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# Preparation of Phorone

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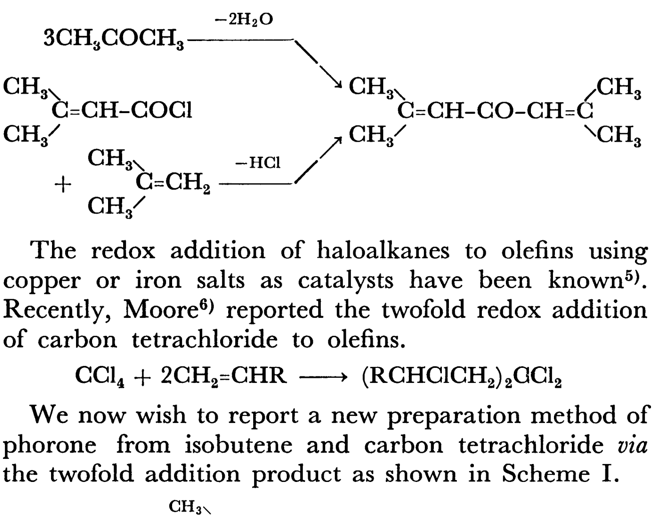
A new method for preparation of 2,6-dimethylhepta-2,5-dien-4-one (**4**; phorone) from isobutene and carbon tetrachloride is described. A redox addition of carbon tetrachloride to isobutene in the presence of ferric chloride, benzoin, and diethylamine hydrochloride yielded 3-methyl-1,1,1,3-tetrachlorobutane (**1**). 2,6-Dimethyl-2,4,4,6-tetrachloroheptane (**2**) was obtained by the addition of **1** to isobutene or the twofold addition of carbon tetrachloride to isobutene. Treating **2** with ethanolic potassium hydroxide gave 2,6-dimethylhepta-1,5-dien-3-yne (**3**). Hydration of **3** by treating with methanolic boron trifluoride in the presence of mercuric oxide and with aqueous sulfuric acid gave **4**.

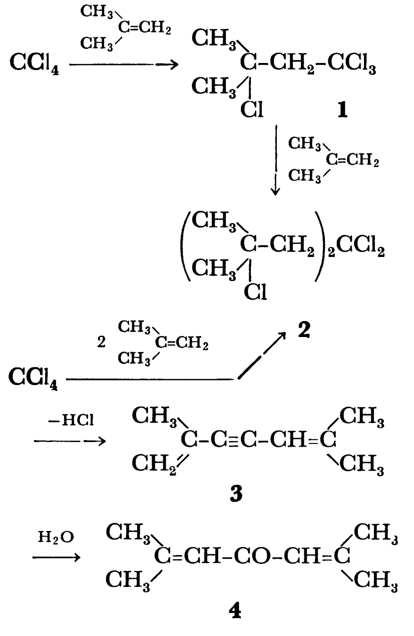
Phorone has been chiefly prepared by dehydrative trimolecular condensation of acetone (method A) under various catalysts such as beryllium chloride[1)], ferric oxide[2)], and bromomagnesium alcoholate[3)], but with less satisfactory results on yield and selectivity. Colonge and Dumont[4)] reported another method (method B) treating $\beta,\beta$-dimethylacrylyl chloride with isobutene in the presence of stannic chloride to yield phorone selectively.



The redox addition of haloalkanes to olefins using copper or iron salts as catalysts have been known[5)]. Recently, Moore[6)] reported the twofold redox addition of carbon tetrachloride to olefins.

$$CCl_4 + 2CH_2{=}CHR \longrightarrow (RCHClCH_2)_2CCl_2$$

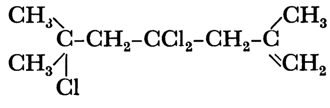
We now wish to report a new preparation method of phorone from isobutene and carbon tetrachloride *via* the twofold addition product as shown in Scheme I.



Scheme I.

The method has the following advantages over the methods described above in spite of having three steps. The yield and selectivity of each steps are better than those of the method A, and starting materials, isobutene and carbon tetrachloride are easily available by comparison with the method B.

According to the procedure of Asscher and Vofsi,[5)] the redox addition of carbon tetrachloride to isobutene in the presence of ferric chloride, benzoin, and diethylamine hydrochloride afforded 3-methyl-1,1,1,3-tetrachlorobutane (**1**)[7)] in a high yield. The compound **1** was treated with an additional mol of isobutene to yield 2,6-dimethyl-2,4,4,6-tetrachloroheptane (**2**) in 46% yield. Also, the compound **2** was directly obtained from 1 mol of carbon tetrachloride and 2 mol of isobutene under the same conditions in 47% yield. The mass spectrum of **2** showed peaks at *m/e* (relative intensity): 235 (1), 233 (8), 231 (20), and 229 (20, M—35) suggesting 1 : 2 adduct of carbon tetrachloride and isobutene. The NMR spectrum of **2** showed two singlet peaks at $\tau$ 8.15 (12H) and $\tau$ 6.96 (4H) corresponding to four equivalent methyl groups and two equivalent methylene groups respectively. Since 2,6-dimethyl-2,4,4,6-tetrachloroheptane (**2**) is a key compound for the preparation of phorone (**4**), we sought the optimum conditions for these redox addition. The results are summarized in Table 1. Thus an optimum result was obtained in Run No. 2. At a temperature above 60 °C the yield of **2** decreased and a dehydrochlorinated product of **2** (**5**; 2,6-dimethyl-4,4,6-trichlorohept-1-ene) and a large amount of distillation residue were formed.



$$(CH_3)_2CCl\text{-}CH_2\text{-}CCl_2\text{-}CH_2\text{-}C(CH_3){=}CH_2$$

**5**

At a lower temperature the yield of **2** also decreased.

Dehydrochlorination of **2** with excess ethanolic potassium hydroxide gave 2,6-dimethylhepta-1,5-dien-3-yne (**3**) and 4-chloro-2,6-dimethyl-6-ethoxyhepta-2,4-diene (**6**) in 62 and 23% yields respectively by GLC analysis (silicone DC 550, 125 °C). The IR spectrum of **3** showed characteristic absorptions at 2200 ($-C{\equiv}C-$) and 895 cm$^{-1}$ ($\rangle C{=}CH_2$).

According to the procedure of Islam and Raphael,[8)] **3** was hydrated by treating with methanolic boron trifluoride in the presence of mercuric oxide and with

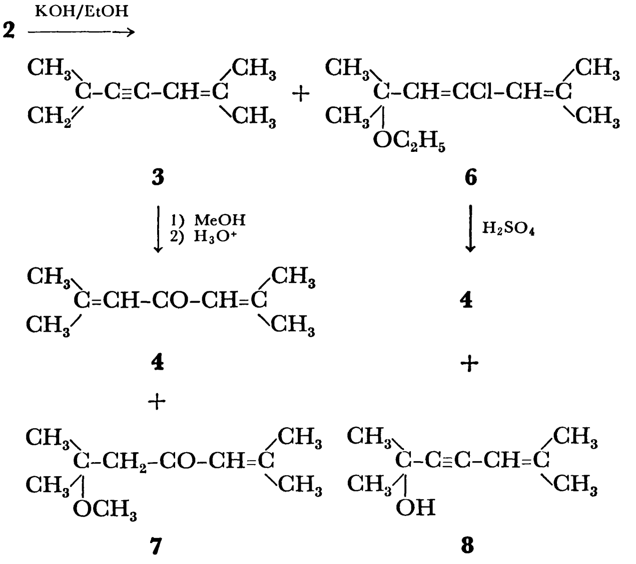
Table 1. Preparation of 2,6-dimethyl-2,4,4,6-tetrachloroheptane (**2**)

| Run number | Reactants | | Reaction condition | | Products (%) | |
|---|---|---|---|---|---|---|
| | Haloalkane | Mole ratio Haloalkane/Isobutene[a] | Temperature (°C) | Time (h) | **2** | **1** |
| 1 | $CCl_4$ | 1/2 | 70 | 23 | 16 | 9[b),c)] |
| 2 | $CCl_4$ | 1/2 | 60 | 23 | 47 | 17[b)] |
| 3 | $CCl_4$ | 1/2 | 60 | 16 | 40 | 26[b)] |
| 4 | $CCl_4$ | 1/2 | 50 | 47 | 45 | 15[b)] |
| 5 | $CCl_4$ | 1/2 | 50 | 23 | 31 | 12[b)] |
| 6 | $CCl_4$ | 1/1 | 60 | 23 | 14 | 39[b)] |
| 7 | $CCl_4$ | 2/1 | 80 | 6 | 0 | 80[d)] |
| 8 | $CCl_4$ | 2/1 | 60 | 23 | 0 | 63[d)] |
| 9 | **1** | 1/1 | 60 | 20 | 46 | —[b)] |

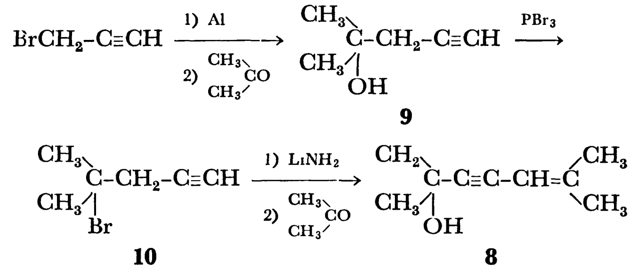
a) Isobutene; 0.30 mol, 2-propanol; 0.45 mol, ferric chloride hexahydrate; 0.0022 mol, benzoin; 0.0022 mol, and diethylamine hydrochloride; 0.0033 mol were used. b) Based on haloalkane. c) A dehydrochlorinated product (**5**; 3%) and a distillation residue(14.3 g) were obtained. d) Based on isobutene.

aqueous sulfuric acid to give 2,6-dimethylhepta-2,5-dien-4-one (**4**, phorone) and 2,6-dimethyl-6-methoxyhept-2-en-4-one (**7**) in 57 and 13% yields respectively by GLC analysis (silicone DC 550, 140 °C). The compound **4** was treated in the same manner as **3** to afford **7** in 62% yield. The structure of **4** was identified by comparing its IR, UV, and NMR spectra with those of an authentic sample.

The treatment of **6** with aqueous sulfuric acid in the presence of mercuric sulfate in water–dioxane (1 : 1) afforded **4** in 27% yield. When **6** was treated with aqueous sulfuric acid in the absence of the mercuric salt, **4** and 2,6-dimethylhept-5-en-3-yn-2-ol (**8**) were obtained in 17 and 72% yields respectively.



The mechanism of formation of **8** is not clear. An IR spectrum of **8** showed characteristic absorptions at 3400 (–OH) and 2220 cm$^{-1}$ (–C≡C–). The structure of **8** was identified by comparing its IR, UV, and NMR spectra with those of an authentic sample which was synthesized independently by the route shown in Scheme II. Thus treating acetone with propargyl aluminium bromide[9] gave 2-methylpent-4-yn-2-ol (**9**). The compound **9** was brominated by phosphorus tribromide to afford 4-bromo-4-methylpent-1-yne (**10**), which was treated with excess lithium amide in liquid ammonia, followed by addition of acetone to give **8**.



Scheme II.

### Experimental

*3-Methyl-1,1,1,3-tetrachlorobutane (**1**).* According to the procedure of Asscher and Vofsi,[5] a mixture of carbon tetrachloride (92.4 g, 0.60 mol), liquid isobutene (28.5 ml, 0.30 mol), isopropanol (27.0 g, 0.45 mol), ferric chloride hexahydrate (0.60 g, 0.0022 mol), benzoin (0.45 g, 0.0022 mol), and diethylamine hydrochloride (0.36 g, 0.0033 mol) was heated at 80 °C for 6 h to afford 3-methyl-1,1,1,3-tetrachlorobutane (**1**) in 80% yield (Table 1, Run 7): bp 75—77 °C (18 Torr), lit,[7] bp 43—45 °C (3 Torr); IR, $\nu_{max}$ cm$^{-1}$: 710 (C–Cl): NMR ($CCl_4$): $\tau$ 8.13 (s, 6H) and 6.61 (s, 2H); MS, *m/e* (relative intensity): 179(1), 177(7), 175 (17), and 173 (20, M−35).

*2,6-Dimethyl-2,4,4,6-tetrachloroheptane (**2**).* A 1 : 1 mixture of **1** and isobutene (Run 9) or 1 : 2 mixture of carbon tetrachloride and isobutene was treated in the similar procedure to the above giving 2,6-dimethyl-2,4,4,6-tetrachloroheptane (**2**) in yields as shown in Table 1: bp 73—75 °C (0.28 Torr); IR, $\nu_{max}$ cm$^{-1}$: 690 (C–Cl); NMR ($CCl_4$): $\tau$ 8.15 (s, 12H) and 6.96 (s, 4H); MS, *m/e* (relative intensity): 235 (1), 233 (8), 231 (20), 229 (20, M−35), 197 (12), 195 (57), and 193 (78, M−71). The reaction was carried out at 70 °C to give 2,6-dimethyl-4,4,6-trichlorohept-1-ene (**5**), which was separated by preparative GLC (carbowax 20 M, 130 °C): IR, $\nu_{max}$ cm$^{-1}$: 1642 and 680; NMR ($CCl_4$): $\tau$ 8.18 (s, 6H), 8.04 (d, 3H; $J$=1.0 Hz), 7.14 (s, 2H), 6.93 (s, 2H), and 4.8—5.1 (m, 2H); MS, *m/e* (relative intensity): 234 (1), 232 (6), 230 (13), 228 (13, M$^+$), 197 (20), 195 (98), and 193 (147, M−35).

*Dehydrochlorination of* **2**. A solution of **2** (5.3 g, 0.020 mol) and potassium hydroxide (9.0 g, 0.16 mol) in ethanol (20 ml) was heated under reflux for 6 h and cooled. After addition of saturated aqueous sodium chloride, the reaction mixture was extracted with ethyl acetate. The extracts were dried over anhydrous magnesium sulfate and evaporated to give 2,6-dimethylhepta-1,5-dien-3-yne (**3**) and 4-chloro-2,6-dimethyl-6-ethoxyhepta-2,4-diene (**6**) in 62 and 23% yields respectively by GLC analysis (silicone DC 550, 125 °C).

Compound **3** and **6** were separated by preparative GLC and their spectral data were obtained as follows: compound **3**[10]; IR, $\nu_{\max}$ cm$^{-1}$: 2200, 1610, and 895; UV, $\lambda_{\max}^{\text{EtOH}}$ mμ: 241, 252, and 265; NMR ($CCl_4$): τ 8.24 (d, 3H; *J*=1.0 Hz), 8.20 (d, 6H; *J*=1.0 Hz), 4.8—5.0 (m, 2H), and 4.7—4.8 (m, 1H); MS, *m/e* (relative intensity): 120 (14, M$^+$) and 105 (10, M−15) and compound **6**; IR, $\nu_{\max}$ cm$^{-1}$: 1635 and 855; UV, $\lambda_{\max}^{\text{EtOH}}$ mμ: 234; NMR ($CCl_4$): τ 8.88 (t, 3H; *J*=6.8 Hz), 8.62 (s, 6H), 8.05—8.25 (m, 6H), 6.64 (q, 2H; *J*=6.8 Hz), and 4.3—4.5 (m, 2H); MS, *m/e* (relative intensity): 204 (10), 202 (24, M$^+$), 189 (15), 187 (39, M−15), 167 (44, M−35), 158 (65), and 156 (169, M−46).

*Phorone (***4***).* Products were separated by preparative GLC and their yields were determined by analytical GLC (silicone DC 550, 140 °C).

*Hydration of* **3**. A mixture of methanol (1.5 ml), mercuric oxide (0.10 g, 0.00046 mol), ethereal boron trifluoride (0.05 ml), and trichloroacetic acid (trace) was heated under reflux for 10 min and cooled. A solution of **3** (0.12 g, 0.001 mol) in methanol (1.5 ml) was added to the mixture in an ice water bath and stirred at room temperature for 20 min. After pouring into cooled 10% aqueous sulfuric acid (20 ml) the mixture was extracted with ether. The extracts were dried over anhydrous sodium carbonate and evaporated to yield phorone (**4**) and 2,6-dimethyl-6-methoxyhept-2-en-4-one (**7**) in 57 and 13% yields respectively. Also **7** was given in 62% yield by stirring phorone and methanol under the same catalyst for 2 h at room temperature. Following spectral data of **7** were obtained: IR, $\nu_{\max}$ cm$^{-1}$: 1680, 1619, and 850; UV, $\lambda_{\max}^{\text{EtOH}}$ mμ: 240; NMR ($CCl_4$): τ 8.83 (s, 6H), 8.15 (d, 3H; *J*=1.0 Hz), 7.91 (d, 3H; *J*=1.0 Hz), 7.55 (s, 2H), 6.88 (s, 3H), and 3.9—4.1 (m, 1H); MS, *m/e* (relative intensity): 170 (10, M$^+$) and 138 (16, M−32).

*Hydrolysis of* **6**. A solution of **6** (0.13 g, 0.00064 mol) in dioxane (1 ml) was added to a solution of mercuric oxide (0.10 g, 0.00046 mol) in 20% aqueous sulfuric acid (1.2 ml) and stirred at room temperature for 3 h. After addition of water the mixture was extracted with ether. The extracts were dried over anhydrous sodium sulfate and evaporated to give phorone in 27% yield. In the absence of mercuric oxide in this system phorone and 2,6-dimethylhept-5-en-3-yn-2-ol (**8**) were obtained in 17 and 72% yields respectively. Following spectral data of **8**[10] were obtained; IR, $\nu_{\max}$ cm$^{-1}$: 3400, 2220, and 1630; UV, $\lambda_{\max}^{\text{EtOH}}$ mμ: 232; NMR ($CCl_4$): τ 8.60 (s, 6H), 8.2—8.4 (m, 6H), 7.95 (s, 1H), and 4.7—4.9 (m, 1H); MS, *m/e* (relative intensity): 138 (18, M$^+$), 123 (111, M−15), and 121 (10, M−17).

*2-Methylpent-4-yn-2-ol (***9***).* According to the procedure of Eiter and Oediger[9], a mixture of propargyl aluminium bromide, prepared from aluminium strips (2.4 g, 0.089 atom), propargyl bromide (1.42 g, 0.12 mol), and mercuric chloride (two spoons), and acetone (7.5 g, 0.13 mol) in tetrahydrofuran (35 ml) was stirred at 0 °C for 1 h to obtain 2-methylpent-4-yn-2-ol (**9**) in 69% yield: bp 68—71 °C (115 Torr); IR, $\nu_{\max}$ cm$^{-1}$: 3400, 3310, and 2140; UV, $\lambda_{\max}^{\text{EtOH}}$ mμ: 238; NMR[11] ($CCl_4$): τ 8.74 (s, 6H), 8.05 (t, 1H; *J*=2.4 Hz), 7.17 (d, 2H; *J*=2.4 Hz), and 7.44 (s, 1H); MS, *m/e* (relative intensity): 83 (25, M−15) and 81 (10, M−17).

*4-Bromo-4-methylpent-1-yne (***10***).* A solution of phosphorus tribromide (3.3 g, 0.012 mol) in ether (10 ml) was dropwise added to a solution of **9** (3.0 g, 0.030 mol) and pyridine (1.2 g, 0.015 mol) in ether (20 ml) below 0 °C and stirred for 30 min at 0 °C. After pouring into ice, the mixture was extracted with ether. The extracts were washed with 5% hydrochloric acid and 5% aqueous sodium carbonate and dried over anhydrous sodium carbonate. Evaporation of ether gave crude **10** in 28% yield, which was not purified further because of its unstability. The IR spectra showed characteristic peaks at 3300, 2210, and 650 cm$^{-1}$.

*2,6-Dimethylhept-5-en-3-yn-2-ol (***8***).* A solution of **10** (1.0 g, 0.0062 mol) in ether (20 ml) was dropwise added at −60 °C to a solution of lithium amide in liquid ammonia (100 ml) and stirred at −65 °C for 3 h. A solution of acetone (1.3 g, 0.020 mol) in ether (15 ml) was dropwise added to the mixture and stirred at −60 °C for 3 h. After addition of ammonium chloride the mixture was allowed to stand overnight to evaporate ammonia. After addition of water the mixture was extracted with ether. The extracts were washed with 5% hydrochloric acid, 5% aqueous sodium hydrogen carbonate, and saturated aqueous sodium chloride successively, and dried over anhydrous sodium sulfate. Evaporation, followed by distillation gave 0.36 g (42%) of **8**, bp 63—67 °C (6 Torr).

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