

Electronic Supplementary Information

Cisplatin and transplatin interaction with methionine: bonding motifs assayed by vibrational spectroscopy in the isolated ionic complexes

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Complete reference [70]

M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, B. Mennucci, G. A. Petersson, H. Nakatsuji, M. Caricato, X. Li, H. P. Hratchian, A. F. Izmaylov, J. Bloino, G. Zheng, J. L. Sonnenberg, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. Bearpark, J. J. Heyd, E. Brothers, K. N. Kudin, V. N. Staroverov, R. Kobayashi, J. Normand, K. Raghavachari, A. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, N. Rega, J. M. Millam, M. Klene, J. E. Knox, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, R. L. Martin, K. Morokuma, V. G. Zakrzewski, G. A. Voth, P. Salvador, J. J. Dannenberg, S. Dapprich, A. D. Daniels, Ö. Farkas, J. B. Foresman, J. V. Ortiz, J. Cioslowski, D. J. Fox, Gaussian 09, Revision D.01, Gaussian, Inc., Wallingford CT, 2009.

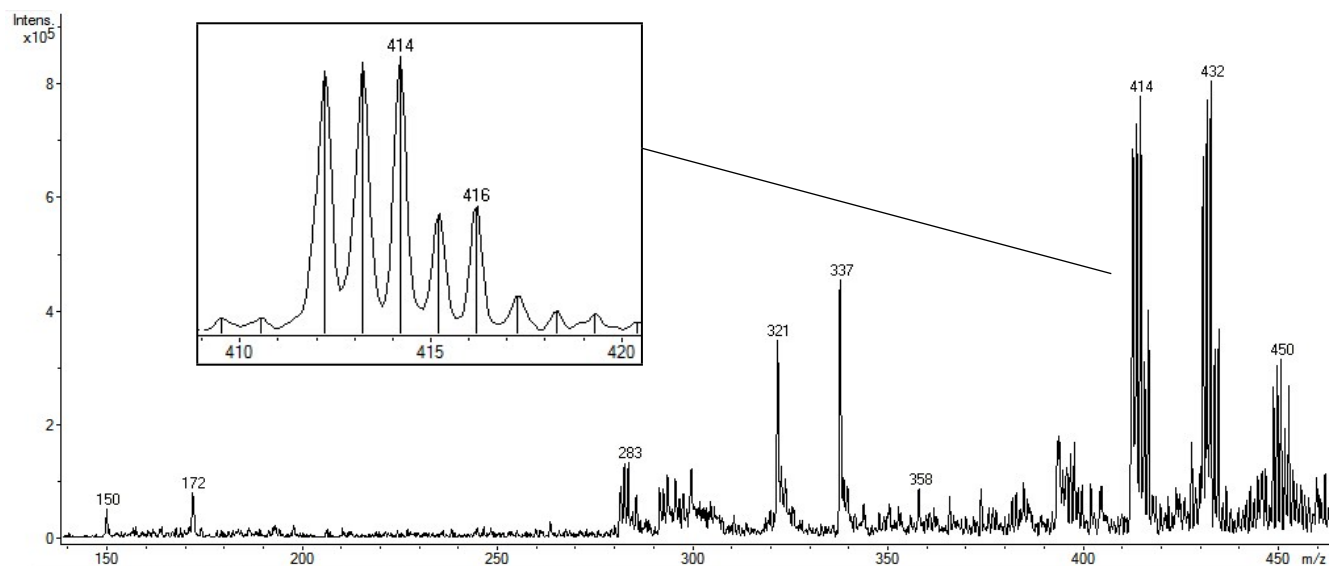


Figure S1. Mass spectrum of a solution of cisplatin and methionine (1:1) 5×10^{-5} M in methanol/water (50/50, v/v) recorded with an Esquire 6000 ion trap mass spectrometer. The species of interest, the *cis*-[PtCl(NH₃)₂Met]⁺ complex, corresponds to the cluster at *m/z* 412-416 and is highlighted in the inset. The signals at *m/z* 150, 172, 321, 337 are related to Met (e. g. *m/z* 150 is protonated Met) while other signals belong to hydrolyzed cisplatin (e. g. *m/z* 281-285 is the *cis*-[PtCl(NH₃)₂(H₂O)]⁺ complex) and other Pt complexes. The ion at *m/z* 430-434 formally corresponds to a five-ligand complex, namely [PtCl(NH₃)₂Met(H₂O)]⁺.

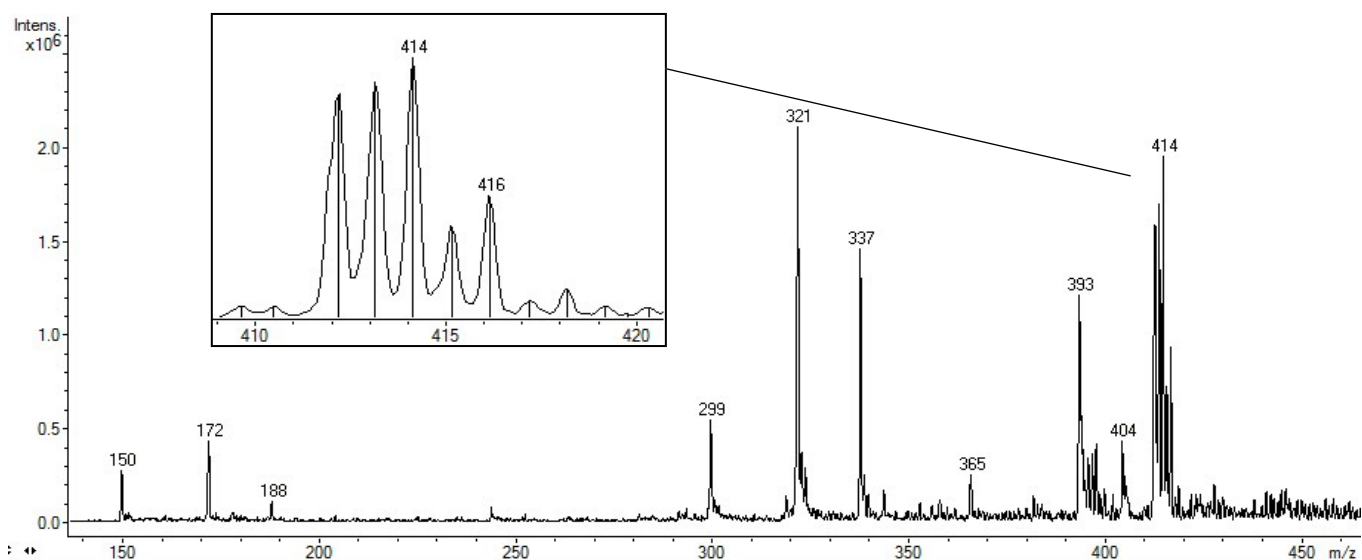


Figure S2. Mass spectrum of a solution of transplatin and methionine (1:1) 5×10^{-5} M in methanol/water (50/50, v/v) recorded with an Esquire 6000 ion trap mass spectrometer. The species of interest, the *trans*-[PtCl(NH₃)₂Met]⁺ complex, corresponds to the cluster at *m/z* 412-416 and is highlighted in the inset. The signals at *m/z* 150, 172, 188, 321, 337 are related to Met (e. g. *m/z* 150 is protonated Met).

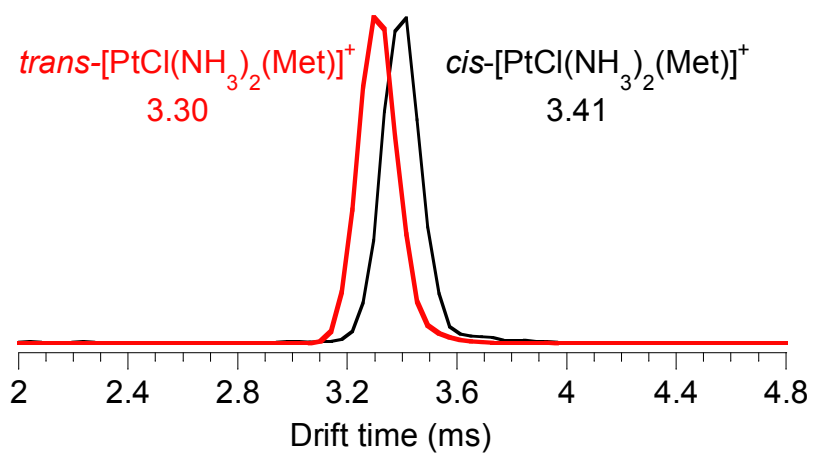


Figure S3. Mobility profile of *cis*- (black profile) and *trans*- (red profile) [PtCl(NH₃)₂(Met)]⁺. The arrival time of the two species is reported in the figure.

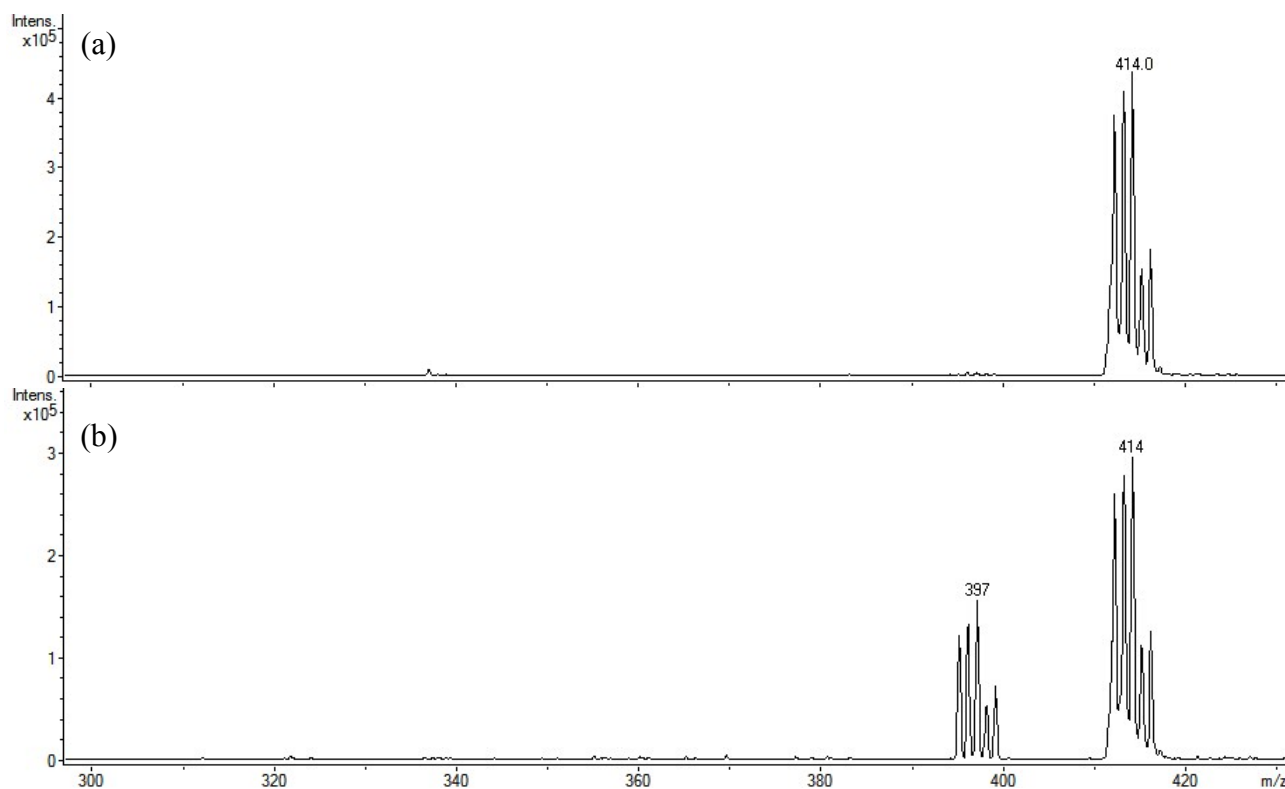


Figure S4. Mass spectra recorded upon selection of *cis*-[PtCl(NH₃)₂(Met)]⁺ (*m/z* 412-416), in a Paul ion trap mass spectrometer (Bruker, Esquire 6000), before (a) and after (b) irradiation at 3570 cm⁻¹. The photofragmentation product by loss of NH₃ is observed at *m/z* 395-399.

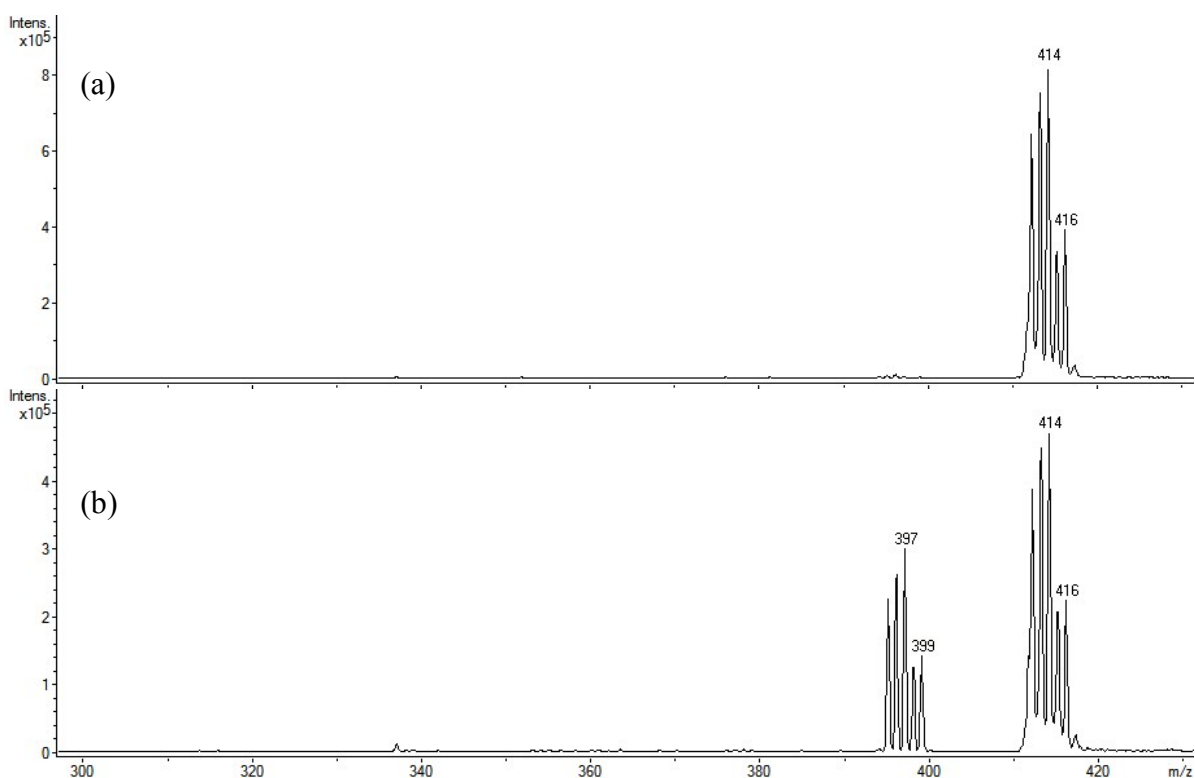


Figure S5. Mass spectra recorded upon selection of *trans*-[PtCl(NH₃)₂(Met)]⁺ (*m/z* 412-416), in a Paul ion trap mass spectrometer (Bruker, Esquire 6000), before (a) and after (b) irradiation at 3570 cm⁻¹. The photofragmentation product by loss of NH₃ is observed at *m/z* 395-399.

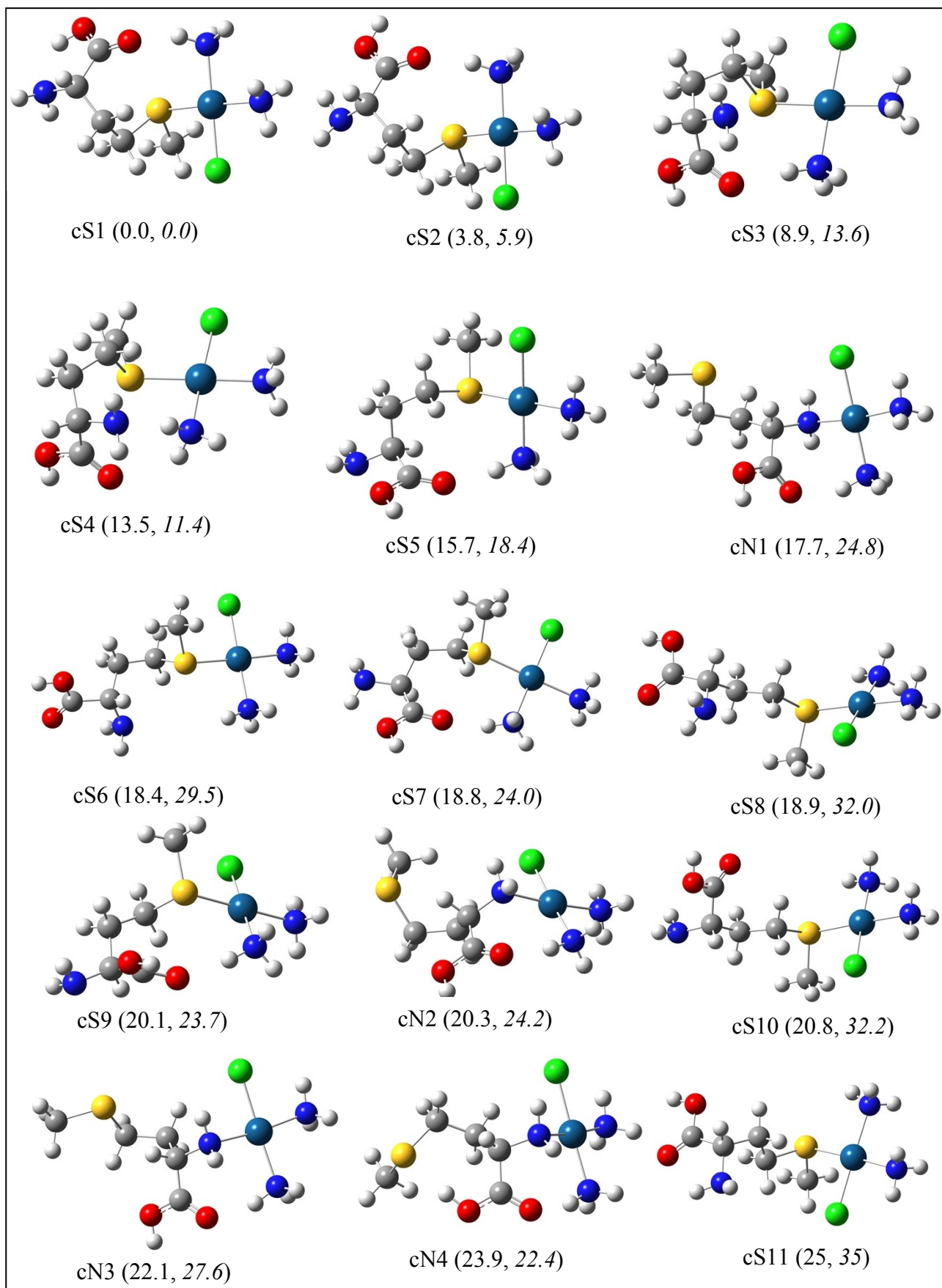


Figure S6. Optimized geometries for the most stable conformers of *cis*-[PtCl(NH₃)₂Met]⁺ involving platination of the amino acid at either thioether sulfur or amino nitrogen or (one example) carbonyl oxygen.

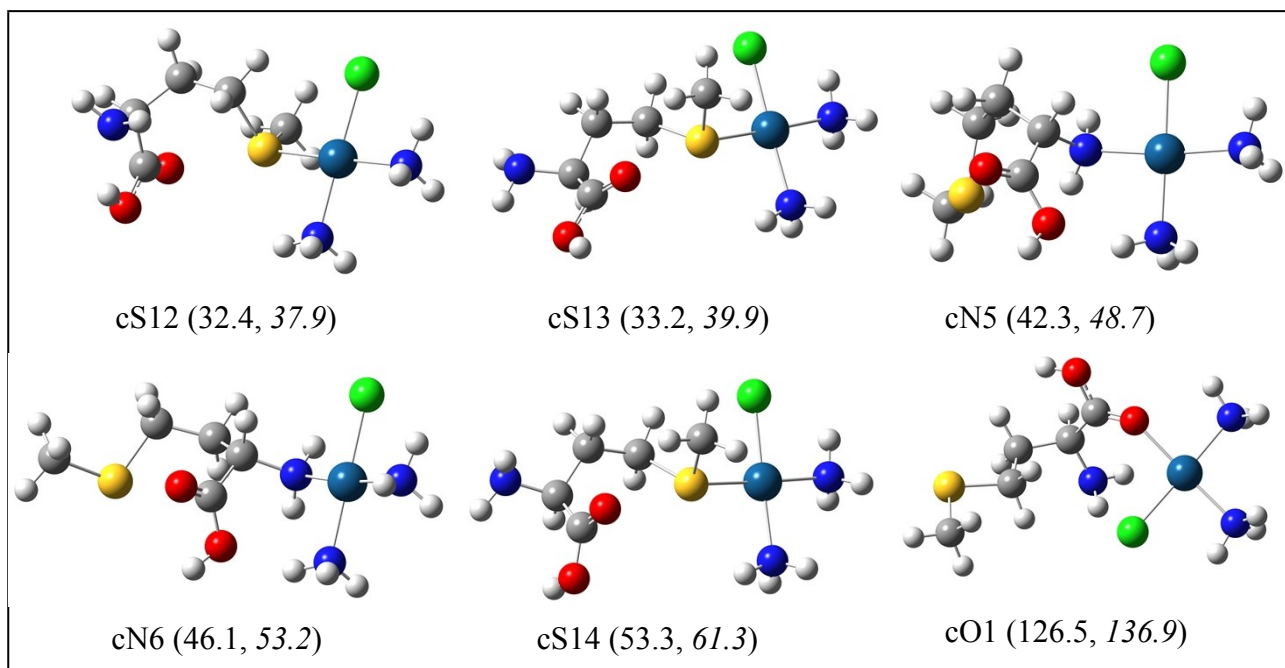


Figure S6 (continuation). Optimized geometries for the most stable conformers of *cis*-[PtCl(NH₃)₂Met]⁺ involving platination of the amino acid at either thioether sulfur or amino nitrogen or (one example) carbonyl oxygen.

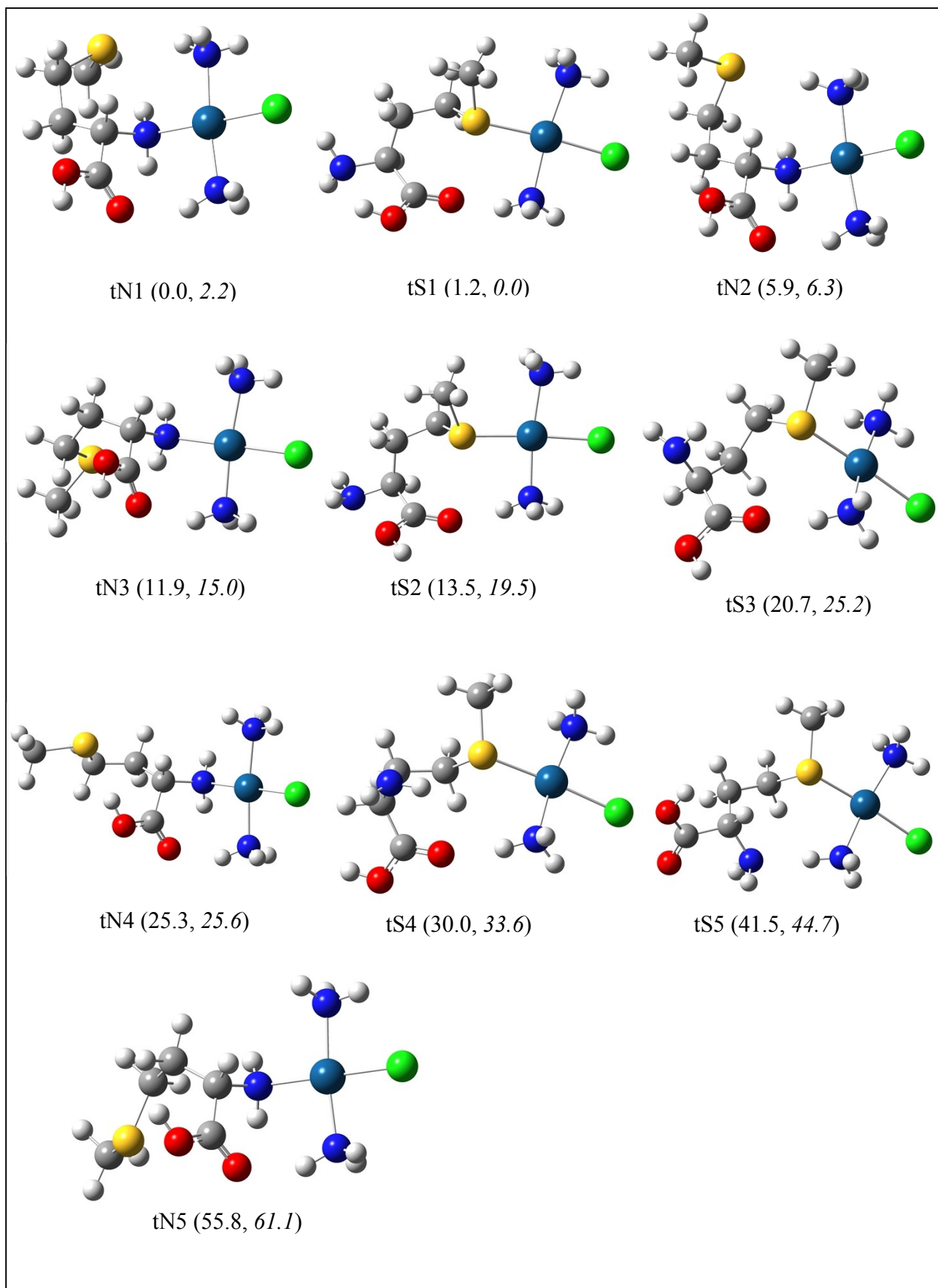


Figure S7. Optimized geometries for the most stable conformers of *trans*-[PtCl(NH₃)₂Met]⁺ involving platination of the amino acid at either thioether sulfur or amino nitrogen.

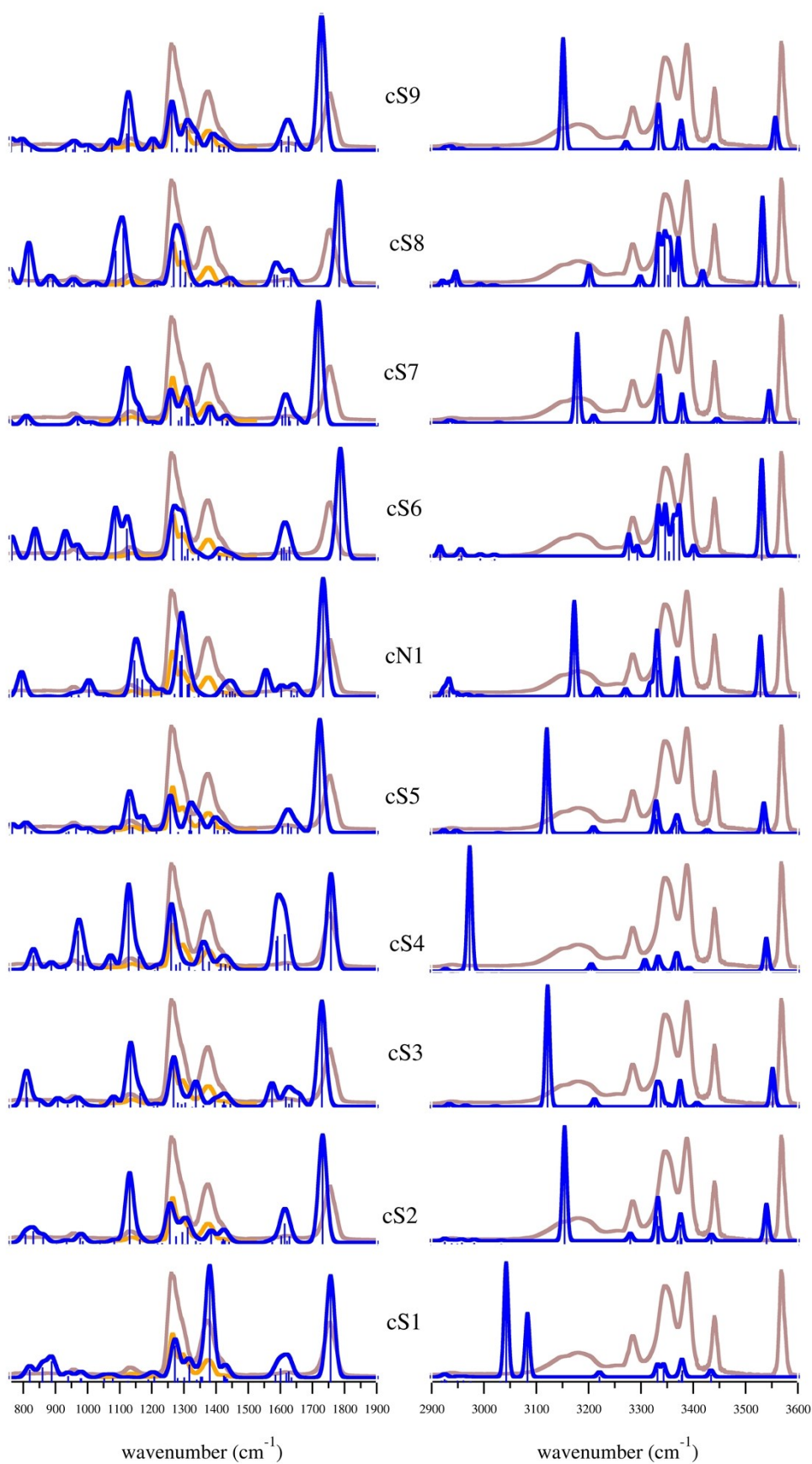


Figure S8. Calculated IR spectra for *cis*-[PtCl(NH₃)₂Met]⁺ isomers. The experimental IRMPD spectrum is plotted in the background (in pale magenta).

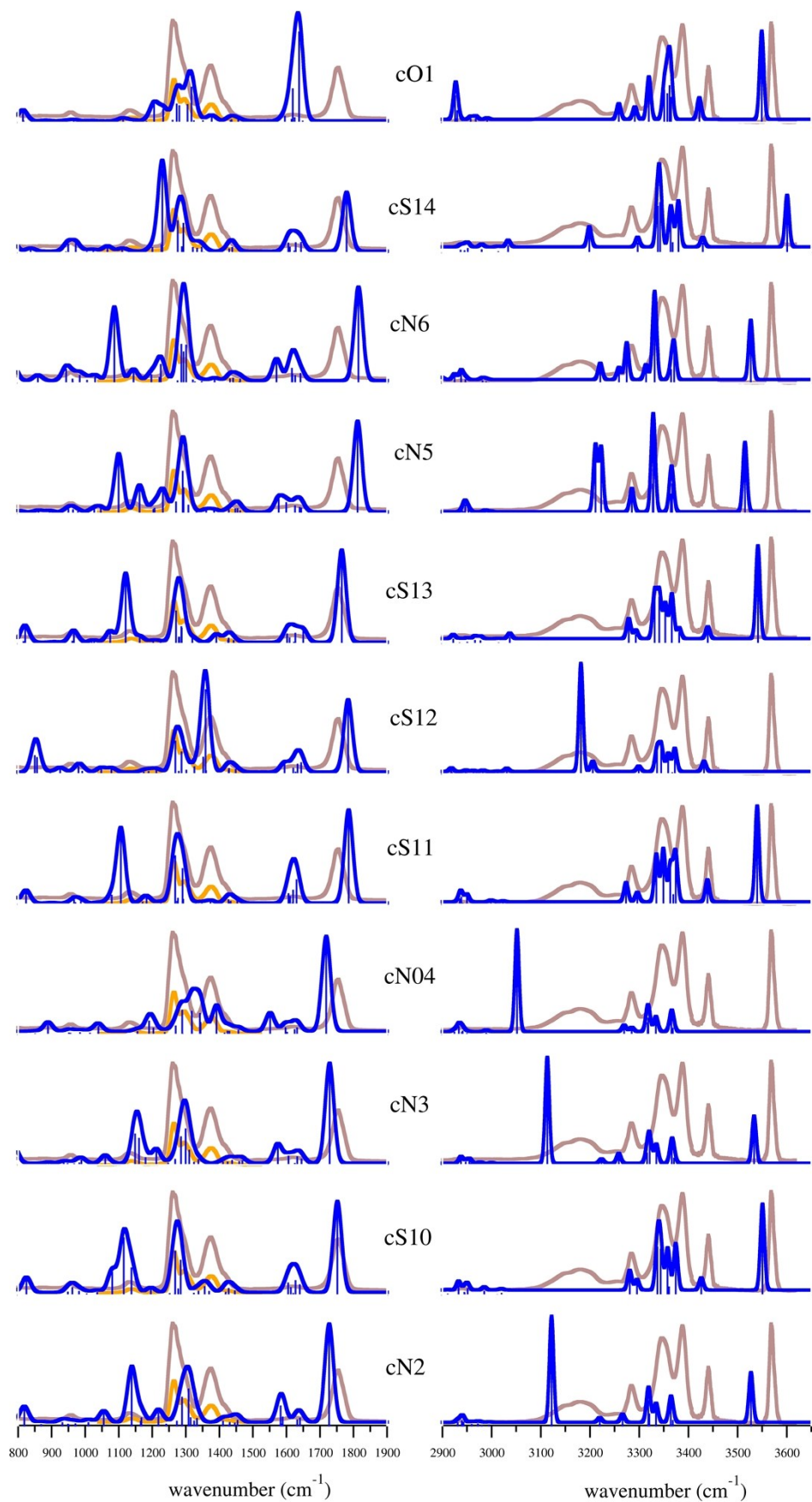


Figure S8. (continuation) Calculated IR spectra for *cis*-[PtCl(NH₃)₂Met]⁺ isomers. The experimental IRMPD spectrum is plotted in the background (in pale magenta).

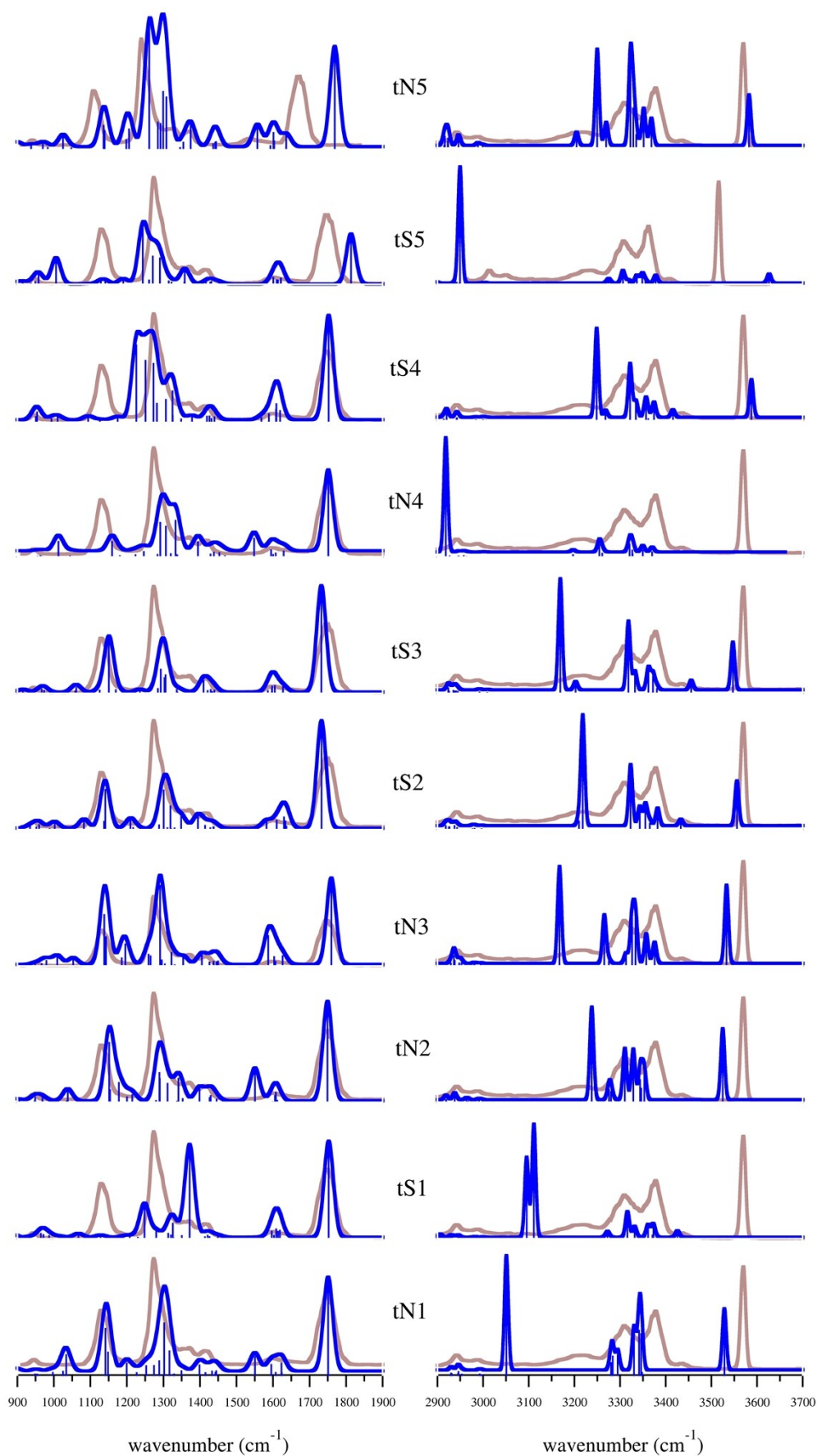


Figure S9. Calculated IR spectra for *trans*-[PtCl(NH₃)₂Met]⁺ isomers. The experimental IRMPD spectrum is plotted in the background (in pale magenta).

Table S1. Selected vibrational transitions observed for *cis*-[PtCl(NH₃)₂(Met)]⁺ in the IRMPD spectra compared with anharmonic frequencies calculated for representative isomers at the B3LYP/BS1 (BS1: 6311+G(2df,pd) for H, N, C and O; 6311+G(3df) for S; Pt:LANL2TZ-f) level, along with mode assignments.

$\nu_{\text{exp}}^{\text{a}}$	$\nu_{\text{calc}}(\text{CS1})^{\text{a,b}}$	$\nu_{\text{calc}}(\text{CS2})^{\text{a,b}}$	$\nu_{\text{calc}}(\text{CN1})^{\text{a,b}}$	Mode assignment ^d
-	820 (42)	807 (37)	-	-NH ₃ β_{t}
-	860 (51)	862 (28)	-	NH ₂ β_{w} , CH ₂ -CH ₂ σ
-	888 (73)	-	-	O-H β_{w}
955	-	977 (22)	-	CH ₃ β_{t}
-	-	-	1004 (48)	NH ₂ -C $_{\alpha}$ σ , molecular deformation
1133	-	1131 (253)	-	O-H β_{s} , NH ₂ β_{t}
-	-	-	1146 (108)	O-H β_{s} , C(=O)-OH σ , CH ₂ β_{w}
-	-	-	1155 (55)	O-H β_{s} , C(=O)-OH σ , CH ₂ β_{w}
-	-	-	1170 (52)	NH ₂ β_{w} , CH ₂ β_{w}
-	-	-	1196 (36)	NH ₂ β_{t} , O-H β_{s}
1260	1272 (130)	1256 (133)	1288 (106)	-NH ₃ β_{u}
-	-	1276 (30)	-	C $_{\alpha}$ -H β
1294 (s) ^c	-	1295 (44)	-	O-H β_{s}
-	1317 (62)	1312 (62)	1294 (123)	NH ₃ β_{u}
-	-	-	1311 (37)	CH ₃ β_{u}
-	-	-	1316 (41)	NH ₂ β_{t} , O-H β_{s}
1376	1380 (404)	-	-	O-H β_{s} , C(=O)-OH σ
-	-	1384 (44)	-	C-OH σ , NH ₂ β_{t} , molecular deformation
1426 (s) ^c	1424 (20)	-	-	C $_{\beta}$ H ₂ β_{s}
-	-	-	1555 (78)	NH ₂ β_{s}
1616	1585 (24)	1603 (30)	1603 (32)	NH ₃ β_{s}
-	1601 (47)	1614 (76)	-	NH ₂ β_{s}
-	1626 (36)	1628 (29)	1634 (20)	NH ₃ β_{s}
1754	1756 (372)	1732 (393)	1733 (345)	C=O σ
2942	-	-	2934 (23)	CH ₃ σ_{s}
3148-3184 (3113-3225)	3042 (500)	3154 (333)	-	NH ₃ σ_{s}
-	3083 (278)	-	-	O-H σ
-	3221 (21)	-	3173 (208)	NH ₃ σ_{s}
3255	-	-	-	
3284	-	3280 (21)	-	NH ₃ σ_{s}
-	-	-	3318 (29)	NH ₂ σ_{a}
3347	-	3331 (82)	3330 (87)	NH ₃ σ_{a}
-	3332 (55)	-	-	NH ₃ σ_{s}
-	3343 (55)	3335 (55)	3332 (60)	NH ₃ σ_{a}
3386	3378 (29)	3376 (58)	3369 (65)	NH ₃ σ_{a}
-	3379 (47)	-	-	NH ₃ σ_{a}
-	-	3280 (21)	-	NH ₃ σ_{s}
3443	3434 (29)	3435 (19)	-	NH ₂ σ_{a}
3564	-	3540 (106)	3528 (132)	O-H σ

^a Wavenumbers in cm⁻¹.

^b Calculated harmonic IR intensities are given in parentheses (km mol⁻¹). Transitions with intensity lower than 20 km mol⁻¹ are (usually) not reported. Frequencies (anharmonic) are not scaled.

^c s, shoulder.

^d σ = stretching mode; σ_{a} = asymmetric stretching; σ_{s} = symmetric stretching; β = bending mode; β_{s} = scissoring (symmetric bending in plane); β_{w} = wagging (symmetric bending out of plane), β_{t} = twisting (asymmetric bending out of plane).

Table S2. Selected vibrational transitions observed for *trans*-[PtCl(NH₃)₂(Met)]⁺ in the IRMPD spectra compared with anharmonic frequencies calculated for representative isomers at the B3LYP/BS1 (BS1: 6311+G(2df,pd) for H, N, C and O; 6311+G(3df) for S; Pt:LANL2TZ-f) level, along with mode assignments.

ν_{exp}^a	$\nu_{\text{calc}}(\text{tN1})^{a,b}$	$\nu_{\text{calc}}(\text{tS1})^{a,b}$	$\nu_{\text{calc}}(\text{tN2})^{a,b}$	$\nu_{\text{calc}}(\text{tS2})^{a,b}$	Mode assignment ^d
-	842 (55)	830 (76), 863 (83) 878 (34)	844 (49)	-	NH ₃ β_w O-H β_w NH ₃ β_w
944	-	965 (22)	-	-	CH ₃ β_w
-	1034 (60)	-	1038 (32)	-	NH ₂ -C σ , C $_{\alpha}$ -C(=O) σ
-	-	-	-	1082 (34)	C $_{\alpha}$ -NH ₂ σ , NH ₂ β_t , C $_{\alpha}$ -H
1130	1141 (137)	-	1152 (175)	1141 (146)	O-H β_s , C(=O)-OH σ
-	1148 (67)	-	1154 (36)	1138 (29)	NH ₂ β_w , C $_{\beta}$ H ₂ β_t , C $_{\gamma}$ H ₂ β_t
-	1199 (35)	-	1178 (57)	1210 (32)	NH ₂ β_t , O-H β_s , C $_{\beta}$ H ₂ β_t , C $_{\gamma}$ H ₂ β_t
1275	1253 (27)	1280 (30)	-	-	NH ₂ β_t , CH ₂ β
-	1274 (28)	-	-	-	NH ₂ β_t , CH ₂ β
-	1289 (42)	1248 (147)	1312 (55)	1301 (144)	NH ₃ β_u
-	1302 (153)	1326 (67)	1290 (69)	1319 (86)	NH ₃ β_u
-	1316 (71)	1313 (22)	-	-	N-H β , C-H β , O-H β_s
1356-1372	-	1372 (405)	1341 (70)	1394 (48)	O-H β_s , C(=O)-OH σ , C $_{\alpha}$ -H β
1416	1399 (30)	-	-	-	O-H β_s , NH ₂ β_t , C $_{\beta}$ H ₂ β_t
-	-	-	1399 (40)	-	C $_{\alpha}$ -COOH σ , C $_{\alpha}$ -H β , NH ₂ β_t
-	1550 (54)	1609 (42)	1551 (96)	1630 (45)	NH ₂ β_s
1600	1595 (31)	1596 (32)	-	1610 (34) / 1634 (30)	NH ₃ β_s
-	1623 (35)	1614 (30) / 1619 (36)	1608 (29)	1582 (29)	NH ₃ β_s
1745	1751 (275)	1752 (414)	1749 (292)	1733 (394)	C=O σ
2942	-	-	-	-	C-H σ_s
2988	-	-	-	-	C-H σ_a
3055	3051 (294)	-	-	-	N(H ₂)-H σ
-	-	3095 (293)	-	-	O-H σ
3202-3226 (3155-3250)	-	3111 (414)	-	3218 (242)	NH ₃ σ_s
3308	3280 (32)	3272 (21)	3238 (204)	-	NH ₃ σ_s
-	3284 (49)	-	3276 (28)	-	NH ₃ σ_s
-	3295 (51)	-	-	-	NH ₂ σ_a
-	-	3316 (94)	-	3323 (135)	NH ₃ σ_a
3378	-	-	3310 (113)	-	NH ₃ σ_s
-	-	-	3329 (112)	-	NH ₂ σ_a
-	3330 (111)	3332 (40)	3353 (65)	-	NH ₃ σ_a
-	3342 (115)	-	3344 (49)	3343 (43)	NH ₃ σ_a
-	3346 (106)	3361 (46)	-	3356 (49)	NH ₃ σ_a
-	-	-	3346 (30)	-	NH ₂ σ_a
-	-	3373 (38)	-	3382 (39)	NH ₃ σ_a
3434	-	3426 (24)	-	3433 (14)	NH ₂ σ_a
3570	3528 (157)	-	3525 (156)	3556 (99)	O-H σ

^a Wavenumbers in cm⁻¹.

^b Calculated harmonic IR intensities are given in parentheses (km mol⁻¹). Transitions with intensity lower than 20 km mol⁻¹ are (usually) not reported. Frequencies (anharmonic) are not scaled.

^cs, shoulder.

^d σ = stretching mode; σ_a = asymmetric stretching; σ_s = symmetric stretching; β = bending mode; β_s = scissoring (symmetric bending in plane); β_w = wagging (symmetric bending out of plane), β_t = twisting (asymmetric bending out of plane).

Table S3. Theoretically calculated thermodynamic parameters for the most stable structures of sampled $[\text{PtCl}(\text{NH}_3)_2\text{Met}]^+$ complexes.

<i>cis</i> - $[\text{PtCl}(\text{NH}_3)_2\text{Met}]^+$		
conformer	$\Delta\text{G}(\text{KJ/mol})$	$\Delta\text{H}(\text{KJ/mol})$
cS1	0.0	0.0
cS2	3.8	5.9
cS3	8.9	13.6
cS4	13.5	11.4
cS5	15.7	18.4
cN1	17.7	24.8
cS6	18.4	29.5
cS7	18.8	24.0
cS8	18.9	32.0
cS9	20.1	23.7
cN2	20.3	24.2
cS10	20.8	32.2
cN3	22.1	27.6
cN4	23.9	22.4
cS11	24.8	35.2
cS12	32.4	37.9
cS13	33.2	39.9
cN5	42.3	48.7
cN6	46.1	53.2
cS14	53.3	61.3
cO1	126.5	136.9

<i>trans</i> - $[\text{PtCl}(\text{NH}_3)_2\text{Met}]^+$		
conformer	$\Delta\text{G}(\text{KJ/mol})$	$\Delta\text{H}(\text{KJ/mol})$
tN1	0.0	2.0
tS1	1.2	0.0
tN2	5.9	6.3
tN3	11.9	15.0
tS2	13.5	19.5
tS3	20.7	25.2
tN4	25.3	25.6
tS4	30.0	33.6
tS5	41.5	44.7
tN5	55.8	61.1