

Ultrasound Methodology for the Synthesis of 2-(4-nitrophenyl)-phenylacetonitrile with Phase-Transfer Catalysis Condition – A Kinetic Study

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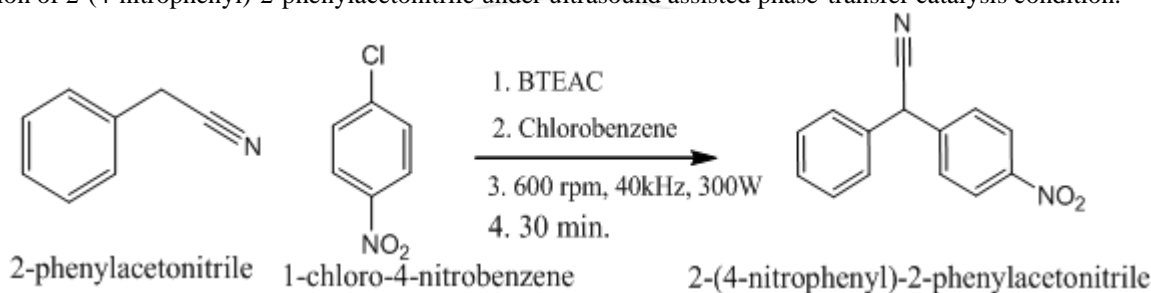
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Graphical Abstract

Preparation of 2-(4-nitrophenyl)-2-phenylacetonitrile under ultrasound assisted phase-transfer catalysis condition.



Abstract: A single-site phase-transfer catalyst viz., Benzyltriethylammonium chloride (BTEAC) containing the catalytic efficiency of BTEAC was ascertained by comparing with another single-site phase-transfer catalyst viz., tetraethylammonium chloride (TEAC) with ultrasonic irradiation (40 kHz, 300W) performed. The pseudo-first-order kinetic equation was applied to describe the overall reaction under ultrasound irradiation (40kHz, 300W) in a batch reactor, the yield of product 2-(4-nitrophenyl)-2-phenyl acetonitrile in the organic phase was 98.6% in 30 min at 65°C and 600 rpm with the observed k_{app} value (TEAC: $k_{app} = 5.12 \times 10^{-3}, \text{min}^{-1}$) almost five fold lesser than Benzyltriethylammonium chloride BTEAC ($k_{app} = 26.72 \times 10^{-3}, \text{min}^{-1}$) along with ultrasound irradiation (40kHz, 300W). The present study provides a method to synthesize 2-(4-nitrophenyl)-2-phenyl acetonitrile by ultrasound-assisted liquid-liquid phase – transfer catalysis.

Keywords: Phase-transfer catalysis; phase-transfer catalyst; ultrasound irradiation; phenylacetonitrile; 1-chloro-4-nitrobenzene

1. Introduction

As the chemical reactants reside in immiscible phases, phase-transfer catalysts have the ability to carry out the heterogeneous reactions by one of the reactants penetrating from its normal phase (generally aqueous phase) to the organic phase where the reaction takes place, which gives a high conversion and selectivity for the desired product under mild reaction conditions [1]. Ever since [2] found that quaternary onium salts as an effective catalyst for enhancing the two-phase reaction, this methodology occupies a unique niche in organic synthesis and it is a commercially matured discipline with over six hundred applications [3] covering a wide spectrum of industries such as pharmaceuticals, agrochemicals, dyes, perfumes, flavours, specialty polymers, pollution control, etc. As the application of phase-transfer catalysts (PTC) grew, much effort was placed on the development of phase-transfer catalysts with higher catalytic efficiency. To this end, researchers have developed “multi-site” phase-transfer catalysts (MPTC) for much higher activity than normal phase-transfer catalysts. Recently, the catalytic behaviour of multi-site phase-transfer

catalysts have been attracted much attention, due to the fact that multiple molecules of the aqueous reactant can be carried into the organic phase once a reaction cycle, thus the catalytic efficiency is enhanced [4 - 6].

Currently, a new analytical and process experimental techniques which are environmental benign techniques viz., ultrasound and microwave irradiation have become immensely popular in promoting various organic reactions [7, 8]. Ultrasound irradiation has been broadly applied in organic synthesis, and shows a good improvement in the reaction rate. When the ultrasonic waves propagate in a liquid solution, the alternate compression and depression are produced to form cavities, within which temperature and pressure can reach 5000K and several hundred bars, and the reaction rate is thus enhanced [9 - 11].

Apparently, the combination of ultrasound irradiation with phase-transfer catalysis might give a synergy effect in promoting the reaction [12, 13]. The Cannizzaro reaction catalyzed by a phase-transfer catalyst under ultrasonic wave of 20 KHz dramatically accelerated the reaction [14]. The liquid-liquid phase-transfer catalyzed

dichlorocyclopropanation of 1,7-octadiene was reported using benzyltriethylammonium chloride as catalyst assisted by ultrasound irradiation, giving the reaction rate greatly accelerated [15]. The reaction of oximes and dichloromethane by PTC assisted by ultrasound got 95% in the silence condition was 16h [16]. Ultrasound irradiation combined with liquid-liquid phase-transfer catalysis reveals a significant improvement in the reaction rate [14 - 17].

C-arylation of phenyl acetonitrile is one of the most widely studied PTC reactions in fine chemical industries which provide pharmaceutically valuable products or intermediates for the synthesis of perfumes, fragrances and plant protection agents [17 -20]. In the present study, we have synthesized a novel multi-site PTC containing three active sites and its catalytic efficiency was studied through C-arylation of phenyl acetonitrile with 1-chloro-4-nitrobenzene assisted by ultrasound were explored.

2. Experimental

2.1 Chemicals

1-chloro-4-nitrobenzene (SRL), sodium hydroxide (SRL), phenylacetonitrile, diethyl ether, Benzyltriethylammonium chloride (SRL), ethanol (SRL) was used without further treatment.

2.2 Instrumentation

FT-IR Spectra were recorded on a Bruker-Tensor 27 FT-IR spectrophotometer. ^1H NMR and ^{13}C spectra were recorded on a Bruker 400 MHz and 100 MHz respectively using TMS as an internal standard. Gas chromatography was carried out using a GC-Varian 3700 model. Ultrasonic water bath, Equitron, Media Instrument Manufacturing Company, Chennai, India-600 004.

3. Ultrasonic Process Equipment

Ultrasonic energy is transmitted to the process vessel through the liquid medium, usually water in the tank. For safety purpose, the sonochemical reactor consisted of two layers of stainless steel body. The sonochemical reactor configuration used in the present work is basically an ultrasonic bath. The internal dimension of the ultrasonic cleaner tank is 48 cm x 28 cm x 20 cm with liquid holding capacity of 5 litres with 40 kHz, 300W. The reactor was a 250 mL three-necked Pyrex round-bottom flask. This reaction vessel was supported at the corner of the ultrasonic cleaning bath 2 cm above from the position of the transducer to get the maximum ultrasound energy.

4. Synthesis of 2-(4-nitrophenyl)-2-phenylacetonitrile

To the mixture of NaOH (20 g, 0.1449 mol) in water (15 mL) and Benzyltriethylammonium chloride (BTEAB) PTC (0.3 g, 4.3859×10^{-4} mol), phenyl acetonitrile (0.5 g, 4.27×10^{-3} mol) was added under overhead stirring to generate the anion. Then 1-chloro-4-nitrobenzene (0.80 g, 5.09×10^{-3} mol) in chlorobenzene (40 mL) was added slowly. The

reaction mixture was heated at 65°C for 6 hours with vigorous stirring. The crude product was isolated by simple extraction with diethyl ether (3 x 25 mL). The organic layer was collected and the solvent was evaporated under reduced pressure. The crude product was chromatographic (SiO_2) employing hexane: ethyl acetate (9:1) as an eluent to obtain a pure monoderivative scheme 1. The identity of the product was confirmed by ^1H NMR and ^{13}C NMR spectra of the product. m.pt. 121-123°C; Yield: 91%; ^1H NMR (300 MHz, CDCl_3): δ 5.087 (s, 1H, CH-CN), 7.264, 8.364 (m, 9H, Ar-CH). ^{13}C NMR (75MHz, CDCl_3): δ 42.78(CH-CN), 125.54, 128.68, 130.09, 130.68, 133.45, 136.32, 142.91, 149.86 (Ar-CH).

5. Reaction mechanism and kinetic model

For synthesizing 2-(4-nitrophenyl)-2-phenylacetonitrile compound, the overall reaction of phenyl acetonitrile and 1-chloro-4-nitrobenzene (CNB) was catalysed by the PTC (BTEAC) (Q^+Cl^-) in the aqueous alkaline (NaOH) bi-phase medium and is represented in scheme 2. The reaction is carried out under PTC assisted ultrasonic irradiation condition. In the current investigation the kinetics was followed in the presence of an excess amount of phenyl acetonitrile and by fixing 1-chloro-4-nitrobenzene as limiting agent. The main reason for investigating this reaction is, the effect of low frequency ultrasound irradiation (40 kHz, 300 W) along with agitation speed (600 rpm) to find out the effect of change of k_{app} value of this system.

5.1 Definition

The conversion (X) of 1-chloro-4-nitrobenzene (CBN) is defines as follows:

$$X = 1 - \frac{[\text{CNB}]_t}{[\text{CNB}]_{0,i}} \quad (1)$$

Where $[\text{CNB}]_0$ and $[\text{CNB}]_{0,i}$ represent the concentration of butyl bromide at time (t) $t=0$ and $t>0$, respectively.

5.2 Rate expression

The rate expression for this reaction may be expressed as ;

$$-r_{\text{CNB}} = k_{\text{app}} [\text{CNB}]_0 \quad (2)$$

Where k_{app} is the apparent reaction rate constant. This reaction is carried out in a batch reactor, so the diminution rate of CNB with time (t) can we expressed as

$$-d[\text{CNB}]_0 / dt = -r_{\text{CNB}} = k_{\text{app}} [\text{CNB}]_0 \quad (3)$$

on integrating the Eq. (3) yields:

$$-\ln \left\{ \frac{[\text{CNB}]_t}{[\text{CNB}]_{0,i}} \right\} = -\ln(1-X) = k_{\text{app}} t \quad (4)$$

Using Eq. (4), we can get the k_{app} value experimentally by plotting $-\ln(1-X)$ against time, (t).

6. Results and Discussion

The reaction was conducted on a 250 mL three-necked Pyrex round-bottom flask which permits agitating the solution, inserting the water condenser to recover organic reactant and taking samples and feeding the reactants. This reaction vessel was suspended at the centre of the sonicator. A known quantity of chlorobenzene (30 mL, solvent), sodium hydroxide (20g, 0.1447 mol), 0.2 g biphenyl IS,

(internal standard) were introduced into the reactor. Then, 0.5g of phenyl acetonitrile (4.27×10^{-3} mol) and 0.60g of 1-chloro-4-nitrobenzene (3.81×10^{-3} mol), 3 mol% of phase-transfer catalyst BTEAC (with respect to 1-chloro-4-nitrobenzene, limiting reagent) were introduced to the reactor to start the reaction. The reaction mixture was stirred at 600 rpm. The phase separation was almost immediate on arresting the stirring process. Samples were collected from the organic layer of the mixture (by stopping the stirring for 20-30 seconds each time) at regular time intervals. A pinch of anhydrous CaCl_2 was placed in the sample vials to absorb any moisture present in the organic layer. Each run consisted of six samples taken over the period ranging from 5 to 30 minutes. The kinetics was followed by estimating the amount of 1-chloro-4-nitrobenzene (limiting reagent) that disappeared using a gas Chromatography (GC-Varian 3700 model). The analyzing conditions were as follows; Column, 30 m x 0.525 mm i.d. capillary column containing 100% poly(dimethyl siloxane); injection temperature, 250°C ; FID detector (280°C). Yields were determined from standard curve using biphenyl as an internal standard.

6.1 Effect of stirring speed

To ascertain the influence of agitation speed on the rate of C-arylation of phenyl acetonitrile, the speed of agitation was varied in the range of 100-1000 rpm along with ultrasound irradiation (40 kHz, 300W) using Benzyltriethylammonium chloride. The result indicates that the rate of the reaction increases linearly as the agitation speed increases from 100 to 600 rpm (Fig. 1). However, on further increasing the agitation speed from 600 to 1000 rpm, there is no significant improvement in the reaction rate constant. This is because the interfacial area per unit volume of dispersion increased linearly with increasing the stirring speed till 600 rpm is reached, where there is no significant increase in the interfacial area per unit volume of dispersion with the corresponding increase in the speed. Thus, increasing the stirring speed changes the particle size of the dispersed phase. Therefore, the agitation speed was set at 600 rpm for studying the reaction phenomena from which the resistance of mass transfer stays at a constant value [21 - 26]. The k_{app} values are evaluated from the linear plot of $-\ln(1-X)$ versus time. The results indicate that the mechanical effects brought up by the use of low frequency ultrasounds (40 kHz, 300W) are responsible of the enhancement of the kinetics by harsh mixing, enhancement of mass transfer and so on. Further, when the same reaction was carried out in the presence tetraethylammonium chloride (TEAC) PTC the observed k_{app} value (PTC: $k_{app} = 5.12 \times 10^{-3}$, min^{-1}) almost five fold lesser than Benzyltriethylammonium chloride BTEAC) PTC ($k_{app} = 26.72 \times 10^{-3}$, min^{-1}) along with ultrasound irradiation (40 kHz, 300W).

6.2 Effect of the amount of BTEAC and TEAC

Experiments were conducted by varying the amount of the BTEAC viz., Benzyltriethylammonium chloride and TEAC viz., tetraethylammonium chloride by keeping other experimental parameters are kept constant. The influence of the amount of TEAC and BTEAC on the C-arylation of phenylacetonitrile has been studied by varying amount of TEAC and BTEAC from 1 mol% to 5 mol % (with respect

to 1-chloro-4-nitrobenzene, limiting reagent) under ultrasound irradiation (40 kHz, 300 W). Apparent rate constants were evaluated from the plot of $-\ln(1-X)$ versus time. As shown in Fig. 2, the rate of the reaction increased with increasing mol % of TEAC & BTEAC along with ultrasound irradiation (40 kHz, 300 W). The k_{app} values are linearly dependent on the amount of multi-site phase-transfer catalyst as well as single-site phase-transfer catalyst. The increasing the k_{app} value is attributed to the positive effect of ultrasound might be enlarged [27].

6.3 Effect of the concentration of 1-chloro-4-nitrobenzene

To investigate the influence of 1-chloro-4-nitrobenzene (CNB) on the kinetics of synthesis of 1-chloro-4-nitrobenzene under ultrasonic irradiation condition (40 kHz, 300W), the amount of CNB was varied from 0.2 g to 0.8 g. The results are shown in (Table-1). The data clearly indicates that the k_{app} value increases with increasing the amount of 1-chloro-4-nitrobenzene. When the 1-chloro-4-nitrobenzene concentration increased, the probability of finding the substrate with active-site of the catalyst and ultrasound enhanced the rate of the reaction [27]. It may be due to reduces the surface area between the aqueous and organic phases, and hence more reactants collide to each other simultaneously we get higher k_{app} value.

6.4 Effect of temperature

The effect of temperature on the reaction between phenyl acetonitrile and 1-chloro-4-nitrobenzene was studied under otherwise similar conditions. The temperature was varied from 30 to 80°C . The kinetic profile of the reaction is obtained by plotting $-\ln(1-X)$ versus time. It is obvious that the reactivity is increased with an increase in the temperature along with ultrasonic effect [28]. The reason is that the number of reactant molecules which possess higher activation energy at a higher temperature and thus the ultrasonic wave easily passes through the reactor. The other point is that the collision of the reactants at higher temperature is also increased. Hence, the apparent rate constant is increased at higher temperature. Arrhenius plots were made in Fig.3 of $-\ln k_{app}$ against $1/T$ to get activation energy of $52.16 \text{ kJ}\cdot\text{mol}^{-1}$.

From the literature survey, the dehydrobromination of (2-bromoethyl) benzene catalyzed by tetraoctylammonium bromide (TOAB), an extraction mechanism was proposed [29] due to lower E_a value ($< 43 \text{ kJ}\cdot\text{mol}^{-1}$). In general, higher activation energy (more than $43 \text{ kJ}\cdot\text{mol}^{-1}$) suggests an interfacial mechanism [30]. The activation energy for the heterogeneous ethylation of phenylacetonitrile was reported to be $53.64 \text{ kJ}\cdot\text{mol}^{-1}$ and for this an interfacial mechanism was proposed [31]. Further, in the N-alkylation of pyrrolidine-2-one, the E_a ($51.35 \text{ kJ}\cdot\text{mol}^{-1}$) was reported by Sasson and Bilman [32], and for this reaction they proposed an interfacial mechanism. They concluded that the deprotonation of the substrate takes place at the interphase and consequently the organic anion is extracted and reacts in the bulk of the organic phase. The rate-determining step in the process is the anion exchange at the interphase. In our study, the observed E_a value is $52.36 \text{ kJ}\cdot\text{mol}^{-1}$. Hence, we

proposed an interfacial mechanism for our present study [30 - 33].

6.5 Influence of amount of water

Fig.4 shows the effect of water on the formation of the product under ultrasound irradiation condition (40kHz, 300W). The observed k_{app} value directly affects both the concentration of sodium hydroxide in the aqueous phase and generation of anions on increasing the volume of water, the concentration of alkali compound in aqueous solution is decreases from 20 to 40 mL. From the literature, the kinetic study of the phase-transfer catalyzed etherification of 4,4'-bis(chloromethyl)-1,1'-biphenyl with phenol in an alkaline solution of potassium hydroxide/organic solvent two-phase medium, similar decrease in rate of the reaction on corresponding increase in volume of water was reported [33, 34].

6.6 Effect of Ultrasound

Ultrasonic irradiation is defines as acoustic waves with frequencies in the 20 kHz -100 MHz range [35, 36]. They create cavities generating locally high temperature and pressures [61-64] or strong electric fields [35 - 37]. Ultrasound is known to accelerate diverse types of organic reactions and it is established in many organic reactions, which are otherwise slow due to poor mass transfer which is by sonication due to cavitation [38]. It has been reported that a combination of PTC and ultrasound is often better than either of the two techniques alone [39].

To ascertain the influence of ultrasonic frequencies on the rate of C-arylation of phenyl acetonitrile with output power of 300W, the ultrasonic frequency was 40 kHz under otherwise similar conditions using BTEAC and TEAC as the catalyst. The kinetic profile of the reaction is obtained by plotting $-\ln(1-X)$ against time. In our experimental condition at 30 minutes, TEAC the k_{app} values is $5.12 \times 10^{-3}, \text{min}^{-1}$ but in the presence BTEAC condition the k_{app} values are $26.72 \times 10^{-3}, \text{min}^{-1}$, respectively (Table-2). The k_{app} value of BTEAC was about five times higher than that of TEAC. It may be due to the quaternary onium phase-transfer catalyst, Q^+X^- generally contains an active centre ($C-N^+$), that carries only one molecule of reactant Na^+OH^- (MY) in the form of catalytic intermediate Q^+OH^- (QY) once a reaction cycle, then QY transferring from the aqueous phase into the inter phase/organic phase. When more than one active centre contained in a catalyst molecule of (MY) can be carried to react in a reaction cycle. In addition, ultrasound irradiation enhances the heterogeneous system may act as homogeneously, hence we get higher k_{app} value compared with conventional method [38 - 41].

6.7 Effect of organic solvents

In this work, the influence of various organic solvents on the rate of C-arylation of phenyl acetonitrile was followed under otherwise standard reaction conditions. Five organic solvents employed in this study are toluene, anisole, cyclohexane, chlorobenzene, and n-hexane. From the plot of $-\ln(1-X)$ against time, the k_{app} values are shown in the Table-3. From the Table-3, chlorobenzene possesses a

higher k_{app} value among the five organic solvents, due to its higher dielectric constant. In another view the ultrasonic irradiation can enhance the rate in the presence of more polar solvents due to passing higher ultrasonic waves to the reactor and makes fruitful collision between the reactants, and hence we get higher k_{app} value for chlorobenzene solvent of this system and also this statement is not always true [42 - 44].

6.8 Effect of varying sodium hydroxide concentrations

In the PTC / base catalyzed reactions, the reaction rate is known to be greatly affected by a concentration of the alkaline compound. The rate of C-arylation of phenyl acetonitrile strongly depends on the strength of the sodium hydroxide. Kinetic experiments were carried out, by employing 20 to 40 g of NaOH under similar reaction conditions. The Kinetic profile of the reaction is obtained by $-\ln(1-X)$ against time. The k_{app} values tremendously increased with increasing in basicity of OH^- ion (Table 4). It suggest that the OH^- ions which are less solvated by water molecules and there by the k_{app} value increases [45, 46].

7. Mechanism

In the present investigation, the dependency of rate of C-arylation of phenyl acetonitrile on stirring speed, [catalyst], [NaOH], temperature and the higher activation energy (E_a) has suggested that the reaction proceeds through interfacial mechanism. The interfacial mechanism for the reactions of carbanions with a variety of electrophiles was proposed by Makosza [46]. A crucial point is the formation of the carbanion by proton abstraction from the CH acid dissolved in a nonpolar solvent by the concentrate aqueous NaOH at the phase boundary. The generated carbanions, as sodium derivatives, remain adsorbed at the surface of the aqueous phase. They cannot migrate into the organic phase. The catalyst, a lipophilic cation, exchanges anions at the interface, and the new "fully lipophilic" ion-pair migrates into the organic phase where the reaction occurs. The free catalyst can, again, undergo the ion exchange at the interface. Rabinovitz et al. [47] reviewed the interfacial mechanism of hydroxide ion initiated alkylation in presence of PTC. In view of the early results and observation, the mechanism for C-arylation of phenylacetonitrile with 1-chloro-4-nitrobenzene under liquid-liquid biphasic condition involves the following steps:

- 1) The organic phase substrate phenyl acetonitrile is deprotonated at the interface by the aqueous phase NaOH and forming an ion-pair $[Na^+R^-]$.
- 2) This ion-pair $[Na^+R^-]$ at the interface reacts with the catalyst MPTC (Q^+Br^-) to form $[Q^+R^-]$ catalyst-anion pair.
- 3) The paired anion $[Q^+R^-]$ moved into the organic phase and then reacts with the arylating agent 1-chloro-4-nitrobenzene to form the arylated product 2-(4-nitrophenyl)-2-phenylacetonitrile and the catalyst return to its original form of Q^+Cl^- (aqueous phase).

8. Conclusion

The arylation of phenylacetonitrile with 1-choloro-4-nitrobenzene catalyzed by the prepared TEAC and BTEAC,

PTC were studied via ultrasound assisted liquid-liquid phase-transfer catalysts in a batch reactor. The reaction mechanism and the apparent rate constants were obtained from the experimental results, the apparent rate constants are found to be directly dependent on each kinetic variables, viz., [BTEAC], [TEAC], [NaOH], ultrasonic frequency, stirring speed and temperature. However it decreases with increase in volume of water. Energy of activation was calculated from the Arrhenius plot. Based on the experimental evidence, an interfacial mechanism has been proposed. Combination of TEAC & BTEAC with ultrasound irradiation resulted in better efficacy as compared to the individual operations.

9. Acknowledgments

The authors would like to Thank, Sri Akilandeswari Women's College, Wandiwash, Tamil Nadu, India – 604 408 and Pachaiyappa's Trust, Chennai, Tamil Nadu, India-600 030 for their grant of permission to do this research work.

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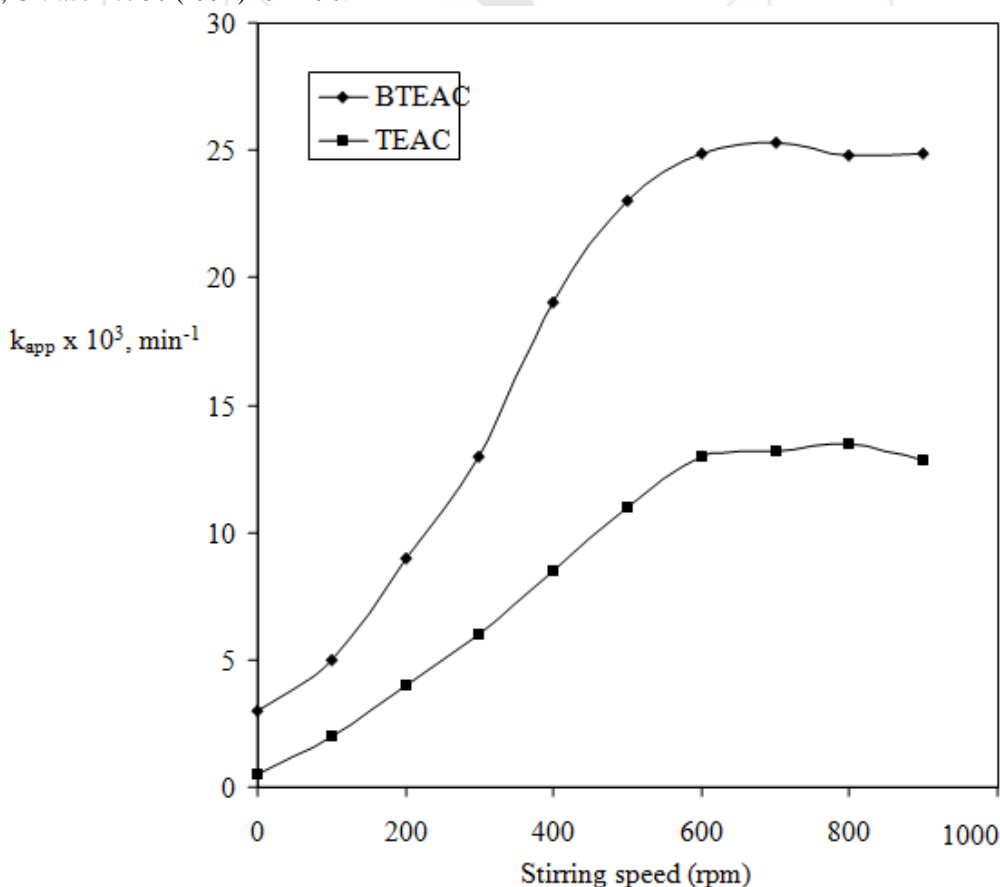


Figure 1: Effect of stirring speed

Figure 1

Plot of the apparent rate constant versus various stirring speeds; 0.5 g of 4-nitrophenol 20 g of NaOH, 30 mL of H₂O, 0.2 g of internal standard (biphenyl), 0.6 g of 1-chloro-4-nitrobenzene, 3 mol % of BTEAC, 30 mL of chlorobenzene, 30 min, 65°C; ultrasound conditions (40 kHz, 300 W).

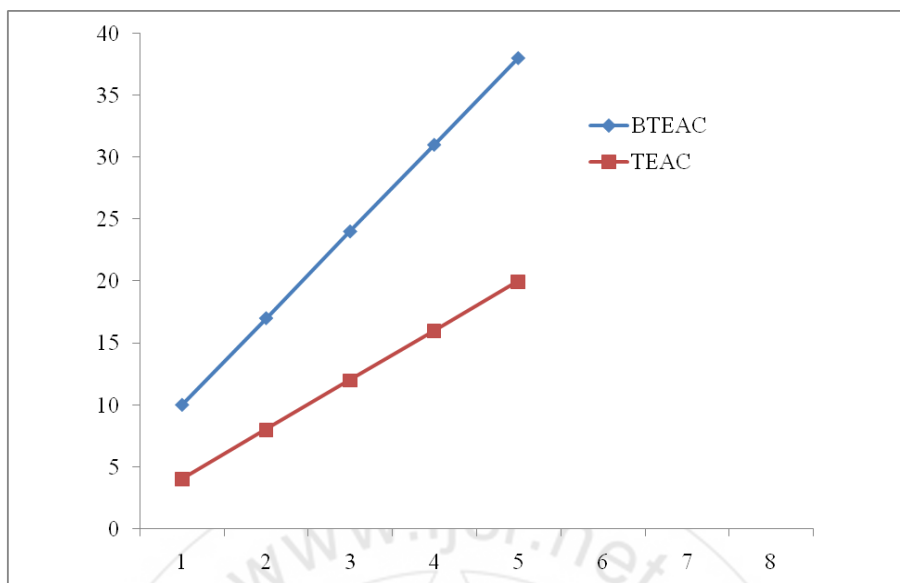


Figure 2: (Effect of BTEAC and TEAC)

Figure 2

Effect of the amount of BTEAC on the apparent rate constant: 0.5 g of 4-nitrophenol 20 g of NaOH, 30 mL of H₂O, 0.2 g of internal standard (biphenyl), 0.6 g of 1-chloro-4-nitrobenzene, 0.3g of BTEAC, 30 mL of chlorobenzene, 65°C; ultrasound conditions (40 kHz, 300 W).

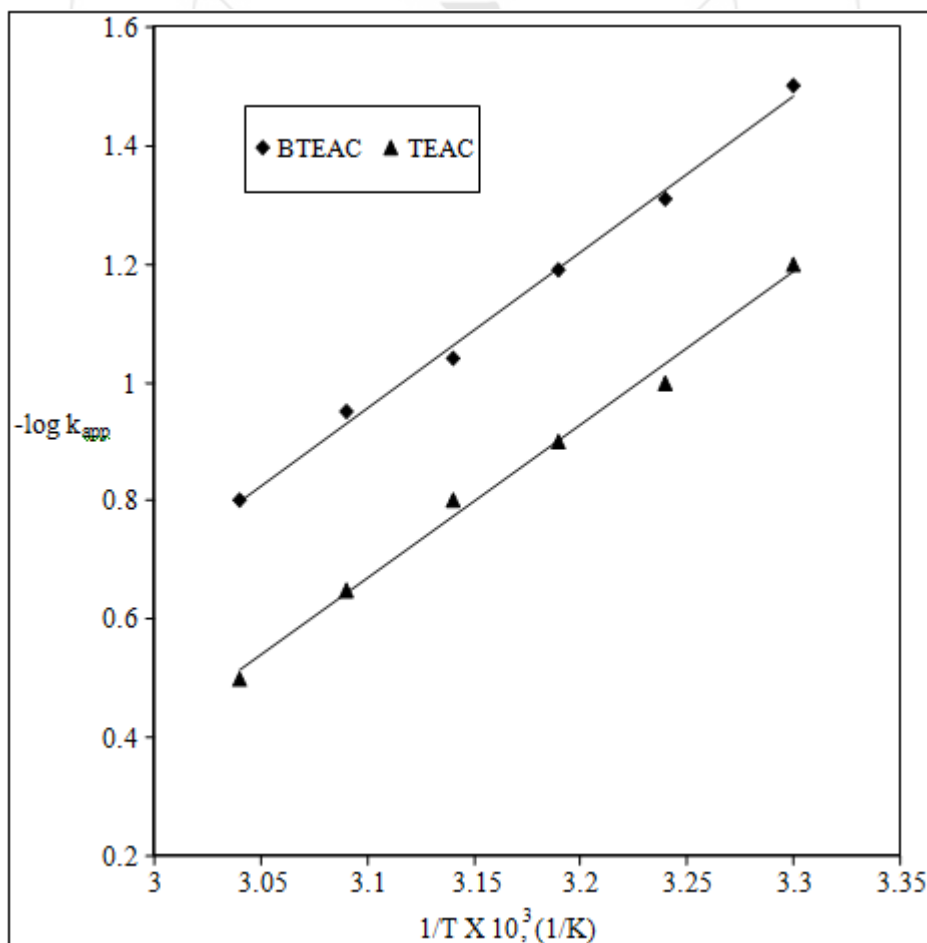


Figure 3: (Effect of Temperature)

Figure 3

Arrhenius plot; 0.5 g of 4-nitrophenol 20 g of NaOH, 30 mL of H₂O, 0.2 g of internal standard (biphenyl), 0.6 g of 1-chloro-4-nitrobenzene, 0.3g of BTEAC, 30 mL of chlorobenzene, 65°C; ultrasound conditions (40 kHz, 300 W).

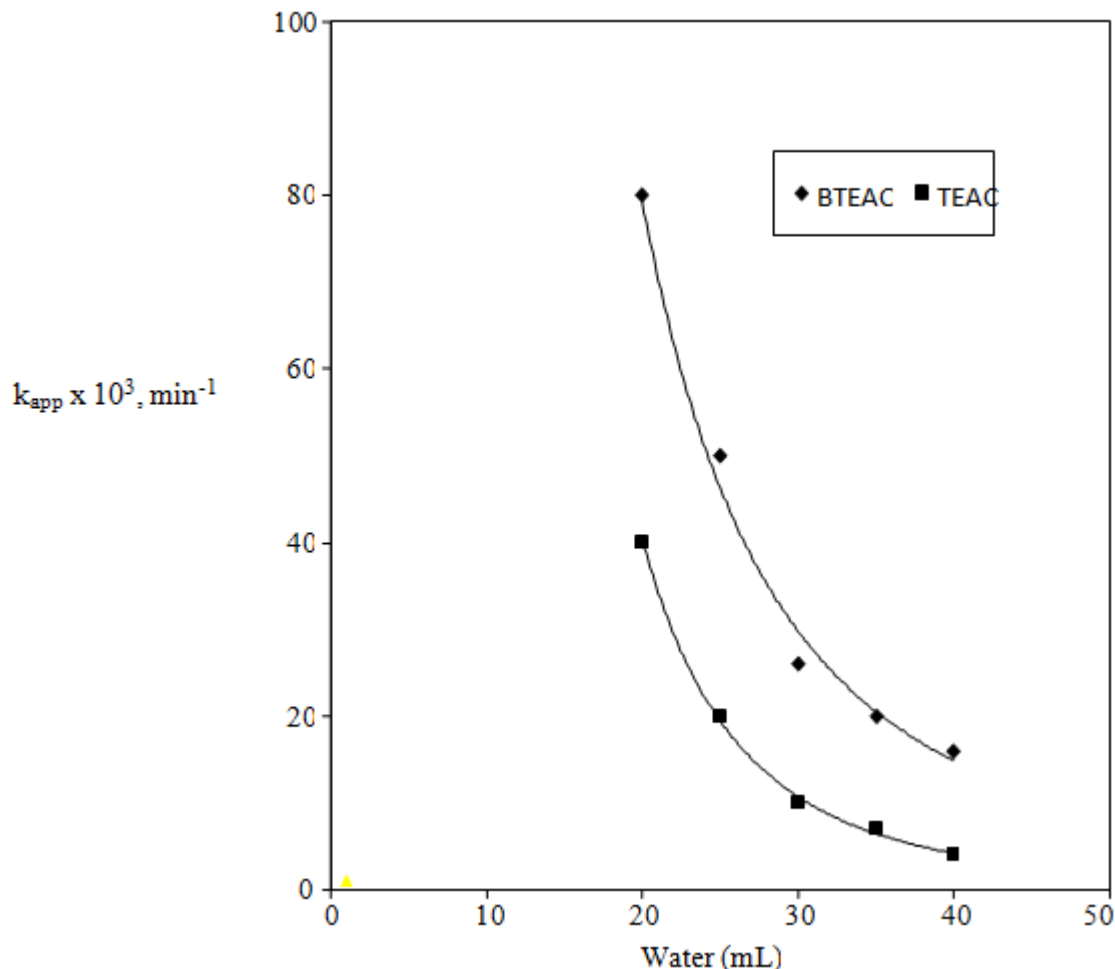


Figure 4: (Effect of amount of water)

Figure 4

Plot of the apparent rate constants versus different volumes of water; 0.5 g of 4-nitrophenol 20 g of NaOH, 30 mL of H₂O, 0.2 g of internal standard (biphenyl), 0.6 g of 1-chloro-4-nitrobenzene, 0.3g of BTEAC, 30 mL of chlorobenzene, 65°C; ultrasound conditions (40 kHz, 300 W).

Table 1: Effect of the amount of 1-chloro-4-nitrobenzene

1-chloro-4-nitrobenzene (CNB), g	k _{app} × 10 ³ , min ⁻¹	
	BTEAC	TEAC
0.2	17.68	3.08
0.4	21.44	4.66
0.6	26.72	5.12
0.7	31.82	6.02
0.8	36.41	7.22

Effect of amount of 1-chloro-4-nitrobenzene (CNB) on the rate of 1-chloro-4-nitrobenzene of phenylacetone under ultrasonic condition: 20g of NaOH, 30 mL of H₂O, 0.2g of internal standard (biphenyl), 0.3 g of BTEAC, 30 mL of chlorobenzene, 600 rpm, 30 min, 65°C; ultrasound conditions (40 kHz, 300 W).

Table 2: Effect of ultrasonic frequency

Ultrasonic frequency (40 kHz, 300W)	k _{app} × 10 ³ , min ⁻¹	
	TEAC	BTEAC
k _{app} × 10 ³ , min ⁻¹	5.12	26.72

Influence of ultrasonic frequencies on the rate of 1-chloro-4-nitrobenzene of phenyl acetonitrile under ultrasonic condition: 20g of NaOH, 30 mL of H₂O, 0.2g of internal standard (biphenyl), 0.3 g of BTEAC, 0.6g 1-chloro-4-nitrobenzene, 30 mL of chlorobenzene, 600 rpm, 30 min, 65°C.

Table 3: Effect of organic solvents

	Solvents				
	Cyclohexane	n-Hexane	Toluene	Anisole	Chlorobenzene
ϵ^2 (Dielectric constant)	2.02	2.28	2.31	4.30	5.60
$k_{app} \times 10^3, \text{min}^{-1}$ BTEAC	12.72	13.62	18.05	19.96	26.72
$k_{app} \times 10^3, \text{min}^{-1}$ TEAC	2.33	2.54	3.63	3.92	5.12

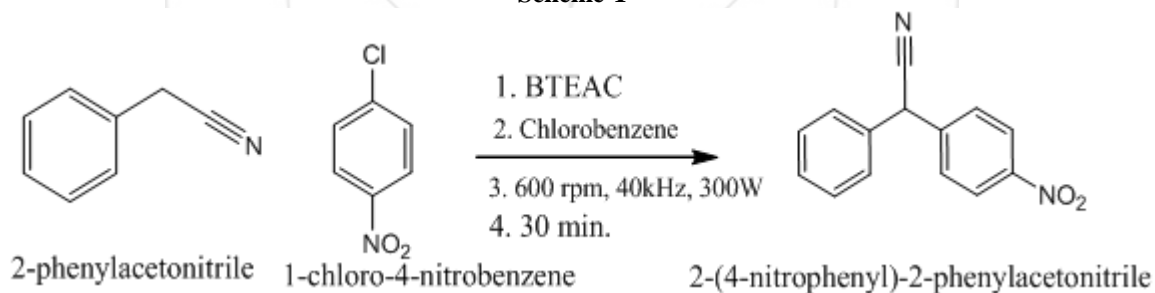
Influence of organic solvents on the rate of 1-chloro-4-nitrobenzene of phenyl acetonitrile under ultrasonic condition: 20g of NaOH, 30 mL of H₂O, 0.2g of internal standard (biphenyl), 0.3 g of BTEAC, 0.6 g 1-chloro-4-nitrobenzene, 600 rpm, 30min, 65°C; ultrasound conditions (40 kHz, 300 W).

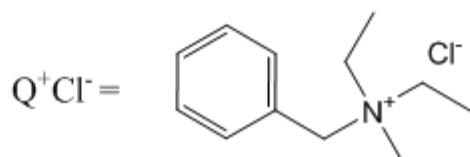
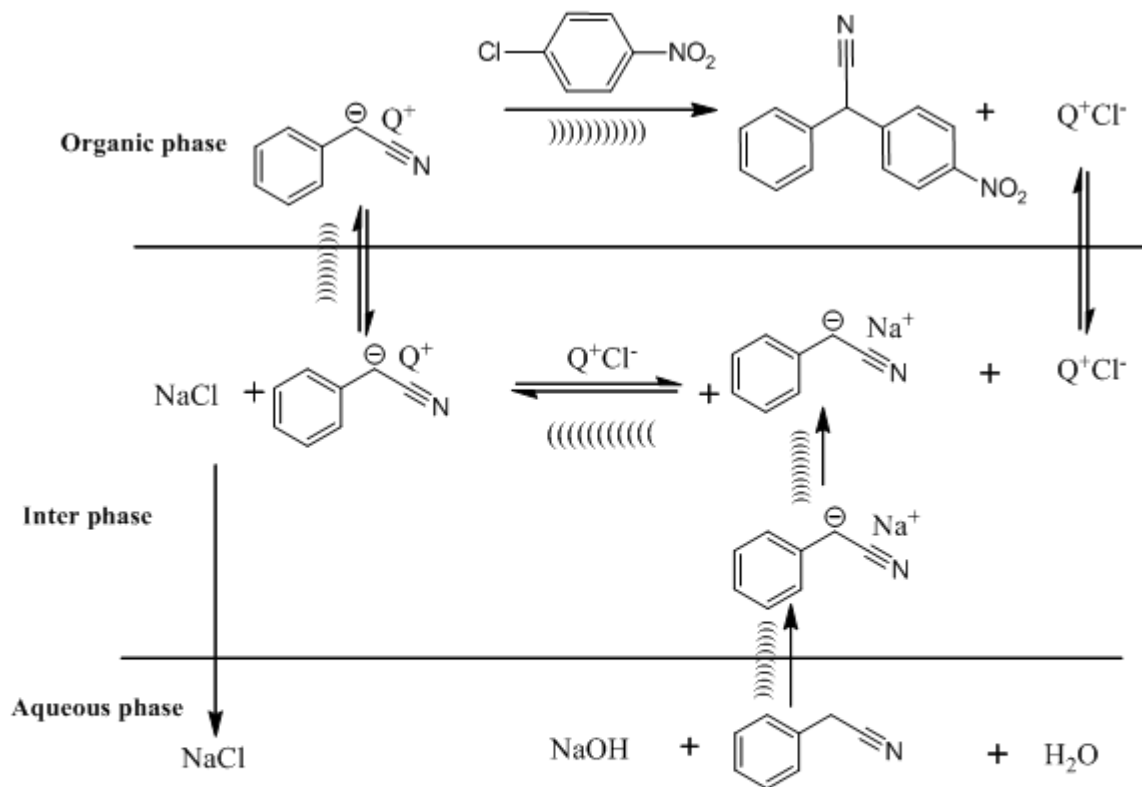
Table 4: Effect of sodium hydroxide

Amount of NaOH(g)	$k_{app} \times 10^3, \text{min}^{-1}$ BTEAC	$k_{app} \times 10^3, \text{min}^{-1}$ TEAC
10	16.22	3.09
15	20.9	4.23
20	26.72	5.12
25	30.46	6.02
30	34.33	6.76

Influence of alkalinity on k_{app} in the 1-chloro-4-nitrobenzene of phenyl acetonitrile under ultrasonic condition: 0.2g of internal standard (biphenyl), 0.3 g of BTEAC, 0.6g 1-chloro-4-nitrobenzene, 30 mL of chlorobenzene, 600 rpm, 30min, 65°C; ultrasound conditions (40 kHz, 300 W).

Scheme-1





Benzyltriethylammonium chloride (BTEAC)

)))))) Ultrasound irradiation (40 kHz, 300W)

Scheme-2 (Reaction mechanism)



Current Data Parameters
 NAME MN-PA-8
 EXPNO 3
 PROCNO 1

F2 - Acquisition Parameters

Date_ 20170616
 Time 18.53
 INSTRUM spect
 PROBHD 5 mm DUL 13C-1
 PULPROG zgpg30
 TD 65536
 SOLVENT CDCl3
 NS 512
 DS 4
 SWH 17985.611 Hz
 FIDRES 0.27433 Hz
 AQ 1.8219508 sec
 RG 16384
 DW 27.800 usec
 DE 6.00 usec
 TE 300.0 K
 CNST2 145.0000000
 D1 2.0000000 sec
 d2 0.00344828 sec
 d12 0.00002000 sec
 DELTA 0.00001184 sec
 TD0 1

===== CHANNEL f1 =====
 NUC1 13C
 P1 9.30 usec
 P2 18.60 usec
 PL1 0.00 dB
 SFO1 75.4752953 MHz

===== CHANNEL f2 =====
 CPDPRG2 waltz16
 NUC2 1H
 F3 13.15 usec
 P4 26.30 usec
 PCPD2 80.00 usec
 PL2 0.00 dB
 PL12 15.68 dB
 SFO2 300.1312005 MHz

F2 - Processing parameters
 SI 32768
 SF 75.4677468 MHz
 GB 0
 LB 1.00 Hz
 GB 0
 PC 1.40

