Supplementary Information

Hirshfeld analysis, anticancer efficacy and molecular docking studies for ferrocenecarboxaldehyde oxime and ferrocene-based aldimine

Jamal Lasri*[a], Naser E Eltayeb[a,b], Saied M Soliman[c], Ehab M M Ali[d,e], Ahmed M Adam[d] & Bandar A Babgi[f]

[a] Department of Chemistry, Rabigh College of Science and Arts, King Abdulaziz University, Jeddah 21589, Saudi Arabia

[b] Department of Chemistry, Faculty of Pure and Applied Sciences, International University of Africa, Khartoum 2469, Sudan

[c] Department of Chemistry, Faculty of Science, Alexandria University, Ibrahimia, Alexandria 21321, Egypt

[d] Department of Biochemistry, Faculty of Science, King Abdulaziz University, Jeddah 21589, Saudi Arabia

[e] Division of Biochemistry, Department of Chemistry, Faculty of Science, Tanta University, Tanta 31527, Egypt

[f] Department of Chemistry, Faculty of Science, King Abdulaziz University, Jeddah 21589, Saudi Arabia

E-mail: jlasri@kau.edu.sa

Received 24 March 2025; accepted (revised) 6 April 2026

Method S1.

Fig. S1. ^{1}H, ^{13}C and DEPT-135 NMR spectra of aldoxime **1** in $CDCl_3$.

Fig. S2. ^{1}H and ^{13}C NMR spectra of aldimine **2** in $CDCl_3$.

Fig. S3. ESI-MS spectrum of aldoxime **1**.

Fig. S4. ESI-MS spectrum of aldimine **2**.

Fig. S5. Shape index and curvedness maps for aldoxime **1**.

Fig. S6. Shape index and curvedness maps for aldimine **2**.

Reference. Reference 1.

Method S1.

Reagents and solvents were obtained from commercial sources and used as received. ^{1}H, ^{13}C and DEPT-135 NMR spectra (in $CDCl_3$) were measured on Bruker Avance III HD 600 MHz (Ascend^{TM} Magnet) spectrometer at room temperature. ^{1}H, ^{13}C and DEPT-135 chemical shifts (δ) are expressed in ppm relative to TMS (Figs. S1-S2). High resolution electrospray ionization mass spectrometry (ESI-MS) spectra were recorded using an impact II mass spectrometer from Bruker. The obtained data were analyzed using Compass DataAnalysis 4.2 software; all mass spectra are reported as *m/z* (Figs. S3-S4). Compounds **1** and **2** have been previously reported by us [1]. CCDC 1812970 and 1812968 for **1** and **2**, respectively, contain the supplementary crystallographic data [1].

*Synthesis of (Z)-ferrocenecarboxaldehyde oxime **1** from ferrocenecarboxaldehyde and hydroxylamine*

To a solution of $NH_2OH.HCl$ (0.83 g, 11.97 mmol) in MeOH (10 mL) was added Na_2CO_3 (0.63 g, 5.98 mmol) and the reaction mixture was stirred for 5 min. Ferrocenecarboxaldehyde (2.33 g, 10.88 mmol) was then added and the reaction was stirred for 12 h at room temperature. The precipitate formed was then filtered off and the filtrate was evaporated *in vacuo*. To the obtained solid was added CH_2Cl_2 (10 mL) then NaCl precipitated and it was filtered off and the solvent was removed *in vacuo* to afford (*Z*)-ferrocenecarboxaldehyde oxime **1** in *ca.* 85% yield.

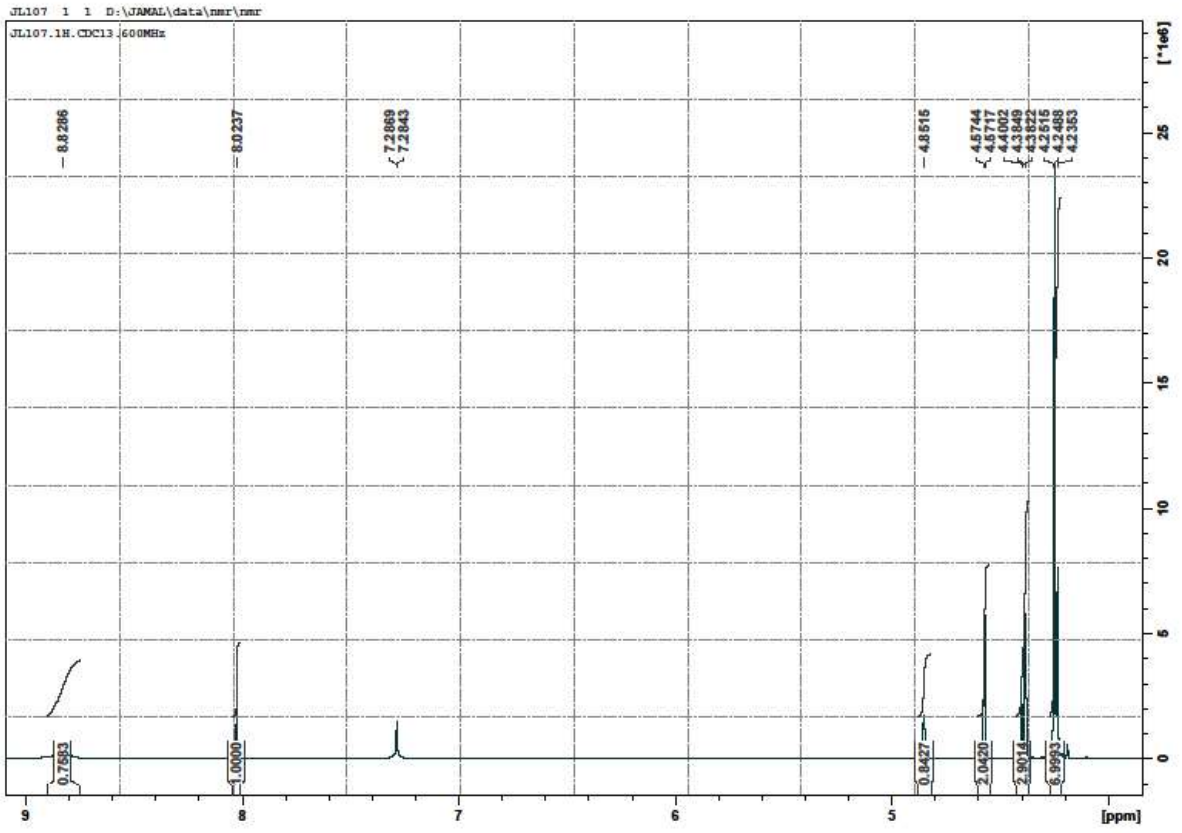
*(Z)-Ferrocenecarboxaldehyde oxime (**1**)* [1]
IR (cm^{-1}): 3195 (OH), 1630 (C=N). ^{1}H NMR ($CDCl_3$), δ: 4.25 (s, 5H, CH_{Fc}), 4.38 (s, 2H, CH_{Fc}), 4.57 (s, 2H, CH_{Fc}), 8.02 (s, 1H, C(*H*)=N). ^{13}C NMR ($CDCl_3$), δ: 67.6 (*C*H$_{Fc}$), 69.3 (*C*H$_{Fc}$), 70.1 (*C*H$_{Fc}$), 76.1 (*C*$_{Fc}$), 150.0 (*C*(H)=N). DEPT-135 NMR ($CDCl_3$), δ: 67.6 (*C*H$_{Fc}$), 69.3 (*C*H$_{Fc}$), 70.1 (*C*H$_{Fc}$), 150.0 (*C*(H)=N). Analysis calculated for $C_{11}H_{11}FeNO$: C 57.68, H 4.84, N 6.11%; found: C 57.60, H 4.89, N 6.19%. ESI^{+}-MS, *m/z*: 230.02 $[M+1]^{+}$.

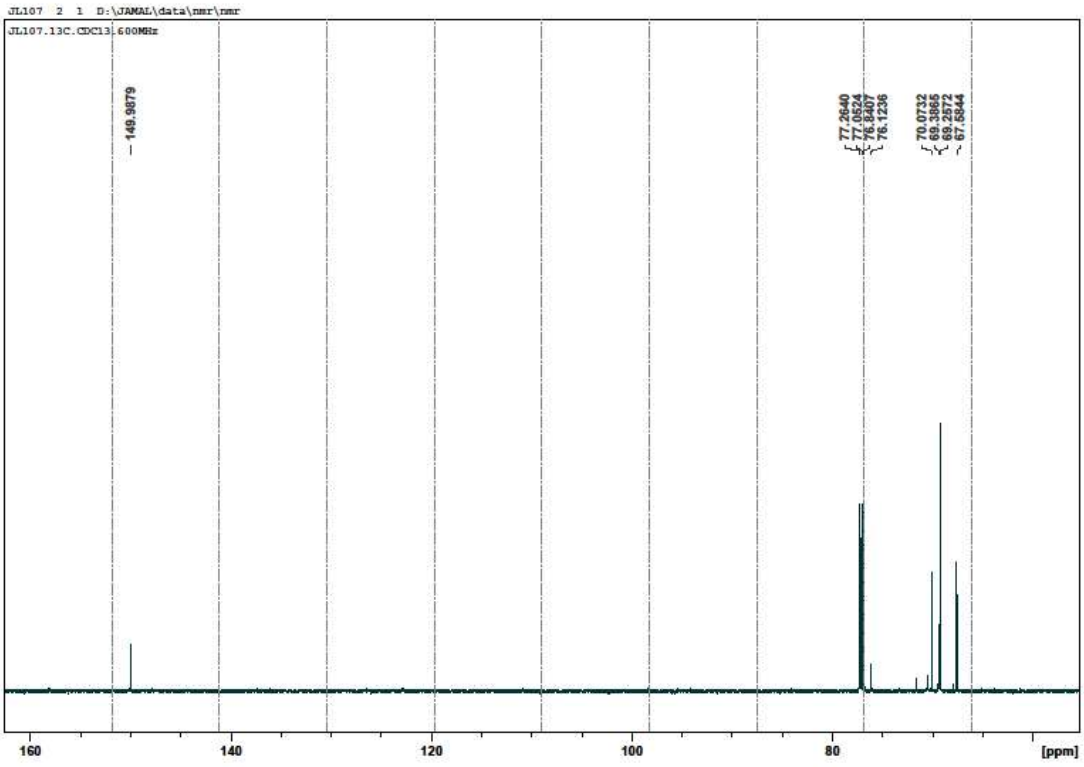
*Synthesis of (E)-ferrocene-based aldimine **2** from ferrocenecarboxaldehyde and 4-aminoantipyrine*

To a solution of ferrocenecarboxaldehyde (2.33 g, 10.88 mmol) in MeOH (10 mL) was added 4-aminoantipyrine (2.21 g, 10.88 mmol) and the reaction mixture was refluxed for 1 h. The precipitate formed was then filtered off and the filtrate was evaporated *in vacuo* to give (*E*)-ferrocene-based aldimine **2** in *ca.* 80% yield.

*(E)-4-(ferrocenylideneamino)-1,5-dimethyl-2-phenyl-1H-pyrazol-3(2H)-one (**2**)* [1]
IR (cm^{-1}): 1642 (C=N), 1598 (C=C). ^{1}H NMR ($CDCl_3$), δ: 2.42 (s, 3H, CH_3C), 3.11 (s, 3H, CH_3N), 4.23 (s, 5H, CH_{Fc}), 4.42 (s, 2H, CH_{Fc}), 4.75 (s, 2H, CH_{Fc}), 7.32 (s, 1H, CH_{ar}), 7.47 (s, 4H, CH_{ar}), 9.52 (s, 1H, C(*H*)=N). ^{13}C NMR ($CDCl_3$), δ: 10.3 (*C*H_3C), 36.2 (*C*H_3N), 68.2 (*C*H_{Fc}), 69.4 (*C*H_{Fc}), 70.6 (*C*H_{Fc}), 82.3 (C_{Fc}), 120.1 (MeC=*C*), 124.0 (*C*H_{ar}), 126.6 (*C*H_{ar}), 129.1 (*C*H_{ar}), 135.0 (C_{ar}), 150.5 (Me*C*=C), 159.8 (*C*(N)=O), 161.2 (*C*(H)=N). Analysis calculated for $C_{22}H_{21}FeN_3O$: C 66.18, H 5.30, N 10.52%; found: C 66.11, H 5.39, N 10.61%. ESI^{+}-MS, *m/z*: 400.11 $[M+1]^{+}$.

Fig. S1. ^{1}H, ^{13}C and DEPT-135 NMR spectra of aldoxime **1** in $CDCl_3$.




JL107 2 1 D:\JAMAL\data\nmr\nmr
JL107.13C.CDCl3.600MHz
149.9879
77.2640
77.0524
76.8407
76.1236
70.0732
69.3865
69.2572
67.5044
160
140
120
100
80
[ppm]

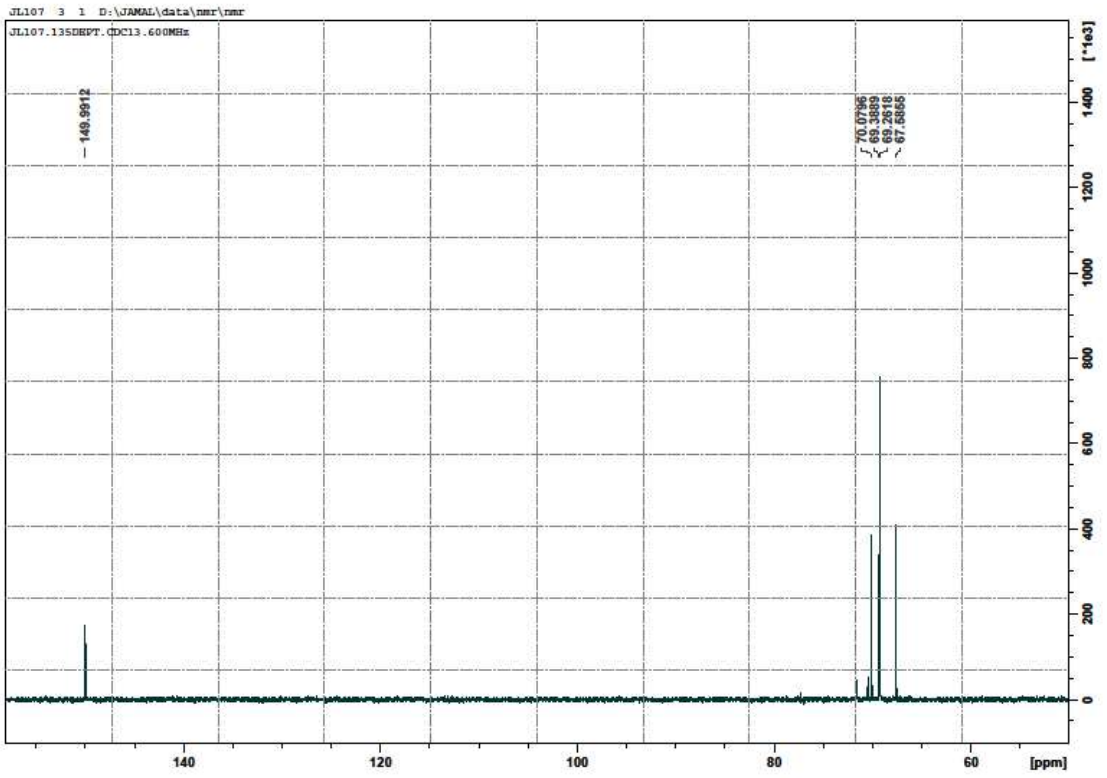
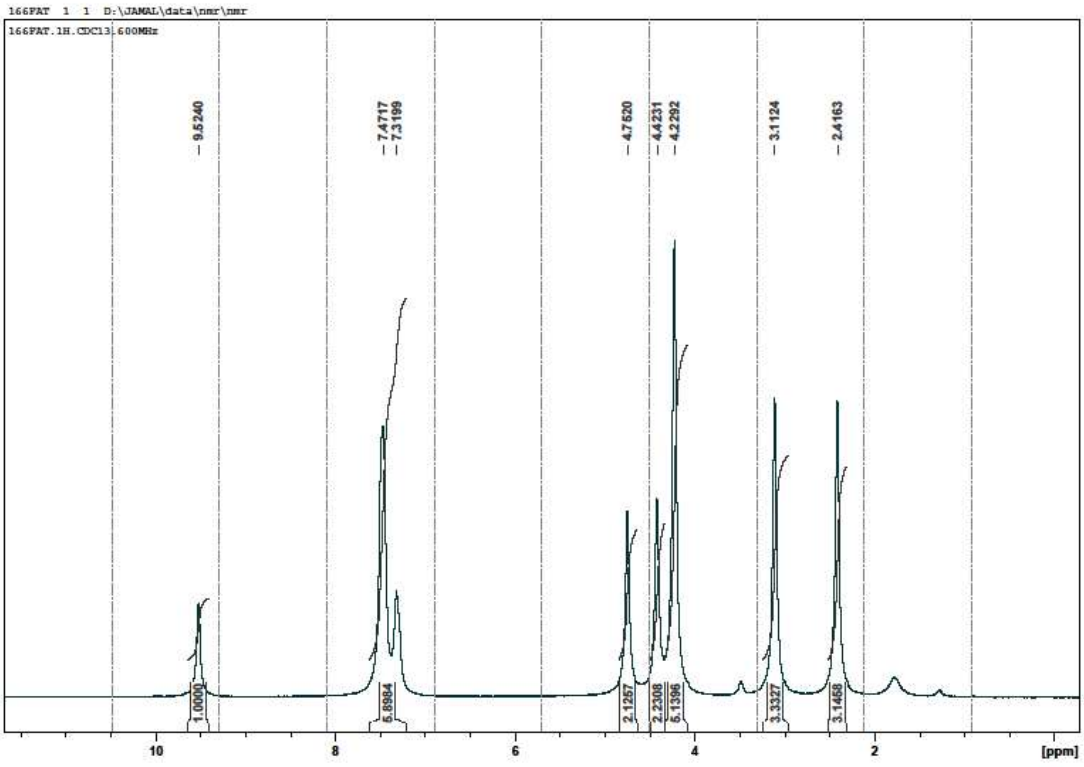


Fig. S2. ^{1}H and ^{13}C NMR spectra of aldimine **2** in $CDCl_3$.


166FAT 1 1 D:\JAMAL\data\nmr\nmr
166FAT.1H.CDCl3.600MHz
9.5240
7.4717
7.3199
4.7620
4.4231
4.2292
3.1124
2.4163
1.0000
6.8984
2.1267
2.2308
5.1396
3.3327
3.1468
10
8
6
4
2
[ppm]

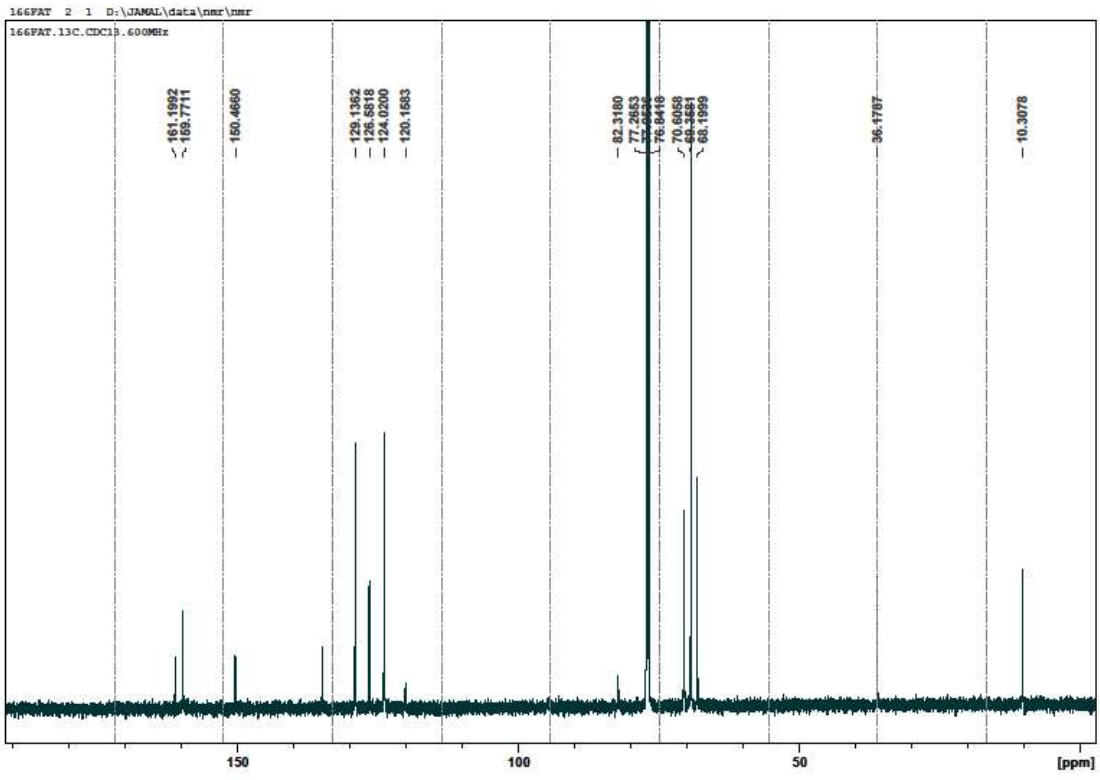

166PAT 2 1 D:\JAMAL\data\nmr\nmr
166PAT.13C.CDCl3.600MHz
161.1992
159.7711
150.4660
129.1362
126.5818
124.0200
120.1683
82.3180
77.2653
76.8416
70.6058
69.3681
68.1999
36.1787
10.3078
150
100
50
[ppm]

Fig. S3. ESI-MS spectrum of aldoxime **1**.

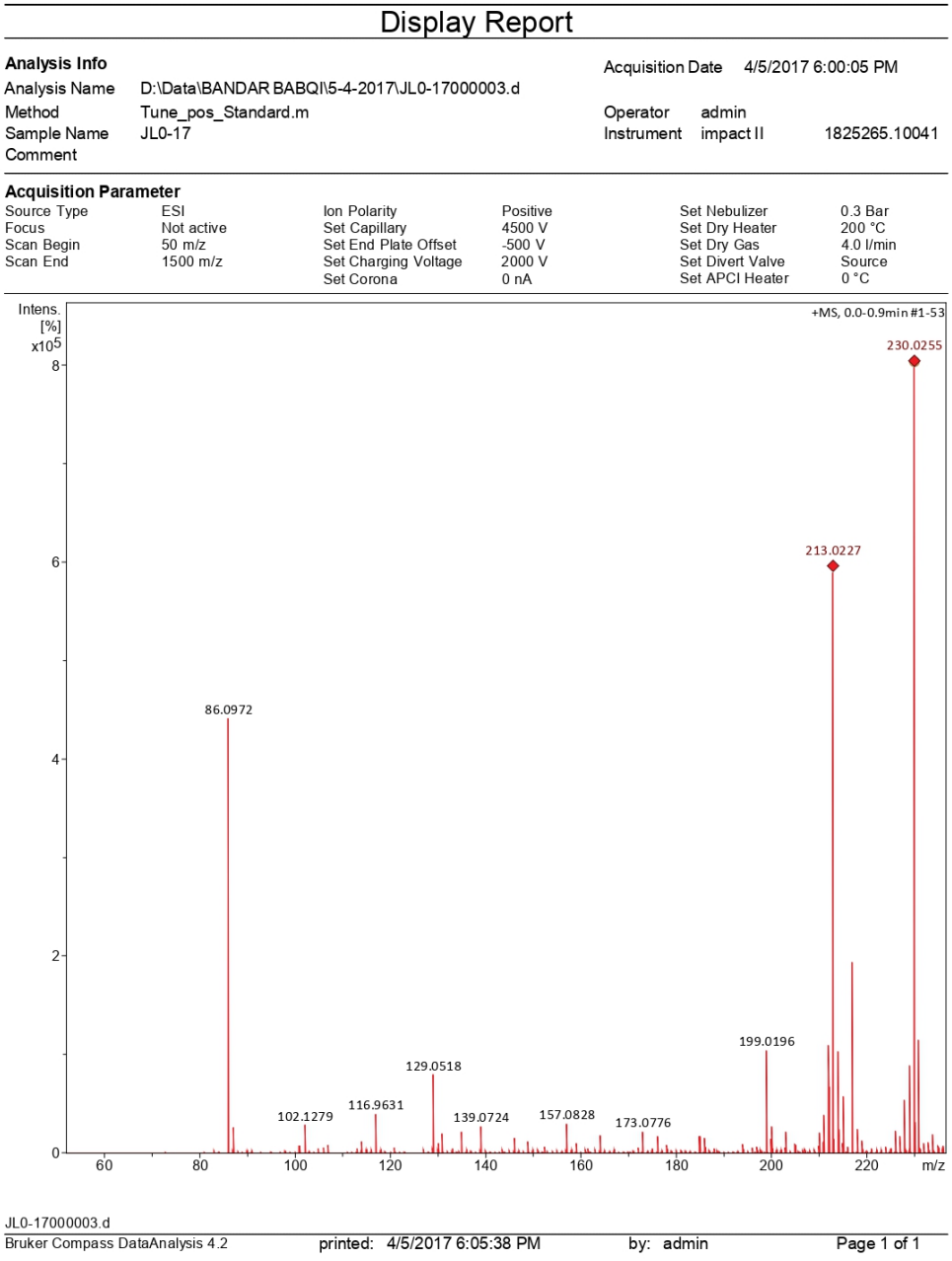


Fig. S4. ESI-MS spectrum of aldimine **2**.

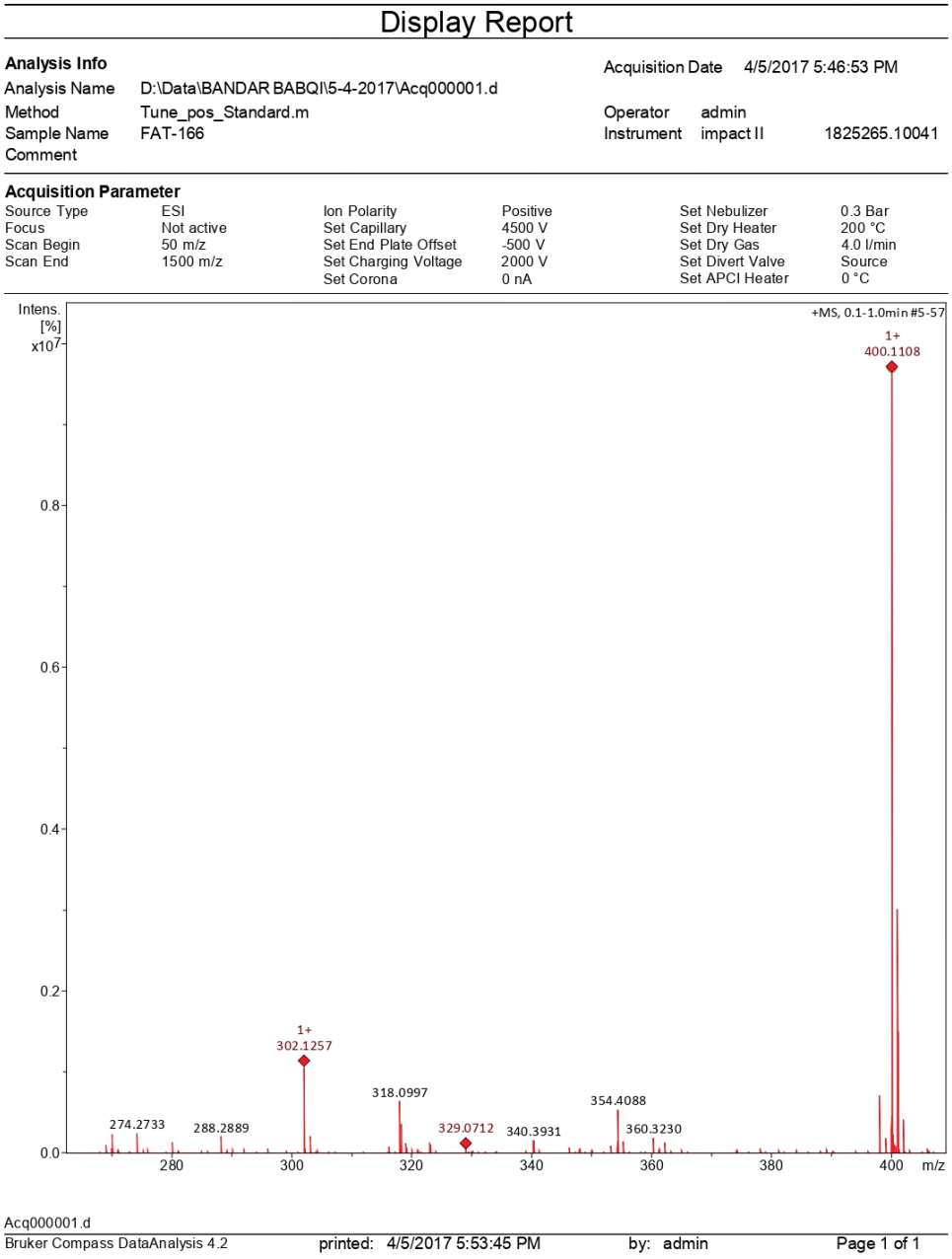


Fig. S5. Shape index and curvedness maps for aldoxime **1**.

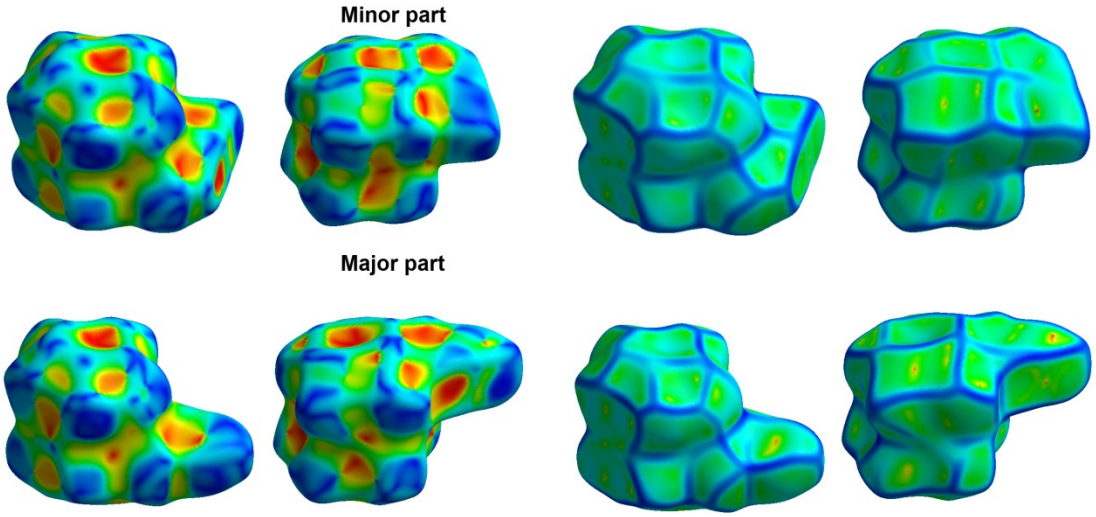
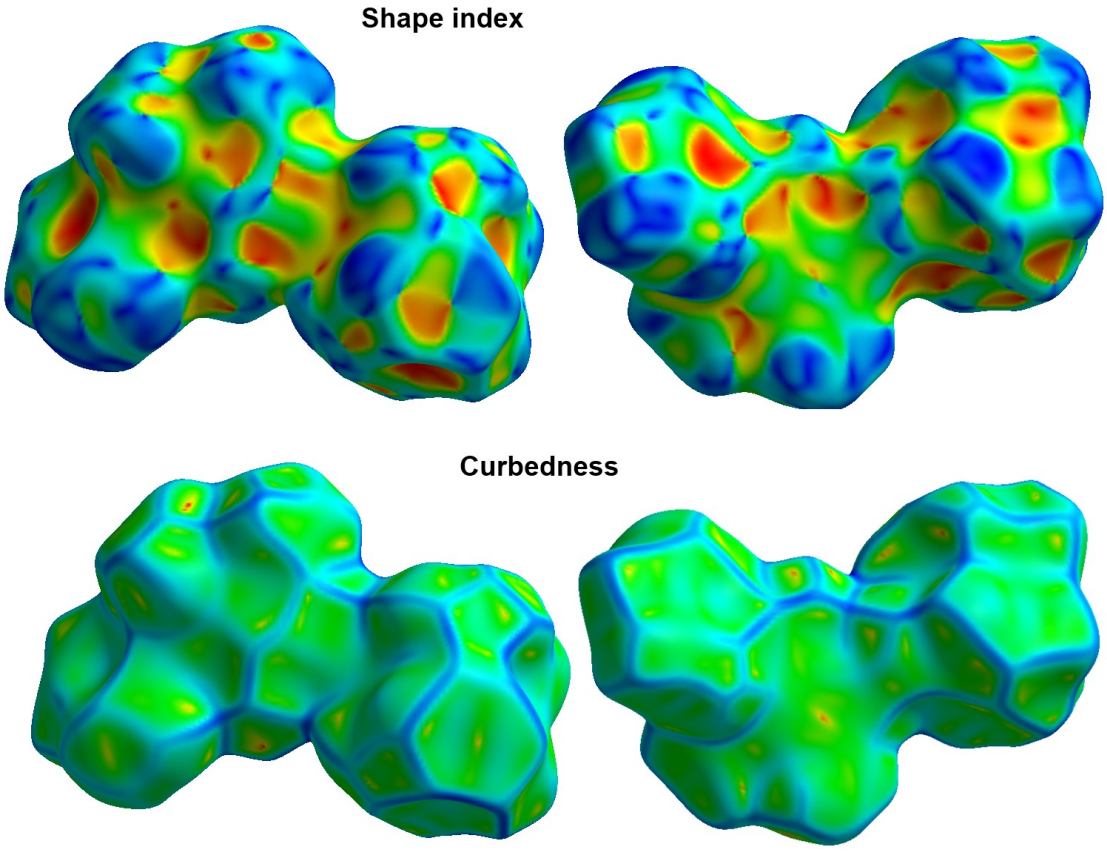


Fig. S6. Shape index and curvedness maps for aldimine **2**.



Reference

1 Lasri J, Elsherbiny A S, Eltayeb N E, Haukka M & El-Hefnawy M E, *J Organomet Chem*, 866 (2018) 21.