Supplementary Material

Efficient synthesis of functionalized spiro[imidazolidine-2-thione-oxindoles] via catalyst-free domino Mannich cyclization

Xin-Ni Ping,[a] Wei Chen,[b] Xiao-Yan Lu,[c] and Jian-Wu Xie*[a]

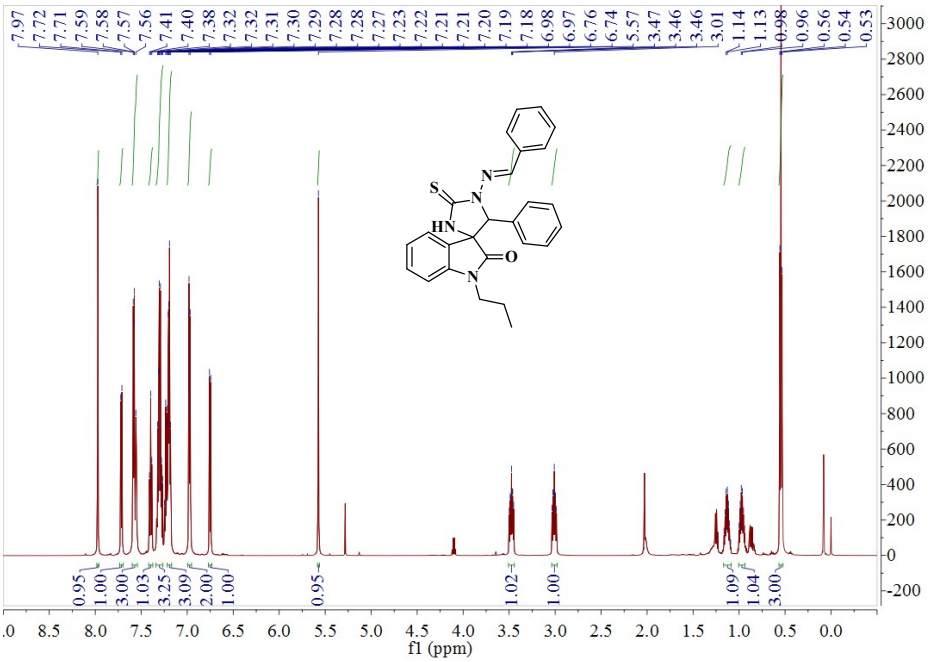
[a] Department of Chemistry and Life Science, Zhejiang Normal University, Jinhua 321004, P. R. China
[b] Zhejiang Pharmaceutical College, Ningbo 315100, P. R. China
[c] Ningbo No. 2 Hospital, Ningbo 315010, P. R. China
E-mail: xiejw@zjnu.cn

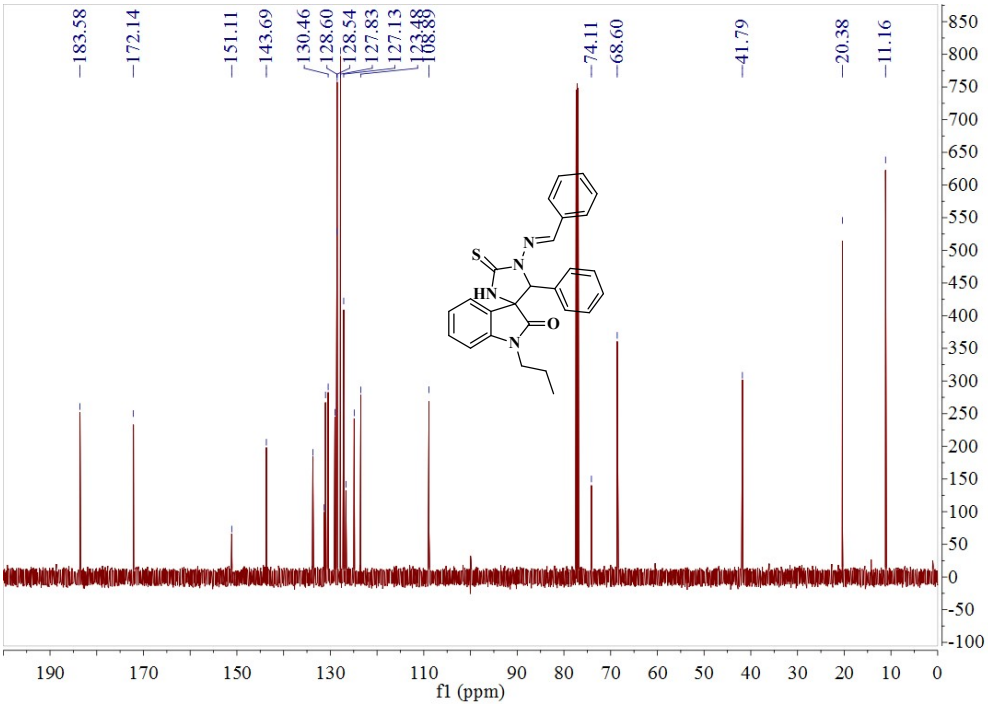
Table of contents

1. Copies of product ^{1}H NMR and ^{13}C NMR

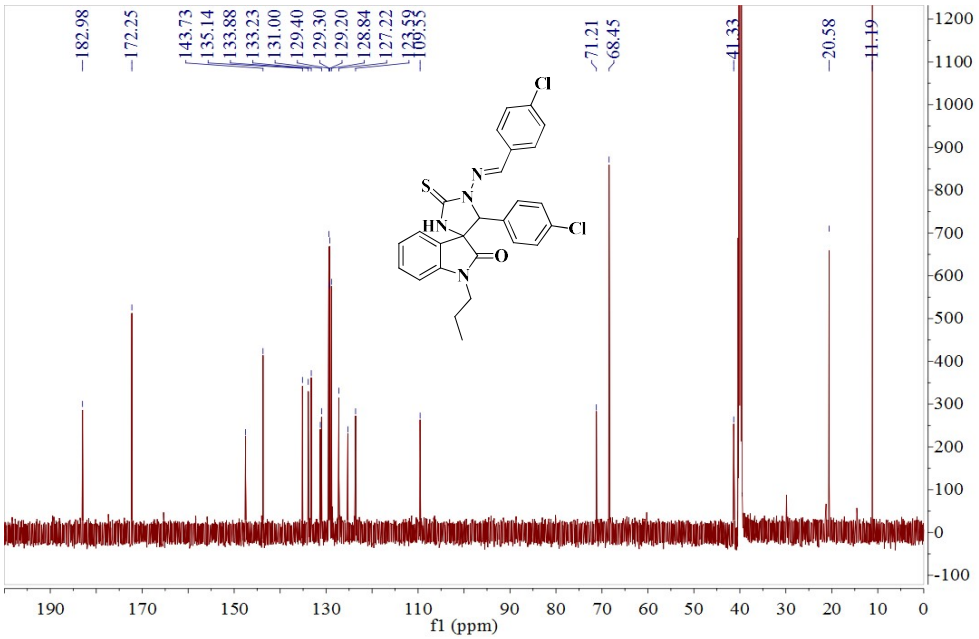
^{1}H NMR, ^{13}C NMR

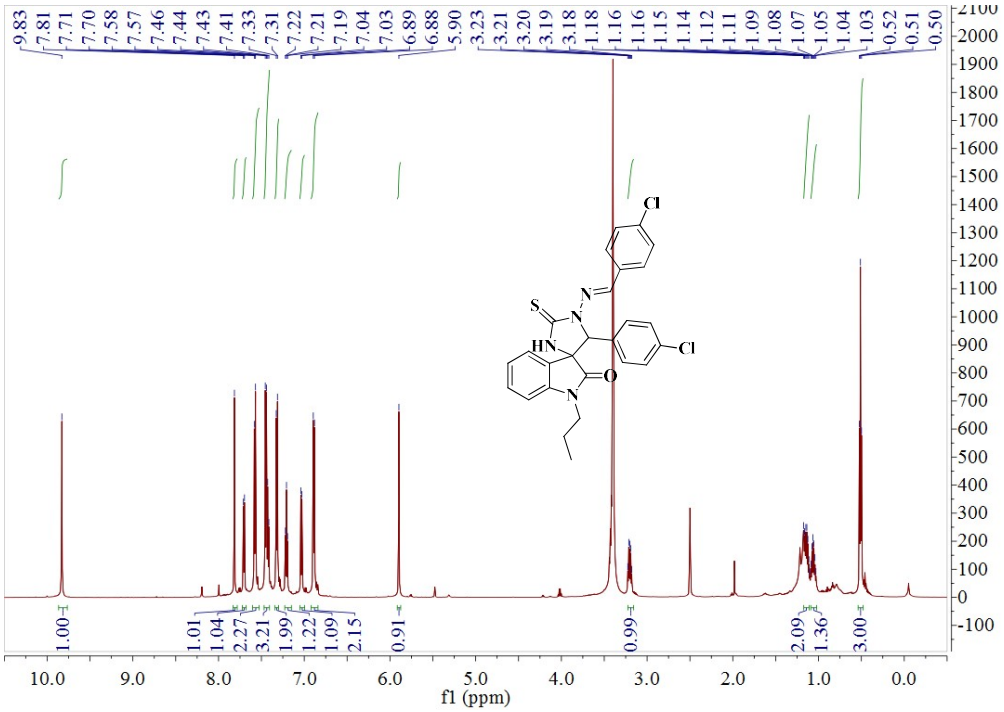
3aa



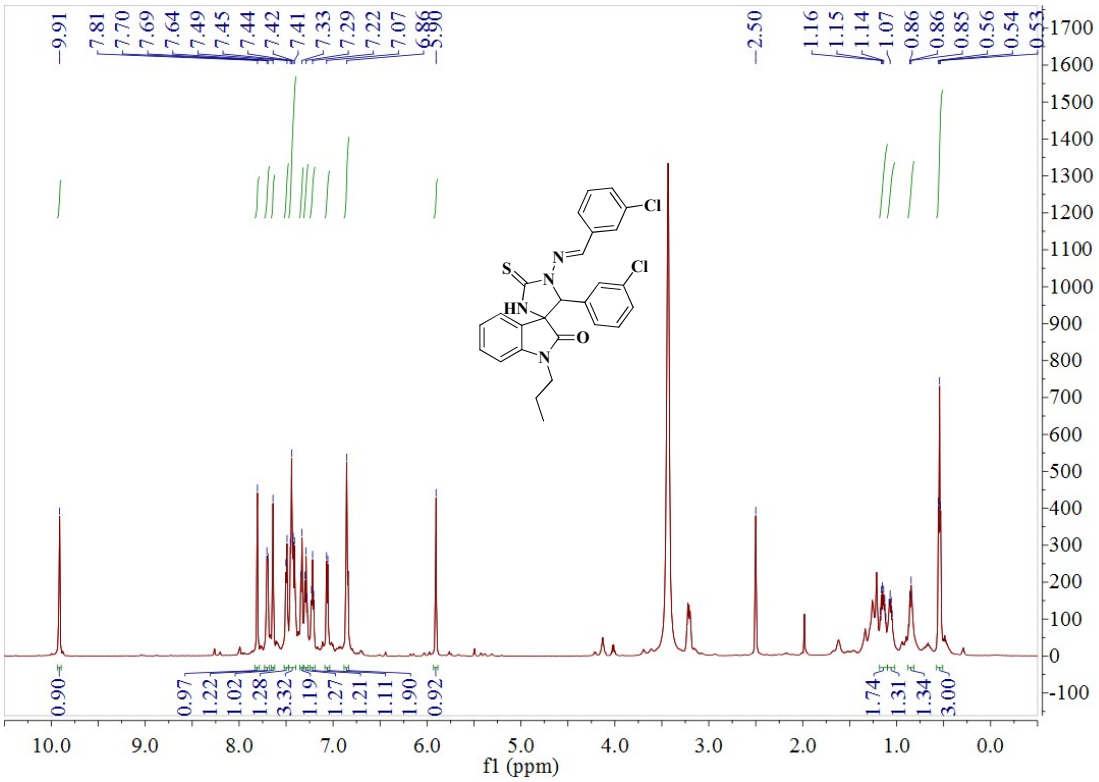


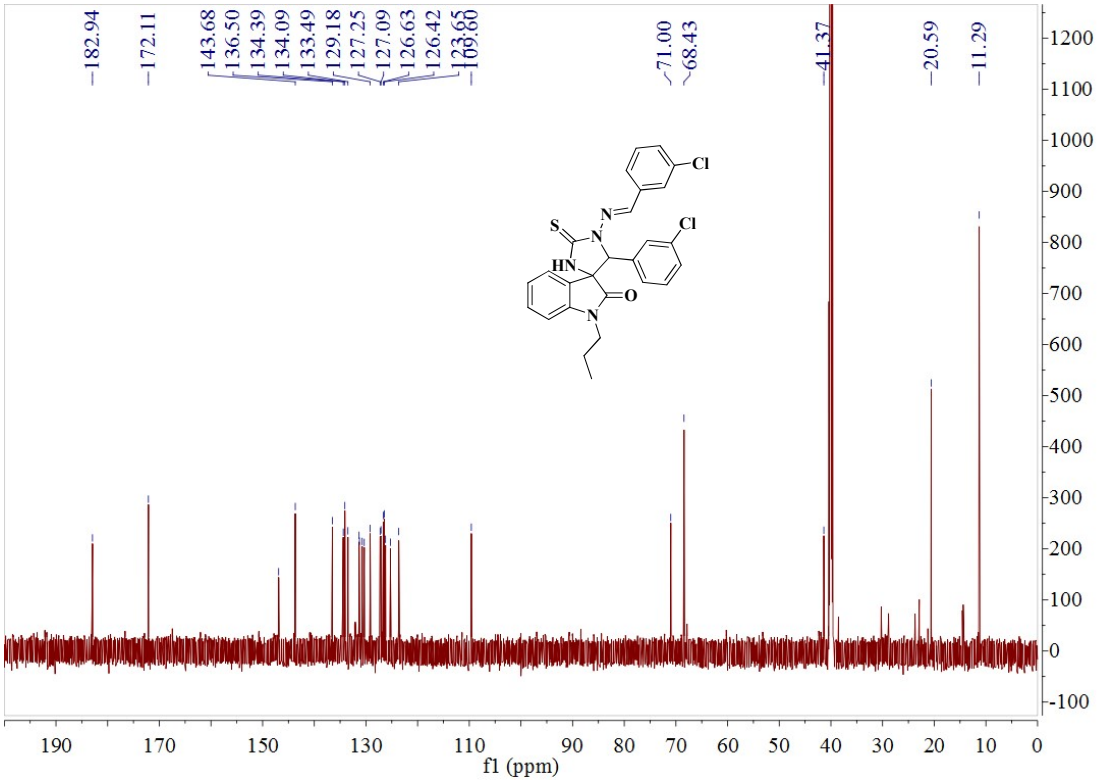
3ab



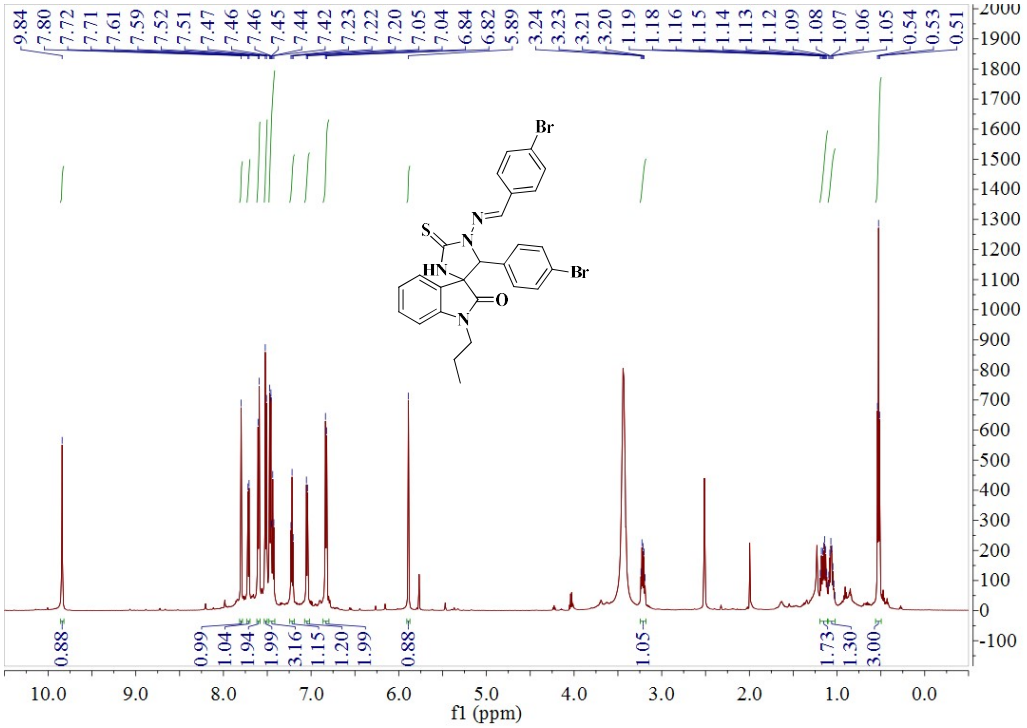


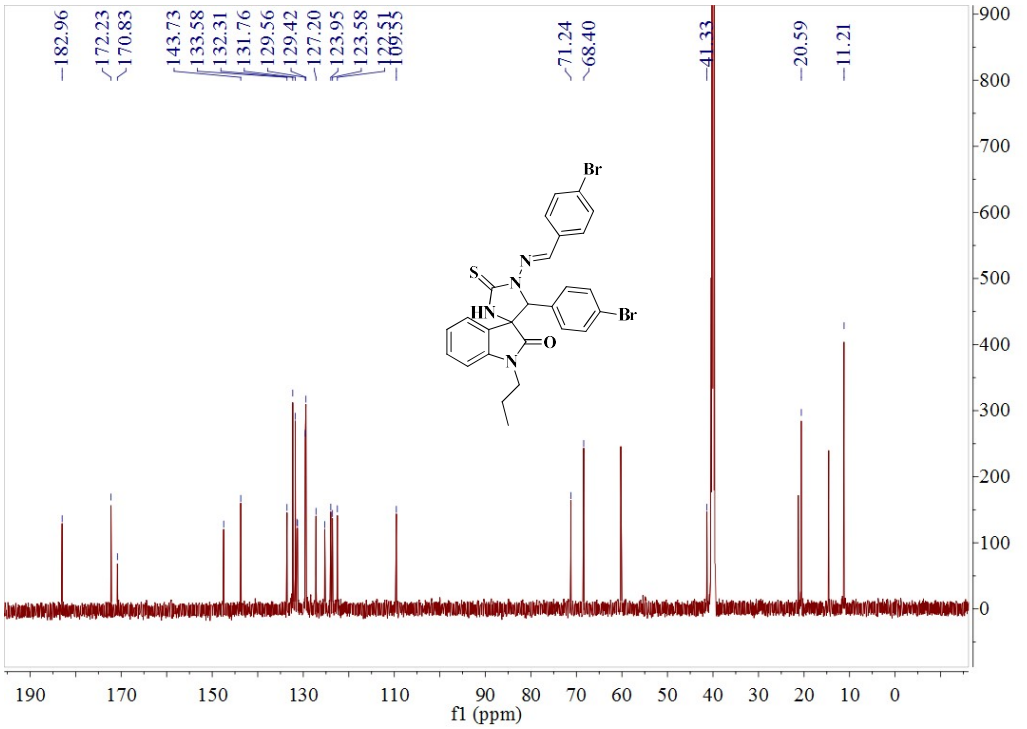
3ac



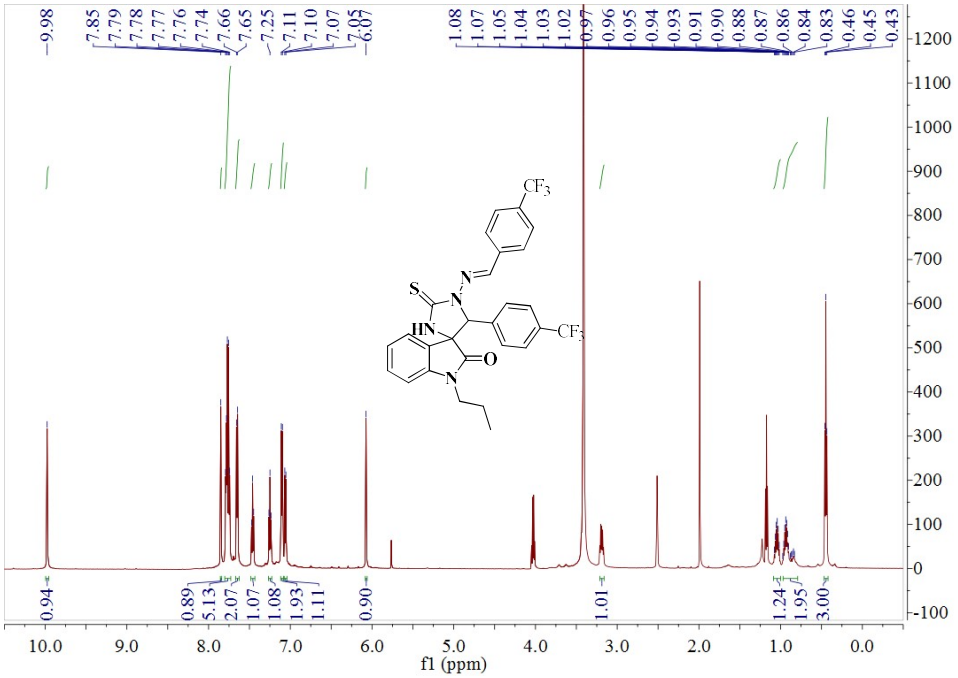


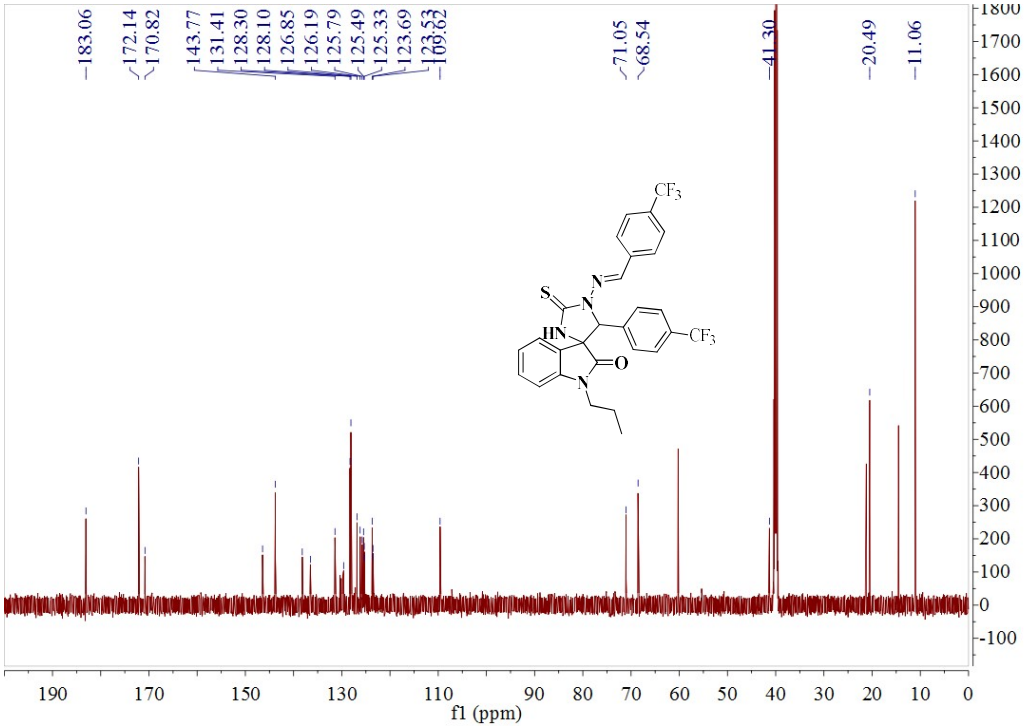
3ad



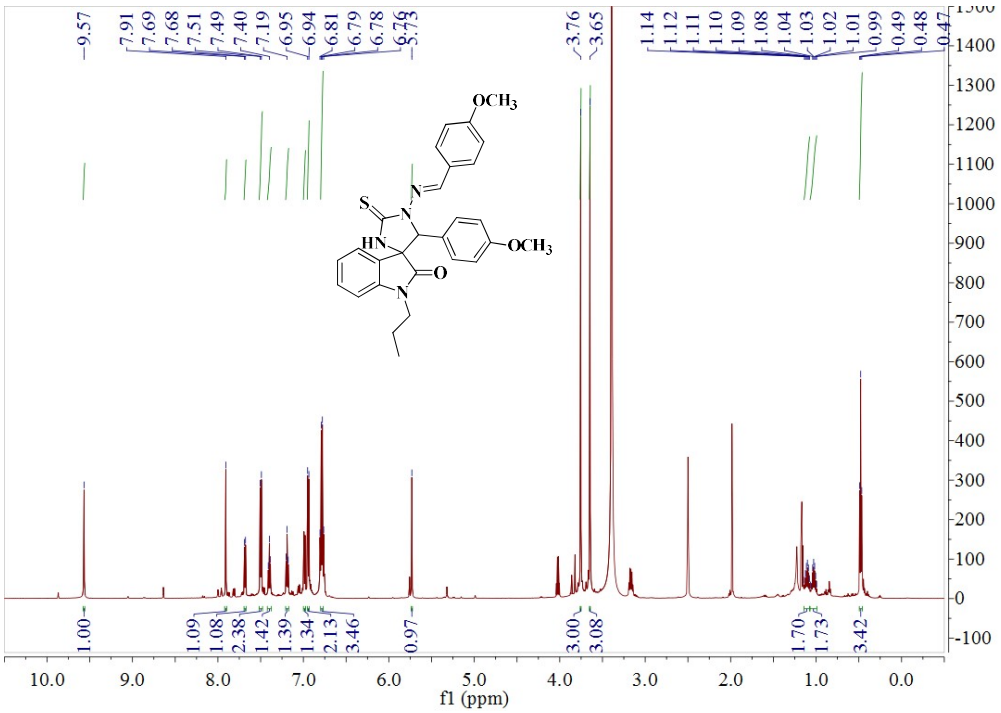


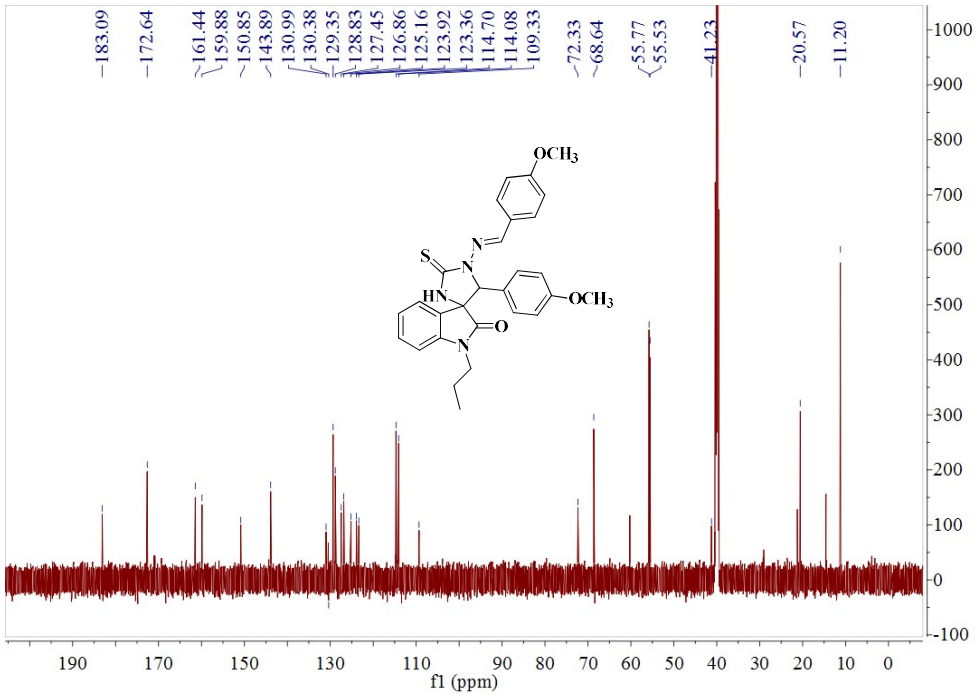
3ae



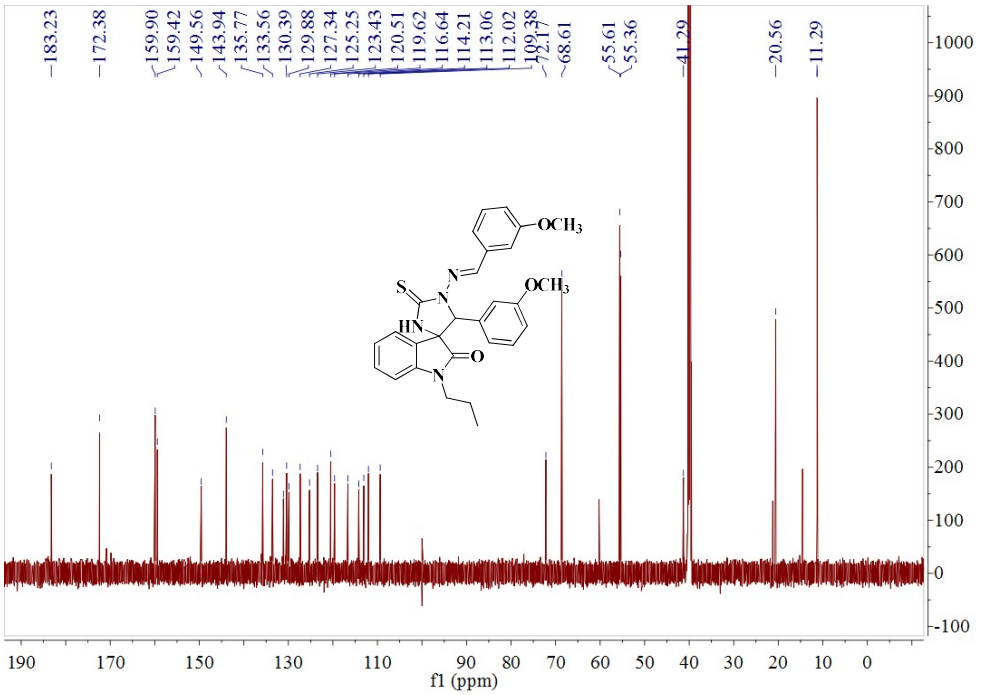


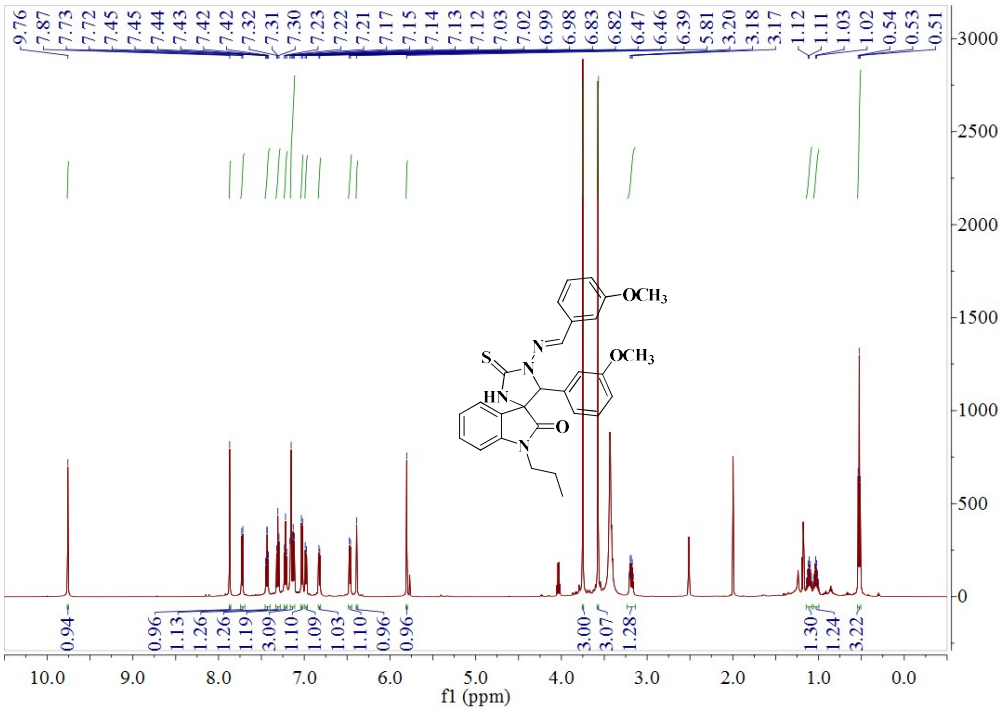
3af



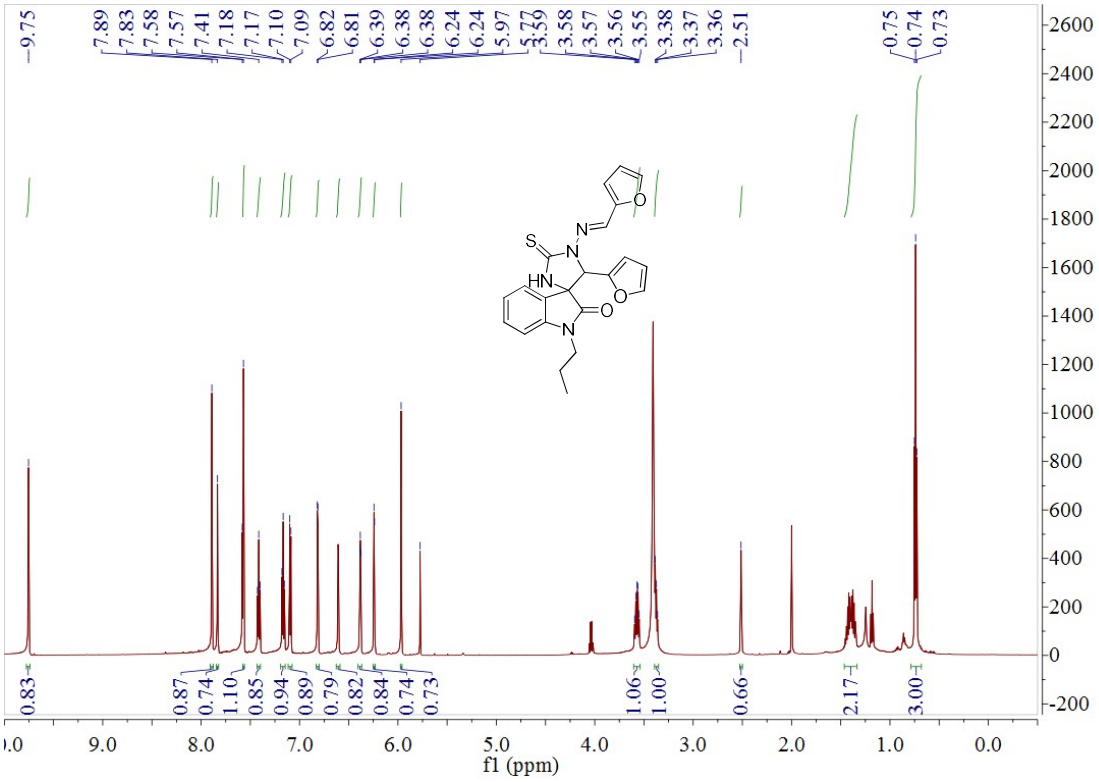


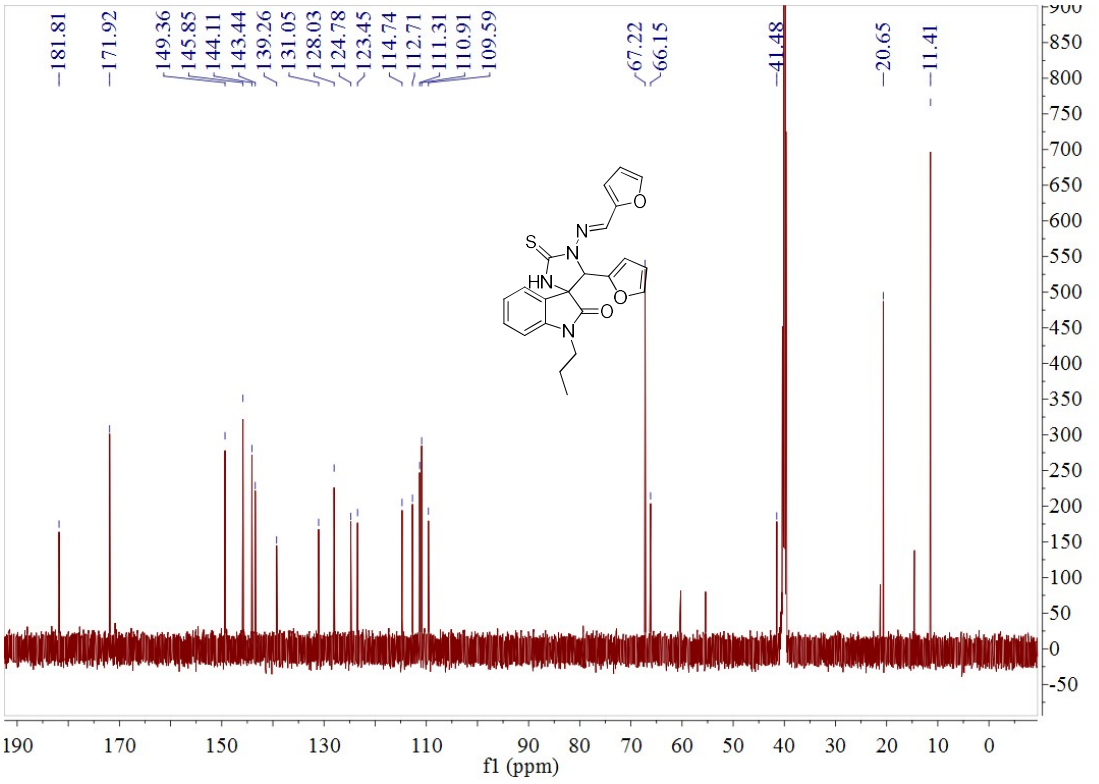
3ag



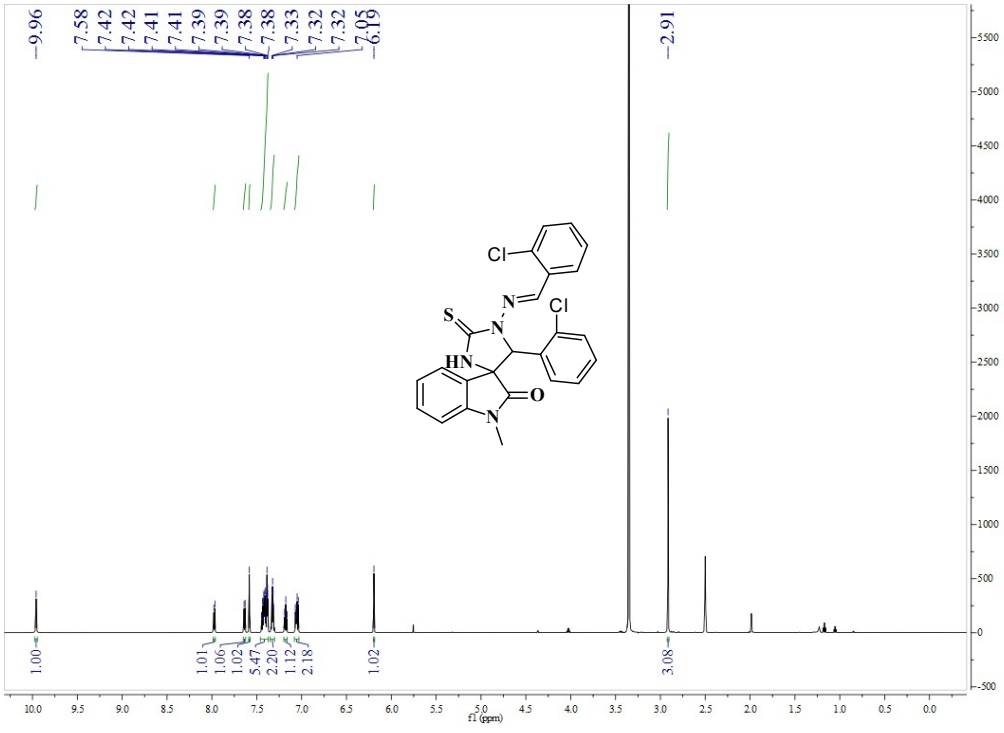


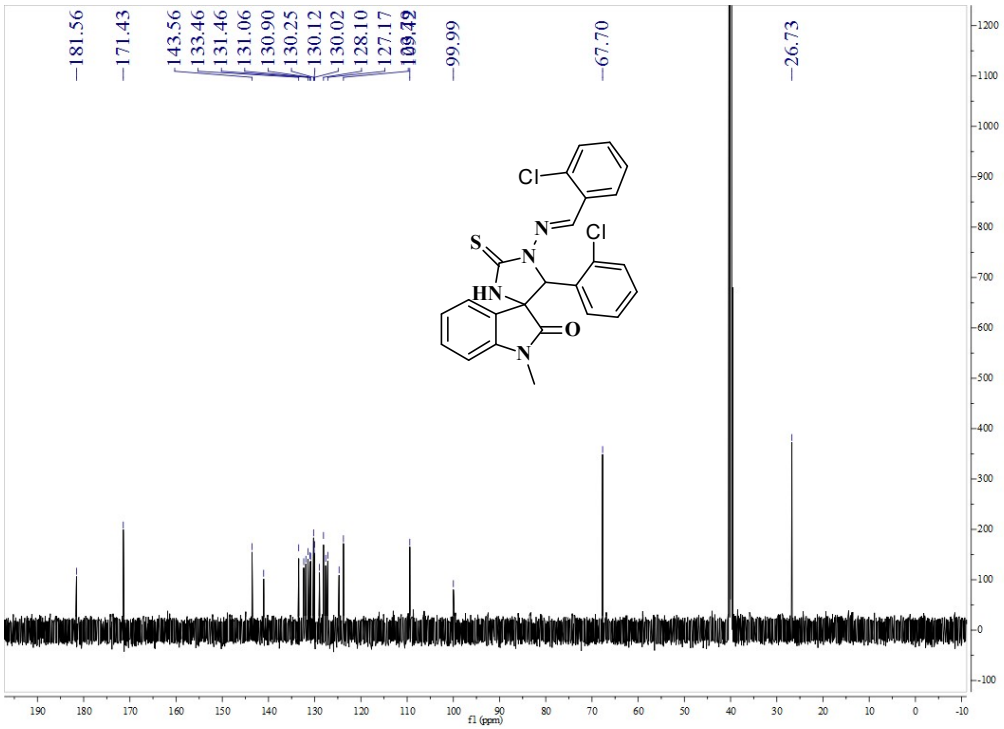
3ah



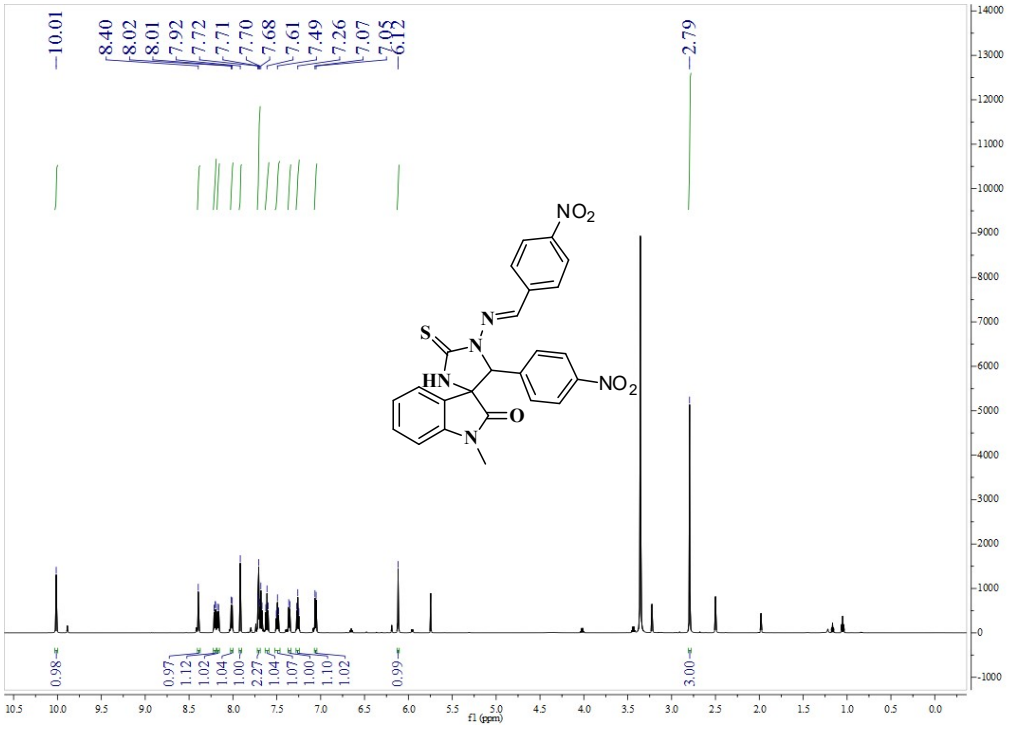


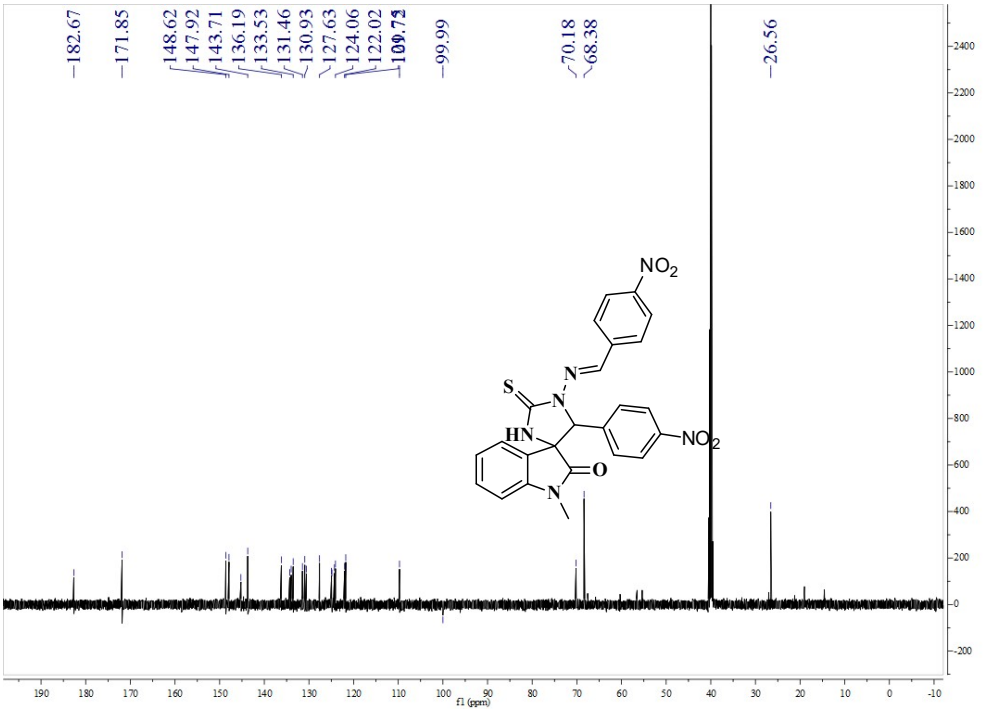
3bi



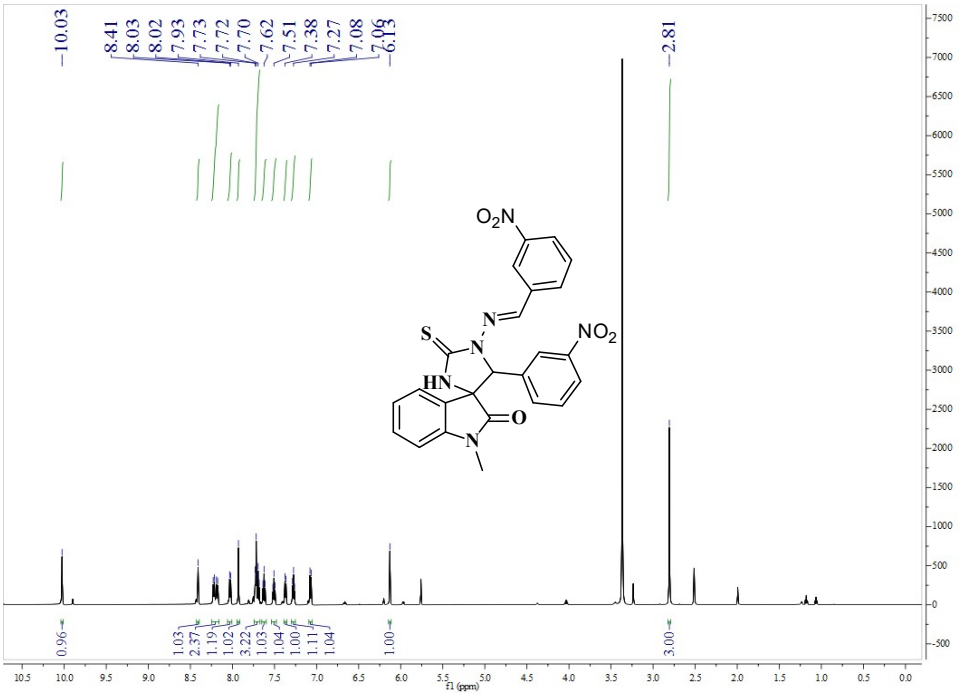


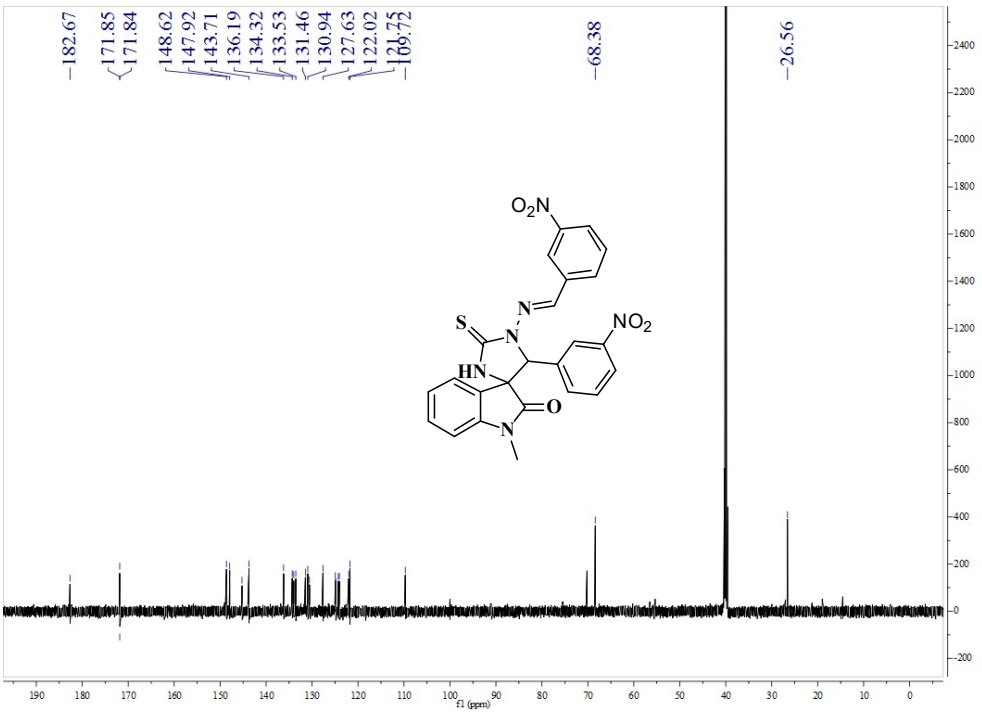
3bj



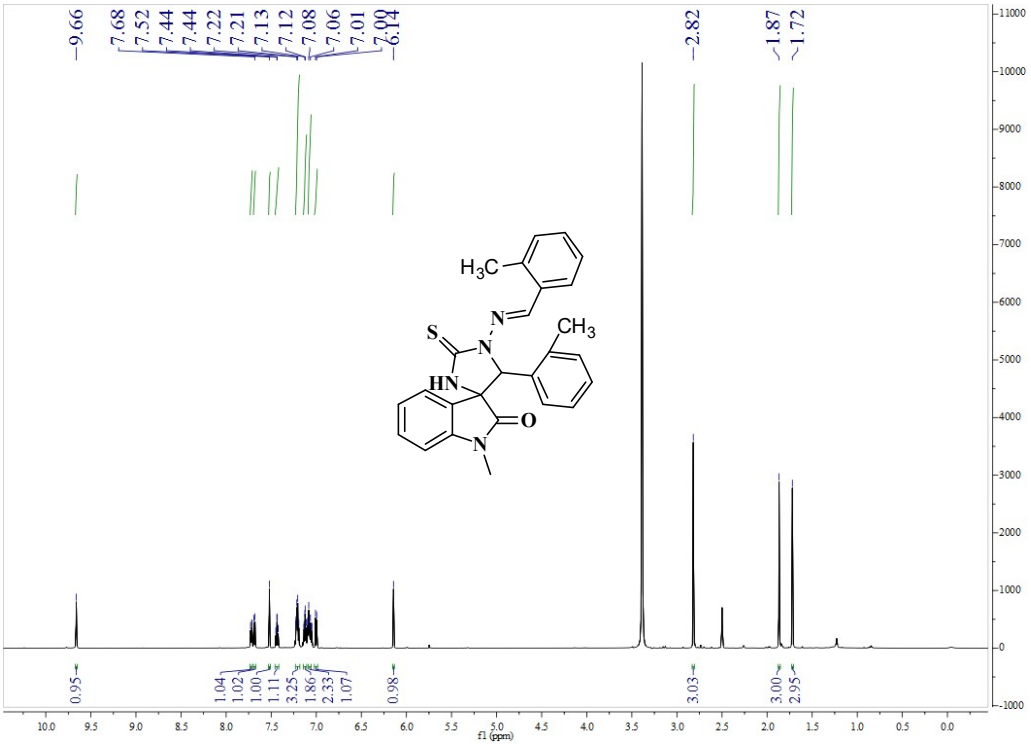


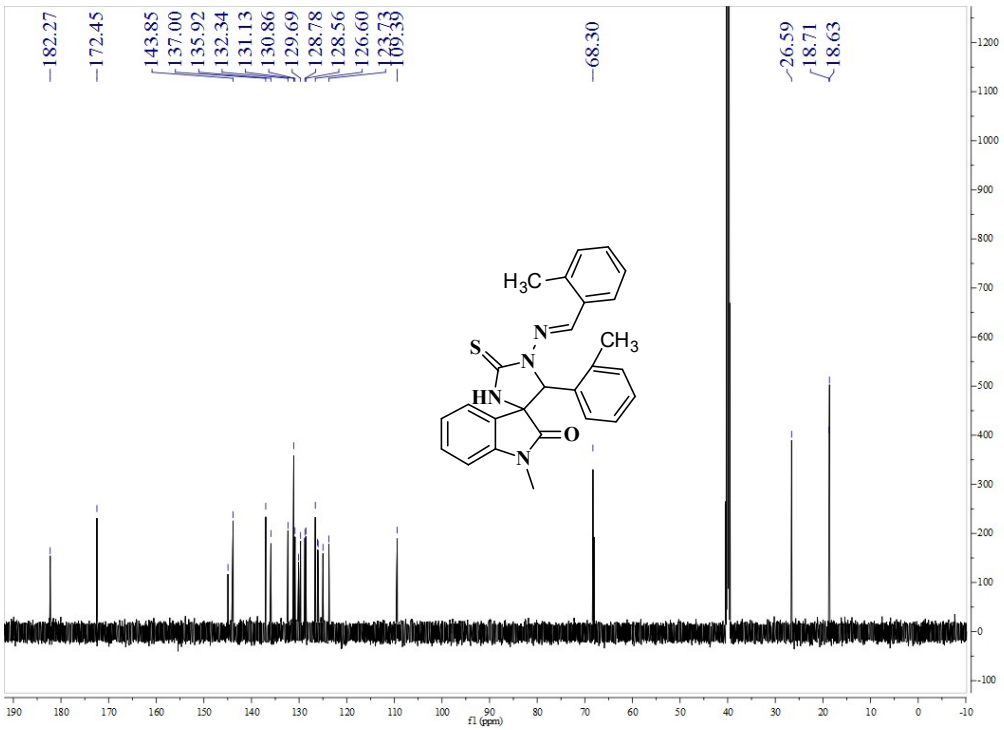
3bk



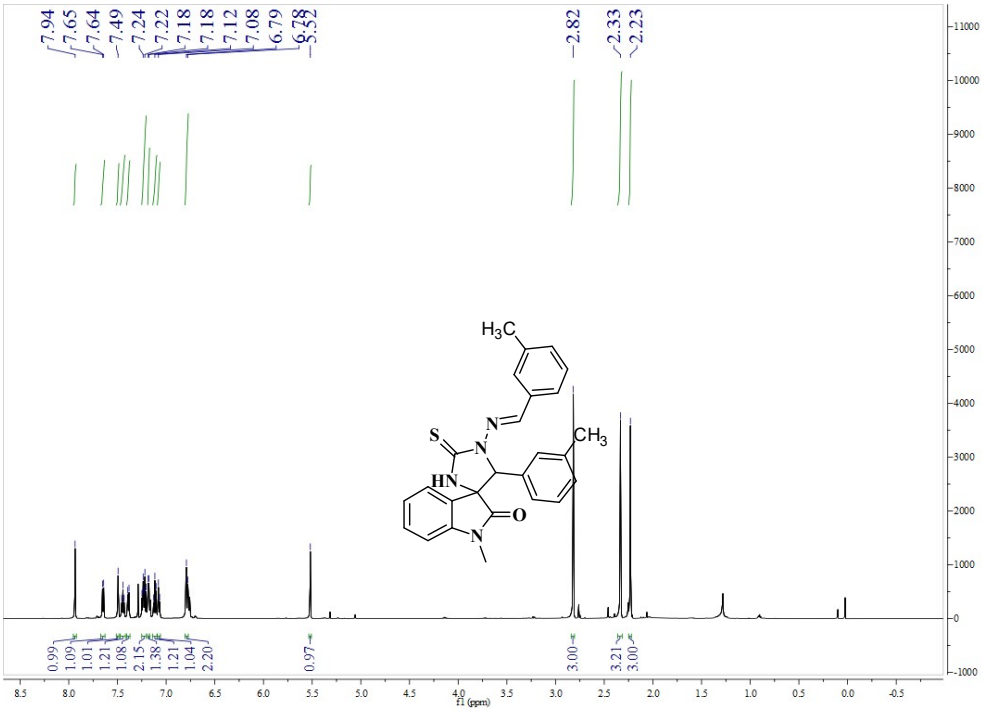


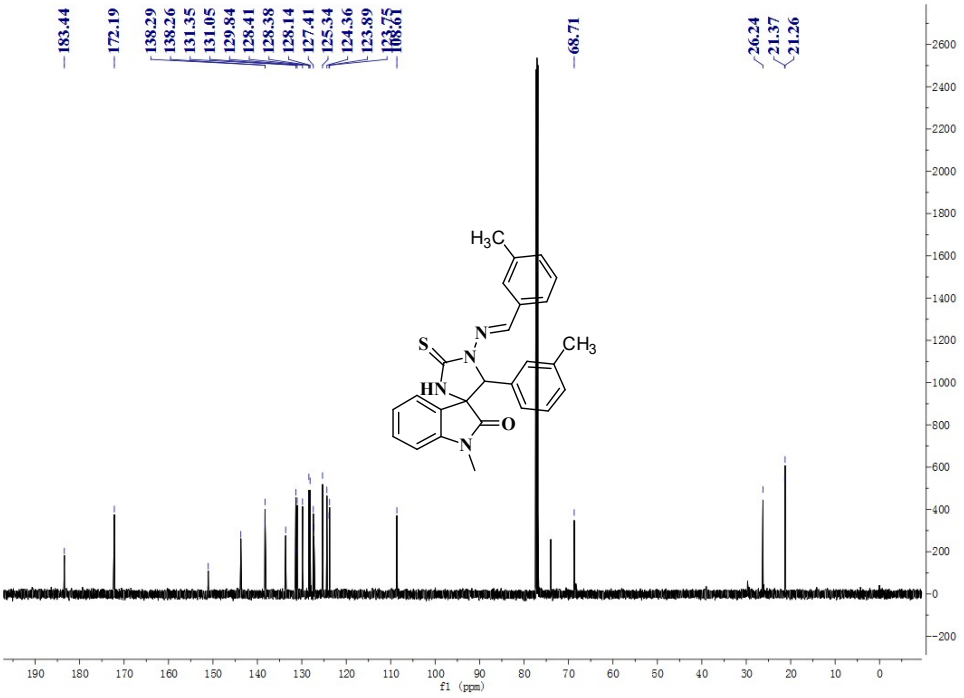
3bl





3bm





2. Crystal data

```
data_a

_audit_creation_method                  SHELXL-97
_chemical_name_systematic
;
 ?
;
_chemical_name_common                   ?
_chemical_melting_point                 ?
_chemical_formula_moiety                'C3.47 H3.20 N0.53 O0.13 S0.13'
_chemical_formula_sum
 'C3.47 H3.20 N0.53 O0.13 S0.13'
_chemical_formula_weight                58.74

loop_
 _atom_type_symbol
 _atom_type_description
 _atom_type_scat_dispersion_real
 _atom_type_scat_dispersion_imag
 _atom_type_scat_source
 'C'   'C'    0.0033    0.0016
 'International Tables Vol C Tables 4.2.6.8 and 6.1.1.4'
 'H'   'H'    0.0000    0.0000
 'International Tables Vol C Tables 4.2.6.8 and 6.1.1.4'
 'N'   'N'    0.0061    0.0033
 'International Tables Vol C Tables 4.2.6.8 and 6.1.1.4'
 'O'   'O'    0.0106    0.0060
 'International Tables Vol C Tables 4.2.6.8 and 6.1.1.4'
 'S'   'S'    0.1246    0.1234
 'International Tables Vol C Tables 4.2.6.8 and 6.1.1.4'

_symmetry_cell_setting                  Monoclinic
_symmetry_space_group_name_H-M          P2(1)/c

loop_
 _symmetry_equiv_pos_as_xyz
 'x, y, z'
 '-x, y+1/2, -z+1/2'
 '-x, -y, -z'
 'x, -y-1/2, z-1/2'
```

```
_cell_length_a                    13.1311(3)
_cell_length_b                    22.3023(4)
_cell_length_c                    8.2940(2)
_cell_angle_alpha                 90.00
_cell_angle_beta                  104.5990(10)
_cell_angle_gamma                   90.00
_cell_volume                      2350.51(9)
_cell_formula_units_Z             30
_cell_measurement_temperature     296(2)
_cell_measurement_reflns_used     ?
_cell_measurement_theta_min       ?
_cell_measurement_theta_max       ?

_exptl_crystal_description        block
_exptl_crystal_colour               colourless
_exptl_crystal_size_max           0.612
_exptl_crystal_size_mid           0.460
_exptl_crystal_size_min           0.432
_exptl_crystal_density_meas       ?
_exptl_crystal_density_diffrn     1.245
_exptl_crystal_density_method     'not measured'
_exptl_crystal_F_000                928
_exptl_absorpt_coefficient_mu     0.163
_exptl_absorpt_correction_type    none
_exptl_absorpt_correction_T_min   ?
_exptl_absorpt_correction_T_max   ?
_exptl_absorpt_process_details    ?

_exptl_special_details
;
 ?
;

_diffrn_ambient_temperature         296(2)
_diffrn_radiation_wavelength        0.71073
_diffrn_radiation_type              MoK\a
_diffrn_radiation_source            'fine-focus sealed tube'
_diffrn_radiation_monochromator     graphite
_diffrn_measurement_device_type     'Bruker P4'
_diffrn_measurement_method            '\w scans'
_diffrn_detector_area_resol_mean    ?
_diffrn_standards_number              ?
_diffrn_standards_interval_count    ?
_diffrn_standards_interval_time     ?
```



```
_diffrn_standards_decay_%          ?
_diffrn_reflns_number              78909
_diffrn_reflns_av_R_equivalents    0.0435
_diffrn_reflns_av_sigmaI/netI      0.0185
_diffrn_reflns_limit_h_min         -17
_diffrn_reflns_limit_h_max         17
_diffrn_reflns_limit_k_min         -29
_diffrn_reflns_limit_k_max         28
_diffrn_reflns_limit_l_min         -10
_diffrn_reflns_limit_l_max         10
_diffrn_reflns_theta_min           1.83
_diffrn_reflns_theta_max           27.54
_reflns_number_total               5419
_reflns_number_gt                  4309
_reflns_threshold_expression       >2sigma(I)

_computing_data_collection         'Bruker XSCANS'
_computing_cell_refinement         'Bruker XSCANS'
_computing_data_reduction          'Bruker SHELXTL'
_computing_structure_solution      'SHELXS-97 (Sheldrick, 1990)'
_computing_structure_refinement    'SHELXL-97 (Sheldrick, 1997)'
_computing_molecular_graphics      'Bruker SHELXTL'
_computing_publication_material    'Bruker SHELXTL'

_refine_special_details
;
 Refinement of F^2^ against ALL reflections.  The weighted R-factor wR and
 goodness of fit S are based on F^2^, conventional R-factors R are based
 on F, with F set to zero for negative F^2^. The threshold expression of
 F^2^ > 2sigma(F^2^) is used only for calculating R-factors(gt) etc. and is
 not relevant to the choice of reflections for refinement.  R-factors based
 on F^2^ are statistically about twice as large as those based on F, and R-
 factors based on ALL data will be even larger.
;

_refine_ls_structure_factor_coef   Fsqd
_refine_ls_matrix_type             full
_refine_ls_weighting_scheme        calc
_refine_ls_weighting_details
 'calc w=1/[\s^2^(Fo^2^)+(0.0596P)^2^+1.4692P] where P=(Fo^2^+2Fc^2^)/3'
_atom_sites_solution_primary       direct
_atom_sites_solution_secondary     difmap
_atom_sites_solution_hydrogens     .
_refine_ls_hydrogen_treatment      .
```

```
_refine_ls_extinction_method          SHELXL
_refine_ls_extinction_coef            0.0070(11)
_refine_ls_extinction_expression
 'Fc^*^=kFc[1+0.001xFc^2^\l^3^/sin(2\q)]^-1/4^'
_refine_ls_number_reflns               5419
_refine_ls_number_parameters           290
_refine_ls_number_restraints           0
_refine_ls_R_factor_all                0.0734
_refine_ls_R_factor_gt                 0.0573
_refine_ls_wR_factor_ref               0.1518
_refine_ls_wR_factor_gt                0.1391
_refine_ls_goodness_of_fit_ref         1.067
_refine_ls_restrained_S_all            1.067
_refine_ls_shift/su_max                0.000
_refine_ls_shift/su_mean               0.000

loop_
 _atom_site_label
 _atom_site_type_symbol
 _atom_site_fract_x
 _atom_site_fract_y
 _atom_site_fract_z
 _atom_site_U_iso_or_equiv
 _atom_site_adp_type
 _atom_site_occupancy
 _atom_site_symmetry_multiplicity
 _atom_site_calc_flag
 _atom_site_refinement_flags
 _atom_site_disorder_assembly
 _atom_site_disorder_group
S S -0.00720(5) 0.57115(3) 0.79465(7) 0.04878(18) Uani 1 1 d . . .
O O 0.27892(13) 0.45997(7) 1.0499(2) 0.0561(4) Uani 1 1 d . . .
N1 N 0.26763(15) 0.35895(8) 0.9984(2) 0.0480(4) Uani 1 1 d . . .
C1 C 0.14755(15) 0.41913(8) 0.8082(2) 0.0359(4) Uani 1 1 d . . .
N2 N 0.06337(13) 0.45785(7) 0.8318(2) 0.0393(4) Uani 1 1 d . . .
H2A H 0.0162 0.4466 0.8810 0.047 Uiso 1 1 calc R . .
C2 C 0.17857(15) 0.45121(8) 0.6597(2) 0.0353(4) Uani 1 1 d . . .
H2B H 0.1375 0.4337 0.5551 0.042 Uiso 1 1 calc R . .
N3 N 0.13899(13) 0.51218(7) 0.6755(2) 0.0405(4) Uani 1 1 d . . .
C3 C 0.06711(14) 0.51304(9) 0.7685(2) 0.0366(4) Uani 1 1 d . . .
N4 N 0.15026(13) 0.56095(7) 0.5789(2) 0.0412(4) Uani 1 1 d . . .
C4 C 0.12329(16) 0.35362(9) 0.7745(3) 0.0400(4) Uani 1 1 d . . .
C5 C 0.0464(2) 0.26298(13) 0.6520(4) 0.0722(8) Uani 1 1 d . . .
H5A H -0.0055 0.2428 0.5736 0.087 Uiso 1 1 calc R . .
```


C6 C 0.1214(3) 0.23082(12) 0.7643(4) 0.0786(9) Uani 1 1 d . . .
H6A H 0.1191 0.1892 0.7606 0.094 Uiso 1 1 calc R . .
C7 C 0.04714(19) 0.32575(11) 0.6543(3) 0.0550(6) Uani 1 1 d . . .
H7A H -0.0023 0.3478 0.5770 0.066 Uiso 1 1 calc R . .
C8 C 0.1997(2) 0.25878(11) 0.8823(4) 0.0662(7) Uani 1 1 d . . .
H8A H 0.2512 0.2367 0.9561 0.079 Uiso 1 1 calc R . .
C9 C 0.19927(18) 0.32043(9) 0.8869(3) 0.0457(5) Uani 1 1 d . . .
C10 C 0.23949(16) 0.41719(9) 0.9673(2) 0.0410(4) Uani 1 1 d . . .
C11 C 0.3572(2) 0.34092(14) 1.1328(3) 0.0676(7) Uani 1 1 d . . .
H11A H 0.3415 0.3030 1.1784 0.081 Uiso 1 1 calc R . .
H11B H 0.3685 0.3706 1.2210 0.081 Uiso 1 1 calc R . .
C12 C 0.4587(3) 0.3344(2) 1.0720(5) 0.1214(16) Uani 1 1 d . . .
H12A H 0.4489 0.3026 0.9897 0.146 Uiso 1 1 calc R . .
H12B H 0.4710 0.3713 1.0181 0.146 Uiso 1 1 calc R . .
C13 C 0.5510(4) 0.3209(4) 1.2067(8) 0.209(4) Uani 1 1 d . . .
H13A H 0.6114 0.3168 1.1623 0.314 Uiso 1 1 calc R . .
H13B H 0.5397 0.2842 1.2600 0.314 Uiso 1 1 calc R . .
H13C H 0.5626 0.3529 1.2867 0.314 Uiso 1 1 calc R . .
C14 C 0.29388(15) 0.44685(9) 0.6639(2) 0.0404(4) Uani 1 1 d . . .
C15 C 0.3255(2) 0.39857(12) 0.5831(3) 0.0613(6) Uani 1 1 d . . .
H15A H 0.2757 0.3716 0.5247 0.074 Uiso 1 1 calc R . .
C16 C 0.4304(3) 0.39044(19) 0.5888(4) 0.0918(11) Uani 1 1 d . . .
H16A H 0.4514 0.3574 0.5370 0.110 Uiso 1 1 calc R . .
C17 C 0.5032(3) 0.4308(2) 0.6704(5) 0.1013(14) Uani 1 1 d . . .
H17A H 0.5737 0.4254 0.6725 0.122 Uiso 1 1 calc R . .
C18 C 0.4731(2) 0.47957(19) 0.7500(4) 0.0873(10) Uani 1 1 d . . .
H18A H 0.5232 0.5071 0.8048 0.105 Uiso 1 1 calc R . .
C19 C 0.36767(18) 0.48742(12) 0.7478(3) 0.0593(6) Uani 1 1 d . . .
H19A H 0.3470 0.5199 0.8025 0.071 Uiso 1 1 calc R . .
C20 C 0.18335(15) 0.55063(9) 0.4499(3) 0.0409(4) Uani 1 1 d . . .
H20A H 0.1938 0.5113 0.4209 0.049 Uiso 1 1 calc R . .
C21 C 0.20518(16) 0.59968(9) 0.3468(3) 0.0427(5) Uani 1 1 d . . .
C22 C 0.20879(19) 0.58800(11) 0.1853(3) 0.0535(5) Uani 1 1 d . . .
H22A H 0.1979 0.5491 0.1440 0.064 Uiso 1 1 calc R . .
C23 C 0.2284(3) 0.63335(16) 0.0841(4) 0.0792(9) Uani 1 1 d . . .
H23A H 0.2303 0.6250 -0.0249 0.095 Uiso 1 1 calc R . .
C24 C 0.2447(4) 0.68950(17) 0.1427(5) 0.1271(18) Uani 1 1 d . . .
H24A H 0.2589 0.7200 0.0749 0.153 Uiso 1 1 calc R . .
C25 C 0.2404(5) 0.70167(16) 0.3005(6) 0.151(2) Uani 1 1 d . . .
H25A H 0.2508 0.7408 0.3398 0.181 Uiso 1 1 calc R . .
C26 C 0.2211(3) 0.65742(13) 0.4041(4) 0.0886(11) Uani 1 1 d . . .
H26A H 0.2187 0.6666 0.5125 0.106 Uiso 1 1 calc R . .

loop_


```
  _atom_site_aniso_label
  _atom_site_aniso_U_11
  _atom_site_aniso_U_22
  _atom_site_aniso_U_33
  _atom_site_aniso_U_23
  _atom_site_aniso_U_13
  _atom_site_aniso_U_12
S 0.0539(3) 0.0469(3) 0.0471(3) 0.0022(2) 0.0157(2) 0.0190(2)
O 0.0556(10) 0.0554(10) 0.0517(9) -0.0139(7) 0.0030(7) -0.0024(8)
N1 0.0518(11) 0.0460(10) 0.0436(9) 0.0062(8) 0.0071(8) 0.0090(8)
C1 0.0357(10) 0.0338(9) 0.0384(9) -0.0010(7) 0.0099(8) 0.0008(7)
N2 0.0359(8) 0.0382(9) 0.0466(9) 0.0014(7) 0.0156(7) 0.0039(7)
C2 0.0358(9) 0.0323(9) 0.0375(9) -0.0005(7) 0.0087(7) 0.0026(7)
N3 0.0439(9) 0.0336(8) 0.0473(9) 0.0046(7) 0.0175(7) 0.0078(7)
C3 0.0325(9) 0.0402(10) 0.0357(9) -0.0019(8) 0.0059(7) 0.0042(8)
N4 0.0418(9) 0.0341(8) 0.0485(9) 0.0049(7) 0.0130(7) 0.0012(7)
C4 0.0426(11) 0.0346(10) 0.0466(11) -0.0024(8) 0.0181(9) -0.0034(8)
C5 0.0775(19) 0.0568(16) 0.089(2) -0.0252(15) 0.0328(16) -0.0287(14)
C6 0.113(3) 0.0352(13) 0.101(2) -0.0036(14) 0.051(2) -0.0127(15)
C7 0.0503(13) 0.0519(13) 0.0640(14) -0.0109(11) 0.0168(11) -0.0101(10)
C8 0.092(2) 0.0368(12) 0.0744(17) 0.0108(11) 0.0301(15) 0.0061(12)
C9 0.0573(13) 0.0361(10) 0.0488(11) 0.0055(9) 0.0227(10) 0.0037(9)
C10 0.0408(10) 0.0436(11) 0.0397(10) -0.0003(8) 0.0122(8) 0.0022(8)
C11 0.0667(16) 0.0769(18) 0.0541(14) 0.0159(13) 0.0057(12) 0.0214(14)
C12 0.082(2) 0.176(4) 0.102(3) 0.022(3) 0.014(2) 0.060(3)
C13 0.108(4) 0.348(10) 0.169(5) 0.070(6) 0.030(4) 0.103(5)
C14 0.0365(10) 0.0433(11) 0.0426(10) 0.0061(8) 0.0122(8) 0.0059(8)
C15 0.0589(15) 0.0694(16) 0.0587(14) -0.0025(12) 0.0207(12) 0.0197(12)
C16 0.071(2) 0.134(3) 0.077(2) 0.003(2) 0.0304(17) 0.050(2)
C17 0.0453(17) 0.178(4) 0.088(2) 0.031(3) 0.0288(17) 0.034(2)
C18 0.0430(15) 0.126(3) 0.088(2) 0.022(2) 0.0074(14) -0.0174(17)
C19 0.0434(12) 0.0658(16) 0.0666(15) 0.0030(12) 0.0099(11) -0.0067(11)
C20 0.0389(10) 0.0364(10) 0.0469(11) 0.0013(8) 0.0097(8) 0.0002(8)
C21 0.0373(10) 0.0419(11) 0.0501(11) 0.0016(9) 0.0131(9) -0.0021(8)
C22 0.0530(13) 0.0576(14) 0.0507(12) 0.0010(10) 0.0143(10) -0.0048(11)
C23 0.092(2) 0.094(2) 0.0569(16) 0.0095(15) 0.0277(15) -0.0137(18)
C24 0.229(6) 0.074(2) 0.103(3) 0.015(2) 0.087(3) -0.036(3)
C25 0.304(7) 0.058(2) 0.131(3) -0.021(2) 0.128(4) -0.072(3)
C26 0.150(3) 0.0559(16) 0.0754(18) -0.0171(14) 0.058(2) -0.0416(19)

_geom_special_details
;
  All esds (except the esd in the dihedral angle between two l.s. planes)
  are estimated using the full covariance matrix.    The cell esds are taken
```



```
  into account individually in the estimation of esds in distances, angles
  and torsion angles; correlations between esds in cell parameters are only
  used when they are defined by crystal symmetry.  An approximate (isotropic)
  treatment of cell esds is used for estimating esds involving l.s. planes.
;

loop_
  _geom_bond_atom_site_label_1
  _geom_bond_atom_site_label_2
  _geom_bond_distance
  _geom_bond_site_symmetry_2
  _geom_bond_publ_flag
S C3 1.6692(19) . ?
O C10 1.212(2) . ?
N1 C10 1.357(3) . ?
N1 C9 1.407(3) . ?
N1 C11 1.458(3) . ?
C1 N2 1.454(2) . ?
C1 C4 1.506(3) . ?
C1 C10 1.548(3) . ?
C1 C2 1.564(3) . ?
N2 C3 1.344(2) . ?
C2 N3 1.473(2) . ?
C2 C14 1.509(3) . ?
N3 C3 1.361(2) . ?
N3 N4 1.381(2) . ?
N4 C20 1.273(3) . ?
C4 C7 1.370(3) . ?
C4 C9 1.394(3) . ?
C5 C6 1.375(5) . ?
C5 C7 1.400(4) . ?
C6 C8 1.378(4) . ?
C8 C9 1.376(3) . ?
C11 C12 1.547(5) . ?
C12 C13 1.458(6) . ?
C14 C19 1.379(3) . ?
C14 C15 1.386(3) . ?
C15 C16 1.378(4) . ?
C16 C17 1.361(6) . ?
C17 C18 1.381(5) . ?
C18 C19 1.392(4) . ?
C20 C21 1.460(3) . ?
C21 C26 1.370(3) . ?
C21 C22 1.378(3) . ?
```


C22 C23 1.379(4) . ?
C23 C24 1.341(5) . ?
C24 C25 1.352(5) . ?
C25 C26 1.374(4) . ?

loop_
 _geom_angle_atom_site_label_1
 _geom_angle_atom_site_label_2
 _geom_angle_atom_site_label_3
 _geom_angle
 _geom_angle_site_symmetry_1
 _geom_angle_site_symmetry_3
 _geom_angle_publ_flag
C10 N1 C9 111.16(17) . . ?
C10 N1 C11 122.5(2) . . ?
C9 N1 C11 126.3(2) . . ?
N2 C1 C4 117.94(16) . . ?
N2 C1 C10 110.95(15) . . ?
C4 C1 C10 102.35(16) . . ?
N2 C1 C2 101.07(14) . . ?
C4 C1 C2 112.49(15) . . ?
C10 C1 C2 112.45(15) . . ?
C3 N2 C1 112.78(15) . . ?
N3 C2 C14 115.59(16) . . ?
N3 C2 C1 100.62(14) . . ?
C14 C2 C1 114.28(15) . . ?
C3 N3 N4 120.58(16) . . ?
C3 N3 C2 111.97(15) . . ?
N4 N3 C2 125.68(15) . . ?
N2 C3 N3 107.90(16) . . ?
N2 C3 S 125.45(15) . . ?
N3 C3 S 126.61(15) . . ?
C20 N4 N3 117.05(17) . . ?
C7 C4 C9 120.9(2) . . ?
C7 C4 C1 131.0(2) . . ?
C9 C4 C1 107.98(18) . . ?
C6 C5 C7 120.7(3) . . ?
C5 C6 C8 121.6(2) . . ?
C4 C7 C5 117.7(3) . . ?
C9 C8 C6 117.7(3) . . ?
C8 C9 C4 121.3(2) . . ?
C8 C9 N1 128.5(2) . . ?
C4 C9 N1 110.23(18) . . ?
O C10 N1 126.1(2) . . ?

O C10 C1 126.17(19) . . ?
N1 C10 C1 107.78(17) . . ?
N1 C11 C12 111.9(2) . . ?
C13 C12 C11 112.8(4) . . ?
C19 C14 C15 119.7(2) . . ?
C19 C14 C2 122.87(19) . . ?
C15 C14 C2 117.4(2) . . ?
C16 C15 C14 120.3(3) . . ?
C17 C16 C15 120.1(3) . . ?
C16 C17 C18 120.6(3) . . ?
C17 C18 C19 119.7(3) . . ?
C14 C19 C18 119.6(3) . . ?
N4 C20 C21 121.03(19) . . ?
C26 C21 C22 118.4(2) . . ?
C26 C21 C20 122.4(2) . . ?
C22 C21 C20 119.2(2) . . ?
C21 C22 C23 120.7(2) . . ?
C24 C23 C22 120.1(3) . . ?
C23 C24 C25 119.8(3) . . ?
C24 C25 C26 121.4(3) . . ?
C21 C26 C25 119.6(3) . . ?

_diffrn_measured_fraction_theta_max 0.999
_diffrn_reflns_theta_full 27.54
_diffrn_measured_fraction_theta_full 0.999
_refine_diff_density_max 0.422
_refine_diff_density_min -0.394
_refine_diff_density_rms 0.048