Supplementary Information

Precise *Klebsiella Pneumoniae* Carbapenem Resistance Prediction by Zn-Cu/MOFs-Embedded Hybrid Nanosheet-Assisted Carbapenemase Activity Analysis

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MALDI-TOF MS analysis

Mass spectra were acquired using an UltrafleXtreme MALDI-TOF/TOF MS (Bruker Daltonic, USA) which was operated by an improved Nd:YAG laser with a detection frequency of 1000 Hz. The analysis mode was set to reflective-positive mode with a laser intensity of 70%, a cumulative laser count of 2,000, and a mass-to-charge ratio detection range of 100 to 1,000 Da. MALDI-TOF MS data were collected from Flexcontrol 3.4 and processed in Flexanalysis 3.4.

Characterization

Deionized water was got through using Milli-Q IQ 7000. Scanning electron microscopy (SEM) was characterized by Keol 2012 microscope. Transmission electron microscopy (TEM) was characterized by JEOL 1011 microscopy (Japan). Fourier transform infrared spectra (FT-IR) was characterized by Thermo Fisher Scientific 10 infrared spectrometer analysis.

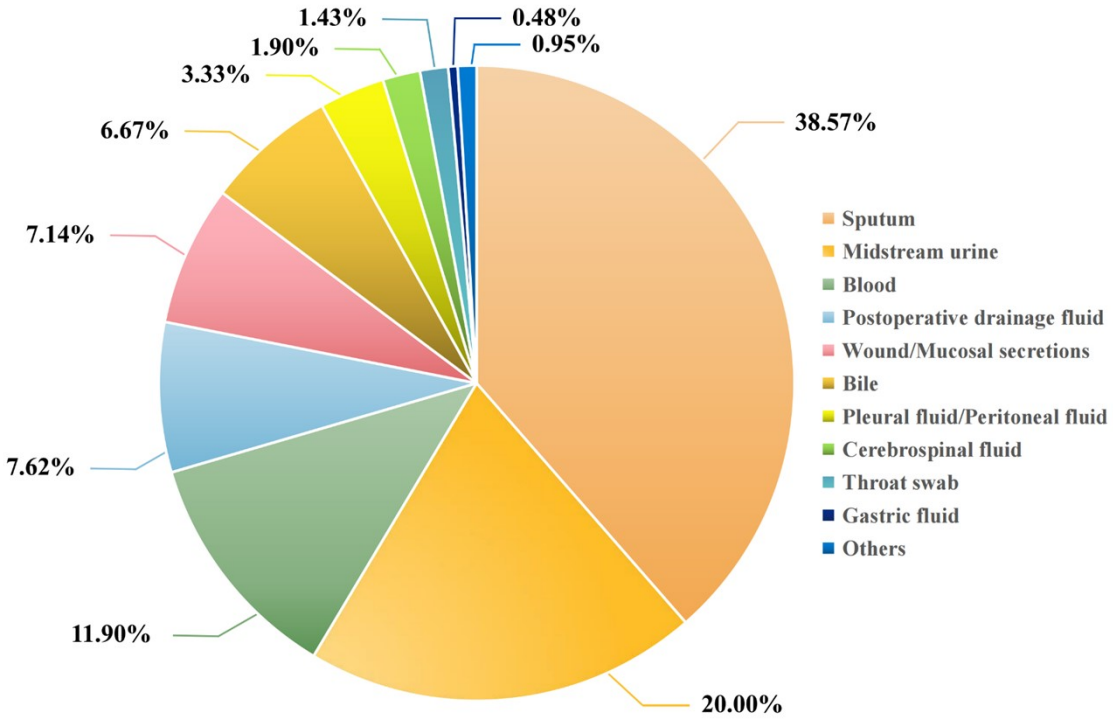

Fig. S1. Distribution of *K. pneumoniae* isolates across different clinical specimen types.

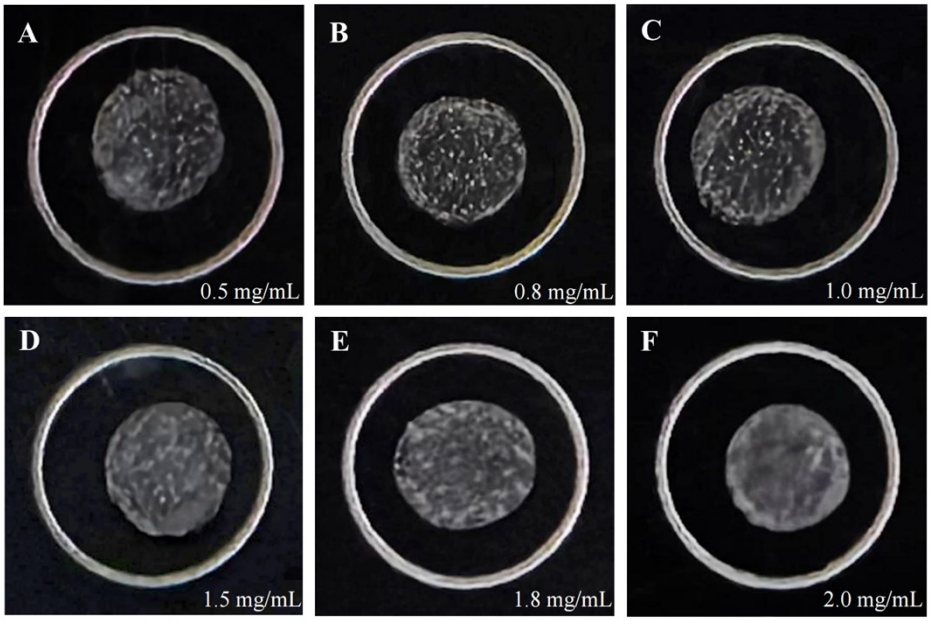

Fig. S2. Dispersion behavior of GNP@Zn-Cu/MOF@Au at different concentrations. (A) 0.5 mg/mL; (B) 0.8 mg/mL; (C) 1.0 mg/mL; (D) 1.5 mg/mL; (E) 1.8 mg/mL; (5) 2.0 mg/mL.

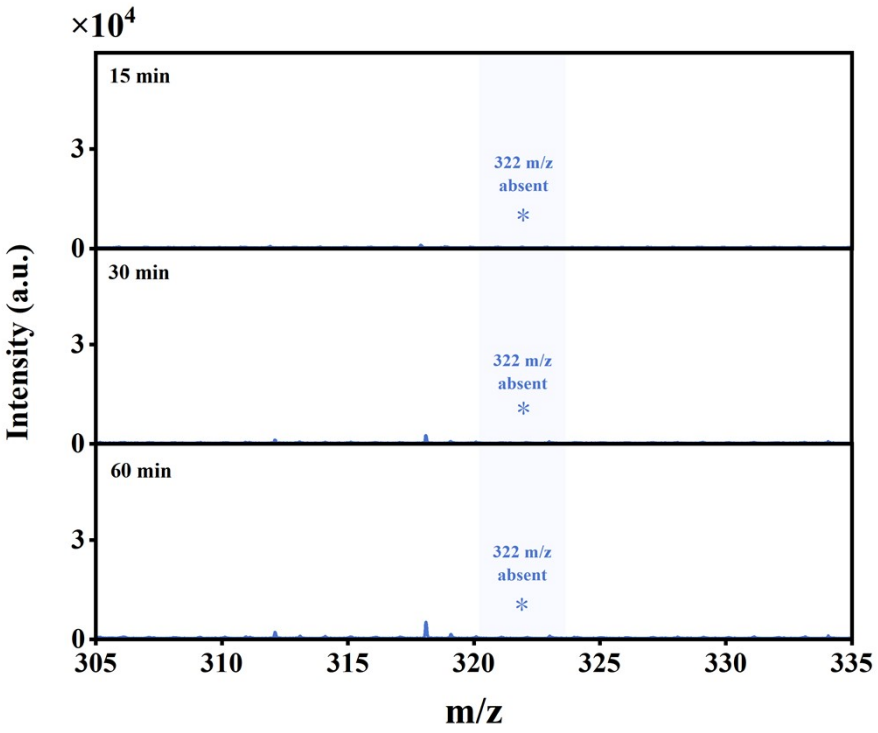

Fig. S3. Representative mass spectra of KPC-2–producing *K. pneumoniae* strains (n = 71) from imipenem hydrolysis assays at different incubation times (15 min, 30 min, and 1 h). In all strains, the [Imipenem + Na]$^+$ peak at 322 m/z disappeared completely after 15 min.

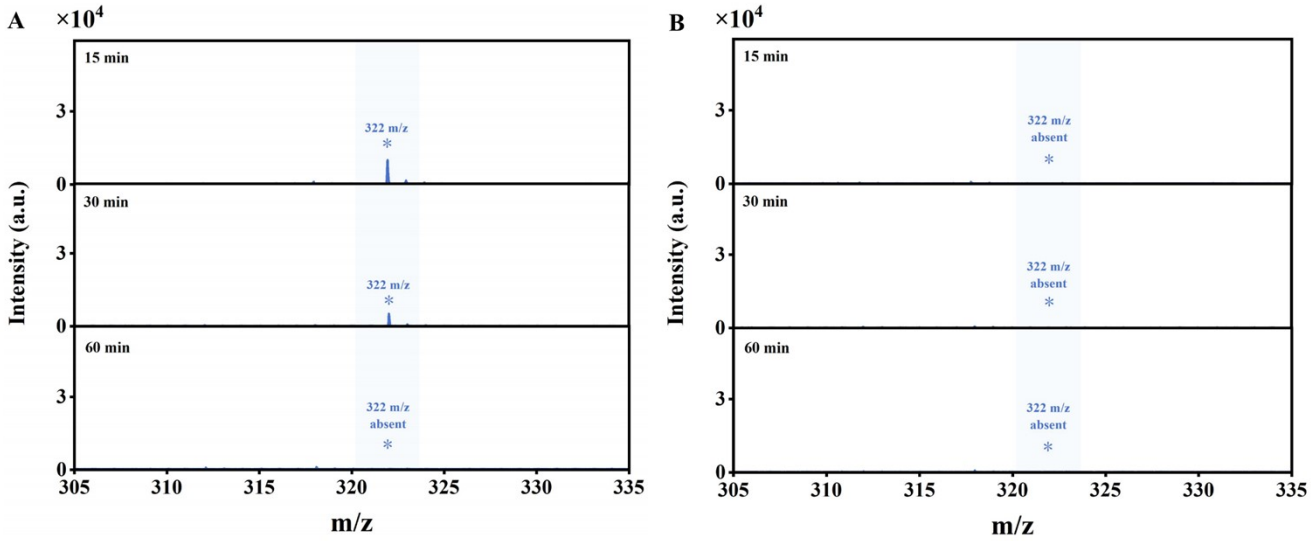

Fig. S4. Representative mass spectra of NDM-1–producing *K. pneumoniae* strains (n = 20) from imipenem hydrolysis assays at different incubation times (15 min, 30 min, and 1 h). (A) In one strain, the [Imipenem + Na]$^+$ peak at 322 m/z persisted at 15 and 30 min but disappeared by 60 min. (B) In the remaining 19 strains, the 322 m/z peak disappeared completely after 15 min.

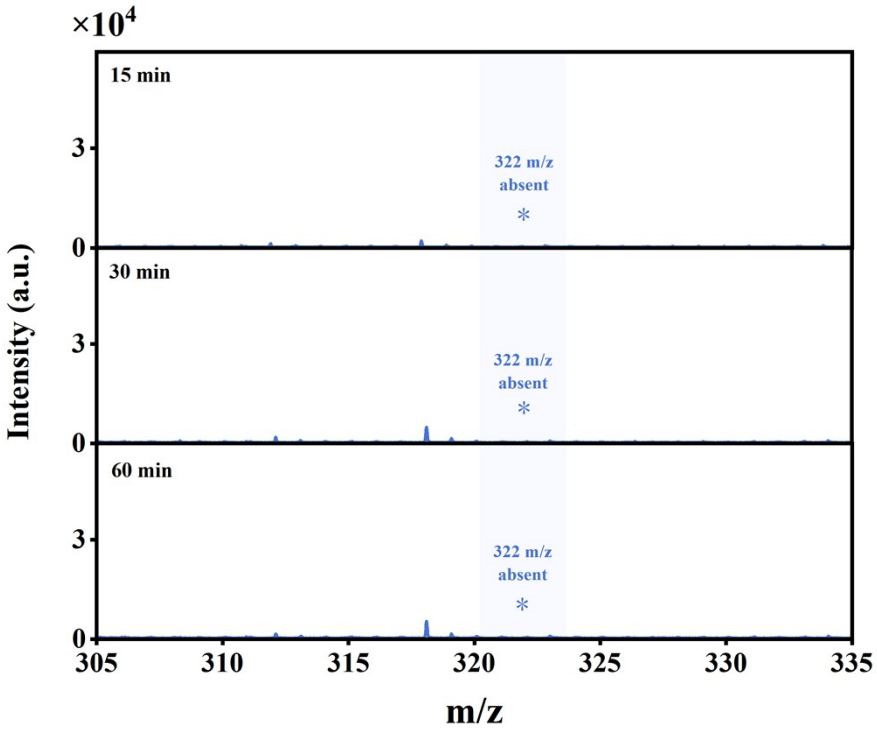

Fig. S5. Representative mass spectra of IMP-1–producing *K. pneumoniae* strains (n = 12) from imipenem hydrolysis assays at different incubation times (15 min, 30 min, and 1 h). In all strains, the [Imipenem + $Na]^+$ peak at 322 m/z disappeared completely after 15 min.

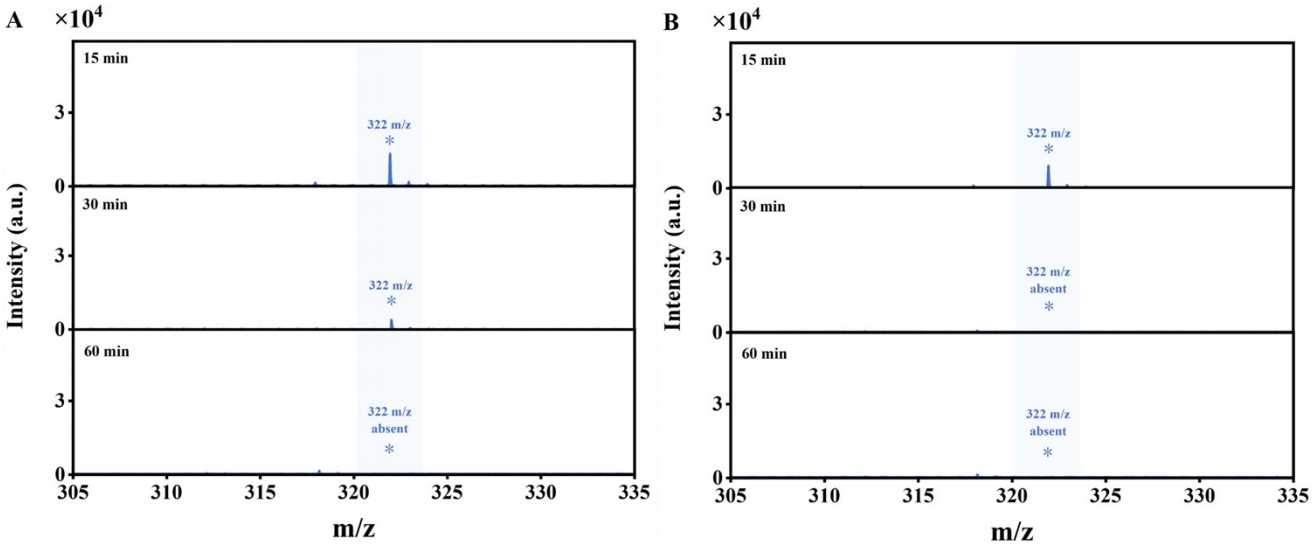

Fig. S6. Representative mass spectra of OXA-48–producing *K. pneumoniae* strains (n = 2) from imipenem hydrolysis assays at different incubation times (15 min, 30 min, and 1 h). (A) In one strain, the [Imipenem + Na]$^+$ peak at 322 m/z persisted at 15 and 30 min but disappeared after 60 min. (B) In the other strain, the 322 m/z peak was still detectable at 15 min but disappeared completely after 30 min.

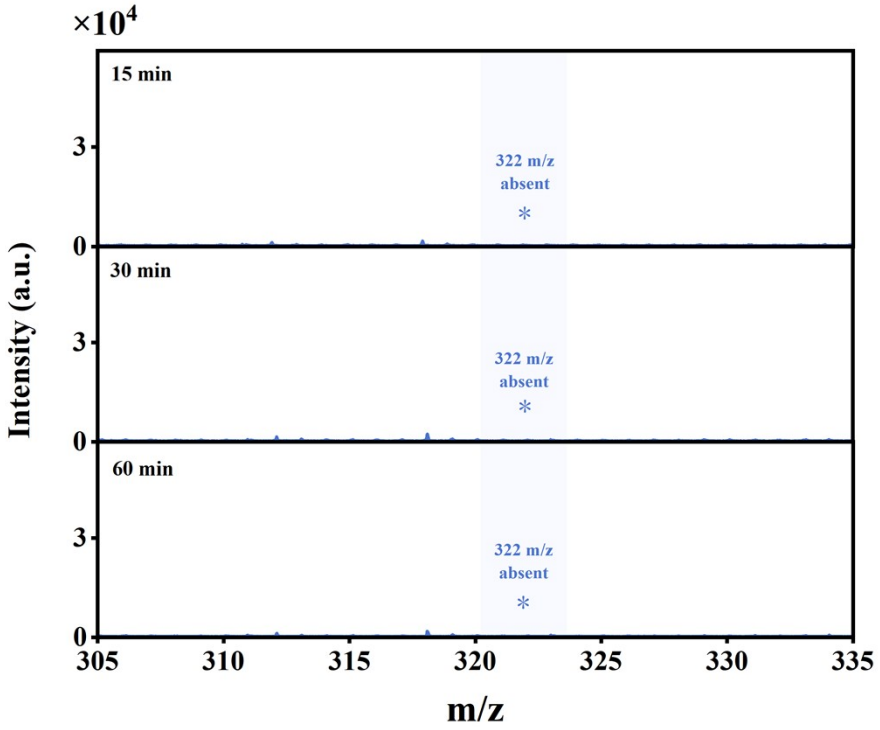

Fig. S7. Representative mass spectra of KPC-3–producing *K. pneumoniae* strains (n = 2) from imipenem hydrolysis assays at different incubation times (15 min, 30 min, and 1 h). In both strains, the [Imipenem + Na]$^+$ peak at 322 m/z disappeared completely after 15 min.

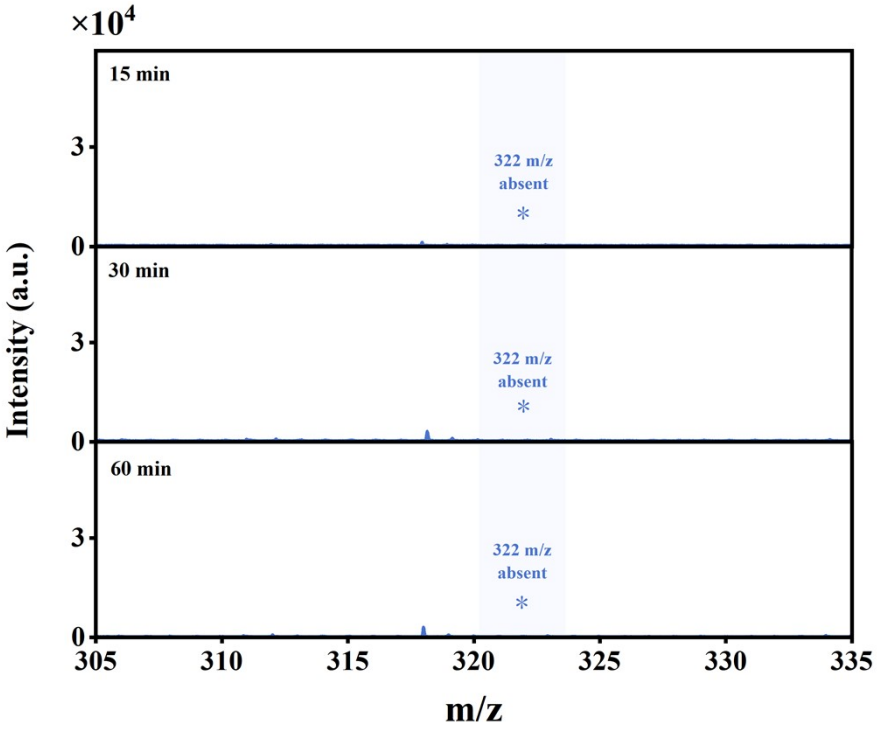

Fig. S8. Representative mass spectra of *K. pneumoniae* strains co-producing KPC-2 and IMP-1 (n = 2) from imipenem hydrolysis assays at different incubation times (15 min, 30 min, and 1 h). In both strains, the [Imipenem + Na]$^+$ peak at 322 m/z disappeared completely after 15 min.

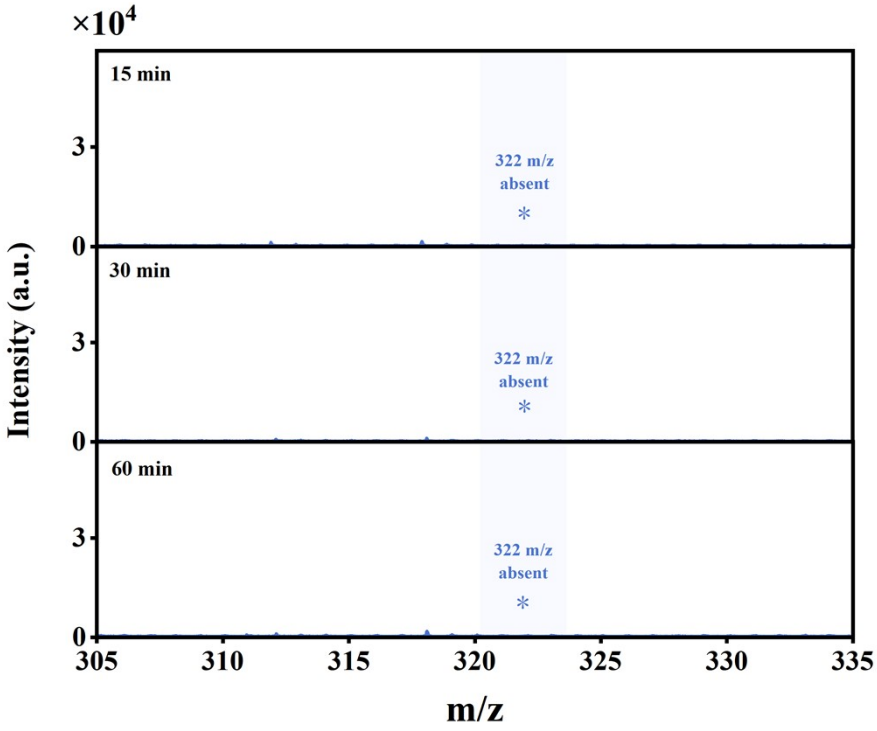

Fig. S9. Representative mass spectra of an IMP-4–producing *K. pneumoniae* strain (n = 1) from imipenem hydrolysis assays at different incubation times (15 min, 30 min, and 1 h). The [Imipenem + Na]$^+$ peak at 322 m/z disappeared completely after 15 min.

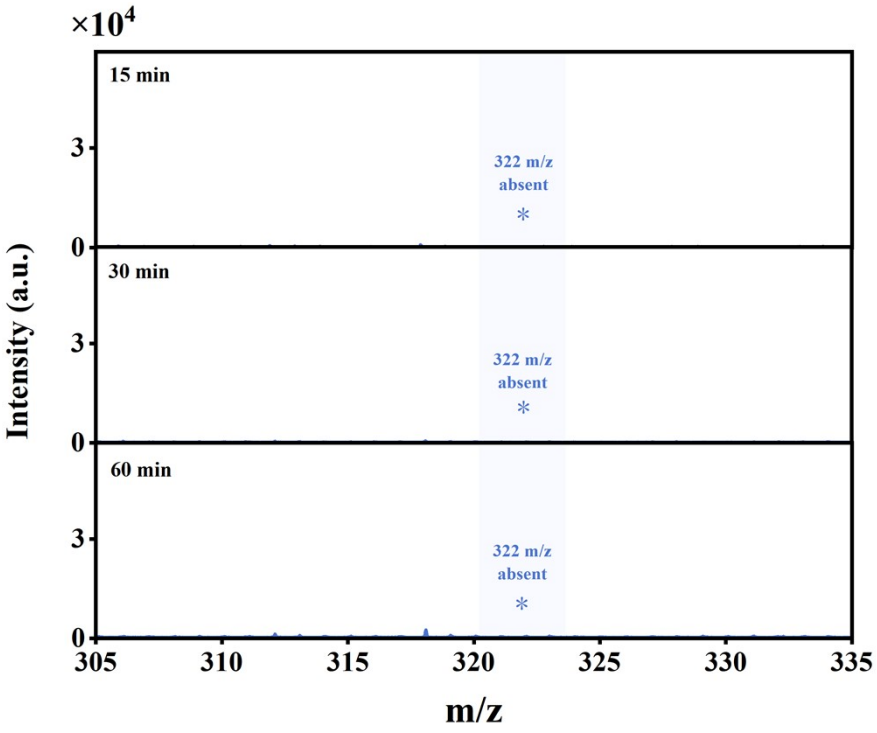

Fig. S10. Representative mass spectra of the *K. pneumoniae* strain co-producing KPC-2 and NDM-1 (n = 1) from imipenem hydrolysis assays at different incubation times (15 min, 30 min, and 1 h). The [Imipenem + Na]$^+$ peak at 322 m/z disappeared completely after 15 min of incubation.

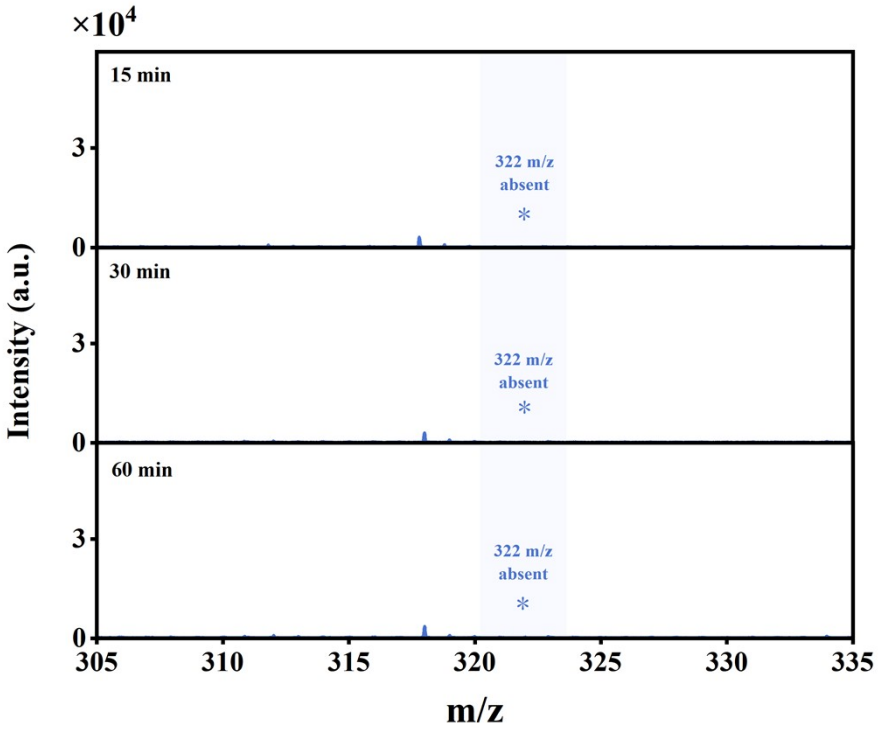

Fig. S11. Representative mass spectra of the *K. pneumoniae* strain co-producing KPC-2 and IMP-4 (n = 1) from imipenem hydrolysis assays at different incubation times (15 min, 30 min, and 1 h). The [Imipenem + Na]$^+$ peak at 322 m/z disappeared completely after 15 min of incubation.