CHEMISTRY LETTERS, pp. 1781-1784, 1994.

A New Ruthenium Catalysed Reaction. Benzylation of Functional Aromatic Compounds

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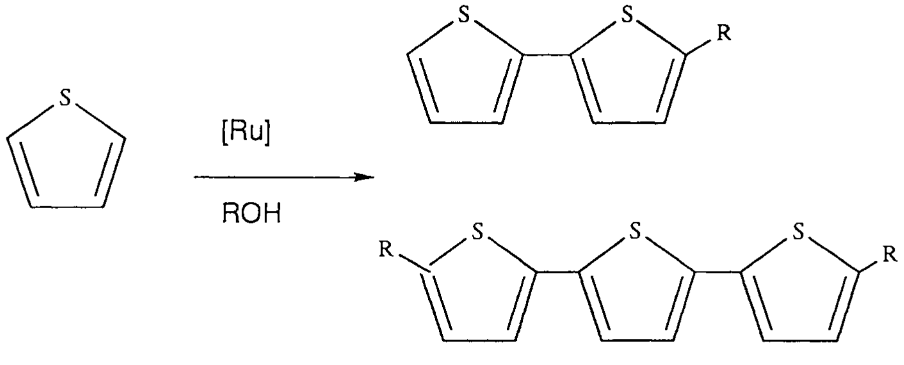
Ruthenium (II) and (III) complexes catalysed of the benzylation of functional aromatic compounds were described. Phenol, benzene and their derivatives were benzylated at 140-160 °C, using a benzylhalide in non-polar solvent or without it.

The benzylation reaction of aromatic substrates, catalysed by Lewis or mineral acids and using benzylalcohols or benzylhalides, is a potential intermediate in organic synthesis.[1)] The general interest of this reaction has increased greatly during the preceding years, as illustrated by the nature of synthetic products and their industrial application derivatives. Benzylphenols are antioxidant agents for a number of organic material.[2)] The benzylation of benzene or alkyl-benzenes leads to synthetic intermediates allowing the modification of the chemical properties of certain types of oils.[3)] We reported some time ago a new alkylation route for heteroarenes[4)] involving a coupling carbon-carbon with ruthenium complexes giving rise to the resultant products, described in Scheme 1.



Scheme 1.

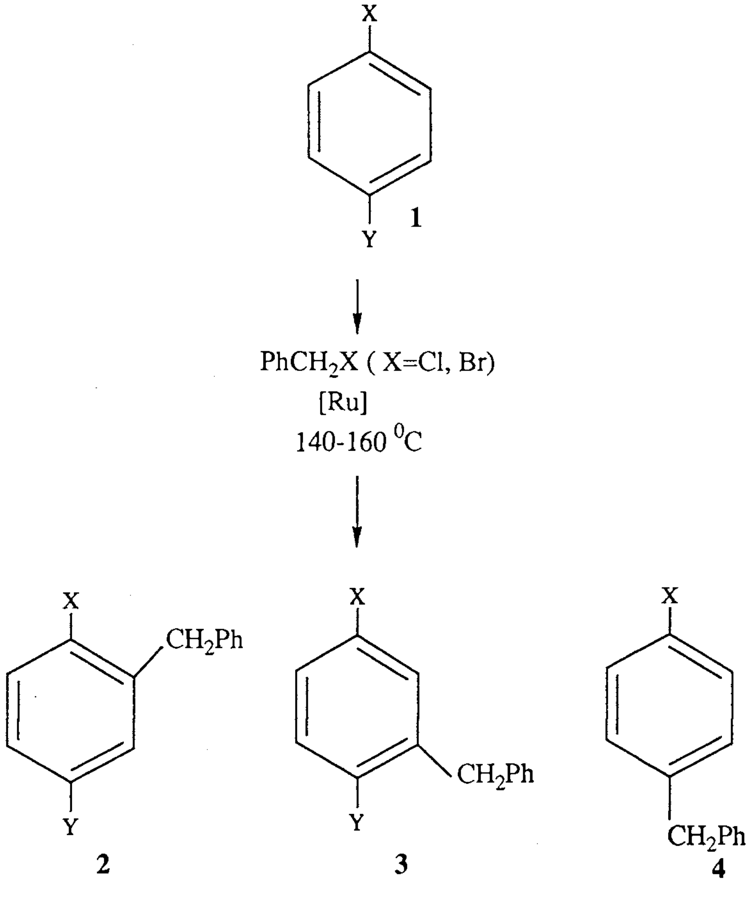
The interest applied in the synthetic uses of activation of C-H aromatic bond by ruthenium (II) and ruthenium (III) led us to extend the study to the alkylation of functional aromatic compounds, using a benzylation agent such as benzylhalide.

We now wish in this preliminary note to report for the first time an original behaviour for ruthenium complexes as Friedel-Crafts benzylation catalysts of phenol, benzene and their derivatives. Table 1 summarises some examples, with $RuCl_3$. xH_2O is found as benzylation catalyst of aromatic compounds activated by

Table 1. Friedel-Crafts benzylation of functional aromatic compounds (Catalyst: $RuCl_3 . xH_2O$)

Entry	Substrate	Yield % a)	Product distribution % b)		
			2	**3**	**4**
1	X=OH,Y=H	58.5(48)	33		67
2	X=OH,Y=CH_3	54.4(42)	39	35	
3	X=OH,Y-Cl	45.0(35)	92	8	
4	X=Y=OH	91.0(78)	100		
5	X=OCH_3,Y=H	52.0(45)	38		62
6	X=Y=H	45.0(29)	100		
7	X=CH_3,Y=H	16.8	20		80
8	X=Y=CH_3	75.0(62)	100		
9	X=C_2H_5,Y=H	78.0(62)	44		56
10	X=Y=Cl	0			
			1-Benzyl-naphthalene	2-Benzyl-naphthalene	
11	naphthalene c)	24.5(18)	70	30	
12	naphthalene d)	35.5(28)	25	75	
13	1-naphthol	61.0(51)	35		65

a) Yields determined by GC analysis (isolated yields). b) Determined by GC (Internal reference: hexadecane). c) Reaction carried out in pentane. d) Reaction carried out without pentane.



Scheme 2.

electro-donating groups as OH, CH_3O, CH_3, C_2H_5. Though, the reaction is applicable to various functional aromatic substrates, the process failed to give the desired product in case of 1,4-dichlorobenzene (entry 10).

It should be noted that the benzylation of anisole in THF, gave the expected products: 2-benzyl and 4-benzylanisoles and in pentane or without solvent, the benzylation process led to the formation of 2-benzyl and 3-benzylphenols. In fact, the bromohydric acid formed during the reaction hydrolysed the methoxy function of anisole (entry 5). Also, the isomers ratio of the benzylated products of naphthalene were in pentane 70/30, became 25/75, if the reaction carried out without solvent (entries 11 and 12).

In a typical procedure: 26.6 mmol of phenol, 29.4 mmol of benzylbromide and 0.25 mmol of $RuCl_3$, xH_2O were combined in a stainless steel autoclave which was rocked and heated at 150 °C for a duration of 24h, whilst stirring under nitrogen. It was allowed to cool to room temperature and 10 cm^3 of THF/pentane 1/1 was added. The resultant mixture was filtered and analysed by GC.

The conversion of phenol into **2** and **4** was 58.5%. The filtrate was evaporated and the residue disolved in ether (5 cm^3) and purified on alumina (elution: benzene - ether), affording **2** and **4** in a total yield of 48%.

A range of ruthenium complexes, as shown in Table 2, have also to act as catalysts for the benzylation of phenol. Ruthenium (II) as well as ruthenium (III) complexes appeared more active than Lewis acids to carry out the benzylation process. There proved to be a greater efficiency in the reaction employing the aprotic solvent (pentane) than that employing in the polar solvent (THF, CH_3CN and CH_2Cl_2). It is also apparent that, without solvent, the ruthenium complexes are able to catalyse the reaction.

Table 2. Effect of the nature of ruthenium complexes on benzylation of phenol.

Catalyst a)	Yield % b)	Phenol c)	
		2-benzyl	4-benzyl
$RuCl_3$, xH_2O	38.5	49	51
$(PcyRuCl_2)_2$	25	48	52
$PcyRuCl_2PMc_3$	35	44	56
$RuCl_3$, xH_2O + PBu_3	37	48	52
$Ru_3(CO)_{12}$	12	31	69
$[Ru(CO)_2(OAc)(PPh_3]_2$	27	57	43
$ZnCl_2$	20	60	40
$SnCl_2$	18.5	63	37

a) Reaction's solvent: THF. b) Isolated yields. c) Determined by GC analysis.

In addition, we have studied the effect of the nature of the benzylation agent on reaction. The presence of electro-withdrawing (Br, Cl, NO_2) or electro-donating (CH_3O) groups had no effect. The conversion of phenol into benzylated product varied in the range of 50-65%. With benzylchloride, the conversion of phenol was 45%.

Prior to concluding, it should be pointed out that the factors determining the mechanism of the benzylation process, are not completely understood. The formation of bibenzyl as major by-product (10-20%) in the reaction suggests a coupling of two radicals of benzyl, assumed to form in our reactional conditions due to the free radical behaviour of ruthenium complexes with alkylhalides. 5)

Consequently, the benzylated product may have resulted from the addition of benzyl radical to the double bond. This mechanism is supported by the fact of the possibility to recycle the catalyst at the end of the reaction, and used it for a new catalytic process.

References

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(Received June 9, 1994)