogravimetric Analysis

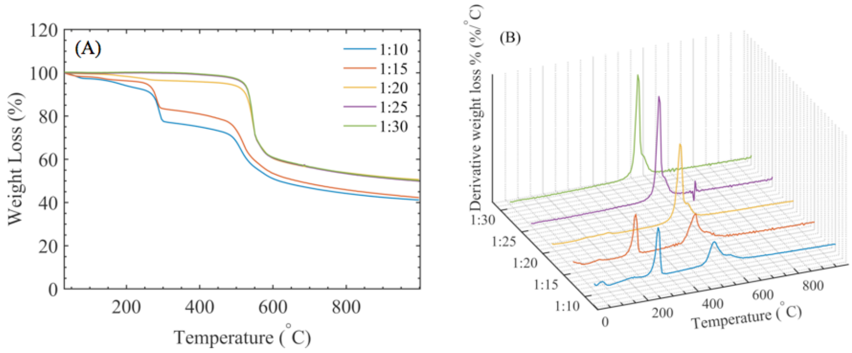

Fig. S8: (A) Thermogravimetric curves of ZIF-67 samples at different Co:Hmim ratios, and (B) first derivative of the weight loss as a function of temperature for the thermogravimetric curves of ZIF samples.

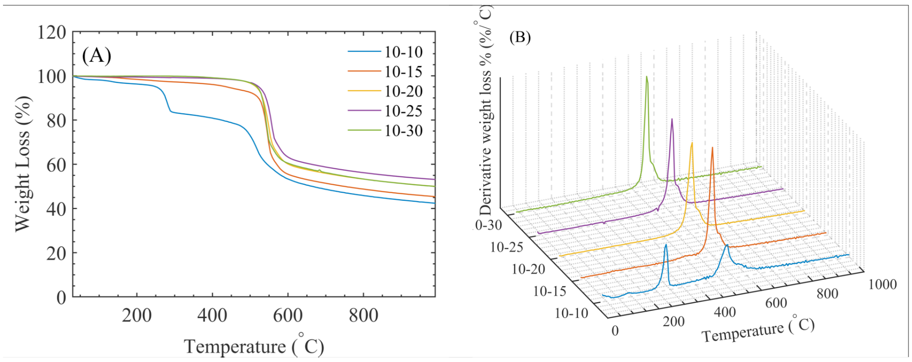

Fig. S9: (A) Thermogravimetric curves of ZIF samples at different Co-Hmim flow rates (mL/min), and (B) and their first derivatives.

4 Nitrogen Adsorption-Desorption Isotherms

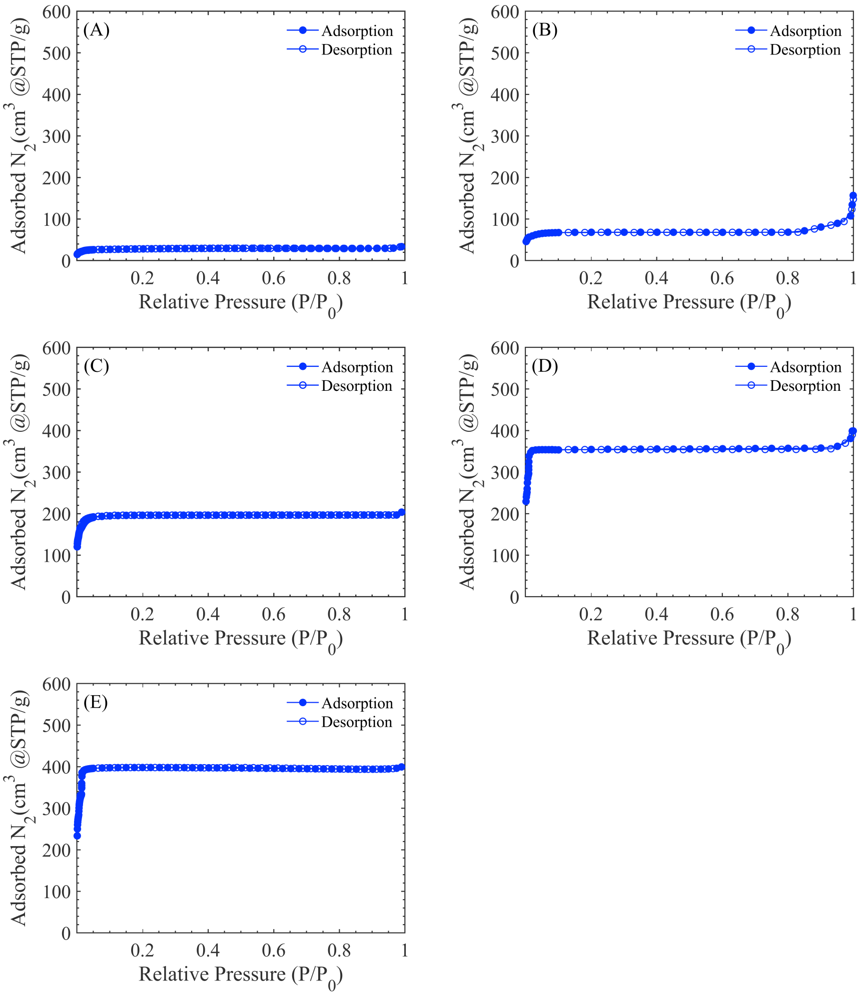

Fig. S10: Nitrogen adsorption and desorption isotherms at 77 K for the ZIF samples at different Zn-Hmim flow rates: (A) 10-10 mL/min, (B) 10-15 mL/min, (C) 10-25 mL/min, (D) 10-25 mL/min, and (E) 10-30 mL/min.

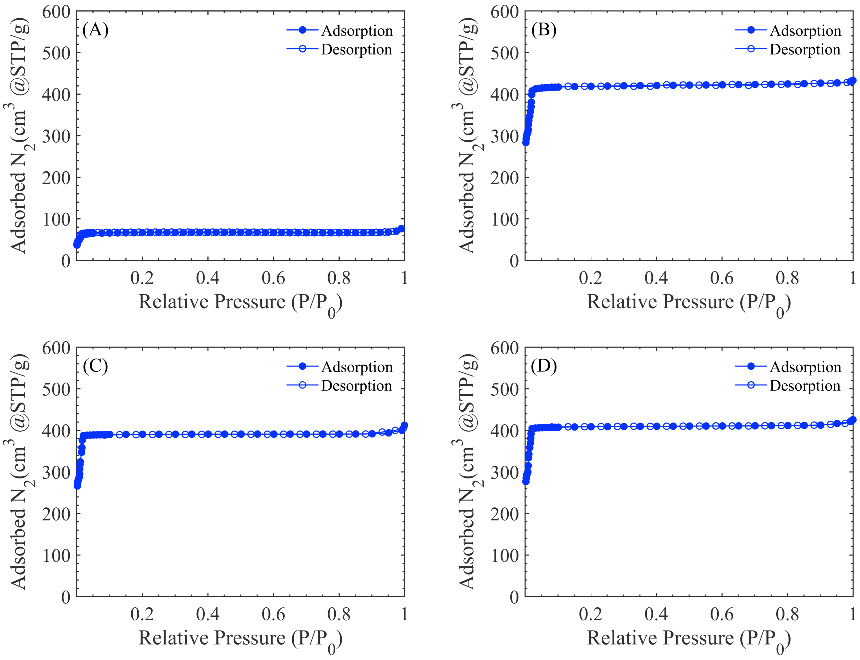

Fig. S11: Nitrogen adsorption and desorption isotherms at 77 K for the ZIF samples at different Co-Hmim flow rates: (A) 10-10 mL/min, (B) 10-15 mL/min, (C) 10-20 mL/min, and (D) 10-25 mL/min.

5 Uv-vis Spectra

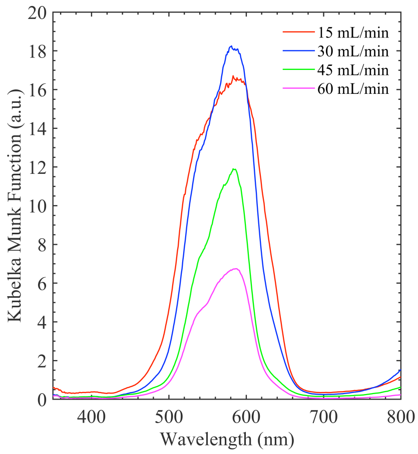

Fig. S12: Visible diffuse reflectance of the ZIF samples as function of the second pump flow rate (mL/min) that contains the (Co^{2+}) solution.

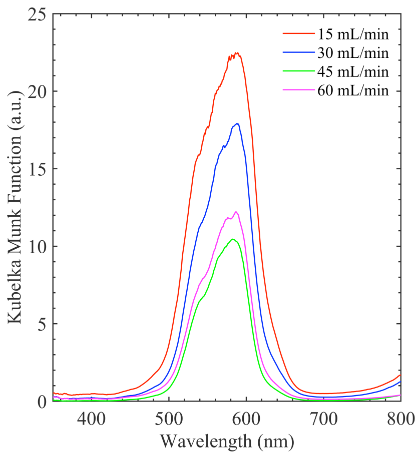

Fig. S13: Visible diffuse reflectance of the ZIF samples as function of the second pump flow rate (mL/min) that contains the (Zn^{2+}) solution.

Co-Hmim flow rate (mL/min)	Specific BET surface area (m^2/g)	Micropore volume (cm^3/g)
10-10	279	0.097
10-15	1335	0.63
10-20	1242	0.60
10-25	1300	0.62

Table S1: Specific BET surface area, micropore volume and micropore area for the as synthesized ZIF-67 samples at different Metal-Hmim flow rates.

Synthesis	Conditions	Particle Size	S_{BET}(m^2/g)
Solvothermal	+TEA, 120 °C, 24 h	96-985 nm	1340
Microwave	120 °C, 30 min	190-350 nm	1075
Microwave	+F127 surf.,120 °C, 30 min	34-59 nm	1600
Microwave	+P123 surf.,120 °C, 30 min	68-104 nm	1020
Mechanochemical	+NH_4NO_3, 45 min, 25 Hz	amorphous	1256
Dry-gel conversion	120 °C, 24 h	agglomerates	1470
Microfluidic	T-mixer, 25 °C	300 nm-900 nm	1700
Microfluidic (ZIF-67)	MIVM, 25 °C	agglomerates	8.49
Microfluidic (This work)	MIVM (2- & 4- syringe), 25 °C	75 nm-1100 nm	1710

Table S2: Various synthetic methods to prepare ZIF-8/67 in water.