Solvent-Free One-Pot Multicomponent, Synthesis, Characterization and Anti-bacterial activity, of some 2-substituted-3-cyano-Pyridine Derivatives

Zakaria H. Aiube
Muna S. Al-rawi
Ahmed K. Ebrahem

Dept. of Chemistry/ College of Education for Pure Science (Ibn Al-Haitham)/ University of Baghdad.

Received in: 18 March 2015, Accepted in: 14 April 2015

Abstract

Solvent-free thermal heating, one-pot condensation of acetophenone, ethyl cyanoacetate or malononitrile and substituted Aromatic aldehyde, ammonium acetate give, 2-oxo-3-cyano-4-substituted Aryl-6-phenyl pyridine [I]a-h , or 2-amino-3-cyano-4-substituted Aryl-6-phenyl pyridine derivatives[II]a-f , respectively.

Treatment of compounds 2-oxo-3-cyano-4-substituted Aryl-6-phenyl pyridine with phosphorous penta sulphide (P₂S₅), give 2-thioxo-3-cyano-4-substituted Aryl-6-phenyl pyridine derivatives[III]a-c.

All prepared compounds are characterized by, C.H.N.S-elmental analysis, melting points, FTIR-and ¹H-NMR-spectral analysis.

Antibacterial examination of synthesized compounds [I]a-c , [II]a-c and [III]a-c against five types of, (G-) and (G+) bacterial . in comparison with common antibiotic like Ampicillin, Amoxicilin and Lincomycin the result shows 2-thioxo-3-cyano-4-substituted Aryl-6-phenyl pyridine derivatives are more reactive than 2-oxo-3-cyano pyridine derivatives or 2-amino-3-cyano pyridine derivatives.

Key words: Solvent-free, one-pot, pyridine derivatives.
**Introduction**

One-pot multi-component reactions, is an important synthetic methodology for a broad spectrum of biological and pharmaceutical organic compounds, in which the simultaneous interaction of three or more components in a sequence of steps to afford the final product [1-4].

3-Cyano-2-pyridone derivatives draw a special attention for their wide spectrum biological activities along with their importance and utility as intermediates in preparing variety of heterocyclic compounds [5-7].

In recent years much attention has been developed of 3-cyanopyridine derivatives because of interesting pharmaceutical and biological activities, such as antimicrobial [8-13], analgesic anti-inflammatory [14]; and antitumor agents [15].

In view of the above mentioned facts, and giving attention to the antimicrobial effects of 3-cyanopyridines derivatives, we use the thermal heating solvent-free one-pot multicomponent reaction as a synthetic methodology for synthesis of three different types of 3-cyano pyridine with different substituted in position-2, like 2-oxo-3-cyanopyridine, 2-amino-3-cyanopyridine and 2-thioxo-3-cyanopyridine derivatives, and antibacterial activities examination against five different types of (G-) and (G+) bacteria species.

![Diagram of synthesized compounds](image)

The scheme for synthesized compounds [I]$_{a-h}$, [II]$_{a-f}$, [III]$_{a-c}$
Experimental

Materials and instruments

All chemicals were supplied from Merck, Fluka and Aldrich Chemicals Co. and used as received.

FTIR spectra were recorded using potassium bromide discs on a Shimadzo (IR prestige-21) FTIR spectrophotometer. ¹H NMR spectra were carried out by company: Bruker, model: ultra shield 400 MHz, origin: Switzerland and are reported in ppm(δ) dutureated. DMSO was used as a solvent with TMS as an internal standard. Elemental analysis (C.H.N.S) were carried out using an EuroEA Elemental Analyzer at (The Central Service Laboratory-College of Education For Pure Science Ibn Al-Haitham). Uncorrected melting points were determined by using Hot-Stage, Gallen Kamp melting point apparatus. The biological activity was performed in Center for Market Research and Consumer Protection, University of Baghdad.

Synthesis Methods

Synthesis 2-oxo -3 -cyano -4 -substituted Aryl -6 -phenyl pyridine [I] a-h.

A- Solvent-free one-pot multicomponent condensation at 140 ⁰C

A stirred mixture of acetophenone (0.01 mol, 1.17 ml), ethyl cyanoacetate (0.01 mol, 1.1 ml), substituted benzddehyde (0.01 mol) and ammonium acetate (0.01, 0.77 g) was heated at (140 C°) in oil bath for 15- minute, progress of reaction was monitored by TLC (petroleum ether: ethyl acetate eluent). Dough was formed, solidified upon cooling, Then ethanol was added, a precipitate began to form, then left in ice-chest for an hour, then filtered, washed with water and ethanol, dried to give a very good yield (80-90 %). Recrystallized from ethanol.

The physical data of these compounds are listed in Table 1. Anal. Calcd. for compound [I]a C₁₈H₁₁N₂OBr : C, 61.53; H, 3.13; N, 7.97 Found: C, 61.88; H, 3.20; N, 8.21, for Calcd. compound [II]h C₁₉H₁₄N₂O₃ : C, 71.69; H, 4.40; N, 8.80 Found: C, 71.82; H, 4.48; N, 8.86.

B-ethanol reflux one-pot multicomponent condensation of acetophenone, ethyl cyanoacetate, substituted aromatic aldehyde and ammonium acetate for 8 h give poor yield (20-45)% of product.

Synthesis 2-amino -3 -cyano -4 -substituted Aryl -6 -phenyl pyridine [II]a-f.

A- Solvent-free one-pot multicomponent condensation at 140 ⁰C

A stirred mixture of acetophenone (0.01 mol, 1.17 ml), malononitrle (0.01 mol, 0.66 g), substituted benzlddehyde (0.01 mol), and ammonium acetate (0.01 mol, 0.77 g) was heated (140 C°) in oil bath for 20 minute, progress of reaction was monitored by TLC (petroleum ether: ethyl acetate eluent). Dough was formed, solidified upon cooling, Then ethanol was added a precipitate began to form, then left in ice-chest for an hour, then filtered, washed with water then ethanol, dried to give a very good yield (75-87 %). Recrystallized from ethanol and acetic acid.
B-ethanol reflux one-pot multicomponent condensation of acetophenone, malononitrile, substituted aromatic aldehyde and ammonium acetate for 8 h give poor yield.

The physical data of these compounds are listed in Table 1. Anal. Calcd. For compound [II]a C_{18}H_{12}N_{3}Br: C, 61.71; H, 3.42; N, 12.00; Found: C, 61.85; H, 3.49; N, 12.28 and Calcd. for compound [II]b C_{18}H_{12}N_{3}Cl: C, 70.70; H, 3.92; N, 13.74; Found: C,71.11; H,4.01; N, 13.86.

Synthesis 2-thioxo-3-cyano-4-substituted Aryl-6-phenyl pyridine [III]a-c.

A mixture of 2-oxo-3-cyano-4-(x'-substituted phenyl)-6-phenyl-2(1H)-pyridinones [II]a-c (0.01 mol) and Phosphorous pentasulphide (P_{2}S_{5}) (0.01 mol) in pyridine (10 mL) was refluxed for 5 h. Then reaction mixture was poured into ice-cold water. The separated solid was filtered off and washed with dilute HCl to afford the corresponding thione derivative, which was crystallized from ethanol.

The physical data of these compounds are listed in Table 1. Anal. Calcd. For compound [III]a C_{18}H_{11}N_{2}SBr: C,58.85; H, 2.99; N, 7.62; S, 8.71; Found: C, 59.12; H, 3.17; N, 7.88; S,8.98 and Calcd. for compound [III]c C_{20}H_{17}N_{3}S : C,72.50; H, 5.13; N, 12.68; S, 9.66; Found: C, 72.72; H, 5.29; N, 12.92; S,9.90.

Evaluation of Antibacterial Activity

Antibacterial activity of synthesized compounds was determined using a disc diffusion method 30 µl of each Gram negative Pseudomonas aeruginosa, Escherichia coli, Proteus mirabilis and gram positive Bacillus subtilis, Staphylococcus aureus bacterial suspension of approximately 10^8 colony cell/ml was incubated at 37 °C for 24 h, were spread on Muller-Hintone agar using sterile collon. Swaks. 30 mg/ml solution of synthesized compounds in DMSO, were prepared and placed into occulted plates. The plates were incubated aerobically at 37°C for 24 h then inhibition zone diameter (mm) were measured.

Results and Discussion

Thermal-heating one-pot multicomponent condensation of equimolecular amounts of substituted benzaldehyde and acetophenone with ethylcyanoacetate and anhydrous ammonium acetate at 140 °C for less than 15 min; afforded an excellent yield of 2-oxo- cyanopyridin derivatives [I]a-h (80-90)%. FTIR-spectral analysis of compounds[I]a-h, showed disappearance of carbonyl stretching bands of acetophenone, substituted benzaldehyde, ethyl cyanoacetate ester and ammonium acetate, and appearance of secondary amide carbonyl stretching band (C=O) at 1643-1699 cm^{-1}, besides the secondary amide (N-H) stretching bands at 3130-3150 cm^{-1} and cyano stretching bands at 2214-2225 cm^{-1}, as well as the appearance of (NO_{2}) a symmetrical and symmetrical stretching bands of compounds [I]d at 1516 and 1350 cm^{-1}, [I]e at 1531,1350 cm^{-1} and [I]g at 1527,1353 cm^{-1}, respectively, while compound [I]f , [I]h showed (O-H) stretching band at 3338 and 3429 cm^{-1}, respectively. The other data of functional groups which are characteristics of these compounds are given in Table 2.

The $^1$HNMR spectrum (in DMSO), of compound [I]b showed pyridine ring proton at C5 as a singlet signal at 6.82 ppm, aromatic proton (9H) of phenyl groups at C4 and C6 of pyridine ring as a multiplet signal at 7.5-7.9 ppm : equivalent to 9-protons, and secondary amide (N-H) proton as a singlet signal at 12.89 ppm. While $^1$HNMR-spectrum of compound [I]g, showed pyridine ring proton at C5 as a singlet signal at 6.9 ppm, aromatic proton (9H) of phenyl groups at C4 and C6 of pyridine ring as a multiplet signal at 7.5-8.3 ppm: equivelant to 9-protons, and secondary amide (N-H) proton as a singlet signal at 13.0 ppm.
Thermal heating one-pot multicomponent reaction of equimolar amounts of acetophenone, substituted benzaldehyde, malonitrile, ammonium acetate at 140 °C for less than 20 minute give a very good yield (75-87%), with high purity of 2-amino-3-cyano-4(4′-substituted phenyl) -6 - phenyl pyridine[II]a-c , which were characterized , (C,H,N,S) elemental analysis , FTIR-spectral analysis and 1H.NMR-spectral analysis.

The FTIR absorption spectra of compound [II]a, showed the disappearance of absorption bands of the starting materials together with appearance of (C=N) of pyridine ring at1610-1643cm-1 and a symmetrical and symmetrical stretching bands of amino group (NH2) at 3460-3487cm-1 and 3305-3375cm-1, respectively, and cyano group (C≡N) stretching band 2206-2214 cm-1.

Moreover, the 1H NMR spectrum (in DMSO), of compound [II] a showed pyridine ring proton at C 5 as a singlet signal at 6.8 ppm , (NH2) proton as a singlet signal at 6.9 ppm (equivalent to 2-proton ) and Aromatic proton (9H) of phenyl groups at C4 and C6 of pyridine ring as a multiplet signal at 7.5-7.7 ppm (equivalent to 9-proton).

Treatment of compounds 2-oxo-3-cyano-4(4′-substituted phenyl) -6 - phenyl (2H) pyridine[I] a-c with phosphorous penta sulfide (P2S5) in pyridine under reflux give corresponding 2-thioxo-3-cyano-4(4′-substituted phenyl) -6 - phenyl (2H) pyridine[III]a-c.

Structure of compounds [III]a-c has been characterized by its melting points ,(C,H,N,S) elemental analysis , FTIR and 1H.NMR-spectral analysis.

FTIR-spectral of compounds [III]a-c , showed disappearance of carbonyl stretching bands of 2-oxo pyridine starting material and appearance of 2-thioxo pyridine (C=S) stretching bands at 1199, 1188, 1184 cm-1, respectively, besides the appearance of secondary thioxo amide (N-H) stretching bends at 3433, 3398, 3394 cm-1, respectively and cyano (C≡N) 2218 , 2218 , 2210 cm-1, respectively .

1H.NMR-spectral analysis of compound [III]a, showed a singlet signal of C5-pyridine ring proton at 7.1 ppm, secondary thioxo amide (N-H) proton at 8.7 ppm, and aromatic proton (9H) of phenyl groups substituted at C4 and C6 of pyridine ring as a multiplet signal at 7.3-8.1 ppm (equivalent to 9-protons ) . While the 1H.NMR-spectrum of compound [III]a, showed C5-pyridine ring proton as singlet signal at 7.1 ppm , secondary thioxo amide (N-H) proton as singlet signal at 8.9 ppm , and aromatic proton (9H) of phenyl groups substituted at C4 and C6 of pyridine ring as a multiplet signal at 7.5-8.0 ppm.

All the spectral data of FTIR spectroscopy of synthesized compounds are listed in Table (2).

**Biological Activity**

Antibacterial activity of synthesized compounds 2-oxo-3-cyano-4-substituted Aryl-6-phenyl pyridine [I] a-c , 2-amino-3-cyano-4-substituted Aryl-6-phenyl pyridine [II]a-c , 2-thioxo-3-cyano-4-substituted Aryl-6-phenyl pyridine [III]a-c respectively in comparison with common antibiotic, Ampicillin, Amoxicilin and Lincomycin against Gram negative Pseudomonas aeruginosa, Escherichia coli, Proteus mirabilis and gram positive Bacillus subtilis, Staphylo coccus aureus.pathogenic species . are given in table (3).

Result showed stronger activity exhibition of compounds [III]a-c against Pseudomonas aeruginosa, Escherichia coli and Staphylo coccus , this may be due to presence of thioxo-group (C=S) at position 2 , of 3-cyanopyridine derivatives .

While all synthesized compounds showed stronger activity against Pseudomonas aeruginosa bacteria .
References:
2- Chebanov V.A.; Sakhno, Y.I.; Desenko, S.M.; Chernenko,V.N; Musatov, V.I.; Shishkina, S.V.; Shishkin O.V. and Kappe C.O., 2007, One-Pot, Multicomponent Route to Pyrazoloquinolinizizinones, Tetrahedron, 63, 1229.
7- Zahira Kibou1 ; Nawel Cheikh1,2, Didier Villemin2; Nouredine Choukchou-Braham1 ; Bachir Mostefa-Kara1 and Mohamed Benabdallah, (2011), A Simple and Efficient Procedure for a 2-Pyridones Synthesis under Solvent-Free Conditions, International Journal of Organic Chemistry, 1, 242-249.
Table No. (1) Physical properties of synthesized compounds [I]a-h, [II]a-f and [III]a-c

<table>
<thead>
<tr>
<th>comp. No.</th>
<th>Molecular Formula</th>
<th>M.P C⁰</th>
<th>Yield% solvent-free At 140 °C</th>
<th>Yield% in ethanol reflux</th>
</tr>
</thead>
<tbody>
<tr>
<td>[II]a</td>
<td>C₁₈H₁₂N₅Br</td>
<td>240-242</td>
<td>87</td>
<td>25</td>
</tr>
<tr>
<td>[II]b</td>
<td>C₁₈H₁₂N₅Cl</td>
<td>252-253</td>
<td>75</td>
<td>18</td>
</tr>
<tr>
<td>[II]c</td>
<td>C₂₀H₁₈N₄</td>
<td>222-224</td>
<td>80</td>
<td>11</td>
</tr>
<tr>
<td>[II]d</td>
<td>C₁₈H₁₂N₄O₂</td>
<td>230-231</td>
<td>84</td>
<td>14</td>
</tr>
<tr>
<td>[II]e</td>
<td>C₁₈H₁₂N₄O₂</td>
<td>218-220</td>
<td>80</td>
<td>14</td>
</tr>
<tr>
<td>[II]f</td>
<td>C₁₈H₁₃N₃O</td>
<td>233-235</td>
<td>78</td>
<td>16</td>
</tr>
<tr>
<td>[I]a</td>
<td>C₁₈H₁₁N₂OBr</td>
<td>&gt;300</td>
<td>90</td>
<td>45</td>
</tr>
<tr>
<td>[I]b</td>
<td>C₁₈H₁₁N₂OCl</td>
<td>&gt;300</td>
<td>88</td>
<td>33</td>
</tr>
<tr>
<td>[I]c</td>
<td>C₂₀H₁₇N₃O</td>
<td>&gt;300</td>
<td>83</td>
<td>25</td>
</tr>
<tr>
<td>[I]d</td>
<td>C₁₈H₁₁N₃O₃</td>
<td>&gt;300</td>
<td>86</td>
<td>28</td>
</tr>
<tr>
<td>[I]e</td>
<td>C₁₈H₁₁N₃O₃</td>
<td>&gt;300</td>
<td>80</td>
<td>36</td>
</tr>
<tr>
<td>[I]f</td>
<td>C₁₈H₁₂N₂O₂</td>
<td>&gt;300</td>
<td>85</td>
<td>28</td>
</tr>
<tr>
<td>[I]g</td>
<td>C₁₈H₁₁N₃O₃</td>
<td>&gt;300</td>
<td>82</td>
<td>20</td>
</tr>
<tr>
<td>[I]h</td>
<td>C₁₈H₁₄N₃O₃</td>
<td>&gt;300</td>
<td>87</td>
<td>22</td>
</tr>
<tr>
<td>[III]a</td>
<td>C₁₈H₁₁N₂SBr</td>
<td>228-230</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[III]b</td>
<td>C₁₈H₁₁N₂SCl</td>
<td>238-239</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[III]c</td>
<td>C₂₀H₁₇N₃S</td>
<td>195-197</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table No.(2): Characteristic FTIR absorption bands of synthesized compounds [I]a-h , [II]a-f and [III]a-c

<table>
<thead>
<tr>
<th>Comp. No.</th>
<th>ν(N-H) cm⁻¹</th>
<th>ν(C-H) cm⁻¹</th>
<th>ν(C≡N) cm⁻¹</th>
<th>ν(C=N) cm⁻¹</th>
<th>ν(C=O) cm⁻¹</th>
<th>ν(C=S) cm⁻¹</th>
<th>ν(C=C) cm⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>[I]a</td>
<td>3138</td>
<td>3028-3055</td>
<td>2214</td>
<td>1608</td>
<td>1643</td>
<td>-</td>
<td>1570-1531</td>
</tr>
<tr>
<td>[I]b</td>
<td>3140</td>
<td>3066-3028</td>
<td>2214</td>
<td>1608</td>
<td>1643</td>
<td>-</td>
<td>1573-1531</td>
</tr>
<tr>
<td>[I]c</td>
<td>3130</td>
<td>3077-3040</td>
<td>2206</td>
<td>1610</td>
<td>1699</td>
<td>-</td>
<td>1564-1517</td>
</tr>
<tr>
<td>[I]d</td>
<td>3150</td>
<td>3062-3020</td>
<td>2210</td>
<td>1608</td>
<td>1674</td>
<td>-</td>
<td>1577-1500</td>
</tr>
<tr>
<td>[I]e</td>
<td>3140</td>
<td>3082-3028</td>
<td>2214</td>
<td>1604</td>
<td>1651</td>
<td>-</td>
<td>1577-1500</td>
</tr>
<tr>
<td>[I]f</td>
<td>3134</td>
<td>3062-3028</td>
<td>2225</td>
<td>1608</td>
<td>1649</td>
<td>-</td>
<td>1575-1519</td>
</tr>
<tr>
<td>[I]g</td>
<td>3148</td>
<td>3077-3040</td>
<td>2218</td>
<td>1603</td>
<td>1643</td>
<td>-</td>
<td>1519-1502</td>
</tr>
<tr>
<td>[I]h</td>
<td>3136</td>
<td>3066-3016</td>
<td>2218</td>
<td>1604</td>
<td>1643</td>
<td>-</td>
<td>1573-1525</td>
</tr>
<tr>
<td>[II]a</td>
<td>3358-3483</td>
<td>3051-3100</td>
<td>2214</td>
<td>1629</td>
<td>-</td>
<td>-</td>
<td>1591-1571</td>
</tr>
<tr>
<td>[II]b</td>
<td>3354-3480</td>
<td>3037-3003</td>
<td>2214</td>
<td>1643</td>
<td>-</td>
<td>-</td>
<td>1573-1544</td>
</tr>
<tr>
<td>[II]c</td>
<td>3350-3464</td>
<td>3116-3080</td>
<td>2206</td>
<td>1612</td>
<td>-</td>
<td>-</td>
<td>1566-1523</td>
</tr>
<tr>
<td>[II]d</td>
<td>3375-3487</td>
<td>3078-3062</td>
<td>2210</td>
<td>1635</td>
<td>-</td>
<td>-</td>
<td>1570-1554</td>
</tr>
<tr>
<td>[II]e</td>
<td>3305-3475</td>
<td>3100-3080</td>
<td>2206</td>
<td>1639</td>
<td>-</td>
<td>-</td>
<td>1573-1550</td>
</tr>
<tr>
<td>[II]f</td>
<td>3311-3468</td>
<td>3064-2988</td>
<td>2210</td>
<td>1629</td>
<td>-</td>
<td>-</td>
<td>1571-1544</td>
</tr>
<tr>
<td>[III]a</td>
<td>3433</td>
<td>3080-3055</td>
<td>2218</td>
<td>1608</td>
<td>-</td>
<td>1199</td>
<td>1573-1554</td>
</tr>
<tr>
<td>[III]b</td>
<td>3433</td>
<td>3100-3059</td>
<td>2218</td>
<td>1608</td>
<td>-</td>
<td>1188</td>
<td>1573-1539</td>
</tr>
<tr>
<td>[III]c</td>
<td>3394</td>
<td>3089-3985</td>
<td>2210</td>
<td>1608</td>
<td>-</td>
<td>1184</td>
<td>1573-1554</td>
</tr>
</tbody>
</table>
Table No.(3): Antibacterial activity of synthesized compounds against five pathogenic Species.

<table>
<thead>
<tr>
<th>Comp. no.</th>
<th>Mean of Inhibition zone Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S. aureus</td>
</tr>
<tr>
<td>[I]a</td>
<td>8</td>
</tr>
<tr>
<td>[I]b</td>
<td>-</td>
</tr>
<tr>
<td>[I]c</td>
<td>-</td>
</tr>
<tr>
<td>[II]a</td>
<td>-</td>
</tr>
<tr>
<td>[II]b</td>
<td>-</td>
</tr>
<tr>
<td>[II]c</td>
<td>-</td>
</tr>
<tr>
<td>[III]a</td>
<td>17</td>
</tr>
<tr>
<td>[III]b</td>
<td>16</td>
</tr>
<tr>
<td>[III]c</td>
<td>16</td>
</tr>
<tr>
<td>Ampicillin</td>
<td>5</td>
</tr>
<tr>
<td>Amoxicilin</td>
<td>15</td>
</tr>
<tr>
<td>Lincomycin</td>
<td>9</td>
</tr>
<tr>
<td>DimethylSulfoxie</td>
<td>0.0</td>
</tr>
</tbody>
</table>
تخليق (بدون مذيب بواء واحد متعدد المكونات) لبعض مشتقات 2-موعض-3-سيانو بريدين ودراسة خواصها البايولوجية وفعاليتها.

زهرى هادي ابوب
منى سمير سعيد
احمد خميس ابراهيم
قسم الكيمياء / كلية التربية للعلوم الصرفة (ابن الهيثم) / جامعة بغداد

استلم البحث في: 18 أذر 2015، قبل البحث في: 14 نيسان 2015

الخلاصة
تكاثف الاستيروفينون وخلات سيانو اثيل أو مالونونيتريل مع الألدهيدات الأروماتية المعوضة وخلات الأمونيوم بواء واحد وبدون مذيب بالتسخين المباشر عند درجة 140 م° ليعطي المركبات 2-اوكسو-3-سيانو-4-موعض-6-فنيل بريدين II، [I][P2S2]، (2-ايثين-3-سيانو-4-اريل موعض-6-فنيل بريدين III)، [I][P2S2] عند معالمة مركبات 2-اوكسو-3-سيانو-4-اريل موعض-6-فنيل بريدين IV مع خماس كبريتيد الفسفر (P2S2) ليعطي مركبات 2-نيال-3-سيانو-4-موعض-6-فنيل بريدين V، [I][P2S2] مع مركبات 2-نيال-3-سيانو-4-موعض-6-فنيل بريدين V مع خماس كبريتيد الفسفر (P2S2) ليعطي مركبات 2-نيال-3-سيانو-4-موعض-6-فنيل بريدين V، [I][P2S2]

درست خواص جميع المركبات المحضر من خلال قياس درجات التصبهرها، تحليل العناصر الدقيق (CHNS)، واوافات الإشعة تحت الحمراء والرنين النووي المغناطيسي (1H NMR، FTIR).

الكلمات المفتاحية: بود، بواء، واحد، مشتقات الباردين.