

Oxidizing Agent Applied for Quinone Synthesis: A Review

Hardesh K Maurya^{1,2*}

¹Department of Applied Chemistry, Babasaheb Bhimrao Ambedkar University, Lucknow-226025 (U.P.) India

²Medicinal Chemistry Department, CSIR-Central Institute of Medicinal and aromatic Plants, Lucknow-226015, India

*Corresponding author: Hardesh K Maurya, Medicinal Chemistry Department, CSIR-Central Institute of Medicinal and aromatic Plants, PO. CIMAP, Kukrail Road, Lucknow-226015, India, Tel: 0919451407702; E-mail: hardesh11@yahoo.co.in

Received: 06 June, 2016; Accepted: 20 June, 2016; Published: 25 June, 2016

Abstract

Synthesis of quinone has attracted considerable attention to scientific community due to presence in nature and for the construction of biologically active quinones homologs and other wide application. Thus this review describes the synthesis of common quinones such as 1,2-benzoquinone, 1,4-benzoquinones, 1,2-naphthoquinone and 1,4-naphthoquinone with covering almost all literature form the first synthesis of quinone.

Keywords: Quinone; Benzoquinone; Naphthoquinone; Anthraquinone; Oxidation; Oxidizing agents

Introduction

Quinone chromophore is present in a wide variety of natural products and drugs such as kinamycin, damavaricin, awamycin, [1] rifamycins, [2] streptovaricins, doxorubicin, mitoxanthone, streptonigrin, lavendamycin, menadione, lapachol [3] etc. and their derivatives have been used as key synthetic intermediates for construction of biologically active compounds associated with antitumor [4] antineoplastic [5] antifungal [6] antibacterial [7] antiviral [8] antimalarial and antitrypanosomal [10] activity. It is also an essential parts of various dyes such as naturally occurring alizarin dye [11] from madder plant.

The biological activity imparted by most of the quinones pertains to their ability to accept one significant role in quinones to accept electrons [11]. One or two electrons in order to form radical anion or dianion species. The electron donating or withdrawing substituents present in quinone play significance role in biological activity as well as in dyeing.

Various reviews had been reported the synthesis of substituted quinones which had covered the synthesis of a selected quinones with their applications for a specific time durations [13,14]. A literature survey revealed that there are no such reviews or book had published which cover the synthesis of a basic quinones in more than hundred year time duration.

Due to presence in nature [1-3] various drugs and dyes, quinones are used for the synthesis of various useful synthetic molecules and considerable attention have evoked chemists to probe the chemistry of quinones.

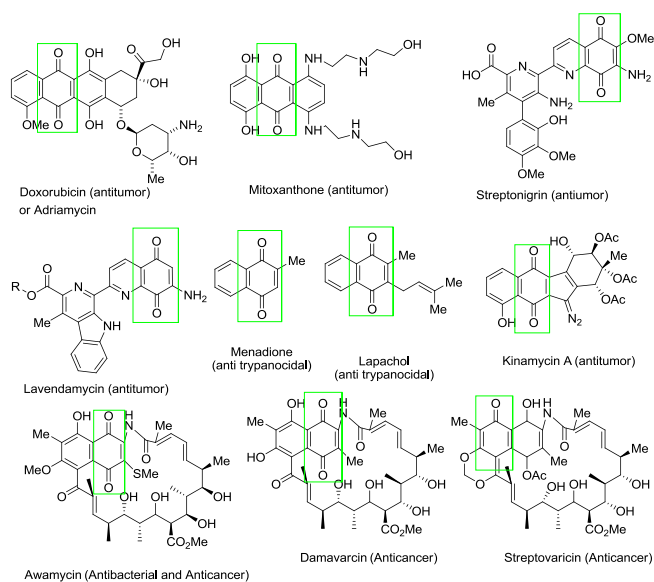
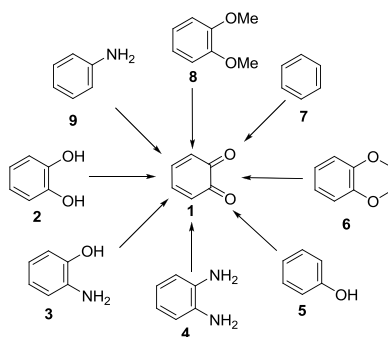


Figure 1: Naturally occurring quinones.

Our aim of this review is to cover various oxidizing agents with their reaction conditions. Thus, various strategies applied for the synthesis of quinones cited in various literatures have been discussed in this review.

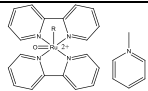
2. Synthesis of 1,2-Benzoquinone (1)



Scheme 1: Synthesis of 1,2-benzoquinone (1).

Synthesis of 1,2-benzoquinone or o-benzoquinone (1) was first reported from the oxidation of pyrocatechol (2) with AgO in 1904 by Willstaetter et al. [15].

Table 1: Synthesis of 1,2-benzoquinone (1)

S.N.	Reactants	Catalyst/ Reaction Condition	Yields (%)
1.	2	AgO, Na ₂ SO ₄ , Et ₂ O, 1h	84 ¹⁵
2	2	TBAD/CH ₂ Cl ₂ , 7 min, reflux	99 ¹⁶
3	2	[Amb] ₂ [W ₂ O ₃ (O ₂) ₄]/ClCH ₂ CH ₂ Cl,	96 ¹⁷
4	2	Ag ₂ O, DMF, 30 min., 0°C	95 ¹⁸
5	2	[Amb] ₂ [Mo ₂ O ₃ (O ₂) ₄]/ CH ₂ Cl ₂ ,	97 ¹⁹
6	2	MnO ₂ /acetone	97 ²⁰
7	2	BaFeO ₄ .H ₂ O	100 ²¹
8	2	[Ce(NO ₃) ₃] ₂ CrO ₄	100 ²²
9	2	Isoquinolinium bromochromate/AcOH, 2h, rt	84 ²³
10	2	O ₂ , Cu(OH) ₂ ,/CHCl ₃	95 ²⁴
11	2	(NH ₄) ₂ S ₂ O ₈ in Wet SiO ₂ , 5 min.	76 ²⁵
12	2	NaBO ₃ in wet [Ce(NO ₃) ₃] ₂ CrO ₄ , 4 min, rt	66 ²⁶
13	2	CF ₃ COOH, aniline DCC, DMSO, Benzene	70 ²⁷
14	2	Cetyltrimethylammonium cerium nitrate /dioxane	60 ²⁸
15	2	H ₂ O ₂ , vanadium substituted Keggin heteropoly acid, H ₂ O, Me ₂ CO, 20°C; 1.5 h, 20°C	49 ²⁹
16	2	H ₂ O ₂ , "sandwich" type substituted polyoxometalates as catalysts H ₂ O, Me ₂ CO, 1 h, 56°C	48 ³⁰
17	2	Ag ₂ O, Na ₂ SO ₄ , Et ₂ O	15 ³¹
18	3	(NaOCl)/AcOEt, dowex 1X8-200	95 ³²
19	3	MNO ₂ /HNO ₃	68 ³³
20	4	NaOCl/CH ₂ Cl ₂	95 ³²
21	5		12 ³⁵
22	5	O ₂ with CuSO ₄ , NaCl, MeOH, 6 h, 60°C	18 ³⁶
22	5	K ₂ (SO ₃) ₂ NO, KH ₂ PO ₄ , MeOH, H ₂ O	91 ³⁷
23	6	O ₃ , O ₂ , CH ₂ Cl ₂	29 ³⁸

Except AgO, 1,2-benzoquinone were also synthesized from pyrocatechol (2) using diversified oxidizing agents such as tetrabutylammonium chromate (TBAD) [16] polymer supported peroxotungstate complex (Amb)₂(W₂O₃(O₂)₄) [17] Ag₂O [18]. Polymer supported anionic peroxomolybdenum complexes (Amb)₂(Mo₂O₃(O₂)₄) [19] MnO₂ [20] barium ferrate monohydrate (BaFeO₄.H₂O), [21] bis[trinitrato cerium (IV)] chromate [Ce(NO₃)₃]₂CrO₄, [22] isoquinolinium bromochromate, [23] O₂ in Cu(OH)₂ [24] ammonium persulfate ((NH₄)₂S₂O₈) in wet SiO₂ [25] NaBO₃ in wet montmorillonite [Ce(NO₃)₃]₂CrO₄, [26] CF₃COOH ("Pfitzner-Moffatt" technique) [27] cetyltrimethyl ammonium cerium nitrate [28] H₂O₂ with vanadium substituted keggins heteropoly acid [29] H₂O₂ with "sandwich" type substituted

polyoxometalates Keggin heteropoly acid [30] Ag₂O [31] (Table 1 and Scheme 1).

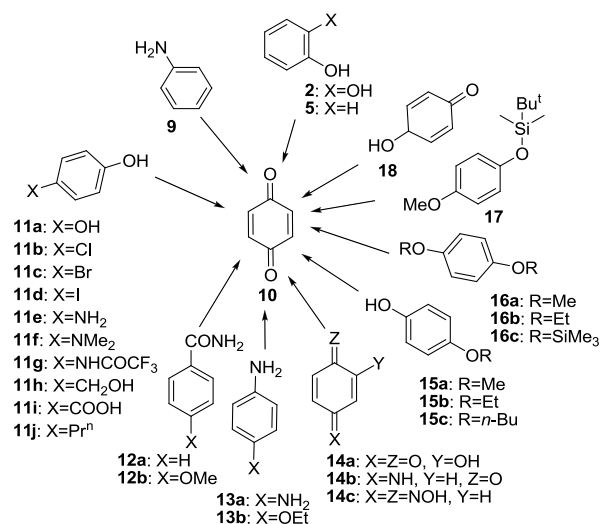
Synthesis of 1,2-benzoquinone (**1**) was also reported from the 2-aminophenol (**3**) using oxidizing agent viz. hypochlorite supported on dowex 1X8-200 [32] or MnO₂/HNO₃ [33]. Benzene-1,2-diamine (**4**) was also converted in 1,2-benzoquinone (**1**) from using oxidizing agent NaOCl/CH₂Cl₂.³² A oxo complex of ruthenium (IV)[35], O₂ with CuSO₄/NaCl.[36]

K₂(SO₃)₂NO with KH₂PO₄ were used to convert phenol (**5**) in 1,2-benzoquinone (**1**). 2,3-dihydrobenzo [*b*] [1,4] dioxine was converted in 1,2-benzoquinone (**1**) from O₃ with O₂ in CH₂Cl₂. [38] *tert*-Butylhydroperoxide (*t*-BuOOH) catalyzed with [Ru^{III}(amp)(bipy)(H₂O)]⁺ complex was used for the synthesis of 1,2-benzoquinone (**1**) and 1,4-benzoquinone (**10**) from benzene (**7**). [39]

It was also reported that 1,2-dimethoxybenzene (**8**) decomposed in 1,2-benzoquinone (**1**) in the presence of K with dibenzo-18-crown-6 ether[40] and aniline (**9**) was also converted in 1,2-benzoquinone (**1**) from periodate in acetic acid [41].

3. Synthesis of 1,4-Benzoquinone

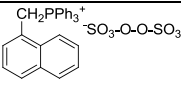
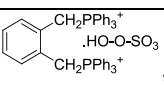
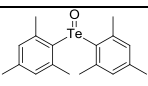
Synthesis of 1,4-benzoquinone or *p*-benzoquinone (**10**) was first reported from the oxidation of hydroquinone (**11a**) with Na₂Cr₂O₇ in H₂SO₄ in 1922 by Vilet [42] (Scheme 2 and Table 2).

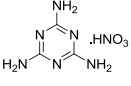


Scheme 2: Synthesis of 1,4-benzoquinone (**10**).



Table 2: Synthesis of 1,4-benzoquinone (**10**)

S.N.	Reactants	Catalyst/ Reaction Condition	Yields (%)
1	11a	Na ₂ Cr ₂ O ₇ , H ₂ SO ₄ , H ₂ O, 30 °C, 30-45 min	92 ⁴²
2	11a	TBAD/CH ₂ Cl ₂ , 10 min, reflux	98 ¹⁶
3	11a	KMNO ₄ , CuSO ₄ .H ₂ O, MW, 4.5 min heated	100 ⁴³

4	11a	Zeolite H-Y-supported Cu (NO ₃) ₂ , 15 min., 70-80 °C/ 30 sec. MW heating	100 ⁴⁴
5	11a	Ce(NH ₄) ₂ (NO ₃) ₆ , 2 h, rt	100 ⁴⁵
6	11a	mesohexakis(pentafluorophenyl)[26] hexaphyrin(1.1.1.1.1.1), CDCl ₃ , 10 min., rt	100 ⁴⁶
7	11a	O ₂ , Cu entrapped in aluminum oxyhydroxide, toluene, 3 h, 25 °C, 1 atm	96 ⁴⁷
8	11a	KMnO ₄ , Carbon, CH ₂ Cl ₂ , 25 min, reflux	99 ⁴⁸
9	11a	 , MeCN, 2 min, reflux	99 ⁴⁹
10	11a	Ce(NH ₄) ₂ (NO ₃) ₆ , MeCN, 2 h, 25°C	98 ⁵⁰
11	11a	CF ₃ (CF ₂) ₁₉ I(OCOCF ₃) ₂ , H ₂ O, MeOH, 2-3 h, rt	99 ⁵¹
12	11a	{-N+(CH ₃) ₂ CH ₂ CH ₂ N+[(CH ₃) ₂ (CH ₂) ₄] _n S ₂ O ₈ ²⁻ ; H ₂ O, reflux, 5 min.	99 ⁵²
13	11a	 , AlCl ₃ , 3 min, rt	98 ⁵³
14	11a	MnO ₂ , acetone / MnO ₂ , H ₂ O, 3 min, MW / MnO ₂ , SiO ₂ , MW / MnO ₂	96 ²⁰ / 98 ^{54a} / 76 ^{54b} / 58 ^{54c}
15	11a	 , xylene, 19 h, reflux	100 ⁵⁵
16	11a	HIO ₃ , Montmorillonite, 35 s, MW/ HIO ₃ , Montmorillonite, 12 min, 100 °C	98 ⁵⁶ / 91 ⁵⁶
17	11a	IO ₄ ⁻ (ultraresin supported), MeOH, CH ₂ Cl ₂ , 1h, rt	100 ⁵⁷
18	11a	H ₂ O ₂ , Ag ₂ O, H ₂ O, MeOH, 40 min, 25°C	94 ⁵⁸
19	11a	Pernigraniline, dioxane, 0.5 h, r	95 ⁵⁹
20	11a	HClO ₄ , Carbon, Cerium(III) perchlorate, Nafion film, H ₂ O, 30 min, 25°C	97 ⁶⁰
21	11a	KBrO ₃ , CH ₂ Cl ₂ , 20 min, rt	97 ⁶¹
22.	11a	Polysorb 1 (iodinated, acetoxylated), PhI(OAc) ₂ (polystyrenesupported), MeOH, 4 h, rt	96 ⁶²
23.	11a	H ₂ SO ₄ , SiO ₂ , Na ₂ Cr ₂ O ₇ .H ₂ O, H ₂ O, CH ₂ Cl ₂ , 25 min, rt	99 ⁶³
24.	11a	KMnO ₄ , H ₂ SO ₄ , Silica, CH ₂ Cl ₂ , 30 min, reflux	99 ⁶⁴
25.	11a	Ce(NH ₄) ₂ (NO ₃) ₆ , Montmorillonite, CH ₂ Cl ₂ , 0.5 h, rt, ultrasound,	98 ⁶⁵
26	11a	[Amb] ₂ [W ₂ O ₃ (O ₂) ₄]/ClCH ₂ CH ₂ Cl	98 ¹⁷
27	11a	O ₂ , montmorillonite, phthalocyanine, dioxane, H ₂ O	98 ⁶⁶

28	11a	(PhCO ₂) ₂ , toluene or AIBN, O ₂ , toluene	100 ⁶⁷
29.	11a	[4-(diacetoxyiodo)- <i>N</i> -methyl benzamide]aminomethylpolystyrene, MeOH	100 ⁶⁸
30	11a	PhI(OAc) ₂ (polymer-supported), CH ₂ Cl ₂	100 ⁶⁹
31	11a	(CTA)2S2O8, MeCN, 5 min, reflux	95 ⁷⁰
32	11a	EBMICC, MeCN, 4 min, rt	95 ⁷¹
33	11a	I ₂ , NaNO ₂ , H ₂ O, MeOH,	94 ⁷²
34	11a	[(6tbp)CuI]B(C ₆ F ₅) ₄ , O ₂ , Et ₂ O, -80 °C, 3 H cooled.	95 ⁷³
35	11a	Ce(NH ₄) ₂ (NO ₃) ₆ , SiO ₂ , H ₂ O, CH ₂ Cl ₂ , rt, 20 min	95 ^{74,75}
36	11a	2,6-dicarboxypyridinium fluorochromate	95 ⁷⁶
37	11a	KBrO ₃ , H ₂ SO ₄ , SiO ₂ , CH ₂ Cl ₂ , 30 min, rt	97 ⁷⁷
38	11a	[Amb] ₂ [Mo ₂ O ₃ (O ₂) ₄], CH ₂ Cl ₂	99 ¹⁹
39	11a	Oxone, Bu ₄ N ⁺ •Br ⁻ , H ₂ O, MeCN, 40 min, rt	91 ⁷⁸
40	11a	 , p-MeC ₆ H ₄ SO ₃ H, Me ₂ CO, 0.05 h, reflux	90 ⁷⁹
41	11a	brominated maleimidedivinyl benzenepolymer, H ₂ SO ₄ , H ₂ O, CH ₂ Cl ₂ , 110 min, rt	90 ⁸⁰
42	11a	(potassium ferrate-modified), (polymer supported), Me(CH ₂) ₄ Me, 2 h, rt	90 ⁸¹
43	11a	NaBO ₃ in wet [Ce(NO ₃) ₃] ₂ CrO ₄ , 1 min, rt	93 ²⁶
44	11a	(NH ₄) ₂ S ₂ O ₈ in Wet SiO ₂ , 5 min.	92 ²⁵
45	11a	Na ₂ Cr ₂ O ₇ •2H ₂ O, SiO ₂ , H ₂ SO ₄ , 30 min.	95 ⁸²
46	11a	O ₂ , Al ₂ O ₃ , CuSO ₄	98 ⁸³
47	11a	H ₂ O ₂ , Ru, MeOH, H ₂ O	99 ⁸⁴
48	11a	Na ₂ SO ₅ , Bu ₄ N ⁺ •HSO ₄ ⁻ , H ₂ O, CH ₂ Cl ₂ , 1,10-Phenanthroline, Cu(OAc) ₂	100 ⁸⁵
49	11a	Iron phthalocyanine, zeolites, AcOH	100 ⁸⁶
50	11a	Ag ₂ [Cr ₂ O ₇], poly-4-vinylpyridine, PhMe	100 ⁸⁷
51	11a	PhCH ₂ N ⁺ Me ₃ •Br ³⁻ , AcONa, H ₂ O, CH ₂ Cl ₂	100 ⁸⁸
52	11a	V ₂ O ₅ , NaClO ₃ , H ₂ SO ₄ , H ₂ O, 22 °C, 1.5 h, 50°C;	90 ⁸⁹
53	11a	Me ₂ S and <i>N</i> -Chlorosuccinimide	100 ⁹⁰
54	11a	PhI(OAc) ₂ , MeOH / PhI=O, RuCl ₂ (PPh ₃) ₃ , Et ₂ O/ <i>p</i> - (HO(Ph)IOS(=O) ₂)C ₆ H ₄ Me, CH ₂ Cl ₂ , MeCN / PHI=O, Et ₂ O	94 ⁹¹ / 93 ⁹¹ / 80 ⁹¹ / 70 ⁹¹
55	11a	2(Na ₂ CO ₃)•3H ₂ O ₂ , Montmorillonite, 2 min, rt	91 ⁹²
56	11a	K ₂ Cr ₂ O ₇ , H ₂ O, Et ₂ O, cooled; 10 min, rt	90 ⁹³
57	11a	pyrazinium dichromate, CH ₂ Cl ₂	96 ⁹⁴

58	11a	NaClO ₃ , V ₂ O ₅ , H ₂ O, CH ₂ Cl ₂ / NaClO ₃ , V ₂ O ₅ , H ₂ O, C ₆ H ₆	99 ⁹⁵ / 98 ⁹⁵
59	11a	H ₂ O, NaIO ₄ , CH ₂ Cl ₂	100 ⁹⁶
60	11a	BaFeO ₄ ·H ₂ O, C ₆ H ₆	100 ²¹
61	11a	SiO ₂ , H ₂ SO ₄ , KClO ₃ , MeCN, 30 min, reflux	90 ⁹⁷
62	11a	Me(CH ₂) ₃ ONO ₂ , CuCl ₂ , MeOH, CH ₂ Cl ₂	93 ⁹⁸
63	11a	Fe(NO ₃) ₃ ·1.5N ₂ O ₄ , CH ₂ Cl ₂	92 ⁹⁹
64	11a	<i>t</i> -BuOOH, MeOH, Polymer-supported vanadium salt	95 ¹⁰⁰
65	11a	O ₂ , Pt, AcOH	97 ¹⁰¹
66	11a	BBCP	100 ¹⁰²
67	11a	[Ce(NO ₃) ₂]CrO ₄ ·2H ₂ O	100 ¹⁰³
68	11a	O ₂ , Au, H ₂ O, CHCl ₃ , 1 h, rt	86 ¹⁰⁴
69	11a	O ₂ , NO ₂ , CH ₂ Cl ₂	94 ¹⁰⁵
70	11a	H ₂ O ₂ , H ₂ SO ₄ , I ₂ , MeOH	97 ¹⁰⁶
71	11a	H ₂ O ₂ , SO ₂ (CH ₂) ₃ SO ₃ H, grafted with silica gel, oxidized, H ₂ O, MeOH, 30 min, rt; 5.5 h, rt	80 ¹⁰⁷
71	11a	BrCl ₂ ⁻ N(Bu ⁿ) ₄ ⁺ , AcOH, H ₂ O	89 ¹⁰⁸
72	11a	AgBrO ₃ , Et ₂ O / NaBrO ₃ , Et ₂ O	90 ¹⁰⁹ / 75 ¹⁰⁹
72	11a	O ₂ , Cu(OH) ₂ /CHCl ₃	95 ²⁴
72	11a	NaOCl, KBr, 4-methoxy-TEMPO, H ₂ O, CH ₂ Cl ₂	95 ¹¹⁰
73	11a	PhI(OAc) ₂ , MeOH / PhSPh, N-chlorosuccinimide, Et ₃ N, MeCN, CH ₂ Cl ₂ / p- (HO(Ph)IOS(=O) ₂)C ₆ H ₄ Me, MeCN, CH ₂ Cl ₂ / Me ₂ S, Et ₃ N, MeCN, N- chlorosuccinimide, CH ₂ Cl ₂	94 ¹¹¹ / 84 ¹¹¹ / 80 ¹¹¹ / 77 ¹¹¹
74	11a	Bu ₄ N ⁺ ·Br ₃ ⁻ , AcOH, H ₂ O, 24 h, rt	80 ¹¹²
75	11a	H ₂ O ₂ , cerium acetate, Cu(OAc) ₂ , H ₂ O / H ₂ O ₂ , cerium acetate, H ₂ O	90 ^{113a} /89 ^{113b}
76	11a	Isoquinoliniumbromochromate / AcOH, 2h, rt	78 ²³
77	11a	NiO ₂ , AcOH, Et ₂ O, 2.5 h, rt	80 ¹¹⁴
78	11a	NaOCl, Dowex 1X8-200, acetone, reflux	83 ¹¹⁵
79	11a	<i>t</i> -BuOOH, Ce(NH ₄) ₂ (NO ₃) ₆	84 ¹¹⁶
80	11a	2Bu ₄ N ⁺ ·Ce(ONO ₂) ₆ ⁻ , CH ₂ Cl ₂	89 ¹¹⁷
81	11a	PhI(O ₂ CCF ₃) ₂ , MeCN, H ₂ O	91 ¹¹⁸
82	11a	1-chloro-2,2,6,6-tetramethylpiperidine, CH ₂ Cl ₂ 12 h, rt	80 ¹¹⁹

83	11a	[Ce(NO ₃) ₃] ₂ CrO ₄	90 ²²
84	11a	peroxidise from horse-radish	89 ¹²⁰
85	11a	MNO ₂ /HNO ₃	90 ³³
86	11a	[Ag(C ₅ H ₅ N) ₂]MnO ₄	90 ¹²¹
87	11a	 ,MeOH, CH ₂ Cl ₂ , 2.5 h, rt	73 ¹²²
88	11a	O ₂ , Pt, H ₂ O, CHCl ₃ , 2 h, rt, 1 atm	75 ¹²³
89	11a	Ce(SO ₄) ₂ , IrCl ₃ , 3 min, heated, MW Ce(SO ₄) ₂ , IrCl ₃ , AcOH, 3 h, 100°C	28 ¹²⁴ / 74 ¹²⁴
90	11a	Nicotinium dichromate, C ₅ H ₅ N, CH ₂ Cl ₂ / PDC, C ₅ H ₅ N, CH ₂ Cl ₂	80 ¹²⁵ / 80 ¹²⁵
91	11a	Al ₂ O ₃ , H ₂ SO ₄ , FeCl ₃ , H ₂ O ₂ , 1.5 min. MW	70 ¹²⁶
92	11a	BTMPDC, MeCN, 5 min, reflux	70 ¹²⁷
93	11a	NaClO ₃ , V ₂ O ₅ , H ₂ SO ₄ , H ₂ O	96 ¹²⁸
94	11a	O ₂ , VO(acac) ₂ , CH ₂ Cl ₂	75 ¹²⁹
95	11a	poly(2-vinylquinolinium)dichro- mate, quinaldinium, toluene	80 ¹³⁰
96	11a	2-tolyl-1,2-benzisoselenazol-3(2H)-one-1-oxide, CH ₂ Cl ₂	81 ¹³¹
97	11a	H ₂ O ₂ , Cu(OAc) ₂ , H ₂ O, 60 min, 35°C, pH 5, catalyst on acrylic resin with aminoguanidyl groups	66 ¹³²
98	11a	Cetyltrimethylammonium cerium nitrate /dioxane	70 ²⁸
99	11a	Bu ₄ N ⁺ •IO ₄ ⁻ , <i>i</i> -BuCMe ₃ , montmorillonite	70 ¹³³
100	11a	 ,C ₆ H ₆ , 4 h, reflux	60 ¹³⁴
101	11a	<i>t</i> -BuOK, C ₁₁ H ₁₅ N ₂ O ₂ (CAS No. 1265626-68-3), CuBr ₂ , H ₂ O, MeCN, 84 h, rt	60 ¹³⁵
102	11a	Fe(NO ₃) ₃ , Bu ₄ N ⁺ •Br ⁻ , H ₂ O, AcOEt, rt; 15 min	60 ¹³⁶
103	11a	H ₂ O ₂ , vanadium substituted Keggin heteropoly acid, H ₂ O, Me ₂ CO, 20 °C; 1.5 h, 20 °C	63 ²⁹
104	11a	Sodium perborate, AcOH	64 ¹³⁷
105	11a	K ₂ FeO ₄ , K10 montmorillonite, <i>n</i> -pentane	56 ¹³⁸
106	11a	O ₂ , NPV ₆ Mo ₆ /C, AcOH	58 ¹³⁹
107	11a	K ₄ H ₄ P ₂ O ₈ , Montmorillonite, <i>i</i> -BuCMe ₃	50 ¹⁴⁰
108	11a	H ₂ O ₂ , Na ₈ H[ΔPW ₉ O ₃₄] · 19H ₂ O (Δ-PW ₉), H ₂ O, Me ₂ CO, 1 h, 56°C	43 ³⁰
109	11a	O ₂ , C ₂₄ H ₃₆ Cu ₂ N ₈ O ₄ ·2ClO ₄ (CAS No. 884843-23-6), MeOH, MeCN, 30 min, rt 1.2 1 h, 30 °C / C ₂₄ H ₃₆ Cu ₂ N ₈ O ₄ ·BF ₄ (CAS No 646535-35-5),	20 ¹⁴² / 14 ¹⁴²

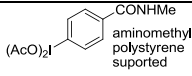
		MeOH, MeCN, 30 min, rt, 1.2 h, 30°C	
110	11a	H ₂ O ₂ , chromium(VI)oxidebis(tri butyl tin)oxide, (i-Pr) ₂ O, benzene	52 ¹⁴³
110	11a	(dibenzo[b,i][1,4,8,11]tetraazacyclotetradecinato)cobalt(II), Chloroform	45 ¹⁴⁴
111	11a	HNO ₃ , AcOH	46 ¹⁴⁵
112	11a	PhTe(=O)OAc, CHCl ₃	38 ¹⁴⁶
113	11a	MnO ₂ , acetone, 20 °C, 30min.	54 ¹⁴⁷

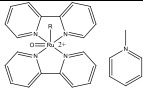
Except Na₂Cr₂O₇ a diversified oxidizing agent (Scheme 2, Table 2) were used for the synthesis of 1,4-benzoquinone (**10**) from the oxidation of hydroquinone (**11a**) viz. TBAD,¹⁶ KMNO₄ with CuSO₄.H₂O in microwave,⁴³ Zeolite H-Y-supported copper(II)nitrate in microwave,⁴⁴ cerium ammonium nitrate in imidazolium ionic liquids,⁴⁵ mesohexakis(pentafluorophenyl)[26] hexaphyrin(1.1.1.1.1.1) in CDCl₃,⁴⁶ oxygen with Cu entrapped in aluminum oxyhydroxide,⁴⁷ wet carbon-based solid acid/potassium permanganate,⁴⁸ alfa-naphthyltriphenylphosphoniumperoxodisulfate,⁴⁹ CAN,⁵⁰ bis(trifluoro acetate) adducts of fluorous alkyl iodides [CF₃(CF₂)₁₉I(OCOFCF₃)₂],⁵¹ a selective and recyclable reagent [{N+(CH₃)₂CH₂CH₂N+ [(CH₃)₂(CH₂)₄]_nS₂O₈²⁻] in H₂O,⁵² o-xylene bis(triphenylphosphoniumperoxy monosulfate),⁵³ MnO₂,²⁰ dielectric activation of MnO₂ in microwave,^{54a} active manganese dioxide on silica under solvent-free conditions using microwaves,^{54b} 2,4,6-trimethylphenyltelluroxide,⁵⁵ iodic acid on the surface of K10 montmorillonite in microwave,⁵⁶ high loading polymer reagents based on polycationic ultraresins (prepared from highly branched polyethylene imine (M_n=10,000) via reductive cross-linking with terephthalaldehyde),⁵⁷ hydrogen peroxide using catalytic amount of silver oxide under batch and continuous-flow conditions,⁵⁸ tailor-made solid polyaniline (pernigraniline catalyst in dioxane,⁵⁹ the glassy carbon modified with Ce(III) ions immobilized in nafion film,⁶⁰ wet carbon-based solid acid/potassiumbromate,⁶¹ macroporous poly styrene-supported(diacetoxy iodo)benzene,⁶² silica supported sulfuric acid/sodium dichromate dehydrate,⁶³ sulfuric acid/potassium permanganate with wet SiO₂,⁶⁴ ultrasonically activated oxidation catalyzed by ceric ammonium nitrate doped on metal exchanged K-10 clay,⁶⁵ polymer supported peroxotungstate complex [Amb]₂[W₂O₃(O₂)₄],¹⁷ O₂, montmorillonite supported metalated phthalocyanine as catalyst,⁶⁶ (PhCO₂)₂ or AIBN with O₂,⁶⁷ aminomethylpolystyrene-supported (diacet oxyiodo)benzene,⁶⁸ polymer-supported hyper valent iodine,⁶⁹ cetyltrimethylammonium peroxodisulfate [(CTA)₂S₂O₈],⁷⁰ ethylenebis(N-methylimidazolium)chlorochromate (EBMICC),⁷¹ I₂, NaNO₂ in water and Methanol,⁷² bis(m-oxo)dicopper(III) with O₂,⁷³ Silica-gel-supported ceric ammonium nitrate (CAN),^{74,75} 2,6-dicarboxypyridinium fluorochromate,⁷⁶ sulfuric acid/ KBrO₃ /wet SiO₂,⁷⁷ polymer supported anionic peroxomolybdenum [Amb]₂[Mo₂O₃(O₂)₄],¹⁹ tetrabutylammonium bromide and Oxone,⁷⁸ melamine nitrate,⁷⁹ brominatedmaleimidedivinyl benzenepolymer with H₂SO₄,⁸⁰ cross-linked poly(4-vinylpyridine)supported potassiumferrate,⁸¹ NaBO₃ in wet montmorillonite,²⁶ ammonium persulfate ((NH₄)₂S₂O₈) in wet SiO₂,²⁵ silica sulfuric acid with sodium dichromate in the presence of wet SiO₂,⁸² O₂, Al₂O₃, CuSO₄,⁸³ H₂O₂ with Ru,⁸⁴ Sodium persulfate in the presence of copper(II)ions,⁸⁵ iron phthalocyanine encapsulated in zeolites,⁸⁶ Poly(vinylpyridine)supported silver dichromates,⁸⁷ quaternary ammonium polyhalides,⁸⁸ V₂O₅ with NaClO₃,⁸⁹ Me₂S and N-Chlorosuccinimide,⁹⁰ organohypervalent iodine reagents,⁹¹ Sodium percarbonate on montmorillonite K10,⁹² K₂Cr₂O₇,⁹³ pyrazinium dichromate,⁹⁴ NaClO₃ with V₂O₅,⁹⁵ NaIO₄,⁹⁶ barium ferrate monohydrate (BaFeO₄.H₂O),²¹ Silica acid/KClO₃/wet SiO₂,⁹⁷ CuCl₂ in Me(CH₂)₃ONO₂,⁹⁸ Dinitrogen tetraoxide complexes of iron(III),⁹⁹ t-BuOOH with polymer-supported vanadium salt,¹⁰⁰ O₂ on platinum catalysts,¹⁰¹ bis(2,2'-bipyridyl)copper(II) permanganate (BBCP),¹⁰² Dinitratocerium(IV) chromate dehydrate,¹⁰³ aerobic oxidation on polymer-incarcerated gold,¹⁰⁴ oxygen with nitrogen oxide,¹⁰⁵ iodine with hydrogen peroxide,¹⁰⁶ H₂O₂ and SO₂(CH₂)₃SO₃H grafted

with silica gel,¹⁰⁷ tetraalkylammonium dichlorobromate,¹⁰⁸ silver/sodium 10engal10l,¹⁰⁹ O₂ in Cu(OH)₂,²⁴ alkali hypochlorite catalyzed by oxammonium salts under two phase condition,¹¹⁰ different (diacetoxyiodo)benzene,¹¹¹ tetrabutyl ammoniumtribromide ion in aqueous acetic acid¹¹² cerium acetate and a cupric acetate,¹¹³ isoquinolinium bromochromate,²³ nickel oxide,¹¹⁴ sodium hypochlorite-Dowex 1X8-200,¹¹⁵ tert-butyl hydroperoxide and catalytic amounts of ceric ammonium nitrate (CAN),¹¹⁶ tetrabutylammoniumcerium(IV)nitrate,¹¹⁷ hypervalent iodine PhI(O₂CCF₃)₂,¹¹⁸ 1-chloro- 2,2,6,6-tetramethylpiperidine,¹¹⁹ bis[trinitrato cerium(IV)]chromate,²² biocatalytic oxidation (peroxidise from horse-radish) in a water-organic solvent two phase system,¹²⁰ bispyridinesilver permanganate,¹²¹ punicin derivative,¹²² Aerobic oxidation by polymer-incarcerated platinum catalyst,¹²³ cerium(IV) catalyzed by iridium(III) in acidic medium,¹²⁴ 3-carboxypyridinium dichromate (NDC),¹²⁵ microwave-assisted Fe(III)-catalysed oxidation with hydrogen peroxide supported on alumina,¹²⁶ bis-(2,4,6-trimethylpyridinium)dichromate (BTMPDC),¹²⁷ V₂O₅ catalysed with NaClO₃ and H₂SO₄ in H₂O,¹²⁸ vanadyl acetylacetonate catalysed O₂,¹²⁹ quinaldinium and poly(2-vinylquinolinium) dichromates,¹³⁰ 2-tolyl-1,2-benzisoselenazol-3(2H)-one 1-oxide,¹³¹ Cu(II) ions immobilized on acrylic resins,¹³² cetyltrimethyl ammonium cerium nitrate,²⁸ clay-supportedtetrabutyl ammoniumperiodate (TBAPI),¹³³ thermal transformations of 5-nitro-spiro[2H-benz-imidazole-2,1'-cyclohexane]1,3-dioxide,¹³⁴ copper-based aerobic oxidation with co-catalysts bifunctional oxazolidine nitroxyl radicals,¹³⁵ ultrasound-assisted (100 W) oxidation by Fe(NO₃)₃ as an oxidant in presence of phase transfer catalyst,¹³⁶ H₂O₂ with vanadium substituted keggin heteropoly acid,²⁹ sodium perborate,¹³⁷ potassium ferrate(VI) in the presence of the K10 montmorillonite,¹³⁸ vanadomolybdo phosphate on active carbon (NPV₆Mo₆/C),¹³⁹ clay-montmorillonite supported potassium peroxydiphosphate,¹⁴⁰ lacunary phosphotungstic acid derivative,³⁰ copper(I)complex [Cu₂L(MeOH)₂](BF₄)₂.2H₂O and dinuclear-copper(II)complex[Cu₂L(MeOH)₂](ClO₄)₄. 2H₂O,¹⁴² hydrogen peroxide in the presence of chromium(VI)oxide-bis(tributyltin)oxide,¹⁴³ (dibenzo[*b,i*][1,4,8,11]tetraazacyclotetr adecinato)cobalt(II),¹⁴⁴ HNO₃ in Acetic acid,¹⁴⁵ benzenetellurinic mixed anhydrides,¹⁴⁶ manganese dioxide. Conversion of hydroquinone (**11a**) to 1,4-benzoquinone (**10**) is a quite popular among the scientist and more than hundred method reported in literature as shown in Table 2 (Scheme 2).

The synthesis of 1,4-benzoquinone (**10**) also achieved from phenol (**5**) as summarized in Table 3 (Scheme 2). A conversion of phenol (**2**) in **10** has been reported first time using H₂O, H₂SO₄, AcOH in 1923.³⁴ Synthesis of 1,4-benzoquinone (**10**) from phenol (**5**) have catalysed by oxoperoxo molybdenum(VI) and tungsten(VI) complexes with 1-(2'-hydroxyphenyl)ethanone oxime,¹⁴⁸ iodic acid on the surface of K10 montmorillonite,⁵⁶ 2,6-dicarboxypyridinium fluorochromate,⁷⁶ tungsten complex of oxoperoxybis(8-quinolinolato-N₁,O₈),¹⁴⁹ Fe²⁺ with H₃Pmo₁₀V₂O₄₀,¹⁵⁰ titanium-superoxide,¹⁵¹ oxidoperoxido tungsten(VI) complexes,¹⁵² H₂O₂ with oxidoperoxidotungsten (VI) complexes and secondary hydroxamic acids,¹⁵² H₂O₂ with oxoperoxo molybdenum(VI) or tungsten(VI) / oxodiperoxomolybdate(VI) or tungstate(VI) complexes,¹⁵³ manganese dioxide in the presence of aniline,¹⁵⁴ titanium superoxide,¹⁵⁵ isoquinolinium bromochromate,²³ chiral cationic (diimino- and diaminodiphosphane)ruthenium complexes,¹⁵⁶ aminomethylpolystyrene-supported (diacetoxy iodo)benzene reagents,¹⁵⁷ chlorine dioxide,¹⁵⁸ 5,10,15,20-tetrakis(4-sulfophenyl)porphine in ethylammonium nitrate,¹⁵⁹ manganese and cobalt salts with activated silica gel supported,¹⁶⁰ sodium perborate on wet montmorillonite K10,²⁶ sodium percarbonate on montmorillonite K10,⁹² ammonium persulfate/wet SiO₂,²⁵ microwave-assisted Fe(III)-catalysed with hydrogen peroxide supported on alumina,¹²⁶ O₂, cobalt salen catalyzed.¹⁶¹ chromium silicalite-2,¹⁶³ methyltrioxorhenium (VII),¹⁶⁴ copper salts and iron as catalytic system with oxygen,¹⁶⁵ A oxo complex of ruthenium (IV),³⁵ O₂ with CuSO₄/NaCl,³⁶ chlorine dioxide,^{166,167} [(bpy)₂(py)Ru(O)]²⁺ (bpy is 2,2'-bipyridine and py is pyridine) in MeCN are reported first order reaction.¹⁶⁸

Table 3: Synthesis of 1,4-benzoquinone (**10**) from phenol (**5**) as shown in Scheme 2.

S.N.	Reactants	Catalyst/ Reaction Condition	Yields (%)
1	5	H ₂ O, H ₂ SO ₄ , AcOH	65 ³⁴
2	5	H ₂ O ₂ , PPh ₄ [MoO(O ₂) ₂ (HPEOH)] / PPh ₄ [WO(O ₂) ₂ (HPEOH)], H ₂ O, CH ₃ CN, 5 h, 78 °C	98 ¹⁴⁸ / 99 ¹⁴⁸
	5	HIO ₃ , montmorillonite, 17 min, 100 °C / HIO ₃ , montmorillonite, 40 s, MW	96 ⁵⁶ / 94 ⁵⁶
3	5	2,6-dicarboxypyridinium fluorochromate, 4 min., rt	94 ⁷⁶
4	5	H ₂ O ₂ , O ₂ , [WO(O ₂)(QO) ₂], MeCN, 10 h, reflux/ H ₂ O ₂ , [WO(O ₂)(QO) ₂], H ₂ O, MeCN, 12 h, 78°C	97 ¹⁴⁹ / 91 ¹⁴⁹
5	5	H ₂ O ₂ , H ₃ Pm ₁₀ V ₂ O ₄₀ , FeSO ₄ , H ₂ O, CHCl ₃ , AcOH	94 ¹⁵⁰
5	5	H ₂ O ₂ , Ti, H ₂ O, AcOH, 50-60°C; 15 min; 1 h, heated	88 ¹⁵¹
6	5	H ₂ O ₂ , oxidoperoxidotungsten(VI) complexes, H ₂ O, MeCN, 12 h, 78°C	87 ¹⁵²
7	5	H ₂ O ₂ , C ₃₀ H ₂₄ N ₂ O ₇ W (CAS No. 1153933-00-6), H ₂ O, MeCN, 12 h, 78°C	91 ¹⁵²
8	5	H ₂ O ₂ , O ₂ , C ₂₄ H ₂₀ P.C ₉ H ₆ NO ₆ W (CAS No. 851956-08-6), H ₂ O, MeCN, rt, 9 h reflux or 12 h reflux / H ₂ O ₂ , O ₂ , C ₂₄ H ₂₀ P.C ₉ H ₆ MoNO ₆ (CAS No 851956-06-4), H ₂ O, MeCN, rt, 12 h reflux	84 ¹⁵³ / 82 ¹⁵³
9	5	H ₂ SO ₄ , MnO ₂ , PhNH ₂ , H ₂ O	95 ¹⁵⁴
10	5	H ₂ O ₂ , Titanium superoxide, H ₂ O, AcOH, 2 h, 50°C	80 ¹⁵⁵
11	5	Isoquinolinium bromochromate/AcOH, 2h, rt	76 ²³
12	5	<i>t</i> -BuOOH, Et ₃ N, C ₄₆ H ₄₇ ClN ₃ P ₂ Ru.BF ₄ (CAS No. 673447-87-5), Benzene, 16 h, rt & Na ₂ S ₂ O ₃ , H ₂ O	80 ¹⁵⁶
13	5	 MeCN, H ₂ O	81 ¹⁵⁷
14	5	ClO ₂ , Me ₂ CO	75 ¹⁵⁸
15	5	O ₂ , 5,10,15,20-tetrakis(4-sulfo phenyl)porphine in ethylammonium nitrate, 20 h, rt	60 ¹⁵⁹
16	5	MnCl ₂ , CoCl ₂ , PhCO ₂ H & O ₂ , Benzene	64 ¹⁶⁰
17	5	NaBO ₃ , Montmorillonite, H ₂ O, 5 min, rt	56 ²⁶
18	5	2(Na ₂ CO ₃)•3H ₂ O ₂ , montmorillonite, 5 min, rt	55 ⁹²
19	5	(NH ₄) ₂ S ₂ O ₈ , wet SiO ₂ , 3 min, rt	55 ²⁵
20	5	Al ₂ O ₃ , H ₂ SO ₄ , FeCl ₃ , 2.8 min, MW	48 ¹²⁶

21	5	O ₂ , Cobalt salen, DMF, 24 h, rt	30 ¹⁶¹
22	5	<i>t</i> -BuOOH, MeOH, chromium silicalite-2	36 ¹⁶³
23	5	H ₂ O ₂ , methyltrioxorhenium (VII), H ₂ O, AcOH	31 ¹⁶⁴
24	5	O ₂ , CuCl, Fe, PhOH, rt, 7 bar; 5 h, 50°C	89 ¹⁶⁵
25	5		88 ³⁵
26	5	O ₂ with CuSO ₄ , NaCl, MeOH, 6 h, 60°C	75 ³⁶
27	5	ClO ₂ , MeCN	50 ¹⁶⁶
28	5	ClO ₂ , O ₂ , EtOH, 10-60°C	50 ¹⁶⁷
29	5	[(bpy) ₂ (py)Ru(O)] ²⁺ , MeCN	88 ¹⁶⁸

Except 1,4-hydroxyquinone (**11a**) and phenol (**5**) other reactant also used for the synthesis of **10** (Table 4, Scheme 2). Pyrocatechol (**2**) converted in **10** using potassium iodide and potassium ferrate as reported by Tajik, H. *et. al.*¹⁶⁹ Oxone (peroxysulfate) very efficiently oxidizes benzene (**7**) to p-quinone (**10**) reported by Shul'pin, G. B. *Et.al.*¹⁷⁰

Binuclear iron(III) phthalocyanine(m-oxodimer)/tetrabutyl ammonium, oxone was reported for the 38% conversion of benzene in 1,4-benzoquinone¹⁷¹.

Aniline (**9**) converted in 1,4-benzoquinone (**10**) catalysed by Mo-V phosphoric heteropolyacids.¹⁷² Tan, S. And co worker optimised reaction condition for the synthesis of p-benzoquinone (**10**) from aniline (**9**) in four step with recycling of manganese dioxide from manganese sulphate.¹⁷³ Aniline (**9**) has also converted in **10** using hypochlorite supported on dowex 1X8-200³² and selenium oxide.¹⁷⁴

4-chlorophenol (**11b**) oxidized by O₂ in H₂O under light in the presence of Titanium superoxide.¹⁵⁵ 2-chlorophenol (**11b**) converted in **10** using iodic acid and K10 montmorillonite, 40 s in MW.⁵⁶ Titanium-superoxide was used as catalyst for the conversion of **11b** in **10**.^{151,155} A detailed selective chemical oxidation of chlorophenols with potassium nitrosodisulfonate were studied by Leyva.¹⁷⁵

4-Bromophenol (**11c**) was converted in 1,4-benzoquinone (**10**) using oxidizing agent iodic acid on the Surface of K10 montmorillonite,⁵⁶ hydrogen peroxide with titanium superoxide^{151,155} and lead oxide with hypochloric acid.¹⁷⁷

Titanium superoxide was also used as catalyst for the conversion of 4-Bromophenol (**11d**) in **10**.^{151,155} 1,4-Benzoquinone (**10**) was reported to synthesize from the oxidation of 4-aminophenol (**11e**) in the presence of HIO₃ with montmorillonite,⁵⁶ cerium(IV) ions in aqueous perchloric acid,¹⁶⁵ sodium hypochlorite,³² sodium borate with montmorillonite,²⁶ hydrogen fluoride with pyridine¹⁷⁸ and potassium dichromate.¹⁷⁹

The synthesis of 1,4-Benzoquinone (**10**) was reported from the heating at 100°C or under microwave irradiation of 4-(*N*-dimethylamino) phenol (**11f**).⁵⁶ Organohypervalent iodine reagents (IBTA) was oxidized 2,2,2-trifluoro-*N*-(4-hydroxy phenyl)acetamide (**11g**) in **10**.^{91,118}

Dirhodiumcaprolactamate [Rh₂(cap)₄] catalyzed oxidation of 4-(hydroxymethyl)phenol (**11h**) was reported for the synthesis of **10**.¹⁸⁰ Leng et. Al. Studied synthesis of **10** from 4-hydroxybenzoic acid (**11i**) in three step using K₂(SO₃)₂NO.¹⁸¹

18-Crown-6 complex [PhI(OH)BF₄·18C6] in the presence of BF₃-Et₂O was utilized for the synthesis of **10** from 4-propylphenol (**11j**).¹⁸²

Benzamides (**12a-b**) converted in 1,4-benzoquinone (**10**) from hypervalent iodine species generated in situ from iodobenzene and oxone,¹⁸³ Benzene-1,4-diamine (**13a**) transformed in 1,4-benzoquinone (**10**) using sodium iodate,⁴⁴ or (diacetoxyiodo)benzene¹⁵⁹ or hydrogen peroxide catalyzed with oxoperoxo molybdenum(VI) and tungsten(VI)/oxodiperoxomolybdate(VI) and tungstate(VI) complexes under different reaction conditions as shown in Table 4 (Scheme 2).^{148,149,152,153}

Ceric ammonium nitrate was used for the conversion of 4-ethoxyaniline (**13b**) in 1,4-benzoquinone (**10**), Table 4 (Scheme 2). 2-Hydroxy-1,4-benzoquinone (**14a**) converted in 1,4-benzoquinone (**10**) using a phase-transferring oxidant cetyltrimethyl ammoniumdichromate.¹⁸⁵

Photolysis of 4-iminocyclohexa-2,5-dienone (**14b**) in aqueous medium produced p-benzoquinone (**10**).¹⁵⁷ Superoxide ion, generated in situ by the phase transfer reaction of potassium superoxide and 18-crown-6, brings about an easy oxidative regeneration of benzoquinone dioxime (**14c**) in **10**.¹⁸⁷

4-Methoxyphenol was converted in 1,4-benzoquinone (**10**) using oxidizing agent tetrabutylammonium dichromate,¹⁶ hypervalent iodine (4-iodophenoxy acetic acid),^{91,120} Silica-gel-supported ceric ammonium nitrate (CAN),^{74,75} tetrabutylammonium bromide and Oxone,⁷⁸ cerium ammonium nitrate coated on silica,^{74,75} sodium hypochlorite,¹⁸⁸ acid-impregnated manganese dioxide,³³ hypervalent iodine with a catalytic amount of 4-iodophenoxyacetic acid with oxone as a cooxidant,^{162,189}

4-Ethoxyphenol (**15b**) was converted in 1,4-benzoquinone (**10**) catalysed by hypervalent iodine with a catalytic amount of 4-iodophenoxyacetic acid with oxone as a cooxidant,¹⁶² organohypervalent iodine (IBTA),^{91,118} tetrabutylammonium bromide with oxone,⁷⁸ hypervalent iodine with a catalytic amount of 4-iodophenoxyacetic acid with oxone as a cooxidant,¹⁸⁹

4-*n*-Butoxyphenol (**15c**) was converted in 1,4-benzoquinone (**10**) catalysed by tetrabutylammonium bromide with oxone,⁷⁸ hypervalent iodine with a catalytic amount of 4-iodophenoxyacetic acid with oxone as a cooxidant,¹⁸⁹

1,4-dimethoxybenzene (**16a**) was converted in **10** using Silica-gel-supported ceric ammonium nitrate (CAN),⁷⁴ organohypervalent iodine (IBTA) reagents,¹⁹⁰ hypervalent iodine with a catalytic amount of 4-iodophenoxyacetic acid with oxone as a cooxidant,¹⁹¹

1,4-Diethoxybenzene (**16b**) was converted in **10** by hypervalent iodine oxidation using a catalytic amount of 4-iodophenoxyacetic acid and oxone as a cooxidant,^{191,192} and ceric ammonium nitrate.¹⁸⁴ 1,4-Benzoquinone (**10**) obtained from trimethylsilyl ethers (**16c**) oxidized using various oxidizing agent such as ionene supported peroxodisulfates,¹⁹³ α-

naphthyltriphenylphosphoniumperoxodisulphate or cetyltrimethyl ammonium peroxodisulfate [(CTA)₂S₂O₈],⁴⁹ phosphomolybdic acid,¹⁹⁴ quinolinium fluorochromate (QFC),¹⁹⁵ Zinc chlorochromate nonahydrate,¹⁹⁶ Lewis acid supported silver bromate catalyzed,¹⁹⁷ Iron trichloride/silicon dioxide.¹⁹⁸

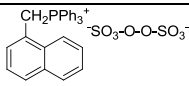
1,4-Benzoquinone (**10**) was also synthesized from *tert*-butyl(4-methoxyphenoxy)dimethylsilane (**17**) in the presence of catalytic hypervalent iodine.^{191,192} 4-hydroxycyclohexa-2,5-dienone (**18**) was converted in 1,4-benzoquinone (**10**) using polymer-supported periodate and iodate as oxidizing agents.¹⁹⁹

Table 4: Synthesis of 1,4-benzoquinone (**10**) from reactants except 1,4-hydroquinone (**11a**) and phenol (**5**) as shown in Scheme 2.

S.N.	Reactants	Catalyst/ Reaction Condition	Yields (%)
1	2	KI, NaOH, H ₂ O, 20 min, 0-5°C, pH 9-10, K ₂ FeO ₄ , 10 min, 0-5°C; 2 h, rt, HCl, H ₂ O, rt	90 ¹⁶⁹
2	9	Mo-V-phosphoric heteropolyacids, >70 °C	100 ¹⁷²
3	9	i) MnSO ₄ , NH ₃ , H ₂ O, rt, pH 10; ii) H ₂ O ₂ , 1 h, 25°C; iii) H ₂ SO ₄ , H ₂ O, 1-1.5 h, 90°C; iv) H ₂ SO ₄ , H ₂ O, rt; 15 min, rt; 4 h, < 10°C; 8 h, rt	84 ¹⁷³
4	9	NaOCl, THF	88 ³²
5	9	i) SeO ₂ , H ₂ O, MeOH, 90 min, reflux; ii) MeCN, 60 min, reflux	75 ¹⁷⁴
6	11b	O ₂ , H ₂ O, 16 h, rt, light	95 ¹⁵⁵
7	11b	HIO ₃ , Montmorillonite, 40 s, MW	84 ⁵⁶
8	11b	H ₂ O ₂ , Ti, H ₂ O, AcOH, 50-60°C; 15 min; 1 h, heated	55 ¹⁵¹
9	11b	H ₂ O ₂ , [Ti(O ₂) ₂] (9CI), H ₂ O, AcOH, 1 h, 50°C	40 ¹⁵⁵
10	11c	HIO ₃ , Montmorillonite, 20 min, 100°C	83 ⁵⁶
11	11c	HIO ₃ , Montmorillonite, 35 s, MW	81 ⁵⁶
12	11c	H ₂ O ₂ , Ti, H ₂ O, AcOH, 50-60°C; 15 min; 1 h, heated	60 ¹⁵¹
13	11c	H ₂ O ₂ , [Ti(O ₂) ₂] (9CI), H ₂ O, AcOH, 1 h, 50°C	66 ¹⁵⁵
14	11c	HClO ₄ , PbO ₂ , H ₂ O, Me ₂ CO, 10 min, rt; 0.5-1 h, rt	62 ¹⁷⁷

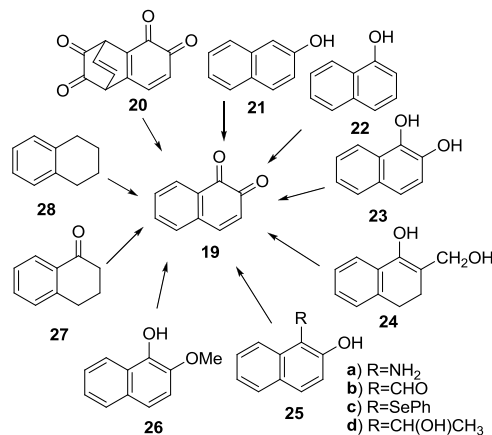
15	11d	H ₂ O ₂ , Ti, H ₂ O, AcOH, 50-60°C; 15 min; 1 h, heated	75 ¹⁵¹
16	11d	H ₂ O ₂ , [Ti(O ₂) ₂] (9Cl), H ₂ O, AcOH, 1 h, 50°C	76 ¹⁵⁵
17	11e	HIO ₃ , montmorillonite, 13 min, 100°C / HIO ₃ , montmorillonite, 30s, MW	90 ⁵⁶ / 93 ⁵⁶
18	11e	NaOCl, (CH ₂ Ome) ₂	97 ³²
19	11e	[ClO ₂ OH] ₄ Ce, PhNHMe, HClO ₄ , H ₂ O	93 ¹⁶⁵
20	11e	NaBO ₃ , Montmorillonite, H ₂ O, 3 min, rt	81 ²⁶
21	11e	C ₅ H ₅ N, HF	80 ¹⁷⁸
22	11e	K ₂ Cr ₂ O ₇ , H ₂ O	75 ¹⁷⁹
23	11f	15 min, 100°C / HIO ₃ , montmorillonite, 40 s, MW	91 ⁵⁶ / 89 ⁵⁶
24	11g	PhI(O ₂ CCF ₃) ₂ , H ₂ O, MeCN	80 ^{91, 118}
25	11h	i) C ₂₄ H ₄₀ N ₄ O ₄ Rh ₂ (Cas No. 138984-26-6), ClCH ₂ CH ₂ Cl, 1 h, rt, then 40°C, ii) <i>t</i> -BuOOH, 1.5 h, 40°C	55 ¹⁸⁰
26	11i	i) HCl, H ₂ O, 24 h, 150-160°C; 160°C to rt; 10 min, rt; ii) KOH, H ₂ O, neutralized; iii) K ₂ (SO ₃) ₂ NO, H ₂ O, 1 h, rt; 2 h, rt	48 ¹⁸¹
27	11j	[PhI(OH)BF ₄ ·18C6].BF ₃ .Et ₂ O, CD ₂ Cl ₂ , 10 min, rt	24 ¹⁸²
28	12a/ 12b	PhI, Oxone, H ₂ O, CH ₃ CN, 7-12 h, rt	98 ¹⁸³ / 94 ¹⁸³
29	13a	NaIO ₄ , H ₂ O, AcOEt, 2-10 min, rt / PhI(Oac) ₂ , Me ₂ CO, 10 min, rt, H ₂ O, rt	98 ⁴⁴ / 90 ¹⁵⁹
30	13a	H ₂ O ₂ , C ₂₄ H ₂₀ P.C ₈ H ₈ MoNO ₇ (Cas No. 1143514-60-6), H ₂ O, MeCN, 6 h, 78°C	60 ¹⁴⁸
	13a	H ₂ O ₂ , C ₂₄ H ₂₀ P.C ₈ H ₈ MoNO ₇ (Cas No. 1143514-60-6), H ₂ O, MeCN, 6 h, 78°C	54 ¹⁴⁸
31	13a	H ₂ O ₂ , 1153933-00-6, H ₂ O, MeCN, 6 h, 78°C	67 ¹⁴⁹
32	13a	H ₂ O ₂ , O ₂ , C ₁₈ H ₁₂ N ₂ O ₅ W (Cas No. 109076-03-1), MeCN, 10 h, reflux	67 ¹⁴⁹

33	13a	H ₂ O ₂ , C ₂₈ H ₂₄ N ₂ O ₇ W (Cas No.1153932-95-6), H ₂ O, MeCN, 6 h, 78°C	63 ¹⁵²
34	13a	H ₂ O ₂ , C ₃₀ H ₂₄ N ₂ O ₇ W (CAS No. 1153933-00-6), H ₂ O, MeCN, 6 h, 78°C	66 ¹⁵²
35	13a	H ₂ O ₂ , O ₂ , C ₂₄ H ₂₀ P.C ₉ H ₆ NO ₆ W (CAS No. 851956-08-6), H ₂ O, MeCN, reflux 5 h, 25°C/	70 ¹⁵³
36	13a	H ₂ O ₂ , C ₂₄ H ₂₀ P.C ₉ H ₆ NO ₆ W (Cas No. 851956-08-6), H ₂ O, MeCN, reflux; 6 h, 25°C	59 ¹⁵³
37	13a	H ₂ O ₂ , C ₂₄ H ₂₀ P.C ₉ H ₆ MoNO ₆ (CAS No.851956-06-4), H ₂ O, MeCN, 6 h, reflux, 25°C	57 ¹⁵³
38	13b	Ce(NH ₄) ₂ (NO ₃) ₆ , H ₂ O, MeCN	43 ¹⁸⁴
39	14a	Cr ₂ O ₇ .Me ₃ N(CH ₂) ₁₅ CH ₃ , CHCl ₃ , 0.5 h, reflux	100 ¹⁸⁵
40	14b	H ₂ O, H _v	100 ¹⁸⁶
41	14c	KO ₂ , 18-Crown-6, DMF, 2-6 h, rt	61 ¹⁸⁷
42	15a	2Bu ₄ N ⁺ •Cr ₂ O ₇ ⁻ , CH ₂ Cl ₂ , 50 min, reflux	96 ¹⁶
43	15a	PhI(O ₂ CCF ₃) ₂ , H ₂ O, MeCN	100 ^{91,120/} 86 ⁹¹
44	15a	SiO ₂ , Ce(NH ₄) ₂ (NO ₃) ₆ , H ₂ O, CH ₂ Cl ₂ , 5 min. rt & 15 min rt	96 ⁷⁴
45	15a	Oxone, Bu ₄ N ⁺ •Br ⁻ , H ₂ O, MeCN, 50 min, rt	91 ⁷⁸
46	15a	Ce(NH ₄) ₂ (NO ₃) ₆ , SiO ₂ , CH ₂ Cl ₂	95 ⁷⁵
47	15a	NaOCl, H ₂ O, DMF, 15 min, rt, pH 7.4	83 ¹⁸⁸
48	15a	MnO ₂ , HNO ₃	96 ³³
49	15a	Oxone, 4-I-Ph-OCH ₂ COOH, F ₃ CCH ₂ OH, H ₂ O, 0.5 h, rt/ Oxone, 4-I-Ph-OCH ₂ COOH, CH ₃ CN, H ₂ O, 16 h, rt	78 ^{162/} 80 ¹⁸⁹
50	15b	Oxone, 4-I-Ph-OCH ₂ COOH, F ₃ CCH ₂ OH, H ₂ O, 0.5 h, rt	97 ¹⁶²
51	15b	PhI(O ₂ CCF ₃) ₂ , H ₂ O, MeCN	100 ⁹¹
52	15b	Oxone, Bu ₄ N ⁺ •Br ⁻ , H ₂ O, MeCN, 60 min, rt	92 ⁷⁸

53	15b	PhI(O ₂ CCF ₃) ₂ , H ₂ O, MeCN	93 ¹¹⁸
54	15b	Oxone, 4-I-Ph-OCH ₂ COOH, CH ₃ CN, H ₂ O, 17 h, rt	79 ¹⁸⁹
55	15c	Oxone, Bu ₄ N ⁺ •Br ⁻ , H ₂ O, MeCN, 60 min, rt	92 ⁷⁸
56	15c	Oxone, 4-I-Ph-OCH ₂ COOH, F ₃ CCH ₂ OH, H ₂ O, 0.5 h, rt / Oxone, 4-I-Ph-OCH ₂ COOH, H ₂ O, MeCN, 17 h, rt	88 ¹⁶³ /77 ¹⁸⁹
57	16a	SiO ₂ , Ce(NH ₄) ₂ (NO ₃) ₆ , H ₂ O, CH ₂ Cl ₂ , 15 min, rt	95 ⁷⁵ /99 ⁷⁴
58	16a	PhI(O ₂ CCF ₃) ₂ , H ₂ O, MeOH	100 ¹⁹⁰
59	16a	4-I-Ph-OCH ₂ COOH, F ₃ CCH ₂ OH, oxone, H ₂ O, 1 h, rt	86 ¹⁹¹
60	16b	4-I-Ph-OCH ₂ COOH, F ₃ CCH ₂ OH, oxone, H ₂ O, 1 h, rt	94 ¹⁹¹ , ¹⁹²
61	16b	Ce(NH ₄) ₂ (NO ₃) ₆ , H ₂ O, MeCN	66 ¹⁸⁴
62	16c	-SO ₃ -O-O-SO ₃ -(ionene polymer supported), H ₂ O, 30 min, reflux	97 ¹⁹³
63	16c	 , MeCN, 3 min, reflux / (CTA) ₂ S ₂ O ₈ , MeCN, 15 min, reflux.	94 ⁴⁹ / 95 ⁴⁹
64	16c	Phosphomolybdic acid, PhMe, 10 min, reflux	92 ¹⁹⁴
65	16c	C ₉ H ₇ NH[CrO ₃ F], CH ₂ Cl ₂	98 ¹⁹⁵
66	16c	Zn(ClCrO ₃) ₂ •9H ₂ O, CH ₂ Cl ₂	90 ¹⁹⁶
67	16c	AgBrO ₃ , AlCl ₃ , MeCN	89 ¹⁹⁷
68	16c	FeCl ₃ , SiO ₂	57 ¹⁹⁸
69	17	Oxone, 2-(4-iodophenoxy)acetic acid, F ₃ CCH ₂ OH, H ₂ O, 1.5 h, rt	94 ¹⁹¹ /79 ¹⁹²
70	18	polymer-supported periodate / iodate	86 ¹⁹⁹ /69 ¹⁹⁹

4. Synthesis of 1,2-naphthoquinone:

Synthesis of 1,2-naphthoquinone (**19**) was first reported from the oxidation of **28** in acetic acid in 1960 by Adler and Britt²⁰⁰ (Scheme 3, Table 5).



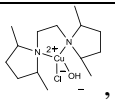
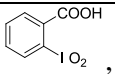
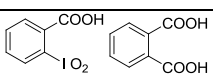
Scheme 3: Synthesis of 1,2-naphthoquinone (**19**)

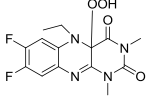
Naphthalen-2-ol (**21**) was generally studied for the synthesis of 1,2-naphthoquinone (**19**) oxidized with *t*-BuOOH in the presence vanadium 18cchiff base containing cyclotriphosphazene as a heterogeneous catalyst,²⁰¹ Dess-Martin periodinane(DMP),²⁰² hydrogen peroxide using “sandwich” type substituted polyoxometalates as catalysts,³⁰ NaBrO₃ in the presence Ce(NH₄)₂(NO₃)₆,²⁰³ μ -oxo-bridged hypervalent iodine(III) compound as an extreme oxidant for aqueous oxidations,²⁰⁴ hydrogen peroxide using vanadiumsubstituted Keggin heteropoly acid as catalyst,²⁹ hydrogen peroxide using phosphotungstateperoxo complexes as catalyst,²⁰⁵ *t*-BuOOH using rhodium catalyst,²⁰⁶ *t*-BuOOH in methanol,¹⁰⁰ PhSe(=O)₂O in THF,²⁰⁷ O₂ in the presence of a copper complex (Cas No. 749898-34-8),²⁰⁸

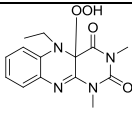
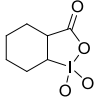
Naphthalen-1-ol (**22**) was also studied for the synthesis of 1,2-naphthoquinone (**19**) oxidized with hypervalent iodine,²⁰⁹ SIBX,²¹⁰ hydrogen peroxide using phosphotungstateperoxo complexes as catalyst,²⁰⁵ NaIO₄,²¹¹ Dess-Martin periodinane(DMP),²⁰² Cetyltrimethylammonium cerium nitrate in dioxane,²⁸ oxygen in the presence of CuCl,²¹² hypervalent iodine PhI(O₂CCF₃)₂,²⁰⁹ organohypervalent iodine PhIO₂,⁹¹ organoselenium (organic seleninic anhydrides),^{141,213} Fremy’s salt,²¹⁴ hydrogen peroxide and potassium catalyzed by 5,10,15,20- tetraarylporphyrinatoiron(III) chlorides,²¹⁵

Naphthalene-1,2-diol (**23**) was converted in 1,2-naphthoquinone (**19**) in the presence of persulfate/copper(II)⁸⁵ as well as polymer-supported periodate and iodate.¹⁹⁹ However, compound **24** was converted in **19** in the presence of 2-iodoxybenzoic acid.²¹⁶ 1-aminonaphthalen-2-ol (**25a**) was converted in **19** using sodium hypochlorite/dowex 1X8-200,³² as well as ferric chloride.²¹⁷ 2-Hydroxy-1-naphthaldehyde (**25b**) was converted in **19** using oxidizing agents such as hydrogenperoxide with flavin catalysts (FIOOH),²¹⁸ oxygen in the presence of flavin catalysts (FIOOH) with Hantzsch’s ester (NAD(P)H coenzymes),²¹⁹ 1-(phenylselenanyl)- naphthalen-2-ol (**25c**) was reported to convert in **19** in the presence of (PhSe(=O))₂O.¹⁴¹ 1-(1-hydroxyethyl)naphthalen-2-ol (**25d**) was achieved to convert in **19** under photooxygenation.²²⁰ 2-methoxynaphthalen-1-ol (**26**) was converted in **19** through demethylation using stabilized 2-iodoxybenzoic Acid.²²¹ while microwave-assisted selenium dioxide mediated selective oxidation of 1-tetralones in 1,2-naphthoquinones was reported in acetic acid.²²² a benzilic oxidation of 1,2,3,4-tetrahydronaphthalene (**28**) was reported to synthesize 1,2-naphthoquinone (**19**) using fluorous seleninic acid in the presence of iodoxybenzene.²²³

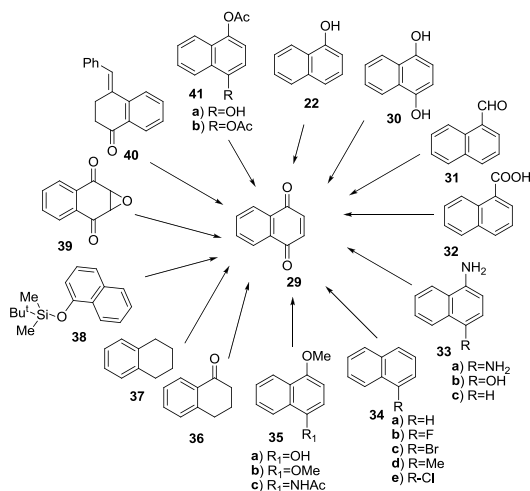
Table 5: Synthesis of 1,2-naphthoquinone (**19**) as shown in Scheme 3.

S.N.	Reactants	Catalyst/ Reaction Condition	Yields (%)
1	20	NaIO ₄ , AcOH, 30mn	70 ²⁰⁰
2	21	<i>t</i> -BuOOH, C ₃₆ H ₄₅ Cl ₃ N ₉ O ₁₅ P ₃ V ₃ (CAS No. 1384844-22-7), C ₄₈ H ₆₀ C ₁₂ N ₁₁ O ₂₀ P ₃ V ₄ (CAS No.1384844-23-8), C ₇₂ H ₉₀ N ₁₅ O ₃₀ P ₃ V ₆ (Cas No. 1384844-24-9), C ₆₀ H ₇₅ ClN ₁₃ O ₂₅ P ₃ V ₅ (Cas No. 1384844-25-0), Me(CH ₂) ₈ Me, MeCN, 4 h, 70°C	85 ²⁰¹
3	21	Martin's reagent (1,1,1-Triacetoxy-1,1-dihydro-1,2-benziodoxol-3(1 <i>H</i>)-one), CH ₂ Cl ₂ , 12 h, rt	87 ²⁰²
4	21	H ₂ O ₂ , H.8Na.O ₃₄ PW ₉ (CAS No. 110697-84-2), H ₂ O, Me ₂ CO, 1 h, 56°C	83 ³⁰
5	21	NaBrO ₃ , AcOH, Ce(NH ₄) ₂ (NO ₃) ₆ , PEG-400, rt to 50°C; 1 h, 50°C	77 ²⁰³
6	21	(PhIOCOCF ₃) ₂ O, H ₂ O, DMF, 1-2 h, 0°C	70 ²⁰⁴
7	21	H ₂ O ₂ , vanadiumsubstituted Keggin heteropoly acid (Cas No.12293-15-1), H ₂ O, Me ₂ CO, 20°C; 1.5 h, 20°C	75 ²⁹
8	21	H ₂ O ₂ , Na ₂ WO ₄ , H ₃ PO ₄ , ClCH ₂ CH ₂ Cl	80 ²⁰⁵
9	21	<i>t</i> -BuOOH, Rh ₂ (cap) ₄ (MeCN) ₂ , H ₂ O, PhMe, 3 h, 40°C	57 ²⁰⁶
10	21	<i>t</i> -BuOOH, MeOH	65 ¹⁰⁰
11	21	PhSe(=O) ₂ O, THF	62 ²⁰⁷
12	21	 , O ₂ , CH ₂ Cl ₂ , 2 d, rt	24 ²⁰⁸
13	22	 , DMF, 1h, rt	53 ²⁰⁹
14	22		99 ²¹⁰
15	22	H ₂ O ₂ , Na ₂ WO ₄ , H ₃ PO ₄ , ClCH ₂ CH ₂ Cl	98 ²⁰⁵

16	22	NaIO ₄ , Me(CH ₂) ₄ CO ₂ H, 30°C to 60°C; 60°C to rt,	70 ²¹¹
17	22	Martin's reagent, CH ₂ Cl ₂ , 12 h, rt	74 ²⁰²
18	22	Cetyltrimethylammonium cerium nitrate, dioxane	75 ²⁸
19	22	CuCl, O ₂ , MeCN	80 ²¹²
20	22	PhI(O ₂ CCF ₃) ₂ , H ₂ O, DMF, 2 h, 0°C	61 ²⁰⁹
21	22	PhIO ₂ , AcOH	65 ⁹¹
22	22	(PhSe(=O)) ₂ O, THF	63 ¹⁴¹
23	22	(PhSe(=O)) ₂ O, THF	54 ²¹³
24	22	Fremy's salt	15 ²¹⁴
25	22	H ₂ O ₂ , Me ₁₂ TPPFe(III)Cl, iron complex (C ₄₄ H ₈ ClF ₂₀ FeN ₄ , CAS No. 36965-71-6),, CH ₂ Cl ₂	30 ²¹⁵
26	23	i) Na ₂ SO ₅ , Bu ₄ N ⁺ •HSO ₄ ⁻ , H ₂ O, CH ₂ Cl ₂ ii) 1,10-Phenanthroline, H ₂ O iii) Cu(Oac) ₂	95 ⁸⁵
27	23	Polymer-supported periodate and iodate	96 ¹⁹⁹
28	24	2-Iodoxybenzoic acid, THF, DMSO, 3 h, rt	70 ²¹⁶
29	25a	NaOCl, Dowex 1X8-200, (CH ₂ Ome) ₂	89 ³²
30	25a	HCl, FeCl ₃ , H ₂ O	94 ²¹⁷
31	25b	 , H ₂ O ₂ , NaHCO ₃ , , H ₂ O, MeOH, 10 min, rt.	95 ²¹⁸

32	25b	 , O ₂ , NaHCO ₃ , H ₂ O, MeCN, 10 min, rt	91 ²¹⁹
33	25c	(PhSe(=O)) ₂ O, THF	89 ¹⁴¹
34	25d	-30 °C	31 ²²⁰
35	26	 , THF, 16 h, rt	83 ²²¹
36	27	SeO ₂ , AcOH, 5 min, 150°C	44 ²²²
37	28	PhIO ₂ , Ph-Se(=O)-(CF ₂) ₇ -CF ₃ , reflux; reflux →rt, Na ₂ S ₂ O ₅ , 3 h, rt	90 ²²³

5. Synthesis of 1,4-naphthoquinone:



Scheme 4: Synthesis of 1,4-naphthoquinone (**29**)

1,4-naphthoquinone (**29**) was synthesized from α -naphthol (**22**) (Table 6) using various oxidizing agents such as oxygen in the presence of catalyst (C₁₂₆H₁₁₂O₃₂S₆, Cas No. 1353640-24-0)²²⁴ oxygen in the presence of boron complex (C₃₆H₂₄BBr₂F₂I₄N₃O₄, cas No. 1256918-97-4),²²⁵ μ -oxo-bridged hypervalent iodine(III) compound as an extreme oxidant for aqueous oxidations,²⁰⁴ hydrogen peroxide (H₂O₂)/methyltrioxorhenium(CH₃ReO₃) catalytic system in a neutral ionic liquid 1-butyl-3-methylimidazolium tetrafluoroborate [bmim]BF₄,²²⁶ photooxygenations by using [60]fullerene-linked silica gels.²²⁷ iodic acid on the surface of K10 montmorillonite.⁵⁶ zinc(II)octakis(4-alkoxycarbonylphenoxyphthalocyanines) together with pegylated silicon(IV) phthalocyanines,²²⁸ K-10supportedphthalocyanine in the presence of PcFe/ZrPO₄,⁶⁶ HIO₃ with montmorillonite in microwave,⁵⁶ hydrogen peroxide/methyltrioxorhenium catalytic system in dimethylcarbonate (DMC),²²⁹

O₂ with cobalt salen,¹⁶¹ iodo-bodipy derivs with photochemically,²³⁰ isoquinolinium bromochromate,²³ H₂O₂ with ruthenium(2,2',6':2''-terpyridine)(2,6-pyridinedicarboxylate),²³¹ *t*-BuOOH in the presence vanadiumchiff base containing cyclotriphosphazene as a heterogeneous catalyst,²⁰¹ H₂O₂ with vanadium substituted keggin heteropoly acid,²⁹ hypervalent iodine PhI(O₂CCF₃)₂,^{209,91} cuprous chlorideoxygen,²¹² nitrosodisulfonate²³² crown ether complexes of a iodonium ions,²³³ PhI(OH)BF₄·18-crown-6,²³⁴ NaBO₃ in wet montmorillonite [Ce(NO₃)₃]₂CrO₄,²⁶ manganese and cobalt salts with activated silica gel,¹⁶⁰ bis(trifluoroacetoxy)iodobenzene,²³⁵ hydrogen peroxide with acetic anhydride,²³⁶ microwave-assisted Fe(III)-catalysed oxidation with hydrogen peroxide supported on alumina,¹²⁶ cetyltrimethyl ammonium cerium nitrate,²⁸ Fremy's salt,²¹⁴ 2-iodoxybenzenesulfonic acid,²³⁷ photooxygenations in a resin-bound,²³⁸ ammonium persulfate/wet SiO₂,²²⁵ sodium percarbonate on montmorillonite K10,⁹² microwave assisted in acetic acid and hydrogenperoxide,²³⁹ methyltrioxorhenium (VII),¹⁶⁴ oxygen in photosensitized condition,²⁴⁰ hydrogen peroxide catalyzed by 5,10,15,20- tetraarylporphyrinatoiron(III) chlorides,²¹⁵ cerium(IV) oxidation,²⁴¹ iodoxybenzene,²⁴² dimethyldioxirane,²⁴³ benzeneseleninic acid,²⁴⁴ H₂O₂ with “sandwich” type substituted polyoxometalates Keggin heteropoly acid,³⁰ cerium(IV)ammonium nitrate.

Table 6: Synthesis of 1,4-naphthoquinone (29) from α -naphthol as shown in Scheme 4.

S.N.	Reactants	Catalyst/ Reaction Condition	Yields (%)
1	22	O ₂ , C ₁₂₆ H ₁₁₂ O ₃₂ S ₆ , (CAS No. 1353640-24-0), PhMe, 80 min, photochem	100 ²²⁴
2	22	O ₂ , C ₃₆ H ₂₄ BBr ₂ F ₂ I ₄ N ₃ O ₄ , (cas No. 1256918-97-4), MeCN, 0.5 h, photochem	100 ²²⁵
3	22	(PhIOCOCF ₃) ₂ O, H ₂ O, MeCN, 30 min, 0°C	97 ²⁰⁴
4	22	H ₂ O ₂ , CH ₃ ReO ₃ , [bmim]BF ₄ , H ₂ O, 24 h, 60°C	98 ²²⁶
5	22	i) [60]fullerene reaction products with aminopropylated silica gels, PhMe, 8 h, 60°C, ii) O ₂ , CDCl ₃ , 90 min, rt / i) Buckminsterfullerene (CAS No. 99685-96-8) reaction products with aminopropylated sil, toluene, 8 h, 60°C, xenon lamp (above 380 nm) ii) O ₂ , 18 h, rt	97 ²²⁷ /36 ²²⁷
6	22	HIO ₃ , Montmorillonite, 20 min, 100 °C	97 ⁵⁶
7	22	zinc(II)octakis(4-alkoxycarbonyl phenoxyphthalocyanines) with pegylated silicon(IV)phthalocyanines, CHCl ₃ , MeOH, 100 min, 0°C	93 ²²⁸
8	22	O ₂ , lamellar zirconium phosphate, ferric phthalocyanine (C ₃₂ H ₁₆ FeN ₈ , CAS No. 34808-44-1), dioxane, H ₂ O	96 ⁶⁶
9	22	HIO ₃ , Montmorillonite, 50 s, MW	93 ⁵⁶
10	22	i) H ₂ O ₂ , CH ₃ ReO ₃ (CAS No. 171078-32-3), 6 h, 60°C, ii) MnO ₂ , 15 min, 60°C	90 ²²⁹
11	22	O ₂ , Cobalt salen, DMF, 24 h, rt	88 ¹⁶¹
12	22	O ₂ , 1437797-58-4, MeOH, CH ₂ Cl ₂ , 30 min, 22°C, h ν	81 ²³⁰
13	22	Isoquinolinium bromochromate/AcOH, 2h, rt	83 ²³
14	22	H ₂ O ₂ , Ru(tpy)pydic, H ₂ O, MeOH, 7 h, 40°C	78 ²³¹

15	22	<i>t</i> -BuOOH, C ₃₆ H ₄₅ Cl ₃ N ₉ O ₁₅ P ₃ V ₃ (CAS No. 1384844-22-7), C ₄₈ H ₆₀ C ₁₂ N ₁₁ O ₂₀ P ₃ V ₄ (CAS No.1384844-23-8), C ₇₂ H ₉₀ N ₁₅ O ₃₀ P ₃ V ₆ (Cas No. 1384844-24-9), C ₆₀ H ₇₅ ClN ₁₃ O ₂₅ P ₃ V ₅ (Cas No. 1384844-25-0), Me(CH ₂) ₈ Me, MeCN, 3.5 h, 70°C	74 ²⁰¹
16	22	H ₂ O ₂ , vanadium substituted Keggin heteropoly acid, H ₂ O, Me ₂ CO, 20°C; 1.5 h, 20°C	79 ²⁹
17	22	PhI(O ₂ CCF ₃) ₂ , DMF, 2h, 0°C	68 ²⁰⁹
18	22	PhI(O ₂ CCF ₃) ₂ , H ₂ O, MeCN	73 ⁹¹
19	22	CuCl, O ₂ , MeCN	80 ²¹²
20	22	K ₂ (SO ₃) ₂ NO	90 ²³²
21	22	Crown ether complexes of aqua(hydroxyl)(aryl)iodonium ions, H ₂ O, 3 h, 0°C →rt	64 ²³³
22	22	PhI(OH)BF ₄ ·18-crown-6, H ₂ O, 3 h, rt	67 ²³⁴
23	22	NaBO ₃ in wet [Ce(NO ₃) ₃] ₂ CrO ₄ , 5 min, rt	63 ²⁶
24	22	MnCl ₂ , CoCl ₂ , PhCO ₂ H & O ₂ , Benzene	65 ¹⁶⁰
25	22	PhI(O ₂ CCF ₃) ₂ , MeCN, H ₂ O	73 ²³⁵
26	22	i) H ₂ O ₂ , Ac ₂ O, H ₂ O, < 40°C; 4 h, 40°C, ii) MeOH, 40°C; 1 h, 50°C	56 ²³⁶
27	22	Al ₂ O ₃ , H ₂ SO ₄ , FeCl ₃ , H ₂ O ₂ , 3.5 min. MW	55 ¹²⁶
28	22	Cetyltrimethylammonium cerium nitrate /dioxane	60 ²⁸
29	22	Fremy's salt	74 ²¹⁴
30	22	i) Na ₂ SO ₄ , Oxone, H ₂ O, MeCN, 24 h, rt; ii) Bu ₄ N ⁺ ·HSO ⁴⁻ , IBS, H ₂ O, MeCN, 3.5 h, 40°C / i) K ₂ CO ₃ , Na ₂ SO ₄ , oxone, AcOEt, 24 h, rt; ii) Bu ₄ N ⁺ ·HSO ⁴⁻ , sodium 2-iodo-5-methylbenzenesulfonate, AcOEt, 1 h, 40°C	51 ²³⁷ 6 ²³⁷ +75 (19)
31	22	resin-bound, O ₂ , Me ₂ CO, 5 h, rt, mercury lamp	53 ²³⁸
32	22	(NH ₄) ₂ S ₂ O ₈ in wet SiO ₂ , 4 min., rt	52 ²⁵
33	22	2(Na ₂ CO ₃)·3H ₂ O ₂ , montmorillonite, 5 min, rt	50 ⁹²
34	22	H ₂ O ₂ , H ₂ O, AcOH, 2 min, MW	51 ²³⁹
35	22	H ₂ O ₂ , methyltrioxorhenium (VII), H ₂ O, AcOH	57 ¹⁶⁴
36	22	9:1 CH ₂ Cl ₂ -MeOH, methylene blue, visible light, oxygen, 15°C	64 ²⁴⁰
37	22	H ₂ O ₂ , 1-methylimidazole, C ₄₈ H ₃₆ ClFeN ₄ O ₄ (CAS No. 36995-20-7), CH ₂ Cl ₂ / H ₂ O ₂ , 1-methylimidazole, C ₅₆ H ₅₂ ClFeN ₄ (CAS No. 77439-21-5), CH ₂ Cl ₂ / H ₂ O ₂ , 1-methylimidazole, iron complex (C ₄₄ H ₈ ClF ₂₀ FeN ₄ , CAS No. 36965-71-6),	49 ²¹⁵ / 39 ²¹⁵ / 32 ²¹⁵

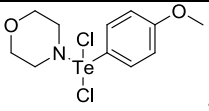
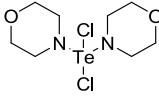
		CH ₂ Cl ₂	
38	22	(NH ₄) ₄ Ce(SO ₄) ₄ , H ₂ SO ₄ , MeCN	20 ²⁴¹
39	22	i) K ₂ CO ₃ , Na ₂ SO ₄ , oxone, AcOEt, 24 h, rt; ii) Bu ₄ N ⁺ •HSO ₄ ⁻ , sodium 2-iodo-5-methylbenzenesulfonate, AcOEt, 1 h, 40°C	6 ²³⁷ +75 (19)
40	22: 19	PhIO ₂ , MeCN, H ₂ O	74 ²⁴² (17:3)
41	22	DMD, Acetone	31 ²⁴³
42	22:19	PhSeO ₂ H, CH ₂ Cl ₂	36:6 ²⁴⁴
43	22	H ₂ O ₂ , “sandwich” type substituted polyoxometalates as catalysts H ₂ O, acetone, 1 h, 56°C	58 ³⁰
44	22	CeNH ₄ nitrate, MeCN, 20 min, rt	31 ²⁴⁵

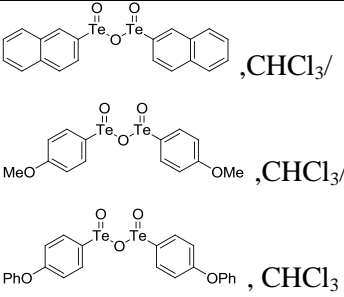
1,4-naphthoquinone (**29**) was synthesized from naphthalene-1,4-diol (**30**) using various oxidizing agents (Table 7) such as oxygen in the presence of μ -oxo-bridged hypervalent iodine(III) compound as an extreme oxidant for aqueous oxidations,²⁰⁴ hydrogen peroxide using catalytic amount of silver oxide under batch and continuous-flow conditions,⁵⁸ aerobic oxidation by polymer-incarcerated platinum catalyst,¹²³ iodic acid on the surface of K10 montmorillonite in microwave,⁵⁶ high loading polymer reagents based on polycationic ultraresins (prepared from highly branched polyethylene imine ($M_n=10,000$) via reductive cross-linking with terephthaldialdehyde),⁵⁷ aerobic oxidation on polymer-incarcerated gold,¹⁰⁴ polymer supported peroxotungstate complex,¹⁷ O₂, montmorillonite supported metalated phthalocyanine as catalyst,⁶⁶ polymer supported anionic peroxomolybdenum complex,¹⁹ organohypervalent iodine,⁹¹ iodine with hydrogen peroxide,¹⁰⁶ hydrogen peroxide in the presence of chromium(VI)oxide-bis(tributyltin)oxide,¹⁴³ thionyl chloride,²⁴⁶ iron-catalyzed with aqueous *tert*-butylhydroperoxide,²⁴⁷ tetrabutylammoniumcerium(IV) nitrate,¹¹⁷ organohypervalent iodine,⁹¹ dibenzoyl peroxide,²⁴⁸ benzeneseleninic anhydride,²⁴⁴ silver(II) oxide-40% nitric acid, tetravalent morpholinotellurium derivatives,²⁵⁰ sodium percarbonate on montmorillonite K10,⁹² sodium perborate on wet montmorillonite K10,²⁶ microwave-assisted Fe(III)-catalysed oxidation by hydrogen peroxide supported on alumina,¹²⁶ sodium perborate,¹³⁷ solid state oxidation with ammonium persulfate/wet SiO₂,²⁵ diaryl telluroxides,²⁵¹ dimethyldioxirane,²⁵² organotellurinic acid anhydrides,²⁵³

Table 7: Synthesis of 1,4-naphthoquinone (**29**) from naphthalene-1,4-diol (**30**) as shown in Scheme 4.

S.N.	Reactants	Catalyst/ Reaction Condition	Yields (%)
1	30	(PhIOCOF ₃) ₂ O, H ₂ O, MeCN, 1-2 h, 0°C	100 ²⁰⁴

2	30	H ₂ O ₂ , Ag ₂ O, H ₂ O, MeOH, 10 min, 25°C	99 ⁵⁸
3	30	O ₂ , Pt, H ₂ O, CHCl ₃ , 2 h, rt, 1 atm	99 ¹²³
4	30	HIO ₃ , montmorillonite, 10 min, 100°C / HIO ₃ , montmorillonite, 30s, MW	98 ⁵⁶ / 98 ⁵⁶
5	30	IO ₄ ⁻ (ultraresin supported), MeOH, CH ₂ Cl ₂ , 1h, rt	100 ⁵⁷
6	30	O ₂ , Au, H ₂ O, CHCl ₃ , 3 h, rt	97 ¹⁰⁴
7	30	K ₂ [WO ₄], amberlyst A-26 bound, ClCH ₂ CH ₂ Cl	96 ¹⁷
8	30	O ₂ , H ₃ PO ₄ montmorillonite, phthalocyanine, dioxane, H ₂ O	96 ⁶⁶
9	30	[Amb] ₂ [Mo ₂ O ₃ (O ₂) ₄], CH ₂ Cl ₂	98 ¹⁹
10	30	PhI=O, RuCl ₂ (PPh ₃) ₃ , Me ₂ CO/ PHI=O, Me ₂ CO	85 ⁹¹ /92 ⁹¹
11	30	H ₂ O ₂ , H ₂ SO ₄ , I ₂ , MeOH	98 ¹⁰⁶
12	30	H ₂ O ₂ , chromium(VI)oxidebis(tri butyltin)oxide, (i-Pr) ₂ O, benzene	100 ¹⁴³
13	30	SOCl ₂ , Benzene	92 ²⁴⁶

14	30	i) t-BuOOH, FeCl ₃ •6H ₂ O, H ₂ O, C ₅ H ₅ N, 10 min, rt, ii) HCl, H ₂ O	82 ²⁴⁷
15	30	2Bu ₄ N ⁺ •Ce(ONO ₂) ₆ , CH ₂ Cl ₂	90 ¹¹⁷
16	30	PhI=O, RuCl ₂ (PPh ₃) ₃ , acetone	85 ⁹¹
17	30	(PhCO ₂) ₂ , Me ₂ CHOH, CH ₂ Cl ₂ / (PhCO ₂) ₂ , DBU, THF	89 ²⁴⁸ / 60 ²⁴
18	30	[PhSe(=O)] ₂ O, THF	92 ²⁴⁴
19	30	AgO, HNO ₃ , Me ₂ CO	78 ²⁴⁹
20	30	 , CH ₂ Cl ₂	87 ²⁵⁰
21	30	 , CH ₂ Cl ₂	74 ²⁵⁰
22	30	2(Na ₂ CO ₃)•3H ₂ O ₂ , montmorillonite, 2 min, rt	75 ⁹²
23	30	NaBO ₃ , montmorillonite, H ₂ O, 2 min, rt	73 ²⁶
24	30	Al ₂ O ₃ , H ₂ SO ₄ , FeCl ₃ , 2.6 min, MW	65 ¹²⁶
25	30	Sodium perborate, AcOH	79 ¹³⁷

26	30	(NH ₄) ₂ S ₂ O ₈ , wet SiO ₂ , 3 min, rt	65 ²⁵
27	30	(4-MeOC ₆ H ₄) ₂ TeO (I), CHCl ₃	76 ²⁵¹
28	30	Dimethyldioxirane, acetone	34 ²⁵²
29	30		96 ²⁵³ / 97 ²⁵³ / 95 ²⁵³

1,4-naphthoquinone (**29**) was generally synthesized from α -naphthol (**22**, Table 6) and naphthalene-1,4-diol (**30**, Table 7). Synthesis of 1,4-naphthoquinone (**29**) was also studied from other reagent as shown in Scheme 5-6. 1-Naphthaldehyde (**31**) was converted in 1,4-naphthoquinone (**29**) using ceric ammonium sulfate²⁴¹ or peroxide oxidations (Table 6).²⁵⁴

1-Naphthoic acid (**32**) was also converted in 1,4-naphthoquinone (**29**) using ceric ammonium sulphate.²⁴¹ Naphthalene-1,4-diamine (**33a**) was also reported to convert in 1,4-naphthoquinone (**29**) using sodium periodate²⁵⁵ or (diacetoxyiodo)benzene.²⁵⁶

Hypochlorite supported on dowex 1X8-200,³² or potassium dichromate were used to synthesize 1,4-naphthoquinone (**29**) from 4-aminonaphthalen-1-ol (**33b**). Naphthalen-1-amine (**33c**) was also converted in 1,4-naphthoquinone (**29**) using oxidizing agents Hypochlorite supported on dowex 1X8-200³² and bis(trifluoroacetoxy)iodobenzene.²³⁵

Naphthalene (**34a**) was applied for the synthesis of 1,4-naphthoquinone (**29**) using various oxidizing combination such as 2,6-dichloropyridine-*N*-oxide in presence of dichlororuthenium(IV) complex of mesotetrakis (2,6-dichlorophenyl)porphyrin,²⁵⁸ oxygen in the presence of vanadium oxide,²⁵⁹ silica gel support with V₂O₅ main catalyst and cocatalysts,²⁶⁰ cerium (IV) in aq. methanesulfonic acid,^{261,262} cerium sulphate Ce₂(SO₄)₃,²⁶³ a cerium complex Ce(ClO₄)₄ catalyzed,²⁶⁴ cerium sulphate,²⁶⁵ ceric methanesulfonate,²⁶⁶

An selective oxidation of 1-fluronaphthalene in 1,4-naphthoquinones has been reported in the presence of a ruthenium complexes as catalyst.²⁶⁷ 4-Methoxynaphthalen-1-ol (**35a**) was converted in 1,4-naphthoquinone (**29**) using oxidizing agents tetra-*n*-butylammonium bromide in oxone,⁷⁸ tert-butyl hydroperoxide with ceric ammonium nitrate,¹²⁸ ceric ammonium nitrate,⁷⁴ 4-iodophenoxyacetate,¹⁸⁹ ceric ammonium nitrate,²⁴⁹ ammonium persulfate,²⁴⁹ tetrabutylammonium

tetrafluoroborate.²⁶⁸

1,4-Dimethoxynaphthalene (**35b**) was converted in 1,4-naphthoquinone (**29**) using oxidizing agents silver oxide,^{249,190} bromosuccinimide,²⁶⁹ hypervalent iodine (III) reagents,¹⁹⁰ ceric ammonium nitrate,¹⁹⁰ cobalt(III)fluoride,²⁷⁰ manganese dioxide,²⁷¹ 4-iodophenoxyacetate,¹⁸⁹ hydrogen halide-treated silica gels, iodosobenzene,²⁷² 4-iodophenoxyacetic acid with oxone.¹⁹¹ N-(4-methoxynaphthalen-1-yl)acetamide (**35c**) was converted in 1,4-naphthoquinone (**29**) using oxidizing agents diacetoxyiodobenzene,²⁷³

1-Tetralone (**36**) was converted in 1,4-naphthoquinone (**29**) using oxidizing agents 2-nitrobenzene peroxysulfonyl radical,²⁷⁴ tert-butylhydroperoxide with Chromium(VI) oxide.²⁷⁵ 1,2,3,4-tetrahydronaphthalene (**37**) was also converted in 1,4-naphthoquinone (**29**) using oxidizing agents tert-butylhydroperoxide and 2-quinoxalinol salen with a side product 36 (26%).²⁷⁶

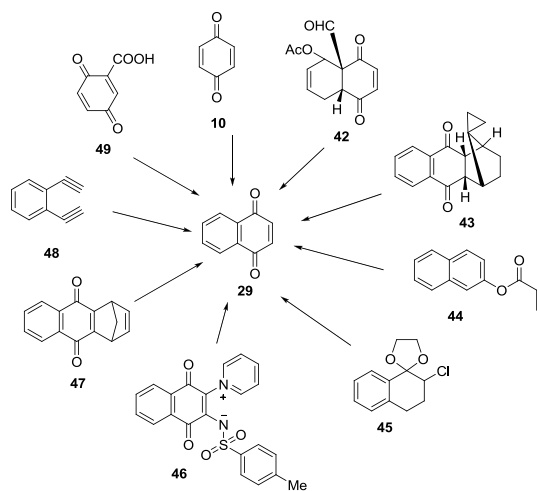
Tert-butyl dimethyl(naphthalen-1-yloxy)silane (**38**) was converted in 1,4-naphthoquinone (**29**) though a aerobic oxidation in the presence of vanadium(IV) catalyst (cas No. 56645-89-5)²⁷⁷ Naphtho[2,3-*b*]oxirene-2,7(1*aH*,7*aH*)-dione (**39**) was converted in 1,4-naphthoquinone (**29**) using oxidizing agents molybdenumhexacarbonyl.²⁷⁸ 4-Benzylidene-3,4-dihydronaphthalen-1(2*H*)-one (**40**) was converted in 1,4-naphthoquinone (**29**) though thermolysis oxidation.²⁷⁹ 4-Hydroxynaphthalen-1-yl acetate (**41a**) was converted in 1,4-naphthoquinone (**29**) using oxidizing agents silver(II)oxide,²⁸⁰ lead tetraacetate in acetic acid.²⁸¹

Table 8: Synthesis of 1,4-naphthoquinone (**29**) as shown in Scheme 4.

S.N	Reactants	Catalyst/ Reaction Condition	Yields (%)
1	31	(NH ₄) ₄ Ce(SO ₄) ₄ , H ₂ SO ₄ , MeCN	50 ²⁴¹
2	31	H ₂ O ₂ , AcOH, AcOOH, AcOH	25 ²⁵³
3	32	(NH ₄) ₄ Ce(SO ₄) ₄ , H ₂ SO ₄ , MeCN	42 ²⁴¹
4	33a	i) NaIO ₄ , H ₂ O, AcOEt, 2 min, rt; ii) 15 min, rt	98 ²⁵⁵
5	33a	i) PhI(OAc) ₂ , Me ₂ CO, 10 min, rt; ii) H ₂ O, rt	90 ²⁵⁶
6	33b	NaOCl, (CH ₂ OMe) ₂	93 ³²
7	33b	K ₂ Cr ₂ O ₇ , H ₂ SO ₄ , H ₂ O, 100 °C / K ₂ Cr ₂ O ₇ , H ₂ SO ₄	81 ^{257a} / 80 ^{257b}
8	33c	NaOCl, (CH ₂ OMe) ₂	90 ³²
9	33c	PhI(O ₂ CCF ₃) ₂ , MeCN, H ₂ O	57 ²³⁵

10	34a	2,6-dichloropyridine- <i>N</i> -oxide, [Ru ^{IV} (2,6-Cl ₂ tp) ₂ Cl ₂], CH ₂ Cl ₂ , 12 h, 40°C,	99 ²⁵⁸
11	34a	O ₂ , V ₂ O ₅ , NH ₄ VO ₃ , SnSO ₄ , K ₂ SO ₄ , CAS No. 7790-62-7, 3000 min	94 ²⁵⁹
12	34a	i) NH ₄ VO ₃ , SiO ₂ , H ₂ O, 2 h, 450°C; ii) H ₂ SO ₄ , K ₂ SO ₄ , CAS No. 7790-62-7, SnSO ₄ , KH ₂ PO ₄ , Na ₂ B ₄ O ₇ , H ₂ O, 2 h, 450°C	92 ²⁶⁰
13	34a	CH ₃ S(=O) ₂ OH.1/4Ce(IV), heptanes, H ₂ O	96 ²⁶¹
14	34a	CH ₃ S(=O) ₂ OH.1/4Ce(IV), MeSO ₃ H, H ₂ O, ClCH ₂ CH ₂ Cl, MeCN	91 ²⁶²
15	34a	i) H ₂ SO ₄ , Ce ₂ (SO ₄) ₃ , H ₂ O, rt → 65°C; ii) 1.2 h, 65°C	82 ²⁶³
16	34a	Ce(ClO ₄) ₄ , HClO ₄ , H ₂ O, MeCN, CCl ₄	80 ²⁶⁴
17	34a	H ₂ SO ₄ , Ce(SO ₄) ₂ ,	84 ²⁶⁵
18	34a	CH ₃ S(=O) ₂ OH.1/4Ce(IV), ClCH ₂ CH ₂ Cl, H ₂ O	89 ²⁶⁶
19	34b	H ₂ O ₂ , CAS No. 198902-93-1, Bu ₃ N ⁺ CH ₂ Ph • Cl ⁻ , H ₂ O, 1 h, 40°C	50 ²⁶⁷
20	35a	Oxone, Bu ₄ N ⁺ •Br ⁻ , H ₂ O, MeCN, 60 min, rt	100 ⁷⁸
21	35a	<i>t</i> -BuOOH, Ce(NH ₄) ₂ (NO ₃) ₆	93 ¹¹⁶
22	35a	Ce(NH ₄) ₂ (NO ₃) ₆ , H ₂ O, CH ₂ Cl ₂ , 20 min, rt	90 ⁷⁴
23	35a	Oxone, 4-I-Ph-OCH ₂ COOH, H ₂ O, MeCN, 10 min, rt	86 ¹⁸⁹
24	35a	Ce(NH ₄) ₂ (NO ₃) ₆ , H ₂ O, MeCN	71 ²⁴⁹
25	35a	(NH ₄) ₂ S ₂ O ₈ , AgNO ₃ , H ₂ O, MeCN	69 ²⁴⁹
26	35a	Bu ₄ N ⁺ BF ₄ ⁻ , MeCN, rt	52 ²⁶⁸
27	35b	AgO, HNO ₃ , Me ₂ CO	100 ²⁴⁹
28	35b	i) Bromosuccinimide, H ₂ SO ₄ , H ₂ O, THF; ii) NaHCO ₃ ; iii) AcOEt	98 ²⁶⁹
29	35b	PhI(O ₂ CCF ₃) ₂ , H ₂ O, MeOH	95 ¹⁹⁰
30	35b	Ce(NH ₄) ₂ (NO ₃) ₆ , H ₂ O, MeCN	93 ¹⁹⁰
31	35b	Ag ₂ O, HNO ₃ , dioxane	87 ¹⁹⁰
32	35b	CoF ₃ , dioxane, H ₂ O	87 ²⁷⁰
33	35b	MnO ₂ , HNO ₃ , CH ₂ Cl ₂ / MnO ₂ , HNO ₃ , benzene	95 ²⁷¹ / 98 ²⁷¹
34	35b	Oxone, 4-I-Ph-OCH ₂ COOH, H ₂ O, MeCN, 10 min, rt	86 ¹⁸⁹

35	35b	SiO ₂ , HCl, PhI=O	52 ²⁷²
36	35b	Oxone, 4-I-Ph-OCH ₂ COOH, F ₃ CCH ₂ OH, H ₂ O, 1 h, rt	34 ¹⁹¹
37	35c	PhI(OAc) ₂ , Et ₃ N, SiO ₂ , MeOH, 5 h, rt	82 ²⁷³
38	36	<i>o</i> -O ₂ NC ₆ H ₄ SO ₂ Cl, KO ₂ , MeCN	85 ²⁷⁴
39	36	<i>t</i> -BuOOH, CrO ₃ , CH ₂ Cl ₂	48 ²⁷⁵
40	37	<i>t</i> -BuOOH, 2-quinoxalinol salen (Cas No.327-92-4), Me(CH ₂) ₈ Me, MeCN, 18 h, reflux	66 ²⁷⁶
41	38	MeCH=CHCHO, O ₂ , AcOOH, vanadium(IV) catalyst (cas No. 156645-89-5), EtC(=O)Et/ MeCH=CHCHO, O ₂ , AcOOH, vanadium(IV) catalyst (cas No. 156645-89-5), <i>i</i> -BuC(=O)Me	78 ²⁷⁷ / 86 ²⁷⁷
42	39	Mo(CO) ₆ , PhMe, 7.5 h, reflux	95 ²⁷⁸
43	40	i) O ₃ , CH ₂ Cl ₂ ; ii) PPh ₃ , CH ₂ Cl ₂	95 ²⁷⁹
44	41a	AgO	70 ²⁸⁰
45	41b	Pb(OAc) ₄ , AcOH	30 ²⁸¹



Scheme 5: Synthesis of 1,4-naphthoquinone (**29**) cont.

(4*aR*,8*aR*)-8*a*-formyl-5,8-dioxo-1,4,4*a*,5,8,8*a*-hexahydro naphthalen-1-yl acetate (**42**) was converted in 1,4-naphthoquinone (**29**) using oxidizing agents manganese dioxide.²⁸²

1,4-Naphthoquinone (**29**) was also synthesized from **43** through a retro Diels-Alder using phenylmaleimide.²⁸³

1,4-Naphthoquinone (**29**) was also synthesized from naphthalen-2-yl propionate (**44**) with a ruthenium catalysts using

hydrogenperoxide as terminal oxidant.²⁶⁷

1,4-Naphthoquinone (**29**) was also synthesized from 2'-chloro-3',4'-dihydro-2'*H*-spiro[[1,3]dioxolane-2,1'-naphthalene] (**45**) with a sodium iodobenzenesulfonate with oxone as a terminal oxidant under phase-transfer conditions.²⁸⁴

1,4-Naphthoquinone (**29**) was also synthesized from (1,4-dioxo-3-(pyridinium-1-yl)-1,4-dihydronaphthalen-2-yl)(tosyl)amide (**46**) with a thiazyl chlorides, alkyl carbamates and thionyl chloride.²⁴⁶

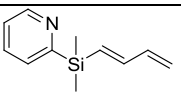
1,4-Naphthoquinone (**29**) was also synthesized from **47** through samarium diiodide-promoted C-C fragmentation.²⁸⁵

1,4-Naphthoquinone (**29**) was also synthesized from 3,6-dioxocyclohexa-1,4-dienecarboxylic acid (**51**) through a Diels-Alder reaction with 1-(trimethylsiloxy)-1,3-butadiene.²⁸⁶

Diels-Alder reaction of 2-pyridyldimethylsilyl group with benzoquinone (**10**) was reported for the synthesis of 1,4-naphthoquinone (**29**).²⁸⁷

1,2-diethynylbenzene (**48**) was applied for the synthesis 1,4-naphthoquinone (**29**) though the nitroxideradical TEMPO.²⁸⁸

Table 9: Synthesis of 1,4-naphthoquinone (**29**) as shown in Scheme 5.

S.N	Reactants	Catalyst/ Reaction Condition	Yields (%)
1.	42	MnO ₂ , benzene	89 ²⁸²
2.	43	Phenylmaleimide, MeCN, 10 h, reflux	87 ²⁸³
3.	44	H ₂ O ₂ , ruthenium catalysts (cas no.198902-93-1), Bu ₃ N ⁺ CH ₂ Ph•Cl ⁻ , H ₂ O, 1 h, 40°C	16 ²⁶⁷
4.	45	Oxone, PhSO ₃ Na, Bu ₄ N ⁺ •HSO ₄ ⁻ , MeCN, 24 h, 60°C	56 ²⁸⁴
5	46	SOCl ₂ , EtOC(=O)NSO, C ₅ H ₅ N, C ₆ H ₆	68 ²⁴⁶
6	47	(Me ₂ N) ₃ P=O, SmI ₂ , THF	64 ²⁸⁵
7	48	Me ₄ -piperidoxyl, PhCl	65 ²⁸⁶
8	49	Me ₃ SiOCH=CH-CH=CH ₂ , CH ₂ Cl ₂	78 ²⁸⁷
9	10	 , HCl, H ₂ O	100 ²⁸⁸

Conclusion

Thus, this review have covered the various methodology applied for the synthesis of 1,2-benzoquinone, 1,4-benzoquinones, 1,2-naphthoquinone and 1,4-naphthoquinone. These methodologies will be useful in future for the preparation of various quinone analogs especially for medicinal chemistry and other fields.

Abbreviation

TBAD: tetrabutylammonium dichromate

Amb: amberlyst

IBTA: $\text{PhI}(\text{O}_2\text{CCF}_3)_2$ (diacetoxyiodo)benzene

BBCP: bis(2,2'-bipyridyl)copper(II) permanganate

BTMPDC: bis-(2,4,6-trimethylpyridinium)dichromate

Buckminsterfullerene (CAS No. 99685-96-8): Carbon (C_{60}) fullerene

CAN: cerium ammonium nitrate

EBMICC: ethylenebis(N-methylimidazolium)chlorochromate

CTA: cetyltrimethylammonium

VO(acac)₂: vanadyl acetylacetonate

$\text{C}_{24}\text{H}_{36}\text{Cu}_2\text{N}_8\text{O}_4 \cdot 2\text{BF}_4$ (CAS No. 646535-35-5): Copper(2+), [m-[(1,2,3,5,6,13a,14,15, 16,18,19,26a-dodecahydro9,13:22,26-dinitrilo-13*H*,26*H*diimidazo[1,2-d:1',2'-o][1,4,12,15]tetraazacyclodocosine-kN4,kN20:kN7,kN17)27,28-di(oxide-kO))]bis(methanol)di-, bis[tetrafluoroborate(1-)] (9CI).

$\text{C}_{46}\text{H}_{47}\text{ClN}_3\text{P}_2\text{Ru} \cdot \text{BF}_4$ (CAS No. 673447-87-5): Ruthenium(1+), (acetonitrile)[N,N'-bis[[2-(diphenylphosphino-kP)phenyl]methyl]-1,2-cyclohexanediamine-kN,kN']chloro-,tetrafluoro borate(1-) (9CI).

$\text{C}_{24}\text{H}_{20}\text{P} \cdot \text{C}_9\text{H}_6\text{MoNO}_6$ (CAS No.851956-06-4): Phosphonium, tetraphenyl-, (PB-7-34-111'12)-oxodiperoxy (8-quinolinolato-kN1,kO8)molybdate(1-) (9CI).

$\text{C}_{24}\text{H}_{20}\text{P} \cdot \text{C}_9\text{H}_6\text{NO}_6\text{W}$ (CAS No. 851956-08-6): Phosphonium, tetraphenyl-, (PB-7-34-111'12)-oxodiperoxy (8-quinolinolato-kN1,kO8)tungstate(1-) (9CI).

$\text{C}_{24}\text{H}_{36}\text{Cu}_2\text{N}_8\text{O}_4 \cdot 2\text{ClO}_4$ (CAS No. 884843-23-6): Copper(2+),[m-[(1,2,3,5,6,13a,14,15,16,18,19,26a-dodecahydro-9,13:22,26-dinitrilo-13*H*,26*H*-diimidazo[1,2-d:1',2'-o][1,4,12,15]tetraazacyclodocosine-kN4,kN20:kN7,kN17) 27,28-di(oxide-kO))]bis(methanol)di-,diperchlorate (9CI).

$\text{C}_{30}\text{H}_{24}\text{N}_2\text{O}_7\text{W}$ (CAS No. 1153933-00-6): Tungsten, bis[N-(hydroxy-kO)-N,3-diphenyl-2-propenamido-kO]oxoperoxy-, (PB-7-34-1123'2')-Coordination Compound.

$\text{C}_{11}\text{H}_{15}\text{N}_2\text{O}_2$ (CAS No. 1265626-68-3): 3-Oxazolidinyloxy, 2,4,4-trimethyl-2-(2-pyridinyl)-

$\text{C}_{24}\text{H}_{40}\text{N}_4\text{O}_4\text{Rh}_2$ (Cas No. 138984-26-6): Rhodium, tetrakis[m-(hexahydro-2*H*-azepin-2-onato-kN¹:kO²)]di-, (Rh-Rh)-Coordination Compound.

$\text{C}_{24}\text{H}_{20}\text{P} \cdot \text{C}_8\text{H}_8\text{MoNO}_7$ (Cas No. 1143514-60-6): Phosphonium, tetraphenyl-, (PB-7-34-111'12)-[1-[2-(hydroxylkO)phenyl]ethanoneoximato-kN]oxodiperoxymolybdate(1-) (1:1)- Coordination Compound.

$\text{C}_{18}\text{H}_{12}\text{N}_2\text{O}_5\text{W}$ (Cas No. 109076-03-1): Tungsten,oxoperoxybis(8-quinolinolato-kN¹, kO⁸)-(PB-7-34-1124'2')-(9CI)-Coordination Compound.

$\text{C}_{28}\text{H}_{24}\text{N}_2\text{O}_7\text{W}$ (Cas No.1153932-95-6): Tungsten,bis[N-(hydroxy-kO)-N-(3-methylphenyl)benzamidato-kO]oxoperoxy-, (PB-7-34-1123'2')-Coordination Compound.

$\text{C}_{24}\text{H}_{20}\text{P} \cdot \text{C}_9\text{H}_6\text{NO}_6\text{W}$ (Cas No. 851956-08-6): Phosphonium, tetraphenyl-, (PB-7-34-111'12)-oxodiperoxy(8-quinolinolato-kN¹, kO⁸)tungstate(1-) (9CI.)

$\text{C}_{36}\text{H}_{24}\text{BBR}_2\text{F}_2\text{I}_4\text{N}_3\text{O}_4$ (Cas No. 1256918-97-4): Boron, [5-(4-bromophenyl)-N-[5-(4-bromophenyl)-4-iodo-3-(2-iodo-3,5-dimethoxyphenyl)-2*H*-pyrrol-2-ylidene-kN]-4-iodo-3-(2-iodo-3,5-dimethoxyphenyl)-1*H*-pyrrol-2-aminato-kN¹]difluoro-, (T-4)-coordination Compound

$\text{C}_{44}\text{H}_8\text{ClF}_{20}\text{FeN}_4$ (Cas No. 36965-71-6): Chloro(meso-tetrakis (pentafluorophenyl)porphinato)iron.

$\text{C}_{48}\text{H}_{36}\text{ClFeN}_4\text{O}_4$ (CAS No. 36995-20-7): Iron, chloro[5,10,15, 20-tetrakis(4-methoxyphenyl)-21*H*,23*H*-porphinato(2-)-kN21, kN22, kN23, kN24]-, (SP-5-12)-Coordination Compound

C₅₆H₅₂ClFeN₄ (CAS No. 77439-21-5): 5,10,15,20-Tetra(2,4,6-trimethylphenyl)porphyrinatoiron(III) chloride

C₁₂₆H₁₁₂O₃₂S₆ (CAS No. 1353640-24-0): Pentaceno[1,14-cd:7,8-c'd']bis[1,2]dithiole-3,4,10,11-tetracarboxylic acid, 7,14-dihydro-7,14-dithioxo-, 3,4,10,11-tetrakis[[3,5-bis[(3,5-dimethoxyphenyl)methoxy]phenyl]methyl]ester

H.8Na.O₃₄PW₉ (CAS No. 110697-84-2): Tungstate(9-), pentadeca-μ-oxopentadecaooxo[μ₉-[phosphato(3-) kO: kO: kO : kO': kO': kO": kO": kO"" : kO""]]nona-,sodium hydrogen (1:8:1) Coordination Compound

SIBX: stabilized 2-Iodoxybenzoic Acid

Acknowledgements

This review is acknowledged to Dr Gajanan Pandey, Coordinator/Head, Department of Applied Chemistry, Babasaheb Bhimrao Ambedkar, University, Lucknow, India.

References

1. H. G. Floss, T. W. Yu, Chem. Rev., 2005, 105, 621.
2. H. Nagoka, Y. Kishi, Tetrahedron, 1981, 37, 3873.
- 3.(a) K. L. Rinehart, W. M. J. Knoll, K. Kakinuma, F. J. Antosz, I. C. Paul, A. H. Wang, F. Reusser, L. H. Li, W. C. Krueger, J. Am. Chem. Soc., 1975, 97, 196; (b) A. H. J. Wang, I. C. Paul, J. Am. Chem. Soc., 1976, 98, 4612; (c) T. W. Doyle, D. M. Balitz, R. E. Grulich, D. E. Nettleton, S. J. Gould, C. H. Tann, A. E. Mews, Tetrahedron Lett., 1981, 22, 4595; (d) J. Monneret, M. Eble, J. Med. Chem., 2001, 36, 483; (e) J. Koeller, M. Eble, Clin. Pharmacol., 1988, 7, 574; (f) L. Salmon-Chemin, E. Buisine, V. Yardley, S. Kohler, M. A. Debreu, R. L. K. Siegel, E. Davioud-Charvet, J. Med. Chem., 2001, 44, 548; (g) S. A. Shaikh, F. Johnson, A. P. Grollman, J. Med. Chem., 1986, 29, 1329; (h) T. Tran, E. Saheba, A.V. Arcerio, V. Chavez, Q.Y. Li, L. E. Martinez, T. P. Primm, Bioorg. Med. Chem., 2004, 12, 3929.
4. E. M. Dnett, C. Wongwiechintana, W. J. Dunn, P. Marrs, J. Med. Chem., 1983, 26, 570.
5. S. Giorgi-Renault, J. Renault, P. Gebel-Servalles, M. Baron, C. Paolett, S. Cros, M. C. Bissery, F. Lavelle, G. Atassi, J. Med. Chem., 1991, 34, 38.
6. V. K. Tandon, H. K. Maurya, D. B. Yadav, A. Tripathi, M. Kumar, P. K. Shukla, Bioorg. Med. Chem. Lett., 2006, 16, 5883.
7. V. K. Tandon, D. B. Yadav, H. K. Maurya, A. K. Chaturvedi, P. K. Shukla, Bioorg. Med. Chem. Lett., 2006, 14, 6120.
8. E. Pérez-Sacau, A. Estévez-Braun, A. G. Ravelo, E. A. Ferro, H. Tokuda, T. Mukainaka, H. Nishino, Bioorg. Med. Chem., 2003, 11, 483.
9. T. S. Lin, L. Y. Zhu, S. P. Xu, A. A. Divo, A. C. Sartorelli, J. Med. Chem., 1991, 34, 1634.
10. L. Salmon-Chemin, E. Buisine, V. Yardley, S. Kohler, M. A. Debreu, V. Landry, C. Sergheraert, S. L. Craft, R. L. Krauth-Siegel, E. David-Charvet, J. Med. Chem., 2001, 44, 548.
11. P. S. Vankar, R. Shanker, D. Mahanta, S. C. Tiwari, Dyes and Pigments 2008, 76, 207–212.
12. R. A. Morton, Ed. Biochemistry of Quinones; Academic Press, New York, 1965.
13. (a) R. H. Thomson, Chem. Quinonoid Compd. 1974, 1, 111-61; (b) Y. Naruta, K. Maruyama, Chem. Quinonoid Compd. 1988, 2, 241-402; (c) S. Akai, Y. Kita, Org. Prep. Proced. Intern. 1998, 30, 603-629; (d) E. A. Theodorakis, T. Ling, E. J. Rueden, E. Poupon, S. H. Kim, Strat. Tact. Org. Syn. 2004, 5, 111-131; (e) P. T. Gallagher, Contemp. Org. Synth. 1996, 3, 433-446.

14. M. B. Carriere, Synthesis and reactions of quinones, National library of Canada, 1998.
15. Willstaetter, Richard, Pfannenstiel, Adolf Berichte der Deutschen Chemischen Gesellschaft, 1904, 37, 4744-4746.
16. A. R. Pourali, A. Goli, J. Chem. Sci. (Bangalore, India), 2011, 123, 63-67.
17. B. Tamami, H. Yeganeh, React. Funct. Polym. 2002, 50, 101-106.
18. E. L. Cavalieri, E. Rogan, PCT Int. Appl., 2003077900, 2003.
19. B. Tamami, H. Yeganeh, Eur. Poly. J., 1999, 35, 1445-1450.
20. M. Hirano, S. Yakabe, H. Chikamori, J. H. Clark, T. Morimoto, J. Chem. Res. (s), 1998, 12, 770-771.
21. H. Firouzabadi, D. Mohajer, M. Entezari-Moghadam, Bull. Chem. Soc. Jap., 1988, 61, 2185-9.
22. H. Firouzabadi, N. Iranpoor, H. Parham, J. Tootan, Syn. Comm. 1984, 14, 631-7.
23. S. V. Khansole, S. Patwari, Y. B. Vibhute, J. Ind. Chem. Soc. 2009, 86, 1343-1346.
24. S. Muralidharan, H. Freiser, J. Mol. Cat. 1989, 50, 181-93.
25. M. M. Hashemi, Z. Karimi-Jaberi, B. Eftekhari-Sis, J. Chem. Res. 2005, 160-161.
26. M. M. Hashemi, B. Eftekhari-Sis, B. Khalili, Z. Karimi-Jaberi, J. Braz. Chem. Soc. 2005, 16, 1082-1084.
27. R. Schobert, Synthesis 1987, 741-742.
28. B. K. Mishra, M. Kuanar, A. Sharma, B. B. Nayak, Indian J. Chem. B, 2001, 40B, 724-726.
29. G. P. Romanelli, P. I. Villabrille, P. G. Vazquez, C. V. Caceres, P. Tundo, Lett. Org. Chem., 2008, 5, 332-335.
30. M. G. Egusquiza, G. P. Romanelli, C. I. Cabello, I. L. Botto, H. J. Thomas, Cat, Comm., 2007, 9, 45-50.
31. J. L. E. Erickson, J. M. Dechary, J. Am. Chem. Soc., 1952, 74, 2644-2646.
32. M. M. Hashemi, Y. A. Beni, J. Chem. Res. (s), 1999, 672-673.
33. R. Cassis, J. A. Valderrama, Synth. Commun., 1983, 13, 347-356.
34. A. Seyewetz, G. Miodon, Bulletin de la Societe Chimique de France 1923, 33, 449-58.
35. W. K. Seok, T. J. Meyer, J. Am. Chem. Soc., 1988, 110, 7358-7367.
36. C. Zhang, Faming Zhuanli Shenqing, 102351656, 2012.
37. A. H. Cook, Eur. Brew. Conv., Proc. Congr., 1961, 40-55.
38. C. Kashima, A. Tomotake, Y. Omote, Heterocycles, 1987, 26, 363-366.
39. D. Chatterjee, A. Mitra, S. Mukherjee, J. Mol. Cat. A: Chem., 2001, 165, 295-298.
40. V. Cerri, et al Gazzetta Chimica Italiana, 1985, 115, 147-148.
41. S. P. Srivastava, J. Ind. Chem. Soc. 1990, 67, 347-348.
42. E. B. Vliet, Org. Synth. 1922, 2, No PP. given.
43. T. X. T. Luu, P. Christensen, F. Duus, T. N. Le, Synth. Comm. 2008, 38, 2011-2014.
44. A. Lalitha, K. Sivakumar, Synth. Commun. 2008, 38, 1745-1752.
45. H. Mehdi, A. Bodor, D. Lantos, I. T. Horvath, D. E. De Vos, K. Binnemans, J. Org. Chem., 2007, 72, 517-524.
46. C. Maeda, H. Shinokubo, A. Osuka, Org. Biomol. Chem. 2006, 4, 200-202.
47. S. Kim, D. Kim, J. Park, Adv. Synth. Catal., 2009, 351, 2573-2578.
48. A. Shokrolahi, A. Zali, M. H. Keshavarz, Chin. Chem. Lett., 2008, 19, 1274-1276.
49. (a) M. M. Lakouraj, M. Tajbakhsh, F. Ramzani-Lehmali, Phosphorus, Sulfur Silicon Relat. Elem. 2008, 183, 1388-1395; (b) M. Tajbakhsh, H. Alinezhad, A. G. Urimi, Phosphorus, Sulfur Silicon Relat. Elem. 2008, 183, 1447-1454.
50. E. Couladouros, A. Strongilos, PCT Int. Appl., 2005121077, 2005.
51. V. Tesevic, J. A. Gladysz, Green Chem., 2005, 7, 833-836.

52. M. Tajbakhsh, M. M. Lakouraj, F. Ramzani-Lehmali, *Synlett* 2006, 1724-1728.
53. M. Tajbakhsh, M.-M. Lakouraj, K. Yadoolahzadeh, *Phosphorus, Sulfur Silicon Relat. Elem.* 2005, 180, 2431-2537.
54. (a) T. K. Lai, J. Banerji, A. Chatterjee, *Indian J. Chem., Sect B* 2005, 44B, 1309; (b) R. S. Varma, R. K. Saini, R. Dahiya, *Tetrahedron Lett.*, 1997, 38, 7823-7824; (c) J. M. Bruce, S. Fitzjohn, R. T. Pardasani, *J. Chem. Res. (s)*, 1981, 252-253.
55. O. Makoto, M. Endo, K. Nishiyama, A. Ouchi, W. Ando, *Chem. Commun.*, 2004, 14, 1672-1673.
56. M. M. Hashemi, M. Akhbari, *Russ. J. Org. Chem.*, 2005, 41, 935-936.
57. M. Barth, S. T. A.; Shah, J. Rademann, *Tetrahedron*, 2004, 60, 8703-8709.
58. F. Derikvand, F. Bigi, R. Maggi, C. G. Piscopo, G. Sartori, *J. Catal.* 2010, 271, 99-103.
59. C.W. Lee, S. H. Jin, K. S. Yoon, H. M. Jeong, K. W. Chi *Tetrahedron Lett.*, 2009, 50, 559-561.
60. S. Domagała, J. Dziegiec, M. Cichomski, *Pol. J. Chem.*, 2007, 81, 1049-1061.
61. A. Zali, A. Shokrolahi, *Synth. Commun.*, 2008, 38, 1064-1069.
62. Y. Shang, T. Y. S. But, H. Togo, P. H. Toy, *Synlett*, 2007, 67-70.
63. B. B. F. Mirjalili, M. Ali Zolfigol, A. Bamoniri, *Phosphorus, Sulfur Silicon Relat. Elem.* 2003, 178, 1845-1849.
64. B. B. F. Mirjalili, M. A. Zolfigol, A. Bamoniri, A. Zarei, *Bull. Korean Chem. Soc.* 2003, 24, 400-402.
65. V. Singh, V. Sapehiya, G. L. Kad, *Synthesis*, 2003, 198-200.
66. D. Villemin, M. Hammadi, M. Hachemi, *Synth. Commun.* 2002, 32, 1501-1515.
67. E. Giorgini, G. Tommasi, P. Stipa, G. Tosi, *Free Radical Res.* 2001, 35, 63-67.
68. S. Ficht, M. Mülbaier, A. Giannis, *Tetrahedron*, 2001, 57, 4863-4866.
69. S.V. Ley, A. W. Thomas, H. Finch *J. Chem. Soc., Perkin Trans. 1* 1999, 669-672.
70. A.G. Urimi, H. Alinezhad, M. Tajbakhsh, *Acta Chim. Slov.* 2008, 55, 451-485.
71. R. Hosseinzadeh, M. Tajbakhsh, H. Khaledi, *J. Chin. Chem. Soc.*, 2008, 55, 239-243.
72. Y. B. Kiran, T. Konakahara, N. Sakai, *Synthesis* 2008, 15, 2327-2332.
73. D. Maiti, J. S. Woertink, A. A. Narducci Sarjeant, E. I. Soloman, K. D. Karlin, *Inorg. Chem.* 2008, 47, 3787-3800.
74. M. Hashmat Ali, M. Niedbalski, G. Bohnert, D. Bryant, *Synth. Commun.*, 2006, 36, 1751-1759.
75. J. L. Grenier, J. P. Catteau, P. Cotelte, *Synth. Comm.*, 1999, 29, 1201-1208.
76. M. Tajbakhsh, R. Hosseinzadeh, M. Sadatshahabi, *Synth. Commun.* 2005, 35, 1547-1554.
77. B. B. F. Mirjalili, M. A. Zolfigol, A. Bamoniri, Z. Zaghaghi, A. Hazar, *Acta Chim. Slov.* 2003, 50, 563-568.
78. T. Yakura, A. Ozono, K. Morimoto, *Chem. Pharm. Bull.* 2011, 59, 132-134.
79. C. Yong-Qiang, J. Hong, *Org. Chem. Int.* 2011, Article ID 753142, 4 pages (doi:10.1155/2011/753142).
80. B. Tamami, A. N. Shirazi, F. Ebrahimzadeh, *Iranian Polym. J.*, 2009, 18, 957-967.
81. Z. Mohammad, A. Karimi, T. Mohammad, *J. Appl. Polym. Sci.*, 2011, 119, 3462-3466.
82. B. B. F. Mirjalili, M. A. Zolfigol, A. Bamoniri, A. Zarei, *J. Chin. Chem. Soc.*, 2004, 51, 509-512.
83. T. Sakamoto, Y. Yonehara, S. Boku, *Jpn. Kokai Tokkyo Koho* 08176059, 1996.
84. Y. Furuyama, Y. Ichikawa, M. Ito, H. Kano, M. Takaoka, T. Yoshizawa, *PCT Int. Appl.*, 9622269, 1996.
85. C. Costantini, M. d'Ischia, G. Prota, *Synthesis*, 1994, 1399-1400.
86. A. Zsigmond, F. Notheisz, M. Bartók, *Stud. Surf. Sci. Catal.*, 1993, 78, 417-424.
87. B. Tamami, M. Hatam, D. Mohadje, *Polymer* 1991, 32, 2666-2670.
88. S. Kajigaeshi, Y. Morikawa, S. Fujisaki, T. Kakinami, K. Nishihira, *Bull. Chem. Soc. Jpn.* 1991, 64, 336-338.
89. H. Chen, J. Zhao, L. Xie, X. Wang, Q. Chen, *Huaxue Yu Shengwu Gongcheng*, 2008, 25, 24-25.

90. T. T. Tidwell, *Org. React.* 1990, 39, No pp. Given.
91. R. M. Moriarty, O. Prakash, *Org. React.* 2001, 57, No pp. Given.
92. M. M. Hashemi, B. Khalili, B. Eftekhari-Sis, *Org. Chem.: An Ind. J.* 2006, 2, 110-112.
93. S. T. Abu-Orabi, M. Salehb, L. Al-Momania, I. Jibril, Y. Yousef, *Jordan J. Chem.* 2006, 1, 109-120.
94. B. Tamami, H. Alinezhad, *Iranian J. Sci. Tech.*, 1997, 21, 375-380.
95. K. Ohashi, M. Umeno, *Jpn. Kokai Tokkyo Koho*, 03287557, 1991.
96. M. Daumas, Y. Vo-Quang, L. Vo-Quang, F. Le Goffic, *Synthesis* 1989, 64-65.
97. B. F. Mirjalili, et al *J. Chem. Res. (S)*, 2003, 273-274.
98. T. Kakuta, T. Shiraishi, *Jpn. Kokai Tokkyo Koho*, 2000001453, 2000.
99. N. Iranpoor, H. Firouzabadi, M. A. Zolfigol, *Bull. Chem. Soc. Jpn.* 1998, 71, 905-908.
100. S. Suresh, S. Skaria, S. Ponrathnam, *Synth. Commun.*, 1996, 26, 2113-2117.
101. G. C. Jones, G. L. Myers, W. D. Nottingham, D. E. Van Sickel, U.S. 5118823, 1992.
102. H. Firouzabadi, A. R. Sardarian, M. Naderi, B. Vessal, *Tetrahedron*, 1984, 40, 5001-5004.
103. H. Firouzabadi, N. Iranpoor, F. Kiaeezadeh, J Toofan, *Synth. Commun.*, 1984, 14, 973-981.
104. H. Miyamura, M. Shiramizu, R. Matsubara, S. Kobayashi, *Chem. Lett.* 2008, 37, 360-361.
105. (a) R. Rathore, E. Bosch, J. K. Kochi, *Tetrahedron Lett.*, 1994, 35, 1335-1338; (b) E. Bosch, R. Rathore, J. K. Kochi, *J. Org. Chem.* 1994, 59, 2529-2536.
106. F. Minisci, A. Citterio, E. Vismara, F. Fontana, S. D. Bernardinis, M. Correale, *J. Org. Chem.*, 1989, 54, 728-731.
107. R. Maggi, C. G. Piscopo, G. Sartori, L. Storaro, E. Moretti, *Appl. Catal., A* 2012, 411-412, 146-152.
108. T. Negoro, H. Yamada, T. Koizumi, *Wakayama Daigaku Kyoikugakubu Kiyō*, 2000, 50, 33-41.
109. H. Firouzabadi, I. Mohammadpoor-Baltork, *Bull. Chem. Soc. Jap.*, 1995, 68, 2319-25.
110. P. L. Anelli, S. Banfi, S. Montanari, S. Quici, *J. Org. Chem.* 1989, 54, 2970-2972.
111. A. Pelter, S. Elgandy, *Tetrahedron Lett.* 1988, 29, 677-680.
112. S. N. Zende, V. A. Kalantre, G. S. Gokavi *J. Solution Chem.*, 2010, 39, 1178-1186.
113. (a) Y. J. Kuo, M. Bellas, U.S. 5075462, 1991; (b) Y. J. Kuo, M. Bellas, U.S. 5075463, 1991
114. M. Kooti, M. Jorfi, *E-J. Chem.*, 2008, 5, 365-369.
115. H. M. Hashemi, Y. Ahamadibeni, *Iranian J. Chem. Chemical. Eng.* 2002, 21, 71-73.
116. K. Krohn, J. Vitz, *J. fuer Prakti. Chem.*, 2000, 342, 825-827.
117. H. A. Muathen, *Indian J. Chem., Sect B*, 1991, 30B, 522-524.
118. Y. Tamura, T. Yakura, H. Tohma, K. Ki-kuchi, Y. Kita, *Synthesis* 1989, 126-127.
119. V. P. Kashparova, E. S. Kagan, I. Y. Zhukova, *Russ. J. Appl. Chem.*, 2004, 77, 964-967.
120. M. Singh, M. Thomas, *Biotech. Lett.*, 1985, 7, 663-664.
121. H. Firouzabadi, B. Vessal, M. Naderi, *Tetrahedron Lett.*, 1982, 23, 1847-1850.
122. M. Albrecht, O. Schneider, A. Schmidt, *Org. Biomol. Chem.* 2009, 7, 1445-1453.
123. H. Miyamura, M. Shiramizu, R. Matsubara, *Angew. Chem. Int. Ed.* 2008, 47, 8093-8095.
124. P. K. Tandon, M. Srivastava, S. B. Singh, *Synth. Commun.* 2008, 38, 2125-2137.
125. F. P. Cossio, M. Lopez, C. Palomo, *Tetrahedron* 1987, 43, 3963-3974.
126. A. Sahu, M. K. Rawal, V. K. Sharma, *Rasayan J. Chem.* 2009, 2, 536-538.
127. L. Shiri, A. Ghorbani-Choghamarani, *Phosphorus, Sulfur Silicon Relat. Elem.*, 2009, 184, 492-498.

128. H. W., Jr. Underwood, W. Walsh, *Org. Synth.*, 1936, 16, No pp. given.
129. D. R. Hwang, C. Y. Chu, S. K. Wang, B. J. Uang, *Synlett*, 1999, 77-78.
130. N. Goudarzian, B. Tamami, *J. Sci. I. R. Iran.* 1990, 1, 372-376.
131. N. Kamigata, M. Takata, H. Matsuyama, M. Kobayashi, *Sulfur Lett.*, 1986, 5, 1-7.
132. A. Jakubiak, I. A. Owsik, B. N. Kolarz, *React. Funct. Polym.*, 2005, 65, 161-167.
133. C. Venkatachalapathy, M. Rajarajan, H. Shayira Banu, K. Pitchumani, *Tetrahedron*, 1999, 55, 4071-4076.
134. V. A. Samsonov, I. Y. Bagryanskaya, Y. V. Gatilov, V. A. Savel'ev, *Russ. Chem. Bull.* 2011, 60, 1723-1728.
135. C. J. Gartshore, D. W. Lupton, *Adv. Synth. Catal.*, 2010, 352, 3321-3328.
136. G. M. Nazeruddin, S. B. Suryawanshi, N. Shaikh Iqbal, *Res. J. Chem. Env.*, 2010, 14, 57-59.
137. A. McKillop, J. A. Tarbin, *Tetrahedron*, 1987, 43, 1753-1758.
138. L. Delaude, P. Laszlo, P. Lehance, *Tetrahedron Lett.*, 1995, 36, 8505-8508.
139. S. Fujibayashi, K. Nakayama, Y. Nishiyama, Y. Ishii, *Chem. Lett.*, 1994, 1345-1348.
140. C. Venkatachalapathy, K. Pitchumani, *React. Kinet. Catal. Lett.* 1999, 66, 245-249.
141. Brewster, A. George, null, 1977, No pp.
142. Z. Hong, P. Zhi-Quan, L. Qin-Hui, M. Guang-Quan, L. De-Liang, C. Jiu-Tong, *Chin. J. Chem.*, 2005, 23, 835-842.
143. M. Inoue, T. Uragaki, S. Enomoto, *Chem. Lett.*, 1986, 2075-2078.
144. K. Sakata, T. Kikutake, Y. Shigaki, M. Hashimoto, H. I. Ogawa, Y. Kato, *Inorg. Chim. Acta.* 1988, 144, 1-3.
145. M. Lemaire, A. Guy, J. Roussel, J. Guette, *Tetrahedron*, 1987, 43, 835-844.
146. T. Fukumoto, T. Matsuki, N. X. Hu, Y. Aso, T. Otsubo, F. Ogura, *Chem. Lett.*, 1990, 2269-2272.
147. K. R. Bharucha, *J. Chem. Soc.* 1956, 2446-2447.
148. N. C. Gharah, S. hakraborty, A. K. Mukherjee, R. Bhattacharyya, *Inorg. Chim. Act.* 2009, 362, 1089-1100.
149. S. K. Maiti, K. M. Abdul Malik, R. Bhattacharyya, *Inorg. Chem. Commun.* 2004, 7, 823.
150. X. Lu, N. Mizuno, M. Misono, *Nippon Kagaku Kaishi*, 1998, 271-274.
151. G. K. Dewkar et al, *Indian Pat. Appl.*, 2003DE01180, 2005.
152. S. K. Maiti, S. Dinda, S. Banerjee, A. Mukherjee, K. R. Bhattacharyya, *Eur. J. Inorg. Chem.*, 2008, 2038-2051
153. S. K. Maiti, S. Banerjee, A. K. Mukherjee, K. M. Abdul Malik, R. Bhattacharyya, *New J. Chem.* 2005, 29, 554-563.
154. A. G. Rybin, E. A. Varvarina, E. N. Zil'berman, *Zhurnal Organicheskoi Khimii*, 1990, 26, 2460.
155. G. K. Dewkar, T. M. Shaikh, S. Pardhy, S. S. Kulkarni, A. Sudalai, *Ind. J. Chem. B*, 2005, 44B, 1530-1532.
156. W.-K. Wong, X.-P. Chen, T.-W. Chik, W.-Y. Wong, J.-P. Guo, F.-W. Lee, *Eur. J. Inorg. Chem.* 2003, 3539-3546.
157. K. C. Nam, J. M. Kim, *Bull. Korean Chem. Soc.*, 1994, 15, 268-270.
158. N. Inoue, T. Ishioka, A. Harata, *Chem. Lett.* 2009, 38, 358-359.
159. M. M. Hashemi, Y. Ahmadibeni, *Monatsh. Chem.* 2003, 134, 411-418.
160. M. P. Uliana, Y. W. Vieira, M. C. Donatoni, A. G. Correa, U. Brocksom, T. J. Brocksom, *J. Brazilian Chem. Soc.* 2008, 19, 1484-1489.
161. T. Yakura, Y. Tian, Y. Yamauchi, Y. Omoto, T. Konishi, *Chem. Pharm. Bull.*, 2009, 57, 252-256.
162. A. Ramani, S. Suresh, M. Sasidharan, A. Sudalai, B. M. Chanda, *J. Chem. Res. (S)*, 1996, 474-475.
163. W. Adam, W. A. Herrmann, J. Lin, C. R. Saha-Moeller, *J. Org. Chem.* 1994, 59, 8281-3.
164. P. P. Moghe, R. M. Deshpande, P. S. Ozarde, B. B. Parkhi, S. S. Boswas, M. G. Kotasthane, P. K. Bahirat, A. V. Pol, *Indian* 2000, IN 184488 A1 20000826.

165. I. M. Ganiev, E. S. Ganieva, N. N. Kabal'nova, *Rus. Chem. Bull.* 2004, 53, 2281-2284.
166. I. M. Ganiev, E. S. Suvorkina, N. N. Kabal nova, *Rus. Chem. Bull.* 2003, 52, 1123-1128.
167. W. K. Seok, J. C. Dobson, T. Meyer, *J. Inorg. Chem.* 1988, 27, 3-5.
168. H. Tajik, A. Dadras, A. Hosseini, *Synth. React. Inorg. Met. Org. Chem.* 2011, 41, 258-261.
169. G. B. Shul'pin, Y. N. Kozlov, L. S. Shul'pina, A. J. L. Pombeiro, *Tetrahedron*, 2012, 68, 8589-8599.
170. H. M. Neu, V. V. Zhdankin, V. N. Nemykin, *Tetrahedron. Lett.* 2010, 51, 6545-6548.
171. M. V. Simonova, E. G. Zhizhina, V. V. Russkikh, K. I. Matveev, *Russ. Chem. Bull.* 2005, 54, 1532-1534.
172. S. Tan, T. Luo, B. Zhu, *Yingyong Huagong*, 2009, 38, 1542-1544.
173. K. Y. Abid, A. R. Tahir, *Qatar Univ. Sci. J.*, 2004, 24, 101-106.
174. I. Manet, S. Monti, P. Bortolus, *Chem. Euro. J.*, 2005, 11, 4274-4282.
175. E. Leyva, I. Crispin, E. Moctezuma, S. Leyva, *Arkivoc* 2003, 203-212.
176. F. A. Khan, S. Choudhury, *Tetrahedron Lett.* 2010, 51, 2541-2544.
177. T. Fukuhara, N. Yoneda, K. Takamura, A. Suzuki, *J. Fluorine Chem.* 1991, 51, 299-304.
178. R. E. Harman, J. Cason, *J. Org. Chem.* 1952, 17, 1058-1062.
179. M. O. Ratnikov, L. E. Farkas, M. P. Doyle, *J. Org. Chem.*, 2012, 77, 10294-10303.
180. M. Lang, A. Muehlbauer, C. Graef, J. Beyer, S. Lang-Fugmann, K. Polborn, W. Steglich, *Eur. J. Org. Chem.* 2008, 816-825.
181. M. Saito, K. Miyamoto, M. Ochiai, *Chem. Comm.* 2011, 47, 3410-3412.
182. A. A. Zagulyaeva, C. T. Banek, M. S. Yusubov, V. V. Zhdankin, *Org. Lett.*, 2010, 12, 4644-4647.
183. A. Jarrahpour, M. Zarei, *Molecules*, 2007, 12, 2364-2379.
184. S. Patel, M. Kuanar, B. B. Nayak, H. Banichul, B. K. Mishra, *Synth. Comm.* 2005, 35, 1033-1037.
185. P. Sukhai, R. A. McClelland, *J. Chem. Soc., Perkin Trans. 2*, 1996, 1529-1530.
186. K. N. Singh, J. Pandey, M. Singh, *Ind. J. Chem. B*, 2006, 45B, 2552-2555.
187. Z.-N. Sun, F.-Q. Liu, Y. Chen, P. K. H. Tam, D. Yang, *Org. Lett.*, 2008, 10, 2171-2174.
188. T. Yakura, T. Konishi, *Synlett*, 2007, 765-768.
189. H. Tohma, H. Morioka, Y. Harayama, M. Hashizume, *Tetrahedron*, 2001, 42, 6899-6902.
190. T. Yakura, M. Omoto, Y. Yamauchi, Y. Tian, A. Ozono, *Tetrahedron*, 2010, 66, 5833-5840.
191. T. Yakura, Y. Yamauchi, Y. Tian, M. Omoto, *Chem. Pharm. Bull.*, 2008, 56, 1632-1634.
192. M. M. Lakouraj, M. Tajbakhsh, F. Ramzani-Lehmali, K. Godrati, *Monatsh. Chem.*, 2008, 139, 537-541.
193. T. S. Jin, Y. W. Li, G. Sun, X. R. Song, *J. Chem. Res. (S)*, 2003, 322-323.
194. M. K. Chaudhuri, S. K. Chettri, S. Lyndem, P. C. Paul, *Bull. Chem. Soc. Jpn.*, 1994, 67, 1894-1898.
195. H. Firouzabadi, A. Sharifi, B. Karimi, *Iranian J. Chem. Chemical Eng.*, 1993, 12, 32-38.
196. H. Firouzabadi, I. Mohammadpoor-Baltork, *Synth. Commun.*, 1994, 24, 1065-77.
197. T. C. Jemphy, K. A. Z. Gogins, Y. Mazur, L. L. Miller, *J. Org. Chem.*, 1981, 46, 4545-4551.
198. C. R. Harrison, P. Hodge, *J. Chem. Soc., Perk. Trans. 1*, 1982, 509-511.
199. E. Adler, B. Berggren, *Acta Chem. Scandinavica*, 1960, 14, 529- 538.
200. P. K. Khatri, S. L. Jain, *Catalysis Lett.*, 2012, 142, 1020-1025.
201. H. B. Luo, Y. Y. Xie, *Chin. Chem. Lett.*, 2003, 14, 555-556.
202. H. Zhu, *Huaxue Shijie*, 2005, 46, 541-543.

203. T. Dohi, T. Nakae, N. Takenaga, T. Uchiyama, K.-I. Fukushima, H. Fujioka, Y. Kita, *Synthesis*, 2012, 44, 1183-1189.
204. V. V. Berentsveig, et. al. *Kinetika i Kataliz*, 1991, 32, 623-629.
205. M. O. Ratnikov, L. E. Farkas, E. C. McLaughlin, G. Chiou, H. Choi, S. H. El-Khalafy, M. P. Doyle, *J. Org. Chem.*, 2011, 76, 2585-2593.
206. M. Rosenfeld, Nathan, null, 1976, No pp.
207. J. Illesinghe, R. Ebeling, B. Ferguson, J. Patel, E. M. Campi, W. R. Jackson, A. J. Robinson, *Aus. J. Chem.*, 2004, 57, 167-176.
208. A. Wu, Y. Duan, D. Xu, T. M. Penning, R. G. Harvey, *Tetrahedron*, 2010, 66, 2111-2118.
209. N. Lebrasseur, J. Gagnepain, A. Ozanne-Beaudenon, J.-M. Léger, S. J. Quideau, *Org. Chem.* 2007, 72, 6280-6283.
210. G. Liu, T. Kuang, *Faming Zhuanli Shenqing*, 101781179, 2010.
211. Wurm, G.; Goessler, B. *Archiv der Pharmazie* 1987, 320, 564-566.
212. Emke, A. null, 1979, No pp.
213. Ishii, H.; Hanaoka, T.; Asaka, T.; Harada, Y.; Ikeda N. *Tetrahedron*, 1976, 32, 2693-8.
214. Chauhan, S. M. S., Kalra, B.; Mohapatra, P. P. *J. Mole. Catal. A: Chem.* 1999, 137, 85-92.
215. Yadav, J. S.; Biswas, S. K.; Srinivas, R. *Synthesis* 2006, 4237-4241.
216. Fieser, Louis, F. *Org. Synth.*, 1937, 17, No pp. Given.
217. Chen, S.; Hossain, M. S.; Foss, F. W. Jr *Org. Lett.* 2012, 14, 2806.
218. Chen, Shuai and Foss, Frank W. *Org. Lett.*, 2012, 14, 5150-5153.
219. Adam, W.; Peters, E. M.; Peters, K.; Prein, M.; van Schnering, H. G. *J. Am. Chem. Soc.* 1995, 117, 6686.
220. Ozanne, A.; Pouységu, L.; Depernet, D.; François, B.; Quideau, S. *Org. Lett.* 2003, 5, 2903-2906.
221. Gelman, D. M.; Perlmutter, P. *Tetrahedron Lett.* 2009, 50, 39-40.
222. Crich, D.; Zou, Y. *J. Org. Chem.* 2005, 70, 3309-3311.
223. Takaguchi, Y.; Tajima, T.; Yamakawa, A. *Jpn. Kokai Tokkyo Koho.* 2012001463, 2012.
224. N. Adarsh, M. Shanmugasundaram, R. R. Avirah, D. Ramaiah, *Chem. Eur. J.* 2012, 18, 12655.
225. R. Bernini, E. Mincione, M. Barontini, G. Fabrizi, M. Pasqualetti, S. Tempesta, *Tetrahedron*, 2006, 62, 7733-7737.
226. T. Hino, T. Anzai, N. Kuramoto, *Tetrahedron Lett.*, 2006, 47, 1429-1432.
227. H. Xu, W.-K. Chan, D. K. P. Ng, *Synthesis*, 2009, 1791-1796.
228. R. Bernini, E. Mincione, M. Barontini, F. Crisante, G. Fabrizi, A. Gambacorta, *Tetrahedron*, 2007, 63, 6895-6900.
229. L. Huang, J. Zhao, S. Guo, C. Zhang, J. Ma, *J. Org. Chem.* 2013, 78, 5627-5637.
230. G. Wienhoefer, K. Schroeder, K. Moeller, K. Junge, M. Beller, *Adv. Synth. Catal.*, 2010, 352, 1615-1620.
231. H. J. Teuber, N. Gotz, *Ber.*, 1954, 87, 1236-1251.
232. M. Ochiai, K. Miyamoto, Y. Yokota, T. Suefuji, M. Shiro, *Angew. Chem., Int. Ed.*, 2005, 44, 75-78.
233. M. Ochiai, K. Miyamoto, M. Shiro, T. Ozawa, K. Yamaguchi, *J. Am. Chem. Soc.* 2003, 125, 13006-13007.
234. R. Barret, M. Daudon, *Tetrahedron Lett.*, 1990, 31, 4871-4872.
235. M. Zhang, W. Chen, C. Li, *Faming Zhuanli Shenqing* 2012, CN 102391091 A 20120328.
236. M. Uyanik, T. Mutsuga, K. Ishihara, *Molecules* 2012, 17, 8604-8616.
237. O. Suchard, R. Kane, B. J. Roe, E. Zimmermann, C. Jung, P. A. Waske, J. Mattay, M. Oelgemoeller, *Tetrahedron*, 2006, 62, 1467-1473.
238. Q.-J. Zhang, X.-S. Yang, C. Zhao, H.-Y. Zhu, *Huaxue Shiji*, 2006, 28, 183-184.

239. J. Griffiths, K.-Y. Chu, C. J. Hawkins, *Chem. Soc. Chem. Commun.* 1976, 17, 676-677.
240. M. V. Bhatt, M. Periasamy, *Tetrahedron*, 1994, 50, 3575-86.
241. D. Murali, G. S. K. Rao, *Indian J. Chem., Sect B*, 1987, 26B, 668-70.
242. W. Adam, C.-G. Zhao, K. Jakka, *Org. React.* 2007, 69, 1-346.
243. D. H. R. Barton, J. P. Finet, M. Thomas, *Tetrahedron*, 1988, 44, 6397-406.
244. W.-B. Pan, L.-M. Wei, L.-L. Wei, C.-C. Wu, F.-R. Chang, Y.-C. Wu, *J. Chin. Chem. Soc.*, 2005, 52, 581-588.
245. S. Shi, T. J. Katz, B. V. Yang, L. Liu, *J. Org. Chem.*, 1995, 60, 85-1297.
246. M. Nakanishi, C. Bolm, *Adv. Synth. Catal.*, 2007, 349, 861-864.
247. P. G. McKay, A. S. Mitchell, *Aust. J. Chem.* 1989, 42, 2295-2297.
248. Y. Tanoue, K. Sakata, M. Hashimoto, S.-I. Morishita, M. Hamada, N. Kai, T. Nagai, *Tetrahedron* 2002, 58, 99-104.
249. D. H. R. Barton, J. P. Finet, C. Giannotti, M. Thomas, *Tetrahedron Lett.*; 1988, 29, 2671-2674.
250. S. V. Ley, C. A. Meerholz, D. H. R. Barton, *Tetrahedron, Supplement*, 1981, 213-223.
251. W. Adam, A. Schoenberger, *Tetrahedron Lett.*, 1992, 33, 53-56.
252. D. H. R. Barton, J. P. Finet, M. Thomas, *Tetrahedron*, 1986, 42, 2319-2324.
253. R. T. Arnold, R. Larson, *J. Org. Chem.*, 1940, 5, 250-252.
254. V. N. Telvekar, B. S. Takale, *Tetrahedron Lett.*, 2010, 51, 3940-3943.
255. V. N. Telvekar, H. M. Bachhav, *Synlett*, 2010, 2059-2062.
256. (a) Fieser, F. Louis, *Org. Synth.* 1925, 5, No pp. Given; (b) Fieser, F. Louis, *Org. Synth.* 1941, collective volume 1, 383-385.
257. J.-L. Zhang, C.-M. Che, *Chem. Eur. J.*, 2005, 11, 3899-3914.
258. T. Cui, Y. Wang, C. Zhang, H. Jin, G. Liu, *Proc. China Assoc. Sci. Technol.*; 2008, 4, 45-48.
259. T. Cui, G. Liu, T. Luo, S. Guo, *Faming Zhuanli Shenqing*, 2009, CN 101462066 A 20090624.
260. S. Harrison, G. Fiset, B. Mahdavi, *Eur. Pat. Appl.*, 1999, EP 919533 A1 19990602.
261. R. P. Kreh, R. M. Spotnitz, J. T. Lundquist, *J. Org. Chem.* 1989, 54, 1526-1531.
262. X.-Q. Cao, X. Liu, Y.-S. Cheng, *Jingxi Yu Zhuanyong Huaxuepin*, 2006, 14, 18-20.
263. V. Steglinska, A. T. Grzejdzia, J. E. Dziegiec, *Pol.* 2001, PL 181601 B1 20010831.
264. H. M. Becher, *PCT Int. Appl.* 1992, WO 9206944 A1 19920430.
265. R. P. Kreh, R. M. Spotnitz, J. T. Lundquist, *Tetrahedron Lett.* 1987, 28, 1067-1068.
266. F. Shi, M. K. Tse, M. Beller, *J. Mol. Catal. A: Chem.* 2007, 270, 68-75.
267. H. R. El-Seedi, S. Yamamura, S. Nishiyam, *Tetrahedron*, 2002, 58, 7485-7489.
268. D. W. Kim, H. Y. Choi, K.-J. Lee, D. Y. Chi, *Org. Lett.*, 2001, 3, 445-447.
269. A. Tomatsu, S. Takemura, K. Hashimoto, M. Nakata, *Synlett*, 1999, 1474-1476
270. R. Araya, R. Tapia, J. A. Valderrama, *J. Chem. Res. (S)*, 1987, 84-85.
271. H. Shomiya, K. Takahide, F. Mitsue, A. Takashi, *Tetrahedron*, 1998, 54, 13737-13750.
272. N. Bodipati, R. K. Pedidinti, *Org. Biomol. Chem.*, 2012, 10, 4549-4553.
273. Y. H. Kim, K. S. Kim, H. K. Lee, *Tetrahedron Lett.*, 1989, 30, 6357-6360.
274. J. Muzart, *Tetrahedron Lett.* 1987, 28, 2131-2132.
275. A. E. V. Gorden, X. Wu, *U.S. Pat.* 20090286968, 2009.
276. M. Mukoyama, T. Takai, E. Hata, T. Yamada, *Jpn. Kokai. Tokkyo. Koho.* JP07258146 A 19951009, 1995.

277. A. Patra, M. Bandyopadhyay, D. Mal, *Tetrahedron Lett.*, 2003, 44, 2355-2357.
278. J. C. Bradley, T. Durst, A. J. Williams, *J. Org. Chem.*, 1992, 57, 6575-6579.
279. C. Escobar, F. Farina, R. Martinez-Utrilla, M. C. Paredes, *J. Chem. Res. (S)*, 1980, 156-157.
280. H. Greenland, J. T. Pinhey, S. Sternhell, *Aus. J. Chem.* 1986, 39, 2067-2074.
281. N. Ardabilchi, J. M. Bruce, J. Khalafy, *J. Sci., Islamic Rep. Iran* 2000, 11, 195-203.
282. S. Kotha, S. Banerjee, M. P. Patil, R. B. Sunoj, *Org. Biomol. Chem.*, 2006, 4, 1854-1856.
283. L.-Q. Cui, K. Liu, C. Zhang, *Org. Biomol. Chem.*, 2011, 9, 2258-2265.
284. D. B. G. Williams, K. Blann, C. W. Holzapfel, *J. Chem. Soc., Perkin Trans.1*, 2001, 219-220.
285. J. W. Grissom, G. U. Gunawardena, *Tetrahedron Lett.*, 1995, 36, 4951-4954
286. (a) M. A. Brimble, R. J. R. Elliott, *Tetrahedron*, 1997, 53, 7715-7730; (b) K. Itami, T. Nokami, J.-I. Yoshida, *Adv. Syn. Catal.*, 2002, 344, 441-451.
287. K. Itami, T. Nokami, J.-I. Yoshida, *Angew.Chem.*, 2001, 40, 1074-1076.