A Simple and Unambiguous Synthesis of α,α- and α,α'-Dihalogeno Ketones[1]

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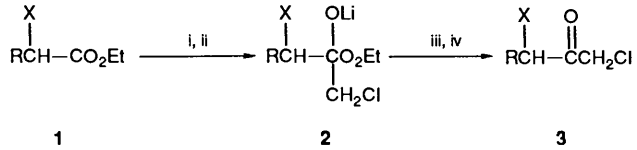
A convenient method for the unambiguous preparation of α,α'-dihalogeno ketones **3** from *in situ*-generated chloromethyllithium and α-chloro or α-bromo carboxylic acid esters **1** at −78 °C, is described. The unambiguous preparation of α,α,-dihalogeno ketones **7** by using *in situ*-generated dihalogenomethyllithium and carboxylic acid esters **5** at −78 °C is also reported.

The α,α- and α,α'-dihalogeno ketones are compounds of particular interest since they are highly functionalized molecules. Their high chemical reactivity enables them to undergo a wide variety of reactions and they are useful in organic synthesis. Thus, α,α'-dihalogeno ketones have been used, for instance, in the Favorskii rearrangement,[2] in the generation of oxyallyl cations,[3] in the mono- and di-alkylation of ketones,[4] in the synthesis of 1-substituted cyclopropanols,[5] in the preparation of substituted thiocyclopropanols,[6] and in the preparation of α-imino ketones and α-diimines.[7] On the other hand, α,α-dihalogeno ketones have been utilized, by example, in the Favorskii rearrangement,[8] in the preparation of but-2-en-4-olides,[9] for selective alkylation of ketones,[10] and in the synthesis of cyclopropane derivatives.[11] However, the major limitation of dihalogeno ketones chemistry is that to our knowledge, there is no effective and simple method of synthesizing a variety of α,α'-dihalogeno ketones bearing either the same or different halogen atoms.[12] On the other hand, although several syntheses of aliphatic α,α,-dihalogeno ketones have been reported[13,14] the methods are not simple[14a,b,e] and most of them can only be used for the preparation of α,α-dichloro ketones. Furthermore, the literature provides only a few examples[15] of direct preparation[16] of α,α-dihalogeno ketones bearing two different halogen atoms.

Recently we have described the utility of *in situ*-generated lithium carbenoids such as chloromethyllithium[17] and dihalogenomethyllithiums[18] in organic synthesis. These results prompted us to study the possibility of obtaining α,α'-dihalogeno ketones from chloromethyllithium and ethyl α-halogenocarboxylates,[1] and α,α-dihalogeno ketones starting from dihalogenomethyllithium and carboxylic acid esters. A process of this type was described some time ago in the literature for the preparation of α,α-dihalogeno ketones;[15] however, our methodology is simpler since the organolithium compound is generated *in situ* in the presence of the carboxylic acid ester. On the other hand, only two examples of the very interesting α-bromo-α-chloro ketones have been previously reported. In the present paper we report a simple, easy and rapid method for the unambiguous preparation of α,α- and α,α,'-dihalogeno ketones with the same or different halogen atoms (Hal = Cl, Br).

Results and Discussion

Preparation of α,α'-Dihalogeno Ketones **3**.—The reaction of different α-chloro or α-bromo carboxylic acid esters **1** with chloromethyllithium (1:1.5 molar ratio) (generated *in situ* by treatment of chloroiodomethane with methyllithium, at −78 °C), in the presence of lithium bromide at −78 °C, led to the corresponding intermediates **2**, which after hydrolysis afforded the α,α'-dihalogeno ketones **3** (Scheme 1 and Table 1). Most of the isolated crude products **3** were pure (> 95% from NMR analysis) and did not need further purification. The intermediate **2** is stable under the reaction conditions due to the presence of the electronegative halogen substituents and it does not undergo elimination of the ethoxide group,[19] so the addition of two molecules of chloromethyllithium to the ester **1** is not possible. However, the reaction of chloromethyllithium with 3-bromo-1-chloropentan-2-one **3e** gave the corresponding alcohol, **4** thus supporting the proposed mechanism (Scheme 2).



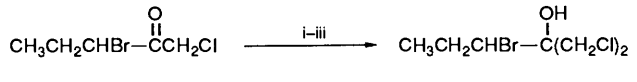
a; R = H, X = Cl
b; R = Cl, X = Cl
c; R = Me, X = Br
d; R = Me, X = Cl
e; R = Et, X = Br
f; R = C_5H_{11}, X = Br
g; R = C_6H_{13}, X = Cl

Scheme 1 *Reagents and conditions:* i, 1.5 mol equiv. $ClCH_2I$–LiBr; ii, 1.5 mol equiv. MeLi, −78 °C; iii HCl–Et_2O, −78 °C; iv, aq. HCl

Table 1 α,α'-Dihalogeno ketones **3** from α-halogeno carboxylic acid esters **1**

Carboxylic acid ester **1**	α,α'-Dihalogeno ketone **3**		
	No.	Yield (%)[a]	B.p./°C (mmHg)
1a	**3a**	60	172–175 (760)[b]
1b	**3b**	50	59–62 (10)[c]
1c	**3c**	64 (36)[d]	68–73 (10)
1d	**3d**	80	53–57 (10)[e]
1e	**3e**	95 (69)[f]	84–88 (10)
1f	**3f**	75	32–35 (0.001)
1g	**3g**	80 (34)[d]	79–82 (0.04)

[a] Isolated yield based on the initial amount of starting α-halogeno carboxylic acid ester **1**. [b] Lit.,[20] b.p. 173 °C (760 mmHg). [c] Lit.,[21] 91–94 °C (30 mmHg). [d] The reaction was carried out in the absence of lithium bromide. [e] Lit.,[20] 55.5 °C (10 mmHg). [f] Reaction time 1h.



Scheme 2 *Reagents and conditions:* i, 2 mol equiv. $ClCH_2I$–LiBr; ii, 3 mol equiv. MeLi, −78 °C; iii, aq. HCl, −78 °C

In general, the yields of α,α'-dihalogeno ketones decrease in the absence of lithium bromide and when the reaction time is

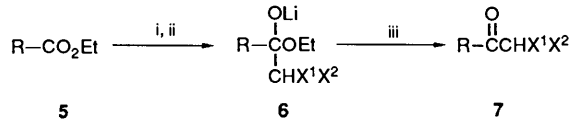
Table 2 α,α-Dihalogeno ketones **7** from carboxylic acid esters **5**

Carboxylic acid ester **5**	Dihalogeno methane	α,α-Dihalogeno ketone **7** No.	Yield (%)[a]	B.p./°C (mmHg) or R_f
5a	CH_2Br_2	**7a-a**	60	81–85 (10)[b]
5a	CH_2BrCl	**7a-b**	64 (50)[c]	76–79 (10)
5a	CH_2Cl_2	**7a-c**	71 (30)[d](42)[e]	53–57 (10)[f]
5b	CH_2Br_2	**7b-a**	75	68–72 (10)[g]
5b	CH_2BrCl	**7b-b**	61 (40)[c]	54–58 (10)
5b	CH_2Cl_2	**7b-c**	75	41–45 (10)[h]
5c	CH_2Br_2	**7c-a**	58	89–92 (10)
5c	CH_2BrCl	**7c-b**	60	76–80 (10)
5c	CH_2Cl_2	**7c-c**	64	59–63 (10)[i]
5d[j]	CH_2BrCl	**7d-b**	60	92–94 (0.1)[k]
5d[j]	CH_2Cl_2	**7d-c**	66	128–132 (10)[l]
5e[j]	CH_2BrCl	**7e-b**	60	0.44[m]
5e[j]	CH_2Cl_2	**7e-c**	62	78–82 (0.5)
5f	CH_2Br_2	**7f-a**	77	108–112 (0.5)
5f	CH_2BrCl	**7f-b**	65	99–102 (0.5)
5f	CH_2Cl_2	**7f-c**	55	66–70 (0.5)

[a] Isolated yield based on the initial amount of starting carboxylic acid ester **5**. [b] Lit.,[22] b.p. 88 °C (17 mmHg). [c] The reaction was carried out at −30 °C. [d] Reaction conditions: 2 h, −78 °C. [e] Reaction conditions: 1 h, −78 °C. [f] Lit.,[14c] 78–80 °C (43 mmHg). [g] Lit.,[23] 70 °C (10 mmHg). [h] Lit.,[14c] 70 °C (48 mmHg). [i] Lit.,[14c] 75 °C (30 mmHg). [j] Methyl ester was used as starting material. [k] Lit.,[15] 93 °C (0.1 mmHg). [l] Lit.,[24] 82–83 °C (1 mmHg). [m] Silica gel, hexane–Et_2O (9.5:0.5).

increased (see Table 1); in the last case dehalogenation compounds were obtained.

Preparation of α,α-Dihalogeno Ketones **7**.—Treatment of several carboxylic acid esters **5** with *in situ*-generated dihalogenomethyllithium (1:2 molar ratio) (see below) at −78 °C led to the corresponding intermediates **6**, which did not undergo elimination of the ethoxide group under the reaction conditions and afforded, after acid hydrolysis, the expected α,α-dihalogeno ketones **7** (Scheme 3 and Table 2).



5 **6** **7**

5 – 7a; R = Pr^n
b; R = Pr^i
c; R = Bu^i
d; R = Ph
e; R = PhCH=CH
f; R = PhC≡C

6,7a –f; - **a**; $X^1 = X^2$ = Br
- **b**; X^1 = Br, X^2 = Cl
- **c**; $X^1 = X^2$ = Cl

Scheme 3 *Reagents and conditions:* i, dihalogenomethane = CH_2Br_2, CH_2BrCl, CH_2Cl_2; ii, R'_2NLi, −78 °C; iii, aq. HCl, −78 °C

It is noteworthy that under these reaction conditions the dihalogeno ketone **7** is the only reaction product (> 95% from NMR analysis) and its isolation requires only removal of the solvent, without further purification. The dihalogenomethyllithium was generated *in situ* from dichloromethane or bromochloromethane and lithium dicyclohexylamide; in the case of dibromomethane the lithiation reaction was carried out with lithium diisopropylamide (LDA), since lithium dicyclohexylamide was not effective with this substrate. The reactions with dichloromethane and bromochloromethane can be also carried out at −30 °C (see Table 2); in these cases the yields are lower and it is necessary to purify the products by fractional distillation. The reaction times are short (*ca.* 0.5 h), the yields of dihalogeno ketones decreasing when the reaction times are longer, due to dehalogenation processes.

In conclusion, this paper describes a convenient, rapid, simple and versatile procedure for the unambiguous synthesis of α,α- and α,α′-dihalogeno ketones starting from readily available materials.

Experimental

General.—IR spectra were determined with a Philips PV-9716 and a Perkin-Elmer 1720-XFT spectrometer, as neat liquids. ^1H and ^{13}C NMR spectra were recorded on a Bruker AC-300 spectrometer, with $SiMe_4$ as internal standard; deuteriochloroform was used as solvent. *J* Values are given in Hz. The purity of the volatile distilled or condensed products was determined with a GLC Varian Vista 6000 instrument equipped with an OV-101 Chromosorb column. MS (EI) were recorded with a Hewlett Packard 5987 A spectrometer. Elemental analysis was carried out with a Perkin-Elmer 240 Elemental Analyser. Starting α-halogeno carboxylic acid esters **1**, chloroiodomethane, dichloromethane, dibromomethane, bromochloromethane, methyllithium, butyllithium, dicyclohexylamine and LDA were of the best commercial grade available (Aldrich, Merck) and were used without further purification. Diethyl ether and tetrahydrofuran (THF) were successively dried with anhydrous calcium chloride, sodium sulphate, sodium and finally with potassium under reflux, and were distilled and stored under argon. All reactions were carried out under argon and all glassware was dried before use. Product **3a** was commercially available (Aldrich) and was characterized by comparison with an authentic sample. (**CAUTION!** Most of the products **3** and **7** are lachrymatory and should be handled in a ventilated hood.)

General Procedure for the Preparation of α,α′-Dihalogeno Ketones **3**.—To a stirred solution of chloroiodomethane (0.43 cm^3, 6 mmol), the α-halogeno carboxylic acid ethyl ester **1** (4 mmol), and lithium bromide (0.35 g, 4 mmol) in THF (10 cm^3) was added an ethereal solution of methyllithium (1.5 mol dm^{-3}; 6.4 mmol) during 5 min at −78 °C under nitrogen. The mixture was stirred for 20 min at this temperature, then the mixture was hydrolysed successively with a diethyl ether solution of HCl (5 mol dm^{-3}; 2 cm^3) and aq. HCl, and extracted with diethyl ether. The extract was dried (Na_2SO_4) and the solvents were removed (15 mmHg) to yield a residue that contained the expected ketone **3** of >95% purity (NMR, GLC). Compounds **3** can be purified by distillation at reduced pressure. 1,1,3-Trichloropropan-2-one **3b** ν_{max}(C=O)/cm^{-1} 1740; δ_H 4.6 (2 H, s, CH_2Cl) and 6.2 (1 H, s, CHCl); δ_C 42.9 (CH_2Cl), 67.6 (CHCl) and 188.8 (C=O); *m/z* 166 (M^+ + 6, <1%), 164 (M^+ + 4, <1), 162 (M^+ + 2, 2), 160 (M^+, 2), 85 (14), 83 (19), 79 (31), 77 (100) and 49 (12).

3-*Bromo*-1-*chlorobutan*-2-*one* **3c** (Found: C, 25.7; H, 3.4. C_4H_6BrClO requires C, 25.91; H, 3.26%); ν_{max}(C=O)/cm^{-1} 1760; δ_H 1.7 (3 H, d, *J* 6, Me), 4.6 (1 H, q, *J* 6, CHBr) and 4.4 (2 H, s, CH_2Cl); δ_C 20.2 (Me), 45.1 (CH_2Cl), 46.8 (CHBr) and 197.1 (C=O); *m/z* 188 (M^+ + 4, 5%), 186 (M^+ + 2, 23), 184 (M^+, 17), 137 (94), 135 (100), 109 (99), 107 (98), 79 (28), 77 (74), 56 (28), 49 (23) and 42 (18).

1,3-Dichlorobutan-2-one **3d**; ν_{max}(C=O)/cm^{-1} 1760; δ_H 1.6 (3 H, d, *J* 7, Me), 4.4 (2 H, s, CH_2Cl) and 4.6 (1 H, q, *J* 7, CHCl); δ_C 19.7 (Me), 45.6 (CH_2Cl), 55.5 (CHCl) and 196.7 (C=O); *m/z* 144 (M^+ + 4, 2%), 142 (M^+ + 2, 9), 140 (M^+, 15), 93 (10), 91 (35), 79 (34), 77 (100), 65 (25), 63 (72), 49 (26) and 42 (18).

3-*Bromo*-1-*chloropentan*-2-*one* **3e** (Found: C, 29.8; H, 4.2. C_5H_8BrClO requires C, 30.11; H, 4.04%); ν_{max}(C=O)/cm^{-1} 1760; δ_H 1.0 (3 H, t, *J* 7, Me), 1.9–2.1 (2 H, m, CH_2), 4.4 (2 H, d, *J* 7,

CH_2Cl) and 4.5 (1 H, t, *J* 7, CHBr); δ_C 11.5 (Me), 26.2 (CH_2), 45.5 (CH_2Cl), 51.1 (CHBr) and 195.5 (C=O); *m/z* 151 ($M^+ + 2 - CH_2Cl$, 62%), 149 ($M^+ - CH_2Cl$, 61), 123 (94), 121 (100), 119 (13), 79 (23), 77 (58), 70 (22), 55 (28), 51 (13), 49 (33), 42 (30), 41 (93) and 39 (42).

3-*Bromo*-1-*chlorooctan*-2-*one* **3f** (Found: C, 39.5; H, 5.6. $C_8H_{14}BrClO$ requires C, 39.78; H, 5.84%); ν_{max}(C=O)/cm^{-1} 1760; δ_H 0.9–1.0 (3 H, m, Me), 1.3–1.5 (6 H, m, $[CH_2]_3Me$), 1.9–2.1 (2 H, m, CH_2CHBr), 4.4 and 4.5 (2 H, 2 d, *J* 13, CH_2Cl) and 4.6 (1 H, t, *J* 7, CHBr); δ_C 13.6 (Me), 22.1, 26.6, 30.8 and 32.8 ($[CH_2]_4$), 45.2 (CH_2Cl), 49.4 (CHBr) and 195.4 (C=O); *m/z* 244 ($M^+ + 4$, <1%), 242 ($M^+ + 2$, <1), 240 (M^+, <1), 174 (13), 172 (51), 170 (40), 107 (11), 105 (20), 83 (100), 79 (11), 77 (28), 69 (12), 55 (60), 43 (18), 41 (29) and 39 (13).

1,3-*Dichlorononan*-2-*one* **3g** (Found: C, 49.9; H, 7.8. $C_9H_{16}Cl_2O$ requires C, 51.20; H, 7.64%); ν_{max}(C=O)/cm^{-1} 1750; δ_H 0.9–1.0 (3 H, m, Me), 1.2–1.4 (8 H, m, $[CH_2]_4Me$), 1.9–2.0 (2 H, m, CH_2CHCl), 4.5 (2 H, d, *J* 7, CH_2Cl) and 4.4–4.6 (1 H, m, CHCl); δ_C 13.7 (Me), 22.2, 25.6, 28.3, 31.2 and 33.2 ($[CH_2]_5$), 45.8 (CH_2Cl), 60.7 (CHCl) and 196.4 (C=O); *m/z* 165 ($M^+ + 4 - CH_2Cl$, <1%), 163 ($M^+ + 2 - CH_2Cl$, <1), 161 ($M^+ - CH_2Cl$, 1), 130 (10), 127 (65), 126 (100), 105 (11), 97 (56), 91 (15), 84 (18), 79 (20), 77 (54), 69 (14), 57 (15), 55 (70), 49 (17), 43 (27), 42 (13), 41 (30) and 39 (16).

Synthesis of 3-*Bromo*-1-*chloro*-2-(*chloromethyl*)*pentan*-2-*ol* **4**.—To a stirred solution of chloroiodomethane (0.36 cm^3, 5 mmol), 3-bromo-1-chloropentan-2-one **3e** (0.50 g, 2.5 mmol), and lithium bromide (0.22 g, 2.5 mmol) in THF (10 cm^3) was added an ethereal solution of methyllithium (1.5 mol dm^{-3}; 12 mmol) during 5 min at −78 °C under nitrogen. The mixture was stirred for 10 min at this temperature, then the mixture was hydrolysed successively with a diethyl ether solution of HCl (5 mol dm^{-3}; 2 cm^3) and aq. HCl and extracted with diethyl ether. The extract was dried (Na_2SO_4), the solvents were removed (15 mmHg) and the resulting residue was distilled to afford the corresponding *alcohol* **4** (0.31 g, 50%), b.p. 90–95 °C (20 mmHg) (Found: C, 28.6; H, 4.2. $C_6H_{11}BrCl_2O$ requires C, 28.83; H, 4.43%); ν_{max}(OH)/cm^{-1} 3500; δ_H 1.1 (3 H, t, *J* 8, Me), 1.8–2.1 (2 H, m, CH_2Me), 2.5–2.6 (1 H, s, OH) and 3.5–4.3 (5 H, m, 2 × CH_2Cl and CHBr); δ_C 12.7 (Me), 24.9 (CH_2Me), 46.5 and 47.4 (2 × CH_2Cl), 61.6 (CHBr) and 74.5 (COH); *m/z* 203 ($M^+ + 4 - CH_2Cl$, 10%), 201 ($M^+ + 2 - CH_2Cl$, 38), 199 ($M^+ - CH_2Cl$, 30), 131 (11), 129 (67), 128 (15), 127 (100), 126 (17), 121 (21), 119 (37), 93 (11), 91 (26), 79 (24), 77 (54), 63 (10), 55 (12), 49 (14), 43 (10), 41 (20) and 39 (17).

General Procedure for the Preparation of α,α-*Dihalogeno Ketones* **7**.—To a stirred solution of a dihalogenomethane (20 mmol) and a starting ethyl alkanoate **1** (10 mmol) in THF (20 cm^3), was added a solution of lithium dicyclohexylamide (in the case of CH_2Cl_2 and CH_2BrCl) or LDA (in the case of CH_2Br_2) (20 mmol) in THF (20 cm^3) during 10 min at −78 °C. The mixture was stirred for 20 min at the same temperature and the mixture was hydrolysed with aq. HCl (6 mol dm^{-3}; 10 cm^3). Then the solid was filtered off, the filtrate was extracted with Et_2O, and the ethereal layer was dried (Na_2SO_4). The solvent was removed (15 mmHg) to yield a residue that contained the expected ketone **7** with >95% purity (NMR, GLC). Compounds **7** can be purified by distillation at reduced pressure. 1,1-Dibromopentan-2-one **7a-a**; ν_{max}(C=O)/cm^{-1} 1710; δ_H 1.0 (3 H, t, *J* 7, Me), 1.7 (2 H, sextet, *J* 7, CH_2Me), 2.9 (2 H, t, *J* 7, CH_2C=O) and 5.8 (1 H, s, CH); δ_C 13.2 (Me), 17.6 (CH_2Me), 36.6 (CH_2CO), 42.9 (CH) and 196.5 (C=O); *m/z* 246 ($M^+ + 4$, <1%), 244 ($M^+ + 2$, 1), 242 (M^+, <1), 71 (100), 43 (44), 41 (22) and 39 (10).

1-*Bromo*-1-*chloropentan*-2-*one* **7a-b** (Found: C, 29.3; H, 4.2. C_5H_8BrClO requires C, 30.11; H, 4.04%); ν_{max}(C=O)/cm^{-1} 1720; δ_H 0.9 (3 H, t, *J* 7, Me), 1.6 (2 H, sextet, *J* 7, CH_2Me), 2.7 (2 H, dt, *J* 7, 2, CH_2C=O) and 5.9 (1 H, s, CH); δ_C 13.2 (Me), 17.2 (CH_2Me), 36.7 (CH_2CO), 57.0 (CH) and 196.7 (C=O); *m/z* 200 ($M^+ + 2$, <1%), 71 (100), 43 (73), 41 (36), and 39 (14).

1,1-Dichloropentan-2-one **7a-c**; ν_{max}(C=O)/cm^{-1} 1720; δ_H 0.9 (3 H, t, *J* 7, Me), 1.6 (2 H, sextet, *J* 7, CH_2Me), 2.7 (2 H, t, *J* 7, CH_2) and 5.8 (1 H, s, CH); δ_C 13.2 (Me), 17.0 (CH_2Me), 36.7 (CH_2CO), 69.7 (CH) and 196.8 (C=O); *m/z* 158 ($M^+ + 4$, <1%), 156 ($M^+ + 2$, <1), 154 (M^+, <1), 85 (16), 83 (24), 76 (17), 71 (83), 48 (10), 43 (100), 41 (47) and 39 (20).

1,1-Dibromo-3-methylbutan-2-one **7b-a**; ν_{max}(C=O)/cm^{-1} 1720; δ_H1.2 (6 H, d, *J* 7, 2 × Me), 3.3 (1 H, septet, *J* 7, CH) and 5.9 (1 H, s, $CHBr_2$); δ_C 20.1 (2 × Me), 34.9 (CH), 41.9 ($CHBr_2$) and 200.1 (C=O); *m/z* 246 ($M^+ + 4$, <1%), 244 ($M^+ + 2$, <1), 242 (M^+, <1), 71 (100), 43 (79), 41 (36) and 39 (16).

1-*Bromo*-1-*chloro*-3-*methylbutan*-2-*one* **7b-b** (Found: C, 29.6; H, 3.8. C_5H_8BrClO requires C, 30.11; H, 4.04%); ν_{max}(C=O)/cm^{-1} 1720; δ_H 1.2, 1.25 (6 H, 2 d, *J* 7, 2 × Me), 3.3 (1 H, septet, *J* 7, CH) and 6.0 (1 H, s, CHBrCl); δ_C 19.5 and 20.0 (2 × Me), 35.0 (CH), 56.1 (CHBrCl) and 200.3 (C=O); *m/z* 202 ($M^+ + 4$, <1%), 200 ($M^+ + 2$, <1), 198 (M^+, <1), 71 (100), 43 (90), 41 (30) and 39 (10).

1,1-Dichloro-3-methylbutan-2-one **7b-c**; ν_{max}(C=O)/cm^{-1} 1730; δ_H 1.2 (6 H, d, *J* 7, 2 × Me), 3.2 (1 H, septet, *J* 7, CH) and 6.0 (1 H, s, $CHCl_2$); δ_C 19.4 (2 × Me), 35.0 (CH), 69.0 ($CHCl_2$) and 200.3 (C=O); *m/z* 87 ($M^+ + 4 - Pr^iCO$, 12%), 85 ($M^+ + 2 - Pr^iCO$, 64), 83 ($M^+ - Pr^iCO$, 100), 78 (20), 76 (53), 71 (25), 55 (12), 51 (10), 50 (33), 49 (19), 48 (79), 47 (27), 43 (39), 42 (10), 41 (68), 40 (11), 39 (85), 38 (19) and 37 (12).

1,1-*Dibromo*-4-*methylpentan*-2-*one* **7c-a** (Found: C, 27.6; H, 3.7. $C_6H_{10}Br_2O$ requires C, 27.94; H, 3.91%); ν_{max}(C=O)/cm^{-1} 1720; δ_H 0.9 (6 H, d, *J* 7, 2 × Me), 2.2 (1 H, nonet, *J* 7, CH), 2.7 (2 H, d, *J* 7, CH_2) and 5.7 (1 H, s, $CHBr_2$); δ_C 22.1 (2 × Me), 24.4 (CH), 43.3 ($CHBr_2$), 43.5 (CH_2) and 195.8 (C=O); *m/z* 260 ($M^+ + 4$, <1%), 258 ($M^+ + 2$, <1), 256 (M^+, <1), 199 (48), 85 (100), 57 (59), 43 (15), 41 (36) and 39 (16).

1-*Bromo*-1-*chloro*-4-*methylpentan*-2-*one* **7c-b** (Found: C, 33.9; H, 4.7 $C_6H_{10}BrClO$ requires C, 33.75; H, 4.72%); ν_{max}(C=O)/cm^{-1} 1720; δ_H 0.9, 0.95 (6 H, 2 d, *J* 7, 2 × Me), 2.1 (1 H, nonet, *J* 7, CH), 2.7 (2 H, d, *J* 7, CH_2) and 5.8 (1 H, s, CHBrCl); δ_C 22.0 and 22.1 (2 × Me), 24.2 (CH), 43.6 (CH_2), 57.2 (CHBrCl) and 196.1 (C=O); *m/z* 131 ($M^+ + 4 - Pr^iCH_2CO$, 2%), 129 ($M^+ + 2 - Pr^iCH_2CO$, 6), 127 ($M^+ - Pr^iCH_2CO$, 4), 85 ($M^+ - CHBrCl$, 100), 57 (93), 43 (23), 41 (40) and 39 (13).

1,1-Dichloro-4-methylpentan-2-one **7c-c**; ν_{max}(C=O)/cm^{-1} 1730; δ_H 1.0 (6 H, d, *J* 7, 2 × Me), 2.2 (1 H, nonet, *J* 7, CH), 2.6 (2 H, d, *J* 7, CH_2) and 5.8 (1 H, s, $CHCl_2$); δ_C 21.7 (2 × Me), 23.8 (CH), 43.2 (CH_2), 69.6 ($CHCl_2$) and 195.8 (C=O); *m/z* 87 ($M^+ + 4 - Pr^iCH_2CO$, 11%), 85 ($M^+ + 2 - Pr^iCH_2CO$, 79), 83 ($M^+ - Pr^iCH_2CO$, 100), 78 (11), 76 (31), 57 (41), 50 (18), 48 (44), 47 (16), 43 (24), 42 (54), 41 (92), 40 (14), 39 (90) and 38 (14).

α-Bromo-α-chloroacetophenone **7d-b**; ν_{max}/cm^{-1} 3060 (C=CH) and 1690 (C=O); δ_H 6.8 (1 H, s, CHClBr), 7.5 (2 H, t *J* 7, CH_m), 7.6 (1 H, t, *J* 7, CH_p), and 8.0 (2 H, m, CH_o); δ_C 54.1 (CHBrCl), 128.7, 129.4, 131.0 and 134.3 (C_6H_5) and 185.8 (C=O); *m/z* 234 ($M^+ + 2$, <1%), 232 (M^+, <1), 105 (100), 77 (37) and 51 (12).

α,α-Dichloroacetophenone **7d-c**; ν_{max}/cm^{-1} 3060 (C=CH) and 1700 (C=O); δ_H 6.8 (1 H, s, $CHCl_2$), 7.4–7.6 (3 H, m, 2 CH_m, CH_p,), and 8.0 (2 H, d, *J* 8 CH_o); δ_C 67.6 ($CHCl_2$), 128.7, 129.4, 131.0 and 134.4 (C_6H_5) and 185.6 (C=O); *m/z* 125 (16%), 105 ($M^+ - CHCl_2$, 72), 89 (12), 85 ($M^+ + 2 - C_6H_5CO$, 38), 83 ($M^+ - C_6H_5CO$, 56), 78 (12), 77 (100), 76 (25), 75 (12), 74 (24), 63 (18), 62 (13), 51 (71), 50 (68), 49 (14), 48 (53), 47 (16), 39 (11) and 38 (12).

(E)-1-*Bromo*-1-*chloro*-4-*phenylbut*-3-*en*-2-*one* **7e-b** (Found: C, 46.0; H, 2.9. $C_{10}H_8BrClO$ requires C, 46.26; H, 3.11%);

ν_{max}(C=CH)/cm^{-1} 3060 and 3020 and 1690 (C=O); δ_H 6.0 (1 H, s, CHClBr), 7.2 (1 H, d, *J* 16, CH=C*H*CO), 7.4–7.7 (5 H, m Ph) and 7.8 (1 H, d, *J* 16, C*H*=CHCO); δ_C 56.9 (CHClBr), 117.6 (CH=*C*HCO), 128.7, 128.9, 131.3 and 133.7 (C_6H_5), 147.6 (*C*H=CHCO) and 185.5 (C=O); *m/z* 262 (M^+ + 4, <1%), 260 (M^+ + 2, <1), 258 (M^+, <1), 132 (10), 131 (100), 115 (34), 103, (45), 102 (16), 77 (34), 76 (12), 63 (12), 51 (24) and 50 (17).

(E)-1,1-*Dichloro*-4-*phenylbut*-3-*en*-2-*one* **7e-c** (Found: C, 55.5; H, 3.9. $C_{10}H_8Cl_2O$ requires C, 55.84; H, 3.75%); ν_{max}/cm^{-1} 3060 and 3020 (C=CH) and 1680 (C=O); δ_H 6.0 (1 H, s, $CHCl_2$), 7.2 (1 H, d, *J* 16, CH=C*H*CO), 7.8 (1 H, d, *J* 16, C*H*=CHCO) and 7.4–7.6 (5 H, m, Ph); δ_C 69.6 ($CHCl_2$), 117.4 (CH=*C*HCO), 128.6, 128.8, 131.3 and 133.5 (C_6H_5), 147.7 (*C*H=CHCO) and 185.4 (C=O); *m/z* 218 (M^+ + 4, <1%), 216 (M^+ + 2, 3), 214 (M^+ + 4), 131 (100), 103 (36), 77 (22) and 51 (12).

1,1-*Dibromo*-4-*phenylbut*-3-*yn*-2-*one* **7f-a** (Found: C, 39.6; H, 2.2. $C_{10}H_6Br_2O$ requires C, 39.78; H, 2.00%); ν_{max}/cm^{-1} 2180 (C≡C) and 1660 (C=O); δ_H 5.9 (1 H, s, $CHBr_2$), 7.3–7.4 (3 H, m, 2 × $CH_{m,}CH_p$) and 7.6 (2 H, d, *J* 8, CH_o); δ_C 42.3 ($CHBr_2$), 83.0 and 97.3 (C≡C), 118.7, 128.6, 131.6 and 133.4 (C_6H_5) and 173.3 (C=O); *m/z* 304 (M^+ + 4, <1%), 302 (M^+ + 2, <1), 300 (M^+, <1) and 129 (100).

1-*Bromo*-1-*chloro*-4-*phenylbut*-3-*yn*-2-*one* **7f-b** (Found: C, 46.4; H, 2.5. $C_{10}H_6BrClO$ requires C, 46.64; H, 2.35%); ν_{max}/cm^{-1} 2180 (C≡C) and 1680 (C=O); δ_H 6.0 (1 H, s, CHBrCl) and 7.3–7.6 (5 H, m, Ph); δ_C 56.7 (CHBrCl), 83.1 and 97.4 (C≡C), 118.6, 128.6, 131.5 and 133.3 (C_6H_5) and 173.5 (C=O); *m/z* 260 (M^+ + 4, <1%), 258 (M^+ + 2, <1), 256 (M^+, <1) and 129 (100).

1,1-*Dichloro*-4-*phenylbut*-3-*yn*-2-*one* **7f-c** (Found: C, 56.1; H, 2.6. $C_{10}H_6Cl_2O$ requires C, 56.38; H, 2.84%); ν_{max}/cm^{-1} 2200 (C≡C) and 1680 (C=O); δ_H 6.0 (1 H, s, $CHCl_2$) and 7.4–7.6 (5 H, m, Ph); δ_C 69.8 ($CHCl_2$), 83.0 and 97.2 (C≡C), 118.0, 128.2, 131.3 and 133.0 (C_6H_5) and173.0 (C=O); *m/z* 130 (11%), 129 (M^+ − $CHCl_2$, 100), 101 (12), 87 (11), 85 (40), 83 (55), 77 (13), 76 (11), 75 (32), 74 (35), 63 (14), 62 (18), 61 (13), 51 (19), 50 (31), 49 (13), 48 (37), 47 (12) and 39 (10).

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