Unanticipated cleavage of 2-nitrophenyl substituted-N-formyl pyrazolines under Bechamp Conditions: Unveiling the Synthesis of 2-aryl quinolines and its mechanistic exploration via DFT studies
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1. Optimisation of reaction conditions for the formation of 2a

In order to get better insight of metal and acidic conditions under Bechamp conditions, we initially treated 1a (1 mmol) with Fe (3 equiv) in HCl (0.5 equiv) using permutation of various solvents (0.5 mL) involving DCM, DCE, toluene, THF, MeOH, MeCN at rt or reflux. The best solvent was found to be MeOH for the formation of 2a. Further screening of metals and Bronsted acids was attempted using MeOH as solvent system at rt or under reflux. Interestingly neither intramolecular Friedel-Crafts acylated product\(^1\) (4a) (in TFA with or without metal) nor pyrazolo[1,5-c]quinazoline (3a)\(^2,3\) (except in Pd/CH\(_3\)COOH; 5%; entry 20) was obtained. All the reactions yielded the formation of 2a, as major component. Fe/HCl/MeOH/reflux emerged to be the best reaction conditions for the formation of 2a.

**Table S1: Optimization of reaction conditions for the formation of 2a**

| Entry | Reaction Conditions | Yield (%)\(^b\) | 2a | 3a | 4a |
|-------|---------------------|-----------------|----|----|----|
| 1.    | Fe/HCl/DCM/reflux   | 32\(^c\)        |    |    |    |
| 2.    | Fe/HCl/DCE/reflux   | 65              |    |    |    |
| 3.    | Fe/HCl/toluene/reflux | 63            |    |    |    |
| 4.    | Fe/HCl/THF/reflux   | 68              |    |    |    |
| 5.    | Fe/HCl/MeOH/reflux  | 91\(^d\)        |    |    |    |
| 6.    | Fe/HCl/MeCN/reflux  | 71              |    |    |    |
| 7.    | Fe/H\(_2\)SO\(_4\)/MeOH/reflux | 62 | -  | -  |
| 8.    | Fe/CH\(_3\)COOH/MeOH/reflux | 69 | -  | -  |
| 9.    | Fe/TFA/MeOH/reflux  | 73              |    |    |    |
| 10.   | Sn/HCl/MeOH/reflux  | 73\(^e\)        |    |    |    |
| 11.   | Sn/H\(_2\)SO\(_4\)/MeOH/reflux | 69 | -  | -  |
| 12.   | Sn/CH\(_3\)COOH/MeOH/reflux | 55 | -  | -  |
| 13.   | Sn/TFA/MeOH/reflux  | 57              |    |    |    |
| 14.   | Zn/HCl/MeOH/reflux  | 63\(^f\)        |    |    |    |
| 15.   | Zn/H\(_2\)SO\(_4\)/MeOH/reflux | 51 | -  | -  |
| 16.   | Zn/CH\(_3\)COOH/MeOH/reflux | 55 | -  | -  |
| 17.   | Zn/TFA/MeOH/reflux  | 50              |    |    |    |
| 18.   | Pd/HCl/MeOH/reflux  | 65\(^g\)        |    |    |    |
| 19.   | Pd/H\(_2\)SO\(_4\)/MeOH/reflux | 51 | -  | -  |
| 20.   | Pd/CH\(_3\)COOH/MeOH/reflux | 34 | 5  |    |
| 21.   | Pd/TFA/MeOH/reflux  | 41              |    |    |    |

\(^a\)The reaction was carried out at 1mmol scale, 3 equivalents of metal and 1a was dissolved in solvent (0.5 mL; wherever specified) and acid (0.5 equivalents); \(^b\)Isolated yields; \(^c\)10% of
product was obtained under neat conditions after heating at 80 °C; 61% of product was obtained at rt; 54% of product was obtained at rt; 49% of product was obtained at rt; 32% of product was obtained at rt.
Supporting Information (SI)

2. Selective reaction monitoring mode (SRM) using LC-MS

Materials & methods

Stock solutions were prepared in the dimethyl sulfoxide, purchased from Spectrochem (Mumbai, India). HPLC grade acetonitrile was purchased from Merck (Mumbai, India). Formic acid was purchased from Sigma-Aldrich (St Louis, MO, USA).

Instrumentation

Samples were analysed on an AB Sciex 3000 (Applied Biosystems, CA, USA) coupled with an Acquity™ UPLC (Waters, Milford, MA, USA) utilizing an Acquity C18 BEH, 1.7 μm, 2.1 × 50 mm column (Waters, Milford, MA, USA). The separations were accomplished using 0.1% v/v formic acid in water (mobile phase A) and 0.1% v/v formic acid in 100% acetonitrile (mobile phase B). The flow rate was 0.4 ml/min with mobile phase B starting with 40% and going up to 70% in 5.0 min. In the next 1.5 min, mobile phase B concentration came back to 40%. Eluates were detected using a Sciex API 3000 triple-quadrupole mass spectrometer equipped with a Turbo ion spray source (Applied Biosystems, Warrington, UK). The ion spray voltage was set at 5 kV and the source temperature at 500 °C. The mass spectrometer was operated in the electrospray positive ion mode and monitored with molecular reaction monitoring (MRM) using the parameters described in below Table. ST1. Data were acquired using Analyst version 1.2 software.

Methodology Reaction

![Reaction Scheme](image)

Scheme S1

Table S2. API 3000 mass spectral conditions

| Parameter                      | 1h2     | 1h1     | 2h       |
|--------------------------------|---------|---------|----------|
| Transition                     | 426/126 | 440.1/167.2 | 377.4/362.0 |
| De-clustering Potential (V)    | 20      | 20      | 20       |
| Focussing Potential (V)        | 80      | 80      | 80       |
| Collision cell exit potential (V) | 15      | 15      | 15       |
Collision gas ion energy (V) | 25 | 34 | 38

Exact Mass: 424.9760
1h2

Exact Mass: 439.0029
1h1
Figure S1. Representative extracted ion chromatogram of mixture of A) 1h2; B) 1h1; C) 2h; with selective reaction monitoring mode (SRM) in LC-MS. X-axis represents retention time in minutes and Y axis represents intensity in counts per seconds (cps).
3. Controlled reaction of N-acetylpyrazoline (1ap) and N-phenylpyrazoline (1ap1) under Bechamp conditions.

Appropriate N-acetylpyrazoline (1ap) and N-phenylpyrazoline (1ap1) respectively were subjected to Bechamp reduction conditions (catalyst Fe (3 equiv), HCl (40%; 0.5 equiv)) for 1h. The reaction led to the formation of 2a from 1ap. Whereas 1ap1 was transformed into mixture of products that were inseparable, as indicated by TLC.

Scheme S2. Reaction of N-acetylpyrazoline and N-phenylpyrazoline under Bechamp conditions.

2a: Yield: 79 %, Colour: Light brown solid. MP: 83 - 85 °C; IR (KBr, cm\(^{-1}\)): 3090 (=C-H stretch), 1640 (C=C stretch), 1320 (C-N stretch) \(^1\)H NMR (CDCl\(_3\), 400 MHz, \(\delta\) with TMS = 0): 8.22 (1H, d, \(J = 8.52\) Hz), 8.17 – 8.14 (3H, m), 7.88 (1H, d, \(J = 8.56\) Hz), 7.82 (1H, d, \(J = 9.16\) Hz), 7.74 – 7.70 (1H, m), 7.54 – 7.52 (3H, m), 7.50 – 7.45 (1H, m); \(^{13}\)C NMR (CDCl\(_3\), 100 MHz, \(\delta\) with TMS = 0): 157.49, 148.35, 139.77, 136.90, 129.81, 129.77, 129.42, 128.95, 127.67, 127.57, 127.26, 126.39, 119.14.

Controlled reaction concerning the formation of deformylated product

N-formylpyrazoline (1a) was treated with 0.5 eq. HCl using methanol as solvent for 12 h. The reaction progression was monitored using TLC. After the completion of reaction, the precipitates (5) so obtained were washed with excess methanol and recrystallized for further reactions.

Scheme S3. Reaction of N-formylpyrazoline (1a)
**Supporting Information (SI)**

5: Yield: 75%, Orange crystalline solid, Mp: 140 – 142 °C; IR (KBr, cm⁻¹): 3310 (N-H), 1518 (N=O), 1333 (N=O), 1299 (C=N); ¹H NMR (CDCl₃, 400 MHz, δ with TMS=0): 7.96 (2H, t, J = 8.4 Hz), 7.65 (3H, m), 7.41 (4H, m), 6.05 (D₂O exchangeable NH, 1H, s), 5.42 (1H, t, J = 13.2 Hz), 3.80, (1H, dd, J = 14.2 Hz), 3.01 (1H, dd, J = 13.2 Hz). MS (ESI): m/z = 267 [M+1] +
### 4. List of absolute Gibbs Free Energies

| Absolute Energy=−784.376289 |
|-------------------------------|
| **0 1**                       |
| C −5.17205100    0.93141000  −0.37901500 |
| C −3.97327000    1.64490900  −0.44801200 |
| C −2.75366900    0.99074200  −0.25719800 |
| C −2.72016100    −0.38947900  0.00982100 |
| C −3.93477600    −1.09571700  0.08055100 |
| C −5.14937200    −0.44327000  −0.11413100 |
| H −6.11965800    1.44251200  −0.53002000 |
| H −3.98442900    2.71265300  −0.65104000 |
| H −1.83931000    1.57184000  −0.31240300 |
| H −3.89871600    −2.15990900  0.29049300 |
| H −6.07971300    −1.00283900  −0.05955700 |
| C −1.45137100    −1.16205800  0.23563000 |
| O −1.50254300    −2.35025200  0.55497000 |
| C −0.14397200    −0.47233900  0.06141000 |
| C  1.01049000    −1.15112200  0.23596200 |
| H −0.13007000    0.56246800  −0.25906800 |
| H  0.91995700    −2.21064400  0.47622400 |
| C  2.37977000    −0.64715500  0.06412700 |
| C  3.34790800    −1.55311200  −0.41669700 |
| C  2.79430100    0.67810800   0.34989800 |
| C  4.65240800    −1.15025600  −0.68940600 |
| H  3.05054400    −2.58218700  −0.60460600 |
| C  4.11207800    1.06905800   0.09094600 |
| C  5.03516300    0.17332000  −0.44641100 |
| H  5.36972600    −1.86594100  −1.08196400 |
| H  4.40425000    2.08426800   0.34430700 |
| H  6.05375900    0.49580100  −0.64492800 |
| N  1.94709300    1.64228300   0.98706100 |
| O  1.22194600    2.40479000  −0.02958200 |
| H  1.47041000    3.32116800   0.17371300 |
| H  1.19751700    1.16028300   1.48143100 |
Absolute Energy=-784.363131
Supporting Information (SI)

Absolute Energy = -784.359705

C  4.93277200  0.72720900  0.11264700
C  4.12817900  0.61490800  1.24956400
C  2.86631400  0.02243600  1.15833300
C  2.39806700 -0.47031500 -0.07078100
C  3.21848700 -0.35711200 -0.27594600
C  4.47404100  0.24021300 -1.11700600
H  5.91362000  1.19067300  0.18386900
H  4.48112400  0.98845000  2.20734100
H  2.25584200 -0.05520400  2.05244200
H  2.84995100 -0.74469200 -2.15083000
H  5.09778000  0.32528100 -0.00318800
C  1.05956000 -1.13382000 -0.23094500
O  0.73494700 -1.63275400 -1.29637300
C  0.13360800 -1.21550100  0.99687300
C -1.27436200 -1.58744700  0.66405100
H  0.15670700 -0.24964000  1.51190500
H -1.52519500 -2.64311400  0.74903000
C -2.28408200 -0.75882900  0.27202600
C -3.60997200 -1.33636700  0.08120500
C -2.16337200  0.71040100  0.05403500
C -4.70529800 -0.57826300 -0.16951300
H -3.69676900 -2.41641300  0.17332400
C -3.38427900  1.48096400 -0.14870600
C -4.58588000  0.86062000 -0.26215000
H -5.68093700 -1.04064700 -0.29071800
H -3.29593100  2.55611500 -0.23859300
H -5.48228800  1.45115800 -0.43693000
N -0.96451000  1.22466300  0.02325300
H  0.56649800 -1.97056400  1.67024900
O -0.99255300  2.61818500 -0.16126500
H -0.04990500  2.83790300 -0.22773400
TS

Absolute Energy = -784.336786

0 1
C 3.51937400 -1.65944100 -0.99964200
C 3.36180300 -0.35356200 -1.47829900
C 2.46596500 0.51697100 -0.86060900
C 1.69430000 0.10034700 0.23682100
C 1.86911000 -1.20671900 0.71432600
C 2.77507400 -2.08030200 0.10264100
H 4.22425500 -2.33652100 -1.47573300
H 3.94642400 -0.01074300 -2.32848600
H 2.36857700 1.53790500 -1.21457200
H 1.31302000 -1.55837000 1.57737400
H 2.89998800 -3.08653400 0.49526000
C 0.74573100 1.11717100 0.88257500
O 1.16106800 2.35564400 0.86244800
C -0.00544300 0.62535200 2.13053700
C -0.98996300 -0.48483300 1.87061300
H -0.54439000 1.49965800 2.52973600
H -1.15687200 -1.21530600 2.66118200
C -1.72925100 -0.58954900 0.73066300
C -2.75401900 -1.60123600 0.54438800
C -1.59599100 0.42592800 -0.33650000
C -3.62076800 -1.53974400 -0.49941700
H -2.82547100 -2.39525300 1.28381900
C -2.58174200 0.49924700 -1.38998900
C -3.54374300 -0.45968300 -1.46256200
H -4.39415000 -2.29328300 -0.61693200
H -2.50436400 1.29949700 -2.11742300
H -4.27210300 -0.42841100 -2.26884000
N -0.57923400 1.22841000 -0.22763700
O -0.38579500 2.32950200 -0.94505400
H 0.41866600 2.71365200 -0.28663400
H 0.71626200 0.33398700 2.90229000
Absolute Energy = -784.355464
Absolute Energy = -707.995057

C      4.74196900  -0.21318800   0.01715300
C      3.92182600  -1.16133200  -0.60187800
C      2.53599000  -1.00352700  -0.61325500
C      1.94355500   0.12684300  -0.01956800
C      2.77928100   1.07435800   0.60116700
C      4.16415100   0.90456900   0.62394900
H      5.82049700  -0.34822900   0.03283500
H      4.36192300  -2.03689800  -1.07236800
H      1.90821300  -1.75648100  -1.07251900
H      2.34177400   1.93908500   1.09308600
H      4.78834800   1.64229000   1.12173600
C      0.48688600   0.38646700  -0.07310700
C     -0.00923900   1.69634300  -0.29450900
C     -1.35114300   1.98009200  -0.33182300
H     -1.70527600   2.99080200  -0.51318400
C     -2.28126200   0.92492500  -0.14579700
C     -3.68862600   1.11304000  -0.16644600
C     -1.78681000  -0.39019700   0.06578700
C     -4.54712200   0.04898800   0.01816600
H     -4.07584800   2.11581800  -0.32997200
C     -2.66816700  -1.47455500   0.25420400
C     -4.03167100  -1.25152500   0.23061500
H     -5.62199400   0.20790500   0.00117000
H     -2.24574500  -2.45855600   0.41419600
H     -4.71427600  -2.08426100   0.37617600
N     -0.39857220  -0.63903100   0.09464800
O     -0.00572200  -1.84834300   0.29513200
H     0.72055300   2.48068300  -0.46269300
Absolute Energy = -632.834856

|     |     |     |     |     |
|-----|-----|-----|-----|-----|
| C   | -4.68484700 | -0.48000400 | 0.02586700 |
| C   | -3.76591200 | -1.47959000 | -0.31094100 |
| C   | -2.39933700 | -1.20435400 | -0.32307500 |
| C   | -1.92121300 | 0.08007900  | -0.00765500 |
| C   | -2.85384800 | 1.07491100  | 0.33398000  |
| C   | -4.22222200 | 0.79712300  | 0.35262200  |
| H   | -5.75027900 | -0.69557500 | 0.03676000  |
| H   | -4.11571200 | -2.47694000 | -0.56605700 |
| H   | -1.68200600 | -1.97726200 | -0.57789700 |
| H   | -2.51680900 | 2.06884500  | 0.61388400  |
| H   | -4.92555800 | 1.57870500  | 0.62891800  |
| C   | -0.45691900 | 0.35161700  | -0.03428000 |
| C   | 0.04388600  | 1.68036000  | -0.20228400 |
| C   | 1.39973300  | 1.89624800  | -0.22417300 |
| H   | -0.64160900 | 2.50984000  | -0.33782500 |
| H   | 1.79974300  | 2.89926100  | -0.35894600 |
| C   | 2.29092900  | 0.80118400  | -0.08428300 |
| C   | 3.70467300  | 0.92909100  | -0.09458600 |
| C   | 1.70225800  | -0.49537200 | 0.06487000  |
| C   | 4.50726400  | -0.18462800 | 0.03889300  |
| H   | 4.14407500  | 1.91790500  | -0.20964100 |
| C   | 2.55568200  | -1.62488200 | 0.20011200  |
| C   | 3.92576500  | -1.47030600 | 0.18709300  |
| H   | 5.58913800  | -0.08124200 | 0.03119000  |
| H   | 2.09244600  | -2.60057000 | 0.31425800  |
| H   | 4.57056300  | -2.33922500 | 0.29157500  |
| N   | 0.35438100  | -0.69037100 | 0.085      |
Supplemental Information (SI)

Water

Absolute Energy = \(-76.419139\)

\[
\begin{array}{ccc}
\text{O} & 0.00000000 & 0.00000000 & 0.11729100 \\
\text{H} & 0.00000000 & 0.77129900 & -0.46916500 \\
\text{H} & 0.00000000 & -0.77129900 & -0.46916500 \\
\end{array}
\]

Figure S2. Formation of quinoline via NH\(_2\) pathway (Path B)
Supporting Information (SI)

Scheme S4. A. 1,5-H shift involving neutral pathway and B. radical cation pathway

Scheme S5. Cis-trans isomerisation of nitro radical anion.
## Nitro Radical anion

![Nitro Radical anion](image)

**Absolute Energy:** -858.393398

| Atom | X         | Y         | Z         |
|------|-----------|-----------|-----------|
| C    | -5.343781  | 0.962910  | -0.26395  |
| C    | -4.16668   | 1.66088   | 0.025405  |
| C    | -2.95243   | 0.98039   | 0.150327  |
| C    | -2.89240   | -0.41644  | -0.008613 |
| C    | -4.08616   | -1.10740  | -0.285099 |
| C    | -5.29685   | -0.42791  | -0.418347 |
| H    | -6.28758   | 1.49576   | -0.362834 |
| H    | -4.19125   | 2.74048   | 0.159005  |
| H    | -2.05528   | 1.54123   | 0.393348  |
| H    | -4.03297   | -2.18721  | -0.387718 |
| H    | -6.20738   | -0.98191  | -0.640511 |
| C    | -1.62016   | -1.22097  | 0.135053  |
| O    | -1.71877   | -2.45894  | 0.285239  |
| C    | -0.35679   | -0.51174  | 0.070092  |
| C    | 0.83164    | -1.16803  | 0.278759  |
| H    | -0.36433   | 0.54746   | -0.136751 |
| H    | 0.72227    | -2.23207  | 0.489073  |
| C    | 2.20269    | -0.74321  | 0.169049  |
| C    | 3.14910    | -1.81387  | 0.136261  |
| C    | 2.76234    | 0.57545   | -0.037543 |
| C    | 4.48618    | -1.65418  | -0.170404 |
H  2.76612000 -2.81489300  0.32455000
C  4.12219500  0.71964700 -0.41234700
C  4.97663400 -0.36270800 -0.47705800
H  5.14745000 -2.51785200 -0.19404700
H  4.47627700  1.72479500 -0.60676800
H  6.02177700 -0.21452400 -0.74008000
N  2.06068500  1.78921400  0.18380000
O  2.51457300  2.85828800 -0.32765600
O  1.04006400  1.79283600  0.92574100
Nitro Radical anion-TS

Absolute Energy: -858.451535

-1 2

\[
\begin{array}{ccc}
\text{C} & -5.15897000 & 0.49005800 & -0.30439200 \\
\text{C} & -4.16773500 & 1.31025200 & 0.24695200 \\
\text{C} & -2.86346200 & 0.83335700 & 0.40704900 \\
\text{C} & -2.51623800 & -0.47347500 & 0.02203600 \\
\text{C} & -3.51613000 & -1.27701400 & -0.55128800 \\
\text{C} & -4.82300500 & -0.80832200 & -0.70504600 \\
\text{H} & -6.17445500 & 0.86216900 & -0.43105100 \\
\text{H} & -4.40741300 & 2.33074700 & 0.54253400 \\
\text{H} & -2.10022200 & 1.49293000 & 0.81036200 \\
\text{H} & -3.22804100 & -2.27208400 & -0.87845000 \\
\text{H} & -5.58185800 & -1.45461700 & -1.14507900 \\
\text{C} & -1.11699500 & -1.05858900 & 0.15512900 \\
\text{O} & -0.83290700 & -2.05008600 & -0.59094600 \\
\text{C} & -0.25967500 & -0.48079800 & 1.09922500 \\
\text{C} & 1.07486400 & -1.03761300 & 1.30431000 \\
\text{H} & -0.62386200 & 0.27124600 & 1.79567800 \\
\text{H} & 1.21248500 & -1.91998600 & 1.94470700 \\
\text{C} & 2.24398200 & -0.63963200 & 0.61202900 \\
\text{C} & 3.37683900 & -1.50697900 & 0.53736400 \\
\end{array}
\]
| Element | X          | Y          | Z          |
|---------|------------|------------|------------|
| C       | 2.35421600 | 0.57241800 | -0.13583900|
| C       | 4.45920400 | -1.24222900| -0.28499100|
| H       | 3.33812600 | -2.43274600| 1.10713000 |
| C       | 3.42299300 | 0.82819500 | -0.98989000|
| C       | 4.48305300 | -0.07797100| -1.07586100|
| H       | 5.28415400 | -1.95013500| -0.33687300|
| H       | 3.43281300 | 1.75560900 | -1.55417400|
| H       | 5.32328100 | 0.12948600 | -1.73345700|
| N       | 1.42695300 | 1.69357500 | 0.06272600 |
| O       | 0.98548600 | 2.25996000 | -0.94679300|
| O       | 1.29475500 | 2.13292700 | 1.21509800 |
Hydroxylamine Radical Cation (9a)

![Image of Hydroxylamine Radical Cation (9a)]

Absolute Energy: -784.106841

|    |    |    |    |
|----|----|----|----|
| C  | 5.23138500 | 0.85208900 | 0.80061500 |
| C  | 4.02469400 | 1.28538300 | 1.35760400 |
| C  | 2.82015100 | 0.72797600 | 0.92966300 |
| C  | 2.81277200 | -0.27883100 | -0.05617500 |
| C  | 4.03655200 | -0.71421800 | -0.60247400 |
| C  | 5.23496200 | -0.14880900 | -0.18009200 |
| H  | 6.16867300 | 1.29084100 | 1.13143700 |
| H  | 4.02274000 | 2.05353500 | 2.12542300 |
| H  | 1.89875000 | 1.06953200 | 1.39161800 |
| H  | 4.02340200 | -1.49587400 | -1.35510700 |
| H  | 6.17382300 | -0.48659100 | -0.60913300 |
| C  | 1.57204300 | -0.93401900 | -0.53490000 |
| O  | 1.58496500 | -1.91629200 | -1.27129500 |
| C  | 0.23009300 | -0.37347700 | -0.13603700 |
| C  | -0.88064500 | -1.12903300 | -0.32419900 |
| H  | 0.17730700 | 0.60479200 | 0.33519000 |
| H  | -0.71989500 | -2.14539500 | -0.68572400 |
| C  | -2.25101700 | -0.76421900 | 0.00415700 |
| Atom | X     | Y     | Z     | X     |
|------|-------|-------|-------|-------|
| C    | -3.11036000 | -1.72276900 | 0.56014800 |
| C    | -2.79969800  | 0.56202700  | -0.21259300 |
| C    | -4.38333100  | -1.37894800 | 1.00842800  |
| H    | -2.74475000  | -2.73705100 | 0.69022600  |
| C    | -4.08964100  | 0.91677100  | 0.27555400  |
| C    | -4.85977300  | -0.04826700 | 0.88273700  |
| H    | -5.01268700  | -2.13251400 | 1.47186300  |
| H    | -4.45290300  | 1.92657600  | 0.12828900  |
| H    | -5.85088700  | 0.20460700  | 1.24639500  |
| N    | -2.10048300  | 1.41831000  | -0.98181800 |
| O    | -2.44502400  | 2.74322700  | -1.01958100 |
| H    | -2.45157000  | 3.01126800  | -1.96153700 |
| H    | -1.17727200  | 1.18267300  | -1.34628100 |
Hydroxylamine Radical Cation_ TS

Absolute Energy: -784.071206

\[ \begin{array}{cccc}
\text{I 2} & \text{C} & -5.22549000 & 0.81006000 & -0.47335300 \\
& \text{C} & -4.07135400 & 1.39908500 & -0.99848400 \\
& \text{C} & -2.82470500 & 0.82316800 & -0.75692100 \\
& \text{C} & -2.72014200 & -0.35261700 & 0.01274200 \\
& \text{C} & -3.89132100 & -0.93635900 & 0.53598200 \\
& \text{C} & -5.13298200 & -0.35830500 & 0.29422800 \\
& \text{H} & -6.19626800 & 1.25972500 & -0.66246600 \\
& \text{H} & -4.14369600 & 2.30236500 & -1.59717300 \\
& \text{H} & -1.94581000 & 1.29998900 & -1.18104100 \\
& \text{H} & -3.80312400 & -1.84162500 & 1.12771900 \\
& \text{H} & -6.03074200 & -0.81444600 & 0.70100300 \\
& \text{O} & 0.13044800 & -0.40697200 & -0.17960900 \\
& \text{C} & 1.00664700 & -1.23696700 & -0.13069200 \\
& \text{H} & -0.16300400 & 0.30363000 & -1.01274700 \\
& \text{H} & 0.85631600 & -2.28342800 & 0.14201000 \\
& \text{C} & 2.34228000 & -0.74833000 & -0.22635600 \\
\end{array} \]
|   |   |   |   |   |   |
|---|---|---|---|---|---|
| C | 3.42295000 | -1.59701700 | -0.53623500 |
| C | 2.63441400 | 0.63297400 | 0.13305900 |
| C | 4.72204400 | -1.10378800 | -0.59355100 |
| H | 3.22249300 | -2.63935700 | -0.76747600 |
| C | 3.97030600 | 1.10931000 | 0.10075200 |
| C | 4.98565300 | 0.24920100 | -0.28268600 |
| H | 5.53927000 | -1.76191200 | -0.87100200 |
| H | 4.17679500 | 2.13412200 | 0.38679200 |
| H | 6.00552600 | 0.61935000 | -0.33095000 |
| N | 1.59602500 | 1.34868900 | 0.60484900 |
| O | 1.83162700 | 2.65614500 | 0.87003600 |
| H | 1.06921300 | 2.97096700 | 1.39435400 |
| H | 0.44379400 | 0.58547800 | 0.54519100 |
5. References

1. N. Ahmed and D. Dev, *Synth. Commun.*, 2013, **43**, 689-704.
2. D. Kumar and R. Kumar, *Tetrahedron Lett.*, 2014, **55**, 2679-2683.
3. D. M. Sawant, S. Sharma, R. S. Pathare, G. Joshi, S. Kalra, S. Sukanya, A. K. Maurya, R. K. Metre, V. K. Agnihotri and S. Khan, *Chem. Comm.*, 2018, **54**(82), 11530-11533.
4. R. Khusnutdinov, A. Bayguzina, R. Aminov and U. Dzemilev, *J. Heterocycl. Chem*, 2016, **53**, 144-146.
Figure S3

$^1$H NMR

![NMR Spectrum](image)

Chemical shift: $\delta = 7.406$ ppm

Compound: 2a

$N$-substituted aromatic system
Figure S5

$^1$H NMR
Figure S6

$^{13}$C NMR
Figure S9

$^{13}$C NMR

[Chemical structure image]

2c
Figure S10

HRMS

S28
Figure S11
$^1$H NMR

[Chemical structure image]
Figure S12  $^{13}$C NMR
Figure S13

HRMS

252.0992

[M+H]^+

H_{3}CO

N

2d

OH

S31
Figure S14

$^1$H NMR
Figure S15  13C NMR

S33
Figure S16

[S+H]^+

HRMS 3.65e7

2e

H3CO

H3CO
Figure S17

$^1$H NMR
Figure S18  $^{13}$C NMR
Figure S20

$^1$H NMR

![NMR Spectrum]

S38
Figure S21

$^{13}$C NMR

[Chemical structure diagram]
Figure S23
$^1$H NMR
Figure S24  
$^{13}$C NMR
Figure S26

$^1$H NMR

N

NH$_2$

2i
Figure S27

$^{13}$C NMR

\( \text{NH}_2 \)

2i
Figure S28

HRMS

[M+H]^+ 221.1051

222.1081

223.1108 274.2246

302.3038 340.2854 362.2409 391.2077 453.3441

475.3264 203.1313 534.1797 571.2573 599.2211

% 100

158.0014 204.0758

0 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620

m/z

2i

NH2

26
Figure S29

$^1$H NMR
Figure S30

$^{13}$C NMR

![NMR spectrum](image)
Figure S32

$^1$H NMR
Figure S35

$^1$H NMR
Figure S36

$^{13}$C NMR

![NMR Spectrum]

Molecular Structure: 

[Chemical Structure Image]

N: parts per Million ($^{13}$C)
Figure S37

**HRMS**

![Chemical Structure](attachment:image.png)

**[M+H]^+**

**2I**
Figure S39

HRMS

[M+H]⁺

2m

180.1003 206.1176 235.1491 266.1223 274.3055 302.2847 302.2847 349.2317 340.2994 377.0924 431.2314 443.3650 453.3980 475.3886 485.3476 551.3906 598.3786 m/z
Figure S40

$^1$H NMR

![NMR Spectrum](image)

2n

---

X: parts per Million; 1H
Figure S41

$^{13}$C NMR

![Chemical Structure](image)
Figure S42

HRMS

HRMS

2n

[Image of a molecular structure with a chemical formula and m/z values]
Figure S43

$^1$H NMR

HRMS
Figure S44 \[^{13}\text{C NMR}\]

\[ \text{HRMS} \]

\[ \text{2o} \]
Figure S46

$^1$H NMR

2p

H$_3$CO

N

Cl

S64
Figure S47

$^{13}$C NMR

![Chemical Structure](image-url)

2p
Figure S48

[Chemical Structure Image]

HRMS
Figure S49

$^1$H NMR
Figure S50

$^{13}$C NMR

MeO$\begin{array}{c}
\text{MeO} \\
\text{H}_2\text{N}
\end{array}$

10
Converted to respective quinoline
Figure S52

$^1$H NMR

![NMR spectrum of compound 11](image)

[Chemical structure of compound 11]

$\text{H}_2\text{N}$

11
$^{13}$C NMR
Converted to respective quinoline

HRMS

[M+H]$^+$

![Chemical Structure]