

Cyclialkylation of aromatics with isoprene Musks to herbicides

Tom Wood, Givaudan Corporation, Clifton, NJ

I Background

It has been said that no successful perfume has been compounded without the use of musk. As Carpenter said, "There is hardly a type from the simplest of colognes to the most subtle and sophisticated of orientals that does not benefit by the inclusion of some musk."¹ Originally, of course, perfumers were dependent on natural sources for musk fixatives. The most prized was Tonquin musk, derived from the musk-deer of Asia.

It is now almost 90 years since Albert Baur made the surprising discovery that the odor of natural musk is imitated in certain nitrated derivatives of benzene.² In 1895, shortly after this discovery, the Givaudan Company was founded in Switzerland to manufacture aroma chemicals and perfume intermediates. The nitro musks were among the earliest products manufactured.

Baur's first musk, trinitro-m-t-butyltoluene, marketed as "Musk Baur" (also known as "Musk B", "Tonquinol," or "Musk Toluene"), was an immediate success, diluted with nine times its weight of acetanilide and selling for about \$500 per kilo, or about one-half the then current price for natural Tonquin musk. Baur's discovery had a tremendous impact on the emerging synthetic aromatics industry and stimulated much research in the area. His discovery was followed in rapid order by three other nitromusks which are still widely used and often referred to as the "workhorses" of the synthetic musks. Baur's original musk was soon replaced by musk xylol, and is no longer used.

No other practical nitromusk was discovered until nearly 40 years later when in 1932 Barbier found a new musk, derived from p-cymene, to which he assigned the structure dinitro-tert-butyl-p-cymene.³ Three years later another useful nitromusk, dinitro-tert-butylhemimellitene,

was discovered by Carpenter.⁴ Both of these new products were destined to become commercially important musks, and their discoveries may be considered milestones in this area.

An outstanding piece of research by Zeide and Dubinin,⁵ published in 1932, established the correct structure of musk ambrette. In 1944, a review of the thorough and convincing paper by these two Russian investigators appeared. Ironically, the review article concludes: "Thus, the chemical structure of all the commercially important musks is now known." In fact, structures of only two were correct and three remained to be corrected. In a series of articles beginning with a paper by Fuson and coworkers (1947)⁷ and concluding with the four papers on nitromusks by Carpenter and coworkers (1951-1954)⁸ much was done to establish the true structures of the commercial nitromusks with exception of one material, Barbier's "Moskene." This was not elucidated until 1955 when Gramppoloff⁹ and Carpenter published papers in the area.

After the discovery of new nitro musks by Barbier and Carpenter, the next milestone was Carpenter's disclosure in 1948 of the first known nitrogen-free artificial musk of benzenoid structure, 2,4-di-tert-butyl-5-methoxybenzaldehyde, "a musk of fine and persistent odor."^{8a,10} This ushered in a period of intense activity in musk research by groups in the aroma chemicals industry.

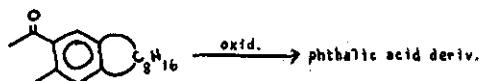
Carpenter's disclosure was soon followed by another event that aroused the interest of all chemists in the fragrance industry and stimulated even greater research activity. This was the appearance on the market in 1952 of a novel nitrogen-free musk which also contained an aromatic ring and which was appropriately named "Phantolid,"* since no apparent clues were available at that time regarding its structure.

Crystallization of the semi-solid commercial product provided the principal component as a

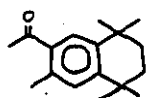
This paper was presented Tuesday afternoon, March 22, 1977, at the Spring Meeting of the American Chemical Society in New Orleans, LA.

*Trademark of Polak's Frutal Works.

white solid, m.p. 59-61°. On the basis of infrared spectra and oxidative degradation studies the structure was partially resolved as follows:



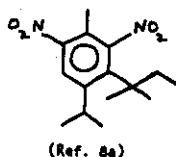
The C_8H_{16} moiety was extremely resistant to oxidation. After a period of several months of experimentation, trying to establish the structure by old-fashioned oxidative degradation methods, we had reached an impasse. I proposed the following structure in the spring of 1953:



7-Acetyl-1,1,4,4,6-pentamethyl-1-tetralin

This was compatible with the analytical data thus far accumulated. Dr. Carpenter, who was directing our work on Phantolid, did not consider this proposed structure a likely candidate and merely shrugged it off, saying that we had to come up with something that would cost less than \$10.00/lb and, indeed, that he did not know any practical route to make the proposed chemical.

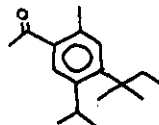
Early in the summer of 1953, Carpenter found that nitration of Phantolid with mixed acid gave a dinitro derivative, m.p. 117, with replacement of an acetyl group by a nitro group. This material had a musk-like odor. Later, a sample of Phantolid and all the analytical data which we had accumulated were sent to Professor Julius Erickson at L.S.U., who was one of our consultants at that time. He was unable to determine the structure beyond what we had already established, from his study of the infrared spectrum and the other data. However, he did point out to us that the dinitro derivative of Phantolid had the same melting point as the Muskene Homolog,^{8b} ("2,6-dinitro-3-tert-amyl-4-isopropyltoluene", so-called) previously prepared by Easter and Carpenter.



A mixed melting point quickly established the identity. Thus, Phantolid was shown to be a p-cymene derivative. As Carpenter expressed it in his letter to Erickson, "We were unable to see the forest for the trees."

Carpenter and Easter again prepared the "3-tert-amyl-4-isopropyltoluene" which they had described previously,^{8b} acetylated it, and obtained Phantolid. This solved the Phantolid

problem as far as Carpenter was concerned.

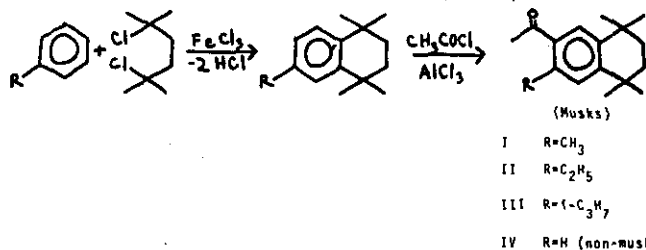


Carpenter's structure for Phantolid

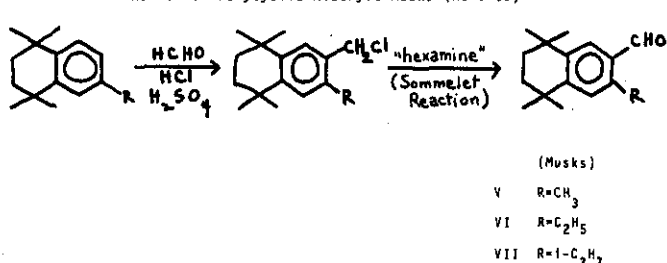
I did not dwell further on the Phantolid but returned to the structure I had proposed in the spring. One day while browsing through the ACS Monograph on "Reactions of Anhydrous Aluminum Chloride in Organic Chemistry" by Charles Allen Thomas (we regarded this book as the Friedel-Crafts Chemists bible), I happened to come across reference to the "cyclialkylation" discovery of Herman Bruson. After reading his paper,¹¹ I realized it would be quite feasible to prepare the compound of the structure that I had proposed earlier in the spring.

The hydrocarbon, 1,1,4,4,6-pentamethyltetralin, was easily prepared in excellent yield. Since it was Friday and I was scheduled to be in Chicago for the National ACS Meeting (September, 1953) during the following week, I gave a generous sample of the tetralin hydrocarbon to my colleague William Easter, with the prediction that he would obtain derivatives of musk-like odor both by acetylation and dinitration. Easter made these derivatives and substantiated my predictions. We found that the methyl group in the 6-position of the acetyl derivative could be replaced by ethyl or isopropyl and the resultant products were still musks. These materials represented a new type of synthetic musk, a polycyclic ketone. Replacement of the acetyl by the formyl, or aldehyde group resulted in equally strong musks.

Route for Polycyclic Ketone Musks (Ref. 12)



Route for Polycyclic Aldehyde Musks (Ref. 13)

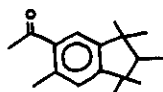


Musks V and VI were found to be phototropic, turning bright yellow on exposure to sunlight and returning to colorless when stored in the

dark.

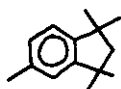
Steps were taken to procure patent protection. Our first application in the series was filed in December, 1953. When we were ready to start manufacture of these new polycyclic musks we found it necessary to license Bruson's cyclialkylation patent,¹⁴ which had one more year before its expiration. The derivative, 7-acetyl-6-ethyl-1,1,4,4-tetra-methyltetralin, showed outstanding fixative properties and was moved rapidly from research and pilot-plant studies to full-scale production in order to achieve the earliest possible commercialization. The product was colorless, light-stable, and closely approached the macrocyclic musks in performance. For this reason it quickly gained worldwide acceptance among perfumers. A preliminary report on our studies in this area was given by Carpenter in 1955.¹ Later, in 1963, Wood and coworkers reported on the chemistry of the Tetralin musks.¹⁵

Although Carpenter and Easter felt sure the problem of Phantolid was solved in August of 1953, it returned to haunt us nearly one year later, in the form of a letter from our Swiss colleague, A. V. Grampoloff, who had found that Phantolid was really an indan derivative and recognized the probable mechanism by which the hydrocarbon intermediate, 1,1,2,3,3,5-hexamethylindan was formed:

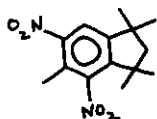


Correct structure of Phantolid

On learning of this, it was apparent that Barbier's *t*-butyl-*p*-cymene, the Moskene intermediate, must have the following structure:



and Moskene, its dinitroderivative, the following:



This was confirmed by an alternate synthesis starting with toluene and mesityl oxide.⁹ Thus, the last of the five commercial nitro musks yielded to research, revealing the structure which had remained a well-kept secret for close to a quarter of a century.

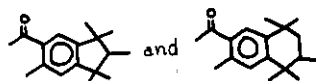
Once Grampoloff had called our attention to a paper by Ipatieff, Pines, and Olberg,¹⁶ where the ability of *p*-cymene to function as a hydrogen donor was elucidated, the mechanism of indan formation in the above reactions became clear to us.

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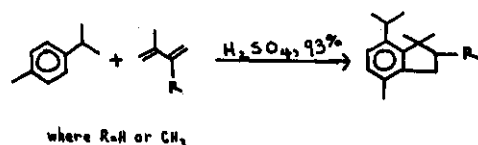
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II Diene-Cyclialkylation of Aromatics (1,1-Dimethylindan Derivatives)

By the end of the 1950s we had prepared many novel polycyclic ketone musks of the acylindan family as well as the tetrahydronaphthalene family. Two of the more interesting musks were derived from *p*-cymene.^{1,2}



Following this lead Angiolini and I extensively investigated reactions of *p*-cymene with olefins, alcohols, glycols, and dienes hoping to find hydrocarbon intermediates for new polycyclic musks. While involved in research in this area, we discovered that *p*-cymene reacts with isoprene or with 2,3-dimethyl-1,3-butadiene in the following manner:



Disappointingly, the acetyl derivatives of both hydrocarbons were odorless. Our research was then extended to reactions of isoprene with m-cymene, cumene, t-butylbenzene, xylenes, pseudocumene and other monoalkyl-, dialkyl-, and trialkylbenzenes. We found that this cyclialkylation-type of reaction occurs readily when alkyl derivatives of benzene having unoccupied vicinal positions are contacted with isoprene in the presence of sulfuric acid. We reported our results in a preliminary publication in 1963,³ where we proposed the name "isoprene-cyclialkylation" for this reaction since it satisfied the conditions originally set forth by Bruson for a "cyclialkylation" process—namely, formation of "a new cycle by attachment of a saturated divalent alkyl group to the aromatic nucleus."⁴

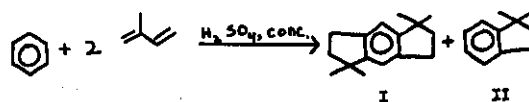
When we originally published, we were unaware of Schmerling's prior discovery in this area and did not give reference to his patent⁵ which had issued in 1958. Here he described the synthesis of a number of symmetrical hydrindacenes by the condensation of 2 moles of isoprene with 1 mole of benzene, p-xylene, or other paradisubstituted benzenes, in the presence of sulfuric or hydrofluoric acid catalyst. By the isoprene-cyclialkylation process we were able to conveniently prepare a great number of alkylsubstituted indans, asymmetric hydrindacenes and 1,1-dimethyltetrahydronaphindans as well as sym.-hydrindacenes.^{6a-e}

Subsequently Eisenbraun and coworkers⁷ at Oklahoma State University reported investigations in the area and have published many of their results.⁸ It is the purpose of this paper to summarize some of our work on the diene-cyclialkylation of benzenoid hydrocarbons and describe some of the useful derivatives we have prepared. Several polycyclic musks, a number of preemergence herbicides, and jet-fuel candidates were prepared via isoprene-cyclialkylation intermediates. These will be discussed in subsequent sections of this paper.

1. Benzene Cyclialkylation

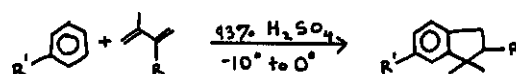
Schmerling⁵ reported the principal product obtained by the reaction of isoprene with benzene in the presence of sulfuric acid to be mainly the sym. hydrindacene along with a small amount of 1,1-dimethylindan, as a by-product. The hydrindacene which we obtained from benzene was reported in our preliminary publication as a colorless solid, m.p. 92-94°. The structure 1,1,7,7-tetramethyl-s-hydrindacene was proposed as a likely possibility—mainly because of its ease of acetylation. Subsequently,

NMR analysis showed that the structure (I) assigned by Schmerling was correct. Eisenbraun has found that the reaction of benzene with isoprene forms a complex mixture of products in addition to those previously reported.⁹



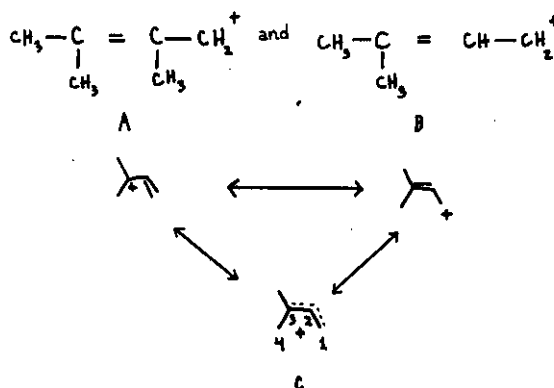
2. Cyclialkylation of Monoalkylbenzenes

We discovered that monoalkylbenzenes can be reacted with isoprene or with 2,3-dimethyl-1,3-butadiene in the presence of sulfuric acid to give fairly good yields of monoalkyl 1,1-dimethylindans or the 2-methyl homologs, under proper conditions.^{6a}



where R' = lower-alkyl (R=H or CH₃) (Ref. 6a)

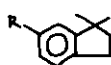
Where R' = (CH₃)₃C, yields as high as 70% of theory were obtained. In our initial publication it was suggested that the cyclialkylation process might proceed via the methylprenyl and prenyl-carbonium ions derived from 2,3-dimethyl-butadiene and isoprene respectively based on the structures of the products formed. Eisenbraun^{7,8b} has suggested that a π -complex distribution of charge over several atoms (C) via the allylic double bond seems reasonable and more appropriate than the previously suggested primary carbonium ion (A or B) as the initial attacking species.



Although the exact nature of the alkylating species is unknown, the products isolated apparently result from alkylation at carbon 1 first, followed then by cyclization through the carbonium ion produced at carbon 3.

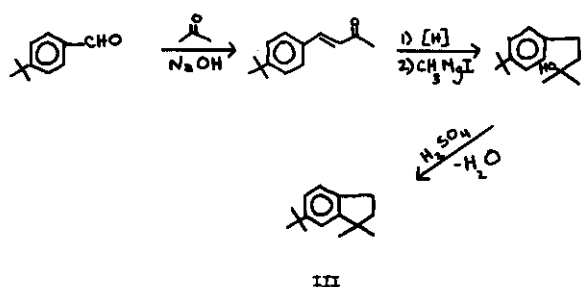
Toluene, ethylbenzene, isopropylbenzene, and t-butylbenzene were cyclialkylated with isoprene and 93% sulfuric acid yielding products resulting from initial substitution in the para and ortho positions of the benzenoid ring.³ Eisenbraun also investigated these reactions

and studied the nature of the products, arriving at similar conclusions. Eisenbraun^{8b} has tabulated his findings as follows:

R		
	<u>%</u>	<u>%</u>
CH ₃	60	40
CH ₂ CH ₃	70	30
CH(CH ₃) ₂	80	20
C(CH ₃) ₃	98	some 1,4-di- <i>t</i> -butyl-1-benzene formed

(Ref. 8b)

The distribution of products shown above shows the steric effect of the alkyl group. Since the 6-*t*-butyl-1,1-dimethylindane was of special interest to us as an intermediate for making a polycyclic musk, we carefully investigated its structure. It was synthesized by the following alternate route:

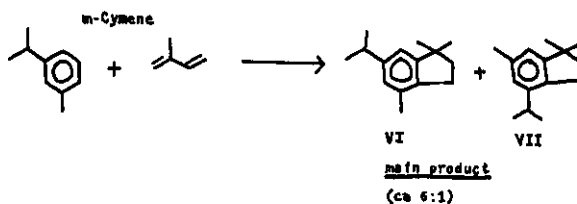
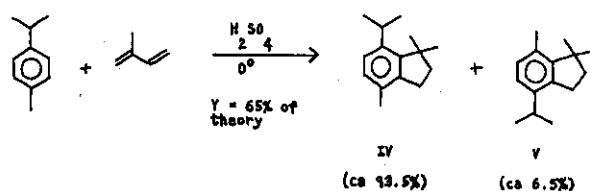


Comparison of III with the 6-*t*-butyl-1,1-dimethylindane made by the isoprene-cyclialkylation route showed the two to be identical by infrared and NMR spectra comparison. Both hydrocarbons yielded identical acetyl and dinitro derivatives. The acetyl derivation had identical properties to the novel musk prepared by Beets, who used yet another synthetic route.¹⁰ However, the synthesis by alternate synthetic routes was not considered unequivocal proof of structure since an acid-catalyzed cyclodehydration step was involved in all synthetic routes. Regular proton NMR and IR spectra were not helpful for distinguishing between 6-*t*-butyl- and 5-*t*-butyl-1,1-dimethylindane. However, ¹³C NMR analysis established the 6-*t*-butyl-1,1-dimethyl structure assignment.¹¹

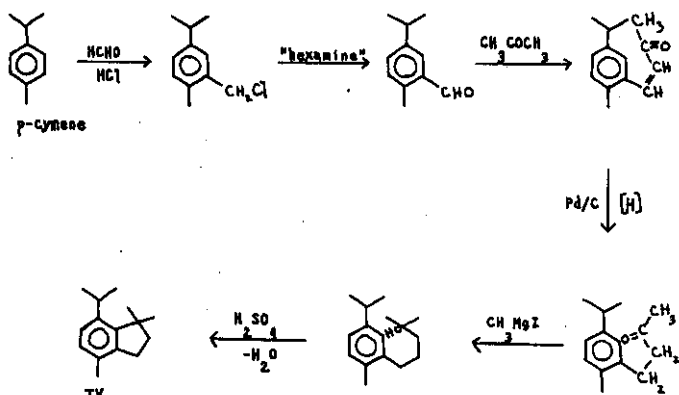
3. Cyclialkylation of Dialkylbenzenes¹²

Since the reaction of isoprene with *p*-cymene was the first case of isoprene-cyclialkylation observed in our laboratories, it was important for us to establish the structure of the hydrocarbon formed in order to gain insight into the nature of the reaction. Although studies of the NMR and infrared spectra pointed to the structure 7-isopropyl-1,1,4-trimethylindane as most probable, we resorted to an alternate synthesis in order to gain further support. The two routes for the hydrocarbon in question were the following:

Route A

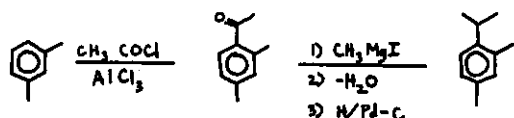


Route B

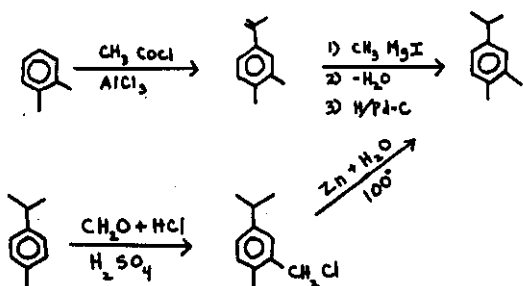


7-isopropyl-1,1,4-trimethylindan

The hydrocarbons derived by the two routes were shown to be identical by IR and VPC comparison. The dinitro and acetyl derivatives were found to be identical by melting points and mixed melting points. This structure proof rested entirely on the structure of the chloromethyl derivative of p-cymene. This was established by the following sequence:



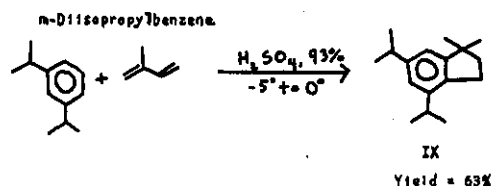
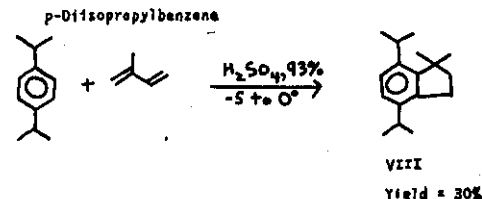
Reference: L. Friedman and R. Koca J.O.C. 33, 1255 (1968)



Reference: L. Friedman and R. Koca J.O.C. 33, 1255 (1968)

On the basis of these results our assignment of the structure 7-isopropyl-1,1,4-trimethylindan, is correct.

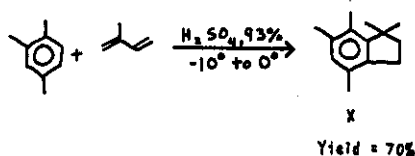
Similarly, many other dialkylbenzenes were cyclialkylated by reaction with isoprene in the presence of 93% sulfuric acid. Representative cases follow.



2-Methyl homologs of the above indan derivatives were also prepared by cyclialkylation of the corresponding dialkylated benzenes with 2,3-dimethyl-1,3-butadiene. This general process for preparing dialkylated 1,1-dimethyl- and 1,1,2-trimethylindans is covered in U.S. Patent 3,240,829.¹²

4. Cyclialkylation of Trialkylbenzenes¹³

Pseudocumene



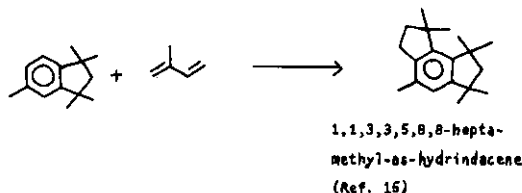
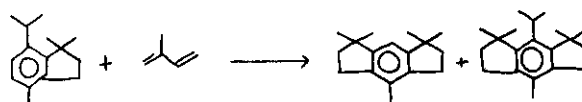
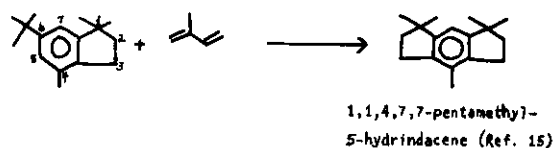
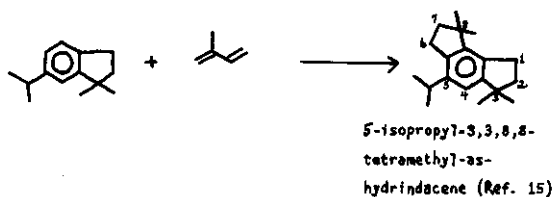
Other trialkylbenzenes which have been successfully cyclialkylated with isoprene or with 2,3-dimethyl-1,3-butadiene are: 1,2,4-triethylbenzene, 1,2,4-triisopropylbenzene, 1,4-dimethyl-2-isopropylbenzene (isopropyl-p-xylene), 1,3-dimethyl-2-(or -4-) isopropylbenzenes (isopropyl meta-xylene), and 1,2-dimethyl-3-(or -4-) isopropylbenzenes (isopropyl orthoxylenes). The cyclialkylation of the monoisopropylated xylenes gave 1,1-dimethylindans in excellent yields. In the case of 1,4-dimethyl-2-isopropylbenzene, the yield was about 85% of theory.¹³

We assigned the structure X shown above on the basis of the known electrophilic substitution reactions of pseudocumene in other alkylation reactions. Our structure assignment was verified by an alternate synthesis via methylmagnesium chloride and the chloromethyl derivative of pseudocumene. The structure of this lat-

ter intermediate has been previously established.¹⁴ Subsequently, in 1966, Eisenbraun and coworkers published an alternate proof of structure for X in connection with their preparation of this material as a reference hydrocarbon for the American Petroleum Institute.^{8b}

5. Hydrindacenes¹⁵

We discovered that reaction of isoprene or 2,3-dimethyl-1,3-butadiene with indan derivatives having two unsubstituted adjacent positions in the aromatic nucleus in the presence of sulfuric acid provides a facile process for preparing a number of polysubstituted hydrindacenes.¹⁵ Typical examples follow.



Having in hand a myriad of novel cyclialkylation hydrocarbons and their derivatives the question arose: What are they good for? Or, as Herman Bruson would put it, "what's the use?"¹⁶ The remainder of this paper will deal with our attempts to find practical applications for some of these products.

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III Candidates for Jet Fuel

It has been proposed that "saturated cyclic hydro carbons, especially bicyclics, obtained by the hydrogenation of substituted aromatics will fulfill the requirements for thermally stable jet and missile fuels."¹ For this reason we thought it would be worthwhile to consider the perhydro derivatives obtained from diisopropyl-1,1-dimethylindan and 7-isopropyl-1,1,4-trimethylindan. Samples were submitted to the Wright Air Development Center at Dayton, Ohio, for further testing. They were found to be satisfactory in all respects except for thermal stability.

Reference

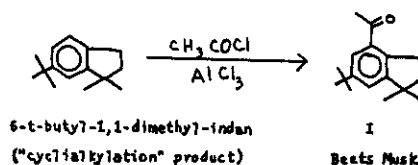
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IV Polycyclic Musks

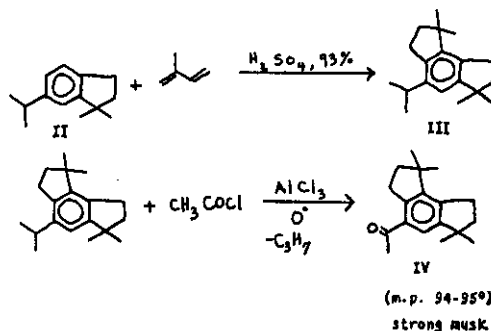
4-Acetyl-6-*t*-butyl-1,1-dimethylindan
 ("Beets Musk")

Soon after our discovery of the isoprene-p-cymene cyclialkylation reaction, Beets disclosed the discovery of a promising new polycyclic musk and its homologs.¹ This material was 4-acetyl-6-t-butyl-1,1-dimethylindan. We immediately recognized the possibility of making the necessary intermediate, 6-t-butyl-1,1-dimethylindan by the reaction of isoprene with t-butylbenzene in the presence of sulfuric acid. By this route the desired hydrocarbon intermediate was produced smoothly in excellent yield and steps were immediately taken to patent this process for its manufacture.^{2,3}



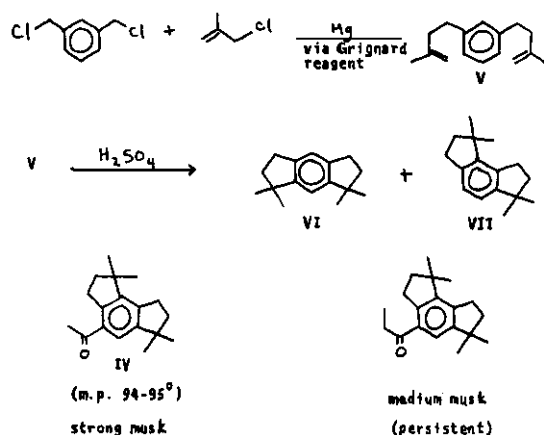
5-Acetyl-3,3,8,8-tetramethyl-as-hydrindacene^{4,5}

Acetylation of diisopropyl-1,1-dimethylindan was found to produce a derivative of musk-like odor which, when highly purified by repeated crystallizations, was devoid of musk odor. This led us to conclude that the odor property was due to a trace impurity produced in the synthetic route. Consideration of possible by-products led us to study the isoprenecyclialkylation of isopropyl-1,1-dimethylindan. This reaction produced the as-hydrindacene, 5-isopropyl-3,3,8,8-tetramethyl-as-hydrindacene, as indicated previously, which on acetylation produced a new tricyclic musk, 5-acetyl-3,3,8,8-tetramethyl-as-hydrindacene, having a strong musk-like odor.



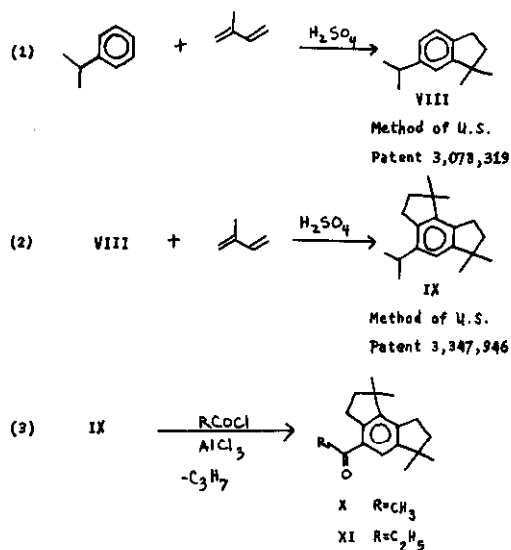
Theimer and Blumenthal of International Flavors and Fragrances were granted a U.S. Patent covering this material as a new composition.⁴ The Theimer team followed an unequivocal route using α , α' -dichloro-m-xylene

and methallyl chloride as starting materials. In the first step of the synthesis, m-bis-(3-methyl-3-butenyl)-benzene V was produced by a Grignard reaction. Cyclization of V using sulfuric acid produced a mixture of two isomeric hydrindacenes, namely 1,1,7,7-tetramethyl-S-hydrindacene (VI) and 1,1,6,6-tetramethyl-as-hydrindacene. The synthetic route was as follows:



Separation of isomers VI and VII was affected by fractionation through a "high plate packed column." Compound VI was obtained as a solid, melting at 45° to 47°. Compound VII was obtained as a liquid fraction. The ketone obtained by acetylation of VI was a solid, m.p. 57°, having a "weak musk odor."

Our synthetic route used the following scheme starting from cumene.

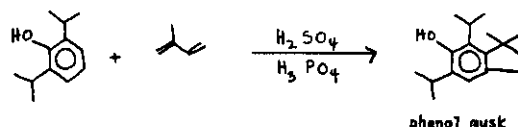


Derivatives X and XI made by acylating the hydrocarbons made by each route were identical. Although we were unable to cover the new musks, we obtained a U.S. Patent protecting our new process and covering the key hydrocarbon IX as a new composition of matter.⁵ This route is undoubtedly the only practical approach for manufacturing the new "as-hydrindacene

musks" X and XI on a commercial scale.

5,7-Diisopropyl-1,1-dimethyl-6-indanol⁶

This novel type of polycyclic musk was prepared by condensing isoprene with 2,6-diisopropylphenol in the presence of a protonic acid catalyst such as sulfuric or phosphoric acid. It is, to the best of our knowledge, the first compound of its class known to exhibit musk-like odor.



Since this "phenol musk" was unique, we prepared eight homologs by the diene-cyclialkylation of other ortho-disubstituted phenols, hoping to discover other musk-like compounds in this area. None of these exhibited this property. These homologs all appear to be new compounds and the method used for their preparation is a novel reaction. The acid-catalyzed isoprene-cyclialkylation of benzenoid hydrocarbons has been previously reported by Schmerling, Wood and Angiolini, and Eisenbraun, but its application to the cyclialkylation of orthodisubstituted phenols is new.⁷

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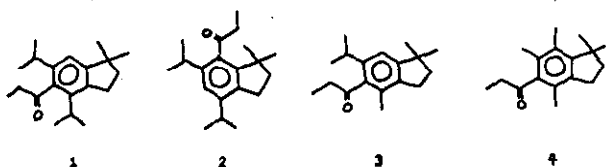
V Herbicides

The discovery of new isoprene-derived herbicides resulted from a cooperative screening program carried out between the Givaudan and Amchem Corporations.¹ This surprising and unexpected development was a by-product of research in the field of polycyclic musks.

Good preemergence activity against grasses is exhibited by all herbicides of this group but to a greater degree by members of the acylated polyalkyl-1,1-dimethylindan family. Fortu-

nately, the most active members of this family are the least costly to prepare, since they are derived in good yield from cheap, widely available petrochemical materials. Isoprene has recently become available in quantity at a low price as a result of the "synthetic natural rubber" program. Thus, these products are inexpensive to manufacture. They have limited persistence in the soil (6 mo.) and seem to be biodegradable. With the present-day concern over possible detrimental effects to the environment of chlorine-containing herbicides, this appears to be a timely discovery.

The most active ketones of this family are the acetyl, propionyl and isobutyryl derivatives of the polyalkyl-1,1-dimethylindans obtained by the isoprene-cyclialkylation of di- and trialkylbenzenes. Preparation of these hydrocarbon intermediates is described in earlier patents.² Formyl derivatives are inactive. The most important compounds from the standpoint of biological activity combined with ease of manufacture are the propionyl derivatives of the indans derived from m-isopropyltoluene, m-diisopropylbenzene and pseudocumene:

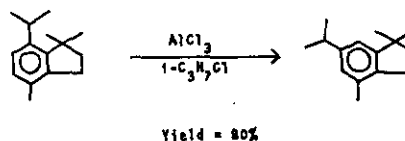


Compounds 1, 2 and 3 exhibit the greatest activity. All are stable to acid and base and insoluble in water. They are nonirritating to the skin, have low toxicity, and possess mild to pleasant odors. They exhibit a high degree of selectivity and are valuable for the elimination of grasses from economic crops such as corn, beans, soybeans, and rice.

Since compound 3 showed the best biological activity, it was considered the most promising candidate for commercialization and extensive studies were made of methods for its manufacture.

An efficient method starting with p-cymene

was discovered which involves isomerization of the intermediate hydrocarbon with anhydrous AlCl_3 , activated by isopropyl chloride.³



This discovery permits the preparation of 6-isopropyl-1,1,4-trimethylindan in close to 90% purity from p-cymene. Propionylation of this hydrocarbon provides a crude product which can be vacuum-distilled to yield a distilled grade of ketone 3 which can be used directly for herbicidal applications since its purity is close to 90%.

Surprisingly, many of the original acylpolyalkyltetralin musks made via the Bruson cyclialkylation process were shown to have pronounced herbicidal activity.⁴ This activity was also exhibited by their propionyl butyryl and isobutyryl homologs. In contradistinction to the case of the polycyclic tetralin musks, the formyl-homologs were practically inactive as herbicides.

The indan derivatives which contain only carbon, hydrogen, and oxygen are unique herbicides, and we are hopeful that they will partly fill the present day need for harmless biodegradable pesticides.

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