

2 **A green and scalable synthesis of 1-amino anthraquinone**

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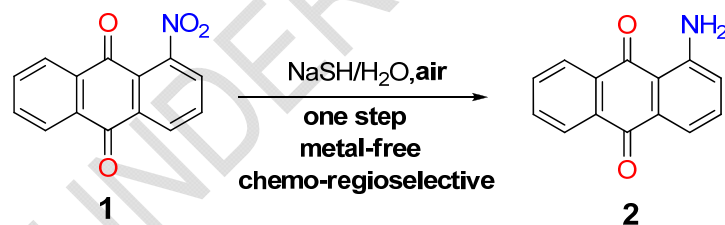
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14
15 **Abstract** 1-amino anthraquinone (**2**) is the most important intermediate in the
16 synthesis of acid dyes. This paper presents a new method for the preparation of title
17 compound (**2**) in a highly chemo- and regioselective reduction of 1-nitro
18 anthraquinone (**1**) by NaHS in water under mild **conditions**. This protocol is clean,
19 operationally simple, easy work-up and could be applied in the industrial production .
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21 **Graphical Abstract**



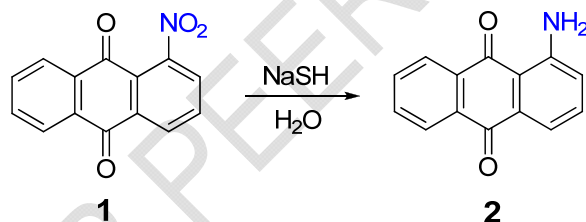
25 **Keywords** nitroanthraquinone, aminoanthraquinone, reduction

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27 **1. Introduction**

28 1-Amino anthraquinone (**2**) is one of the most important intermediates^[1] in the
29 synthesis of functional dyes.^[2] To date, a variety of methods for the the synthesis of

30 1-amino anthraquinone (**2**) have been disclosed^[3], most of these protocols employing
31 1-nitro anthraquinone (**1**) as a starting material.^[4] 1-amino anthraquinone (**2**) can be
32 obtained by single-step reduction from compound (**1**). These reductants include
33 ammonium formate,^[5] sodium sulfate(Na₂S),^[2] sodium borohydride (NaBH₄),^[6]
34 Gold-Catalyzed CO-H₂O system^[7] and bis(cyclopentadienyl)titanium(IV)
35 dichloride-indium system^[8]. However, none of these reagent is suitable for industrial
36 production due to drawbacks like high cost, toxic substance, complex work-up, etc.^[9]
37 In recent years, the demand for 1-amino anthraquinone (**2**) in the dye industry has
38 increased rapidly. Hence, it is important to developed an efficient and scalable method
39 for synthesis of 1-amino anthraquinone (**2**).

40 As shown in **Scheme 1**, we reported here a facial, green and scalable method for
41 the preparation of 1-amino anthraquinone (**2**) by using NaSH as a reductant,^[10] the
42 solvent water meets the requirements of green chemistry and it should be suitable for
43 industrial production.



44 **1** **2**
45 **Scheme 1.** Synthesis of compound 2

47 2. Experimental section

48 All reactions were monitored by TLC, Melting points were measured on Melting
49 Point M-565 (BUCHI). NMR and mass spectra were recorded on a Bruker Avanc
50 III-HD 400 NMR and a TripleTOF Mass spectrometers, respectively. All reagents: e.g.
51 Na₂S·9H₂O, NaSH, NaBH₄, Na₂S₂O₄ were purchased from Adamas, P. R. China, and
52 used without further purification.^[11]

54 Synthesis of 1-amino anthraquinone (**2**)

55 A 250 mL three-necked flask is equipped with a stirrer and thermometer and a
56 dropping funnel. The flask is charged with a solution of NaSH (3.00 g, 0.05 mol) in

57 water (15 mL) and stirred at 60 °C for 1h. Then 1-nitro anthraquinone (**1**) powder
58 (3.04 g, 0.01 mol) was added over 10 minutes and the reaction mixture quickly turned
59 to red. The mixture was stirred at 60 °C for another 1h and the progress of the reaction
60 was monitored by TLC. The reaction mixture was filtered and the red precipitates
61 were washed with water, and recrystallization from ethanol to give compound **2** as a
62 red powder (2.79 g, yied 92%), m.p. 253 °C (lit^[8]253-255°C)

63

64 ¹H NMR (400 MHz, CDCl₃): δ8.30 (d, *J* = 8.0 Hz, 1H), 8.26 (d, *J* = 8.0 Hz, 1H), 7.78 (t, *J* = 8.0
65 Hz, 1H), 7.73 (t, *J* = 8.0 Hz, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.47 (t, *J* = 8.0 Hz, 1H), 6.98 (d, *J* =
66 8.0 Hz, 1H), 6.87 (s, 2H).

67 ¹³C NMR (100 MHz, CDCl₃): δ185.3, 183.6, 151.0, 134.8 (2C), 134.4, 134.0, 133.2 (2C), 126.8
68 (2C), 123.1, 117.3, 113.7.

69 MS(ESI): *m/z* = 224 (M+H)

70

71 **3. Results and discussion**

72 The key factor to obtain compound **2** is how to efficiently and selectively reduce
73 the nitro-group of compound **1** without affecting the carbonyl group.^[12] We
74 investigated the effects of different reagents and solvents, the results were shown in
75 **Table 1**. The reaction solvent plays an important role in this reaction, water is better
76 than alcohols or the alcohol solutions. Both Na₂S and NaHS can be severe as a good
77 reducing agents, but when the reaction scale is kilogram level, we found that Na₂S is
78 difficult to agitate in the 5L three round-bottomed flasks, while NaHS do not have this
79 problem. Based on this point, NaHS is much more suitable in industrial large-scale
80 production. The poor solubility of sulfide in ethanol lead to a decrease of yield. We
81 also examined reagents NaBH₄ and Na₂S₂O₄, which gave compound **2** in 45% and 35%
82 yield respectively. The optimal condition was using AgNO₃ (40%), and K₂S₂O₈ (2
83 equiv) in water at 60 °C for 2 h (entry 4, **Table 1**).

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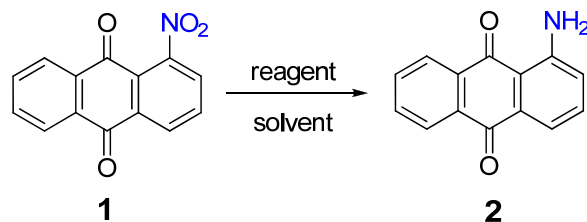
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Table 1. Reduction of 1-nitroanthraquinone (**1**) under different conditions



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Entry	Reagent	Solvent(v/v)	Temperature(°C)	Yield(%)
1	Na ₂ S	H ₂ O	60	80%
2	Na ₂ S	EtOH	60	35%
3	Na ₂ S	EtOH/ H ₂ O(1/1)	60	63%
4	NaSH	H₂O	60	92%
5	NaSH	EtOH	60	24%
6	NaSH	EtOH/ H ₂ O(1/1)	60	59%
7	NaBH ₄	isopropanol	60	45%
8	Na ₂ S ₂ O ₄	EtOH	60	35%

92
93

Reaction Conditions: compound **1** (0.05mol), reagent (2 equiv), 2 hour under open air

94 **4. Conclusions**

95 In summary, a NaHS-mediated new method for the synthesis of 1-amino
96 anthraquinone (**2**) has been developed. This protocol is easily operational, efficient,
97 and is amenable to the kilogram-scale synthesis of compound (**2**). This chemistry also
98 provides a new selective reduction of aromatic nitro-group without using metal
99 catalyst.

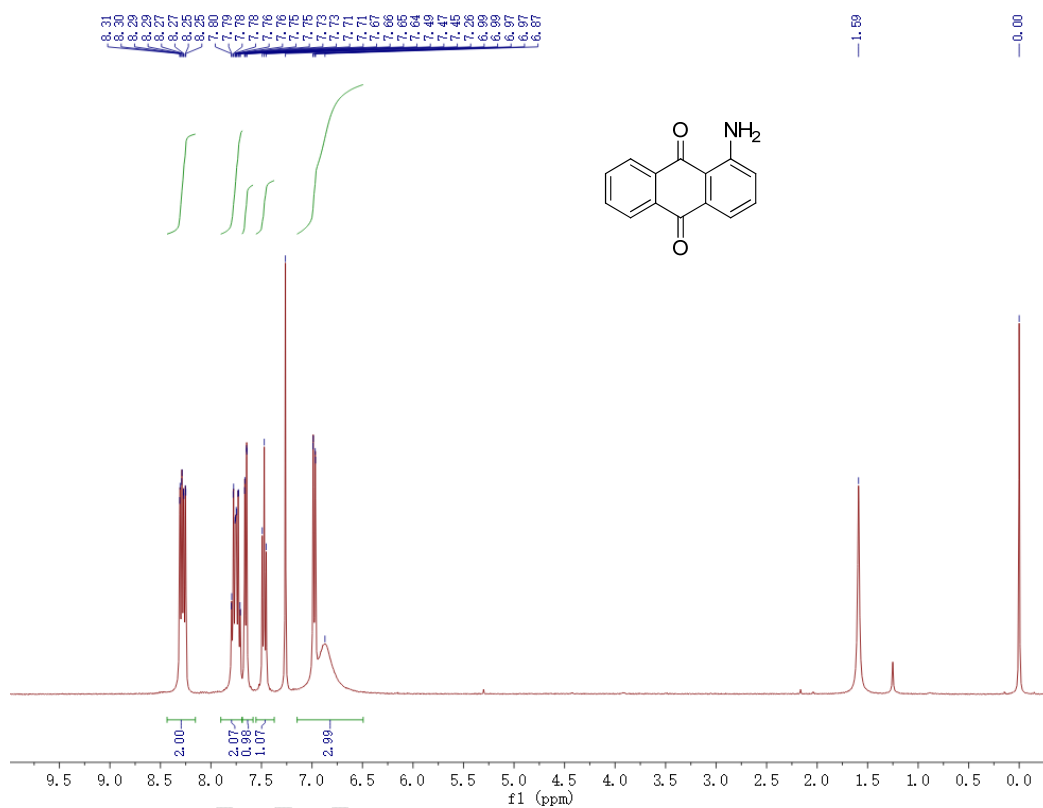
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102 **References**

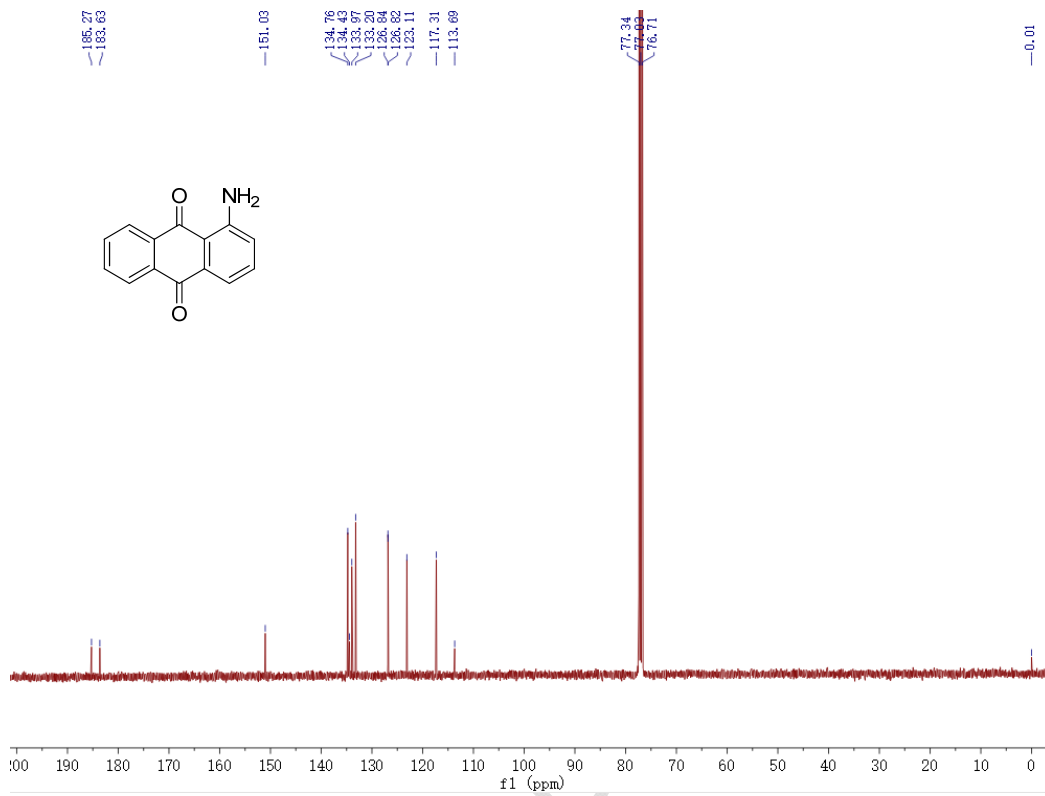
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122 ¹H NMR of compound 2



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124 ¹³C NMR of compound 2

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