New PEPPSI-type Pd(II)NHC complexes bearing Substituted NHC: Synthesis, characterization , DFT calculations and catalytic activity in direct C-H arylation of thiophene 4,5-dimethylthiazole with aryl bromides

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Table 9. HDOCK docking results for complexes 3a–3g against seven protein targets (PDB IDs: 1JIJ, 1SZ2, 1E5M, 6CBZ, 1FDW, 5GWK, and 2WTT), showing the docking score, confidence score, residues involved in the peripheral (PAS) and catalytic (CAS) active sites, and RMSD (Å) values for the top-ranked binding poses.

Compound	Docking score	Confidence score	PAS	CAS	RMSD
Protein: 1JIJ					
3a	-128.79	0.3955	ALA43A, GLY49A, GLY83A, LYS84A, ARG88A, PHE232A, GLY233A, LYS234A, GLY238A, ALA239A, TRP241A	THR42A, SER45A, HIS47A, HIS50A, SER82A, SER85A, ASP195A	86.33
3b	-130.89	0.4056	GLY38A, ALA39A, ASP40A, GLY49A, THR75A, LYS84A, ARG88A, ILE103A, TYR170A, GLN174A, GLN196A, LEU223A, TRP241A	THR42A, HIS47A, HIS50A, ASP80A, SER82A, ASP195A	86.79
3c	-129.10	0.3970	GLY38A, ALA39A, ASP40A, ALA43A, GLY49A, PHE54A, LYS84A, ARG88A, TYR170A,	THR42A, SER45A, HIS47A, HIS50A, ASP80A, SER82A, ASP195A	86.64

			GLN174A, GLN196A, LEU223A, TRP241A		
3d	-135.66	0.4288	GLY38A, ALA39A, ASP40A, ALA43A, GLY49A, PRO53A, LYS84A, TYR170A, GLN174A, VAL191A, GLY192A, GLY193A, GLN196A, ASN199A, ILE221A, PRO222A, LEU223A, VAL224A, TRP241A	CYS37A, THR42A, HIS47A, HIS50A, ASP80A, SER82A, SER194A, ASP195A	88.67
3e	-136.67	0.4337	GLY38A, ALA39A, ASP40A, ALA43A, GLY49A, PRO53A, LYS84A, TYR170A, GLN174A, VAL191A, GLY192A, GLY193A, GLN196A, ASN199A, ILE221A, PRO222A, LEU223A, VAL224A, TRP241A	CYS37A, THR42A, HIS47A, HIS50A, ASP80A, SER82A, SER194A, ASP195A	88.83
3f	-145.63	0.4782	GLY38A, ALA39A, ASP40A, ALA43A, GLY49A, PRO53A, GLY83A, LYS84A, ARG88A, TYR170A, GLN174A, GLY192A, GLY193A,	CYS37A, THR42A, HIS47A, HIS50A, ASP80A, SER82A, SER194A, ASP195A	88.82

			GLN196A, ASN199A, PRO222A, LEU223A, VAL224A, TRP241A		
3g	-142.70	0.4636	GLY38A, ALA39A, ASP40A, ALA43A, GLY49A, GLY79A, LYS84A, ARG88A, ILE103A, TYR170A, GLN174A, GLN196A, LEU223A, TRP241A	THR42A, SER45A, HIS47A, HIS50A, ASP80A, ASP195A	86.18
Protein: 1SZ2					
3a	-112.53	0.3210	ASP9A, VAL10A, GLY11A, GLY12A, THR13A, ASN14A, ALA15A, ARG16A, THR32A, ALA64A, PHE101A, GLY134A, ALA135A, GLY136A, THR137A, GLY138A, LEU139A, GLY140A, GLY262A, GLY263A, ASP302A, ASN303A, PRO304A, GLY305A	ASP100A	13.78
3b	-119.04	0.3500	ILE108A, PRO109A, MSE110A, LEU111A, PRO124A, GLY127A, ILE130A, LYS149A,	HIS146A, GLU126A	36.62

			ARG150A, TRP151A, GLY256A, GLY257A, PHE259A, TYR297A, LEU321A		
3c	-126.55	0.3688	ILE108A, PRO109A, MSE110A, LEU111A, LEU116A, PRO124A, VAL125A, GLY127A, LYS128A, ILE130A, LYS149A, ARG150A, TRP151A, GLY256A, PHE259A, LEU321A	HIS146A, GLU126A	36.54
3d	-120.82	0.3581	ALA64A, CYS65A, PRO66A, THR75A, ASN76A, GLY138A, LEU139A, GLY140A, GLY156A, HIS183A, ARG188A	ASN99A, ASP100A, GLU157A, HIS160A, SER185A, GLU187A	21.00
3e	-122.59	0.3663	ASP9A, VAL10A, GLY11A, GLY12A, THR13A, ASN14A, ALA15A, ARG16A, THR32A, ALA64A, PHE101A, GLY134A, ALA135A, GLY136A, THR137A, GLY138A, LEU139A,	ASP100A	13.43

			GLY140A, LYS216A, GLY262A, GLY263A, ASP302A, ASN303A, PRO304A, GLY305A		
3f	-129.60	0.3994	ASP9A, VAL10A, GLY11A, GLY12A, THR13A, ASN14A, ALA15A, ARG16A, THR32A, ALA64A, PHE101A, GLY134A, ALA135A, GLY136A, THR137A, GLY138A, LEU139A, GLY140A, LYS216A, GLY262A, GLY263A, ILE264A, ARG267A, ASP302A, ASN303A, PRO304A, GLY305A	ASP100A	13.30
3g	-122.54	0.3661	ALA64A, THR75A, ASN76A, THR137A, GLY138A, ARG188A, VAL189A, SER191A, PRO193A, GLY194A, VAL196A, ASN197A,	HIS160A, GLU187A	16.35

			ARG200A, PRO215A		
Protein: 1E5M					
3a	-110.50	0.3122	ARG43A, VAL57A, LYS58A, PHE60A, ALA62A, THR63A, ARG68A, ALA71A, LYS72A, MET74A, ARG76A, LYS116A	HIS79A, ASP59A, ASP61A, ASP75A	73.23
3b	-113.64	0.3258	LEU14A, ILE17A, ASN22A, THR23A, GLN64A, PHE65A, CYS83A, GLN86A, GLN87A	ASN90A, ASP91A	63.30
3c	-113.97	0.3273	ARG43A, PHE44A, PHE60A, ALA62A, ALA71A, LYS72A, MET74A, ARG76A, LYS116A, VAL117A, ASP120A, GLN121A, MET140A, ILE198A, THR199A, PRO200A	HIS79A, ASP61A, ASP75A	77.69
3d	-116.99	0.3407	ARG43A, PHE60A, ALA62A, THR63A, ARG68A, ALA71A, LYS72A, MET74A, ARG76A, LYS116A, VAL117A, ASP120A, MET140A	HIS79A, ASP61A, ASP75A	73.44
3e	-118.86	0.3491	PHE 60A, ALA 62A, THR 63A, ARG 68A, ALA 71A, VAL 117A, MET 140A	ASP 120A, ASP 61A, HIS 79A, ARG 43A, LYS 72A, ASP 75A, ARG 76A	73.33
3f	-121.50	0.3612	ILE 17A, GLN 86A, GLN 25A	THR 23A, GLN 64A, ASN 22A,	65.61

				ASP 59A, CYS 83A, ASN 90A, PHE 65A, GLN 87A, PHE 60A	
3g	-116.90	0.3403	ARG 179A, CYS 268A, ALA 265A, ASP 293A	TRP 289A, THR 267A, MET 266A, TYR 264A	99.79
Protein: 6CBZ					
3a	-115.36	0.3334	LEU 403A, PRO 406A	PRO 324A, TRP 393A, ILE 326A, GLU 323A, ARG 394A, GLY 390A, MET 396A	14.64
3b	-117.41	0.3426	GLY 390A, PRO 406A, LEU 403A	TRP 393A, PRO 324A, ILE 326A, ARG 394A, MET 396A, GLU 323A	14.61
3c	-119.28	0.3511	ARG 394A, GLY 442A, PRO 325A, ILE 326A	PRO 324A, TRP 393A, GLU 323A, HIS 398A	15.11
3d	-117.70	0.3439	VAL 446A, LEU 320A, GLY 390A, ILE 326A, GLY 442A, PRO 325A	LYS 449A, GLU 323A, ARG 394A, TRP 393A, PHE 445A, PRO 324A	15.59
3e	-117.19	0.3416	MET 396A, GLY 390A, ILE 326A, PRO 325A	GLU 323A, LEU 403A, ARG 394A, PRO 324A, LYS 449A, TRP 393A, PHE 445A	16.46
3f	-125.51	0.3799	ALA 430A, MET 517A	HIS 516A, THR 431A, HIS 513A, MET 427A, ARG 434A, SER 433A, ILE 510A, MET 437A	22.84
3g	-124.66	0.3759	HIS 398A, GLY 442A, PHE 445A, LEU 320A, GLY 390A, ILE 326A	TRP 393A, PRO 324A, ARG 394A, GLU 323A	14.37
Protein: 1FDW					

3a	-135.68	0.4289	VAL 188A, ASN 152A, LYS 223A, GLY 94A, PRO 187A, VAL 143A	LEU 149A, PHE 226A, LEU 96A, TYR 155A, PHE 259A, TYR 218A, SER 222A	62.46
3b	-141.36	0.4569	LEU 149A, VAL 143A, GLY 186A	PHE 226A, TYR 218A, ASN 152A, SER 142A, VAL 225A, TYR 155A, GLY 94A, LEU 95A, PRO 187A	62.00
3c	-139.49	0.4476	ARG 227A, SER 222A, GLY 186A, LYS 223A, LEU 149A, SER 142A	PHE 226A, LEU 219A, THR 190A, ASN 152A, LEU 96A	62.54
3d	-150.44	0.5022	GLN 221A, GLY 186A, PRO 187A, VAL 225A, TYR 218A, ALA 191A, LEU 95A, CYS 185A, SER 222A	PHE 226A, TYR 155A, SER 142A, ASN 152A, THR 190A, LEU 93A, GLY 94A, VAL 188A, LEU 149A	61.38
3e	-154.86	0.5243	VAL 188A, GLY 94A, PRO 187A, VAL 225A, GLN 221A, LEU 95A, CYS 185A	PHE 226A, TYR 155A, ASN 152A, SER 142A, TYR 218A, LEU 93A, THR 190A, GLY 186A, LEU 149A	61.64
3f	-143.21	0.4661	GLY 94A, SER 222A, VAL 225A, LEU 95A	LEU 149A, LEU 219A, PHE 226A, LEU 96A, PHE 259A, TYR 155A, VAL 188A, LYS 223A, TYR 218A, GLY 186A, PRO 187A	62.80
3g	-145.20	0.4760	GLY13A, ILE14A, GLY94A, LEU95A, LEU96A, VAL143A, GLY144A, LEU149A,	SER142A, ASN152A, CYS185A	60.53

			TYR155A, GLY186A, PRO187A, VAL188A, THR190A, TYR218A, SER222A, VAL225A, PHE226A		
Protein: 5GWK					
3a	-147.27	0.4864	PHE731A, PHE734A, LYS735A, ARG815A, PRO820A, PHE828A, ARG835A, TYR841A, TRP893A	ASP823A, HIS824A	52.95
3b	-144.99	0.4750	PHE731A, PHE734A, LYS735A, ARG815A, PRO820A, LYS821A, PHE828A, ARG835A, VAL836A, TYR841A, TRP893A	ASP823A, HIS824A	52.60
3c	-147.22	0.4861	LEU826A, LYS827A, PHE828A, TYR830A, ARG835A, TRP893A, MET923A, TRP927A, LYS1091A, GLN1094A	ASP823A, HIS824A	56.73

3d	-151.08	0.5054	PHE731A, PHE734A, LYS735A, ASN737A, ARG815A, PRO820A, PHE828A, ARG835A, VAL836A, TYR841A, TRP893A	ASP823A, HIS824A	52.46
3e	-152.00	0.5100	PHE731A, PHE734A, LYS735A, ASN737A, ARG815A, PRO820A, PHE828A, ARG835A, TYR841A, TRP893A	ASP823A, HIS824A	52.31
3f	-164.95	0.5742	THR825A, LEU826A, LYS827A, PHE828A, TYR830A, ARG835A, TRP893A, MET923A, TRP927A, LYS1091A, ALA893A, GLN1094A, GLN1095A	ASP823A, HIS824A	57.48
3g	-154.88	0.5244	PHE731A, LYS735A, LEU826A, LYS827A, PHE828A, TYR830A,	ASP823A, HIS824A	55.78

			ARG835A, TRP893A, TRP927A, LYS1091A, GLN1094A		
Protein: 2WTT					
3a	-145.47	0.4774	MSE369A, LYS370A, TYR389C, ARG390C, GLN393C, GLN394C, ARG362E, PHE365E, MSE369E, LYS370E, TYR355F, GLN394G	GLU366A, GLU373A, GLU363D, GLU366E	33.05
3b	-159.33	0.5465	MSE369A, LYS370A, LYS372A, MSE378C, TYR389C, ARG390C, GLN393C, GLN394C, ARG362E, PHE365E, MSE369E, LYS370E, TYR355F, GLN394G	GLU366A, GLU373A, GLU363D, GLU366E	32.84
3c	-163.02	0.5647	MSE369A, LYS370A, LYS372A, MSE378C, TYR389C, ARG390C, GLN393C, GLN394C,	GLU366A, GLU373A, GLU363D, GLU366E	32.87

			ARG362E, PHE365E, MSE369E, LYS370E, TYR355F, GLN394G		
3d	-150.89	0.5044	MSE369A, LYS370A, GLN383C, TYR389C, ARG390C, GLN393C, GLN394C, ARG362E, PHE365E, MSE369E, LYS370E, TYR355F, GLN394G	GLU366A, GLU373A, GLU363D, GLU366E	33.24
3e	-152.78	0.5139	MSE369A, LYS370A, GLN383C, TYR389C, ARG390C, GLN393C, GLN394C, ARG362E, PHE365E, MSE369E, LYS370E, TYR355F, GLN394G	GLU366A, GLU373A, GLU363D, GLU366E	33.38
3f	-155.45	0.5272	MSE369A, LYS370A, GLN383C, TYR389C, ARG390C, GLN393C, GLN394C, ARG362E,	GLU366A, GLU373A, GLU363D, GLU366E	33.24

			PHE365E, MSE369E, LYS370E, TYR355F, GLN394G		
3g	-156.98	0.5348	MSE369A, LYS370A, LYS372A, MSE378C, TYR389C, ARG390C, GLN393C, ASN364D, ARG362E, PHE365E, MSE369E, LYS370E, TYR355F, GLN394G	GLU366A, GLU373A, GLU363D, GLU366E	33.10

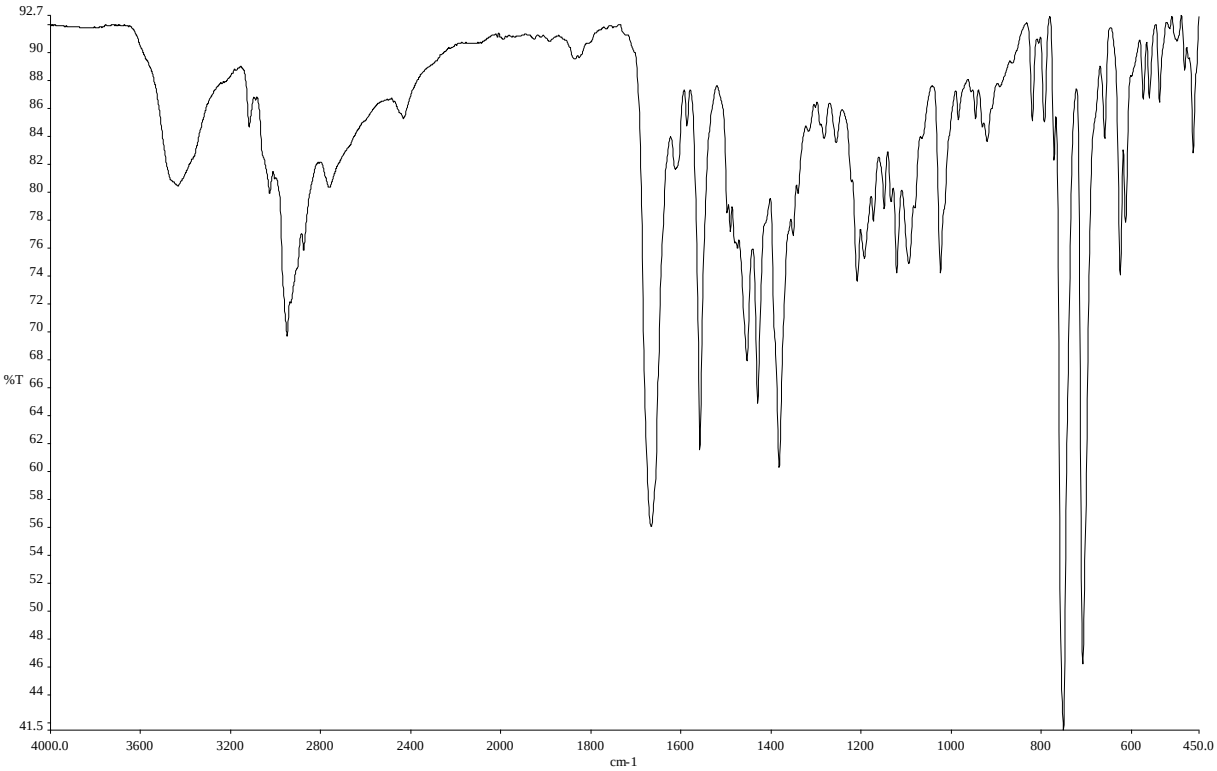

Figure 1. IR Spectrum of 2a

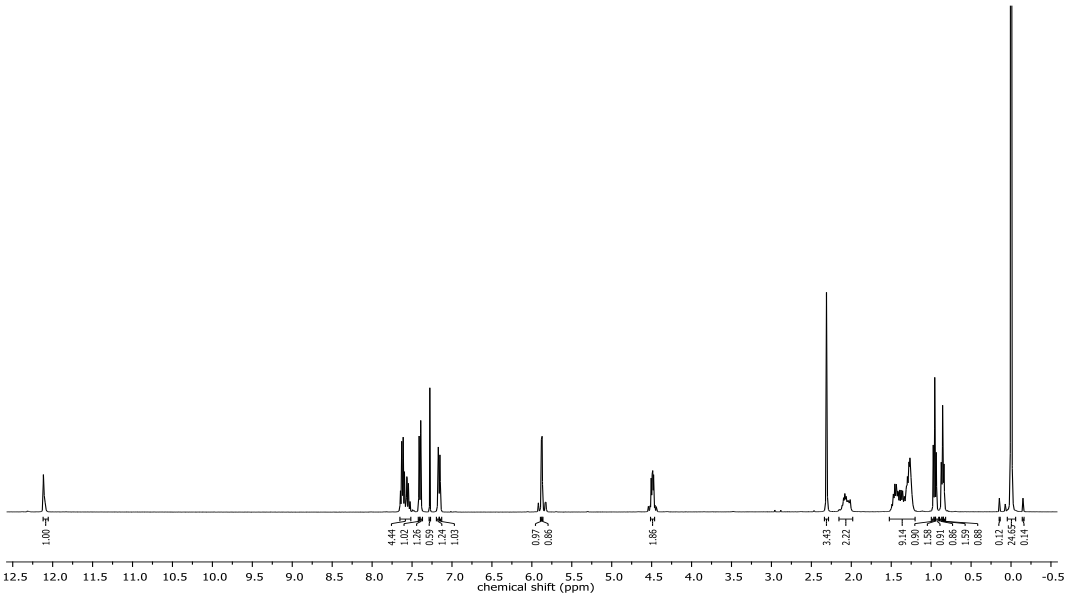

Figure 2. ^{1}H NMR Spectrum of 2a

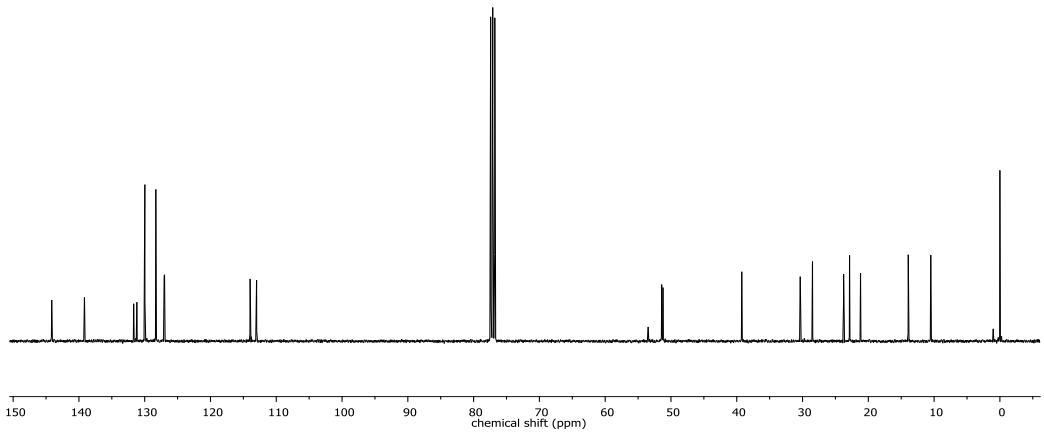

Figure 3. ^{13}C NMR Spectrum of 2a

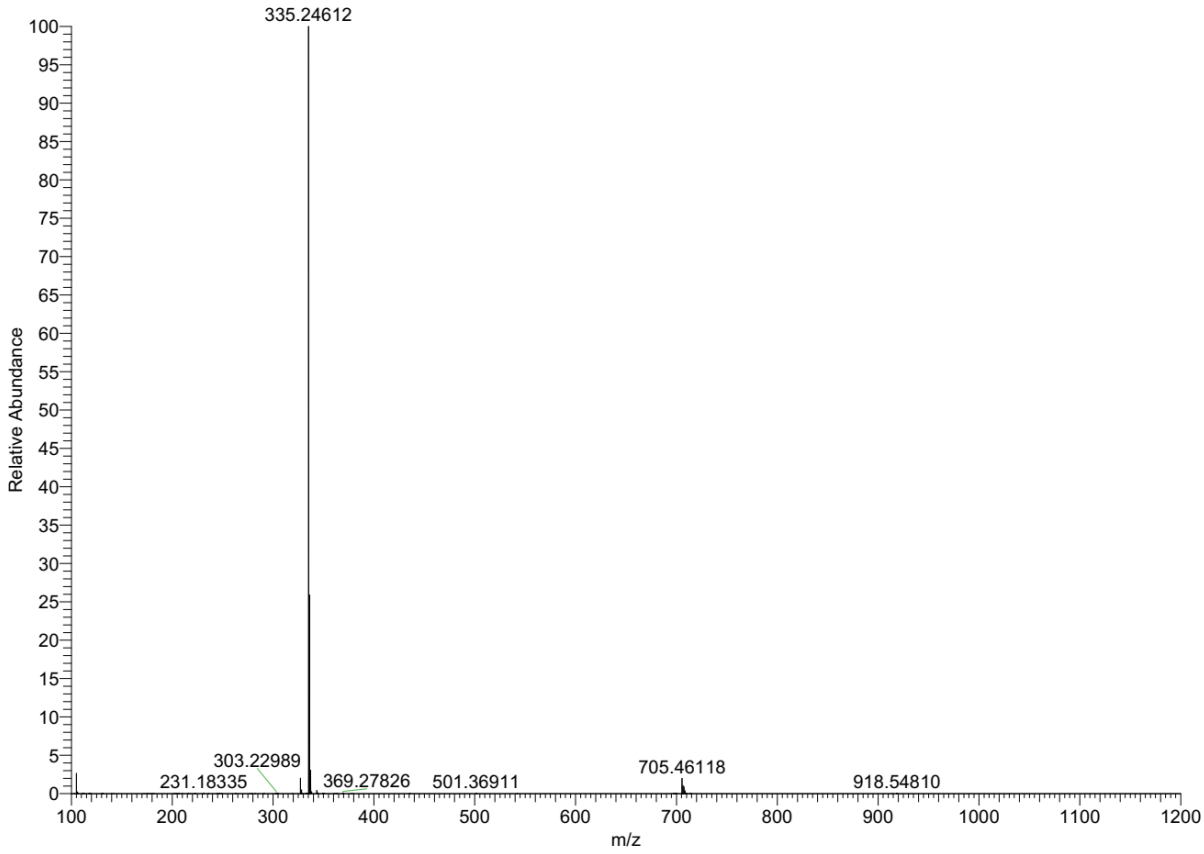

Figure 4. Mass Spectrum of 2a

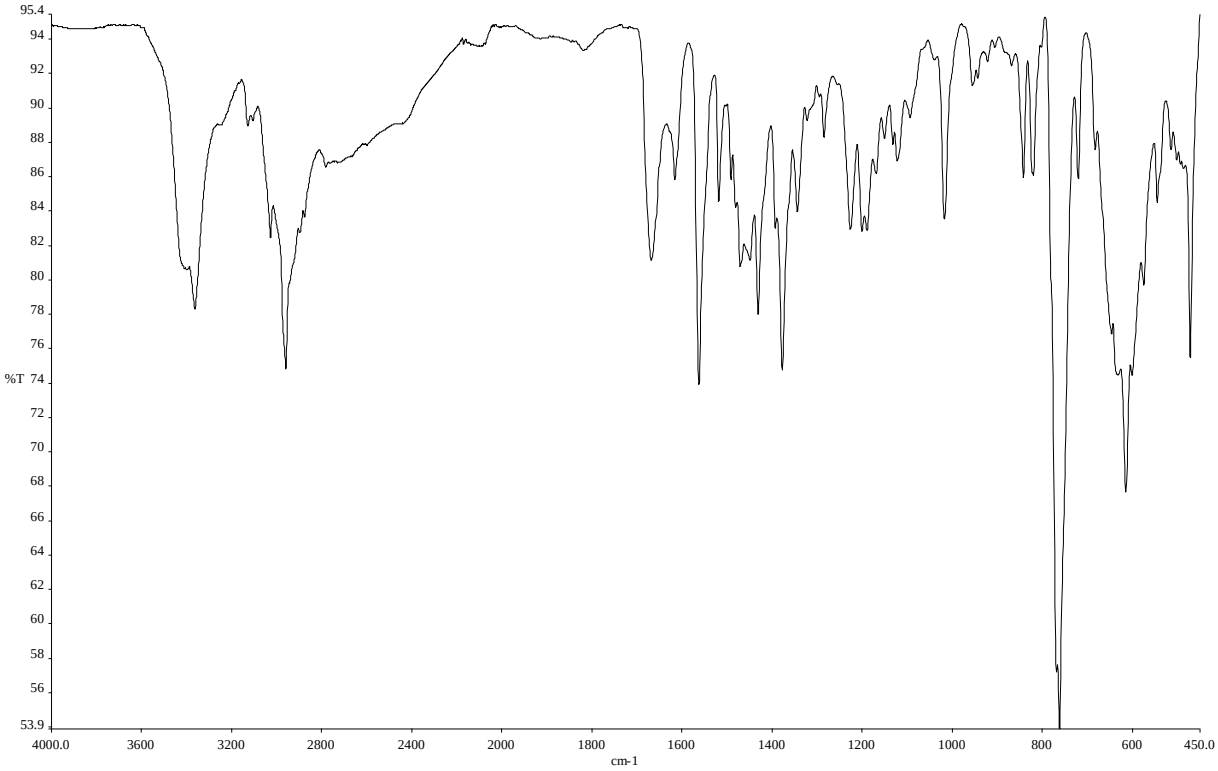

Figure 5. IR Spectrum of 2b

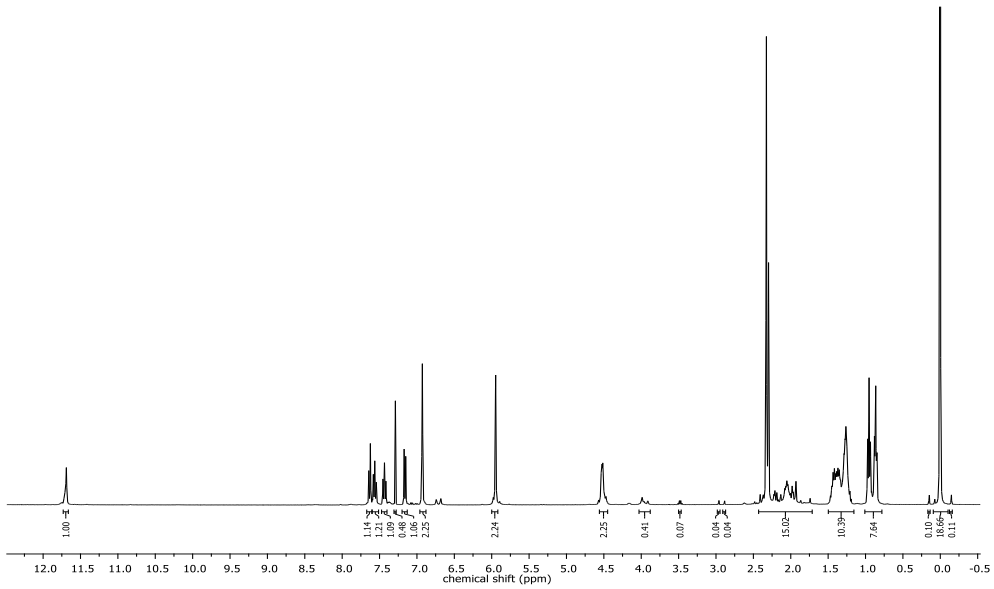

Figure 6. ^{1}H NMR Spectrum of 2b

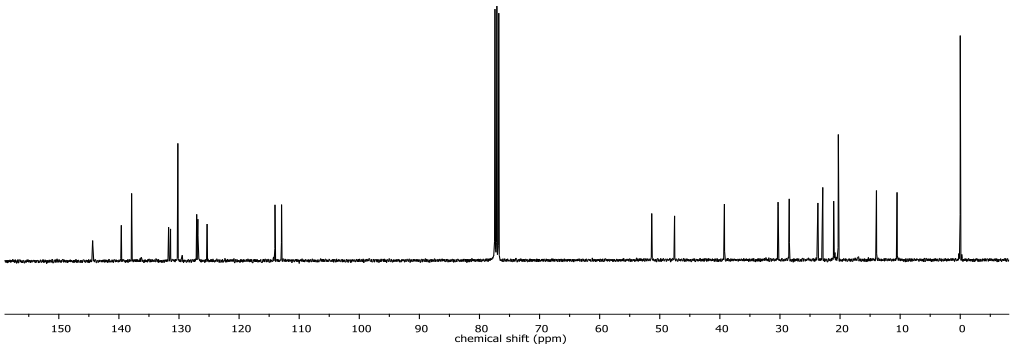

Figure 7. ^{13}C NMR Spectrum of 2b

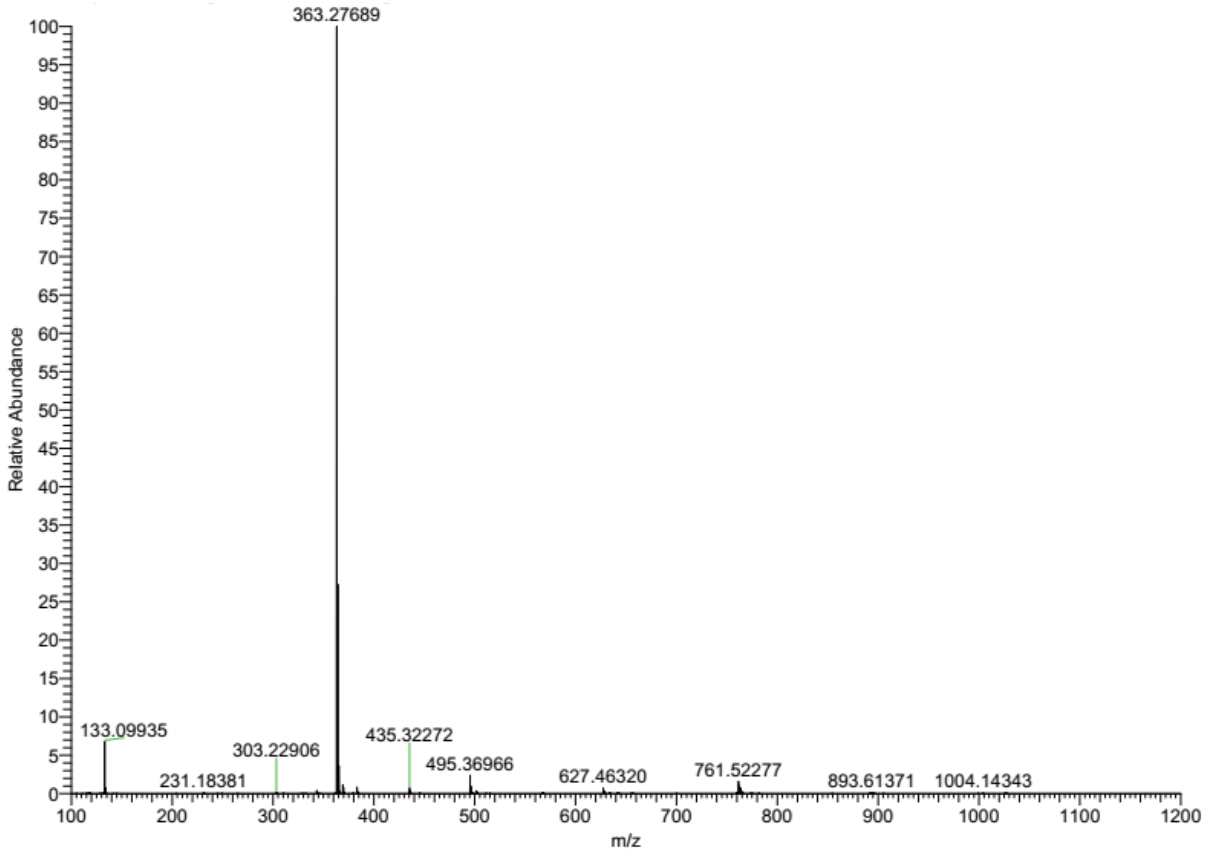

Figure 8. Mass Spectrum of 2b

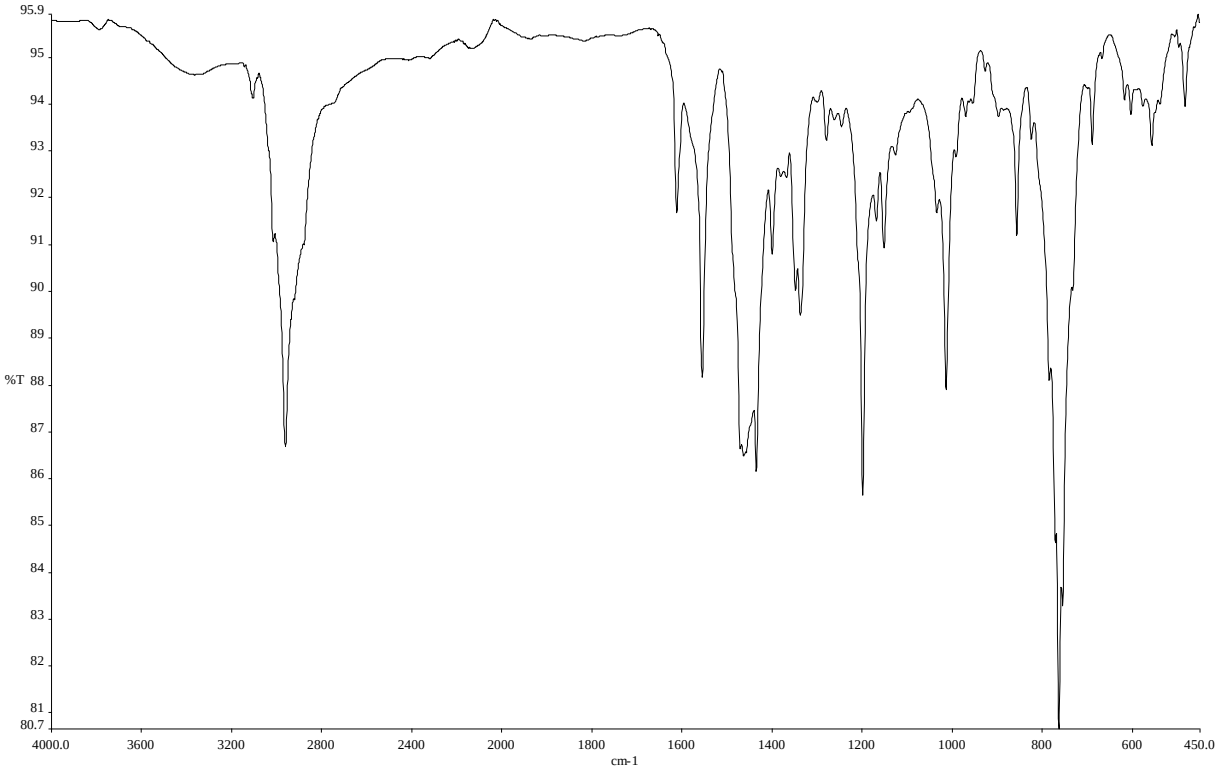

Figure 9. IR Spectrum of 2c

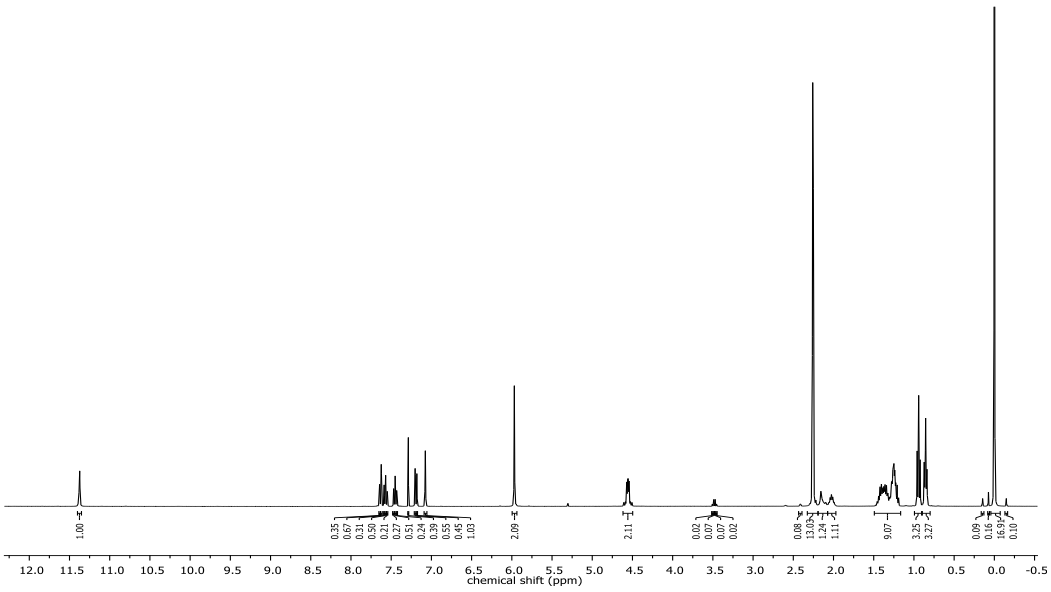

Figure 10. ^{1}H NMR Spectrum of 2c

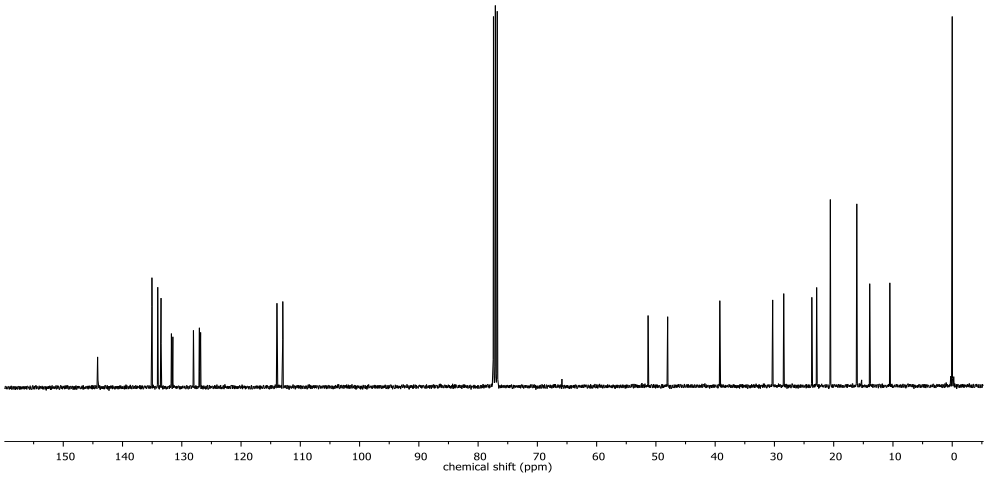

Figure 11. ^{13}C NMR Spectrum of 2c

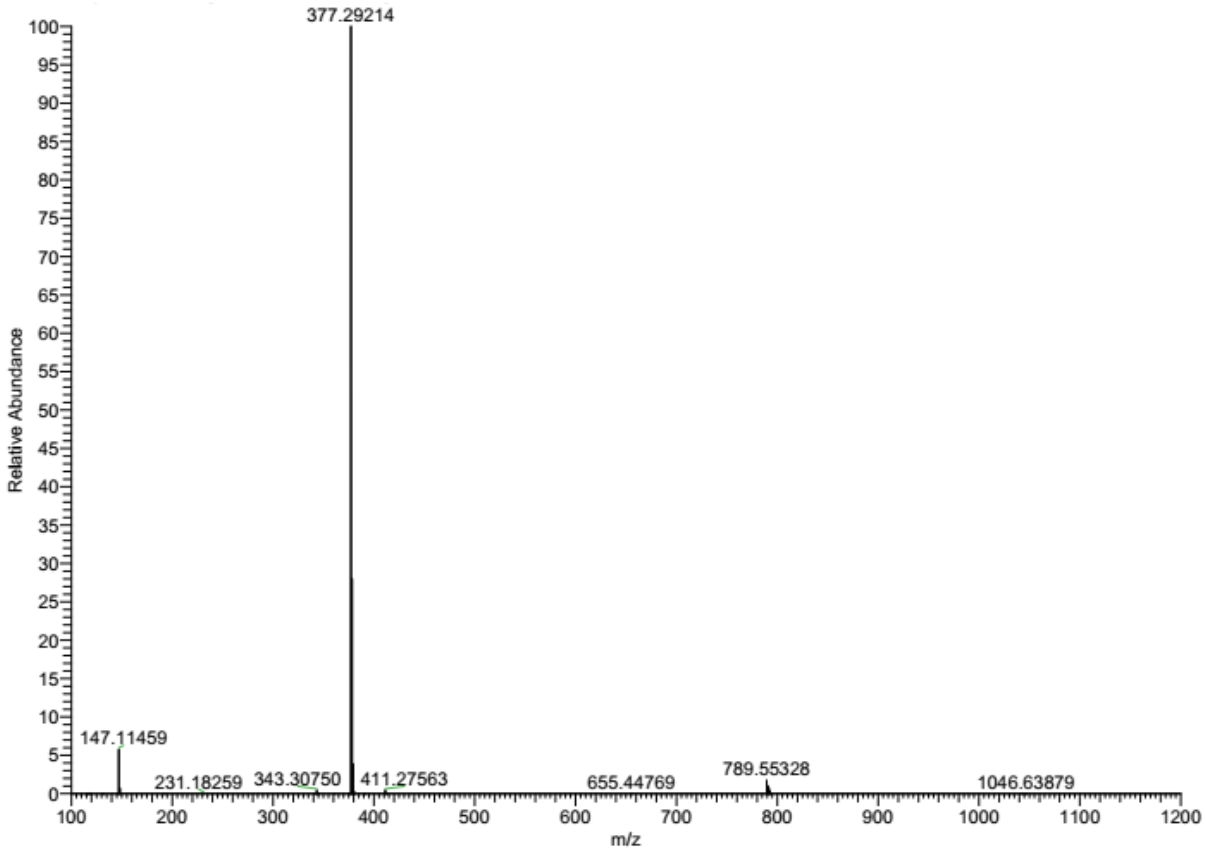

Figure 12. Mass Spectrum of 2c

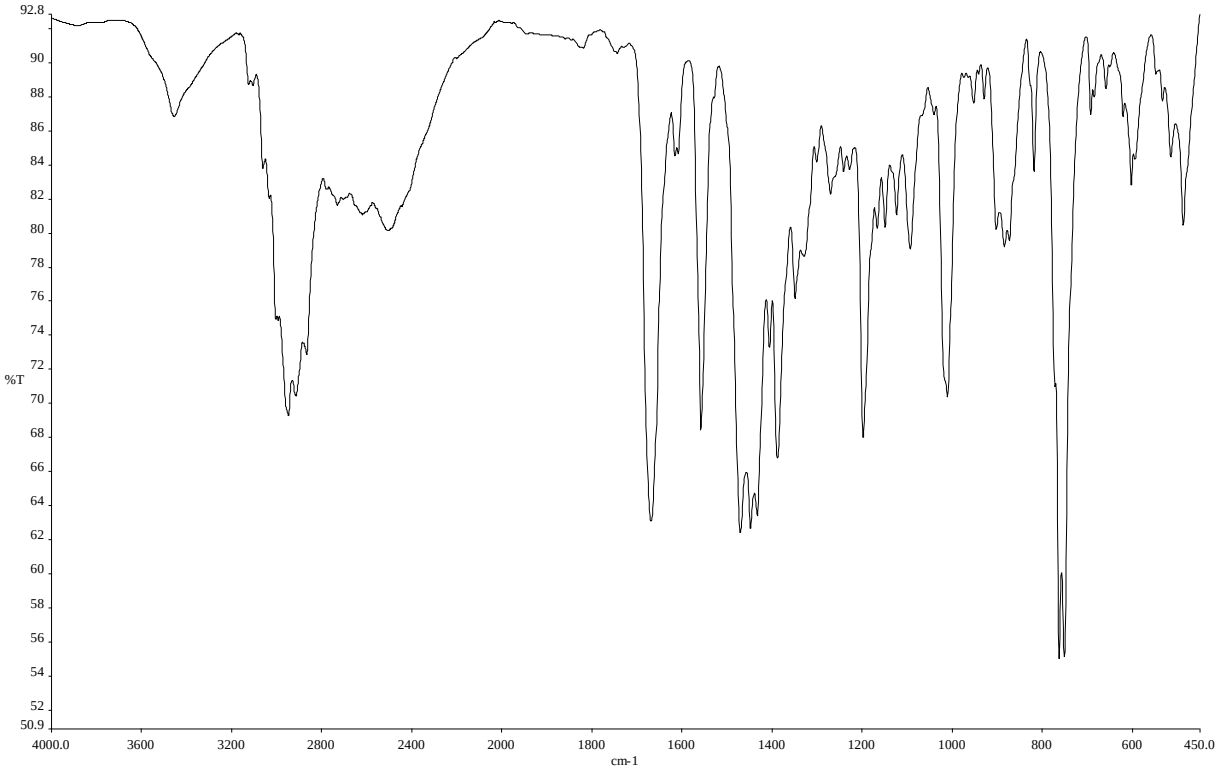

Figure 13. IR Spectrum of 2d

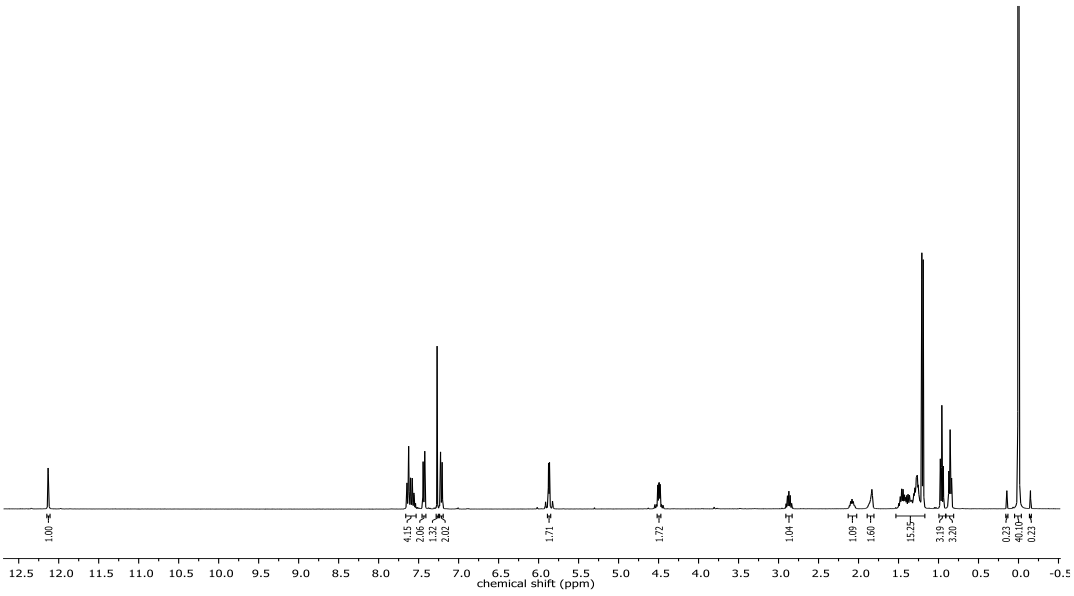

Figure 14. ^{1}H NMR Spectrum of 2d

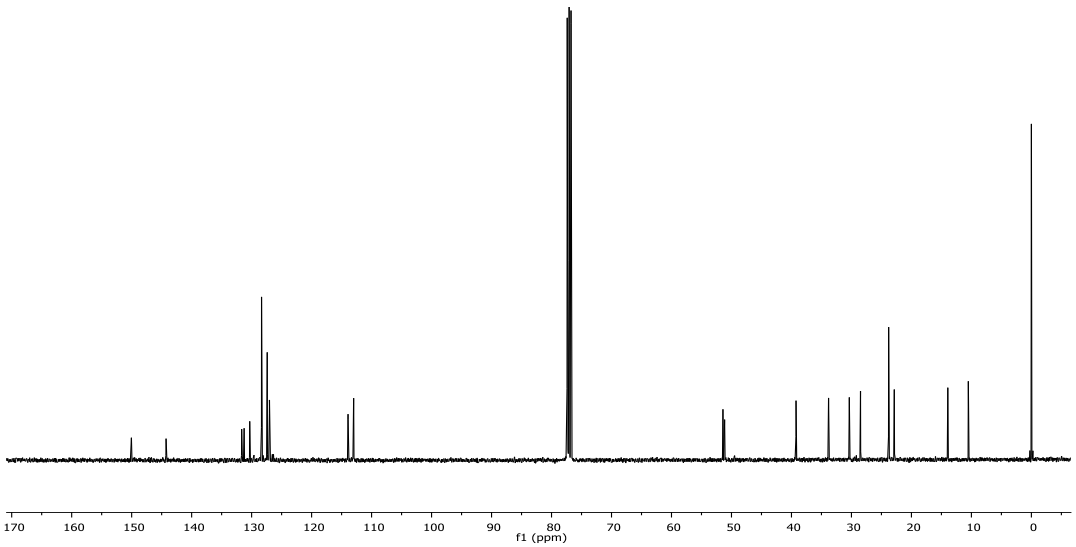

Figure 15. ^{13}C NMR Spectrum of 2d

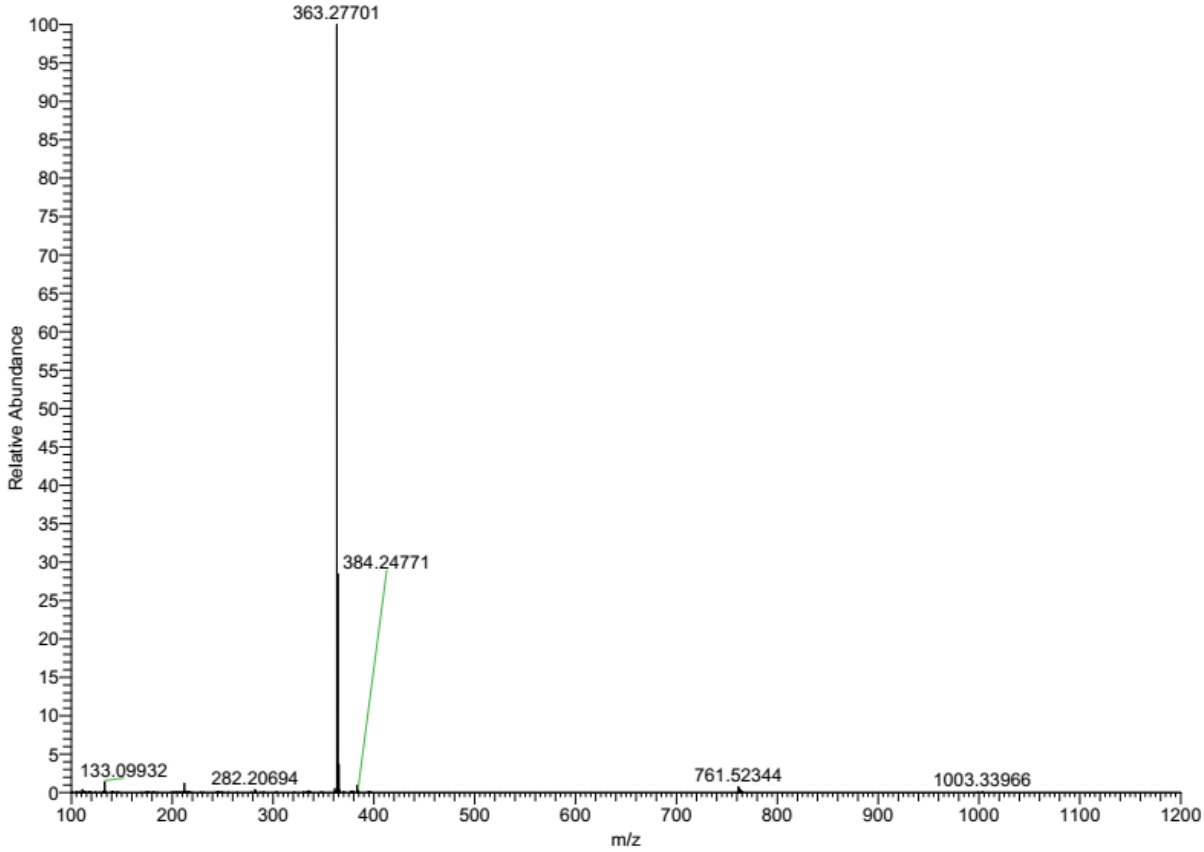

Figure 16. Mass Spectrum of 2d

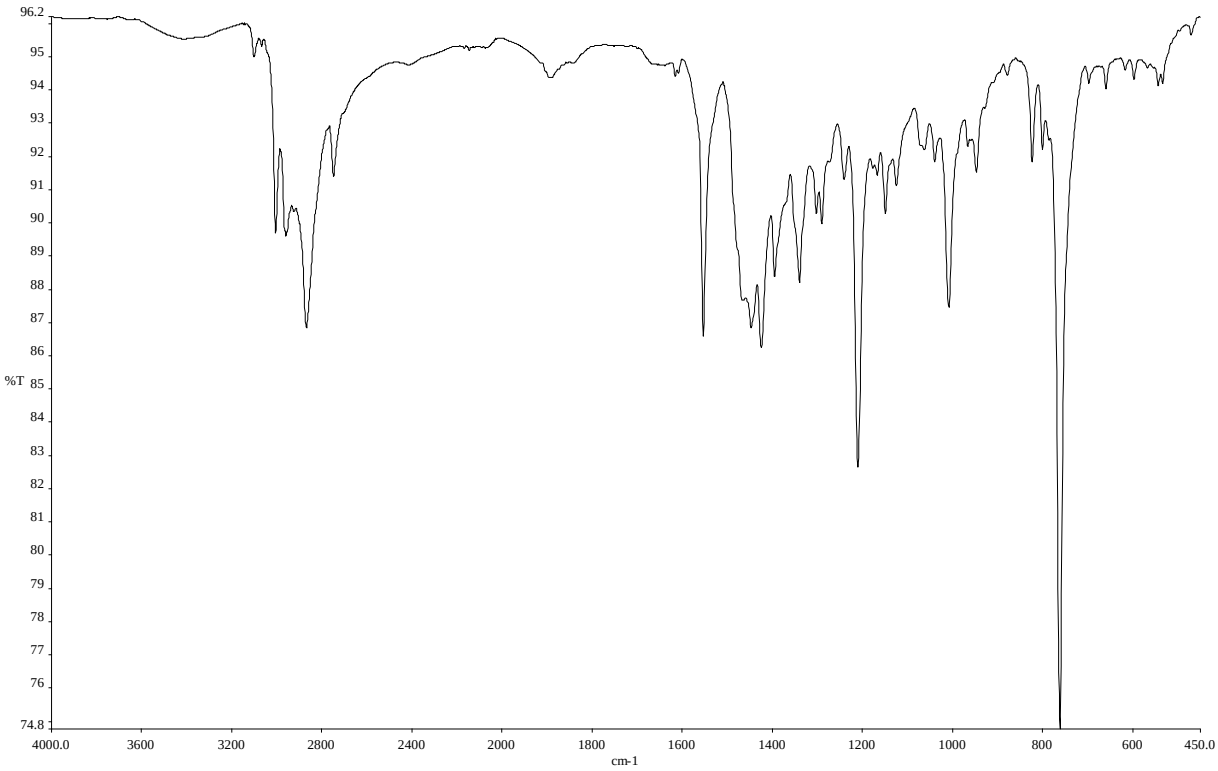

Figure 17. IR Spectrum of 2e

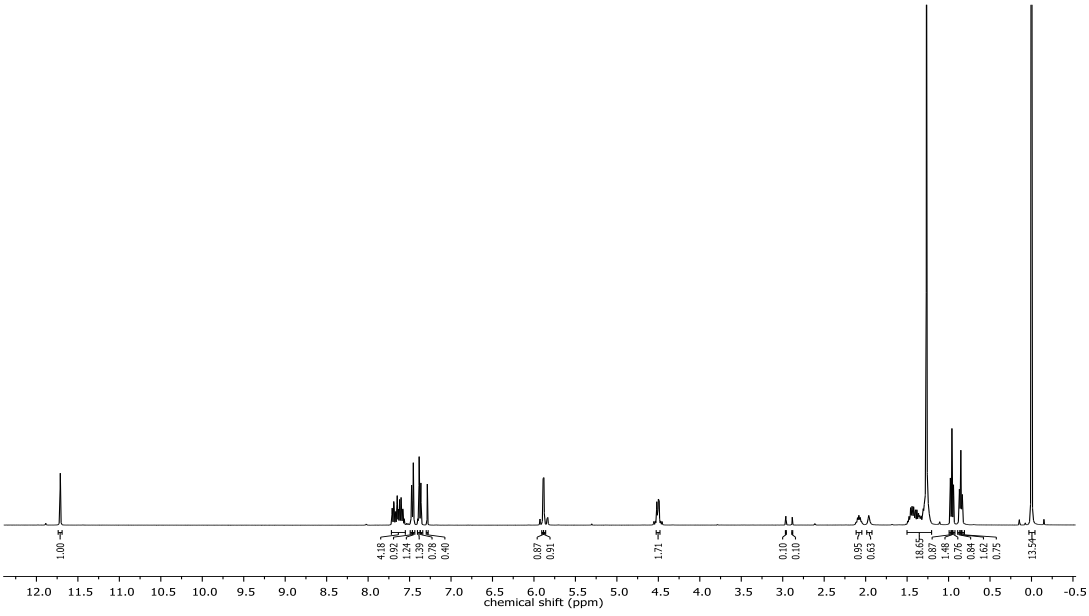

Figure 18. ^{1}H NMR Spectrum of 2e

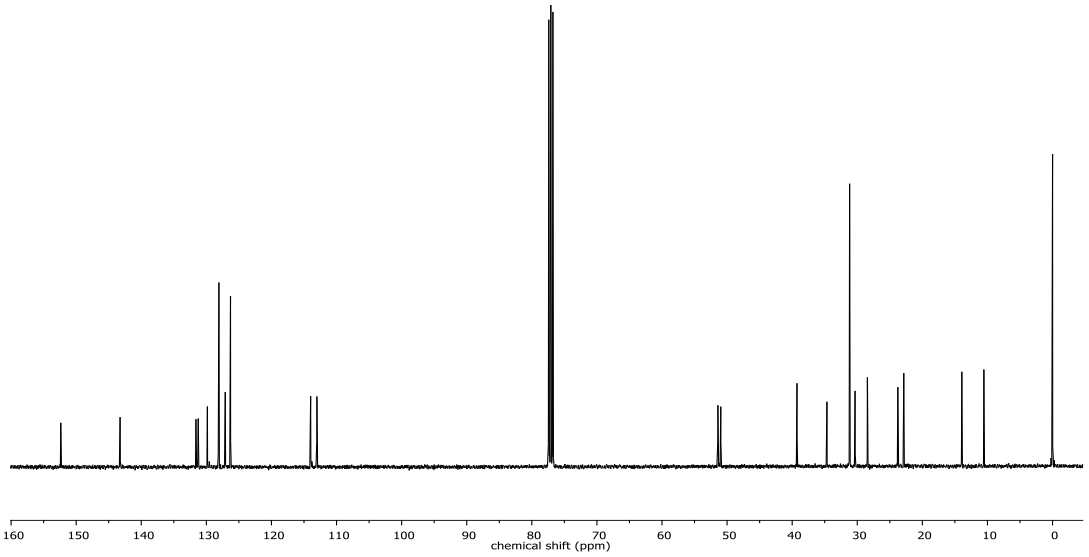

Figure 19. ^{13}C NMR Spectrum of 2e

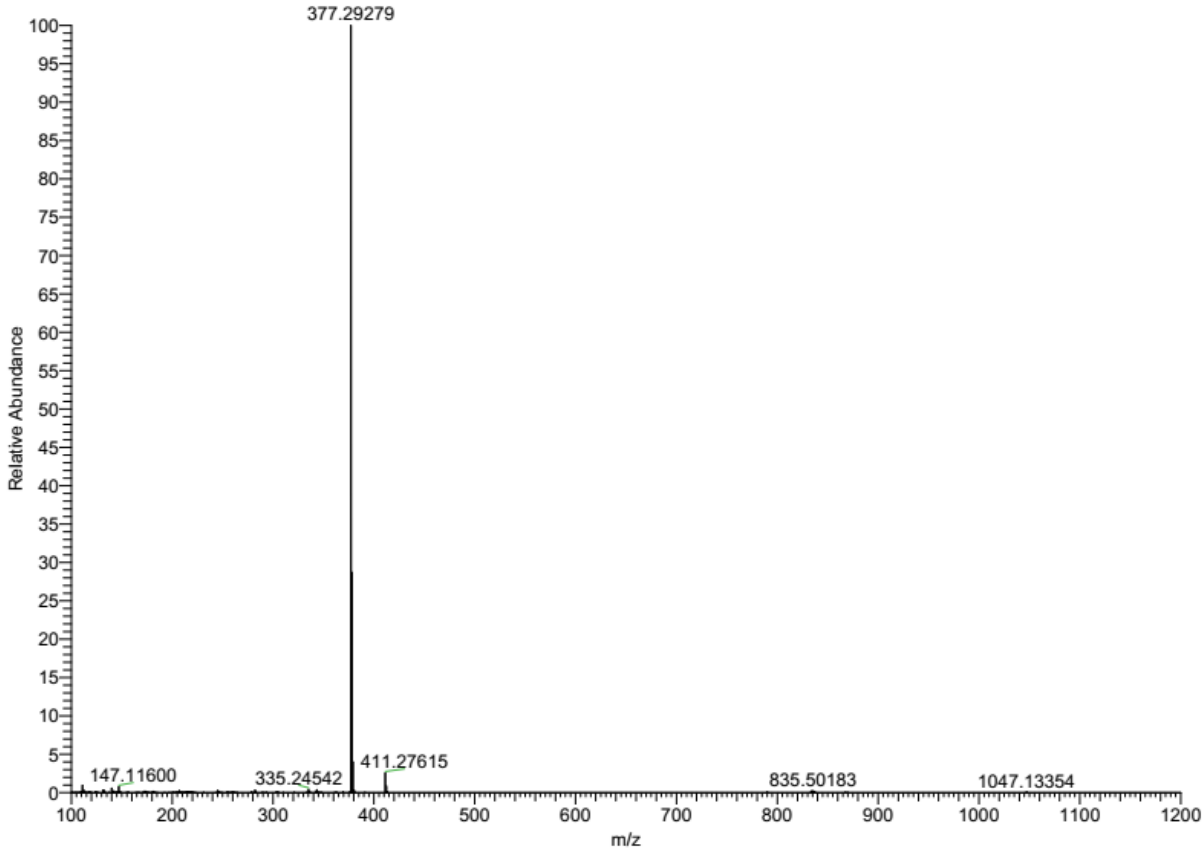

Figure 20. Mass Spectrum of 2e

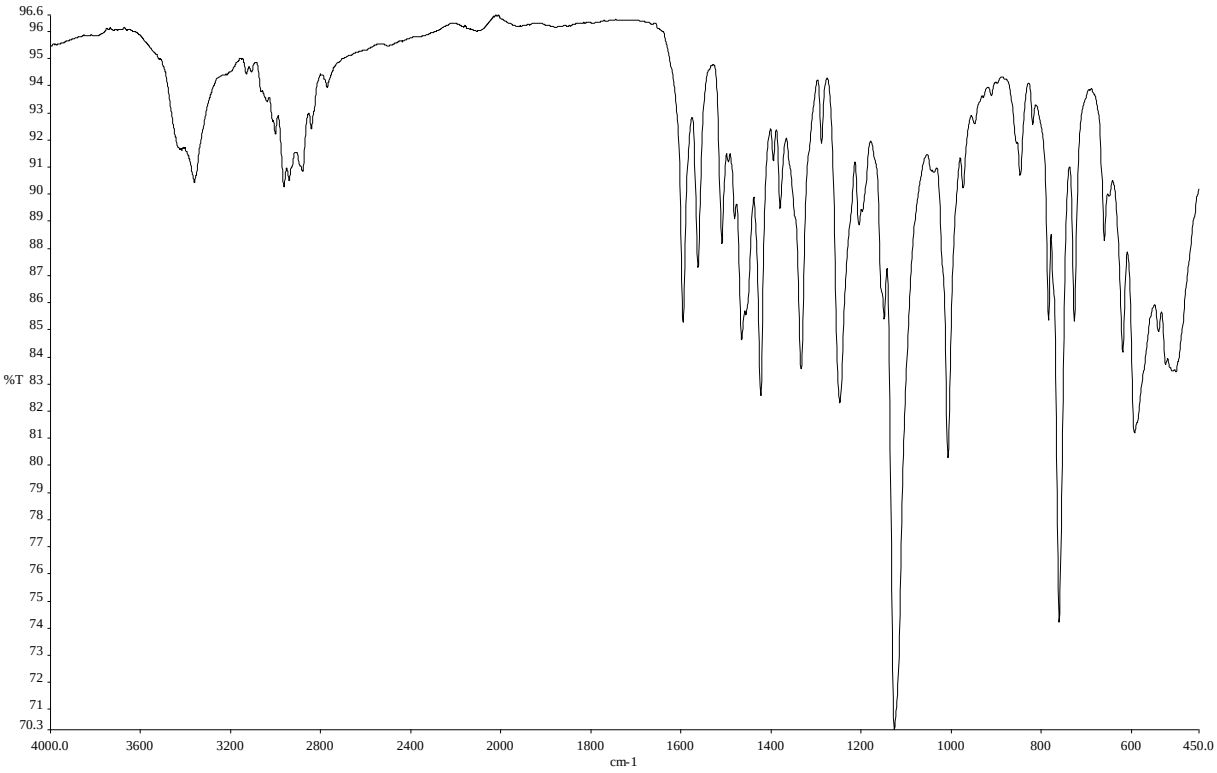

Figure 21. IR Spectrum of 2f

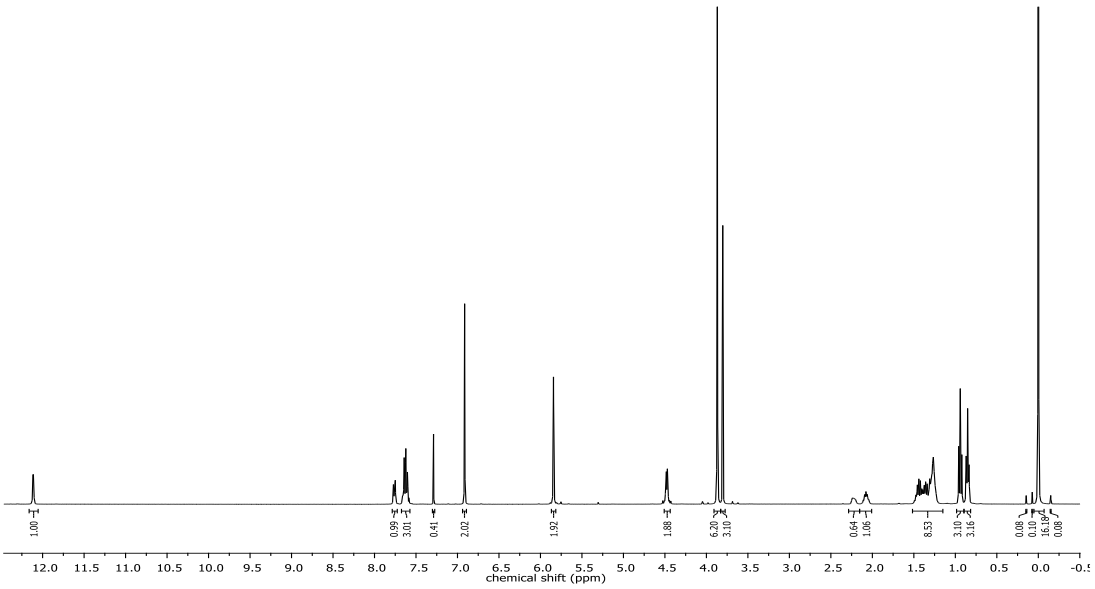

Figure 22. ^{1}H NMR Spectrum of 2f

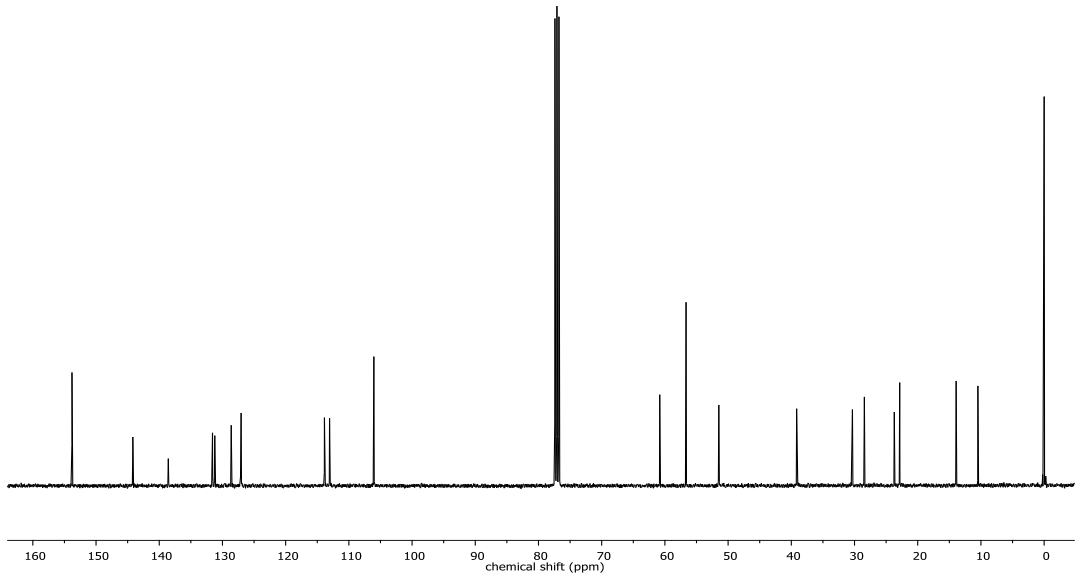

Figure 23. ^{13}C NMR Spectrum of 2f

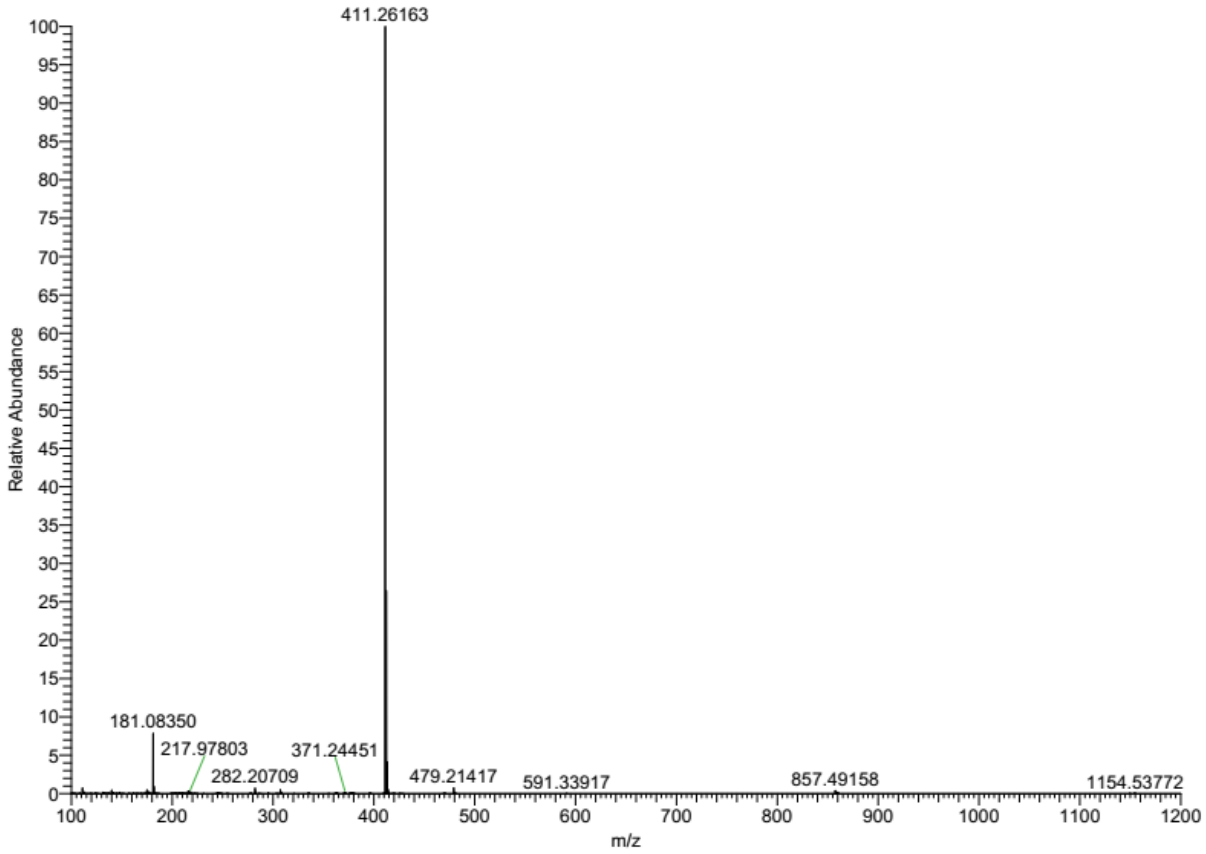

Figure 24. Mass Spectrum of 2f

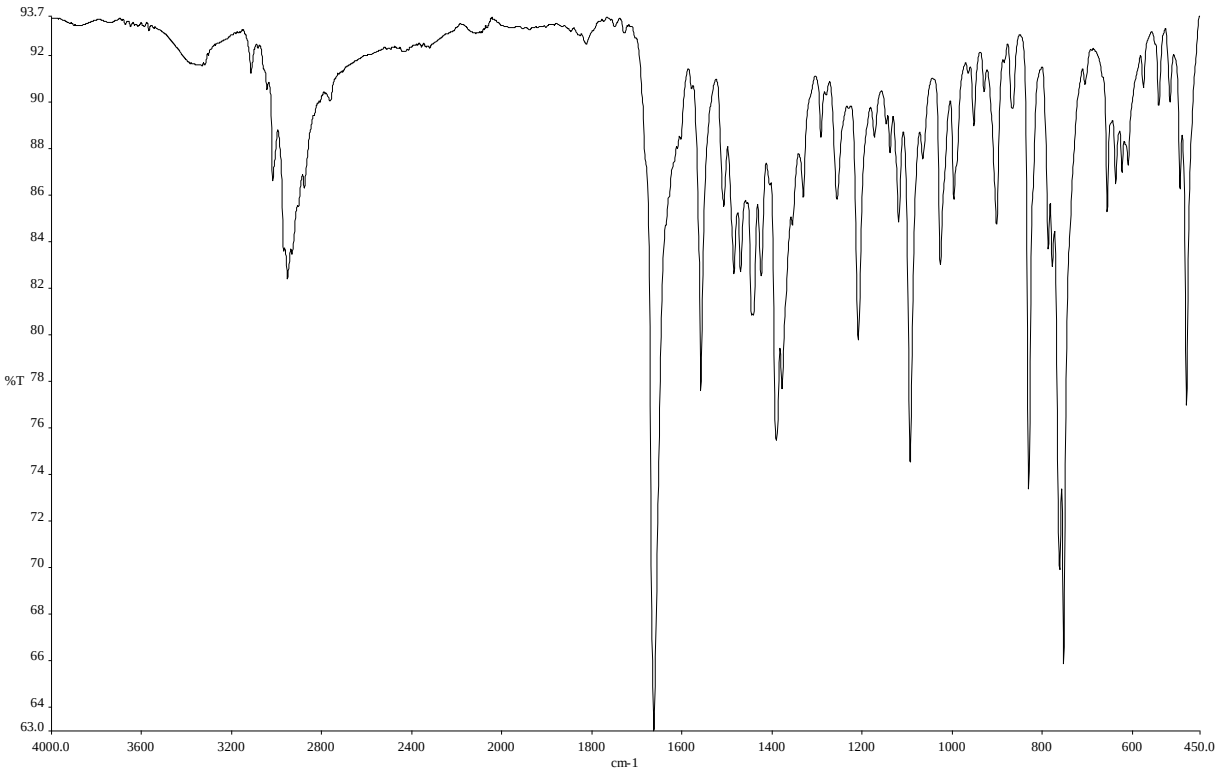

Figure 25. IR Spectrum of 2g

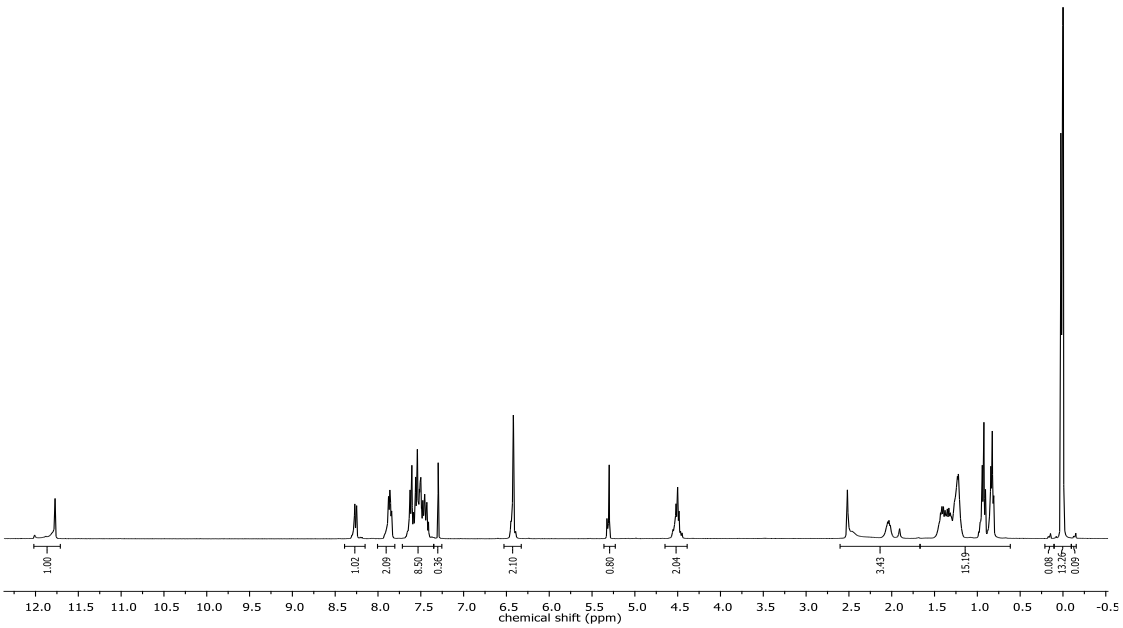

Figure 26. ^{1}H NMR Spectrum of 2g

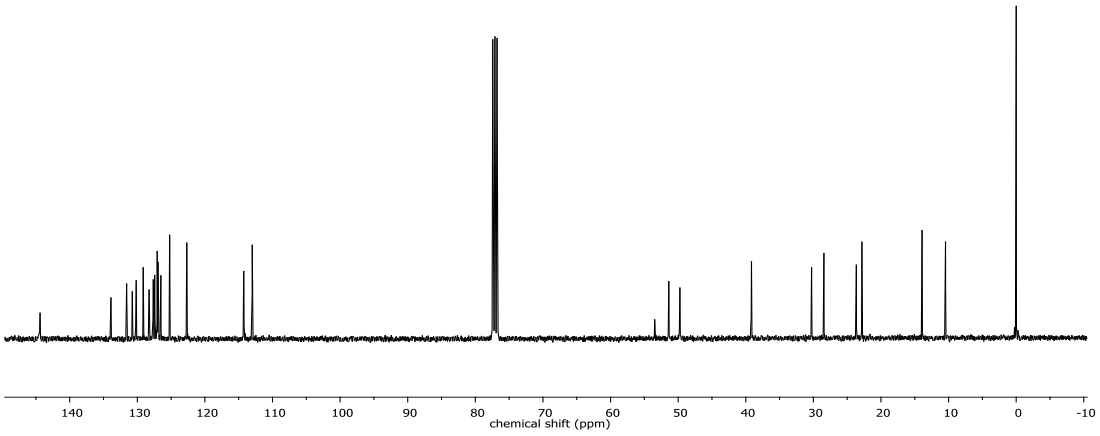

Figure 27. ^{13}C NMR Spectrum of 2g

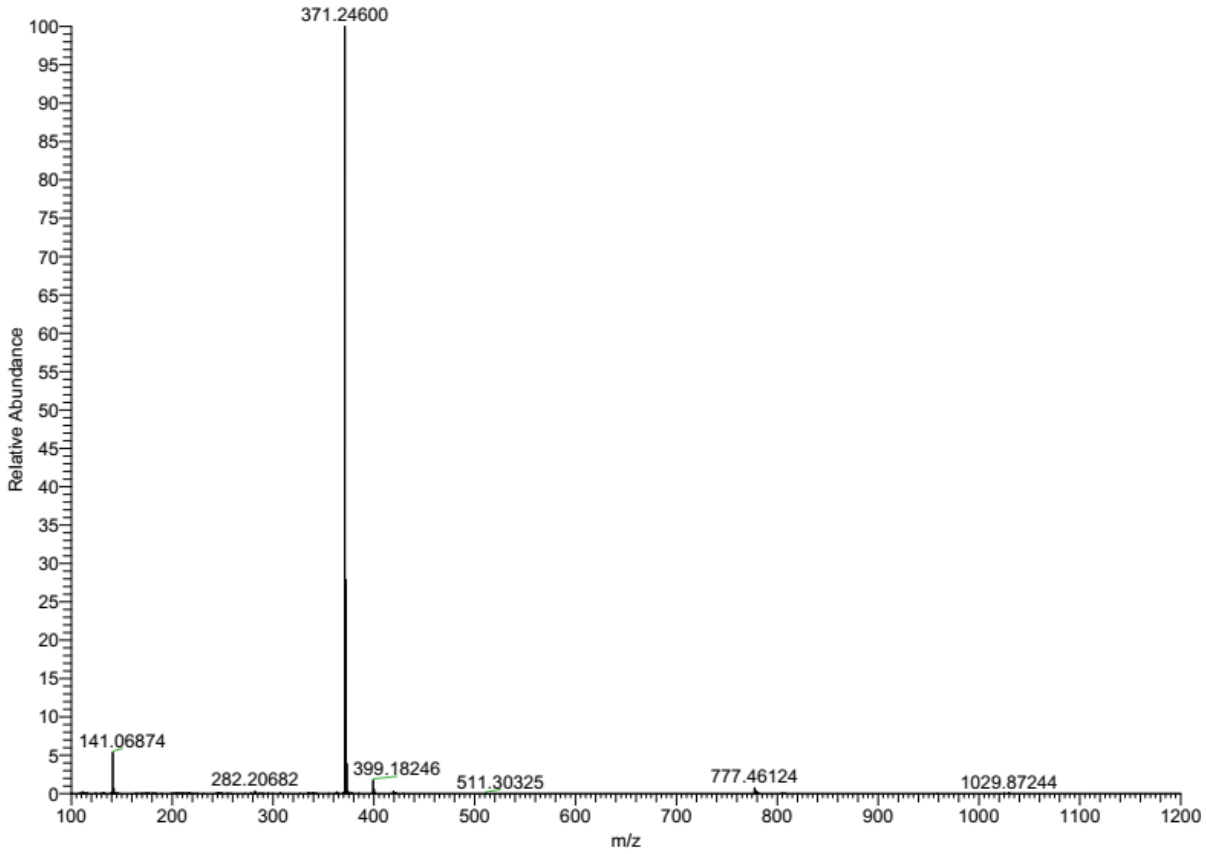

Figure 28. Mass Spectrum of 2g

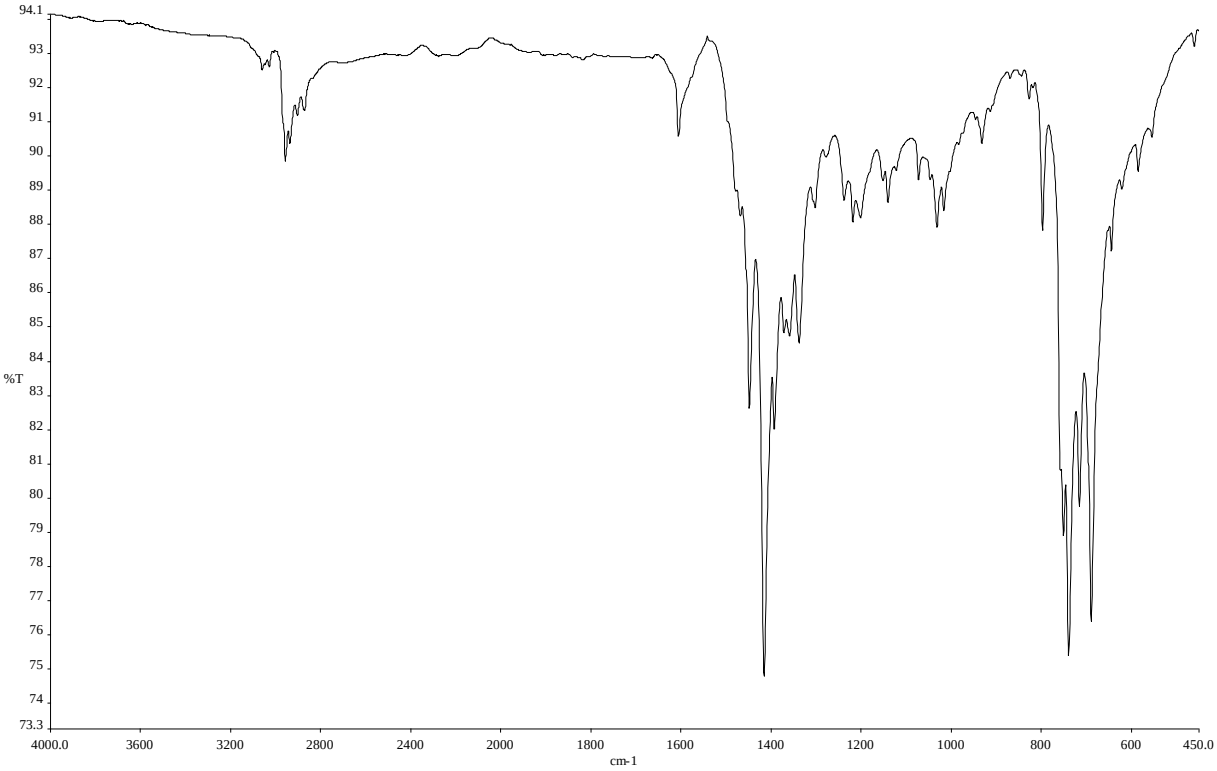

Figure 29. IR Spectrum of 3a

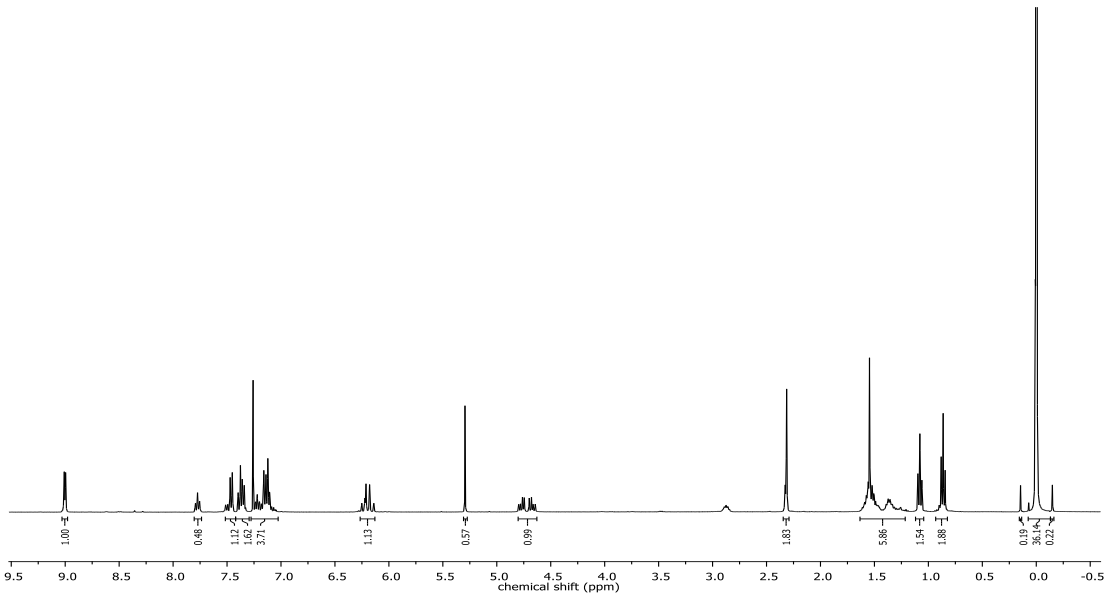

Figure 30. ^{1}H NMR Spectrum of 3a

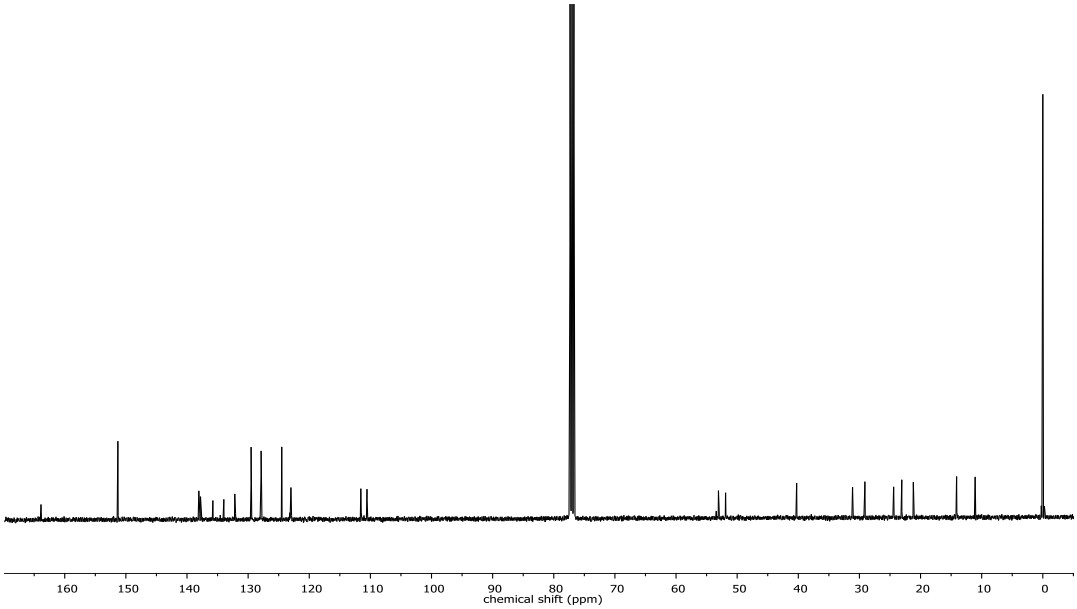

Figure 31. ^{13}C NMR Spectrum of 3a

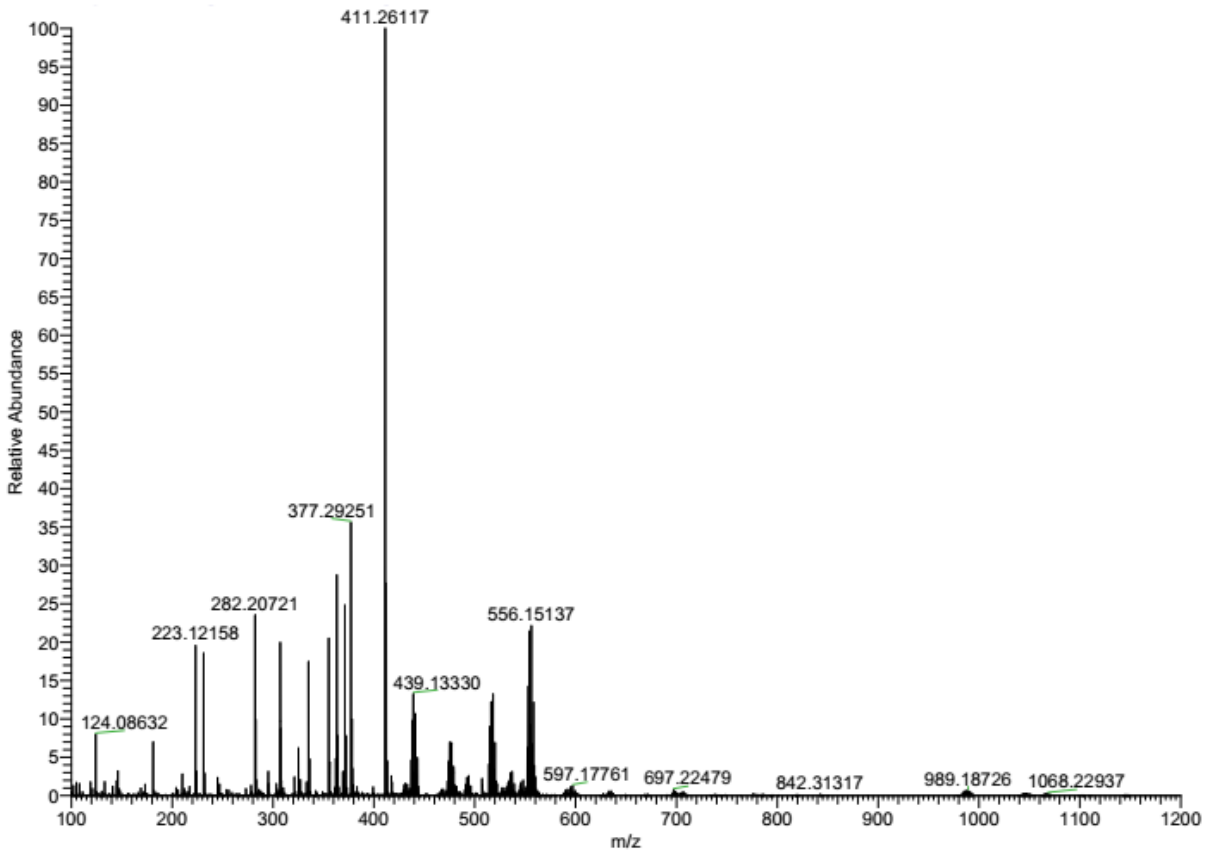

Figure 32. Mass Spectrum of 3a

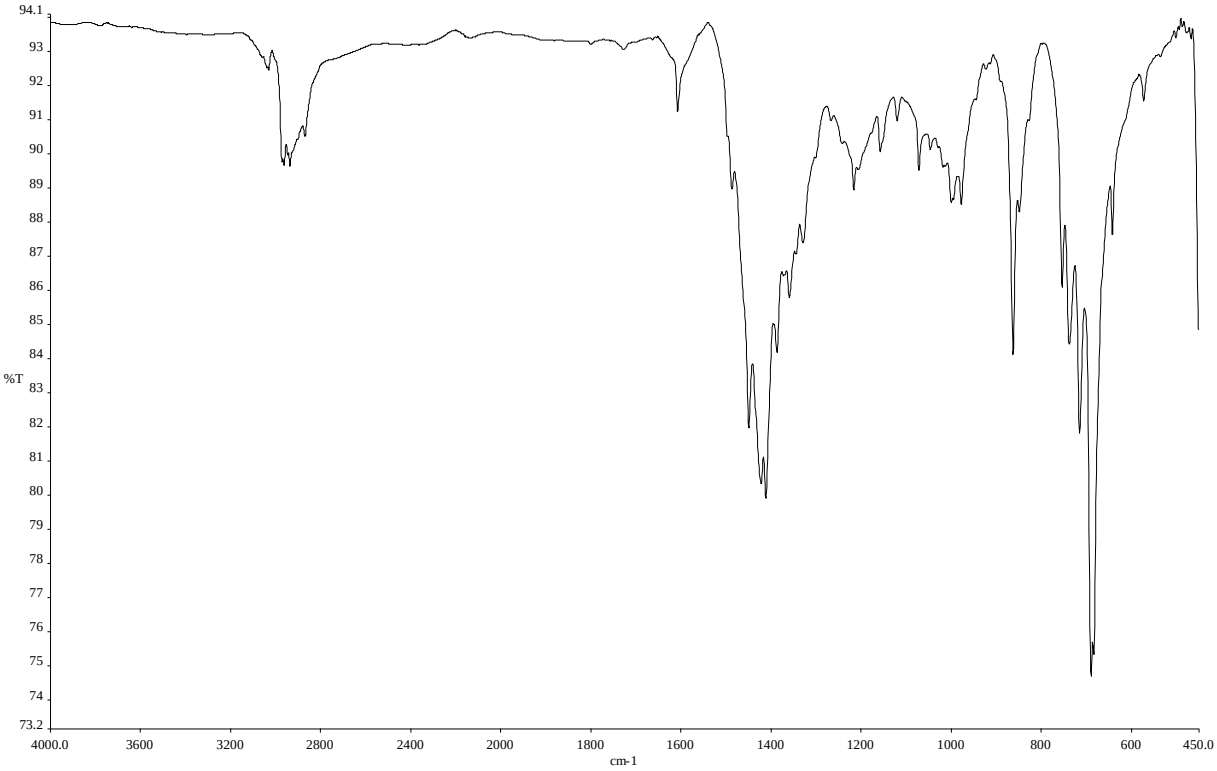

Figure 33. IR Spectrum of 3b

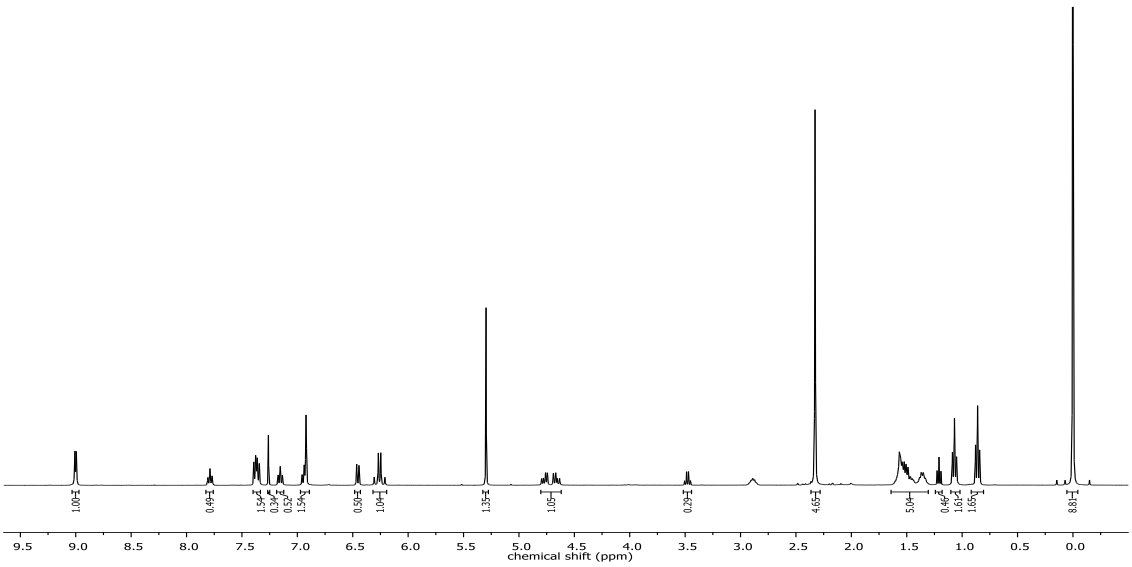

Figure 34. ^{1}H NMR Spectrum of 3b

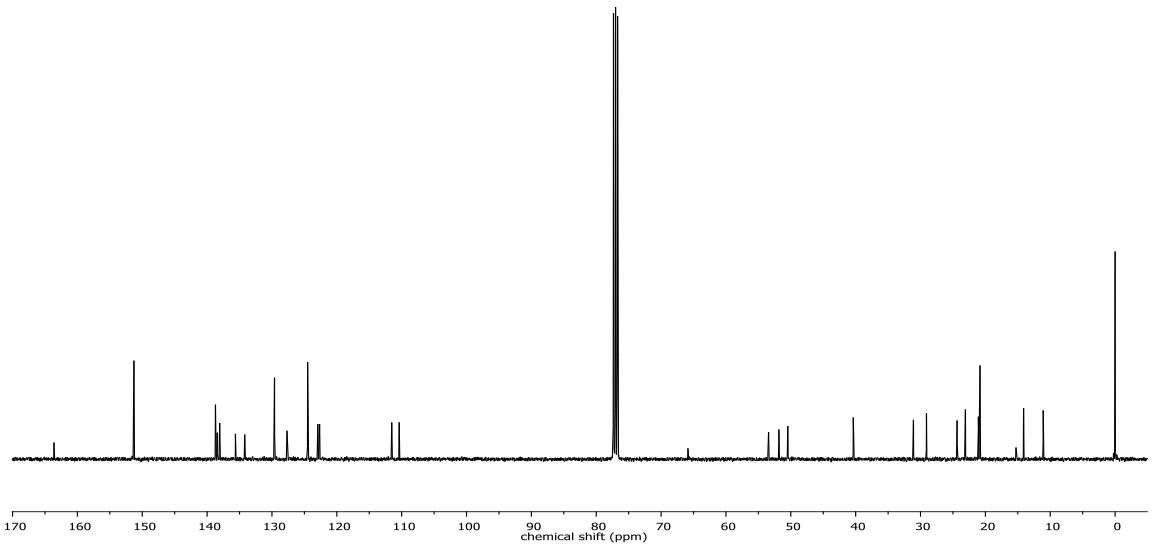

Figure 35. ^{13}C NMR Spectrum of 3b

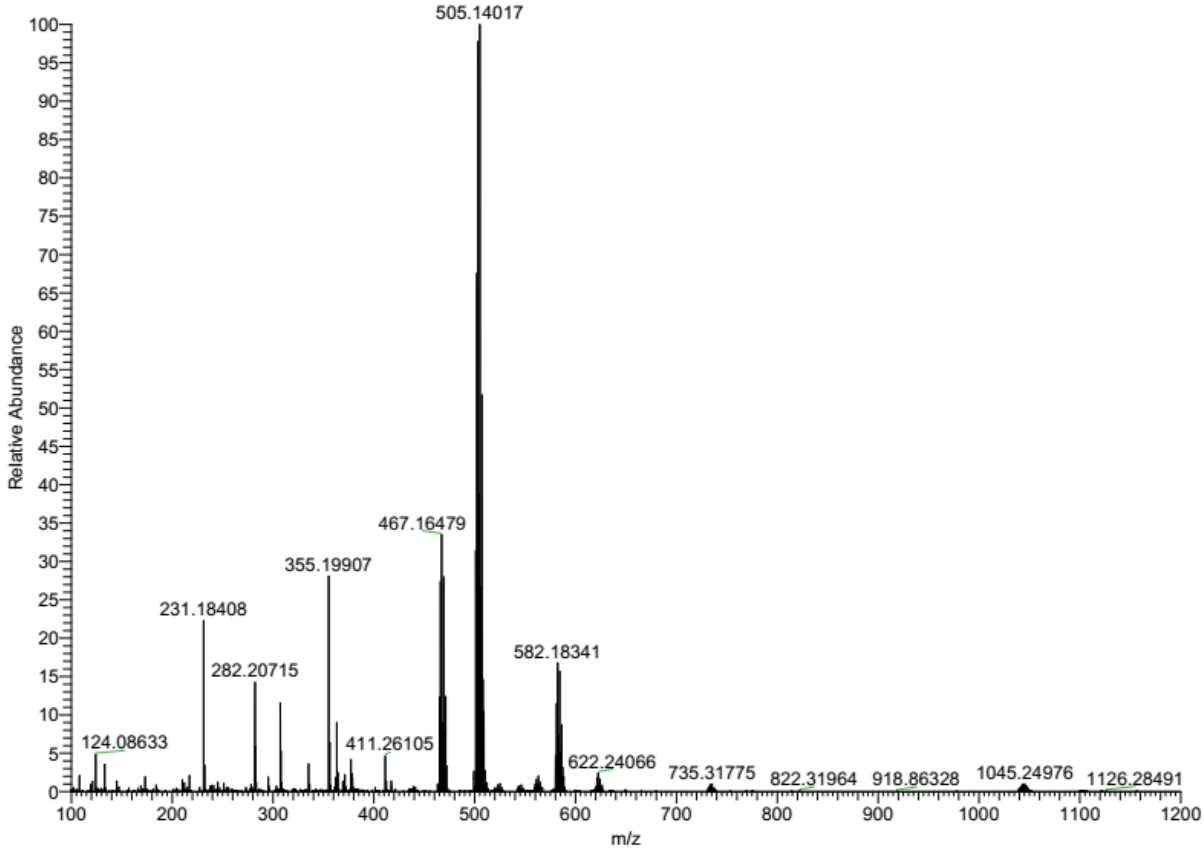

Figure 36. Mass Spectrum of 3b

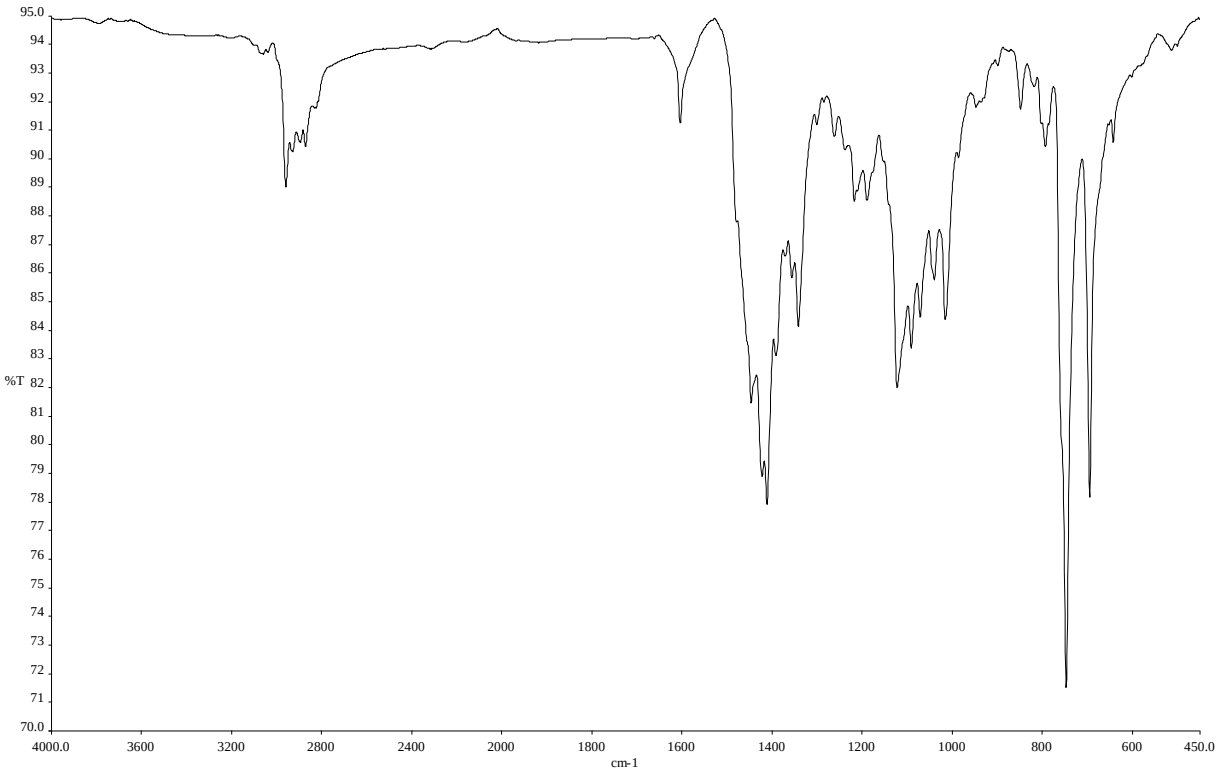

Figure 37. IR Spectrum of 3c

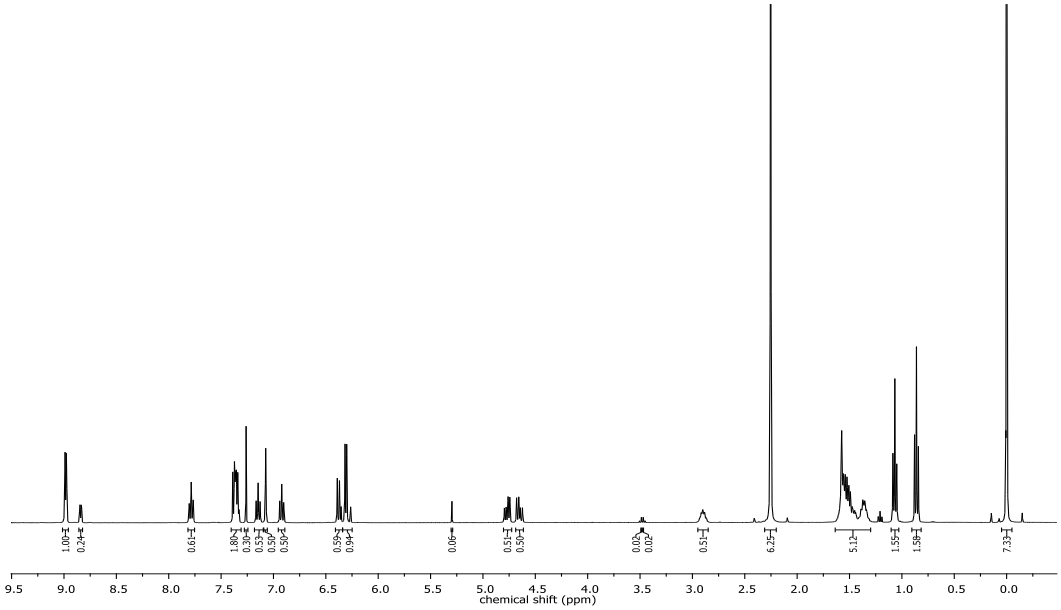

Figure 38. ^{1}H NMR Spectrum of 3c

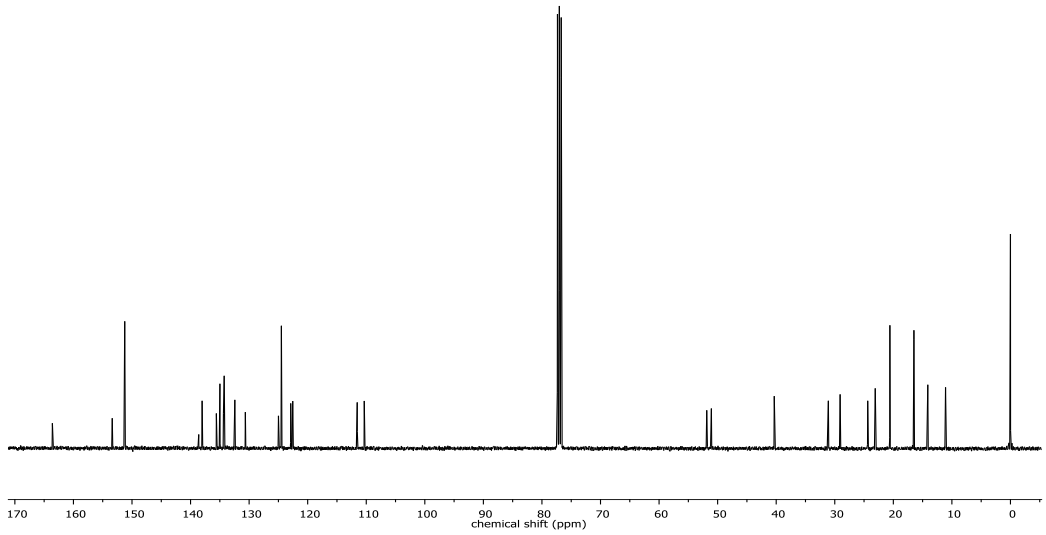

Figure 39. ^{13}C NMR Spectrum of 3c

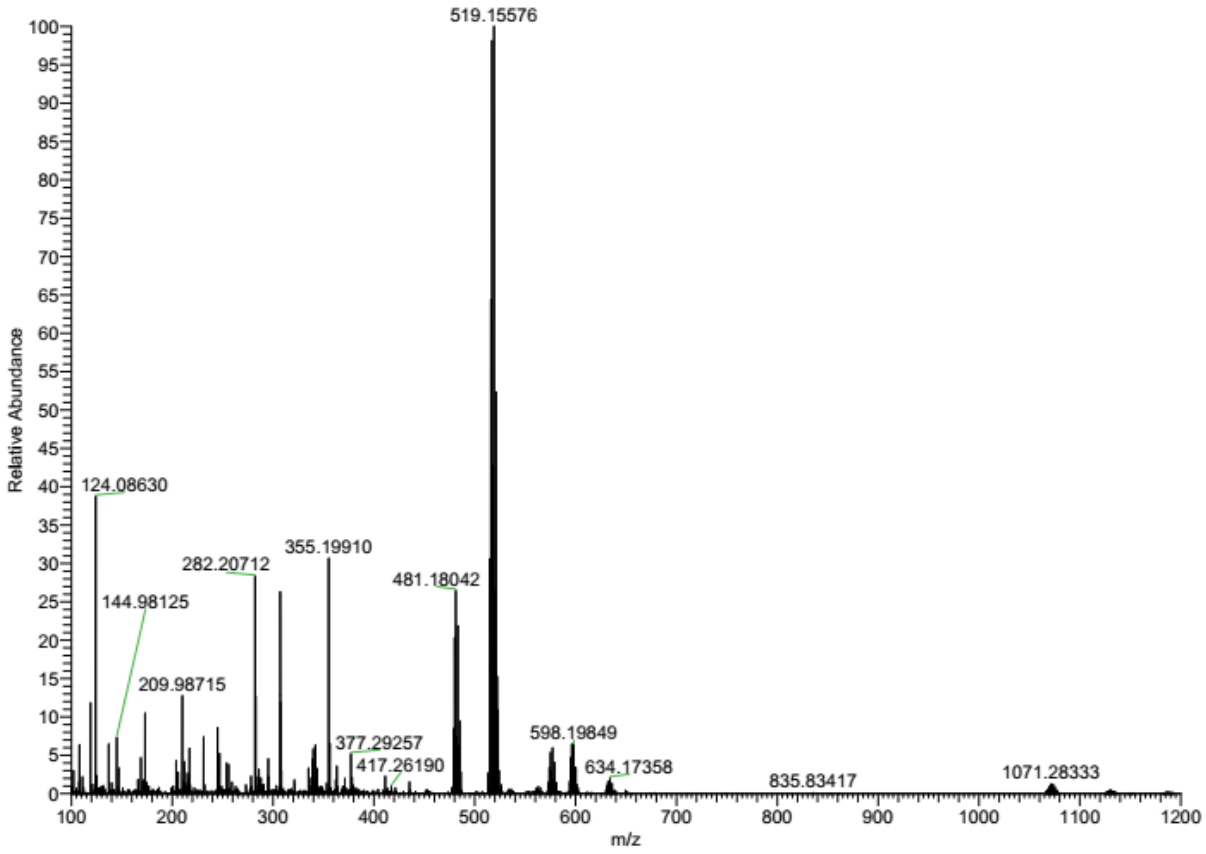

Figure 40. Mass Spectrum of 3c

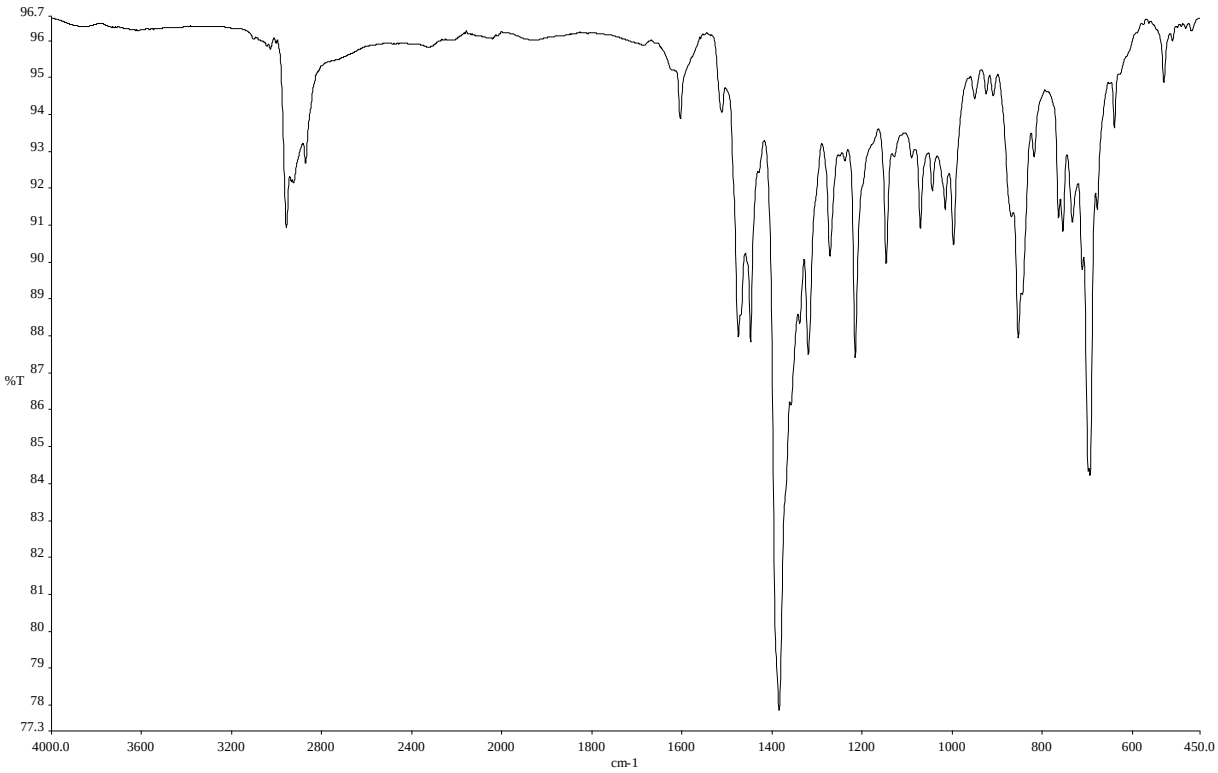

Figure 41. ^{1}H NMR Spectrum of 3d

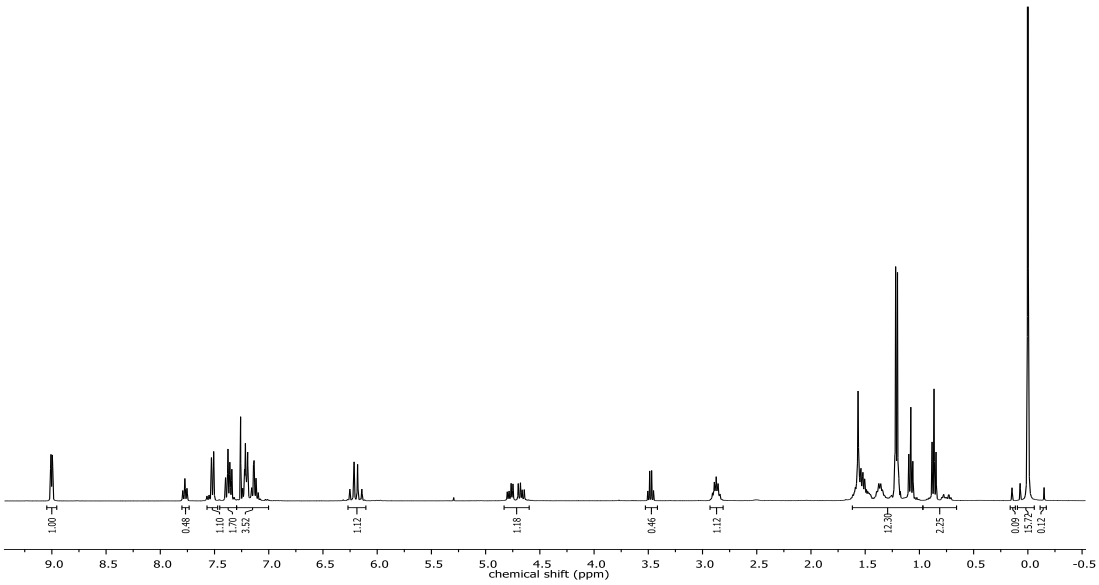

Figure 42. ^{1}H NMR Spectrum of 3d

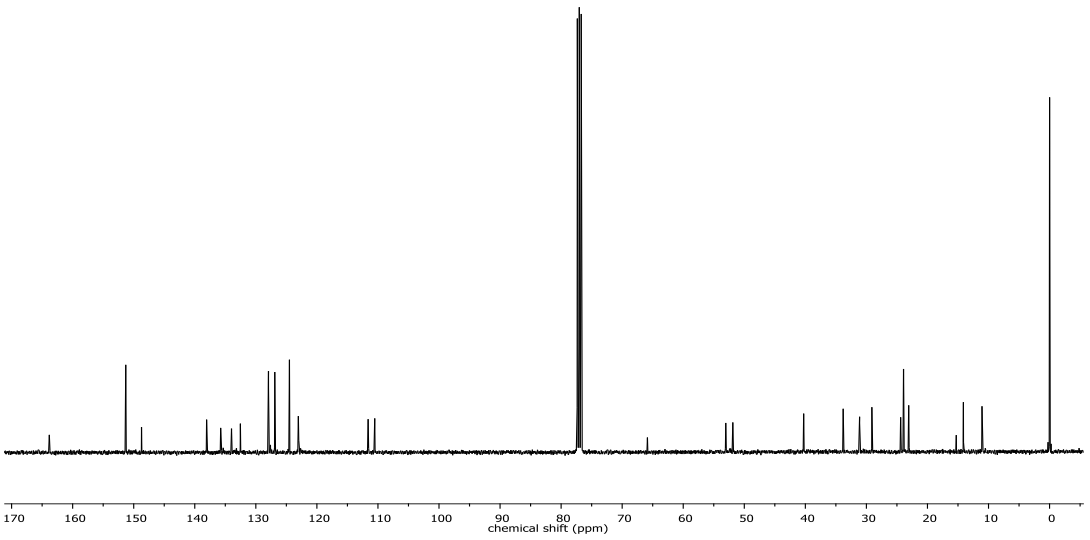

Figure 43. ^{13}C NMR Spectrum of 3d

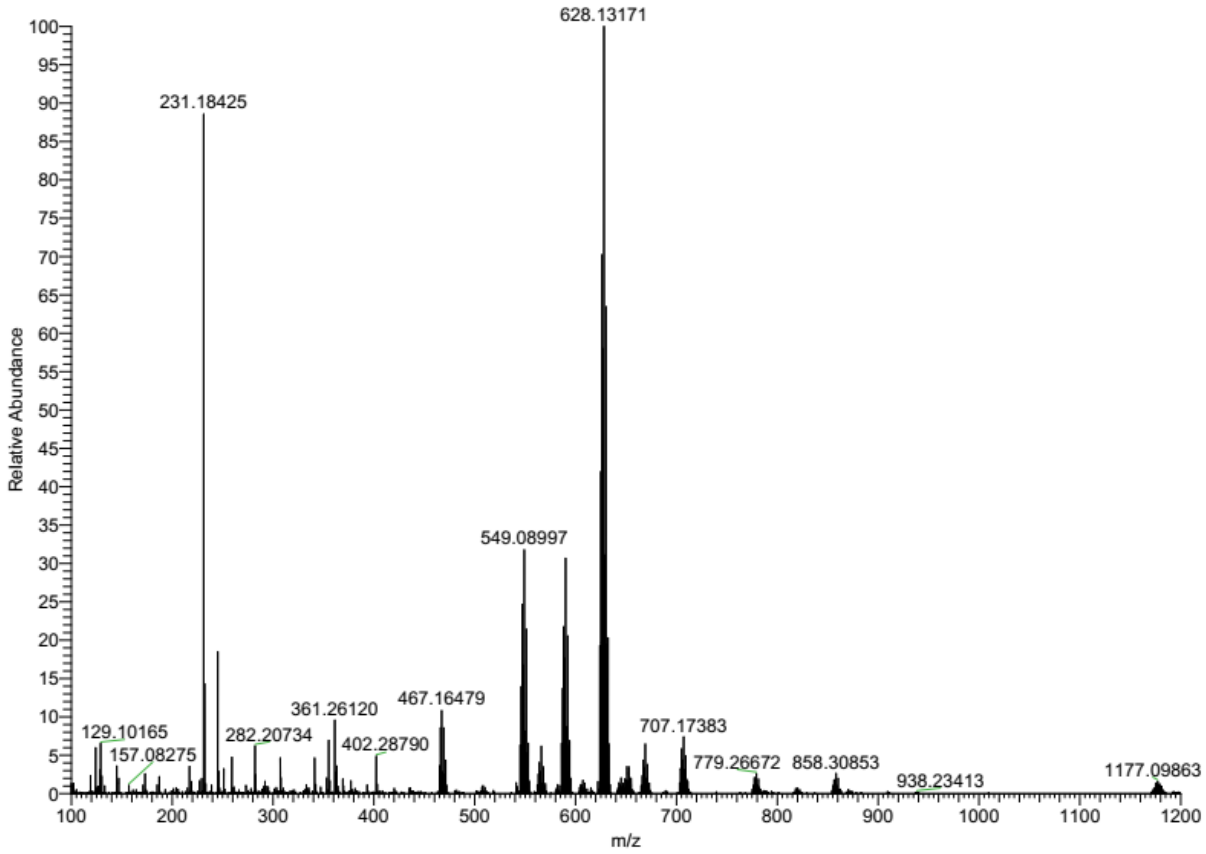

Figure 44. Mass Spectrum of 3d

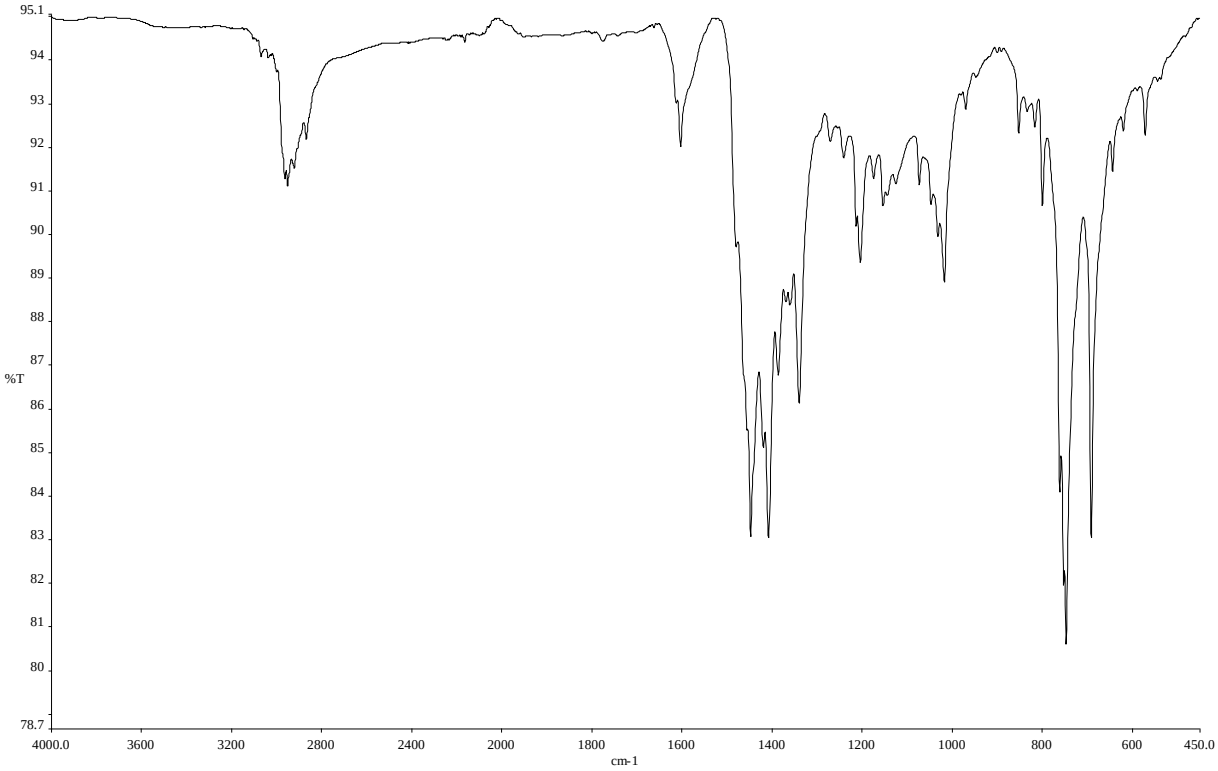

Figure 45. IR Spectrum of 3e

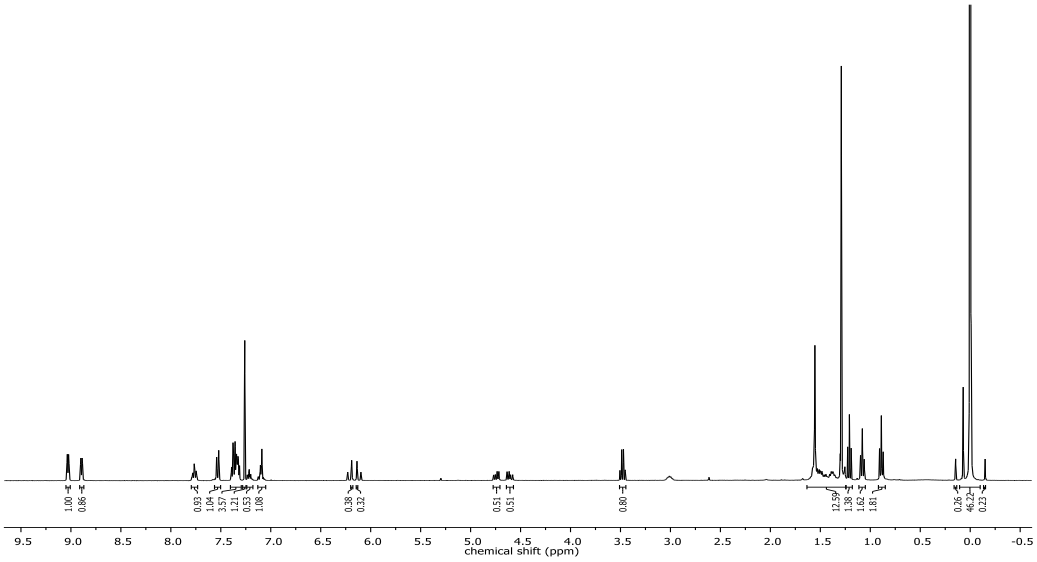

Figure 46. ^{1}H NMR Spectrum of 3e

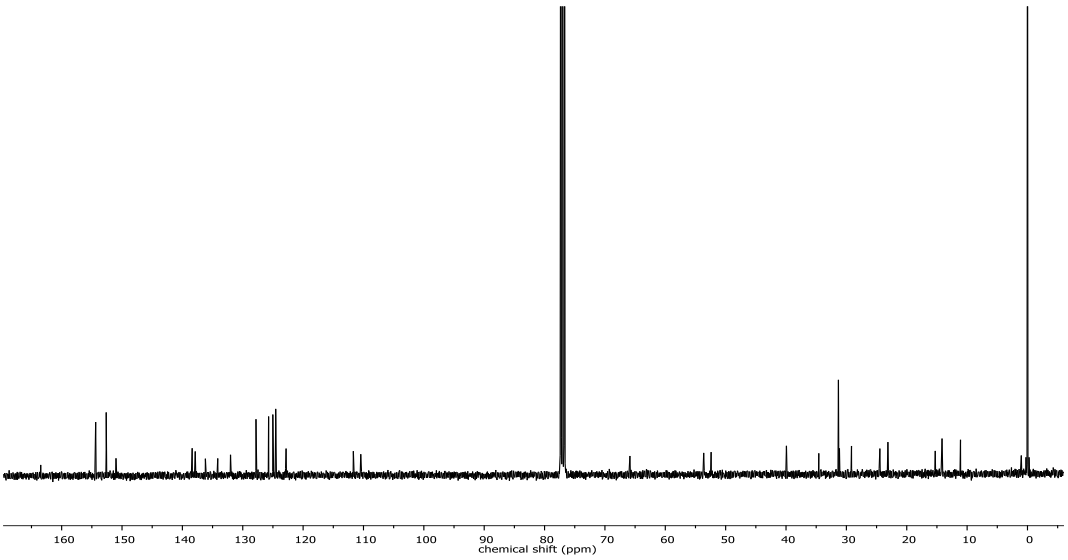

Figure 47. ^{13}C NMR Spectrum of 3e

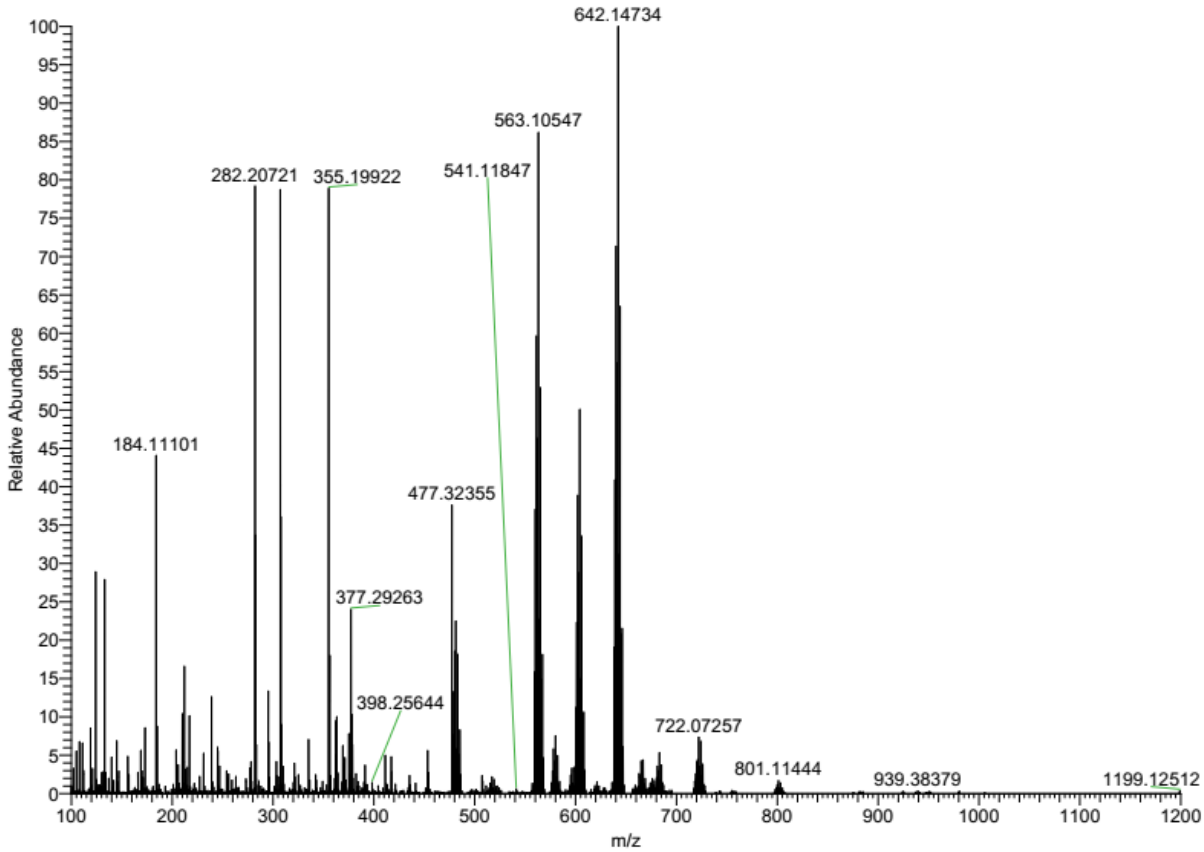

Figure 48. Mass Spectrum of 3e

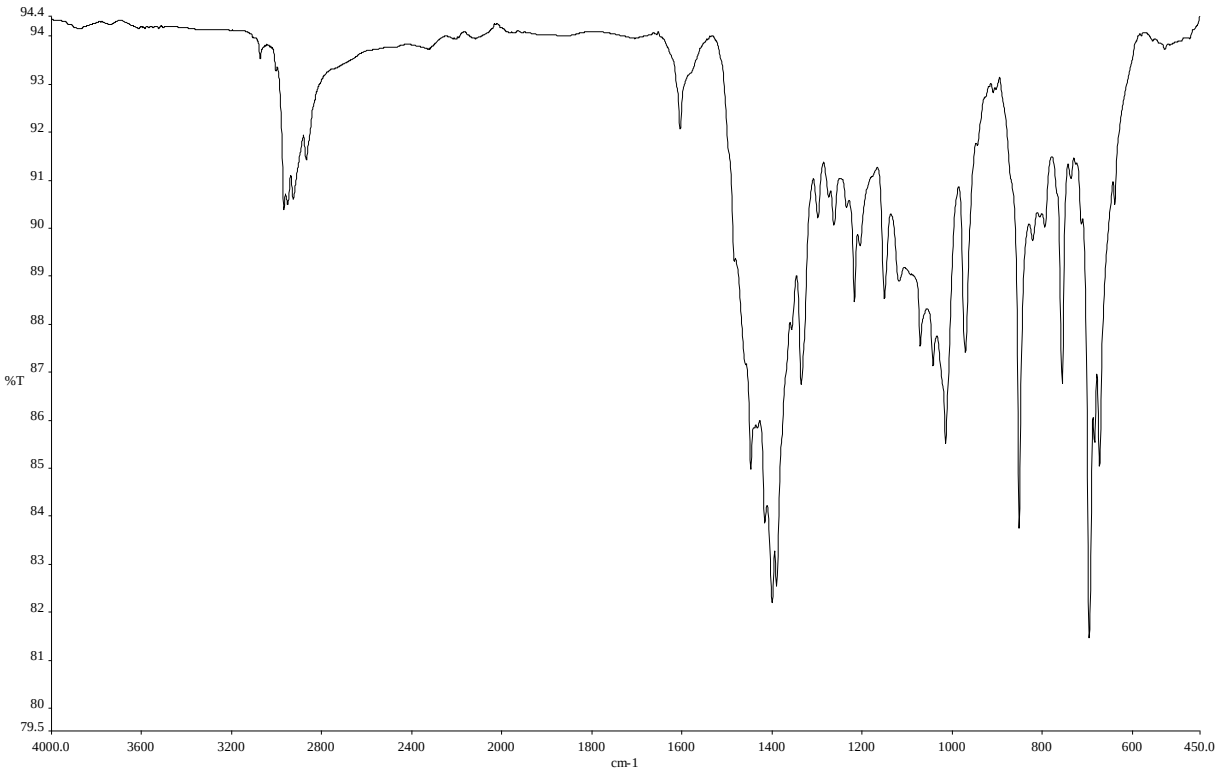

Figure 49. IR Spectrum of 3f

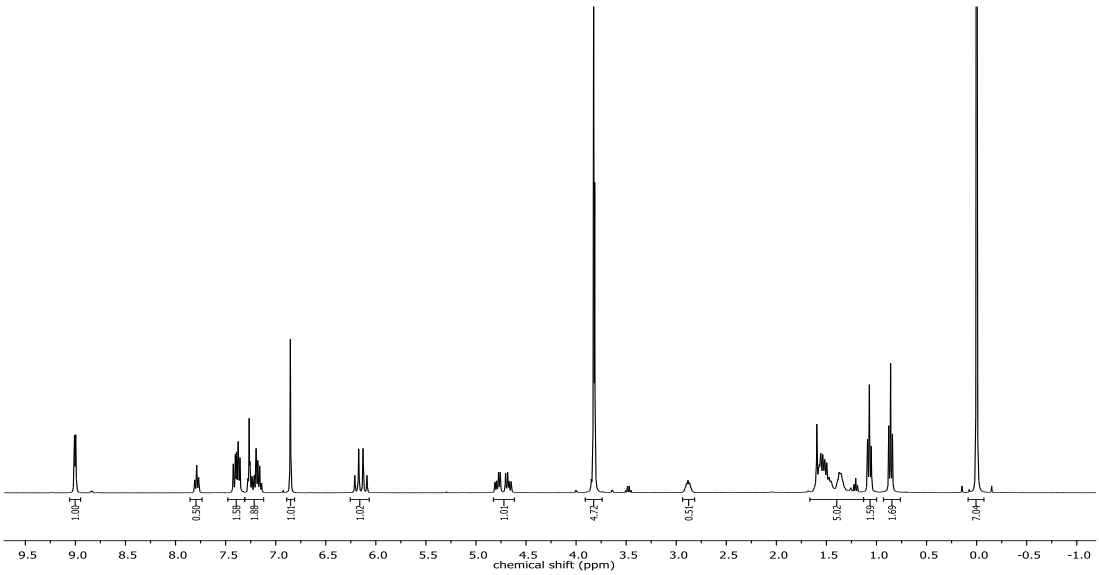

Figure 50. ^{1}H NMR Spectrum of 3f

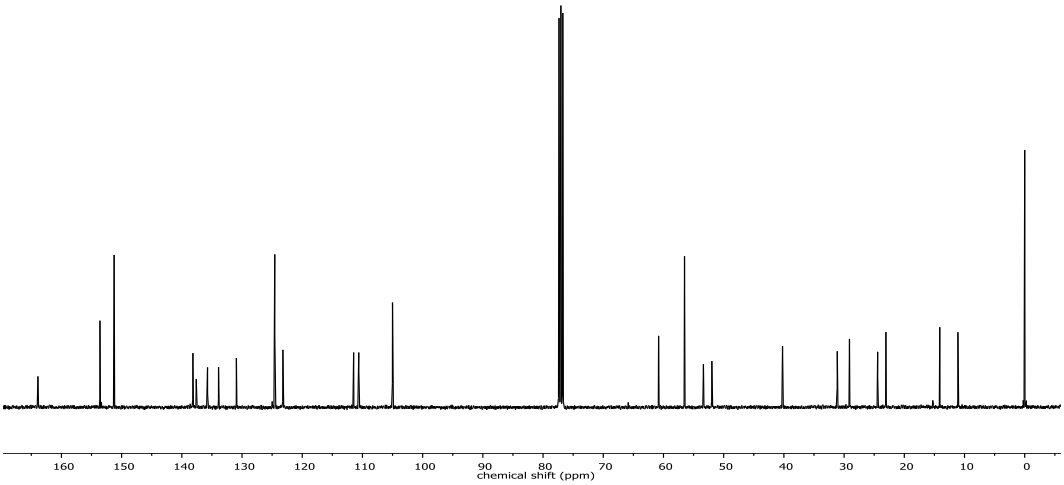

Figure 51. ^{13}C NMR Spectrum of 3f

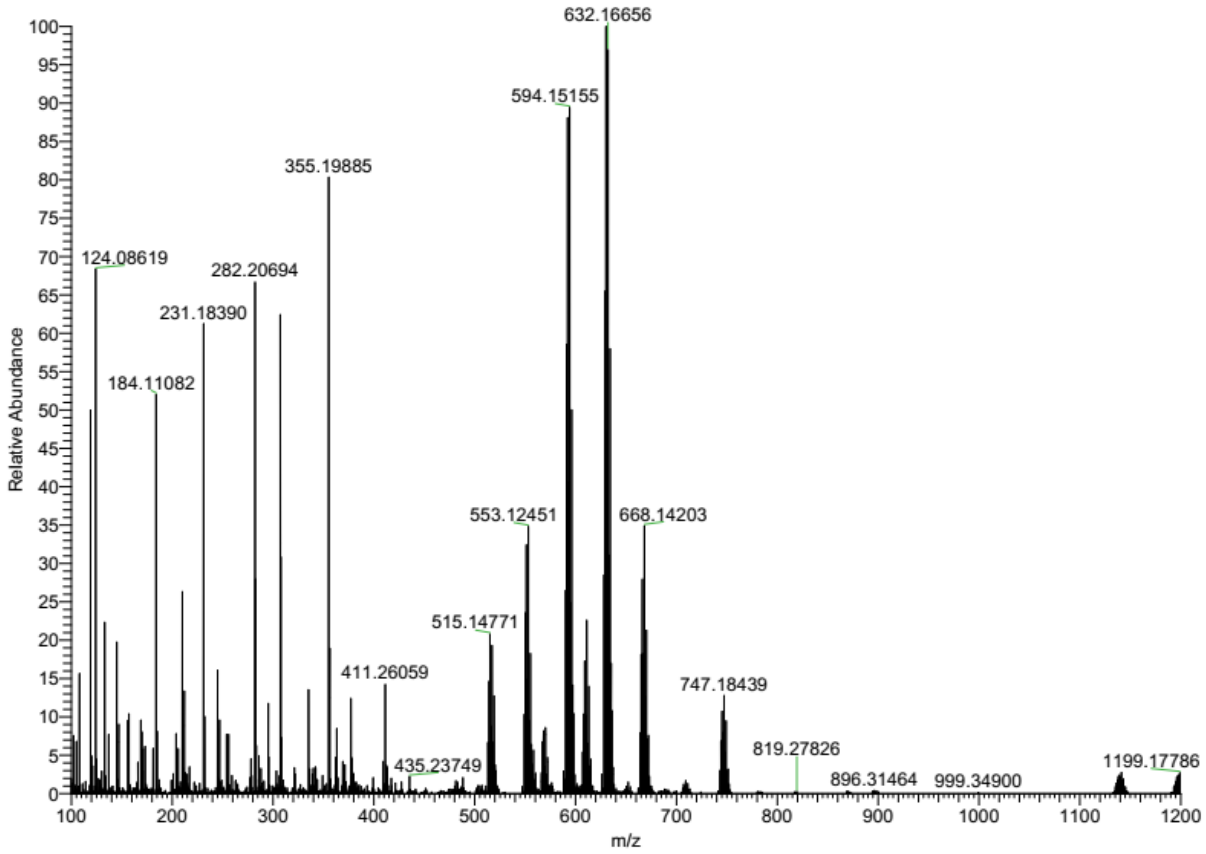

Figure 52. Mass Spectrum of 3f

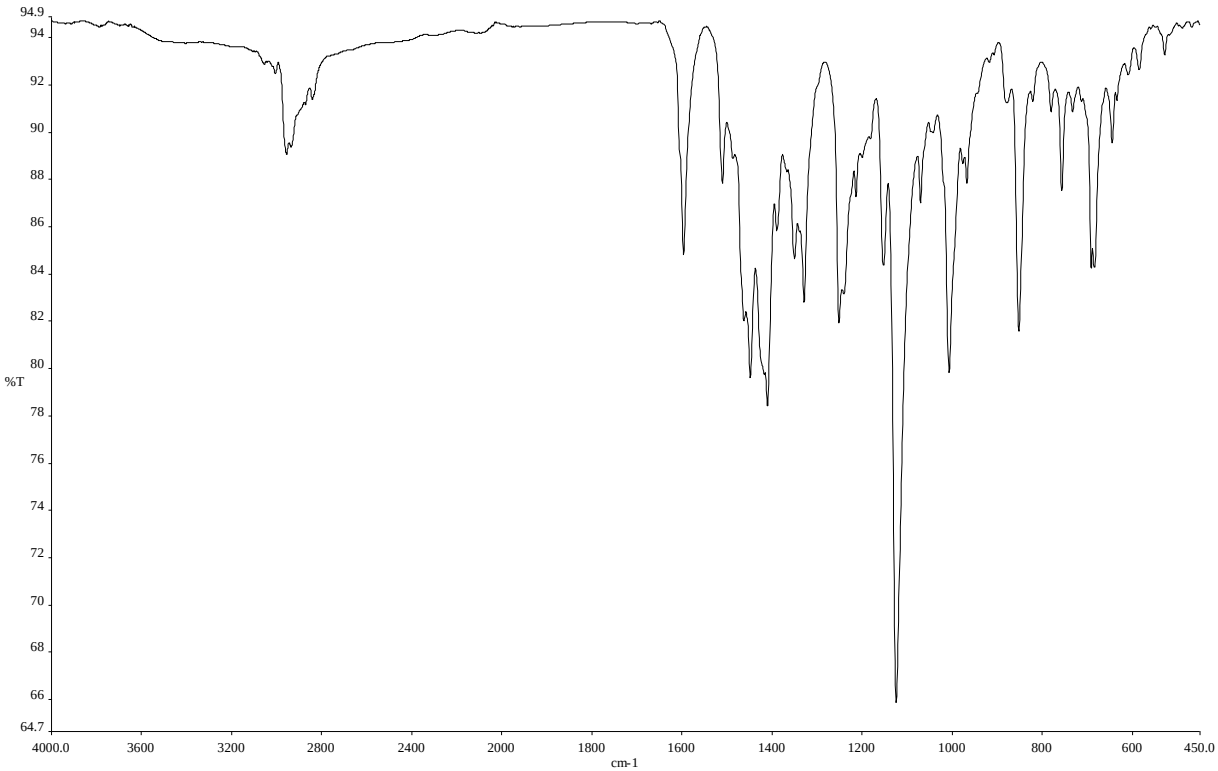

Figure 53. IR Spectrum of 3g

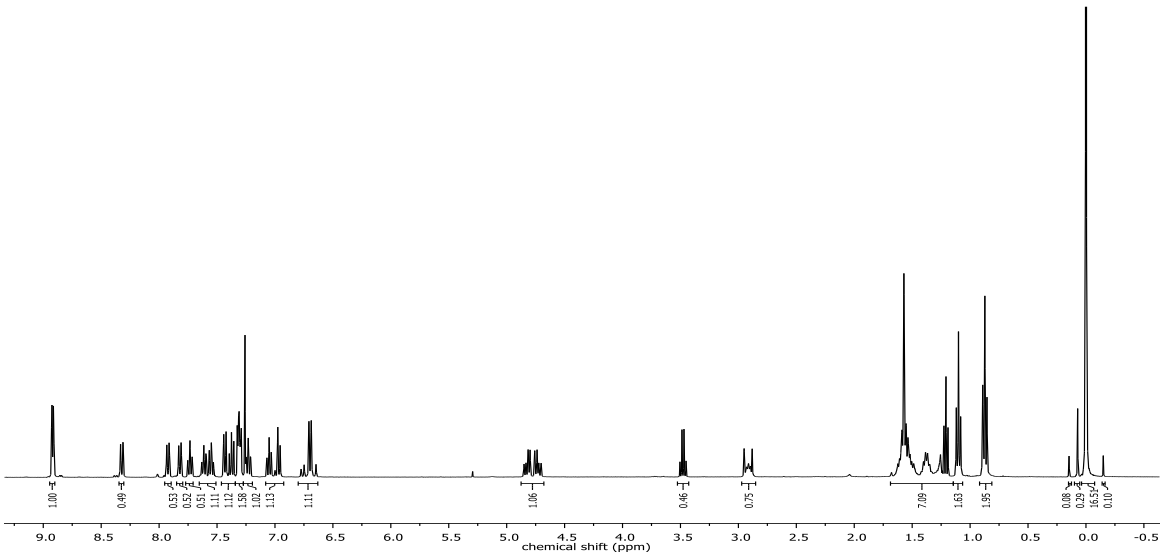

Figure 54. ^{1}H NMR Spectrum of 3g

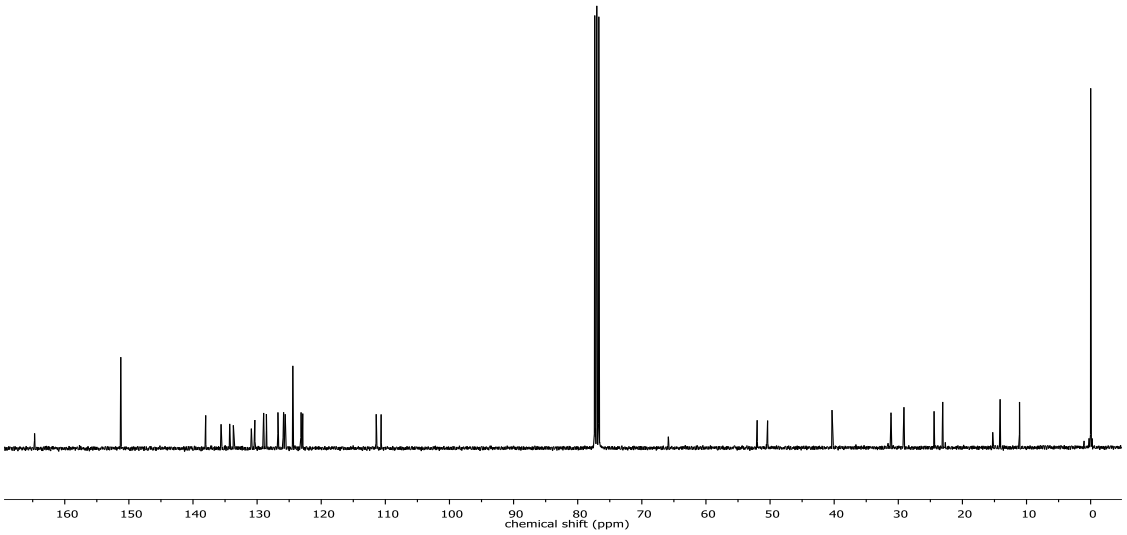

Figure 55. ^{13}C NMR Spectrum of 3g

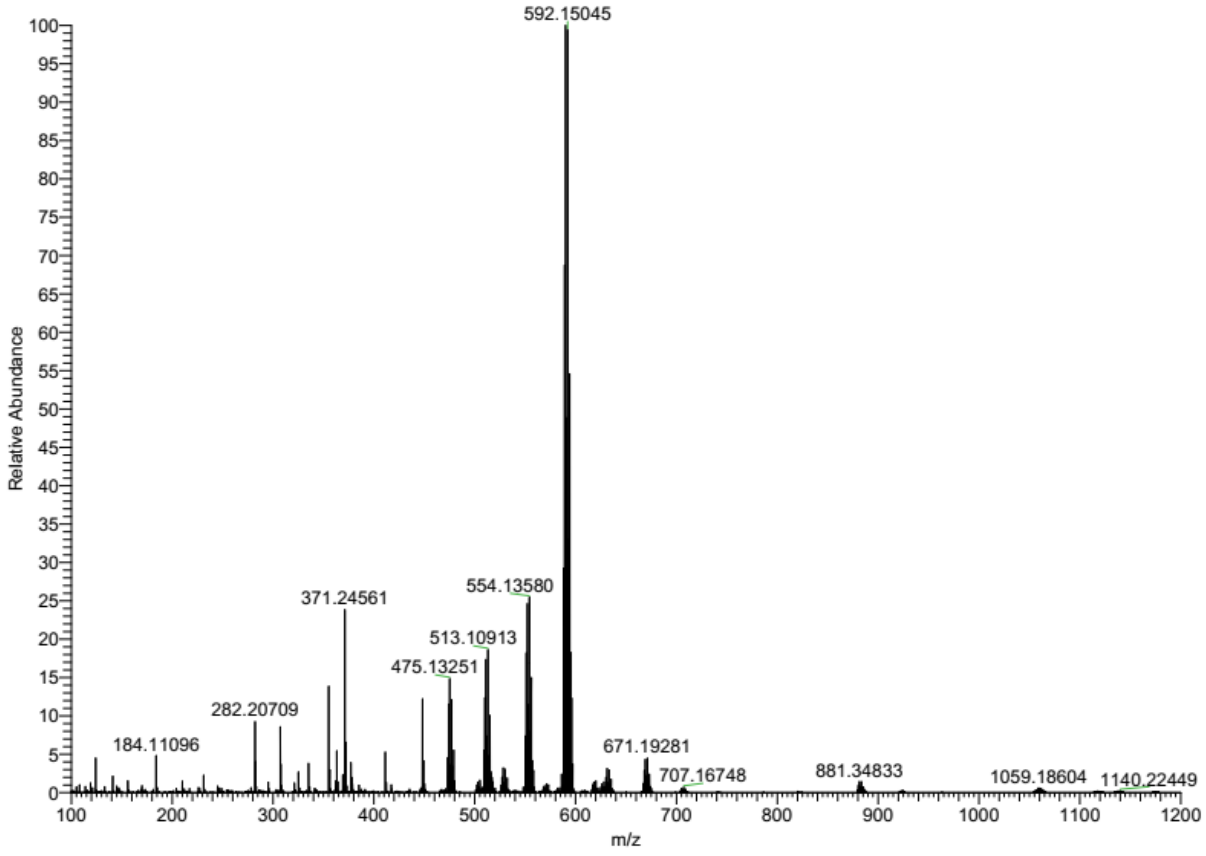

Figure 56. Mass Spectrum of 3g