

HETEROCYCLES, Vol. 85, No. 10, 2012, pp. 2415 - 2419. © 2012 The Japan Institute of Heterocyclic Chemistry
Received, 26th July, 2012, Accepted, 29th August, 2012, Published online, 6th September, 2012
DOI: 10.3987/COM-12-12556

RUTHENIUM PORPHYRIN CATALYZED FRIEDEL–CRAFTS TYPE REACTION OF ARENES WITH IMINES

Takuma Terada, Takuya Kurahashi,* and Seijiro Matsubara*

Department of Material Chemistry, Graduate School of Engineering, Kyoto University, Kyoto 615-8510, Japan; tkuraha@orgrxn.mbox.media.kyoto-u.ac.jp; matsubar@orgrxn.mbox.media.kyoto-u.ac.jp

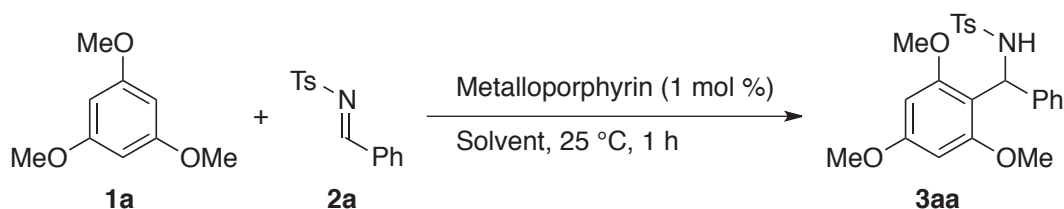
Abstract – Cationic ruthenium porphyrin complex was found to be an efficient catalyst for the Friedel–Crafts type reaction of arenes with imines. The use of a structurally rigid tetradentate porphyrin as the equatorial ligand and weakly coordinating axial ligand is the key to bring out the catalytic reactivity of ruthenium for the reaction.

In the past few decades, many transition metal complexes have emerged as powerful catalyst for the Friedel–Crafts type reaction. The transformation is considered to be triggered by activation of the electrophiles through coordination to electrophilic metal complex to provide key intermediates such as alkyl cations and acyl cations.^{1,2} Thus, taking into account the Lewis acidity of the metal complexes, we supposed that higher-valent complexes that do not oxidize the substrate are favorable catalysts for the Friedel–Crafts type reaction. In this context, we presumed that a cationic high-valent metalloporphyrin would be an ideal catalyst because the structurally rigid tetradentate porphyrin ligand with a large π -conjugated planar aromatic structure can help in maintaining the high oxidation state of the metal throughout the catalytic process.³ Herein, we report that the cationic ruthenium porphyrin complex catalyzes the Friedel–Crafts type reaction of arenes with imines.⁴

Our investigation began with attempted Friedel–Crafts type reaction of trimethoxybenzene (**1a**) with aldimine (**2a**) in the presence of 1 mol % of cationic ruthenium porphyrin catalyst [Ru(TBPP)](SbF₆)₂ in MeCN at ambient temperature for 1 h. This resulted in formation of **3aa** in 97% yield (Table 1, entry 1). Of note, non-ruthenium cationic metalloporphyrin complexes such as [Mn(TPP)]SbF₆, [Fe(TPP)]SbF₆, and [Co(TPP)]SbF₆ did not show any catalytic activity (entries 2 and 4). We also examined the effect of various counteranions such as BF₄[−] and Cl[−], which would act as axial ligands, on the cationic nature of ruthenium (entries 5–6).⁵ The desired product **3aa** was not obtained when using other ruthenium catalysts such as [Ru(TBPP)]Cl₂ and [Ru(TBPP)](BF₄)₂. Among various reaction solvents examined,

toluene gave the best yield of the product (entries 7–9). It was found that the use of mono cationic ruthenium complex $[\text{RuCl}(\text{TPPB})](\text{SbF}_6)$ as a catalyst resulted in formation of **3aa** in slightly lower yield than that of $[\text{Ru}(\text{TPPB})](\text{SbF}_6)_2$ (entry 10).

Table 1. Metalloporphyrin catalyzed reaction of **1a** with **2a**



Entry	Metalloporphyrin	Solvent	3aa (Yield /%) ^a
1	$[\text{Ru}(\text{TBPP})](\text{SbF}_6)_2$	MeCN	97
2	$[\text{Mn}(\text{TPP})]\text{SbF}_6$	MeCN	<1
3	$[\text{Fe}(\text{TPP})]\text{SbF}_6$	MeCN	<1
4	$[\text{Co}(\text{TPP})]\text{SbF}_6$	MeCN	<1
5	$[\text{Ru}(\text{TBPP})]\text{Cl}_2$	MeCN	<1
6	$[\text{Ru}(\text{TBPP})](\text{BF}_4)_2$	MeCN	<1
7	$[\text{Ru}(\text{TBPP})](\text{SbF}_6)_2$	CH_2Cl_2	92
8	$[\text{Ru}(\text{TBPP})](\text{SbF}_6)_2$	1,4-dioxane	96
9	$[\text{Ru}(\text{TBPP})](\text{SbF}_6)_2$	toluene	98
10	$[\text{RuCl}(\text{TBPP})](\text{SbF}_6)$	toluene	97

^aNMR yields are given. ^cTPP, *meso*-tetraphenylporphinato.

^bTBPP, *meso*-tetra(4-*tert*-butyl)phenylporphinato.

With the optimized conditions in hand, we next investigated the scope of the reaction using various imines and the results are summarized in Table 2. Imines **2** possessing electron-withdrawing and –donating substituents on the phenyl group also reacted with **1a** to afford the correspondingly substituted **3** in excellent yields. It is worth to note that acetoxy, cyano, and nitro substituents were well tolerated under the present reaction conditions and the corresponding adducts were isolated in excellent yields. Naphthyl aldimines reacted with **1a** in the presence of the ruthenium catalyst to furnish the correspondingly substituted products **3ag** and **3ah** respectively. Notably, aliphatic aldimine **2i** also reacted with **1a** to afford **3ai** in 96% isolated yield. Imine **2** bearing a nosyl (Ns:

2-nitrobenzenesulfonyl) substituent, which is more easily removable than the tosyl group, reacted with **1a** to yield **3aj** in 67% yield. Furthermore, the reaction of imine possessing Boc and Cbz protection group with **1a** provided **3ak** and **3al** in 90% and 71% isolated yields, respectively.

Table 2. [Ru(TBPP)](SbF₆)₂ catalyzed reaction of **1a** with imines **2**

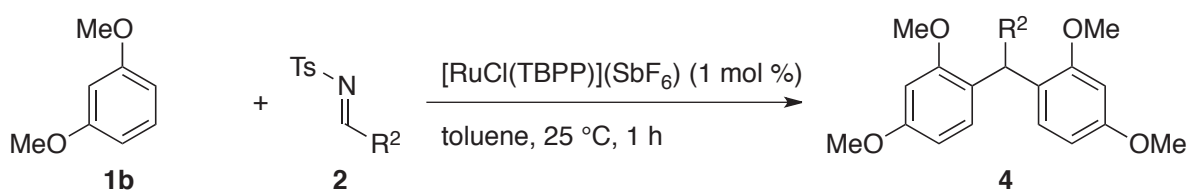
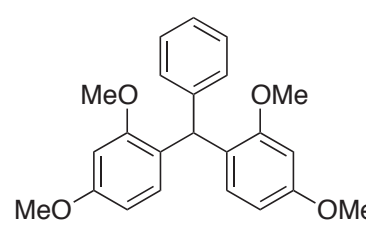
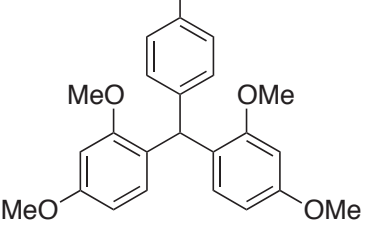
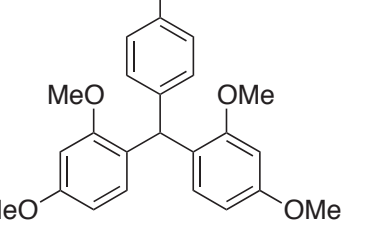
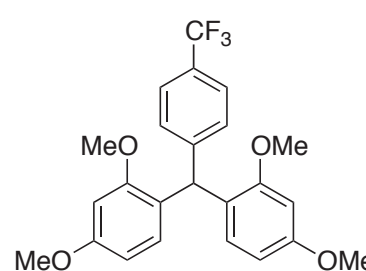
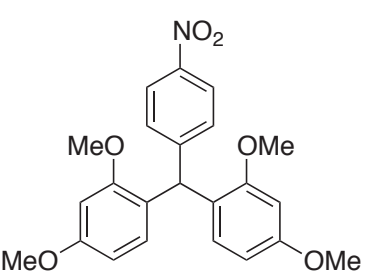
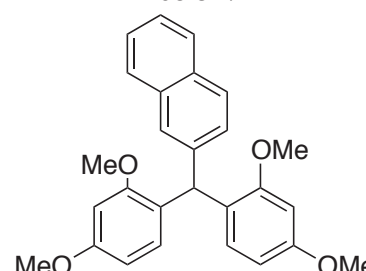
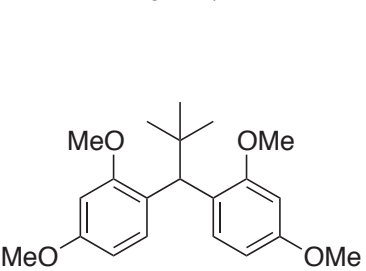
1a	2	3
Product (Yield /%) ^a		
		3aa 86%
		3ab 85%
		3ac 83%
		3ad 94%
		3ae 72%
		3af 71%
		3ag 60%
		3ah 70%
		3ai 96%
		3aj 67%
		3ak 90%
		3al 71%

^aIsolated yields are given.

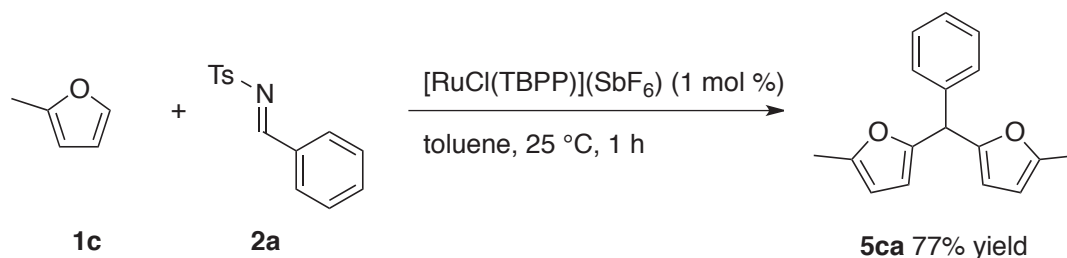
During the course of our study, we found that the reaction of imine **2a** with less sterically hindered arene such as **1b** in the presence of [Ru(TBPP)](SbF₆)₂ catalyst furnish **4ba** in 59% yield via double arylation

and elimination of tosyl amide (Table 3). Further examination of reaction condition revealed that the use of $[\text{RuCl}(\text{TBPP})](\text{SbF}_6)$ in place of $[\text{Ru}(\text{TBPP})](\text{SbF}_6)_2$ gave better result and **4ba** was obtained in 69% yield. Imines **2** possessing electron-withdrawing and -donating substituents on the phenyl group also reacted with **1b** to afford the correspondingly substituted triarylmethanes **4** in excellent yields. Naphthyl aldimines **2g** and **2h** reacted with **1b** to furnish **4bg** and **4bh** in 47% and 49% isolated yields, respectively. Aliphatic aldimine **2i** also reacted with **1b** to afford **4bi** in 44% yield. It was also found that the $[\text{RuCl}(\text{TBPP})](\text{SbF}_6)$ catalyzed reaction of 2-methylfuran (**1c**) in place of **1b** with **2a** also afforded **5ca** in 77% isolated yield via elimination of tosyl amide (Scheme 1). However, the reaction of less electron-rich arenes such as toluene and anisole did not afford any products.

Table 3. $[\text{RuCl}(\text{TBPP})](\text{SbF}_6)$ catalyzed reaction of **1b** with imines **2**

		
Product (Yield /%) ^a		
	4ba 69%	
	4bd 54%	
	4be 52%	
	4bh 49%	
		4bi 44%

^aIsolated yields are given.

Scheme 1. [RuCl(TBPP)](SbF₆) catalyzed reaction of **1c** with imines **2a**

In conclusion, we demonstrated the catalytic efficiency of the ruthenium-porphyrin complexes [Ru(TBPP)](SbF₆)₂ and [RuCl(TBPP)](SbF₆) for the Friedel–Crafts type reaction of imines with arenes. The high activation ability of the catalyst that competes with the high chemoselectivity could be attributed to the cationic ruthenium, which in turn was due to the rigid tetradentate planar porphyrin ligand and the weakly coordinating axial SbF₆ ligand. Efforts toward elucidation of the unique reactivity of the cationic ruthenium-porphyrin complex are underway.

ACKNOWLEDGEMENTS

This work was supported by Grants-in-Aid from the Ministry of Education, Culture, Sports, Science, and Technology, Japan. T. K. acknowledges Asahi Glass Foundation, Tokuyama Science Foundation, Kurata Memorial Hitachi Science and Technology Foundation.

REFERENCES

1. C. Friedel and J.-M. Crafts, *R. Hebd. Seances Acad. Sci.*, 1877, **84**, 1392; M. Bandini, A. Melloni, and A. Umani-Ronchi, *Angew. Chem. Int. Ed.*, 2004, **43**, 550.
2. A. Ishii, V. A. Soloshonok, and K. Mikami, *J. Org. Chem.*, 2000, **65**, 1597; N. Gathergood, W. Zhuang, and K. A. Jørgensen, *J. Am. Chem. Soc.*, 2000, **122**, 12517; W. Zhuang, N. Gathergood, R. G. Hazell, and K. A. Jørgensen, *J. Org. Chem.*, 2001, **66**, 1009; M. P. A. Lyle, N. D. Draper, and P. D. Wilson, *Org. Lett.*, 2005, **7**, 901; P. Thirupathi and S. S. Kim, *J. Org. Chem.*, 2010, **75**, 5240.
3. For some examples of the use of metalloporphyrins in non-oxidative bond formation, see: K. Suda, K. Baba, S.-I. Nakajima, and T. Takanami, *Chem. Commun.*, 2002, 2570; K. Suda, T. Kikkawa, S.-I. Nakajima, and T. Takanami, *J. Am. Chem. Soc.*, 2004, **126**, 9554; J. Chen and C.-M. Che, *Angew. Chem. Int. Ed.*, 2004, **43**, 4950; J. A. R. Schmidt, E. B. Lobkovsky, and G. W. Coates, *J. Am. Chem. Soc.*, 2005, **127**, 11426.
4. R. C. Young, J. K. Nagle, T. J. Meyer, and D. G. Whitten, *J. Am. Chem. Soc.*, 1978, **100**, 4773; W.-H. Leung, T. S. M. Hun, H.-w. Hou, and K.-Y. Wu, *J. Chem. Soc., Dalton Trans.*, 1997, 237.
5. W. Beck and K. Sünkel, *Chem. Rev.*, 1988, **88**, 1405.