Recent progress in nitrogen-centered radical reactions promoted by visible-light.

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  1) Oximes as the precursors
  2) O-acyl or sulfonyl hydroxylamine as the precursors
  3) N-aminopyridinium salts as the precursors
  4) Azides as the precursors
  5) N–halo compounds as the precursors
  6) Hydrazones as the precursors
  7) Amides as the precursors
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- Radical stabilization energies (RSEs) for selected N-centered radicals
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Strategies of nitrogen-centered radicals

In 1880s

HOFMANN-LÖFFLER-FREYTAG REACTION

\[
\begin{align*}
N\text{-halogenated amine} & \xrightarrow{\Delta \text{ or } hv \text{ or radical initiator}} \delta\text{-halogenated amine} \\
& \xrightarrow{\text{base}} \text{Cyclic amine}
\end{align*}
\]

Radical Initiators
\[(\text{nBu}_3\text{Sn})_2/\text{hv}, \text{Et}_3\text{B/O}_2, \text{UV-irradiation}\]

Metal Catalysis
\[(M = \text{Co, Cu, Rh, Fe, Pd, etc.})\]

Visible-Light Irradiation

Radical precursors in Vis. photocatalyzed radical amination reaction

Radical precursors in Vis. photocatalyzed radical amination reactions

1) Oximes as the precursors
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7) Amides as the precursors
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9) 2H–azirines as the precursors
Conversion of N–O bonds into N-centred radicals from oximes

Types of oximes
Oxime ethers as the precursors

2,4-dinitro-substituted O-aryl oxime ether

Oxime ethers as the precursors

Metal-free hydroimination and iminohydroxylation cyclization reactions

Oxime ethers as the precursors

Oxidative cyclization of O-methyl oxime ethers

Carbonyl oximes as the precursors

O-Ac carbonyl oximes

Dioxime oxalates

Carbonyl oximes as the precursors


Acyl oximes
Carbonyl oximes as the precursors

One pot approach

Carbonyl oximes as the precursors
Carbonyl oximes as the precursors

Carboimination of unactivated alkenes

Radical precursors in Vis. photocatalyzed radical amination reactions

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O-acyl hydroxylamine as the precursors

Amination of arenes and heteroarenes

O-sulfonyl hydroxylamine as the precursors

Enantioselective direct α-Amination of aldehydes

O-sulfonyl hydroxylamine as the precursors

O-sulfonyl hydroxylamine as the precursors

Amidation of heteroarenes

O-sulfonyl hydroxylamine as the precursors

Enantioselective radical amination of 2-acyl imidazoles

Radical precursors in Vis. photocatalyzed radical amination reactions

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N-aminopyridinium salts as the precursors

Different approaches to N-radicals of N-aminopyridinium salts
N-aminopyridinium salts as the precursors

Hydroamination of olefins

N-aminopyridinium salts as the precursors

Direct amidation of arenes and heteroarenes

N-aminopyridininium salts as the precursors

N-aminopyridinium salts as the precursors


Intermolecular aminohydroxylation of olefins
Radical precursors in Vis. photocatalyzed radical amination reactions

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Azides as the precursors

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N–halo compounds as the precursors

Amidation of arenes and heteroarenes

N–halo compounds as the precursors

Amidation of heteroarenes

N–halo compounds as the precursors

Amidation of arenes and heteroarenes

N–halo compounds as the precursors

Remote C(sp$^3$)–H amidation and chlorination

N–halo compounds as the precursors

N–halo compounds as the precursors

\[
\begin{align*}
R^1 & = \text{alkyl, aryl} \\
R^2 & = \text{alkyl}
\end{align*}
\]

Chloramination of olefins

N–halo compounds as the precursors

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Hydrazones as the precursors

Hydroamination of β,γ-unsaturated hydrazones

Hydrazones as the precursors

Hydrazones as the precursors

N-radical cascade reaction and oxidative deprotonation

Hydrazone as the precursors

N-radical cascade reaction and oxidative deprotonation

Hydrazones as the precursors

Hydrazones as the precursors

Smiles cascade: access to phthalazine derivatives

Hydrazones as the precursors

**Radical precursors in Vis. photocatalyzed radical amination reactions**

1) Oximes as the precursors  
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Amides as the precursors

Oxidative PCET Activation of Amide N-H Bonds

N-H BDFE for N-aryl amide ~ 100 kcal/mol

PCET 'BDFE' (kcal/mol) = 1.37 $pK_a$(H-B) + 23.06 $E(M^n)$ + $C_{solv}$

Carboaminations and hydroamidation of alkenes

Amides as the precursors

\[
\text{Ph} - \text{N} - \text{CH} = \text{CH} - \text{Me} \quad \xrightarrow{3 \text{ mol\% photocatalyst}} \quad \text{Ph} - \text{N} = \text{CH} - \text{CO}_2\text{Me}
\]

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<th>Entry</th>
<th>Photocatalyst</th>
<th>Base</th>
<th>( \text{&quot;BDFE&quot;} )</th>
<th>Yield (%)</th>
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<td>76</td>
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<td>50</td>
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<th>Change from best conditions (entry 15)</th>
<th>Yield (%)</th>
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<tr>
<td>22</td>
<td>no photocatalyst</td>
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<tr>
<td>23</td>
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</tr>
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<td>24</td>
<td>1 mol% Ir[d(CF(_3))ppy](_2)(bpy)PF(_6)</td>
<td>76</td>
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<tr>
<td>25</td>
<td>10 mol% NBu(_2)OP(O)(OBu)(_2)</td>
<td>78</td>
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<tr>
<td>26</td>
<td>1.1 equivalents of acrylate</td>
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</tr>
<tr>
<td>27</td>
<td>0.1 M in CH(_2)Cl(_2)</td>
<td>80</td>
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</table>
Amides as the precursors

Amides as the precursors

Amides as the precursors


Alkylation of remote C–H bonds


Sulfonamides as the precursors

Desulfonylation of tosyl amides

J. Xuan, W.-J. Xiao, Chem. – Asian J. 2013, 8, 1090–1094.
Sulfonyloxy oximes as the precursors

Sulfonamides as the precursors

Direct oxidative C–H amidation of heteroarenes with sulfonamides

Sulfonamides as the precursors

Radical precursors in Vis. photocatalyzed radical amination reactions

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N-Radical ions
Secondary amines as the precursors

Preparation of N-arylindoles

Secondary amines as the precursors

Preparation of N-arylindoles

Secondary amines as the precursors

Olefin hydroamination with aminium radical cations

Secondary amines as the precursors

Intermolecular [3+2] cycloaddition

Secondary amines as the precursors

Secondary amines as the precursors

Intermolecular [4+2] cycloaddition

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9) 2H–azirines as the precursors
2H-azirines as the precursors

[3+2] Cycloaddition for pyrrole Synthesis

2H–azirines as the precursors

\[ \text{[3 + 2] Cycloaddition/Oxidative aromatization} \]

Radical stabilization energies (RSEs) for selected N-centered radicals

Conclusions and outlook

Radical precursors

1) Oximes
2) O-acyl or sulfonyl hydroxylamine
3) N-aminopyridinium salts
4) Azides as the precursors
5) N–halo compounds
6) Hydrazones
7) Amides
8) Secondary amines
9) 2H–azirines

Challenges:

(1) The activation of other more challenging N–H bonds and exploration of new reaction modes; (2) the asymmetric variants of N-radicals and radical ion-mediated reactions.

We believe that the development of a dual catalytic system by combination of the visible light photoredox catalysis with other catalytic strategies such as organocatalysis or transition-metal catalysis or use of chiral photocatalysts would provide potential solutions to those challenging problems.
Thanks