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SYNTHESIS OF BENZOYL CYANIDES BY PHASE TRANSFER CATALYSIS

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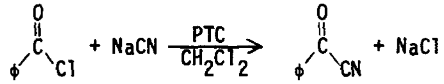
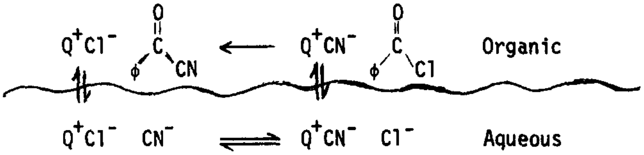
Benzoyl cyanide has been known since 1832 when it was prepared by Wöhler and Liebig by reaction of benzoyl chloride with mercuric cyanide.[1] More recently acid cyanides have been prepared by the reaction of acid chlorides with either silver cyanide[2,3] or cuprous cyanide.[4] In addition to the fact that neither AgCN nor CuCN is an economical source of cyanide, the yields obtained in these reactions are only moderate. We should like to report that benzoyl cyanides can be prepared by the reaction of benzoyl chlorides with sodium cyanides under phase transfer catalysis (PTC) conditions in yields comparable to the best previously reported.[4]

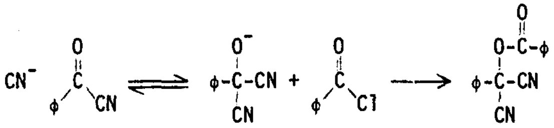


Starks has shown that S_n2 displacement reactions involving cyanide anion, usually carried out in DMSO solvent,[5] can be carried out on water insoluble alkyl halides using a two phase system with a quarternary alkyl ammonium salt added as phase transfer catalyst.[6] Catalysis depends on the solubility of the ammonium salt in both phases.[7] Thus, the quarternary alkyl ammonium salt is soluble in the aqueous phase due to its charge, while it is soluble in the organic phase due to its lypophilic alkyl groups. The quarternary alkyl ammonium cation transports cyanide into the organic phase by ion pairing. In our system reaction occurs by addition of the organic soluble cyanide to the carbonyl group of the benzoyl chloride followed by loss of chloride anion to form benzoyl cyanide and the quarternary alkyl ammonium chloride ion pair. Migration of the Q^+Cl^- ion pair into the aqueous phase followed by anion exchange with cyanide ion leads to the Q^+CN^- ion pair and further reaction.



An advantage of the two phase system is that benzoyl chloride and benzoyl cyanide both of which are sensitive to hydrolysis are protected from water in the organic phase.

The yields of distilled products we obtained are generally around 60% based on benzoyl chloride. However, these yields are not limited by hydrolysis, but rather by a competing reaction. Namely, addition of cyanide anion to the carbonyl group of benzoyl cyanide rather than to the carbonyl group of benzoyl chloride. The alkoxide anion thus formed may be trapped by reaction with benzoyl chloride to yield α-benzoyloxy-α-phenylmalonitrile,[8] the dimer of benzoyl cyanide. This dimer is formed in roughly 35% yield except in the case of p-chloro benzoyl chloride where it becomes the major product. Control experiments run with pure benzoyl cyanide and cyanide anion under our PTC conditions did not lead to dimer formation in the absence of benzoyl chloride.

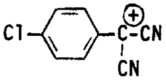
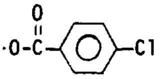


A typical preparation follows:

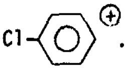
In a 500 ml round bottom flask equipped with a magnetic stirring bar and a nitrogen inlet tube was placed 51 g (0.36 mole) of benzoyl chloride, 100 mg (.03 mmole) of tetrabutyl ammonium bromide and 300 ml of CH_2Cl_2. After the catalyst dissolved, 20 ml of H_2O and 18 g (0.37 moles) of NaCN were added while the reaction flask was cooled to 0°C. The reaction was followed by the disappearance of the acid chloride band at 1775 cm^{-1} in the ir and the appearance of the benzoyl cyanide band at 1675 cm^{-1} and the dimer band at 1745 cm^{-1}. When the benzoyl chloride band disappears (usually about one hour) the solids were filtered, washed with CH_2Cl_2, the organic layer separated, dried over anhydrous $MgSO_4$, filtered, and the solvent removed by evaporation under reduced pressure. The product was then distilled through a 15 cm Vigreux column, a fraction bp 105°/0.1 mm was collected, 25 g (60% yield). The product solidified on standing, mp 30-32°, lit. mp 30-32°.[9] The material which did not distill was triturated with cold 95% ethanol and the solids filtered. The solids were recrystallized from

95% ethanol. A 35% yield of the dimer, mp 94-95°, lit. mp 95°,[8] was obtained. In a similar way a 72% yield of p-methylbenzoyl cyanide was obtained, mp 47-49°, lit. mp 50-51°.[10] p-Methoxybenzoyl cyanide was obtained in 60% yield, mp 52-54°, lit. mp 56-57°;[10] while p-chlorobenzoyl cyanide was obtained in only 22% yield, mp 37-39°, lit. mp 37-39°.[10] The dimer of p-chlorobenzoyl cyanide, mp 157-159° - 46% yield, is a new compound. It had the following spectral properties. Nmr: d(2H) 7.42δ, J = 9 Hz, d(2H) 7.52δ, J = 9 Hz, d(2H) 7.78δ, J = 9 Hz, d(2H) 7.94δ, J = 9 Hz. The ir showed a carbonyl stretch at 1745 cm^{-1}. Anal. calculated for $C_{16}H_8Cl_2N_2O_2$: C, 58.03%; H, 2.44%. Found: C, 57.99%; H, 2.69%.

Interestingly, no mass spectral data has been reported on either benzoyl cyanides or on their dimers. The mass spectrum of Benzoyl cyanide is dominated by four ions: the parent at m/e = 131 (relative intensity 92%), the P-CN ion at m/e = 105 (100%), a P-CO ion at m/e = 103 (58%) and an ion at m/e = 77 (85%).[11] A major pathway leading to formation of the m/e = 77 ion is loss of CO from the m/e = 105 ion. A metastable peak at m* = 56.5 supports this process. The mass spectrum of the dimer of p-chlorobenzoyl cyanide is almost equally simple.[11] The cluster of peaks associated with the Parent, P + 2 and P + 4 begins at m/e = 330 (15%), m/e = 332 (13%), m/e = 334 (3%). The next major pair of ions is the

 formed by loss of the 

at m/e = 175 (71%) and m/e = 177 (30%). The pair of ions associated with the p-chlorobenzoyl acylium ion is observed at m/e = 139 (100%) and m/e = 141 (65%). The final major pair of ions is found at m/e = 111 (35%) and m/e = 113 (15%). Its structure is probably



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11. Complete mass spectral data has been submitted to the Mass Spectrometry Data Center, Atomic Weapons Research Establishment, Aldermaston, Berkshire, England.

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