Fluorinated acetylenes. Part 8 [1]. Preparation and some reactions of 5,5,5-trifluoropent-3-yn-2-ol, 5,5,5-trifluoro-1-phenylpent-3-yn-2-ol and the derived ester, 2-acetoxy-5,5,5-trifluoropent-3-yne

Lakhdar Sibous and Anthony E. Tipping*

Chemistry Department, University of Manchester Institute of Science and Technology, Manchester M60 1QD (UK)

(Received March 23, 1992; accepted July 7, 1992)

Abstract

Treatment of the salt $CF_3C{\equiv}CLi$ (**3**) with the aldehydes RCH_2CHO (R = H and Ph) affords the secondary alcohols $CF_3C{\equiv}CCHROH$ (**1a**) R = Me and (**1b**) R = CH_2Ph. Alcohol **1a** does not give the corresponding ketone on attempted oxidation (pyridinium chlorochromate or $Na_2Cr_2O_7/H_2SO_4$), but alcohol **1b** is oxidized to the diketone $(CF_3C{\equiv}CCOCHPh)_2$ (**7**) (41%) by active MnO_2. The acetate $CF_3C{\equiv}CCHMeO_2CMe$ (**2**) undergoes facile reaction with diazomethane to give 3-[(1′-acetoxy)ethyl]-4-trifluoromethylpyrazole (**10a**) and hence the 3- and 5-[(1′-acetoxy)ethyl-1-methyl-4-trifluoromethylpyrazoles (**11a**) and (**12a**), respectively. Cycloaddition also takes place between ester **2** and furan, but the major products (considered to be isomeric 1:1 adducts) have not been fully characterised. Although, ester **2** undergoes reaction with trifluoronitrosomethane, a cycloadduct has not been isolated, while nucleophilic attack by imidazole on the triple bond leads to the (*Z*)-alkene (**18**).

Introduction

The facile reaction of lithium acetylides with aldehydes to give secondary alcohols after acidification has been used to prepare trifluoropropynyl-substituted carbinols [1, 2]. Ketones and esters formed from such alcohols by oxidation and treatment with acid chlorides, respectively, were required in a continuation of a study of reactions, especially cycloadditions, of alkynes containing the CF_3 group. In the present work, the alcohols $CF_3C{\equiv}CCHROH$ (**1a**) R = Me and (**1b**) R = CH_2Ph have been prepared and their oxidations studied. Cycloaddition reactions of the acetyl derivative **2** of alcohol **1a** with diazomethane, furan and trifluoronitrosomethane have been investigated as well as the reaction with imidazole.

Results and discussion

The reaction of 3,3,3-trifluoropropynyl-lithium (**3**) with the aldehydes CH_3CHO and $PhCH_2CHO$ gave the corresponding alcohols **1a** (85%) and **1b** (61%), respectively, after treatment with aqueous acid.

*To whom enquiries should be addressed.

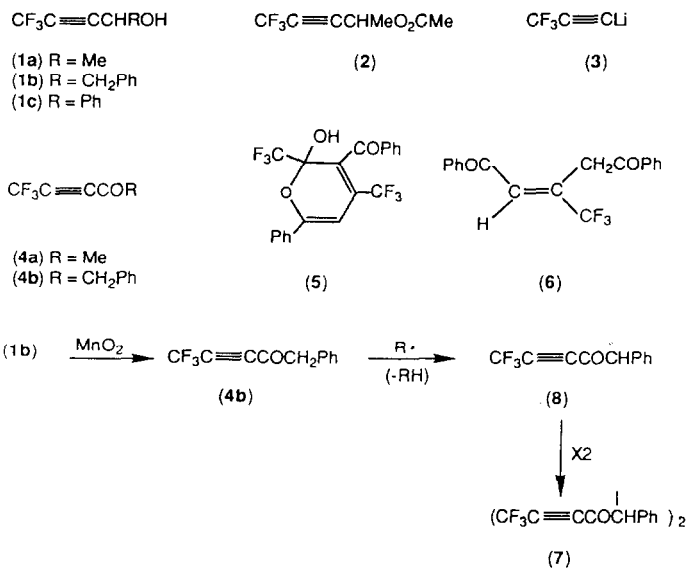
0022-1139/93/$6.00

Attempted oxidation [pyridinium chlorochromate (PCC)/CH_2Cl_2/20 °C or $Na_2Cr_2O_7/H_2SO_4$ (aq.)/30 °C] of alcohol **1a** to the ketone **4a** was unsuccessful and the alcohol was recovered unchanged in high yield. Although this lack of reactivity towards oxidation parallels that observed with the alcohol **1c** [1], it contrasts with that found with the hydrocarbon α,β-acetylenic alcohols, which have been reported to be oxidised readily by PCC to the corresponding carbonyl compounds in high yield [3].

Active manganese(IV) oxide has been found to oxidise the alcohol MeC≡CCHPhOH to the ketone MeC≡CCOPh (80%) at room temperature [4] and the alcohol **1c** to a mixture of the α-pyran **5** (70%) and the endione **6** (23%) [1]. In the present work, treatment of alcohol **1b** with an excess of active MnO_2 (molar ratio 1:10) under nitrogen in CH_2Cl_2 as the solvent at room temperature (24 h) and then 30 °C (2 h), gave a mixture of unchanged **1b** and a ketone (IR, 1700 cm^{-1}, C=O str.). Separation by DCFC afforded unchanged **1b** (75% recovered) and the diketone **7** (41%).

Evidence has been put forward that oxidations with active MnO_2 can involve free-radical intermediates [5, 6] and the participation of hydroxyl radicals (presumed to arise from hydrated MnO_2) has been proposed to account for the formation of pyrenediones from pyrene [6].

It is considered that the product **7** is formed via oxidation to the ketone **4b** and thence the secondary benzylic radical **8** (Scheme 1). Formation of the diketone $(PhCOCHPh)_2$ from ketone $PhCOCH_2Ph$ with active MnO_2 in refluxing $CHCl_3$ has been explained similarly [7].



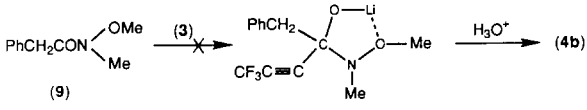
Scheme 1.

It has been reported that *N*-methoxy-*N*-methylamides combine cleanly with both Grignard and organolithium reagents to form 1:1 adducts in which the metal atom is coordinated to the methoxy oxygen. On treatment with aqueous acid the 1:1 adducts give ketones [8]. Therefore the *N*-methoxy-*N*-methylamide (**9**) was synthesized (from *N*,*O*-dimethylhydroxylamine and phenylacetyl chloride) in 69% yield and its reaction with salt **3** was investigated as a route to ketone **4b** as shown in Scheme 2. However, even at −50 °C, treatment of an ethereal solution of amide **9** with an ethereal solution of salt **3** resulted in extensive tar formation and after acidification the ketone **4b** was not detected.

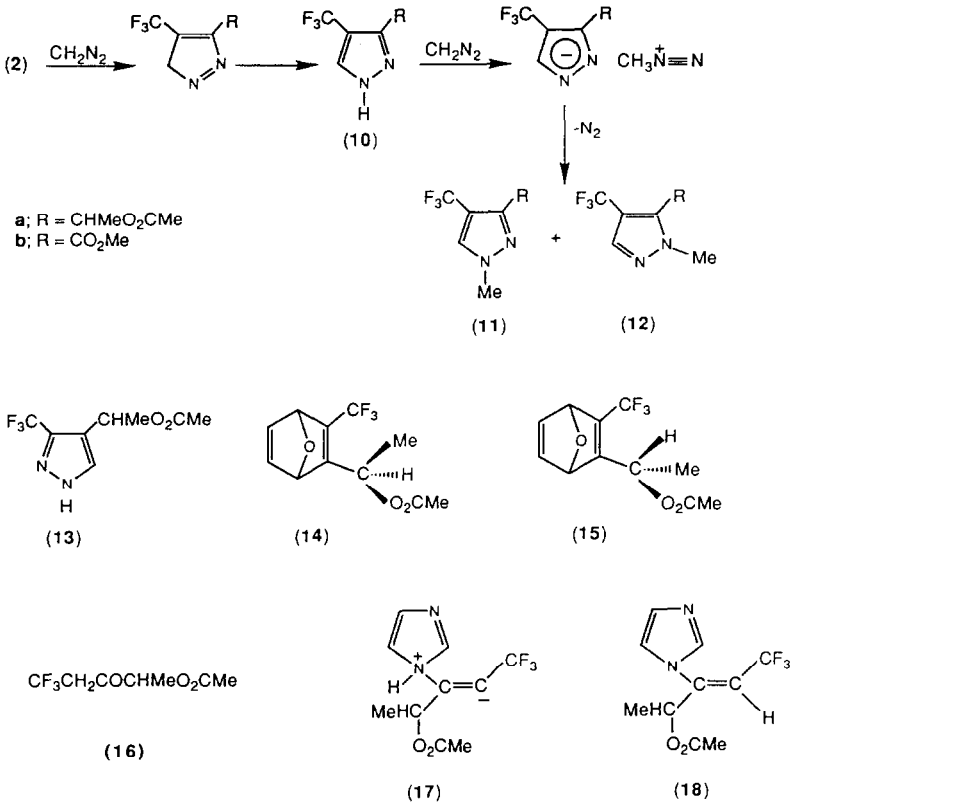
The ester **2** was obtained in 91% yield by treatment of alcohol **1a** with acetyl chloride and on reaction of the ester with diazomethane (1:1 molar ratio), 3-[(1′-acetoxy)ethyl]-4-trifluoromethylpyrazole (**10a**) (63%) was obtained. With an excess of diazomethane the initially-formed pyrazole **10a** underwent further reaction to afford a 1:1 mixture (83%) of 3- and 5-[(1′-acetoxy)ethyl]-1-methyl-4-trifluoromethylpyrazoles (**11a**) and (**12a**), respectively (Scheme 3). Since diazomethane additions are generally dipole HOMO controlled the regiospecific addition to ester **2** to give pyrazole **10a** infers that the larger frontier orbital coefficient in the LUMO of the alkyne is associated with the carbon bonded to CF_3, cf. alkyne $CF_3C{\equiv}CCO_2Me$ [1].

The structures of the products **10a–12a** were confirmed by a comparison of their ^{13}C NMR spectra with those of the corresponding products **10b–12b** obtained by reaction of diazomethane with the acid $CF_3C{\equiv}CCO_2H$ [1], the structures of which had been determined by X-ray crystallographic studies. The magnitude of the quartet splittings (J = 3–4 Hz) observed for the ring HC= carbons in the ^{13}C NMR spectra also confirmed that these carbons were γ to fluorine; in the alternative regioisomer **13**, the HC= carbon is δ to fluorine and coupling would not be expected.

Reaction did not occur between ester **2** and furan at 50 °C, but at 100 °C a 2:1 molar ratio of reactants gave a major product which was separated by DCFC and analysed correctly for a 2:2 adduct + H_2O or a 1:1 adduct + 0.5H_2O; the water could not be removed by chemical means ($MgSO_4$ or P_2O_5). The ^1H NMR spectrum showed the presence of two CH=CH, four ring CH−O, two $MeCO_2$ and two MeCH–O protons and the ^{19}F NMR spectrum showed two CF_3 absorptions at δ *c.* 16 ppm in the CF_3C= region. These data are consistent with the product being a mixture of two 1:1 adducts, possibly the diastereomers **14** and **15**. However, the mass spectrum was inconclusive and showed peaks at *m/z* 514 [0.9% $(2M+H_2O)^+$] and 496 (0.1%, $2M^+$), consistent with a 2:2 adduct, a base peak at *m/z* 160 ($C_7H_6F_2O_2^+$) and an absence of peaks at *m/z* 248 (M^+) or 266 $(M+H_2O)^+$.



Scheme 2.



Scheme 3.

It is difficult to reconcile the NMR spectra with a 2:2 adduct and the identity of the product must await a future study involving **2** or related esters; see following paper.

Trifluoronitrosomethane has been reported to react with alkynes of the type $CFX_2C{\equiv}CY$ (X = Cl or F, Y = Cl or Br) at low temperature (−70 to 0 °C) to give oxazetines, the 1:1 cycloadducts [9], and with alkynes of the type $(CF_3)_2NC{\equiv}CR$ [R = Br, CF_3, $N(CF_3)_2$] at *c.* 90 °C to afford open-chain 1:1 adducts via ring opening of the intermediate oxazetines [10]. The reaction of trifluoronitrosomethane with ester **2** (molar ratio 3:2) at 85 °C was very slow and after three weeks unchanged trifluoronitrosomethane (73%) was recovered. The higher-boiling residue was shown by TLC and ^1H and ^{19}F NMR spectroscopy to be a complex mixture which contained unchanged ester **2** and a compound with a CF_3CH_2 group (δ_H 3.40 ppm, q, $J = 10.4$ Hz; $\delta_F + 16.0$ ppm, t, $J = 10.4$ Hz). Attempted DCFC separation of the mixture gave only pure ketone **16** (24%), the product of hydration of the triple bond in **2**. Since the Pyrex reaction tube had been carefully flamed out prior to use, it is likely that the hydration occurred via reaction involving traces of protons and ≡SiOH groups on the walls of the vessel.

Although, cycloadducts have been formed by reaction between 1,2-disubstituted imidazoles and alkynes such as dimethyl acetylenedicarboxylate [11], if the 1-position is unsubstituted as in 2- or 4-methylimidazole or in imidazole itself then Michael adducts are produced [12, 13]. The reaction between imidazole and ester **2** at 20 °C during 2 d gave an adduct (77%) as a single isomer after DCFC purification. Nucleophilic attack on the triple bond of ester **2** would be expected to give initially the (*Z*)-zwitterion **17** in which the negative charge is *anti* to the position occupied by the incoming nucleophile. The zwitterion is unlikely to undergo isomerization to the (*E*)-isomer and hence intramolecular proton transfer from nitrogen is not favourable. The product is therefore considered to be the (*Z*)-alkene **18** (97%), which arose by intermolecular protonation of the (*Z*)-zwitterion **17** or the derived carbanion.

Experimental

Starting materials

3,3,3-Trifluoropropyne was prepared (*c.* 70% yield) by reaction of 1,1,2-trichloro-3,3,3,-trifluoropropene with zinc dust and zinc(II) chloride in DMF at 100 °C followed by addition of water at 60 °C [14], and its lithium salt **3** was made by bubbling the alkyne into a stirred mixture of n-butyl-lithium (1.55 M solution in hexane) in anhydrous diethyl ether at −78 °C under a nitrogen atmosphere in a flask fitted with a dropping funnel and a cold finger (−78 °C). Active manganese(IV) oxide was prepared by the method of Attenburrow *et al.* [15]. All other reagents were commercial samples, which were purified before use if necessary, except for trifluoronitrosomethane which was a research sample prepared in this Department (by the route $(CF_3CO)_2O + N_2O_3 \rightarrow CF_3CO_2NO \xrightarrow{\text{heat}} CF_3NO + CO_2$ [16]).

General techniques

Components of reaction product mixtures were separated by column chromatography using silica (Kieselgel 60) or dry column 'flash' chromatography (DCFC) using silica (60H Merck GF_{256}) after examination by TLC methods.

Spectra were recorded on instruments described previously [^{1}H NMR at 220 MHz (internal reference Me_4Si); ^{19}F NMR at 84.6 MHz (external reference CF_3CO_2H); and ^{13}C NMR at 20.1 MHz (internal reference Me_4Si)] [1]; chemical shifts to low field of reference are designated positive.

Reactions of 3,3,3-trifluoropropynyl-lithium (3)

(a) With acetaldehyde

Acetaldehyde (4.00 g, 90.0 mmol) was added dropwise to a stirred solution of the salt **3** [prepared from n-butyl-lithium (3.26 g, 51.0 mmol)

and trifluoropropyne (5.13 g, 54.0 mmol) in anhydrous diethyl ether (100 cm^3)] at −35 °C and stirring was continued (1 h). Dilute hydrochloric acid (2 M, 50 cm^3) was added at room temperature and the organic layer was separated, dried ($MgSO_4$) and most of the ether removed at low pressure to give a liquid residue which was purified by fractional condensation *in vacuo* to afford 5,5,5,-trifluoropent-3-yn-2-ol (**1a**) (nc) (6.01 g, 43.3 mmol, 85%) (Analysis: Found: C, 43.1; H, 3.9%. $C_5H_5F_3O$ requires: C, 43.4; H, 3.6%). Boiling point, 116–118 °C, ^1H NMR ($CDCl_3$) δ: 4.66 (s, 1H, OH); 3.57 (qq, 1H, CH−O, $J_{Me-H}=7.0$, $J_{CF-H}=3.6$ Hz); and 1.10 (d, 3H, CH_3, $J=7.0$ Hz) ppm. ^{19}F NMR δ: +26.7 (d, $CF_3C{\equiv}C$, $J=3.6$ Hz) ppm. IR ($\nu_{max.}$): 3330 (broad, O−H str.); 2993 (m, C−H str.); 2275 (w, C≡C str.); 1280 (s, C−F str.); and 1150 and 1050 (s, C−O str.) cm^{-1}. Mass spectrum *m/z*: 123 [100.0%, $(M-CH_3)^+$]; 103 (36.0, $C_4HF_2O^+$); 90 (71.3, $C_3F_2O^+$); 75 (87.8, $C_3HF_2^+$); 69 (25.7, CF_3^+); and 43 (88.6, $C_2H_3O^+$).

(b) With phenylacetaldehyde

Phenylacetaldehyde (4.10 g, 43.0 mmol) was added dropwise to a stirred solution of the salt **3** [prepared from n-butyl-lithium (2.62 g, 41.0 mmol) and trifluoropropyne (4.05 g, 43.0 mmol) in anhydrous diethyl ether (100 cm^3) at −35 °C and stirring was continued (1 h). Work-up as in the previous experiment gave a liquid (8.0 g) which was purified by DCFC (CH_2Cl_2 as eluant) to afford 5,5,5-trifluoro-1-phenylpent-3-yn-2-ol (**1b**) (nc) (5.40 g, 25.2 mmol, 61%) (Analysis: Found: C, 61.4; H, 4.2; F, 26.2%; mol.wt., 214. $C_{11}H_9F_3O$ requires: C, 61.7; H, 4.2; F, 26.6%; mol.wt., 214). ^1H NMR ($CDCl_3$) δ: 7.0 (s, 5H, C_6H_5); 3.9 (tq, 1H, CH−O, $J_{CH-H}=6.8$, $J_{CF-H}=2.8$ Hz); 3.0 (d, 2H, CH_2, $J=6.8$ Hz); and 2.8 (s, 1H, O−H) ppm. ^{19}F NMR δ: +27.8 (d, $CF_3C{\equiv}C$, $J=2.8$ Hz) ppm. ^{13}C NMR δ: 135.0 (s, *ipso*-C_6H_5); 129.7 (s, *p*-C_6H_5); 128.6 (s, *m*-C_6H_5); 127.4 (s, *o*-C_6H_5); 113.9 (q, CF_3, $^1J=257.4$ Hz); 87.1 (q, $CF_3C{\equiv}C$, $^3J=6.2$ Hz); 72.8 (q, $CF_3{-}C{\equiv}C$, $^2J=52.9$ Hz); 62.4 (s, CH−O); and 42.7 (s, CH_2) ppm. IR ($\nu_{max.}$): 3385 (broad, O−H str.); 3040 (w, arom. C−H str.); 2925 (m, aliph. C−H str.); 2260 (m, C≡C str.); 1260 (s, C−F str.); and 1150 (s, C−O str.) cm^{-1}. Mass spectrum *m/z*: 214 (1.2%, M^+); 196 [10.9, $(M-H_2O)^+$]; 177 (6.9, $C_{11}H_7F_2^+$); 145 [2.5, $(M-CF_3)^+$]; 91 (100.0, $C_7H_7^+$); 65 (20.6, $C_5H_5^+$); and 39 (10.6, $C_3H_3^+$).

(c) With N-methoxy-N-methylphenylacetamide

A mixture of *N*,O-dimethylhydroxylamine hydrochloride (3.47 g, 35.5 mmol) and phenylacetyl chloride (5.00 g, 32.34 mmol) in ethanol-free anhydrous chloroform (150 cm^3) was stirred at room temperature (1 h). The mixture was cooled to 0 °C and pyridine (5.98 g, 71.15 mmol) was slowly added and stirring continued at 0 °C (1 h) and then at room temperature (1 h). Removal of the solvent (rotavapor) gave a residue which was partitioned between brine and a mixture of diethyl ether and dichloromethane (1:1 v/v). The organic layer was separated, dried ($MgSO_4$) and the solvent removed (rotavapor) to give an oil (4.42 g), which on purification by DCFC (CH_2Cl_2 as eluant) afforded *N*-methoxy-*N*-methylphenylacetamide (**9**) (nc) (3.99 g,

22.29 mmol, 69%) (Analysis: Found: C, 66.7; H, 7.6; N, 7.7%; mol.wt., 179. $C_{10}H_{13}NO_2$ requires; C, 67.0; H, 7.3; N, 7.8%; mol.wt., 179). ^{1}H NMR ($CDCl_3$) δ: 6.67 (s, 5H, C_6H_5); 3.16 (s, 2H, CH_2); 2.90 (s, 3H, OCH_3); and 2.40 (s, 3H, NCH_3) ppm. ^{13}C NMR δ: 172.0 (C=O); 134.65 (*ipso*-C_6H_5); 129.0, 128.1 and 126.4 (*p*-, *m*- and *o*-C_6H_5); 60.9 (CH_2); 39.0 (CH_3O); and 31.8 (CH_3N) ppm. IR ($\nu_{max.}$): 3040 (w, arom. C–H str.); 2950 (m, aliph. C–H str.); 1670 (s, C=O str.); 1500 and 1450 (s, arom. C=C str.); 1010 (s, C–O str.); and 700 and 730 (s, C–H out of plane bend) cm^{-1}. Mass spectrum *m/z*: 179 (25.8%, M^+); 148 [1.7, $(M-OMe)^+$]; 118 (44.6, $C_8H_6O^+$); 91 (100.0, $C_7H_7^+$); 61 (21.1, $C_2H_7NO^+$); and 39 (5.4, CH_3O^+).

A solution of the amide **9** (5.6 g, 31.1 mmol) cooled to −50 °C was treated with a cold (−50 °C) solution of the salt **3** [prepared from n-butyllithium (2.48 g, 38.8 mmol) and 3,3,3-trifluoropropyne (4.0 g, 42.5 mmol) in diethyl ether (100 cm^3)] which was transferred slowly through a narrow tube from a separate flask under nitrogen pressure. Extensive tar formation occurred and, after warming to room temperature followed by treatment with dilute hydrochloric acid (2 M, 50 cm^3) and then work-up as in the previous experiment, no identified material was obtained. The reaction was not investigated further.

Reactions of the acetylenic alcohol ***1a***

(a) With acetyl chloride

The ynol **1a** (3.15 g, 23.0 mmol) was stirred under a nitrogen atmosphere, acetyl chloride (2.20 g, 28.0 mmol) was added dropwise over 30 min and the mixture was stirred (1 h) and then heated under reflux (2 h). Fractional distillation of the resulting material gave 2-acetoxy-5,5,5-trifluoropent-3-yne (**2**) (nc) (3.75 g, 20.8 mmol, 91%) (Analysis: Found: C, 46.7; H, 4.1; F, 31.4%; mol. wt., 180. $C_7H_7F_3O_2$ requires: C, 46.6; H, 3.8; F, 31.6%; mol.wt., 180). Boiling point, 126–128 °C. ^{1}H NMR ($CDCl_3$) δ: 5.1 (qq, 1H, CH–O, $J_{Me-H}=6.5$, $J_{CF-H}=3.6$ Hz); 1.6 (s, 3H, O_2CCH_3); and 1.1 (d, 3H, CH_3, $J=6.5$ Hz) ppm. ^{19}F NMR δ: +26.5 (d, $CF_3C{\equiv}C$, $J=3.6$ Hz) ppm. IR ($\nu_{max.}$): 3000 (w, C–H str.); 2280 (m, C≡C str.); 1750 (s, C=O str.); 1375 (m, C–H def.); 1282 (s, C–F str.); and 1150 and 1043 (s, C–O str.) cm^{-1}. Mass spectrum *m/z*: 180 (0.5%, M^+); 165 [4.1, $(M-Me)^+$]; 13.7 [7.4, $(M-CH_3CO)^+$]; 121 (55.7, $(M-CH_3CO_2)^+$]; 111 (15.9, $C_6H_7O_2^+$); 101 (100.0, $C_5H_3F_2^+$); 87 (16.0, $C_4H_7O_2^+$); 69 (71.0, CF_3^+); and 51 (65.0, CHF_2^+ and $C_4H_3^+$).

(b) Attempted oxidation

(i) A stirred suspension of pyridinium chlorochromate (3.25 g, 13.0 mmol) in dichloromethane (10 cm^3) was treated with a solution of the ynol **1a** (1.40 g, 10.0 mmol) in dichloromethane (5 cm^3). Stirring was continued (1.5 h), anhydrous diethyl ether (10 cm^3) was added and the liquid was decanted from the black solid. Removal of the solvent gave the unchanged ynol **1a** (1.20 g, 8.6 mmol, 86% recovered).

(ii) A solution, prepared from sodium dichromate dihydrate (2.14 g, 7.15 mmol), concentrated sulphuric acid (2.87 g) and water (6.4 cm^3), was added dropwise to a stirred solution of the ynol **1a** (2.80 g, 20.3 mmol) in diethyl ether (10 cm^3) with the temperature being kept between 25 °C and 30 °C and stirring was continued (2 h). The volatile material was removed *in vacuo* and then subjected to fractional condensation *in vacuo* to afford the unchanged ynol **1a** (2.52 g, 18.3 mmol, 90% recovered) (−45 and 0 °C fraction) and diethyl ether (−196 °C fraction).

Reactions of the acetate 2

(a) With diazomethane (1:1 molar ratio)

A solution (20.80 cm^3) of diazomethane (0.25 g, 5.50 mmol) in diethyl ether was added dropwise to a stirred solution of the acetate **2** (1.00 g, 5.50 mmol) in diethyl ether (25 cm^3) kept at 0 °C and the stirring was continued (1 h). Removal of the solvent (rotavapor) gave an oily residue (1.20 g) which was purified by DCFC (CH_2Cl_2 as eluant) to afford 3-[(1-acetoxy)ethyl]-4-trifluoromethylpyrazole (**10a**) (nc) (0.78 g, 3.50 mmol, 63%) (Analysis: Found: C, 43.0; H, 4.4; F, 25.6; N, 12.3%; mol.wt., 222. $C_8H_9F_3N_2O_2$ requires C, 43.2; H, 4.1; F, 25.7; N, 12.6%; mol.wt., 222). ^1H NMR ($CDCl_3$) δ: 12.40 (broad, 1H, NH); 7.75 (s, 1H, =CH−); 6.02 (q, 1H, CH−O, J_{Me-H}, 7.0 Hz); 1.96 (s, 3H, O_2CCH_3); and 1.52 (d, 3H, CH_3, J = 7.0 Hz) ppm. ^{19}F NMR δ: +22.9 (s, CF_3C=C) ppm. ^{13}C NMR δ: 170.1 (s, O−C=O); 148.2 (broad, C=N); 131.8 (q, CF_3−C=*C*H−N, ^3J = 3.4 Hz); 122.6 (q, CF_3, ^1J = 266.3 Hz); 110.2 (q, CF_3−*C*=C, ^2J = 37.7 Hz); 65.5 (s, CH−O); 21.0 (s, CH_3); and 20.3 (s, CH_3) ppm. IR ($\nu_{max.}$): 3250 (broad, N−H str.); 2900 and 2840 (m, C−H str.); 1730 (s, C=O str.); 1550 (m, C=C str.); 1500 and 1450 (m, C=N str.); 1250 (s, C−F str.); 1130 (s, C−O str.); and 760 (m, C−H def.) cm^{-1}. Mass spectrum *m/z*: 222 (12.1%, M^+); 180 [100.0, $(M-CH_2CO^+)$]; 179 [26.4 $(M-CH_3CO)^+$]; 163 (76.7, $C_6H_6F_3N_2^+$); 143 (85.7, $C_6H_5F_2N_2^+$); 43 (17.3, CH_3CO^+); and 29 (50.7, CHO^+).

(b) With diazomethane (1:2 molar ratio)

Treatment of a stirred solution of acetate **2** (1.00 g, 5.50 mmol) in diethyl ether (50 cm^3) at −20 °C with stirring continued at −20 °C (0.5 h) and then at room temperature (12 h) gave a colourless oily liquid (1.42 g) after removal of the solvent *in vacuo*. Purification of the liquid by DCFC (CH_2Cl_2 as eluant) gave a 1:1 mixture of 3-[1′-acetoxy)ethyl]-1-methyl-4-trifluoromethylpyrazole (**11a**) (nc) and 5-[1′-acetoxy)ethyl]-1-methyl-4-trifluoromethylpyrazole (**12a**) (nc) (1.08 g, 4.57 mmol, 83%) (Analysis: Found: C, 45.5; H, 4.6; F, 23.8; N, 12.1%; mol.wt., 236. $C_9H_{11}F_3N_2O_2$ requires: C, 45.7; H, 4.7; F, 24.1; N, 11.9%; mol.wt., 236). ^1H NMR ($CDCl_3$) δ: **12a**: 8.87 (s, 1H, HC=N); 6.06 (q, 1H, CH−O, J = 7.0 Hz); 3.92 (s, 3H, N−CH_3); 2.00 (s, 3H, O_2CCH_3); and 1.56 (d, 3H, CH_3, J = 7.0 Hz) ppm; and δ **11a**: 7.66 (s, 1H, HC=C); 6.16 (q, 1H, CH−O, J = 7.0 Hz); 4.01 (s, 3H, N−CH_3); 2.09 (s, 3H, O_2CCH_3); and 1.56 (d, 3H, CH_3, J = 7.0 Hz) ppm. ^{19}F NMR δ: +22.8 and +23.4 (CF_3C=C) ppm. ^{13}C NMR δ: 169.9 and 169.6 (2s,

2O–C=O); 149.0 (br, C=N); 147.8 (br, =C–N); 136.4 (q, CH=N, ^3J=3.9 Hz); 131.3 (q, =CH–N, ^3J=3.7 Hz); 122.6 and 122.5 (2q, $2CF_3$, ^1J=266 Hz); 110.2 and 109.8 (2q, $2CF_3C$=C, ^2J=38 Hz); 65.7 and 65.3 (2s, 2CH–O); 39.0 and 38.1 (2s, 2N–CH_3); and 21.1, 20.4, 19.4 and 17.9 (4s, $4CH_3$) ppm. IR ($\nu_{max.}$): 2970 (m, C–H str.); 1740 (s, C=O str.); 1600 (m, C=C str.); 1500 and 1450 (m, C=N str.); 1260 (s, C–F str.); and 1080 (s, C–O str.) cm^{-1}. Mass spectrum *m/z*: 236 (16.7%, M^+); 194 [79.9, $(M-CH_2CO)^+$]; 177 [100.0, $(M-CH_3CO_2)^+$]; 157 (65.7, $C_7H_7F_2N_2^+$); 143 (31.7, $C_6H_5F_2N_2^+$); 69 (12.4, CF_3^+); 43 (46.5, CH_3CO^+); and 29 (36.3, CHO^+).

(c) With imidazole

Acetate **2** (1.00 g, 5.50 mmol), imidazole (0.19 g, 2.78 mmol) and dichloromethane (10 cm^3) were sealed *in vacuo* in a Rotaflo tube (*c.* 30 cm^3) and the tube was shaken at room temperature (48 h). Removal of the volatile material *in vacuo* [unchanged ester **2** (0.60 g, 3.33 mmol, 60% recovered) and dichloromethane] gave a residue (0.59 g), which was purified by liquid chromatography (eluant CH_2Cl_2) to afford a thick oil identified as (*Z*)-4-acetoxy-3-(imidazol-1-yl)-1,1,1-trifluoropent-2-ene (**18**) (nc) (0.53 g, 2.13 mmol, 97%) (Analysis: Found: C, 48.1; H, 4.6; F, 22.9; N, 11.4%; mol.wt., 248. $C_{10}H_{11}F_3N_2O_2$ requires C, 48.3; H, 4.4; F, 23.0; N, 11.3%; mol.wt., 248). ^{1}H NMR ($CDCl_3$) δ: 7.57 (s, 1H, CH=N); 7.10 (broad, 2H, CH=CH); 6.12 (q, 1H, =$CHCF_3$, J_{CF-H}=7.8 Hz); 5.50 (q, 1H, O–C*H*CH_3, J_{Me-H}=7.0 Hz); 2.63 (s, 3H, O_2CCH_3); and 1.28 (d, 3H, C*H*$_3$CH, J=7.0 Hz) ppm. ^{19}F NMR δ: +20.4 (d, CF_3CH=, J=7.8 Hz) ppm. IR ($\nu_{max.}$): 3100 and 2920 (m, C–H str.); 1745 (s, C=O str.); 1680 (m, C=C str.); 1460 (s, C=N str.); 1260 (s, C–F str.); and 1060 (m, C–O str.) cm^{-1}. Mass spectrum *m/z*: 248 (10.4%, M^+); 205 [10.3, $(M-MeCO_2)^+$]; 191 (63.0, $C_7H_6F_3N_2O^+$); 119 (53.8, $C_7H_7N_2^+$); 93 (26.8, $C_5H_5N_2^+$); 87 (37.0, $C_4H_7O_2^+$); 69 (26.2, CF_3^+); 43 (100.0, CH_3CO^+); and 29 (6.8, CHO^+).

(d) With trifluoronitrosomethane

A mixture of acetate **2** (0.50 g, 2.77 mmol) and an excess of trifluoronitrosomethane (0.41 g, 4.14 mmol) was sealed *in vacuo* in a Rotaflo tube (*c.* 50 cm^3) and heated at 85 °C for three weeks. The volatile material which was removed *in vacuo* was identified as unchanged trifluoronitrosomethane (0.30 g, 3.03 mmol, 73% recovered), while the residue (0.60 g) was shown by TLC methods (eluant CH_2Cl_2) to contain unchanged **2**, one major component and a number of minor components. Separation of the major component by DCFC (eluant CH_2Cl_2) gave 2-acetoxy-5,5,5-trifluoropentan-3-one (**16**) (nc) (0.14 g, 0.67 mmol, 24%) (Analysis: Found: C, 42.3; H, 4.6%; mol.wt., 198. $C_7H_9F_3O_3$ requires: C, 42.4; H, 4.5%; mol.wt., 198). ^{1}H NMR ($CDCl_3$) δ: 5.10 (q, 1H, CH–O, J_{Me-H}=7.0 Hz); 3.40 (q, 2H, CH_2CF_3, J_{CF-CH}=10.4 Hz); 2.13 (s, 3H, O_2CCH_3); and 1.32 (d, 3H, CH_3) ppm. ^{19}F NMR δ: +16.0 (t, CF_3CH_2, J=10.4 Hz) ppm. ^{13}C NMR δ: 197.9 (s, C=O); 170.5 (s, O–C=O); 123.4 (q, CF_3, ^1J=276.7 Hz); 74.5 (s, CH–O); 42.0 (q, CF_3CH_2, ^2J=28.7 Hz); 20.5 (s, CH_3); and 15.5 (s, CH_3) ppm. IR ($\nu_{max.}$):

3000 (m, C—H str.); 1750 (s, C=O str.); 1250 (s, C—F str.); and 1150 (s, C—O str.) cm^{-1}. Mass spectrum *m/z*: 198 (0.2%, M^+); 111 (46.5, $CF_3CH_2CO^+$); 87 (100.0, $C_4H_7O_2^+$); 69 (44.4, CF_3^+); 43 (46.5, CH_3CO^+); and 29 (37.8, CHO^+).

(e) With furan

A mixture of ester **2** (2.00 g, 11.10 mmol), furan (0.35 g, 5.14 mmol) and diethyl ether (10 cm^3) was sealed *in vacuo* and heated at 100 °C for 4 d. The tube was opened, the contents washed out with diethyl ether and the solvent and unchanged ester **2** removed *in vacuo* to afford a reddish oil (1.35 g), which was shown by TLC methods (eluant CH_2Cl_2) to contain one major and several minor components. The major component was purified by liquid chromatography (eluant, CH_2Cl_2) and tentatively identified as a mixture of two isomers (1:1 ratio) of a hydrated 1:1 adduct (1.09 g, 4.28 mmol, 83%) (Analysis: Found: C, 51.2; H, 4.7; F, 21.9%. $C_{11}H_{11}F_3O_3 \cdot 0.5H_2O$ requires: C, 51.3; H, 4.6; F, 22.3%). ^1H NMR ($CDCl_3$) δ: 7.19 (mult., 2H, CH=CH); 7.17 (dd, 1H, CH=, J=5.2 and 2.0 Hz); 7.03 (dd, 1H, CH=, J=5.2 and 2.0 Hz); 5.95 (q, 1H, CH_3CH—O, J=6.8 Hz); 5.88 (q, 1H, CH_3CH—O, J=6.8 Hz); 5.52 (broad, 2H, 2 ring CH—O); 5.50 (broad, 1H, ring CH—O); 5.48 (broad, 1H, ring CH—O); 2.05 (s, 3H, O_2CCH_3); 2.02 (s, 3H, O_2CCH_3); 1.48 (d, 3H, CH_3CH, J=6.8 Hz); and 1.22 (d, 3H, CH_3CH, J=6.8 Hz) ppm. ^{19}F NMR δ: +15.6 (s, CF_3); and +15.8 (s, CF_3) ppm. IR ($\nu_{max.}$): 3350 (m, O—H str. in H_2O); 3000 (m, vinylic C—H str.); 2940 (m, aliph. C—H str.); 1750 (s, C=O str.); 1670 (s, C=C str.); 1350 and 1235 (s, C—F str.); and 1150 (s, C—O str.) cm^{-1}. Reaction did not take place at 50 °C during 12 d.

*Oxidation of 5,5,5-trifluoro-1-phenylpent-3-yn-2-ol (**1b**) with activated manganese(IV) oxide*

Activated manganese(IV) oxide (8.60 g, 98.9 mmol) was added to a stirred solution of the acetylene alcohol **1b** (2.00 g, 9.34 mmol) in dichloromethane (20 cm^3) under a nitrogen atmosphere and stirring was continued (24 h). Samples were checked regularly by TLC methods and a minor product was observed. The mixture was heated at 30 °C (2 h) and was then filtered and the solvent removed (rotary evaporator) from the filtrate to give a residue (1.80 g) consisting of the unchanged alcohol **1b** and a ketone (IR). Separation of this material by DCFC (eluant CH_2Cl_2) gave the unchanged alcohol **1b** (1.50 g, 7.0 mmol, 75% recovered) and a yellow solid identified as 1,1,1,10,10,10-hexafluoro-5,6-diphenyldeca-2,8-diyn-4,7-dione (**7**) (nc) (0.21 g, 0.48 mmol, 41%) (Analysis: Found: C, 62.8; H, 3.0%; mol.wt., 422. $C_{22}H_{12}F_6O_2$ requires: C, 62.6; H, 2.8%; mol.wt., 422). ^1H NMR ($CDCl_3$ δ: 7.2 (broad, 5H, C_6H_5); and 2.7 (s, 1H, CHCO) ppm. ^{19}F NMR δ: +26.5 (s, $CF_3C{\equiv}C$) ppm. IR ($\nu_{max.}$): 3040 (w, arom. C—H str.); 2275 (m, C≡C str.); 1700 (s, C=O str.); 1600 (m, arom. C=C str.); 1275 (s, C—F str.); and 700 (m, arom, C—H def.) cm^{-1}. Mass spectrum *m/z*: 422 (17.7%, M^+); 211 (70.9, $C_{11}H_6F_3O^+$); 180 (27.3, $C_{14}H_{12}^+$); 121 (18.6, $C_4F_3O^+$); 105 (100.0,

$C_7H_5O^+$); 91 (99.8, $C_7H_7^+$); 77 (36.9, $C_6H_5^+$); 51 (20.1, $C_4H_3^+$); and 29 (28.8, CHO^+).

References

1 For Part 7, see S. Tajammal and A. E. Tipping, *J. Fluorine Chem.*, *47* (1990) 45.
2 F. G. Drakesmith, O. J. Steward and P. Tarrant, *J. Org. Chem.*, *33* (1968) 280.
3 T. T. Minasyan and S. O. Badanyan, *Arm. Khim. Zh.*, *32* (1972) 542.
4 K. R. Bharucha, *J. Chem. Soc.*, (1956) 2446.
5 J. M. Goldman, *J. Org. Chem.*, *34* (1969) 3291.
6 A. J. Fatiadi, *J. Org. Chem.*, *36* (1971) 889.
7 A. J. Fatiadi, *Synthesis*, (1976) 152.
8 S. Nahm and S. M. Weinreb, *Tetrahedron Lett.*, *22* (1981) 3815.
9 S. P. Makarov, V. A. Shpanskii, V. A. Ginsburg, A. I. Shschekotikhin, A. S. Filatov, L. L. Martynova, I. V. Pavlovskaya, A. F. Golovaneva and A. Ya. Yakubovich, *Dokl. Akad. Nauk SSSR*, *142* (1962) 596.
10 J. Freear and A. E. Tipping, *J. Chem. Soc. C* (1969) 1963.
11 O. Diels, K. A. Alder, H. Winckler and E. Petersen, *Justus Liebigs Ann. Chem.*, *498* (1932) 1.
12 R. M. Acheson, M. W. Foxton, P. J. Abbot and K. R. Mills, *J. Chem. Soc. C* (1967) 822.
13 R. Huisgen, B. Giese and H. Huber, *Tetrahedron Lett.*, (1967) 1883.
14 W. G. Finnegan and W. P. Norris, *J. Org. Chem.*, *28* (1963) 1139.
15 J. Attenburrow, A. F. B. Cameron, J. H. Chapman, R. M. Evans, B. A. Hems, A. B. A. Jansen and T. Walker, *J. Chem. Soc.*, (1952) 1094.
16 R. E. Banks, M. G. Barlow, R. N. Haszeldine and M. K. McCreath, *J. Chem. Soc. C*, (1966) 1350.