Montmorillonite K10 Clay-Microwave Assisted Isomerisation of Acetates of the Baylis-Hillman Adducts: A Facile Method of Stereoselective Synthesis of (*E*)-Trisubstituted Alkenes

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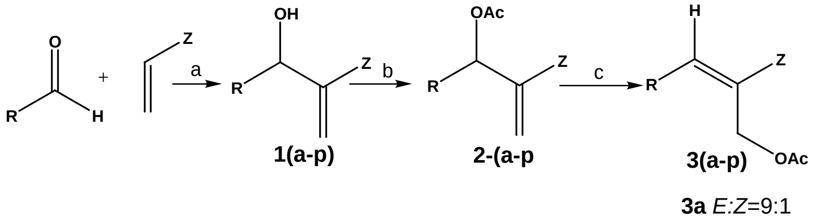
Dedicated to Professor K. Rajagopalan on the occasion of his 60th Birthday.

Abstract: Montmorillonite K10-microwave assisted stereoselective isomerisation of acetates of the Baylis-Hillman adducts furnished (*E*)-trisubstituted alkenes in high yields. A comparative study of this reaction with Mont-K10, ion-exchanged clay (Fe^{3+}-Mont-K10) and acid treated regional natural Kaolinite clay and the efficiency of these clays in this reaction is described.

Key words: montmorillonite K10 clay, microwave, stereoselective isomerisation, Baylis-Hillman reaction, *E*-alkenes, ion-exchanged clay, natural kaolinite clay

The usefulness of montmorillonite K10 clay in organic synthesis and its application as a catalyst for a number of organic reactions are well documented.[1-4] The montmorillonite K10 and its structurally modified clays are known to act as both Bronsted and Lewis acid catalysts for a variety of industrially important organic reactions.[1] The clay catalysts are known as eco-friendly acid catalysts which have potential for replacing the conventional mineral acids and are non-pollutant. The advantages of the clay-catalyzed reactions are that they are generally mild, solvent free and work-up is easy. The Baylis-Hillman reaction is one of the important Carbon-Carbon bond forming reactions and has been used in organic synthesis for the synthesis of a variety of compounds having diverse functional groups and has been used as the starting point for a variety of synthetic organic transformations.[5-13] Stereoselective synthesis of (*E*)-trisubstituted alkenes is one of the difficult tasks in organic synthesis and only a few methods are known in the literature.[8, 9,14] Stereoselective isomerisation of acetates of Baylis-Hillman adducts catalyzed by TMSOTf,[8,9] trifluoroacetic acid,[10] benzyl-trimethylammonium fluoride[11] have appeared in the literature. Montmorillonite K10-microwave combination has been utilized for effecting many organic transformations as a catalyst.[15-17] In continuation of our research work on clay catalysis, [18-20] we herein report the mont- K10-microwave assisted stereoselective isomerisation of acetates of Baylis-Hillman adducts into its (*E*)- trisubstituted olefins.

The general isomerisation studies are schematically represented in Scheme 1. The Baylis-Hillman acetate adducts **2 (a-p)** were prepared according to the literature procedure.[8] Stirring the acetate **2a** with 50% w/w montmorillonite K10 clay in CH_2Cl_2 at r.t. for 48 h furnished the starting material with 20% deacylated product. Heating the same reaction mixture at reflux for 24 h again furnished only the starting material. However, when a slurry of the acetate **2a** with 50% w/w mont-K10 clay without any solvent was irradiated in a microwave oven for 6 min., a clean isomerised product **3a** was obtained in 60% yield (5-10% decomposition) as determined by ^1H NMR. Among the several variations tested to optimize the condition,[21] the following conditions involving acetate **2a** with 30% w/w of mont-K10 clay, 70% microwave power level (PL) and 13 min. irradiation time was found to be best and yielded the clean isomerised product **3a** (in 9:1, *E:Z* isomer)[22] in 74% after column purification. The microwave irradiation of the acetate **2a** under similar conditions without any clay furnished the starting material quantitatively confirming the necessity of clay catalyst for this reaction. Adduct **2a** (deacetylated) under similar conditions furnished 20% of the isomerised product with remaining decomposed products. Hence acetate protection of the Baylis-Hillman adducts is necessary for good yields. The results are summarised in Table 1.



R=Ph, 4-Cl-Ph, 2,4-Cl_2-Ph, 4-CH_3-Ph, 4-CH_3O-Ph, Naphth-1-yl, Naphth-2-yl;
Z= CO_2Et, CN, $COCH_3$

Scheme 1 *Reagents and Conditions:* a) DABCO, Neat; b) Acetyl chloride, Py. 0 °C, 1h; c) 30% w/w mont. K10, MW, 13 min (70% PL), Neat, 57–80%.
Isomerisation of Baylis-Hillman adducts catalysed by mont.K10-microwave irradiation

Table 1 Mont K10 clay[a]-Microwave[b] combine assisted isomerisation of Baylis-Hillman acetates **2a** into **3a** under various conditions.

Entry	Condition	Product	*E/Z*[c]
1	50% w/w mont-K10, CH_2Cl_2, RT, 48 h	**2a** recovered with 20% deacylated product.	-
2	50% w/w mont-K10, CH_2Cl_2, 40 °C,24h	**2a** recovered quantitatively.	-
3	MW, 6 min. without clay	**2a** recovered quantitatively.	-
4	50% w/w mont. K10, MW, 6 min.	**3a** isolated in 60% (5-10% decomposition).	9:1
5	30%w/w mont. K10,MW,13min(70%PL)	**3a** isolated in 74% yield.	9:1

[a] Montmorillonite K10 clay was dried at 85 °C for 2h before each use.

[b] Microwave irradiation was carried out on a KenStar (model MWO 9817) microwave oven (800 W/operating frequency 2450 MHz).

[c] *E/Z* ratio was assigned based on ^{1}H and ^{13}C NMR.

Table 2 Montmorillonite K10 clay [a]-microwave combine assisted isomerisation of Baylis-Hillman acetates **2 (a-p)** into **3(a-p)**

Entry	Reactant	R	Z	Condition[c]	Product, *(E/Z)*[d]	Yield (%)[e]
1	**2a**	-Ph	$-CO_2Et$	Clay, MW, 13 min.	**3a**, 9:1	74
2	**2b**	-Ph	-CN	Clay, MW, 15 min.	**3b**, 9.5:0.5	68
3	**2c**	-Naphth-1-yl	$-CO_2Et$	Clay, MW, 13 min.	**3c,** 9.4:0.6	70
4	**2d**	-Naphth-1-yl	-CN	Clay, MW (80%PL), 16 min.	**3d,** 9.2:0.8	62
5	**2e**	4-Cl-Ph-	$-CO_2Et$	Clay, MW, 13 min.	**3e,** 9.3:0.7	60
6	**2f**	4-Cl-Ph-	-CN	Clay, MW (80%PL), 16 min.	**3f,** 9.5:0.5	57
7	**2g**	-Ph	$COCH_3$	Clay, MW, 13 min.	**3g,** 9.6:0.4	59
8	**2h**	4-Me-Ph	$-CO_2Et$	Clay, MW, 13 min.	**3h,** 9:1	71
9	**2i**	4-Me-Ph	-CN	Clay, MW (80%PL), 16 min.	**3i,** 8:2	66
10	**2j**	2,4-Cl_2-Ph	$-CO_2Et$	Clay, MW, 13 min.	**3j,** 9.2:0.8	72
11	**2k**	2,4-Cl_2-Ph	-CN	Clay, MW (80%PL), 16 min.	**3k,** 8.7:1.3	70
12	**2l**	4-MeO-Ph	$-CO_2Et$	Clay, MW, 13 min.	**3l,** 9.6:0.4	80
13	**2m**	4-MeO-Ph	-CN	Clay, MW (80%PL), 16 min.	**3m,** 9.2:0.8	76
14	**2n**	-Naphth-2-yl	$-CO_2Et$	Clay, MW, 13 min.	**3n,** 9.1:0.9	68
15	**2o**	-Naphth-2-yl	-CN	Clay, MW (80%PL), 16 min.	**3o,** 9.5:0.5	62
16	**2p**	4-Me-Ph	$COCH_3$	Clay, MW, 13 min.	**3p,** 9.1:0.9	65

[a] Montmorillonite K10 clay was dried at 85 °C for 2 h before each use.

[b] Microwave irradiation was carried out on a KenStar microwave oven with 70% PL.

[c] 30% w/w montmorillonite-K10 clay was used in each case.

[d] *E/Z*-ratio was assigned based on ^{1}H and ^{13}C NMR.

[e] After column purification.

In order to exemplify the general nature of this reaction, we chose a variety of Baylis-Hillman adducts **2(a-p)**, which underwent facile isomerisation with mont-K10-microwave combination to give clean isomerised products **3(a-p)** in good yield. Yields of adduct with nitrile and carbonyl groups were lower compared to the ester functional group at the activated alkene and needed longer irradiation time with higher power level. The isomer ratio (*E:Z*) of the isomerised products were as estimated by ^{1}H NMR (by integrating the peaks at δ 7.9 and 7.83) (for -CN substitution the ratio is more comparable to the $-CO_2Et$ substitution at the alkene). The results are summarised in Table 2.

The efficiency of commercial montmorillonite-K10 (2:1 layer type, available from Aldrich Co.,)[1,2] clay was compared with Fe^{3+}-mont-K10[23] (an ion exchanged clay) as well as acid treated regional natural kaolinite clay.[24,25] The use of Fe^{3+}-mont-K10 was found to be as good as montmorillonite K10 clay while with acid treated regional natural kaolinite (1:1 layer type) clay, the reaction was unsuccessful and starting material was recovered quantitatively. The reason for this observation with natural kaolinite clay[24,25] may be that the interlayer distance is < 7 Å when compared to montmorillonite K10 clay whose interlayer gap is 10 Å where the clay reactions actually taken place.[1,2] Due to the small interlayer distance in the acid treated regional natural kaolinite clay,[25] the reacting molecules are presumably unable to enter the interlayer space and hence the reaction failed. The results are summarised in Table 3. The clay recovered from the reaction mixture by filtration can be recycled three times without losing its activity by activating the clay at 100 °C for 3 h. In conclusion, we have demonstrated the usefulness of

Table 3 Comparison of mont-K10[a], Fe^{3+}-mont.-K10[a] and acid treated regional natural kaolinite clay catalysts on isomerisation of acetate of the adduct **2a** into **3a.**

Clay	Condition [b]	*E/Z*-Ratio [c]	Yield (%)[d]
Montmorillonite- K10	30% w/w clay, MW, 13 min.	9:1	74
Fe^{3+}-mont. K10	30% w/w clay, MW, 6 min	9:1	72
Natural kaolinite clay	30% w/w clay, MW, 8 min	-	No reaction

[a] All the clays were dried at 85 °C for 2 h before each use.

[b] Microwave irradiation was carried out on a KenStar microwave oven (70% PL).

[c] *E/Z*- ratio was estimated based on ^{1}H and ^{13}C NMR.

[d] After column purification

montmorillonite K10 clay-microwave combination as an alternative, useful, speedy and efficient catalyst for the isomerisation of a variety of acetates of Baylis-Hillman adducts which provides stereoselective (*E*)-alkenes. Further studies involving the above catalyst system are underway.

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(21) ***Typical experimental procedure for isomerisation:*** A mixture of the acetates of Baylis-Hillman adducts (200 mg, 0.8 mmole) and montmorillonite K-10 (60 mg, 30% w/w of the adduct) was taken in a stoppered 25 mL conical flask and irradiated in the microwave oven (70% power mode) for 13 minutes. The mixture was cooled to room temperature and treated with CH_2Cl_2 (10 mL). Montmorillonite K-10 clay was recovered by filtration and washed with CH_2Cl_2 (2 x 5 mL). The solvent was removed in vacuo and the crude mixture was purified by silica gel column chromatography using petroleum ether-ethyl acetate (92:8) to give pure colourless isomerised products in 9:1 (*E:Z*) isomers as estimated by ^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz).

(22) The ^{1}H NMR spectra of the isomerised product **3a** showed a peak at δ 7.83 for the presence of *E*-vinylic proton and a minor peak at δ 7.9 for *Z*-isomer. In the ^{13}C NMR spectra of trisubstituted olefins, the allylic carbon *cis* to aromatic group appears up field while the same carbon *trans* to aromatic ring appears down field. The values we obtained herein are exactly matching with the values reported[8,9] in the literature.

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