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REACTION OF CUPRIC(II) HALIDES WITH ORGANIC COMPOUNDS-VIII

PYRENE AND SOME 3-SUBSTITUTED PYRENES

A D.Mosnaim,M.E.Wolf,I.Saavedra, A.M. Amaro, and G.Cordano

Faculty of Medicine, University of Chile, Santiago,Chile

D.C. Nonhebel,

Department of Pure and Applied Chemistry,University of Strathclyde, Glasgow, Scotland

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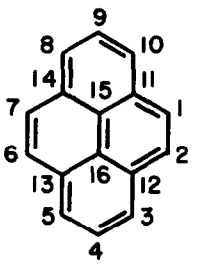
Halogenation reactions of polycyclic aromatic hydrocarbons and their derivatives have been of considerable interest to chemists. Earlier work showed that halogenation of naphthalene, anthracene,and pyrene, among others, by molecular halogens, proceeded either via an ionic or a free radical mechanism, or a mixture of both, depending on the conditions used.[1] We have recently reported on the free radical nature of the Cupric(II) halides halogenation of anthracene and some of its derivatives in anhydrous, non-polar solvents.[2,3] On this paper we will discuss some aspects of the halogenation mechanism of pyrene and some of its 3-substituted derivatives by Cupric(II) halides, under similar conditions.

Commercial pyrene was recrystallized from methanol to constant melting point. 3-Formylpyrene (1) was obtained after Vilsmaier[2], m.p. 125° (54%); 3-acetylpyrene(2), m.p. 89-90° (84%), 3-propionylpyrene(3), m p. 83-84° (64%), 3-benzoylpyrene(4), m p. 126-128° (88%), 3-p-chlorobenzoylpyrene(5), m.p. 165-168° (from pet. ether, b. 60-80°)(27%), ν max.C=O (CCl_4) 1658 cm^{-1}, elem anal fitted $C_{22}H_{14}ClO$, and 3-o-chlorobenzoylpyrene(6), m p. 145-148° (from pet.ether, b. 60-80°)(25%), ν max. C=O (CCl_4) 1654 cm^{-1}, elem anal. fitted $C_{22}H_{14}ClO$, were synthesized by a Friedel-Crafts reaction involving pyrene and the corresponding acyl halide. 3-Methylpyrene(7), m.p 74-75° (86%), 3-ethylpyrene(8), m p. 92-93° (79%), and 3-propylpyrene(9),

m.p. 37° (from ethanol) (68%), ν max. (aliphatic C-H) 2915 cm^{-1}, elem.anal. fitted $C_{19}H_{16}$, were obtained by a Huang-Minlon[4] reduction of the corresponding acyl compound. 3-Benzylpyrene (10), m.p. 89° (36%) was synthesized by a Friedel-Crafts reaction involving pyrene and benzyl chloride. 3-Chloropyrene (11), m.p. 119° (98%) and 3-bromopyrene (12), m.p. 95° (98%), were obtained by the reaction of pyrene and the corresponding Cupric (II) halide in refluxing chlorobenzene, under anhydrous conditions.



(I) R = CHO-
(II) R = CH_3-CO-
(III) R = CH_3-CH_2-CO-
(IV) R = C_3H_7-CO-
(V) R = p-Cl-C_6H_4-CO-
(VI) R = o-Cl-C_6H_4-CO-
(VII) R = CH_3-
(VIII) R = CH_3-CH_2-
(IX) R = CH_3-CH_2-CH_2-
(X) R = C_6H_5-CH_2-
(XI) R = Cl-
(XII) R = Br-

In each case 0.2 mM of either anhydrous $CuCl_2$ or $CuBr_2$ was added to a stirred refluxing solution (0.1 mM) of the corresponding pyrene derivative, in either CCl_4 or PhCl, and the mixture further refluxed for 4 hrs (Table I). The inorganic salt was filtered out and the organic solvent flash evaporated to dryness under reduced pressure. The organic residue was analyzed by G.L.C. and T.L.C. As expected, on stereoelectronic grounds, halogenation of pyrene by Cu(II) halides proceeded via the corresponding 3-halogenopyrene, the reaction postulated to mediate by an electrophilic mechanism[2]. The rate of this reaction, as monitored by the evolution of the corresponding acid halide, has been found to be mainly depending on the halide used and temperature at which is carried out. The nature of the solvent has also been shown to have some effect on this rate[5].

Accordingly, electron-withdrawn or electron-releasing substituents at position 3 would respectively decrease or enhance the rate of pyrene's further halogenation, as well as to direct the position of new substituents. Table I shows the amount of unchanged initial compound left after reacting with the Cu(II) halide under the described conditions, as determined by G.L.C.[2], either from the crude organic residue or after being purified by T.L.C.[6] It also shows the number of products formed, again as determined by the above techniques, during the particular reactions, as well as their concentration. When possible,

they were identified by comparing their G.L.C. retention time and T.L.C. Rf values with that of authentic compounds. In other instances, their elemental analysis were obtained (Table I).

The gas chromatographic response factor, i.e. the relationship between the molar concentration of a tested standard sample and the area under its G.L.C. peak was calculated for each of the compounds reported in Table 1. The results obtained showed that this ratio was fairly similar for all of the compounds studied, and it did not experiment appreciable changes when these compounds were in mixture. However, in some of the reactions studied, we could not either purify and/or identify one or more compounds shown by G.L.C. to be present in the crude organic residue. For their quantitation, we assumed in every case their gas chromatographic response factor to be the same as that of pyrene. The number of these compounds obtained in the different reactions as well as their estimated total concentration is given in Table I.

As expected, substitution in pyrene's 3 position by either acetyl, propionyl, benzoyl, and p- or o-chlorobenzoyl groups deactivate the ring to further electrophilic substitution. Thus, these compounds did not react to any significant extent with Cupric(II) chloride or bromide even under refluxing chlobenzene. Notwithstanding, 3-formylpyrene yielded, under these conditions, some 3-halogenated pyrene. On the other hand, electron-releasing groups substituting on pyrene's 3 position enhanced its further halogenation by the Cupric(II) halides. Thus (Table 1), they form a number of disubstituted pyrenes, depending on the reaction conditions. It is important to note that the halogenation reaction did not, to any appreciable extent, occur on the 3-substituent group, as shown by NMR analysis of the products of these reactions.

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+.- Present Address The Chicago Medical School, Chicago, Illinois 60612, U.S.A.

-TABLE I-

COMPOUND 3-X-Pyrene (X)	HALIDE (CuX_2)	SOLVENT (REFLUXING)	TIME (Hr)	REACTION MIXTURE PRODUCT(S) (COMPOUND(S)) (%)*
H	$CuCl_2$	CCl_4	4	Py[a] (>98)
H	$CuCl_2$	PhCl	4	3-ClPy[a] (40); 3,X-DichloroPy[b] (47); 3,X'-DichloroPy[b] (7) (2; 6%)[c]
H	$CuBr_2$	CCl_4	4	Py[a] (>98)
H	$CuBr_2$	PhCl	4	3-BrPy[a] (>98)
CH_3	$CuCl_2$	CCl_4	4	3-MePy[a] (>98)
CH_3	$CuCl_2$	PhCl	4	3-ClPy[a] (50); 3-Me-X-ClPy[b] (44); 3,X-DichloroPy[b] (>2) (1; 4%)[c]
CH_3	$CuBr_2$	CCl_4	4	3-MePy[a] (>98)
CH_3	$CuBr_2$	PhCl	4	3-BrPy[a] (60); 3-Me-X-BrPy[b] (38) (1; <2%)[c]
C_2H_5	$CuCl_2$	CCl_4	4	3-EtPy[a] (72); 3-Et-X-ClPy[b] (23) (2; 5%)[c]
C_2H_5	$CuCl_2$	PhCl	4	3-Et-X-ClPy[b] (90) (2; 10%)[c]
C_2H_5	$CuBr_2$	CCl_4	4	3-EtPy[a] (80); 3-BrPy[a] (<2), 3-Et-X-BrPy[b] (13) (2; 5%)[c]
C_2H_5	$CuBr_2$	PhCl	4	3-BrPy[a] (5); 3-Et-X-BrPy[b] (87) (2; 8%)[c]
C_3H_7	$CuCl_2$	CCl_4	4	3-PropylPy[a] (63); 3-ClPy[a] (4); 3-Propyl-X-ClPy[b] (26) (3, 7%)[c]
C_3H_7	$CuCl_2$	PhCl	4	3-PropylPy[a] (5); 3-ClPy[a] (7); 3-Propyl-X-ClPy[b] (73) (3; 15%)[c]
C_3H_7	$CuBr_2$	CCl_4	4	3-PropylPy[a] (57); 3-Propyl-X-BrPy[b] (38) (2; 5%)[c]
C_3H_7	$CuBr_2$	PhCl	4	3-BrPy[a] (4); 3-Propyl-X-BrPy[b] (88) (2; 8%)[c]
$C_6H_5CH_2$	$CuCl_2$	CCl_4	4	3-BenzylPy[a] (78); 3-ClPy[a] (16) (3; 6%)[c]
$C_6H_5CH_2$	$CuCl_2$	PhCl	4	3-BenzylPy[a] (5); 3-ClPy[a] (60); 3-Benzyl-X-ClPy[b] (23) (2; 12%)[c]
$C_6H_5CH_2$	$CuBr_2$	CCl_4	4	3-BenzylPy[a] (58); 3-BrPy[a] (14); 3-Benzyl-X-BrPy[b] (20), 3-X-DiBromoPy (6) (1, <2%)[c]
$C_6H_5CH_2$	$CuBr_2$	PhCl	4	3-BenzylPy[a] (4); 3-BrPy[a] (27); 3-Benzyl-X-BrPy (42), 3-Benzyl-X'-BrPy (23), 3-X'-DiBrPy (4) (1; <2%)[c]
CHO	$CuCl_2$	PhCl	4	3-FormylPy[a] (61); 3-ClPy (29) (2; 10%)[c]
CHO	$CuBr_2$	PhCl	4	3-FormylPy[a] (53), 3-BrPy[a] (45) (1, <2%)[c]

*Per cent yields determined by gas-liquid chromatography, [a]Compounds identified by comparison of their G.L.C. and T.L.C. characteristics with that of authentic samples, [b]Satisfactory elemental analysis, after T.L.C. purification, was obtained for these compounds, [c]Number of extra G.L.C. peaks corresponding to non-isolated, unidentified reaction products and their total concentration expressed as percentage of the total crude organic residue as determined by G.L.C., using a gas chromatographic response factor similar to that of pyrene.