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SYNTHESIS OF 4-NITROCYCLOPENTA[cd]PYRENE

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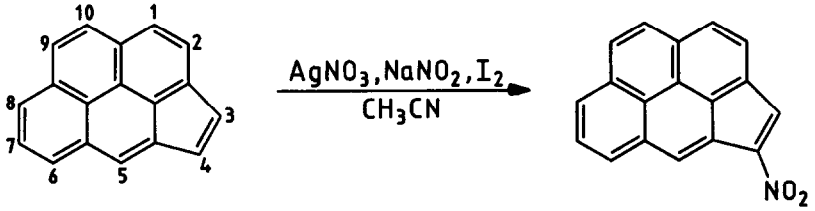
Abstract. Nitration of cyclopenta[cd]pyrene in the presence of silver nitrate, sodium nitrite and iodine in acetonitrile yields 4-nitrocyclopenta[cd]pyrene.

Polycyclic aromatic hydrocarbons (PAH) and their nitro derivatives are found throughout the environment[1,2] and are known to possess mutagenic and carcinogenic properties.[3,4] PAH readily react with nitrogen oxides under thermal or photochemical conditions to form nitro derivatives.[5,6] The mutagenic properties of these derivatives are related to their structure.[3,5] Therefore, highly purified samples of the suspect nitro-PAH are required as analytical standards for confirmation of chemical structures of pollutants and subsequent biological testing.

Recently an efficient procedure for the synthesis of the ubiquitous hydrocarbon cyclopenta[cd]pyrene (CPP) was developed in our laboratories.[7] The 3,4 double bond in this molecule is probably the biologically reactive site. We now wish to report the specific nitration of CPP leading to the novel compound 4-nitrocyclopenta[cd]pyrene.

Cyclopenta[cd]pyrene is a very reactive and acid-sensitive compound.[8] Nitration with NO_2 or nitric acid in acetic anhydride causes degradation.[8] 4-NitroCPP can be prepared in good yield (43 %) by an oxidatively initiated nucleophilic substitution of the parent hydrocarbon.



$AgNO_3$ (53 mg, 0.311 mmol) and $NaNO_2$ (146 mg, 2.116 mmol) were added to a stirred solution of cyclopenta[cd]pyrene (35 mg, 0.155 mmol) in 50 ml dry acetonitrile. The mixture was cooled to 0 °C and I_2 (78 mg, 0.307 mmol) was added. A precipitate of AgI appeared and the colour of the mixture turned from orange to red. After 10 minutes, TLC (silica, hexane/dichloromethane 8:2) showed that CPP had disappeared completely, but the nitro substituted product could not yet be detected. After additional stirring for 2 hours, during which the red colour intensified, water was added and the remaining I_2 was destroyed with Na_2SO_3. The mixture was twice extracted with CH_2Cl_2 and the organic layer was washed with saturated NaCl solution until the aqueous layer remained colourless. The organic layer was dried on Na_2SO_4, filtered, and evaporated to dryness. The product was chromatographed on silica gel (25 g, 70 - 230 mesh) with hexane/dichloromethane 8:2, yielding 18 mg (0.066 mmol, 43 %) 4-nitrocyclopenta[cd]-pyrene. Like many other nitro-PAH[5,9] the product is sensitive to light, heat and moisture. A considerable amount (30 %) of a ketone, cyclopenta[cd]pyren-3(4H)-one[7], was also isolated.

4-Nitrocyclopenta[cd]pyrene was identified on the basis of its mass and ^1H NMR spectra:

Exact mass: m/e 271.0646; calculated for $C_{18}H_9NO_2$ 271.0633. ^1H NMR (300 MHz, $CDCl_3$/TMS): 9.12 (H-5, s); 8.66 (H-6/8, d, $J_{6/8,7}$ = 7.9); 8.46 (H-8/6, d, $J_{8/6,7}$ = 7.9); 8.39 (H-3, s); 8.28 (H-1/2, d, $J_{1,2}$ = 8.0); 8.23 (H-9/10, d, $J_{9,10}$ = 9.0); 8.21 (H-2/1, d, $J_{2,1}$ = 8.0); 8.17 (H-10/9, d, $J_{10,9}$ = 9.0); 8.13 (H-7, t, $J_{7,6/8}$ = 7.9).

Nitration of an unsaturated compound (cyclohexene) with $AgNO_2$ and I_2 was first reported by Birckenbach in 1932.[10] The mechanism was investigated by Hassner et al.[11] for a variety of olefins. Free radical attack of NO_2 (from $AgNO_2$ and I_2) followed by reaction of the resulting radical with iodine yields an iodo-nitro adduct which upon treatment with base loses HI. Ristagno and Shine[12] have nitrated perylene and pyrene with $AgNO_2$ and I_2. The aromatic molecule is oxidized to a radical cation which subsequently reacts with NO_2^-. After electron transfer to another radical cation and loss of a proton the nitro derivative is formed.

Upon treatment with $AgNO_3$, $NaNO_2$ and I_2 cyclopenta[cd]pyrene disappears rather quickly. Formation of the nitro derivative is, however, a relatively slow process. This points to the occurrence of a long-lived intermediate along the reaction pathway. In the mechanism proposed by Ristagno and Shine all intermediates are expected to be very short-lived.

The 3,4 double bond in CPP has considerable olefinic character.[7] The mechanism of nitration may be rather similar to that proposed by Hassner et al. Free radical attack of NO_2 on the 3,4 double bond of CPP is, however, not a primary step in the nitration since it is known that CPP undergoes degradation upon treatment with NO_2.[8] Instead, I^+ or a complex between Ag^+ and I_2 might be the attacking species, resulting in the formation of an iodonium ion. This will then react with nitrite ion, yielding an iodo-nitro adduct which undergoes dehydroiodination, in which the departure of iodide ion is probably assisted by Ag^+.

The nitrations described by Birckenbach[10], Hassner et al.[11] and Ristagno and Shine[12] were performed with $AgNO_2$ and I_2. With CPP this method failed to produce a nitro derivative, the only detectable product being cyclopenta[cd]pyren-3(4H)-one. The fact that nitration does occur with $AgNO_3$, $NaNO_2$ and I_2 in acetonitrile may be related to the ambident character of the nitrite ion. In acetonitrile the metal ions and the nitrite ions will not be strongly solvated and may exist as ion pairs. Sodium ions are expected to coordinate with the hard positions in the nitrite ion, i.e. the oxygen atoms, leaving the nitrogen atom free to attack the soft iodonium ion. Silver ions, being relatively soft, will keep close to the nitrogen atom, thus blocking the formation of nitro compounds and promoting attack of NO_2^- with its oxygens. The ensuing nitrite ester might be the precursor of the ketone. The regioselectivity (only the 4-nitro and the 3-keto derivatives are formed) is under investigation.

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