The Synthesis of Aliphatic Dicarboxylic Acid Diiodides and Aromatic Analogues[1]

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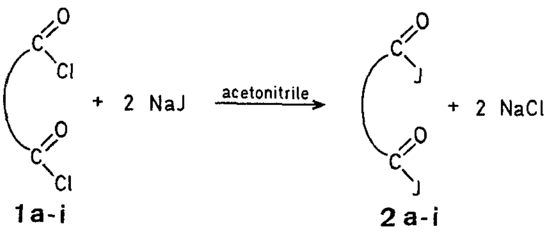
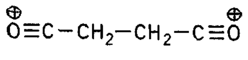
Although a variety of alkanoyl, alkenoyl, and aroyl iodides have been synthesized recently[2,3], compounds containing more than one iodocarbonyl group have hitherto been unknown. We now report the preparation and isolation of some representative aliphatic and aromatic dicarboxylic acid diiodides (**2a–i**) as well as the tricarboxylic acid triiodide **2j**. The synthetic method is similar to that used for monoacyl iodides: Acyl chlorides (**1**) are allowed to react with a solution of sodium iodide in acetonitrile in the previously described[2] low-temperature reactor-extractor and the resultant bis-iodocarbonyl compounds are extracted into pentane.



The yields of isolated alkanedioyl diiodides increase with increasing chain length: **2c** (37%), **2d** (46%), **2e** (67%), **2f** (92%); this order corresponds to the order of increasing lipophilicity. Thus, whilst the actual conversion (%) into iodocarbonyl compounds may be similar for all four substances, the isolation of product by extraction into pentane is facilitated by each additional methylene group. The isolation of hexandioyl di-iodide (**2e**) is remarkable (also for demonstrating our technique) in that **2e** appears as heavy, snow-white crystals during isolation in the extraction flask and even earlier in the lower side arm of the low-temperature reactor-extractor. When exposed to air, **2e** is oxidized readily, first turning yellow and then brown with simultaneous fuming.

Note that butanedioic diiodide (**2c**) can be prepared and isolated without difficulty, whereas the derived butanedioyl dication (**3c**) has eluded all attempts at its generation in superacidic media[4].



$$\overset{\oplus}{O}\equiv C-CH_2-CH_2-C\equiv\overset{\oplus}{O}$$ **3c**

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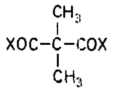
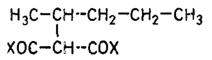
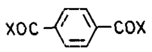
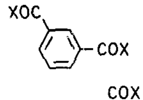
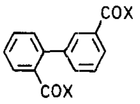
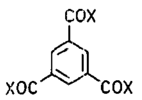
Table 1. Diacyl Diiodides (**2a–i**) and Benzene-1,3,5-tricarbonyl Triiodide (**2j**) from the Chlorides (**1**)

1 (X=Cl), 2 (X=J)	m.p. or b.p./torr [°C] of **1**	Reaction time [h]	Extraction time [h]	Yield[a] [%]	m.p. or b.p./torr [°C] of **2**	Molecular formula[b]	
a  $XOC-C(CH_3)_2-COX$	b.p. 165°	0.5	6	90		$C_5H_6J_2O_2$	(351.9)
b  $H_3C-CH(CH_2-CH_2-CH_3)$ / $XOC-CH-COX$	b.p. 80°/1	1	5	75		$C_8H_{12}J_2O_2$	(394.0)
c $XOC-CH_2-CH_2-COX$	b.p. 88°/19	0.5	8	37		$C_4H_4J_2O_2$	(337.9)
d $XOC-(CH_2)_3-COX$	b.p. 100°/15	1	22	46		$C_5H_6J_2O_2$	(351.9)
e $XOC-(CH_2)_4-COX$	b.p. 126°/12	1	8	67 (27)[c]		$C_6H_8J_2O_2$	(365.9)
f $XOC-(CH_2)_8-COX$	b.p. 175°/11	1	8	92		$C_{10}H_{16}J_2O_2$	(422.0)
g 	m.p. 82°	0.5	4	94	m.p. 45°	$C_8H_4J_2O_2$	(385.9)
h 	m.p. 43–44°	0.5	4	92	m.p. 68°	$C_8H_4J_2O_2$	(385.9)
i 	m.p. 93–94°	0.5	6	70		$C_{14}H_8J_2O_2$	(462.0)
j 	m.p. 34–36°	1	16	92		$C_9H_3J_3O_3$	(540.7)

[a] Yields of isolated product obtained by standard procedure. The yields have not been optimized.

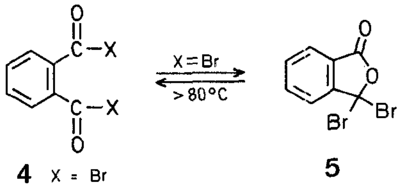
[b] Sufficiently correct and reproducible microanalyses cannot be obtained because of instability of the products.

[c] Yield obtained in initial experiment.

Attempts to isolate the parent malonyl diiodide (**2k**) were not successful. However, trapping experiments with ethylene oxide suggested that **2k** was formed from malonyl dichloride (**1k**)[5]. Hence **2k**, like the polar acetyl iodide[2], cannot be extracted into pentane from acetonitrile. The malonyl diiodide moiety, however, can be formed by attaching a 2-pentyl group to malonyl dichloride and converting the resultant 2-pentylmalonyl dichloride (**1b**) into the sufficiently lipophilic diiodide **2b** which, after extraction with pentane, is isolated in 75% yield. Even the sterically hindered dimethylmalonyl diiodide (**2a**) which contains two bulky iodocarbonyl functionalities at the same quaternary C-atom, was prepared and isolated in 90% yield. Thus, in agreement with previous experience, steric hindrance to nucleophilic attack at a carbonyl C-atom by iodide ion is generally not serious[2], although the lipophilic iodide ion has the largest ionic diameter (4.3 Å) of all simple stable anions.

Aromatic dicarboxylic acid diiodides tend to crystallize so easily that their isolation may sometimes be less easy. For example, biphenyl-2,2′-dicarboxylic acid diiodide (**2i**) is readily soluble in acetonitrile, also in the cold. However, during its preparation by the standard method, **2i** partially appears as a finely divided solid on the acetonitrile-pentane interface, thus thwarting its extraction into pentane. After removing the cooling bath and allowing the acetonitrile mother liquor to reach room temperature, **2i** dissolves and may be extracted. Triiodide **2j** was isolated in 92% yield.

Attempts to prepare phthaloyl iodide (**6**) were not successful. It has been reported that phthaloyl bromide (**4**) is difficult to obtain and that its formation requires heating of **5** above 80 °C[6].



4 X = Br
6 X = J

5

Products **2** were shown to be at least 95% pure by ^{13}C-N.M.R. spectrometry, i.e., acyl chlorides (**1**) and/or decomposition products are not present to any significant extent (>5%). ^{1}H-N.M.R. spectrometry is less suitable as a purity criterion since additional peaks would be more difficult to detect. In our hands, C,H analyses of identical samples of **2** gave too different results to be appropriate criteria for the purity of **2**.

The physical properties of acyl iodides and diacyl iodides cover a wide range, from the volatile trifluoroacetyl iodide (b.p. ~0°/760 torr)[7] to dense liquids and heavy crystalline solids. Only few acyl iodides are as polar as acetyl iodide and malonyl diiodide (**2k**), which cannot be extracted from acetonitrile into pentane. At least some diacyl diiodides are more lipophilic than the corresponding dichlorides. For instance, terephthalic acid diiodide (**2g**) dissolves readily in tetrachloromethane, a solvent of low polarity ($E_T = 32.5$)[8], whereas **1g** can be recrystallized from boiling tetrachloromethane (b.p. 77 °C) and is practically insoluble in pentane ($E_T = 31$)[8]. Compounds **2g** and **2h** could be distilled at 100 °C/~1 torr and kept unchanged at 25 °C in a sealed tube under argon for a few days. Apparently, electron-attracting groups impede S_N1-like heterolysis and oxidative attack[2] at iodine in **2**.

Table 2. I.R. and ^{1}H-N.M.R. (90 MHz) Data of Compounds **1** and **2**

Compound	I.R. (CCl_4) ν [cm^{-1}]	^{1}H-N.M.R. ($CDCl_3/TMS_{int}$) δ [ppm]
1a	1790 (vs); 1750 (m); 910 (s); 720 (s)	1.6 (s)
2a	1800 (vs); 1750 (vs); 870 (s); 690 (s)	1.5 (s)
1b	2980 (s); 2940 (s); 1780 (vs)	0.9–1.4 (m, 10H); 2.45 (m, 1H); 4.15 (d, $^3J=7$ Hz, 1H)
2b	2970 (s); 2940 (s); 1760 (vs)	0.9–1.4 (m, 10H); 2.4 (m, 1H); 4.75 (d, $^3J=7$ Hz, 1H)
1c	1780 (br, vs); 960 (s); 915 (m)	3.2 (s)
2c	1780 (br, vs); 880 (s)	3.2 (s)
1d	1800 (br, vs); 930 (s)	2.1 (m, $^3J=7$ Hz, 2H); 3.1 (t, $^3J=7$ Hz, 4H)
2d	1790 (br, vs); 885 (s)	2.0 (m, $^3J=7$ Hz, 2H); 3.2 (t, $^3J=7$ Hz, 4H)
1e	1800 (vs); 935 (s)	1.8 (t, $^3J=7$ Hz, 4H); 2.9 (t, $^3J=7$ Hz, 4H)
2e	1800 (br, vs); 925 (s)	1.7 (t, $^3J=7$ Hz, 4H); 3.1 (t, $^3J=7$ Hz, 4H)
1f	2940 (vs); 2860 (s); 1800 (vs)	1.44 (br s, 8H); 1.8 (br m, 4H); 3.0 (t, $^3J=7$ Hz, 4H)
2f	2940 (vs); 2880 (s); 1800 (br, vs)	1.42 (br s, 8H); 1.7 (br m, 4H); 3.19 (t, $^3J=7$ Hz, 4H)
1g	1762 (s); 1728 (vs)	8.25 (s)
2g	1760 (vs); 1735 (m)	7.42 (s)
1h	1765 (s); 1745 (s)	7.6–8.9 (m)
2h	1750 (s); 1738 (s)	7.5–8.7 (m)
1i	1778 (s); 1736 (m); 1195 (s)	7.2–8.6 (m)
2i	1779 (s); 1762 (m)	7.2–8.6 (m)
1j	1770 (br, vs); 1150 (vs); 1025 (vs); 680 (s)	9.1 (s)
2j	1760 (vs); 1135 (vs); 990 (s); 665 (s)	8.8 (s)

Table 3. ^{13}C-N.M.R. (20.15 MHz, $CDCl_3/TMS_{int}$) Data of Compounds **1** and **2**, δ [ppm]

Compound	C-1 (C=O)	C-2	Δ(C-1)[a]	Δ(C-2)[a]	Other signals
1a	171.9	69.3			23.2
2a	159.7	77.9	−12.2	8.6	23.1
1b	167.2 166.8	78.4			35.9, 35.2, 19.7, 16.3, 13.8 36.0, 35.2, 19.2, 16.0, 13.8
2b	150.5 149.6	96.2	−16.7 −17.2	17.8	
1c	172.5	41.7			
2c	156.9	55.0	−15.6	13.3	
1d	173.2	45.1			20.5
2d	160.1	57.6	−13.1	12.5	21.3
1e	173.3	46.5			24.0
2e	161.1	59.4	−12.2	12.9	23.8
1f	173.6	47.0			28.7, 28.3, 25.6
2f	162.3	60.0	−11.3	13.0	28.4, 27.5, 25.3
1g	167.5				138.4, 131.1
2g	157.6		−9.9		141.8, 132.6
1h	167.2				137.2, 134.5, 133.6, 130.2
2h	157.1		−10.1		137.4, 135.3, 134.3, 129.5
1i	167.2				142.2, 134.1, 133.1, 132.3, 130.4, 128.4
2i	158.0		−9.2		138.4, 136.4, 136.2, 133.4, 130.3, 128.4
1j	166.1				138.2, 135.6
2j	154.8		−11.3		138.7, 138.6

[a] Chemical shift difference for C-1 etc., on going from acyl iodide (**2a–f**) to acyl chloride (**1a–f**). In compounds **1g–j** and **2g–j**, C-1 refers to carbonyl C-atoms.

Most of the acyl chlorides (**1**) used in the present investigation are commercially available. Compounds **1a** and **1b** were prepared from dimethylmalonic acid[9] and 2-pentylmalonic acid[10], respectively, as described[2].

Diacyl Diiodides (2) from Diacyl Dichlorides (1); General Procedure: The conversion is carried out in the low-temperature reactor-extractor described in Ref.[2,11] using the following quantities of reactants and solvent: Diacyl dichloride **1a–i** (25 mmol) or triacyl trichloride **1j** (4.4 g, 17 mmol), powdered sodium iodide (15 g, 100 mmol), absolute acetonitrile (100 ml). The resultant iodocarbonyl compounds are isolated by standard extraction into pentane[2] with the exception that in the case of the readily crystallizing product **2i** the temperature is allowed to reach 25 °C.

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