

Supplementary data

Design, preparation and characterization of

$\text{Fe}_3\text{O}_4@\text{SiO}_2@\text{ECH}@\text{Thiocarbazide}@\text{Au(III)}@\text{Chitosan}$ nanoparticles as a catalyst for the synthesis of 3, 4-dihydropyrano [3,2 -c]chromenes

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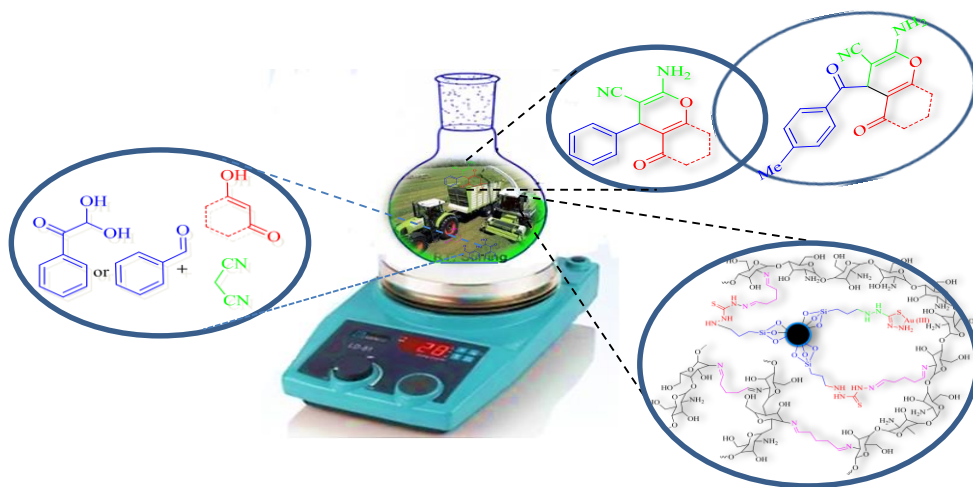


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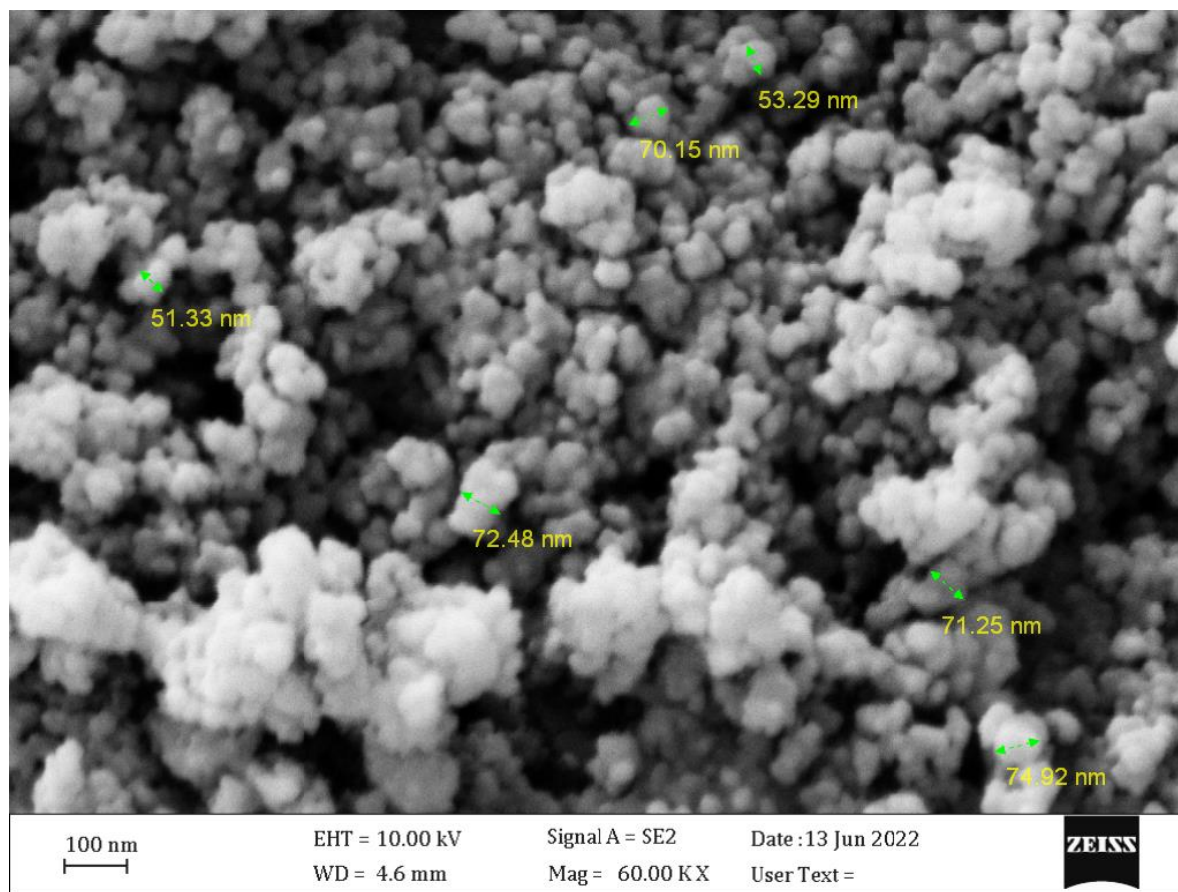


Figure 1: SEM image of $\text{Fe}_3\text{O}_4@\text{SiO}_2@\text{ECH}@\text{Thiocarbazide}@\text{Au(III)}@\text{Chitosan}$

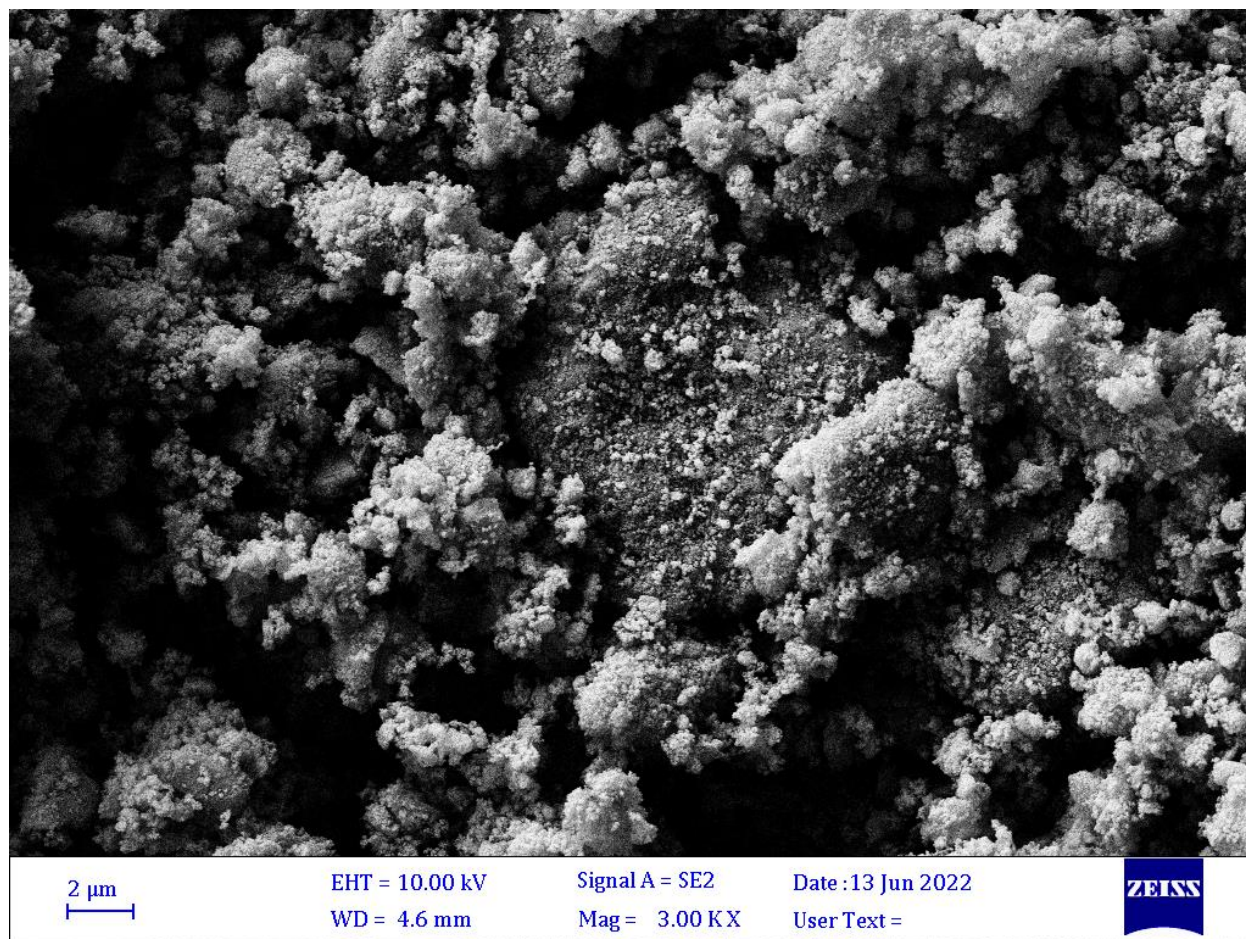


Figure 2: SEM image of Fe₃O₄@SiO₂@ECH@Thiocarbazide@Au(III)@Chitosan

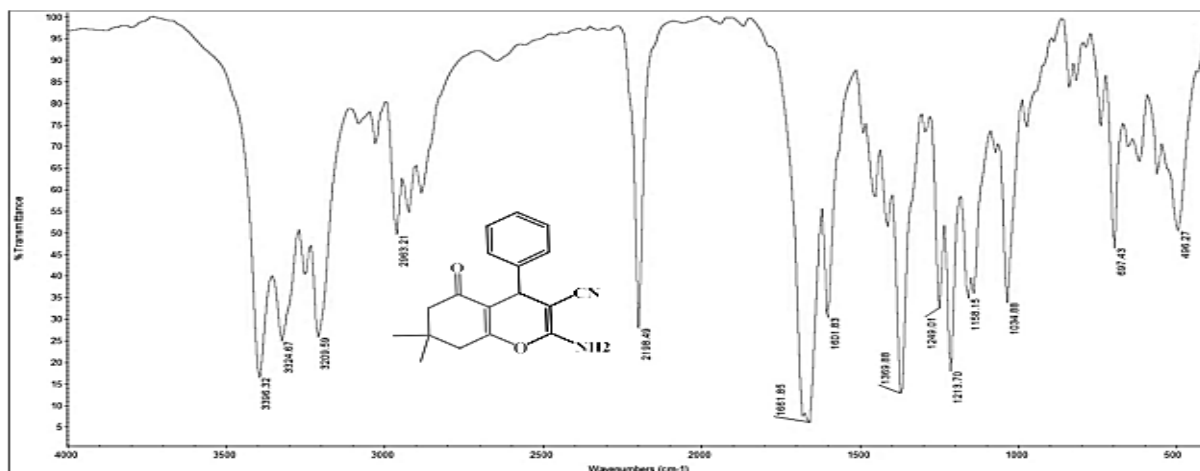


Figure 3: FT-IR spectrum of 2-amino-7,7-dimethyl-5-oxo-4-phenyl-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

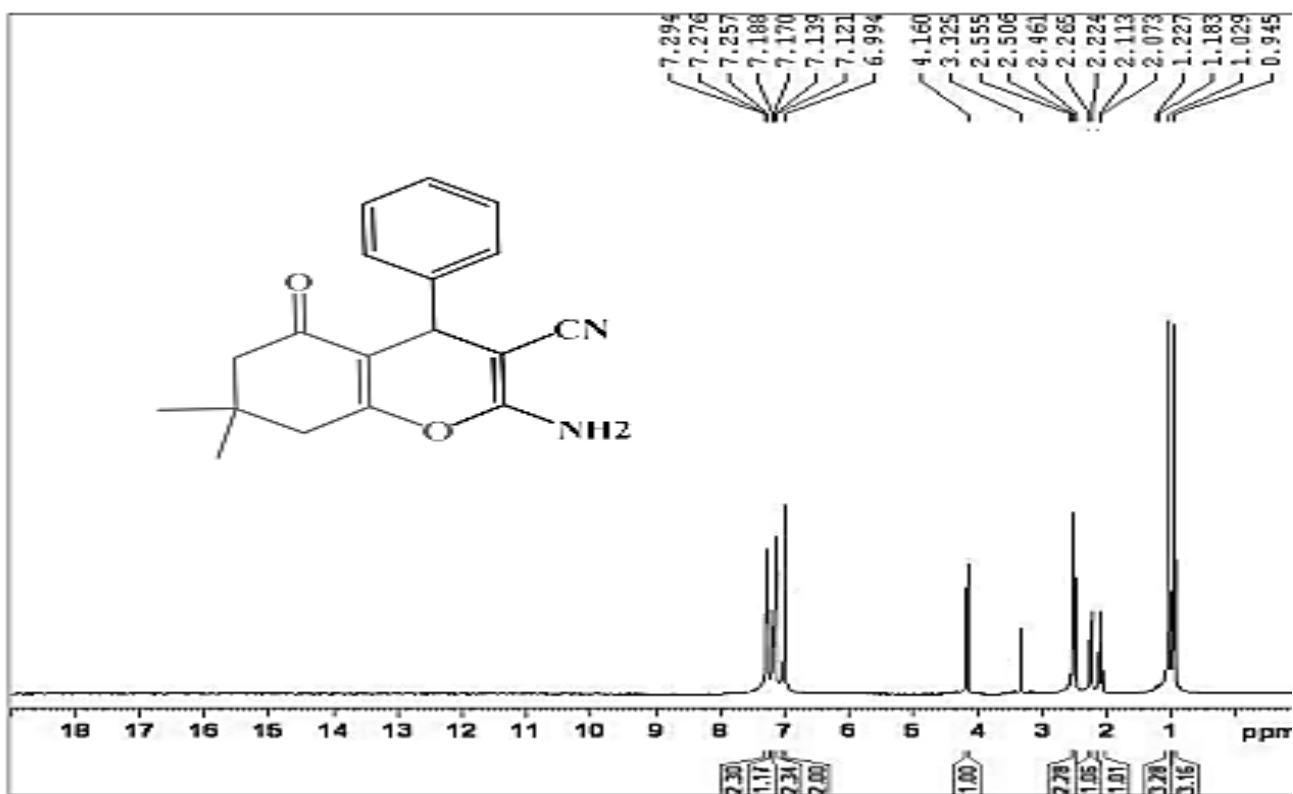


Figure 4: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-7,7-dimethyl-5-oxo-4-phenyl-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

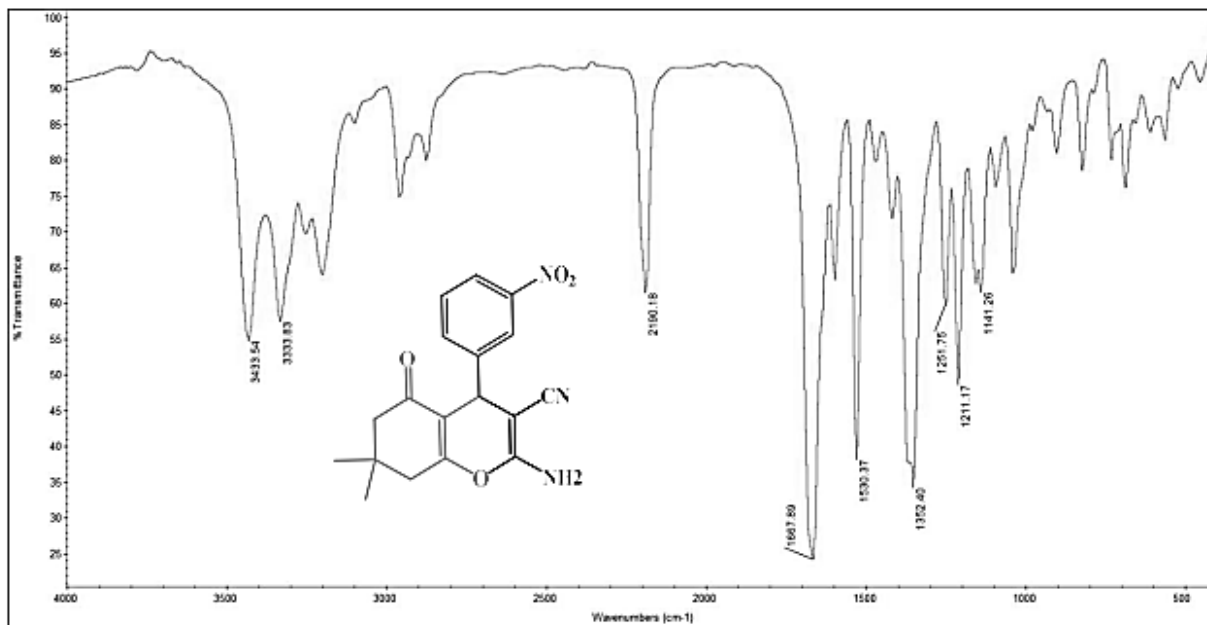


Figure 5: FT-IR spectrum of 2-amino-7,7-dimethyl-4-(3-nitrophenyl)-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

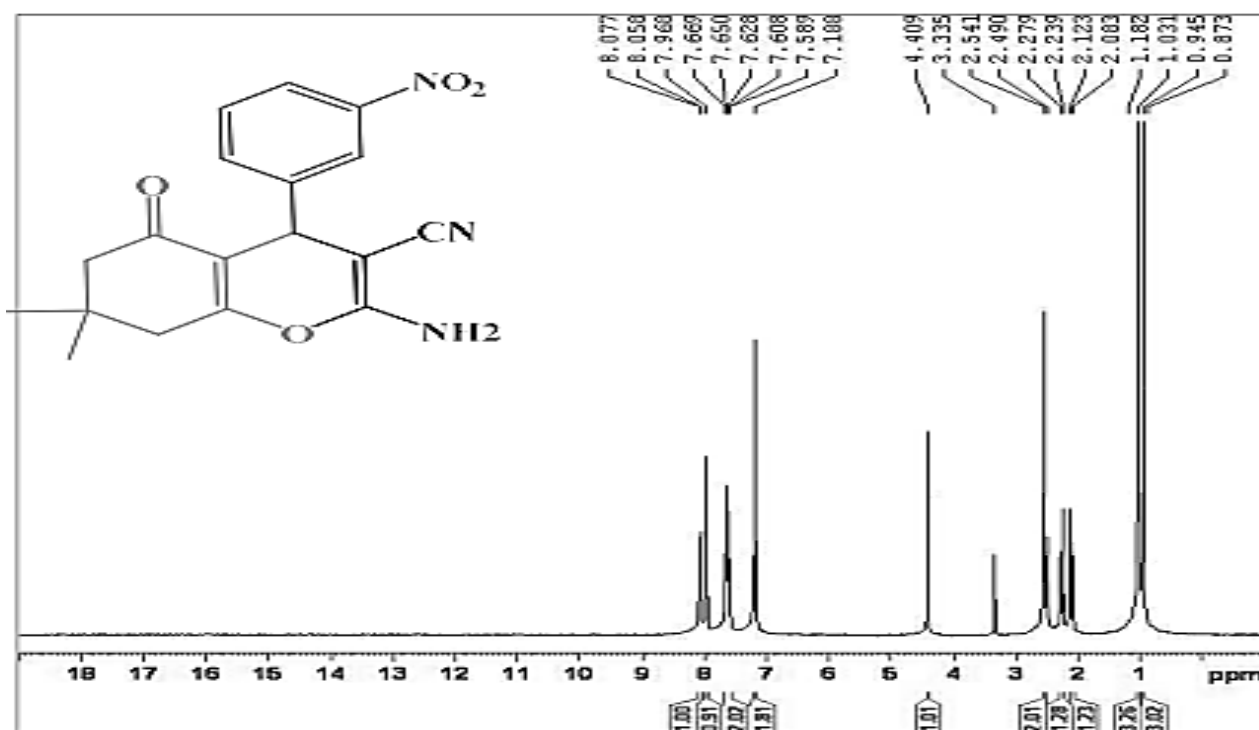


Figure 6: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-7,7-dimethyl-4-(3-nitrophenyl)-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

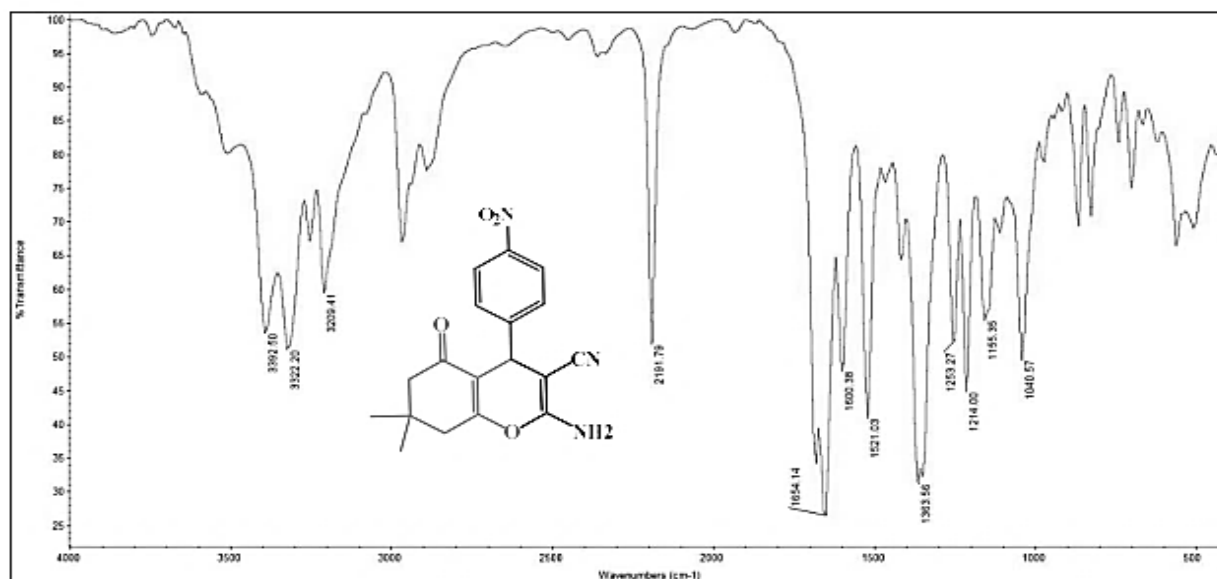


Figure 7: FT-IR spectrum of 2-amino-7,7-dimethyl-4-(4-nitrophenyl)-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

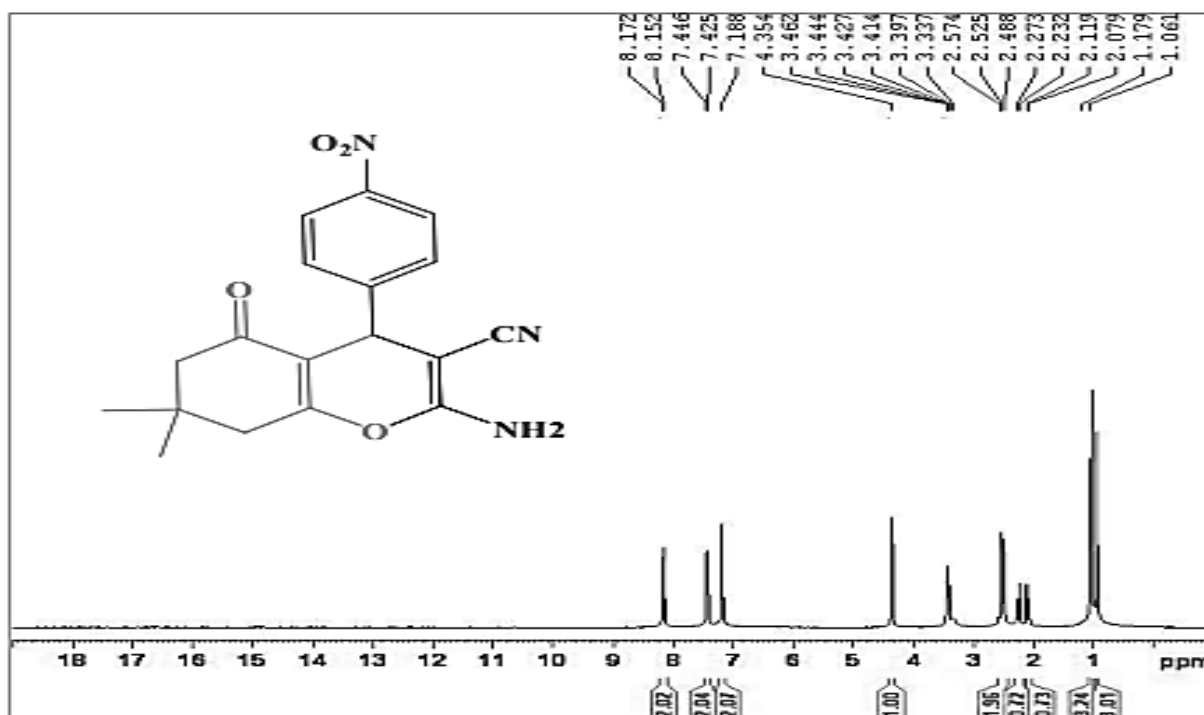


Figure 8: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-7,7-dimethyl-4-(4-nitrophenyl)-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

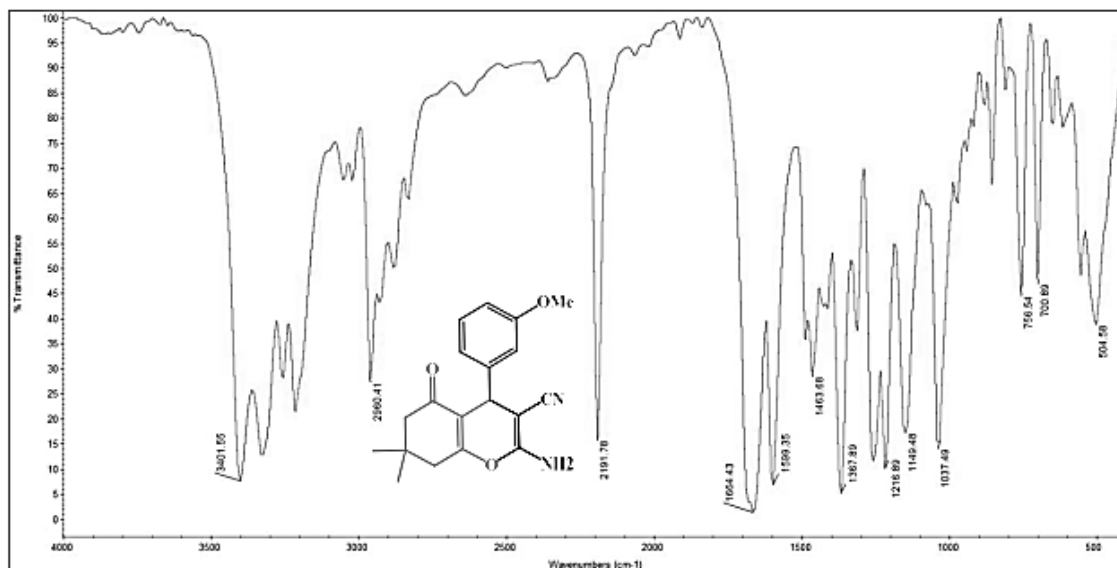


Figure 9: FT-IR spectrum of 2-amino-4-(3-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

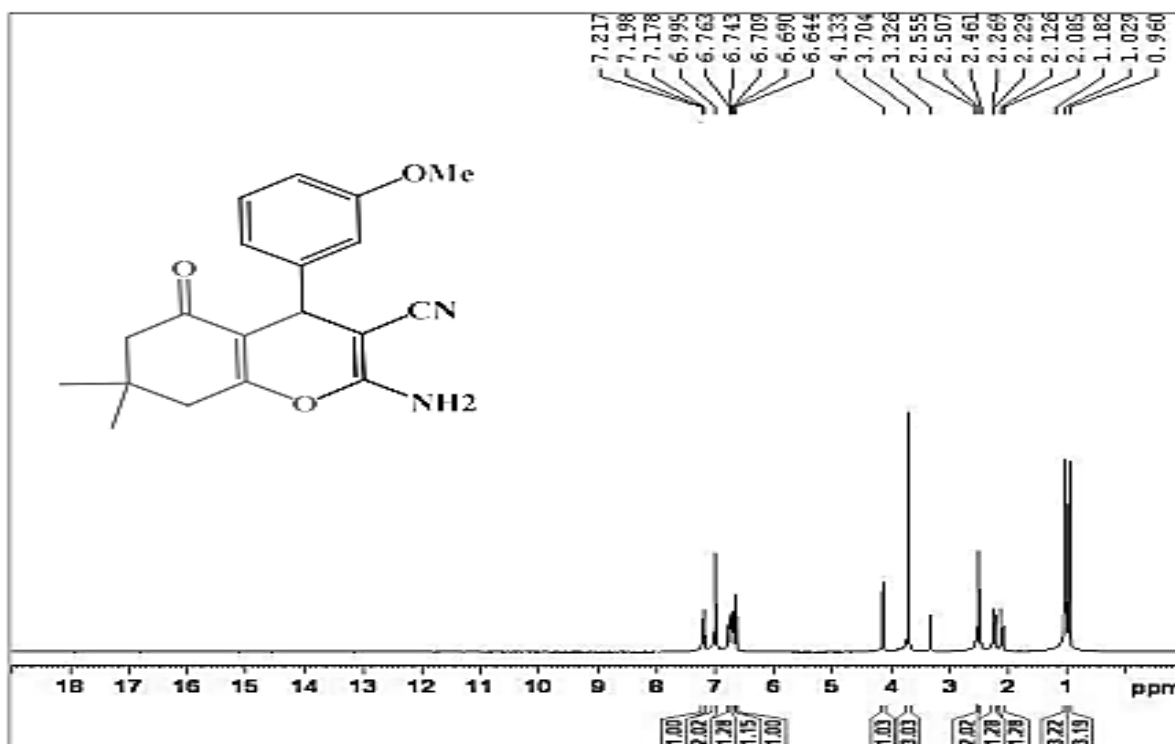


Figure 10: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-4-(3-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

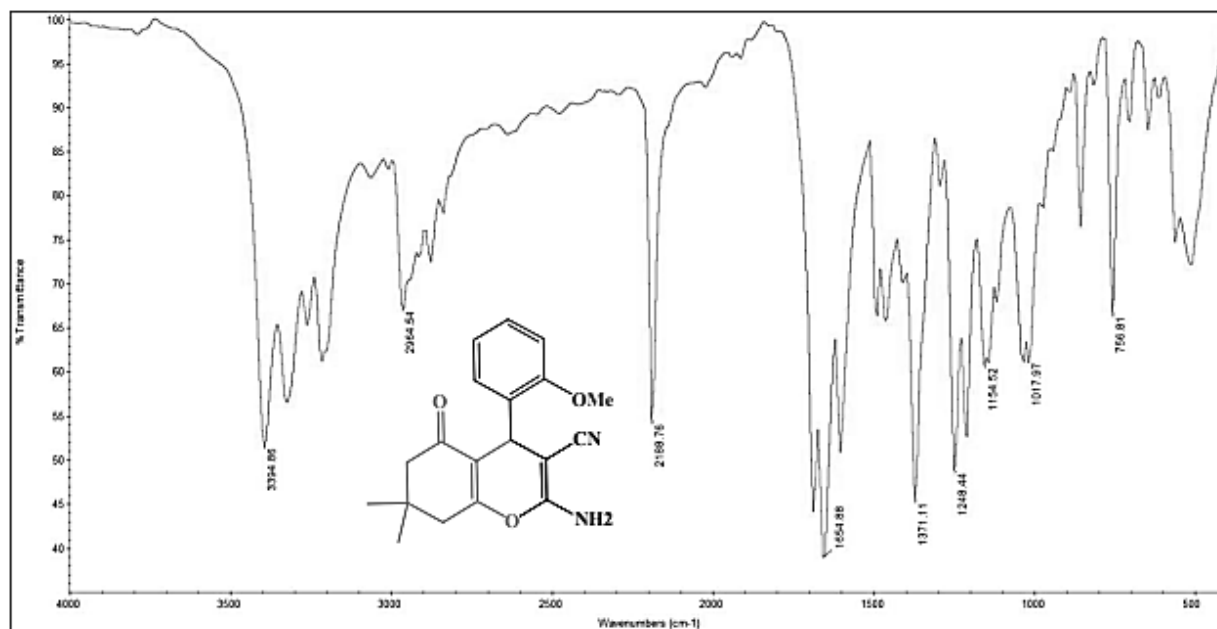


Figure 11: FTIR spectrum of 2-amino-4-(2-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

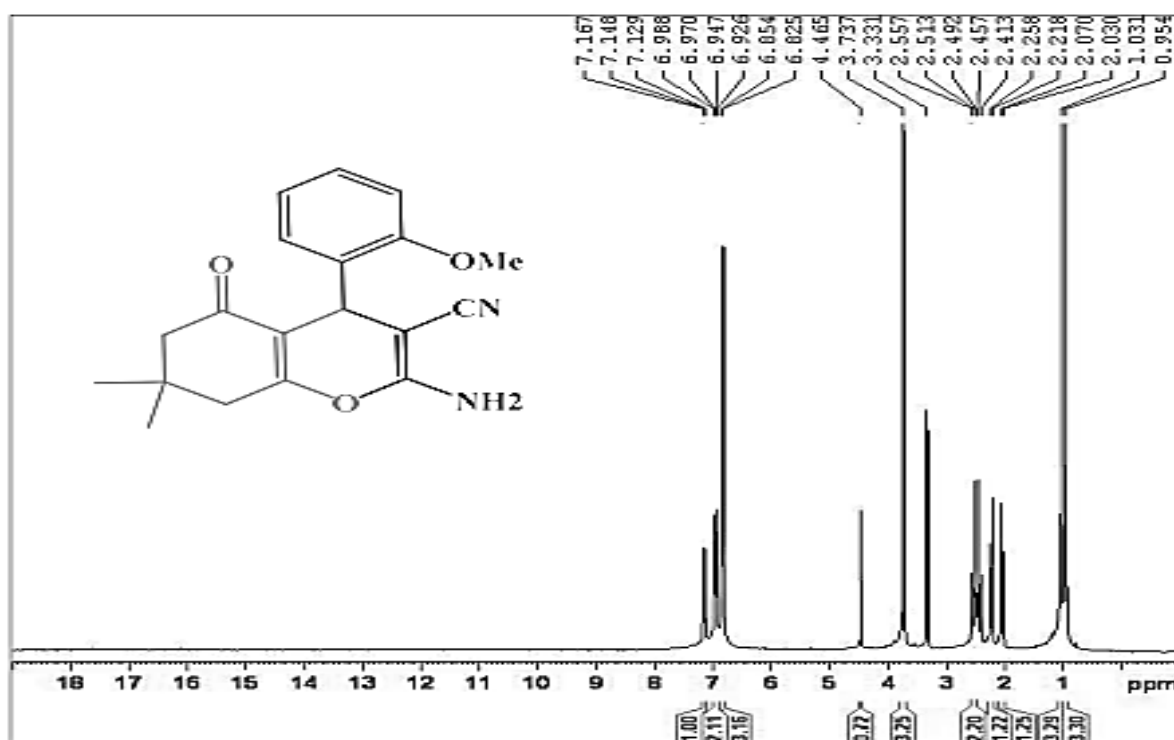


Figure 12: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-4-(2-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

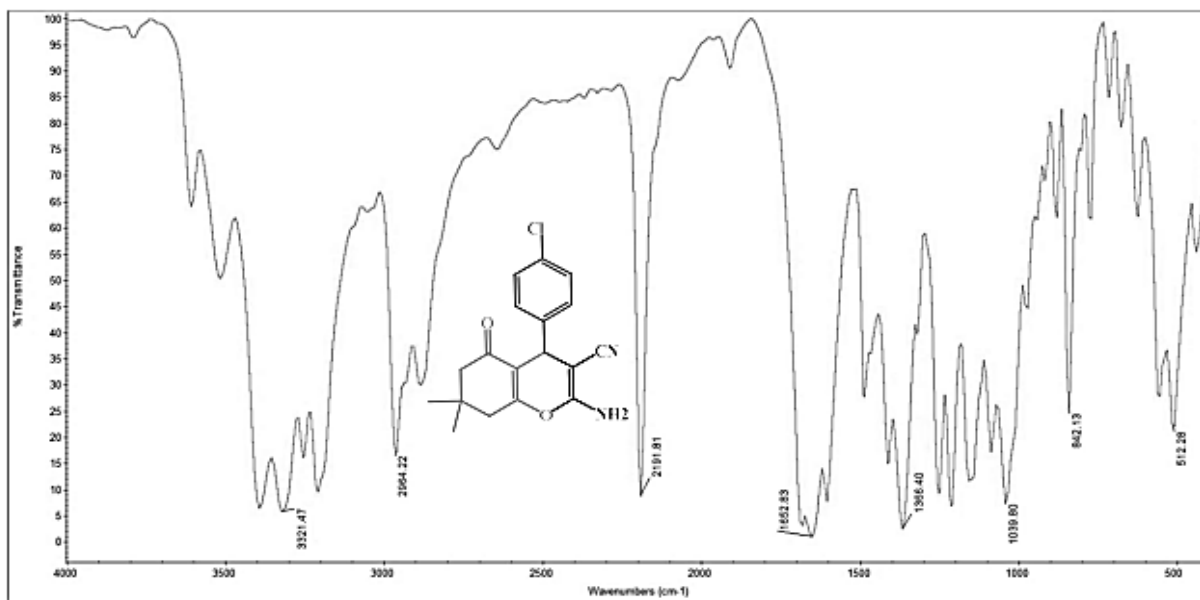


Figure 13: FT-IR spectrum of 2-amino-4-(4-chlorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

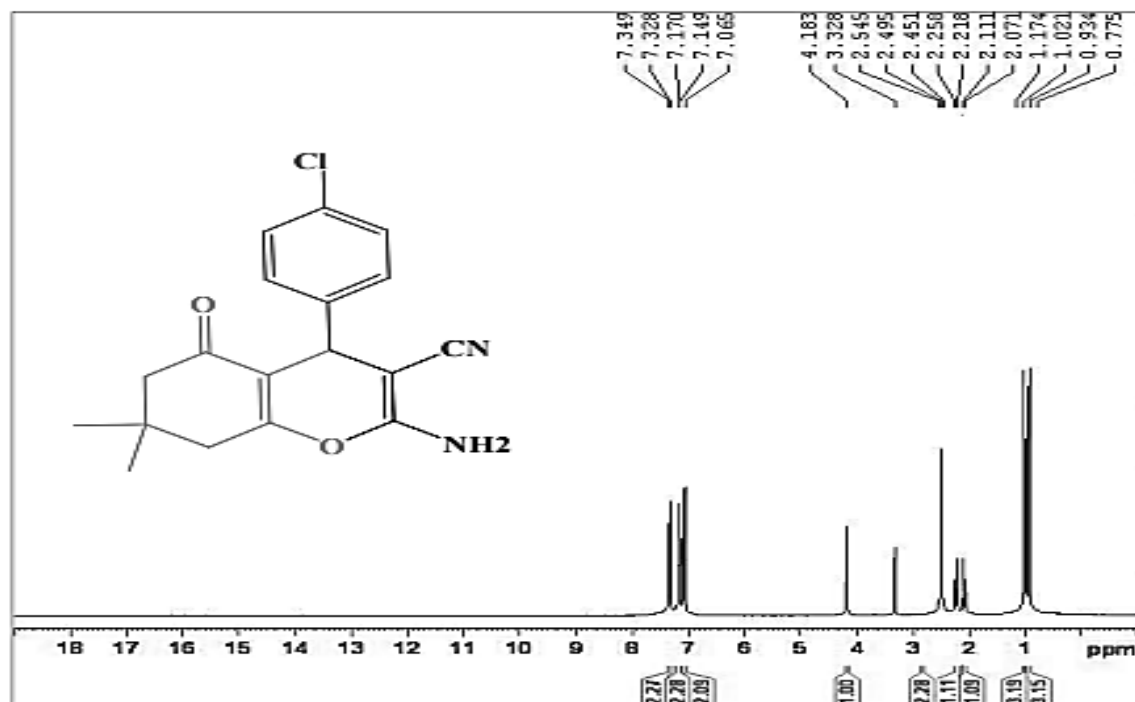


Figure 14: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-4-(4-chlorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

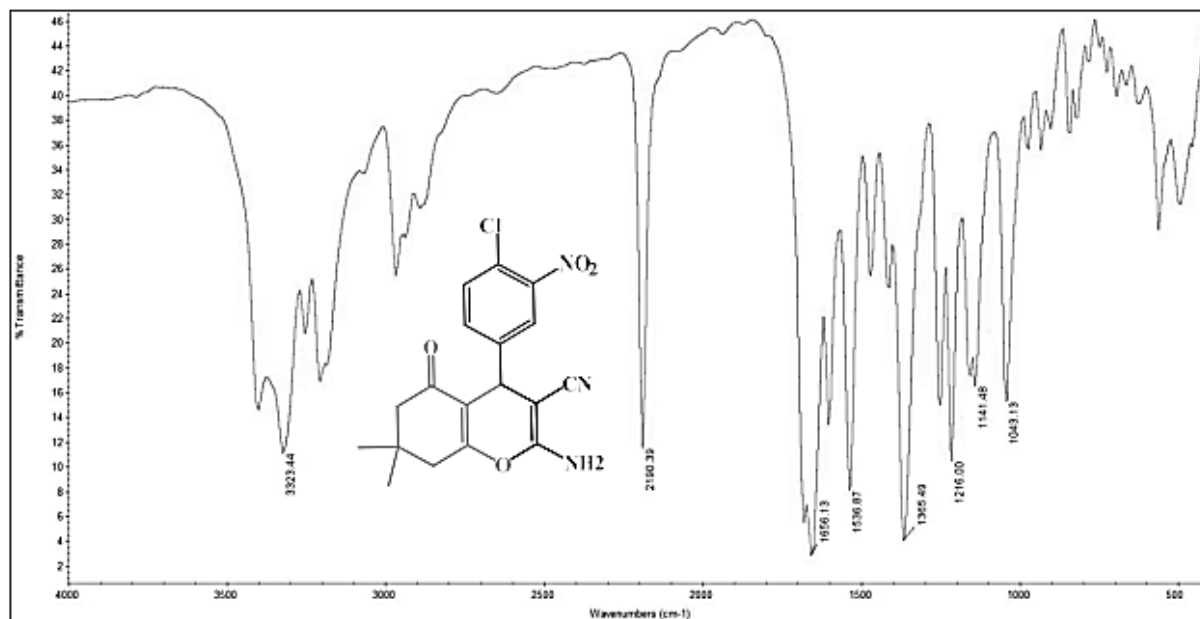


Figure 15: FT-IR spectrum of 2-amino-4-(4-chloro-3-nitrophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

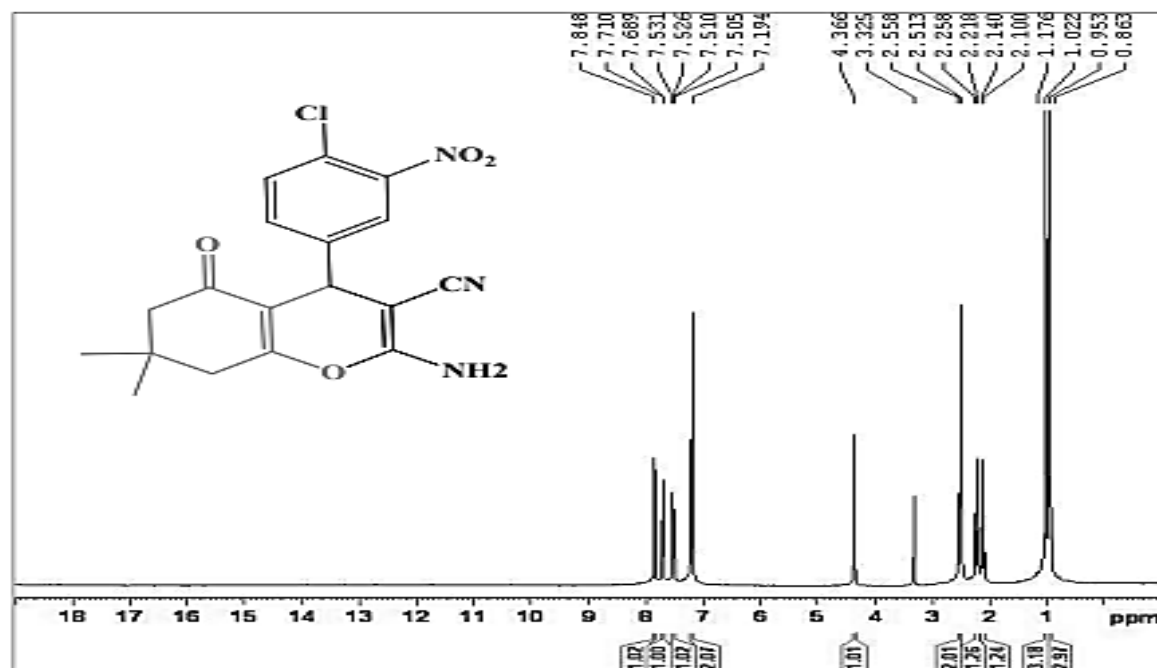


Figure S16: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-4-(4-chloro-3-nitrophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

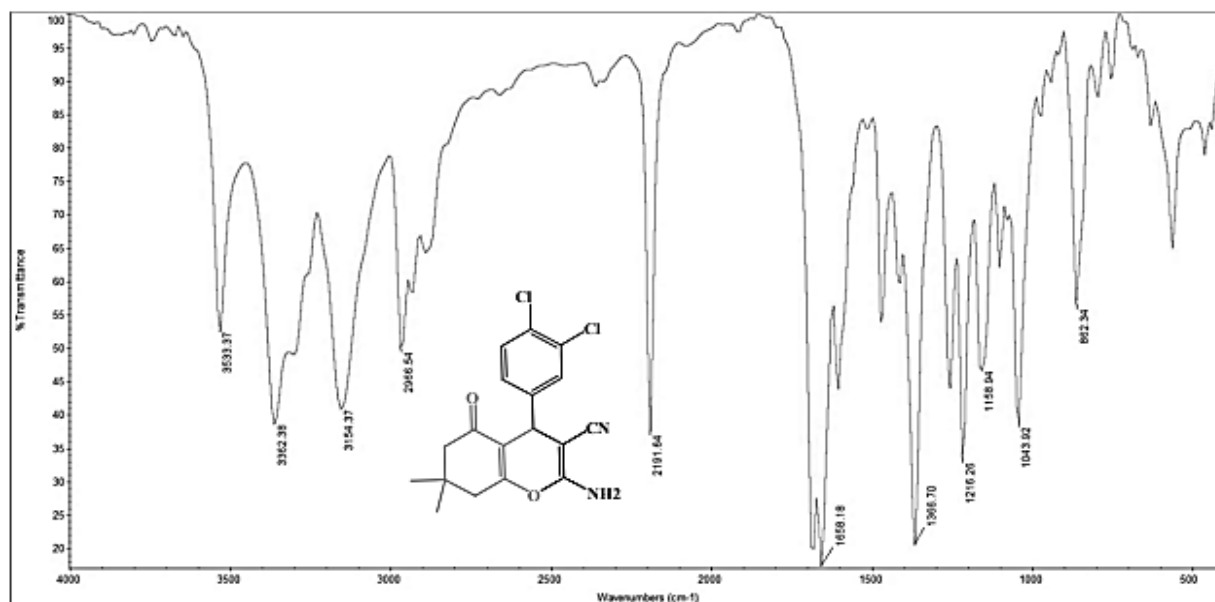


Figure 17: FT-IR spectrum of 2-amino-4-(3,4-dichlorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

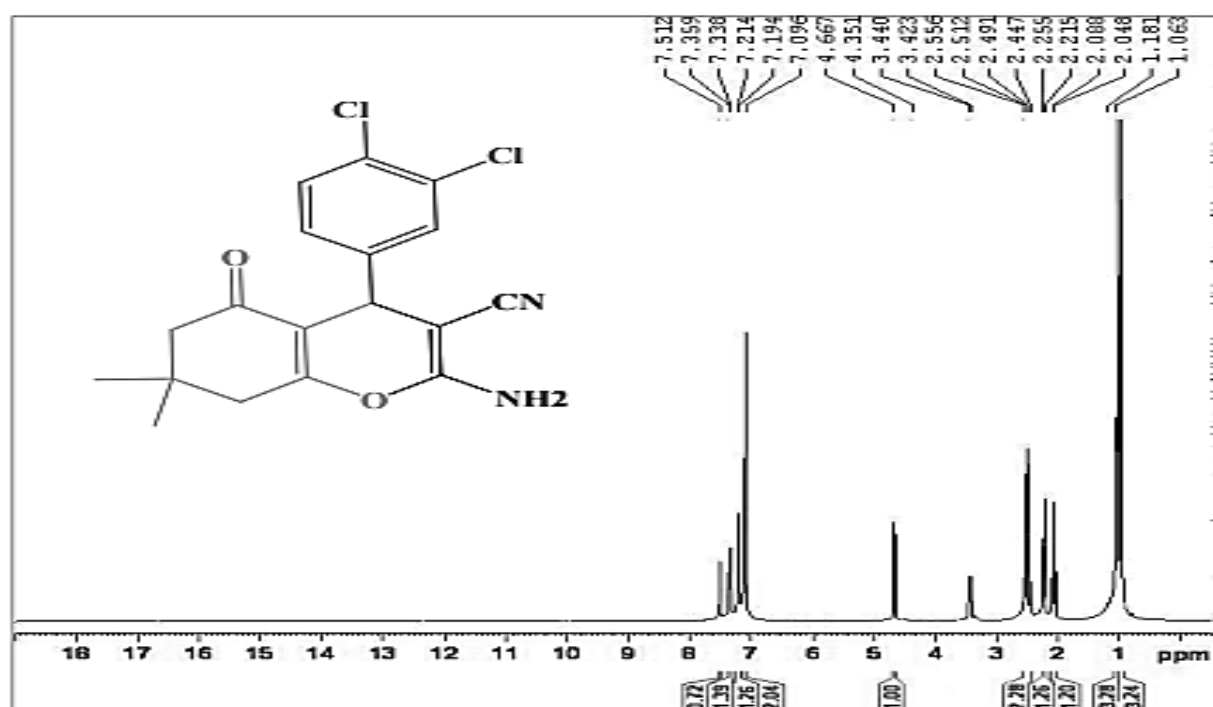


Figure S18: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-4-(3,4-dichlorophenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

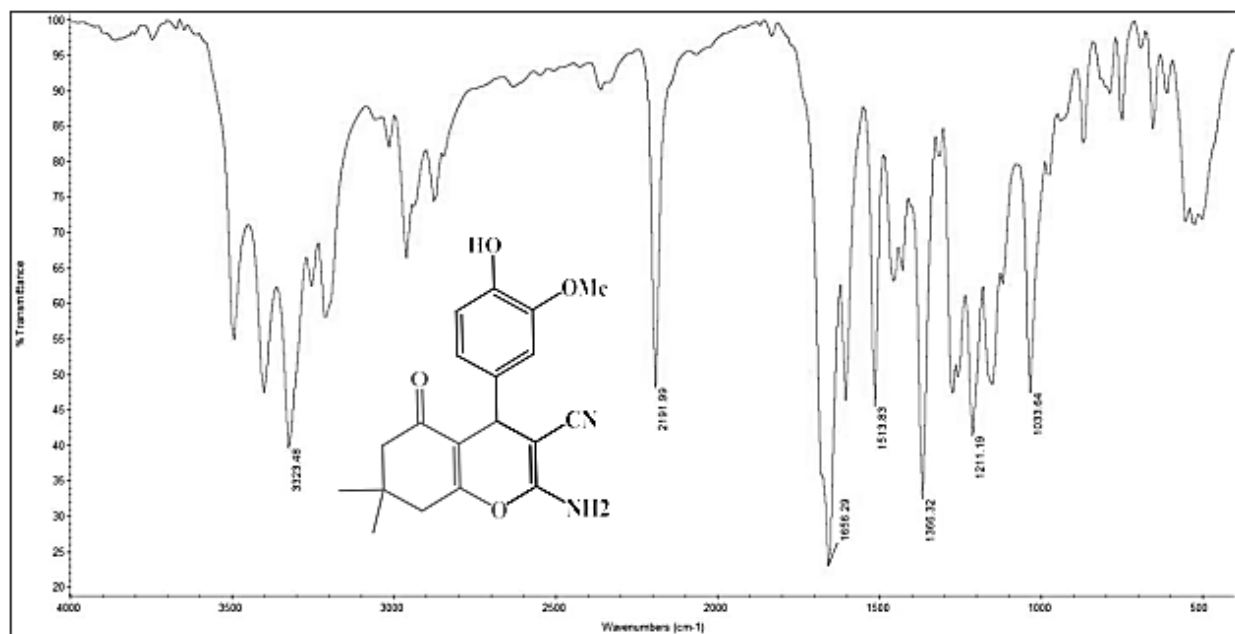


Figure 19: FT-IR spectrum of 2-amino-4-(4-hydroxy-3-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

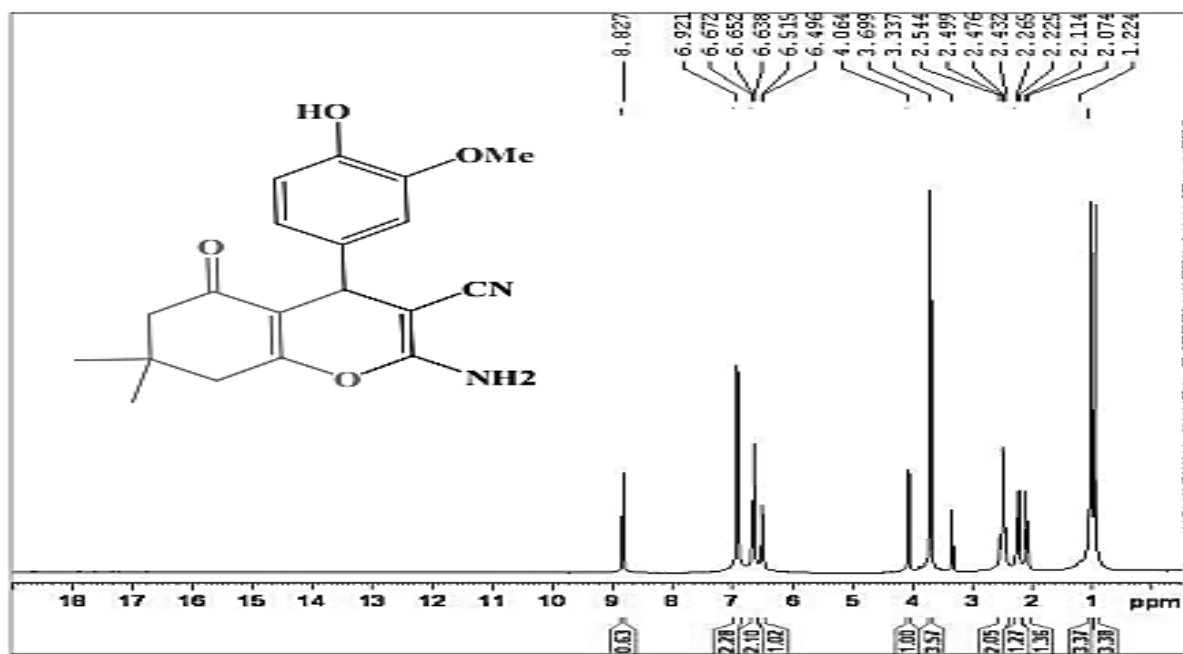


Figure 20: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-4-(4-hydroxy-3-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

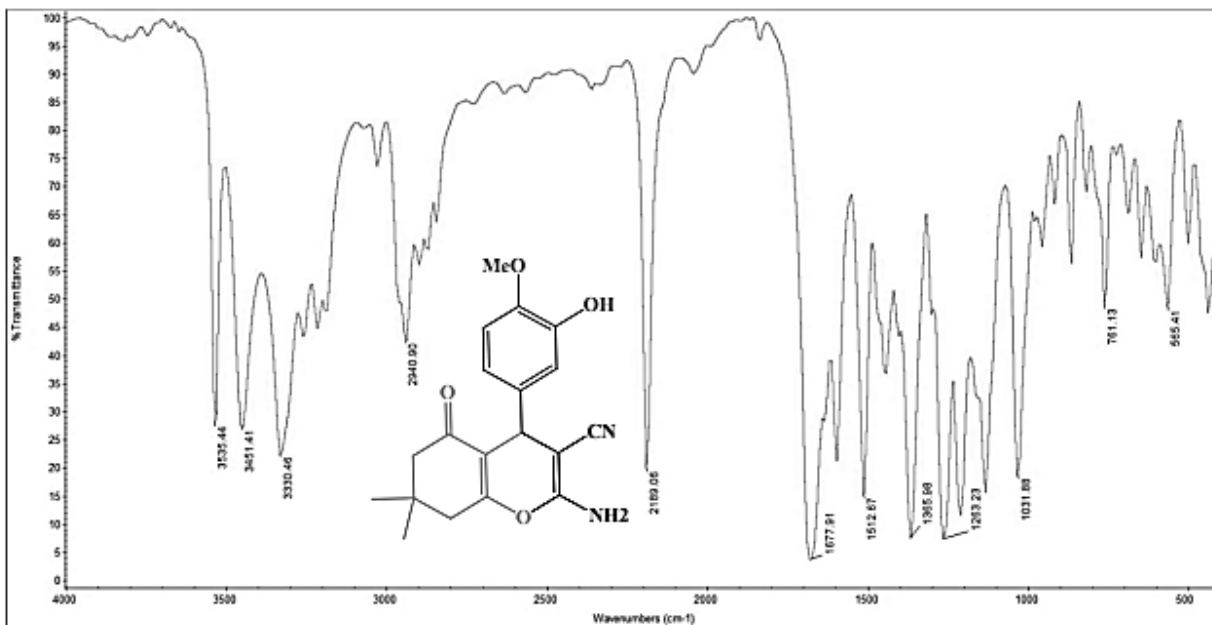


Figure 21: FT-IR spectrum of 2-amino-4-(3-hydroxy-4-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

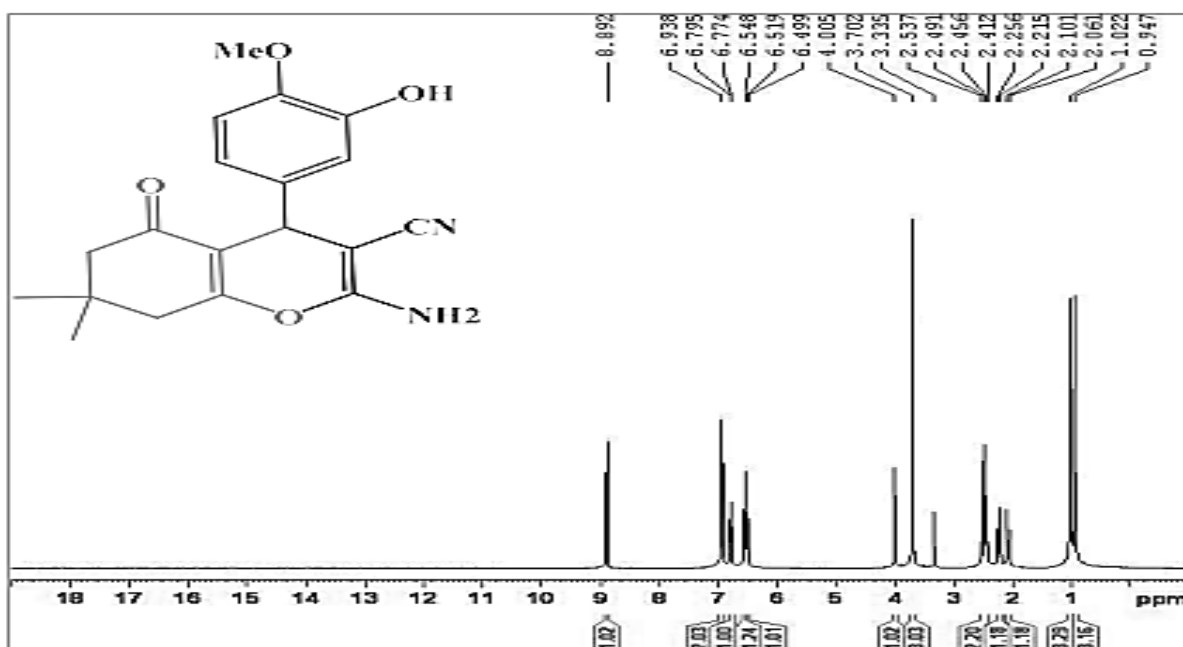


Figure 22: ¹H NMR (CDCl₃, 400 MHz) spectrum of 2-amino-4-(3-hydroxy-4-methoxyphenyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

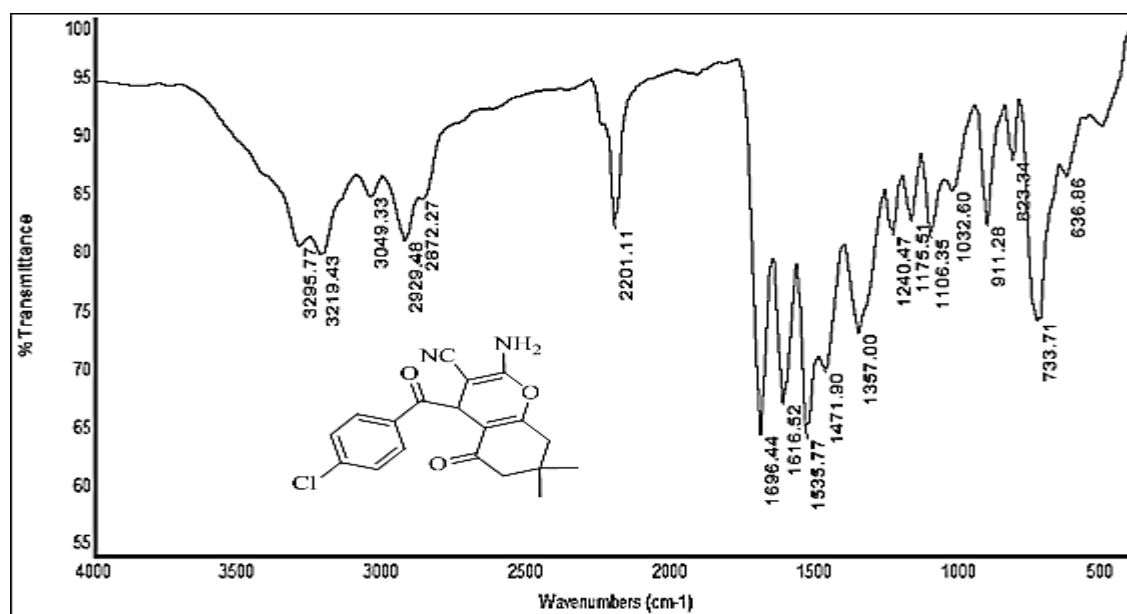


Figure 23: FT-IR spectrum of 2-Amino-4-(4-chlorobenzoyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

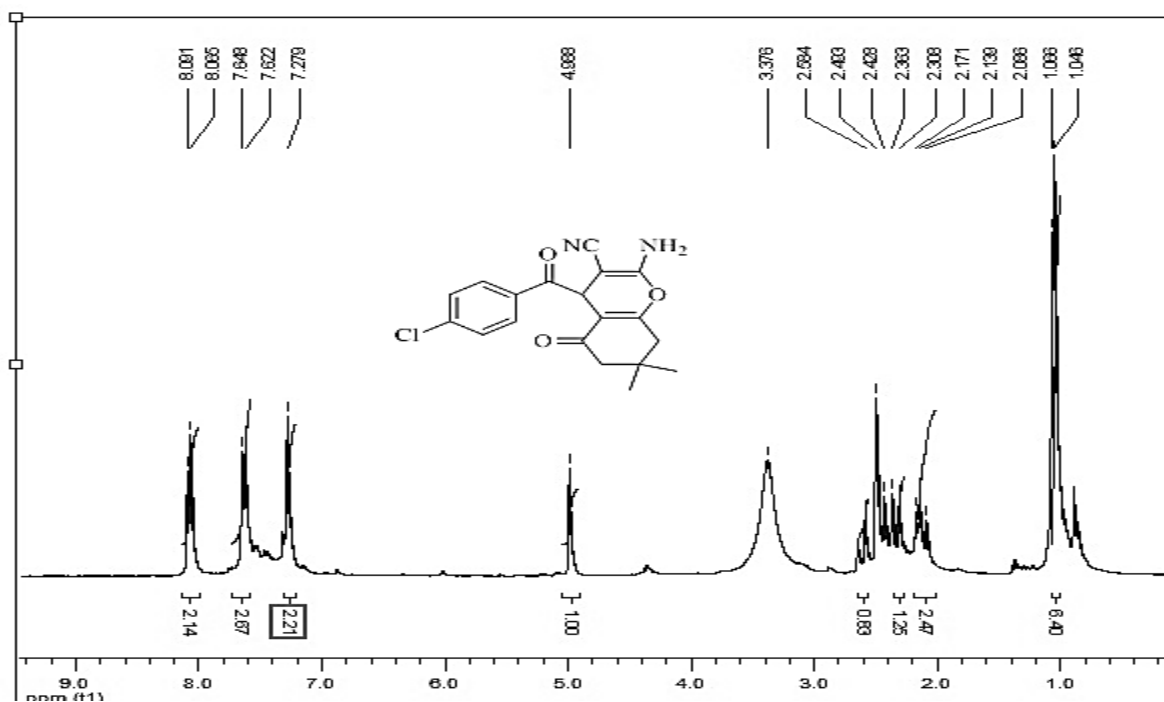


Figure 24: ¹H NMR (DMSO-d₆, 300 MHz) spectrum of 2-Amino-4-(4-chlorobenzoyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

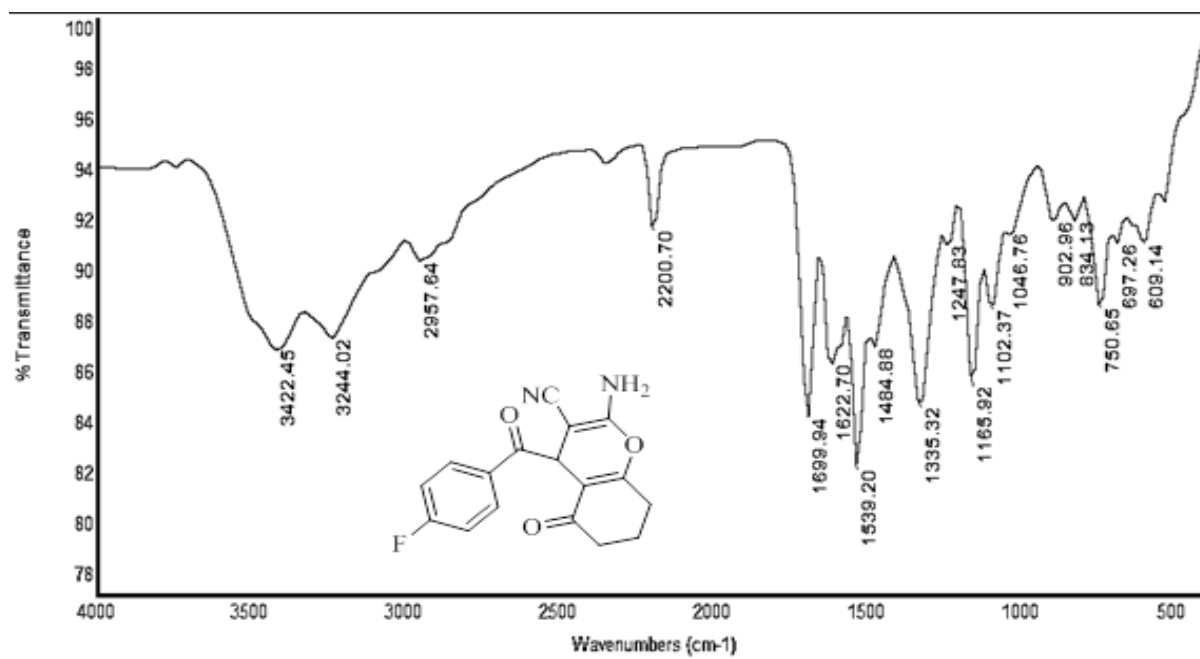


Figure 25: FT-IR spectrum of 2-Amino-4-(4-fluorobenzoyl)-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

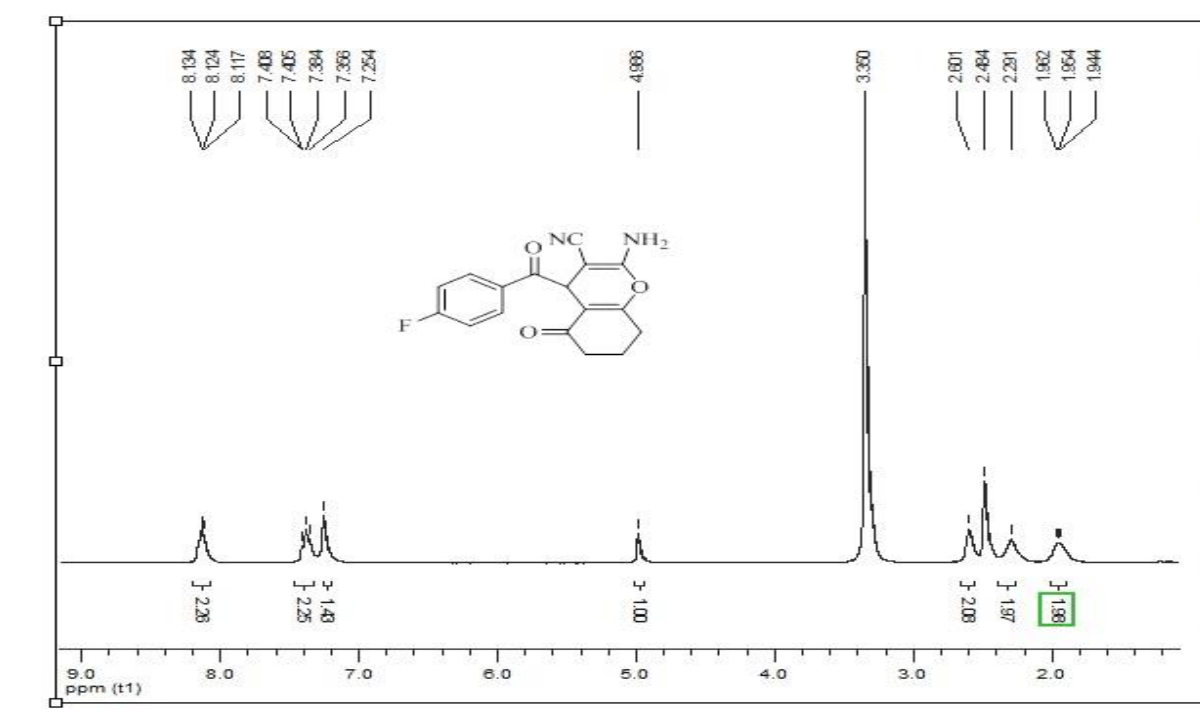


Figure 26: ¹H NMR (DMSO-d₆, 300 MHz) spectrum of 2-Amino-4-(4-fluorobenzoyl)-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

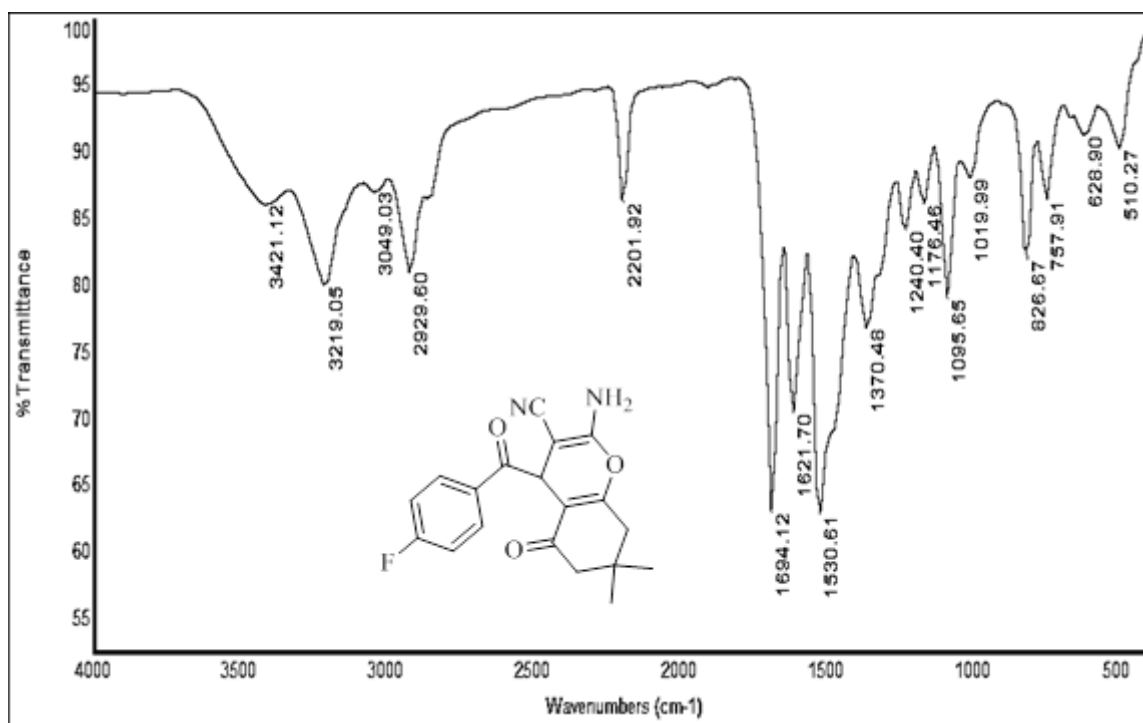


Figure 27: FT-IR spectrum of 2-Amino-4-(4-fluorobenzoyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

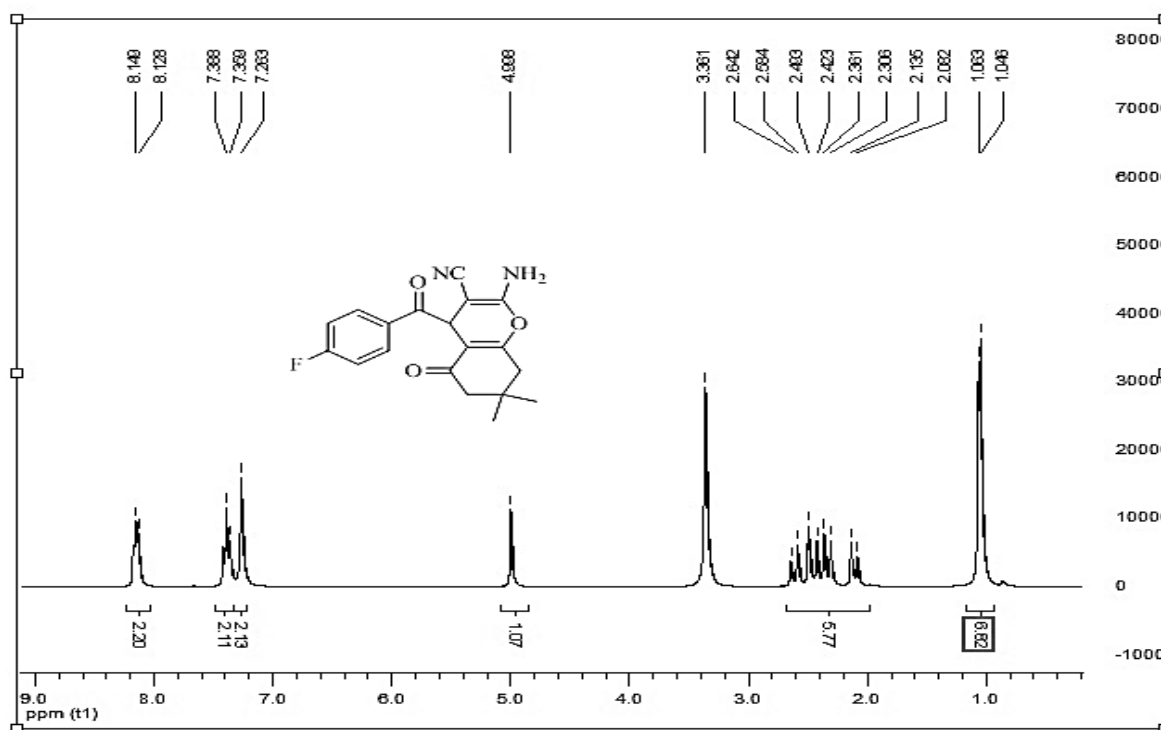


Figure 28: ¹H NMR (DMSO-d₆ 300 MHz) spectrum of 2-Amino-4-(4-fluorobenzoyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

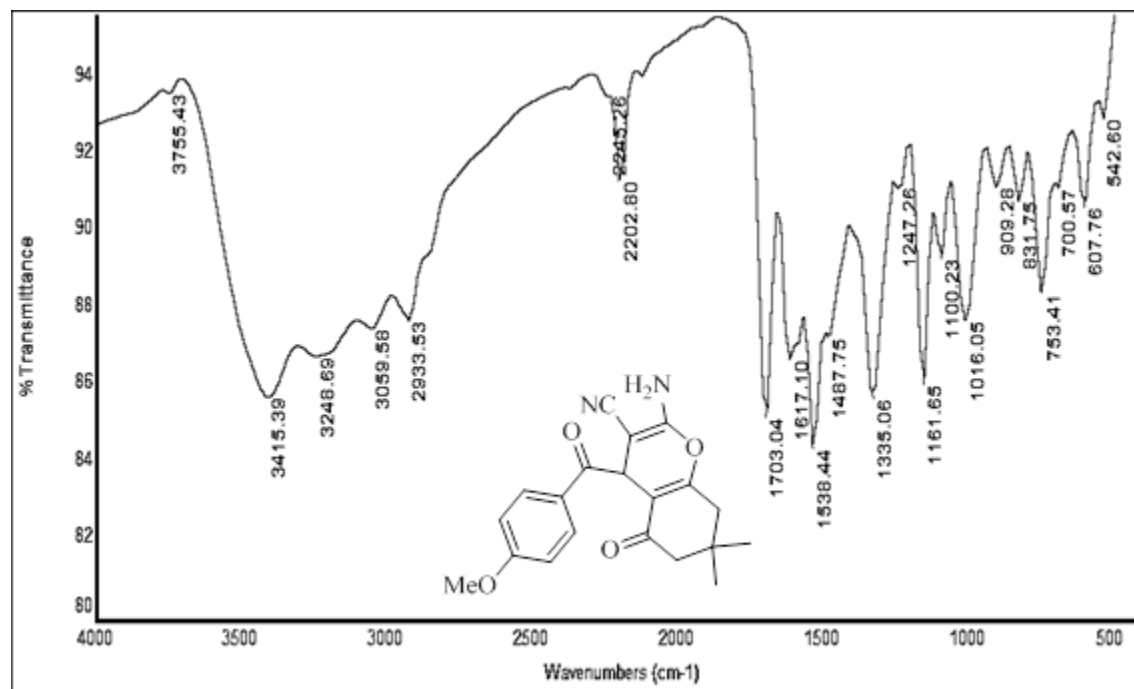


Figure 29: FT-IR spectrum of 2-Amino-4-(4-methoxybenzoyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile

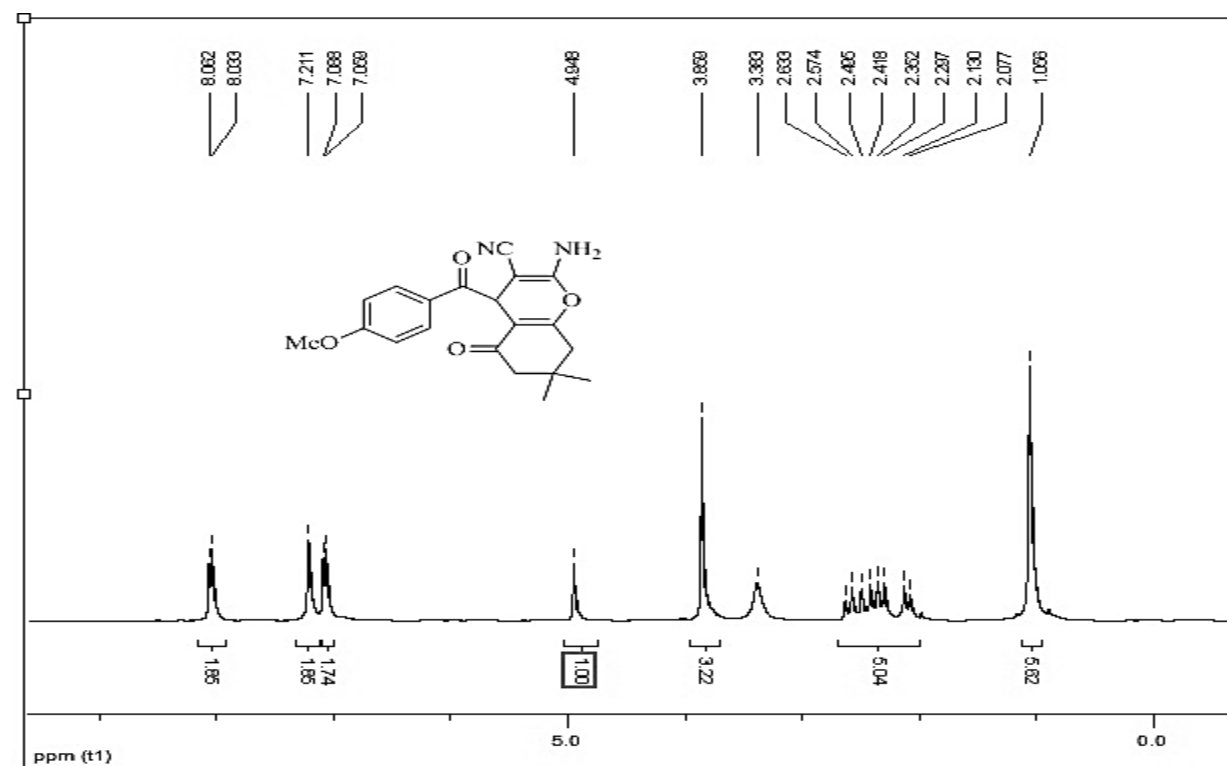


Figure 30: ¹H NMR (DMSO-d₆ 300 MHz) spectrum of 2-Amino-4-(4-methoxybenzoyl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3-carbonitrile