On the Probability that Ring-forming Multicomponent Reactions are Green: Setting Thresholds for Intrinsic Greenness Based on Design Strategy and Experimental Reaction Performance

John Andraos
CareerChem, 504-1129 Don Mills Road, Don Mills, ON M3B 2W4 Canada
c1000@careerchem.com

Supporting Information – Part 3

MCR 2011

\[ [(4+1) + (2+2+1+1) + (3+3) + (4+1+1)] \]

\[ x + y + 54 \]

\[ \begin{array}{c}
\text{Ph} \\
\text{NH}_2 \\
\text{HN} \\
\text{Ph} \\
\text{O} \\
\text{HO} \\
\end{array} \xrightarrow{239} \begin{array}{c}
\text{Ph} \\
\text{N} \\
\text{N} \\
\text{R}_1 \\
\text{R}_2 \\
\text{H} \\
\end{array} \xrightarrow{-2 \text{H}_2\text{O}} \begin{array}{c}
\text{Ph} \\
\text{N} \\
\text{N} \\
\text{R}_1 \\
\text{R}_2 \\
\text{H} \\
\end{array} \]

\[ 109 \]

\[ x + y + 366 \]

\[ [(2+2+2) + (2+2+2) + (2+1+2+1) + (4+1)] \]
\[(2+2+1) + (4+2) + (4+2)\]

Wu, T.C.; Wu, Y.T. *Synlett* **2011**, 741

\[[(2+2+1) + (4+2) + (4+2)]\]


\[[(5+0) + (2+2+1) + (5+1)]\]

[(5+1) + (3+1+1)]

Li, S.; Wu, J. *Org. Lett.* 2011, 13, 712

[(3+1+1) + (4+2)]


[(3+1+1) + (4+1)]

[(2+1+1+1) + (5+1)]


2 \times + 56

[(2+1+1+1) + (4+2)]

\[ \text{(2+1+2+1) + (2+2+1)} \]

[(4+2) + (3+2+1)]

Sheibani, H.; Esfandiarpoor, Z. J. Heterocyclic Chem. 2011, 48, 1122


Majumder, S.; Bhuyan, P.J. *Synlett* **2011**, *1547*


\[ (6+0) + (3+2+1) \]


\[ (5+1) + (3+2+1) \]

Yu, X.; Qiu, G.; Liu, J.; Wu, J. *Synthesis* 2011, 2268

\[ \begin{align*}
74 & \quad \text{NH}_2 \quad \text{NH}_2 \\
165 & \quad \text{S} \quad \text{NO}_2 \quad \text{MeO} \quad \text{O} \\
\text{R} & \quad \text{x} + 83 \\
\end{align*} \]

\[ \begin{align*}
\text{NH} & \quad \text{NO}_2 \\
\text{R} & \quad \text{x} + 194 \\
- 2 \text{MeSH} & - \text{MeOH} \\
\end{align*} \]


\[ \begin{align*}
x & + 159 \\
\text{R}_1 & \quad \text{H} \quad \text{N} \quad \text{R}_1 \\
\text{R}_2 & \quad \text{COOMe} \quad \text{COOMe} \\
\text{y} & + 55 \\
\text{H} & + 280 \\
\end{align*} \]

\[ \begin{align*}
\text{[}(3+2) + (3+2)\text{]} \\
\text{Shaabani, A.; Mahyari, M.; Seyyedhamzeh, M.; Keshipour, S.; Ng, S.W. *Tetrahedron Lett.* 2011, 52, 4388} \\
\end{align*} \]

\[ \begin{align*}
x & + 26 \\
136.28 & \\
x & + 26 \\
65 & \\
167 & \\
167 & \\
\text{2 x} & + 535.38 \\
\text{- 2 NaCl} \\
\end{align*} \]

Zang, Q.; Javed, S.; Ullah, F.; Zhou, A.; Knudtson, C.A.; Bi, D.; Basha, F.Z.; Organ, M.G.; Hanson, P.R. *Synthesis* **2011**, *2743*


\[
\text{[(3+3) + (3+3)]}
\]

Mukhopadhyay, C.; Das, P.; Butcher, R.J. *Org. Lett.* **2011**, *13*, 4664

\[
\text{[(4+2) + (4+2)]}
\]

Masters, K.S.; Nieger, M.; Bräse, S. *Synlett* **2011**, 399
[(4+1) + (4+1)]


Han, D.J.; Huang, Z.B.; Ji, S.J. *J. Heterocyclic Chem.* 2011, 48, 1393

[(4+2) + (4+1)]


[(2+2+1) + (4+1)]


[(4+2+1) + (4+1)]

[(4+2+1) + (4+2)]

[(2+2+2) + (3+2)]
\[(2+2+1) + (3+2)\]


![Chemical structure](image1)

\[ (2+2+1) + (5+1) \]


![Chemical structure](image2)

\[ 4+1 \]

Liang, Y.; Meng, T.; Zhang, H.J.; Xi, Z. *Synlett* **2011**, *911*

![Chemical structure](image3)


Riguet, E. J. Org. Chem. 2011, 76, 8143

\[
\begin{align*}
R_1 & \quad \text{N} \\
R_2 & \quad \text{O} \\
100 & \quad \text{H}_2\text{N}R_4 \\
\text{N} & \quad \text{O} \\
R_3 & \quad \text{N} \\
\end{align*}
\]

\[
\begin{align*}
z + 26 & \\
R_3 & \quad \text{N} \\
R_2 & \quad \text{O} \\
\text{H}_2\text{N}R_4 & \\
\text{N} & \quad \text{O} \\
R_3 & \quad \text{N} \\
\end{align*}
\]

\[
\begin{align*}
- \text{H}_2\text{O} & \\
x + y + 115 & \\
R_2 & \quad \text{N} \\
R_1 & \quad \text{O} \\
\text{R}_2 & \quad \text{O} \\
\text{R}_4 & \quad \text{O} \\
\end{align*}
\]

\[
\begin{align*}
x + y + z + w + 239 & \\
R_2 & \quad \text{N} \\
R_1 & \quad \text{O} \\
\text{R}_2 & \quad \text{O} \\
\text{R}_4 & \quad \text{O} \\
\end{align*}
\]


\[
\begin{align*}
x + 26 & \\
\text{Ar} & \quad \text{O} \\
\text{OH} & \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\end{align*}
\]

\[
\begin{align*}
x + y + 154 & \\
\text{Ar} & \quad \text{O} \\
\text{OH} & \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\end{align*}
\]

\[
\begin{align*}
z + 45 & \\
\text{Ar} & \quad \text{O} \\
\text{OH} & \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\end{align*}
\]

\[
\begin{align*}
2 x + 2 y + z + 193 & \\
\text{Ar} & \quad \text{O} \\
\text{OH} & \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\text{O} & \quad \text{N}\text{Ar} \\
\end{align*}
\]

Sayama, S. Heterocycles 2011, 83, 1267

\[
\begin{align*}
\text{4/3} & \\
\text{Br} & \quad \text{S} & \quad \text{Br} \\
\text{4/3 (361.45)} & \\
\text{125} & \\
\text{x + 29} & \\
\end{align*}
\]

\[
\begin{align*}
\text{3 pyridine} & \\
\text{- 3 pyridinium bromide} & \\
\text{- 4/3 Sb} & \\
\text{- H}_2\text{O} & \\
\end{align*}
\]


Garcia-Gonzalez, M.C.; Gonzalez-Zamora, E.; Santillan, R.; Farfan, N. *Synlett* **2011**, *308*


[3+2]
Ramazani, A.; Ahmadi, Y.; Malekzadeh, A.M.; Rezaei, A. *Heteroatom Chem.* 2011, 22, 692

\[
\begin{align*}
\text{HN} & \quad \text{Ar}_1 \\
\text{O} & \quad \text{Ar}_2 \\
\text{R} & + x + 45 \\
\text{O} & \quad \text{PPh}_3 \\
\text{- O=PPh}_3 & \quad \text{- H}_2\text{O} \\
\text{HN} & \quad \text{Ar}_2 \\
\text{O} & \quad \text{Ar}_1 \\
\text{R} & + x + y + z + 182
\end{align*}
\]


\[
\begin{align*}
\text{HN} & \quad \text{Ar} \\
\text{H} & \quad \text{R}_1 \\
\text{O} & \quad \text{NH}_2 \\
\text{S} & \quad \text{NH}_2 \\
\text{O} & \quad 76 \\
\text{H}_2\text{O} & \quad \text{TiCl}_4 \\
\text{(cat.)} & \quad \text{HCl} \\
\text{- H}_2\text{O} & \quad \text{- H}_2\text{O} \\
\text{Cl} & \quad \text{R}_2 \\
\text{H} & \quad \text{O} \\
\text{y + 77.45} & \quad \text{x + y + z + 111}
\end{align*}
\]


\[
\begin{align*}
\text{Na} & \quad \text{N} & \quad \text{N} \\
\text{BF}_4 & \quad \text{N} & \quad \text{Na} \\
\text{N=N} & \quad \text{Ar} \\
\text{Na} & \quad \text{N} & \quad \text{N} \\
\text{N} & \quad \text{Na} & \quad \text{N} \\
\text{N=N} & \quad \text{Ar} \\
\text{CuNPs} & \quad \text{(cat.)} & \quad \text{- NaBF}_4 \\
\text{- N}_2 & \quad \text{- NaCl} \\
\text{y + 25} & \quad \text{x + y + 67}
\end{align*}
\]

NP = nanoparticles

\[
\begin{align*}
\text{Cl} & \quad \text{R}_2 \\
\text{N=N} & \quad \text{Na} \\
\text{Na} & \quad \text{N} & \quad \text{N} \\
\text{N=N} & \quad \text{R}_1 \\
\text{CuNPs} & \quad \text{(cat.)} & \quad \text{- NaCl} \\
\text{- NaCl} & \quad \text{x + y + 67}
\end{align*}
\]

NP = nanoparticles


Adib, M.; Ansari, S.; Bijanzadeh, H.R. *Synlett* **2011**, *619*


Wang, W.; Wu, J.; Xia, C.; Li, F. Green Chem. 2011, 13, 3440


Cimarelli, C.; Fratoni, D.; Palmieri, G. Tetrahedron Asym. 2011, 22, 1542


Lakshmi, N.V.; Kiruthika, S.E.; Perumal, P.T. *Synlett* **2011**, 1389
Zare, L.; Mahmoodi, N.; Yahyazadeh, A.; Mamaghani, M.; Tabatabaeian, K. J. Heterocyclic Chem. 2011, 48, 864

Patil, D.R.; Deshmukh, M.B.; Salunkhe, S.M.; Anbhule, P.V. J. Heterocyclic Chem. 2011, 48, 1342


Murai, T.; Ohashi, T.; Shibahara, F. Chem. Lett. 2011, 40, 70
Babu, T.H.; Perumal, P.T. Synlett 2011, 341

[5+0]


[6+0]


[5+1]


\[
\begin{align*}
\text{CuCl (cat.)} & \rightarrow \\
\text{N}_2 & \rightarrow \\
x + y + 154 & \rightarrow \\
z + 106 & \rightarrow \\
x + y + z + w + 248 & \rightarrow
\end{align*}
\]

[6+1]


\[
\begin{align*}
\text{CuCl (cat.)} & \rightarrow \\
\text{- N}_2 & \rightarrow \\
x + y + 224 & \rightarrow \\
x + y + z + w + 248 & \rightarrow
\end{align*}
\]


\[
\begin{align*}
y + 26 & \rightarrow \\
x + 16 & \rightarrow \\
x + y + 242 & \rightarrow
\end{align*}
\]

\[
\begin{align*}
&\text{HO} - \text{CH} - \text{N} - \text{CH} - \text{N} - \text{O} - \text{R}_2 \\
&x + 253 \quad y + 16
\end{align*}
\]

\[
\begin{align*}
&\text{HO} - \text{CH} - \text{N} - \text{CH} - \text{N} - \text{O} - \text{R}_2 \\
&\text{N} + \text{H} - \text{C} - \text{N} - \text{R}_3 \\
&z + 40
\end{align*}
\]

\[
\begin{align*}
&\text{HO} - \text{CH} - \text{N} - \text{CH} - \text{N} - \text{O} - \text{R}_2 \\
&x + y + z + 291
\end{align*}
\]

[9+1]

Cheng, J.; Jiang, X.; Ma, S. *Org. Lett.* **2011**, 13, 5200

\[
\begin{align*}
&\text{H}_2\text{N} - \text{R}_1 \\
&y + 127
\end{align*}
\]

\[
\begin{align*}
&\text{Ts} - \text{N} - \text{R}_1 \\
&\text{H}_2\text{N} - \text{R}_1 \\
&x + 16
\end{align*}
\]

\[
\begin{align*}
&\text{Ts} - \text{N} - \text{R}_1 \\
&\text{H}_2\text{N} - \text{R}_1 \\
&x + 2y + 289
\end{align*}
\]

[2+1+1]


Facoetti, D.; Abbiati, G.; Dell’Acqua, M.; Rossi, E. Tetrahedron 2011, 67, 6833


NP = nanoparticles


![Chemical Structure](image)

Vicente-Garcia, E.; Ramon, R.; Lavilla, R. *Synthesis* 2011, 2237

![Chemical Structure](image)


![Chemical Structure](image)


\[ \begin{align*}
    &\text{N} & &\text{O} & &\text{COOMe} \\
    &\text{CN} & &\text{S} & &\text{Ar}_1 \\
    &\text{HS} & &\text{Ar}_2 & &\text{N} \\
    &\text{CH} & &\text{H} & &\text{N} \\
    &\text{x} + y + 174 & &\text{O} & &\text{1/2 O}_2 \\
    &\text{- 2 H}_2\text{O} & &\text{- 2 H}_2\text{O} & &\text{1/2 O}_2 \\
\end{align*} \]


\[ \begin{align*}
    &\text{COOMe} & &\text{COOMe} & &\text{COOMe} \\
    &\text{N-methylimidazole} & &\text{cat.} & &\text{N-methylimidazole} \\
    &\text{EtOH} & &\text{EtOH} & &\text{EtOH} \\
    &\text{x} + y + 174 & &\text{O} & &\text{O} \\
\end{align*} \]


\[ \begin{align*}
    &\text{R}_1\text{NH}_2 & &\text{O}_2\text{S} & &\text{Cl} \\
    &\text{O} & &\text{O} & &\text{O} \\
    &\text{R}_2 & &\text{R}_2 & &\text{R}_2 \\
    &\text{y} + 85 & &\text{z} + 125.45 & &\text{x} + y + z + 172 \\
\end{align*} \]


\[
x + y + 66 \quad 113 \quad x + y + 66 \quad 2x + 2y + 155
\]


\[
x + 213.9 \quad y + 26 \quad x + y + z + 158
\]


\[
x + y + z + w + 133
\]

Chen, C.H.; Yellol, G.S.; Lin, P.T.; Sun, C.M. *Org. Lett.* **2011**, *13*, 5120


![Chemical Reaction](image1)


![Chemical Reaction](image2)


![Chemical Reaction](image3)


![Chemical Reaction](image4)

Wang, X.; Lu, G.; Yan, F.; Ma, W.; Wu, L. *J. Heterocyclic Chem.* 2011, 48, 1379


Zhang, Y.; Li, P.; Wang, L. *J. Heterocyclic Chem.* 2011, 48, 153

\[
x + 25
\]

\[
\begin{align*}
R_1 & \quad R_2 \\
\text{NH}_2 & \quad \text{O} \\
\text{O}_2 & \quad \text{O} \\
\text{Ar} & \quad \text{Ar} \\
\text{H}_2O & \quad \text{H}_2O \\
\text{O}_2 & \quad \text{H}_2O \\
\end{align*}
\]


Han, G.F.; Cui, B.; Chen, L.Z.; Wang, R.H.; Jin, Y. J. Heterocyclic Chem. 2011, 48, 312


Wan, J.P.; Wang, C.; Pan, Y. *Tetrahedron* 2011, 67, 922


Li, L.; Wu, Q.; Liu, B.K.; Lin, X.F. Synthesis 2011, 563

Majumdar, K.S.; Ponra, S.; Ghosh, D.; Taber, A. Synlett 2011, 104

\[ x + 125 \]

\[ R_1 \begin{array}{c} N \end{array} R_2 \]  
\[ \xrightarrow{\text{Me}_3\text{SiCl then H}_2\text{O}} \]  
\[ - 2 \text{H}_2\text{O} \]  
\[ - \text{HCl} \]  
\[ - \text{Me}_3\text{SiOH} \]  
\[ \rightarrow \]
\[ \begin{array}{c} - \end{array} R_1 \begin{array}{c} N \end{array} R_2 \]

\[ 60 \]

\[ y + 29 \]

\[ x + y + 178 \]

[1+1+1]


\[ x + 29 \]

\[ \begin{array}{c} O \end{array} \begin{array}{c} \text{Ar}_1 \end{array} \begin{array}{c} \text{Ar}_2 \end{array} \]
\[ \xrightarrow{- \text{H}_2\text{O} \quad - \text{HSCN}} \]
\[ \begin{array}{c} \text{Ar}_1 \end{array} \begin{array}{c} \text{Ar}_2 \end{array} \begin{array}{c} O \end{array} \]

\[ y + 100 \]

\[ x + y + 196 \]


\[ x + 16 \]

\[ \begin{array}{c} R_2 \end{array} \begin{array}{c} \text{CON}_{\text{R}_1} \end{array} \begin{array}{c} \text{COOEt} \end{array} \]
\[ \xrightarrow{- \text{H}_2\text{O}} \]
\[ \begin{array}{c} R_2 \end{array} \begin{array}{c} \text{CON}_{\text{R}_1} \end{array} \begin{array}{c} \text{COOEt} \end{array} \]

\[ y + 29 \]

\[ 114 \]

\[ x + y + 113 \]

[2+2+1]


\[ u + v + w + 53 \]

\[
\begin{array}{c}
R_4 \quad R_5 \quad \text{O} \\
R_3 \quad H_2N \\
\end{array}
\]

\[
\begin{array}{c}
R_1 \quad R_2 \\
\end{array}
\]

\[ z + 29 \]

\[ \xrightarrow{-H_2O} \]

\[
\begin{array}{c}
R_4 \quad R_5 \quad R_6 \quad \text{O} \\
R_3 \quad \text{N} \\
R_1 \\
R_2 \\
\end{array}
\]

\[ x + y + z + u + v + w + 121 \]


\[ R_3 \quad \text{I} \quad z + 127 \]

\[
\begin{array}{c}
\text{N} \\
R_1 \quad \text{N} \\
R_2 \\
\text{O} \\
\text{O} \\
\end{array}
\]

\[ \xrightarrow{\text{[Pd(allyl)Cl]}_2 \text{(cat.)} - \text{HI}} \]

\[
\begin{array}{c}
R_3 \\
R_1 \\
R_2 \\
\text{N} \\
\text{N} \\
\text{O} \\
\end{array}
\]

\[ 2 \times x + 2 \times y + z + 109 \]


\[
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{H}_2\text{N} \\
\text{Ph} \\
\text{Ph} \\
\end{array}
\]

\[ 106 \]

\[
\begin{array}{c}
\text{O} \\
\text{O} \\
\text{Ph} \\
\text{Ph} \\
\text{CN} \\
\text{CN} \\
\end{array}
\]

\[ 376 \]

\[ 132 \]

\[ 156 \]

\[ 156 \]


Rostamnia, S.; Lamei, K. *Synlett* **2011**, *3080*


\[
\begin{align*}
&v + 16 \\
&x + y + z + 25 \quad w + 26
\end{align*}
\]


\[
\begin{align*}
&2x + 106 \\
&1/2 O_2 \\
&7 H_2O
\end{align*}
\]


\[
x + y + z + 25 \quad v + 41
\]

\[
x + y + z + w + v + 80
\]


\[
x + 106
\]

\[
y + 25
\]

\[
z + w + 43
\]

\[
x + y + z + w + 146
\]


\[
y + 133.45
\]

\[
x + 16
\]

\[
76
\]

\[
x + 157
\]


Alimohammadi, K.; Sarrafi, Y.; Tajbakhsh, M.; Yeganegi, S.; Hamzehloueian, M. 
*Tetrahedron* 2011, 67, 1589


Rahmati, A.; Kouzehrash, M.A. *Synthesis* 2011, 2913
Lamberth, C. *Synlett* 2011, 1740

\[
\begin{align*}
\text{Cl} & \quad \text{N} & \quad \text{NH}_2 \\
\text{N} & \quad \text{Cl} & \quad \text{N} & \quad \text{R}_1 & \quad \rightarrow & \quad \text{Cl} & \quad \text{N} & \quad \text{NH} & \quad \text{H} & \quad \text{R}_1 \\
129.45 & \quad x+105 & \quad \rightarrow & \quad x+y+242.45
\end{align*}
\]


\[
\begin{align*}
\text{Ph} & \quad \text{COOEt} & \quad \text{Ph} & \quad \text{H} & \quad \text{COOEt} \\
98 & \quad \text{Ph} & \quad 106 & \quad \text{InBr}_3 & \quad \text{(cat.)} & \quad - \text{H}_2\text{O} & \quad 280
\end{align*}
\]


\[
\begin{align*}
\text{OH} & \quad \text{NH}_2 & \quad \text{SH} & \quad \text{O} & \quad \text{Ar} & \quad \rightarrow & \quad \text{O} & \quad \text{N} & \quad \text{Ar} & \quad -2\text{H}_2\text{O} & \quad x+y+101
\end{align*}
\]

Mishra, S.; Ghosh, R. *Synthesis* 2011, 3463
\[
\begin{align*}
&N\text{H}_2\text{R}_2\text{R}_3 + 29\text{ y} + 29\text{ R}_1 + \text{CuI (cat.)} - \text{H}_2\text{O} \\
&\xrightarrow{} \text{N} + \text{H} + \text{H} + \text{R}_3 + \text{R}_2 + \text{R}_1 + 129
\end{align*}
\]


\[
\begin{align*}
&x + 29 \\
&\text{R}_1 + \text{R}_2 + \text{R}_3 + \text{HCl} + \text{NH}_2\text{H}_2\text{O} - \text{H}_2\text{O} - [\text{HCl}] \\
&\xrightarrow{} \text{Ar} + \text{N} + \text{N} + \text{Cl} + \text{COOMe} + 135.45 \text{ y} + 135.45 \\
&\xrightarrow{} \text{Ar} + \text{N} + \text{N} + \text{COOMe} + 125 \text{ x} + 125
\end{align*}
\]


\[
\begin{align*}
&\Theta + \text{O} + \text{N} + \text{O} + \text{S} + \text{Br} + 155.9 \text{ y} \\
&\xrightarrow{} \Theta + \text{O} + \text{N} + \text{O} + \text{S} + \text{Br} + 155.9 \text{ y} + 155.9 \\
&\xrightarrow{2\text{ Et}_3\text{N}} \text{x} + 2\text{ Et}_3\text{N} + \text{H}_2\text{O} - 2\text{ [Et}_3\text{NH}]\text{Cl}
\end{align*}
\]


\[
\text{MeOOC} \quad \overset{142}{\text{y + 29}} \quad \text{NH}_2 \quad \overset{x + 16}{\text{Ar}_2} \quad \text{MeOH} \\
\text{MeOOC} \quad \overset{x + y + 155}{\text{Ar}_1} \quad \text{OH} \quad \overset{- \text{MeOH}}{\text{Ar}_1}
\]


\[
\begin{align*}
\text{O}_2\text{N} & \quad \overset{73}{\text{72}} \\
\text{NH}_2 & \quad \overset{175}{\text{H}_{2}\text{O}} \\
\text{O}_2\text{N} & \quad \overset{- \text{MeOH}}{\text{270}} \\
\text{O}_2\text{N} & \quad \overset{- \text{H}_2\text{O}}{\text{270}}
\end{align*}
\]


\[
\begin{align*}
x + z + 105 \\
\text{R}_1 & \quad \overset{y + 16}{\text{R}_2} \\
\text{H}_2\text{N} & \quad \overset{- 2\text{H}_2\text{O}}{\text{R}_3}
\end{align*}
\]


![Reaction Scheme](image1.png)


![Reaction Scheme](image2.png)


![Reaction Scheme](image3.png)

![Chemical structure diagram]

Satoh, Y.; Obora, Y. *Org. Lett.* 2011, 13, 2568

![Chemical structure diagram]


![Chemical structure diagram]


\[ x + y + 40 \quad x + y + 40 \]


Terzidis, M.A.; Tsiaras, V.G.; Stephanidou-Stephanatou, J.; Tsoleridis, C.A. *Synthesis* **2011**, *97*

Li, M.; Pan, L.; Wen, L.R. *Heterocycles* **2011**, *83*, *169*


\[
z + w + v + 53 \quad \xrightarrow{142} \quad x + y + 29
\]

\[
\text{[3+3+1]}
\]

\[
y + z + 145
\]

\[
\text{[4+2+1]}
\]

\[

Cheng, C.; Jiang, B.; Tu, S.J.; Li, G. Green Chem. 2011, 13, 2107

[5+1+1]
Cao, H.; Vieira, T.O.; Alper, H. Org. Lett. 2011, 13, 11

[4+1+1]

Chari, M.A. Tetrahedron Lett. 2011, 52, 6108
Sellstedt, M.; Almqvist, F. Org. Lett. 2011, 13, 5278


([4+1+1] + (5+1))


[2+2+1+1]


Santra, S.; Andreana, P.R. J. Org. Chem. 2011, 76, 2261

Mukhopadhyay, C.; Rana, S.; Butcher, R.J.; Schmiedekamp, A.M. Tetrahedron Lett. 2011, 52, 5835

[3+1+1+1]


[2+1+1+1]


Han, Y.; Hou, H.; Fu, Q.; Yan, C.G. *Tetrahedron* **2011**, *67*, 2313


Niralwad, K.S.; Shingate, B.B.; Shingare, M.S. *J. Heterocyclic Chem.* **2011**, *48*, 742

Ciez, D.; Svetlik, J. Synlett 2011, 315
[2+1+2+1]

![Chemical structure](attachment:image1.png)


![Chemical structure](attachment:image2.png)


![Chemical structure](attachment:image3.png)


Khalafi-Nezhad, A.; Panahi, F. Synthesis **2011**, 984


[3+1+3+1]

[1+1+1+1+1]
[5+3+5+3]

[2+1+1+1+1]


[(2+2+1+1) + (2+2+1)]


\[
\begin{align*}
&\text{Cl}^\text{IV} \text{Zr}^\text{IV} \text{Cp} \text{Cp} \\ &\text{nBuLi} \rightarrow \text{Zr}^\text{II} \text{Cp} \\
&\text{Si} \text{Cp} \text{Cp} \text{Ar} \\
&2x + 106
\end{align*}
\]

\[
\begin{align*}
&\text{Cl}^\text{IV} \text{Zr}^\text{IV} \text{Cp} \text{Cp} \\
&\text{nBuLi} \rightarrow \text{Zr}^\text{II} \text{Cp} \\
&\text{Si} \text{Cp} \text{Cp} \text{Ar} \\
&2x + 106
\end{align*}
\]

\[
\begin{align*}
&\text{Zr}^\text{IV} \text{Cp} \text{Cp} \\
&\text{Si} \text{Cp} \text{Cp} \text{Ar} \\
&2x + 106
\end{align*}
\]

\[
\begin{align*}
&\text{Zr}^\text{IV} \text{Cp} \text{Cp} \\
&\text{Si} \text{Cp} \text{Cp} \text{Ar} \\
&2x + 106
\end{align*}
\]

\[
\begin{align*}
&\text{Zr}^\text{IV} \text{Cp} \text{Cp} \\
&\text{Si} \text{Cp} \text{Cp} \text{Ar} \\
&2x + 106
\end{align*}
\]

\[
\begin{align*}
&\text{Zr}^\text{IV} \text{Cp} \text{Cp} \\
&\text{Si} \text{Cp} \text{Cp} \text{Ar} \\
&2x + 106
\end{align*}
\]

\[
\begin{align*}
&\text{Zr}^\text{IV} \text{Cp} \text{Cp} \\
&\text{Si} \text{Cp} \text{Cp} \text{Ar} \\
&2x + 106
\end{align*}
\]

\[
\begin{align*}
&\text{Zr}^\text{IV} \text{Cp} \text{Cp} \\
&\text{Si} \text{Cp} \text{Cp} \text{Ar} \\
&2x + 106
\end{align*}
\]

\[
\begin{align*}
&\text{Zr}^\text{IV} \text{Cp} \text{Cp} \\
&\text{Si} \text{Cp} \text{Cp} \text{Ar} \\
&2x + 106
\end{align*}
\]

[7+1+7+1]

\[
\begin{align*}
[(2+2+1) + (2+2+1)]
\end{align*}
\]


\[
\begin{align*}
[(3+2+1) + (3+2+1)]
\end{align*}
\]

[(4+1+1) + (4+1) + (4+1)]


[4+4+4+3]

[(3+2) + (3+2) + (3+2)]

Parsons, P.J.; Cooper, N.; Renshaw, M.; Walsh, L.; Coles, M.P. Org. Lett. 2011, 13, 3834

[(2+2+2+1) + (5+0)]

\[(2+2+1) + (2+2+1)\]

[(3+1+1) + (12+0)]