ZEOLITES AS CATALYSTS IN ORGANIC REACTIONS. CLAISEN-SCHMIDT CONDENSATION OF ACETOPHENONE WITH BENZALDEHYDE

M.J. CLIMENT *, H. GARCIA, J. PRIMO

Departamento de Química, ETSII, Universidad Politécnica de Valencia, Apartado 22012, 46071-Valencia, Spain

and

A. CORMA

Instituto de Catálisis y Petroleoquímica, C.S.I.C., Serrano 119, 28006-Madrid, Spain

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HY zeolites catalyze the crossed aldol condensation of acetophenone with benzaldehyde, in benzene at 80 ° C, to give trans- and cis-chalcones. Together with these expected products, 3,3-diphenylpropiophenone is also produced. In the analogous basic condensation, using phase transfer catalysis, the Michael adduct was not detected, and besides chalcone a small percentage of the Cannizzaro reaction product was observed.

1. Introduction

Substituted chalcones constitute important key intermediates, especially in the synthesis of naturally ocurring heterocyclic compounds of the flavonoid family [1]. The most general preparation procedure for these types of organic substrates consists of the Claisen-Schmidt condensation of aryl ketones with benzaldehydes [1,2].

Although basic condensating agents are usually employed, acid catalysts could have the advantage of avoiding the competitive Cannizzaro reaction of the aldehyde and also other undesired side reactions when base-sensitive groups are involved.

It has been reported [3] that acid zeolites can catalyze crossed aldol reactions of an aliphatic aldehyde with formaldehyde. As far as we know, these results have not been applied to general organic synthesis in the liquid phase at moderate temperatures, where the use of zeolites [4] and clays [5] as heterogeneous catalysts still remains quite limited.

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* To whom correspondence should be addressed.

In the present work we report the use of large pore HY zeolites as catalysts for the crossed aldol condensation of acetophenone with benzaldehyde. Since many useful synthetic procedures are based on this type of reaction [6], we feel that our results are relevant so far as extending the scope of zeolites in organic reactions [7].

2. Experimental

A HY zeolite was prepared starting from a SK-40 NaY. Sodium was exchanged by NH_4^+ at 80 ° C, and then the sample was calcined at 550 ° C. Exchange-calcination was repeated several times. The sodium content of the final HY sample was lower than 0.02% wt, and the unit cell size of the zeolite was 24.40 Å.

The acid condensation was performed by heating at 80 ° C a benzenic solution (50 ml) of equimolar amounts of acetophenone (120 mg) and benzaldehyde (105 mg) in the presence of the HY sample (1 g), previously activated at 150 ° C and 1 Torr for 3 h. Reaction proceeds cleanly to give, trans and cis chalcones (1 and 2) and 3,3-diphenylpropiophenone (3); no other products were detected by GC/MS (Hewlett-Packard 5988 A) in the reaction mixture.

Basic condensation of acetophenone (1.20 g) and benzaldehyde (1.06 g) was carried out under phase transfer conditions stirring at room temperature an equimolecular mixture of both carbonyl compounds in benzene (50 ml), with an aqueous solution (10 ml) of NaOH (2.50 g) and tetraethylammonium hydroxyde (1.00 g) as catalyst. After 2 hours, the benzenic layer was collected and the aqueous solution was acidified with diluted HCl and extracted throughly with CH_2Cl_2. The analysis (GC/MS) of the reaction mixtures indicated the presence of trans- (89%) and cis-chalcone (3%), benzoic acid (2%) and benzyl alcohol (2%).

3. Results and discussion

From fig. 1 it is seen that both cis and trans chalcones are formed, the ratio of trans to cis being close to 11. Besides the chalcones, 3,3-diphenylpropiophenone is also formed (scheme 1). Products arising from the self condensation of acetophenone or alkylation of benzene by benzaldehyde are not formed. This can be explained by a greater reactivity of aldehyde carbonyl groups and the higher nucleophilic character of the enolic species. This is consistent with the reported preferent obtention of chalcones under basic conditions using phase transfer catalysis where, however, benzoic acid and benzyl alcohol (the Cannizzaro products) are present and the Michael adduct could not be detected.

Two routes can be envisaged to explain the formation of 3,3-diphenylpropiophenone in the HY catalyzed reaction. One through the condensation of the

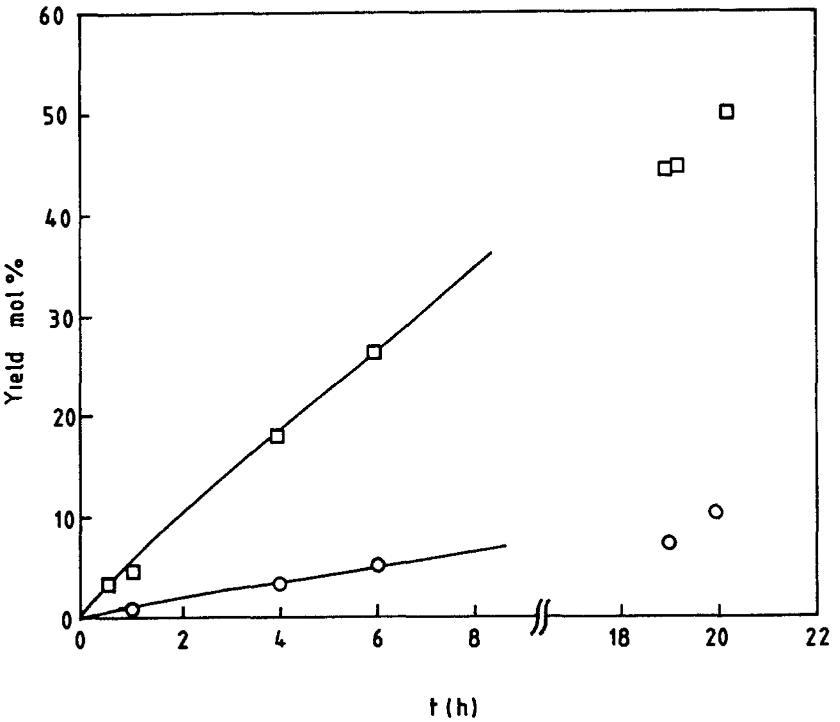
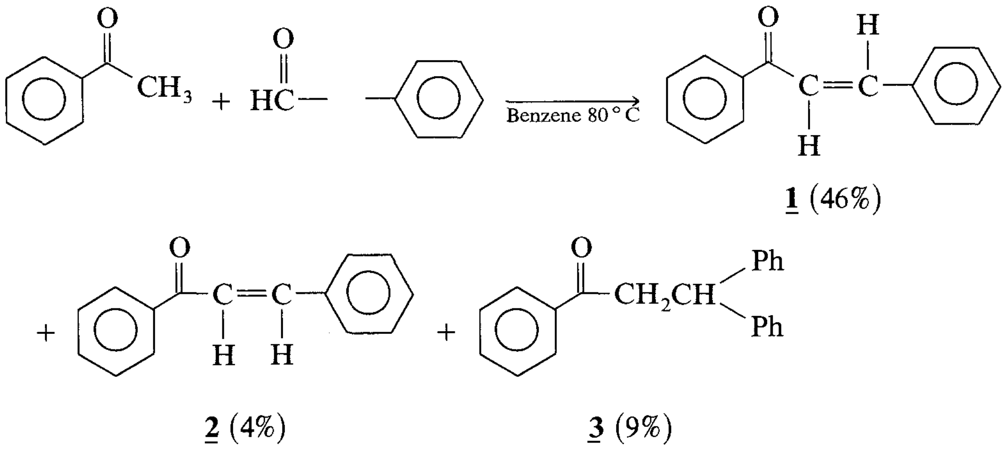
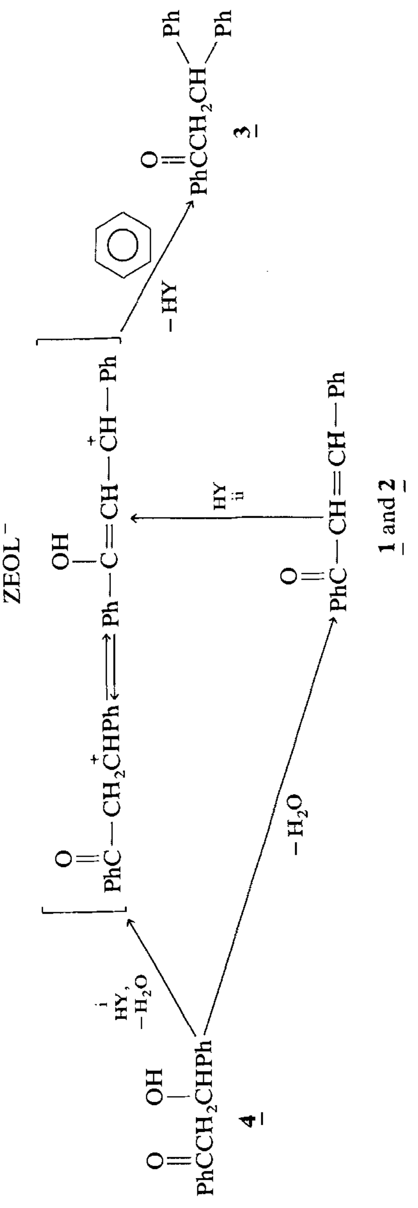


Fig. 1. Products formed during the condensation of acetophenone with benzaldehyde. Cis plus trans-chalcone (□); 3,3-diphenylpropiophenone (○).

intermediate non isolable 3, hydroxy-3-phenylprophenone (4) followed by the attack of a benzene molecule from the solvent (route i in scheme 2). The other would involve the protonation of the chalcones, probably at the carbonyl oxygen atom, to generate a strong electrophilic intermediate which can attack the benzene ring from the solvent (route ii in scheme 2).



Scheme 1.



Scheme 2.

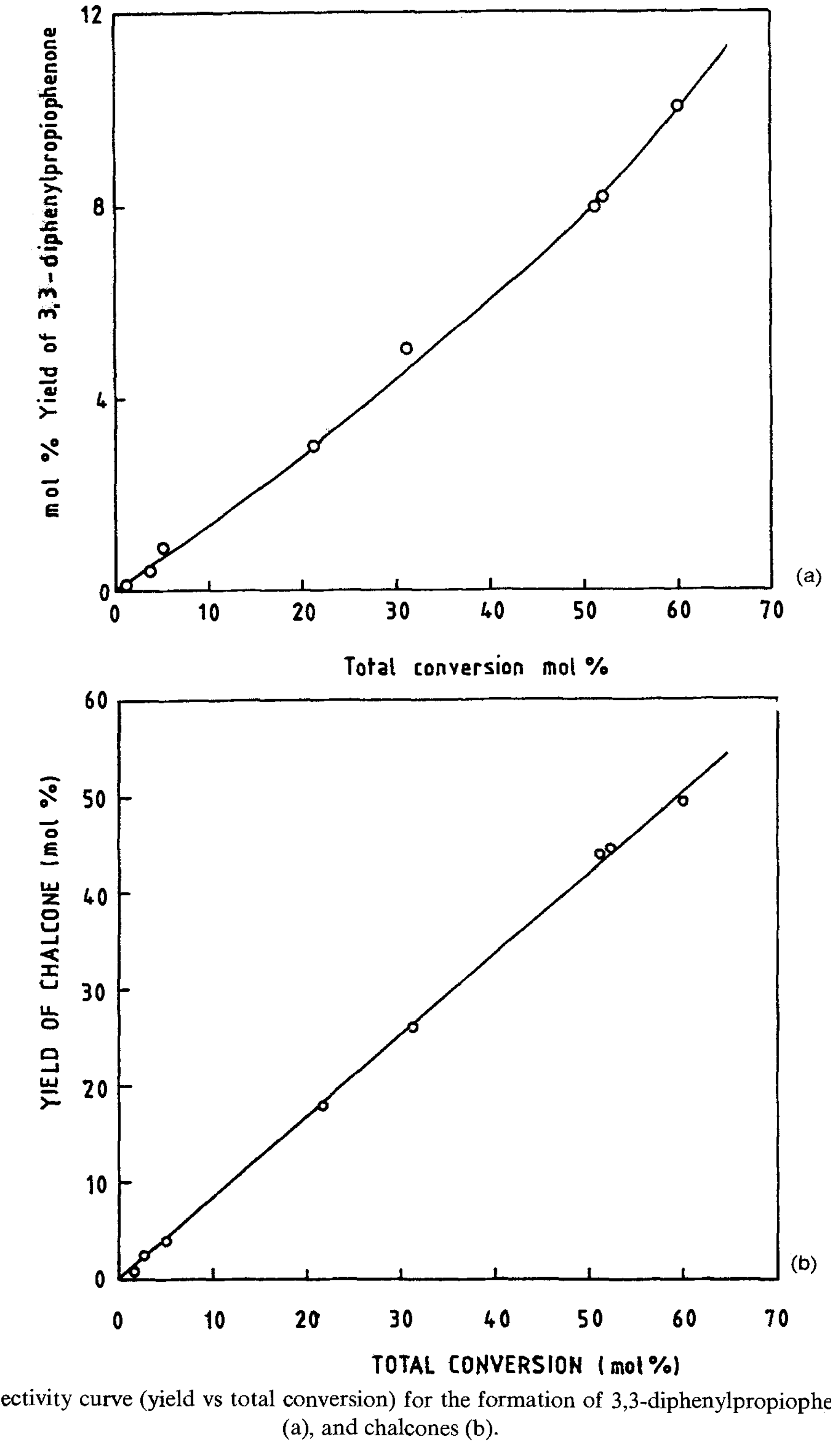


Fig. 2. Selectivity curve (yield vs total conversion) for the formation of 3,3-diphenylpropiophenone (a), and chalcones (b).

In the first case it should appear as a primary and stable product, while in the second case as a secondary and stable product. Finally, if the reaction can occur in both ways, 3,3-diphenylpropiophenone should behave as a primary plus secondary stable product.

Figure 2a shows that the curve of yield of (3) versus total conversion has a positive slope when total conversion goes to zero, indicating that this is a primary product. Moreover, the slope increases with conversion showing that it is also a secondary product, i.e., it is also formed by protonation of chalcones. From these results, one would expect the chalcones to behave as a primary and unstable product. Figure 2b does not show, however, such unstability, probably due to the comparatively lower rate of formation of 3,3-diphenylpropiophenone from chalcones, with respect to the formation of chalcones, and even with respect to the reaction of route i.

It is noteworthy that the normal preparation of 3 starting from chalcone requires the addition of strong nucleophilic (basic) reagents, usually phenylmagnesium bromide. In this context it is significant that the aryl ketone 3 has been formed in acid medium, in which the weakly attacking nucleophil is benzene itself. This fact indicates that the acid sites of the zeolite must have a strong interaction with the precursor, making this substract much more susceptible to nucleophilic reactions.

In summary, we have shown that HY zeolites catalyze the Claisen-Schmidt condensation of acetophenone with benzaldehyde, in the liquid phase and at moderate temperature, to give chalcones (1, 2). Together with these products 3,3-diphenylpropiophenone is also present in the final reaction mixture. Current work is now directed to determine the influence of the structure features of zeolites on the course of the reaction, as well as to the synthesis of related compounds.

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References

[1] a) J.B. Harborne, T.S. Mabry and H. Mabry, *The Flavonoids* (Academic Press, New York, 1976);
b) S.B. Harborne and T.J. Mabry, The flavonoids: in: *Advances in Research* (Chapman and Hall, New York, 1982).
[2] D.N. Dahr, *The Chemistry of Chalcones and Related Compounds* (Wiley, New York, 1981).
[3] G.P. Hagen, U.S. Pat. 4433174 (February 21, 1984) Standard Oil Company.
[4] W. Hölderich, M. Hesse and F. Näumann, Angew. Chem. Int. Ed. Engl. 27 (1988) 226.

[5] J.H. Purnell, J.M. Thomas, P. Diddams, J.A. Ballantine and W. Jones, Catal. Lett. 2 (1989) 125, and references thereof.

[6] H.O. House, *Modern Synthetic in Organic Synthesis*, 2nd ed. (W.A. Benjamin, New York, 1972).

[7] a) A. Corma, H. García and J. Primo, J. Chem. Res. 5 (1988) 40;
b) A. Corma, M.J. Climent, H. García and J. Primo, Appl. Catal, in press.