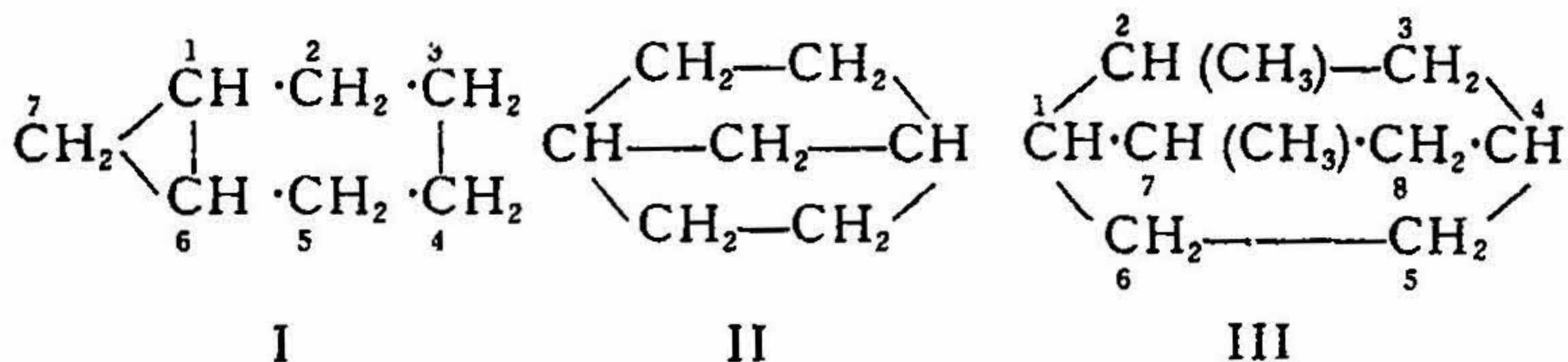


I. THE SYSTEMATIC NOMENCLATURE OF POLYCYCLIC CARBON SYSTEMS.

By J. J. Sudborough.

A. von Baeyer¹ was the first to devise a system of nomenclature applicable to bicyclic compounds. He regards the molecule of such a compound as built up of a system of bridges proceeding from the two carbon atoms (tertiary carbons) common to the two rings. The prefix *bicyclo-* is used for all such compounds and the number of carbon atoms constituting each bridge apart from the original tertiary carbons is indicated, and the final name gives the number of carbon atoms present in all three bridges combined.

Thus I is *bicyclo(0.1.4)heptane* and II is *bicyclo(1.2.2)heptane* and III is *2:7-dimethyl-bicyclo(2.2.2)octane*.

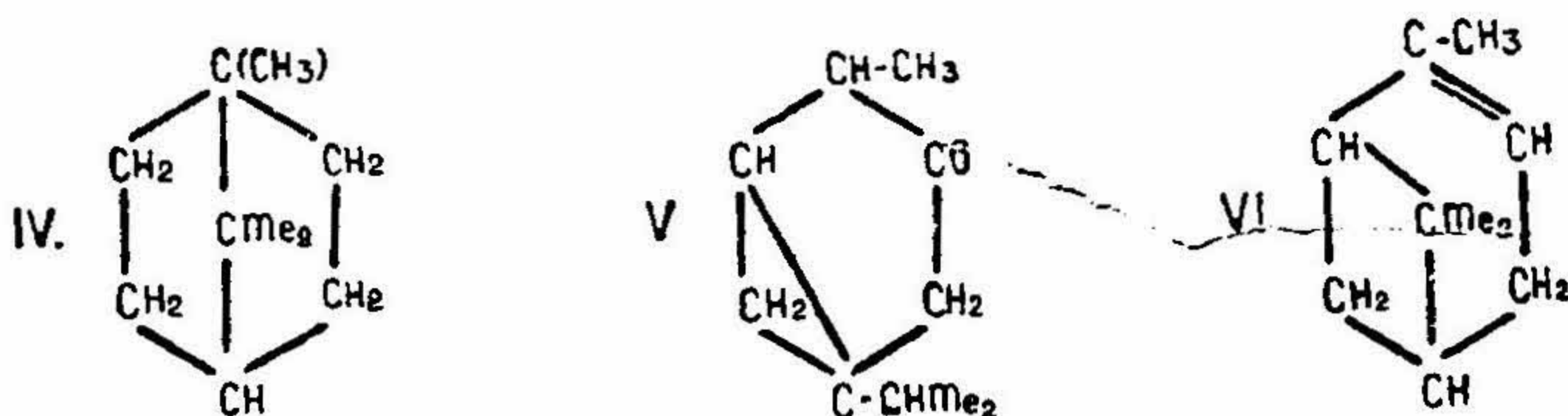


In numbering the carbon atoms it is usual to start with one of the tertiary atoms and, if the two rings are not equal, to number the carbon atoms of the larger ring first.

Such a system is quite useful for bicyclic compounds, *i.e.*, monocyclic compounds with a single bridge, but it is difficult to expand it so as to comprise multi-bridged compounds.

A disadvantage to which several authorities have drawn attention is the fact that the same numbers are used in two different ways, *viz.*, to indicate the positions of substituents in the molecule and to give the number of carbon atoms in each bridge. To a certain extent this defect is remedied by enclosing the second set of figures in brackets.

Borsche¹ distinguishes between plain bridges or diagonal unions, as in I, and bridges consisting of one or more CH₂ groups as in II and III. The former he denotes by a capital Pi and the latter by a capital Gamma, just as an olefine linking is denoted by a capital Delta. The diagonal linkings and bridges are regarded as substituents in the original ring, and the carbon atoms in the bridges are not included in the specific name, thus I would be II¹⁽⁶⁾-cycloheptane II would be $\Gamma^{1(4)}$ -methylene-cyclohexane, camphane, IV, is 1-methyl- $\Gamma^{1(4)}$ -dimethylmethylene-cyclohexane, thujone, V, is 1-methyl-4-iso-propyl-II⁴⁽⁶⁾-cyclohexan-2-one, and α -pinene, VI, is 1-methyl- $\Gamma^{2(4)}$ -dimethylmethylene- $\Delta^{1(6)}$ -cyclohexene.



Behal² numbers the carbon atoms of the main ring in the usual manner, but denotes the carbon atoms of bridges by a, b & c, thus α -pinene is termed a:a:1-trimethyl-bicyclo-4.a.6- Δ^2 -heptene. The numbers 4. a. 6 indicate that the bridge proceeds from carbon atom No. 4 of the ring, contains one carbon atom, a, and terminates at carbon atom No. 6 of the ring.

Grignard³ raises several objections to Baeyer's system and in his own scheme adopts a basal ring and regards this as crossed by one or more bridges. The characteristic name gives the number of carbon atoms in the basal ring and not the sum of the atoms constituting the ring and its bridges, thus both II and III are bicyclohexane derivatives.⁴ The bridges are usually as short and simple as possible and the numbering of the carbon atoms in the bridges follows after that of the basal ring as in Baeyer's system. The bridges are regarded as substituents in the basal ring, and in the name of the compound numbers are given indicating the carbon atoms from which the bridge starts and ends and also the numbers of the carbon atoms in the bridge. The name also gives the number of rings, but as there is some diversity of opinion as to the number of rings present in such compounds as the tricyclenes the number of rings is taken as twice that of the bridges present.⁵ Camphane, IV, would be termed bicyclo-1.7.4-

¹ *Annalen*, 1910, 377, 73.

² *Ibid.*, p. 124.

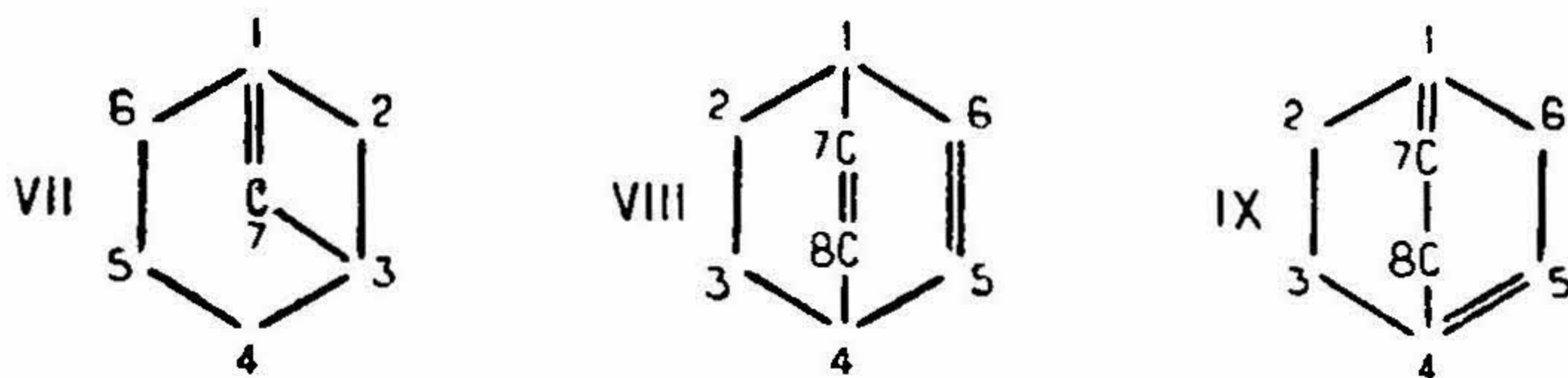
³ This is not a safe rule to adopt as with a-CH bridge in a cyclohexane ring three smaller rings would be produced.

⁴ *Bull. Soc. chim.*, 1912, [IV], 11, 269.

⁵ Compare also Kondakow *J. pr. Chem.*, 1906, [II], 74, 420.

hexane, thujone, V, would be 1-methyl-4-isopropyl-*bicyclo*-4.6-hexan-2-one, pinene, VI, would be 1:7:7-trimethyl-*bicyclo*-4.7.6- Δ^1 -hexene, and III would be 2:7-dimethyl-*bicyclo*-1.7.8.4-hexane.

If there is an ethylene linking in the bridge this is denoted by the term *bicycleno* and the carbon atom from which the olefine linking starts is denoted by a dash against the number, e.g.,



are termed respectively *bicycleno*-1'.7.3-hexane, *bicycleno*-1.7'.8.4- Δ^5 -hexene and *bicycleno*-1'.7.8.4- Δ^4 -hexene, as compared with Baeyer's names *bicyclo*(1.1.3)- $\Delta^{1(7)}$ -heptene, *bicyclo*(2.2.2)- $\Delta^{5:7}$ -octadiene, *bicyclo*(2.2.2)- $\Delta^{4:1(7)}$ octadiene.¹

In 1896 Bredt² suggested the term *meso* to indicate a bridge, e.g., *mesomethylene* and also the *o*, *m*, or *p* prefix to indicate whether the two carbon atoms in the ring joined by the methylene bridge were in the ortho, meta or para positions. Thus camphor is a derivative of *p-meso*-methylene-*cyclohexane*. Pinene is a derivative of *m-meso*-methylene-*cyclohexane* and carone is a derivative of *o-meso*-methylene-*cyclohexane*.

Bredt and Savelsberg³ criticise the earlier systems of nomenclature. They prefer a system of nomenclature which does not attempt to indicate the number of rings present, as authorities do not agree on the question. They also prefer the idea of a basal carbon ring to Baeyer's idea of a system of bridges, and the name given indicates the number of carbon atoms in the basal ring, e.g., camphor is a *cyclohexane* rather than a *bicycloheptane* derivative. Like Borsche, they distinguish between diagonal linkings and bridges and restrict the latter term to the following cases:—

(a) A methylene or substituted methylene group between two meta- or para-, but not ortho- carbon atoms in a hexamethylene ring and also for the carbonyl group in similar positions.

(b) For meta- or para-union in *cyclohexane* by long chains of carbon atoms.

¹ Compounds of the types VII and IX are not likely to be encountered as Bredt (*Annalen*, 1924, 437, 1) claims that a double linking cannot be attached to the same carbon atom as a bridge.

² *Annalen* 1896, 292, 123.

³ *J. pr. Chem.*, 1918, [II], 97, 1.

In this way they differentiate between bridged compounds and condensed ring systems, as the latter can be regarded as formed from a monocyclic system by the introduction of a diagonal linking.

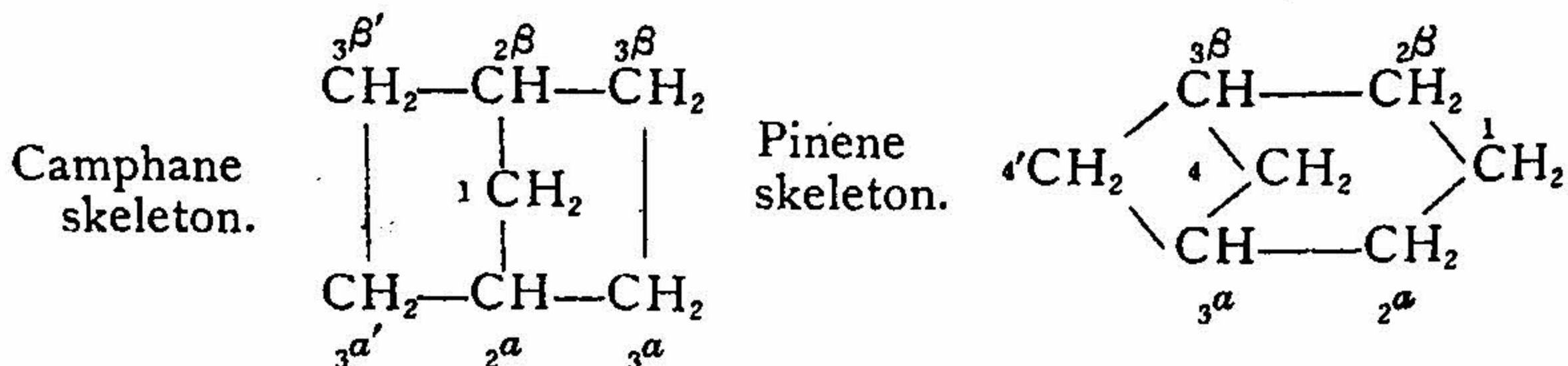
The following is their classification of cyclic compounds.

Classification of Ring Systems.

- | | | | |
|------------------|------|---|---|
| I. Simple rings | .... |  | ..... |
| II. Double rings | | { | A. Rings with bridges.
(<i>a</i>) in 1 : 3 or meta-position.
(<i>b</i>) in 1 : 4 or para-position.
B. Condensed rings.
(<i>a</i>) with amphi-union.
(<i>b</i>) with spiro-union. |
| III. Poly-rings | | | C. Rings with bridges in peri-union.
D. Combination of A and B. |

Bredt and Savelsberg point out that the capital Gamma, which Borsche¹ recommends for denoting a bridge, has already been adopted by Baeyer² for denoting geometrical isomerism. They give a detailed classification of certain bridged *cyclohexane* derivatives and their system is based upon the symmetrical relationships of the ring components. Thus in camphane seven carbon atoms may be grouped as follows :—

(*a*) one carbon atom termed No. 1 differently situated from all the others ; (*b*) two carbon atoms similarly situated and each attached directly to C atom No. 1. These are called No. 2 and are distinguished as 2^{*a*} and 2^{*β*}. ; (*c*) four carbon atoms, No. 3, similarly situated and each attached to a carbon atom No. 2 and not directly to No. 1. They are distinguished as 3^{*a*}, 3^{*a'*}, 3^{*β*}, 3^{*β'*}.

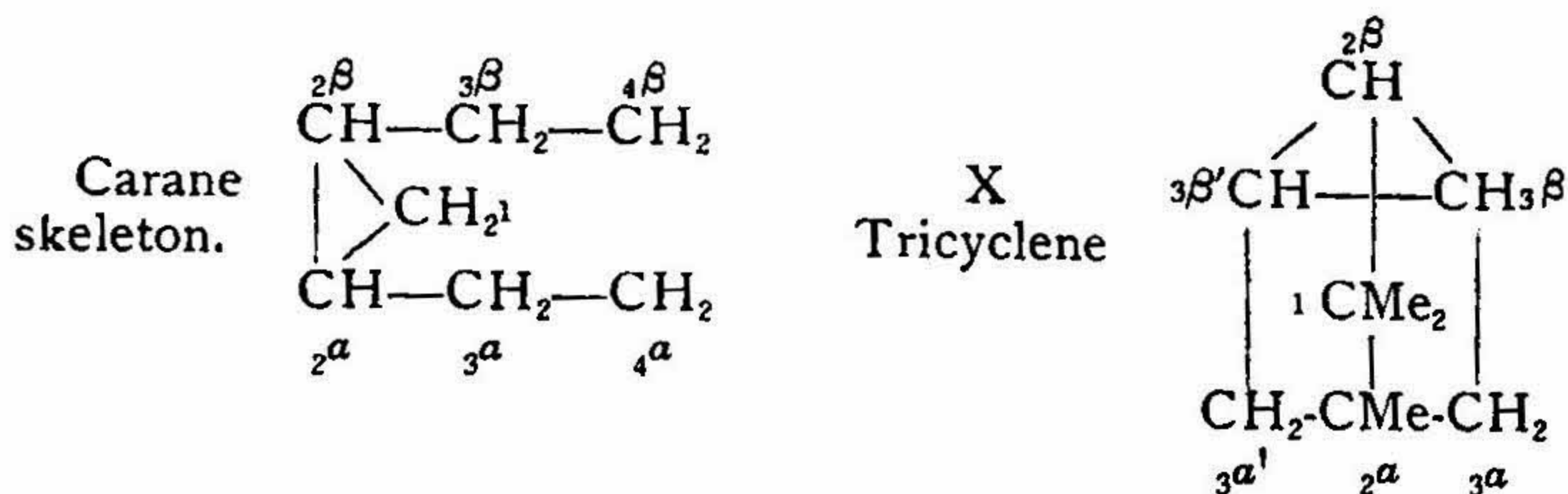


Camphane is *p*-mesomethylene-1.1.2-trimethylcyclohexane.
 fenchane is *p*-mesomethylene-2^{*a*}3^{*ββ*}-trimethylcyclohexane.
 isofenchane is *p*-mesomethylene-3^{*aββ*}-trimethylcyclohexane.

¹ *Annalen*, 1910, 377, 74.

² *Ibid.*, 1888, 245, 137.

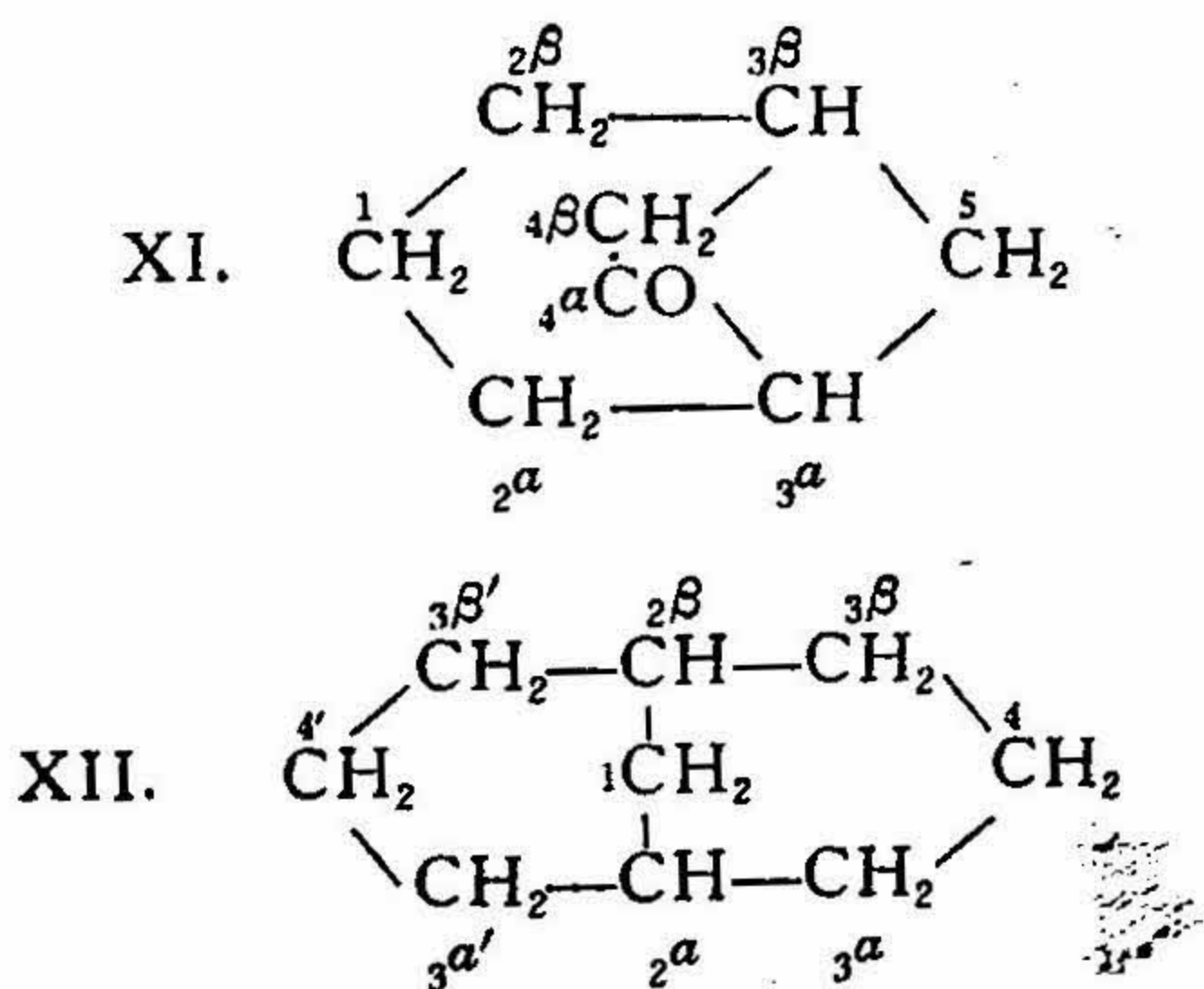
- bornylene is *p*-mesomethylene-1.1.2 α -trimethyl- Δ -3 α -cyclohexene.
 camphene is *p*-mesomethylene-3 α -methylene-3 $\beta\beta$ -dimethylcyclohexane.
 pinene is *m*-mesomethylene-4.4.2 β -trimethyl- Δ 1(2 β)-cyclohexene.
 pino-camphone is *m*-mesomethylene-4.4.2-trimethyl-cyclohexan-1-one.



Carane is regarded as condensed hexamethylene and trimethylene rings, and is termed *amphimethylenecyclohexane*.

Bredt and Holz's¹ tricyclene X is *p*-mesomethylene-1.1.2 α -trimethyl-3 $\beta\beta'$ -pericyclo-R-hexane² and teresantalic acid is *p*-mesomethylene-1.2 α -dimethyl-3 $\alpha\alpha'$ -pericyclo-R-hexane-1-carboxylic acid.

Komppa and Hirn's³ ketobicyclo (1.2.3)octane (XI) is *m*-mesodimethylenone-R-hexane and Meerwein and Schurmann's⁴ bicyclo (1.3.3) nonane (XII) is *m*-mesotrimethylene-R-hexane, and their bicyclo-



¹ *J. pr. Chem.*, 1917, (II), 95, 133.

² The term *peri* is used as positions 3 β and 3 β' or 3 α and 3 α' are regarded as comparable with the *peri*-positions in the naphthalene formula.

³ *Ber.*, 1903, 36, 3610.

⁴ *Annalen*, 1913, 398, 196.

(1.3.3)nona-2:6-dione-1:3:5:7-tetracarboxylic acid¹ is *m*-mesotrimethylene-3^α-one-R-hexane-3^{β'}-one-2^{αβ}-4.4'-tetracarboxylic acid.

Beesley and Thorpe² point out the need of a comprehensive system of nomenclature for associated ring compounds. They raise objections to the systems of both Borsche and Bredt and Savelsberg and suggest a new system.

They classify all isocyclic compounds containing associated rings under A or B or a combination of both (C).

A. Compounds derived from an alkylated monocyclic compound by the formation of a new ring or rings by the linking of a carbon atom of the original ring with a carbon atom of the side chain, thus compounds denoted by formulae XIII, XIV, XV and XVIII can be regarded as derived from *n*-butylcyclopentane, XVI from *isopropylcyclopentane*, XVII from *n*-butylcyclobutane by the formation of two new rings.

B. Compounds formed from two different cyclic systems by the union of one, two or more carbon atoms of one ring with one, two or more of the second, e.g., XXIII, XX and XXI are all formed by the union of a *cyclopentane* and a *cyclopropane*, XXII and XXIV by the union of two *cyclopropanes*.

C. Compounds containing both the A and B types of linking, e.g., XXV, XXVI and XXXI.

In naming the compounds, the names of the ring and side chain are given, and in addition a large Roman numeral, which indicates whether the linking between the ring and side chain or two rings is effected by means of 1, 2, 3 or 4 pairs of carbon atoms.³ Small Arabic numerals before and after the Roman figure indicate the carbon atoms of the side chain and ring or of the two rings which are linked up, and the order in which they are given shows the actual pairs of atoms united.

In naming compounds of type A the name for the side chain comes first and is followed by that of the ring, and the side chain is always termed methane, ethane, propane, etc., and not methyl, methene, ethene, etc. In naming compounds of type B the simpler ring is always placed first.

In numbering the carbon atoms the side chain is numbered independently of the ring and in compounds of type B each ring

¹ *Annalen*, 1913, 398, 223.

² *J. Chem. Soc.*, 1920, 117, 591.

³ The Roman numeral 1 in type A would indicate that the substance is a simple alkylated cycloparaffin and for these compounds the older names methylcyclopropane, etc., are retained.

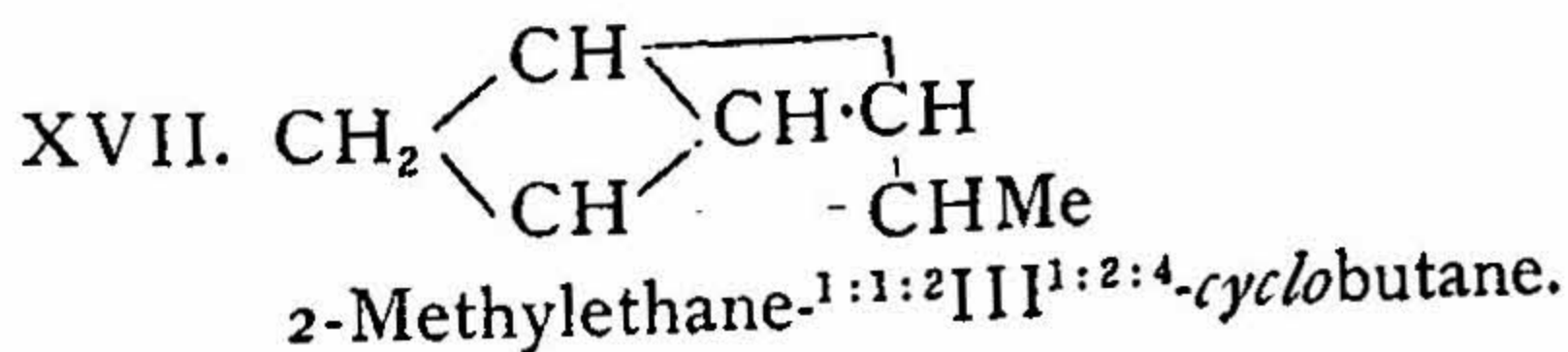
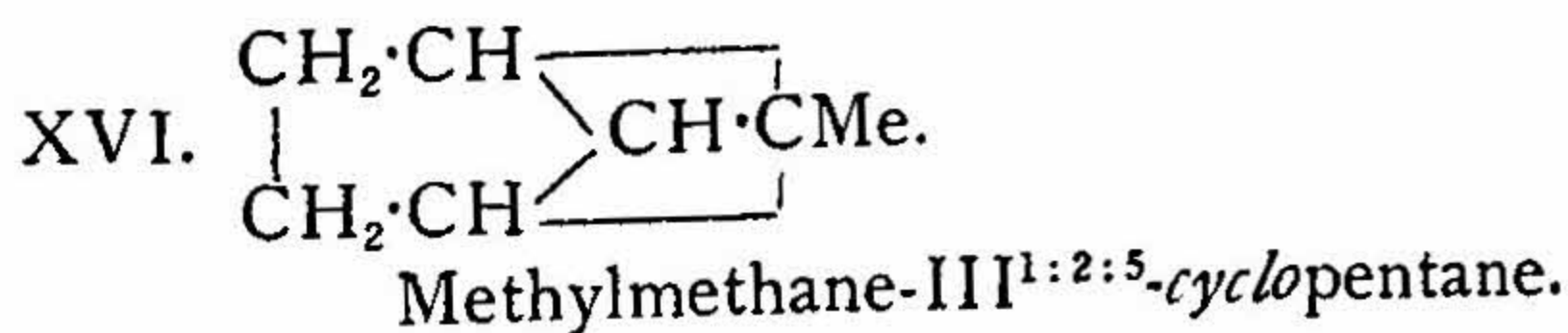
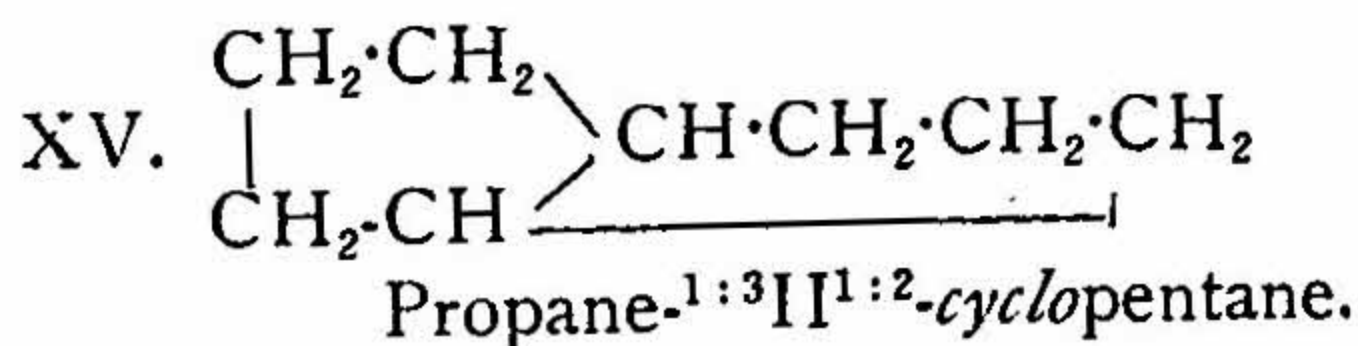
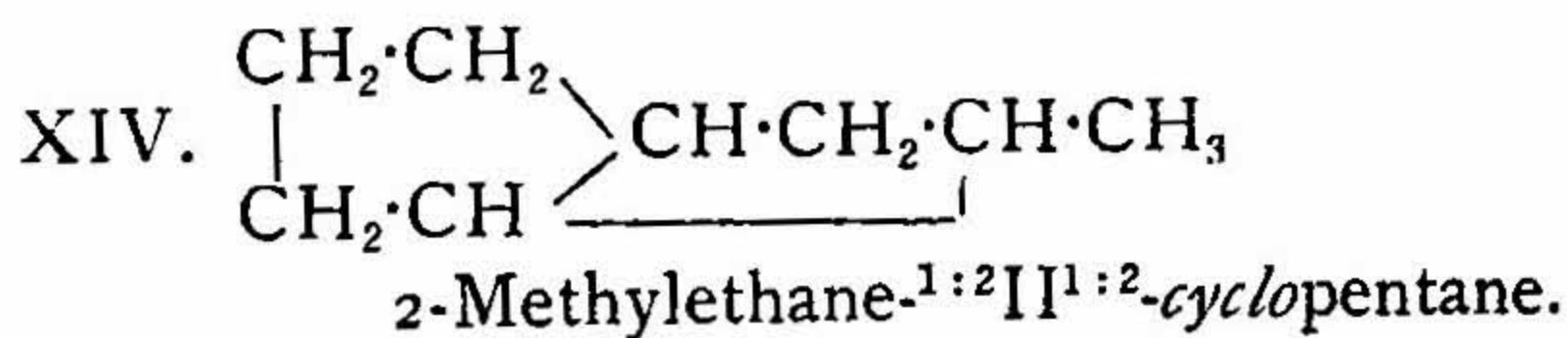
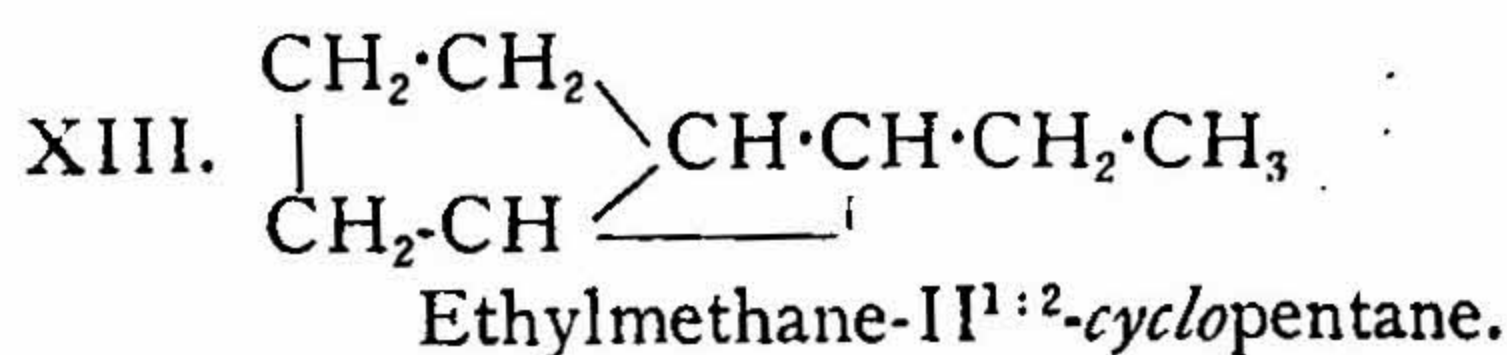
is numbered separately. In all types of compounds the numbering begins with one of the linked carbon atoms, i.e., with a tertiary or quaternary carbon atom, and then proceeds clockwise in the case of each ring and in the usual manner in the cases of a side chain. With compounds of type A the simplest portion of the chain entering into ring formation should be used in the name and any attached groups should be named as substituents of the simple chain. Thus XXVII is 2-methyl-ethane-^{1:1:2}III^{1:2:6}-cyclohexane and not propane^{1:1:2}III^{1:2:6}-cyclohexane.

XXVIII is dimethylmethane-II^{1:4}-1-methylcyclohexan-2-one and not ethane-^{1:2}II^{1:3}-2:2:3-trimethylcyclopentan-4-one.

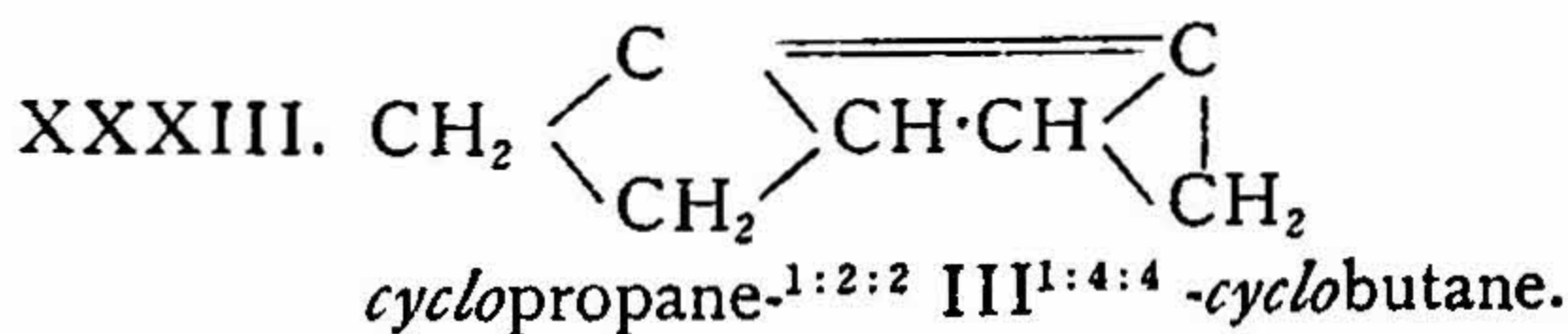
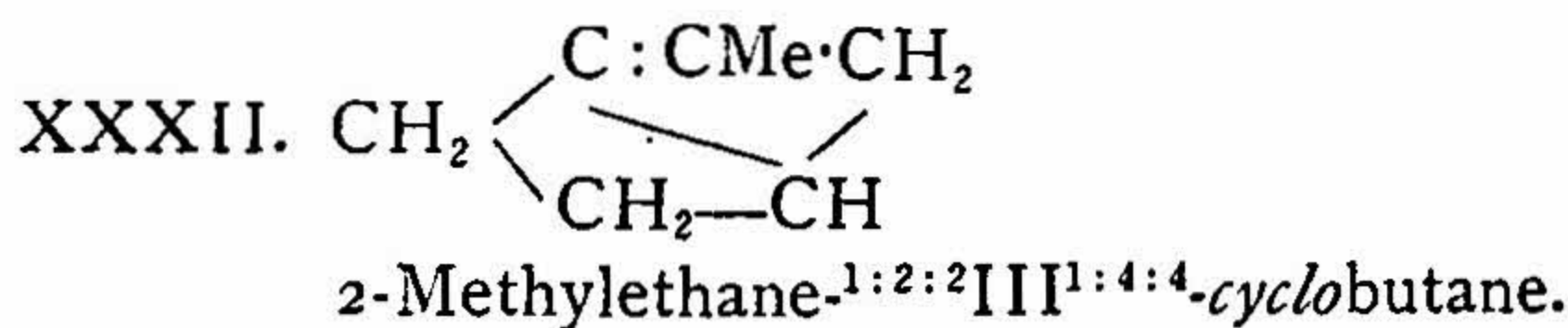
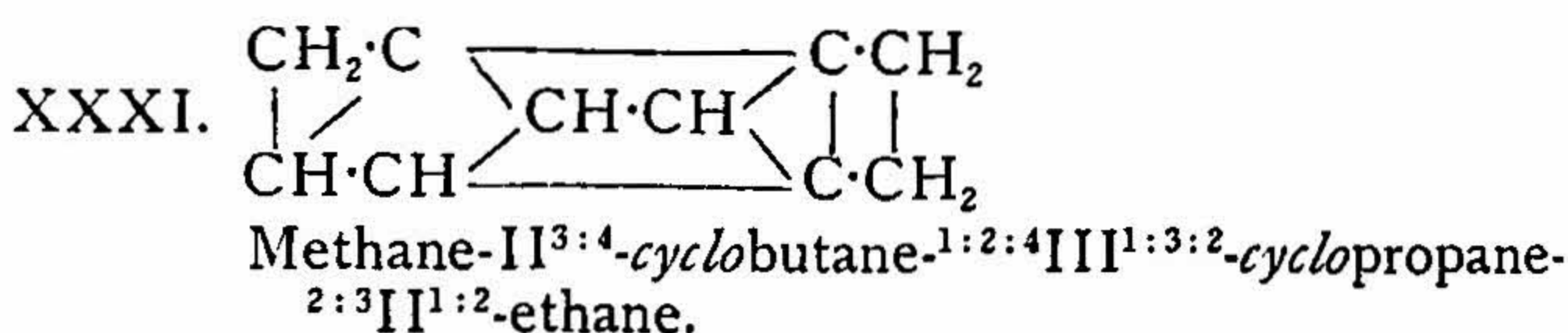
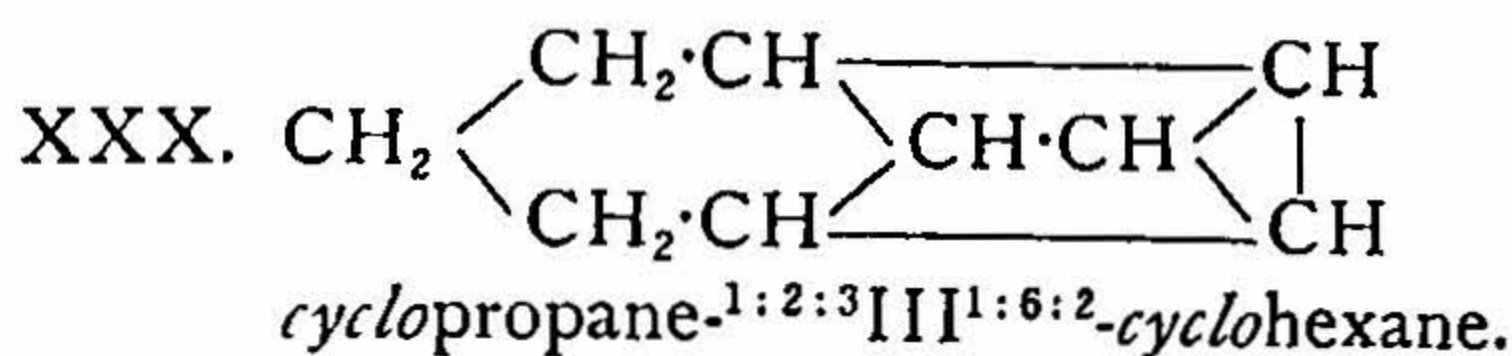
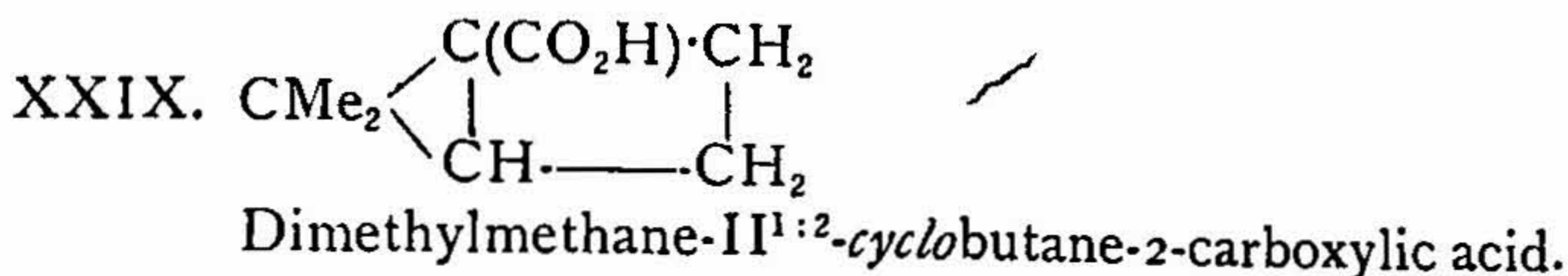
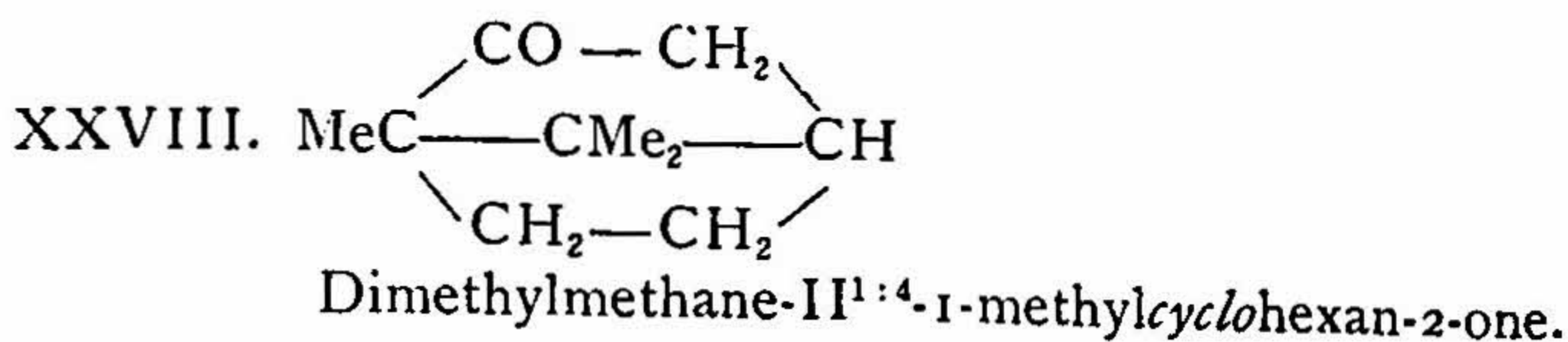
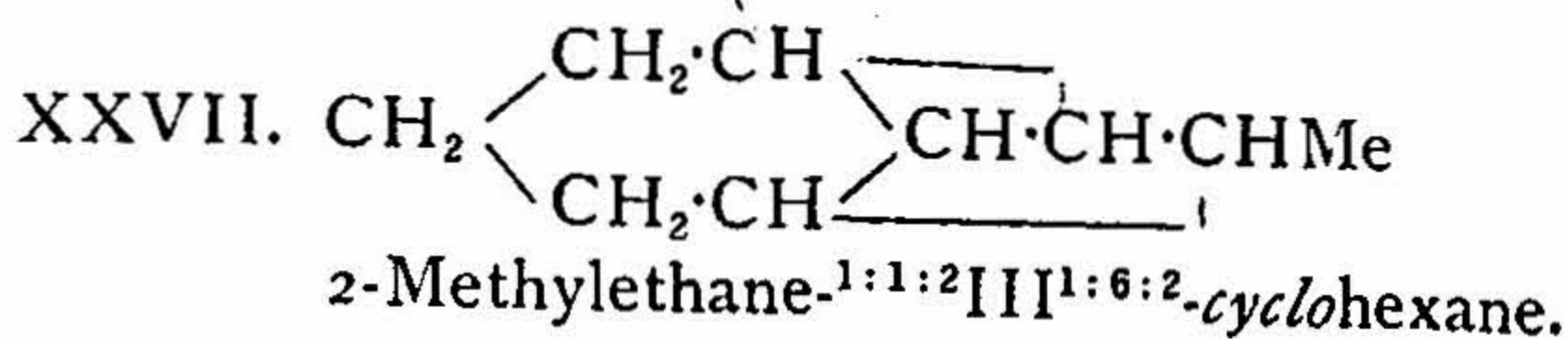
The figures taken in order on either side of the Roman number show, in each case, the actual carbon atoms linked.

In the case of a compound which can be assigned to class C and also A or B, e.g., XXIV, the simple type rather than the mixed type is selected for naming.

This system of nomenclature is well illustrated by means of the following examples taken from Beesley and Thorpe's paper:—



- XVIII. $\begin{array}{c} \text{CH}_2\cdot\text{CH} \\ | \\ \text{CH}_2-\text{C} \end{array} \begin{array}{l} \diagdown \\ \diagup \\ \diagdown \\ \diagup \end{array} \begin{array}{c} \text{CH}\cdot\text{CH}\cdot\text{CH} \\ \text{CH}_2 \end{array}$
 Propane-^{1:1:2:3}I V^{1:5:2:2}-cyclopentane.
- XIX. $\begin{array}{c} \text{CH} - \text{CH} \\ / \quad \backslash \\ \text{CH} - \text{C} - \text{C} - \text{CH} \\ \backslash \quad / \\ \text{CH} - \text{CH} \end{array}$
 Ethane-^{1:1:1:2:2:2}V I^{1:2:3:4:5:6}-cyclohexane.
- XX. $\begin{array}{c} \text{CH}_2\cdot\text{CH} \\ | \\ \text{CH}_2\cdot\text{CH}_2 \end{array} \begin{array}{l} \diagdown \\ \diagup \\ \diagdown \\ \diagup \end{array} \begin{array}{c} \text{CH}\cdot\text{CH} \\ \text{CH}_2 \end{array}$
 cyclopropane-^{1:2}II ^{1:5}-cyclopentane.
- XXI. $\begin{array}{c} \text{CH}_2\cdot\text{CH} \\ | \\ \text{CH}_2\cdot\text{CH} \end{array} \begin{array}{l} \diagdown \\ \diagup \\ \diagdown \\ \diagup \end{array} \begin{array}{c} \text{CH}\cdot\text{CH} \\ \text{CH} \end{array}$
 cyclopropane-^{1:2:3}III ^{1:5:2}-cyclopentane.
- XXII. $\begin{array}{c} \text{CH} \\ / \quad \backslash \\ \text{CH} - \text{CH} \\ \backslash \quad / \\ \text{CH} \end{array}$
 cyclopropane-^{1:2:3}III ^{1:2:3}-cyclopropane.
- XXIII. $\begin{array}{c} \text{CH}_2\cdot\text{CH}_2 \\ | \\ \text{CH}_2\cdot\text{CH}_2 \end{array} \begin{array}{l} \diagdown \\ \diagup \\ \diagdown \\ \diagup \end{array} \begin{array}{c} \text{CH}\cdot\text{CH} \\ \text{CH}_2 \end{array}$
 cyclopropylcyclopentane.
- XXIV. $\text{CH}_2 \begin{array}{l} \diagdown \\ \diagup \\ \diagdown \\ \diagup \end{array} \begin{array}{c} \text{CH}\cdot\text{CH} \\ | \quad | \\ \text{CH}\cdot\text{CH} \end{array} \text{CH}_2$
 cyclopropane-^{1:3}II ^{1:2}-cyclopropane.
- XXV. $\begin{array}{c} \text{CH}_2\cdot\text{C} \\ | \\ \text{CH}\cdot\text{CH} \end{array} \begin{array}{l} \diagdown \\ \diagup \\ \diagdown \\ \diagup \end{array} \begin{array}{c} \text{CH} \\ \text{CH} \end{array}$
 Methane-II ^{3:4}-cyclobutane-^{1:4:2}III ^{1:2:3}-cyclopropane.
- XXVI. $\begin{array}{c} \text{CH}_2\cdot\text{C} \\ | \\ \text{CH}_2\cdot\text{C} \end{array} \begin{array}{l} \diagdown \\ \diagup \\ \diagdown \\ \diagup \end{array} \begin{array}{c} \text{CH}\cdot\text{CH} \\ \text{CH} \end{array}$
 Ethane-^{1:2}II ^{2:3}-cyclopropane-^{1:3:2}III ^{1:2:3}-cyclopropane.



An olefine linking between two carbon atoms, not both in the same ring, is indicated by the number of the carbon atom occurring twice, both before and after the Roman figure.

SUGGESTED NOMENCLATURE.

It is clear from the criticisms which each author has raised against systems previously suggested that no one system meets with general acceptance and even the latest scheme due to Beesley and Thorpe has disadvantages.

The most obvious one is that complex cyclic systems for purposes of naming are divided into the three main groups A, B and C and that the system adopted is somewhat different in A and B and becomes complex for compounds belonging to the mixed type C.

A minor objection is that the same numbers are used for the carbon atoms forming two different rings in one and the same compound.

A third objection is that under the rules given two different names may be given to the same formula, *e.g.*, XVI can be called methylmethane-III^{1:2:3}-cyclopentane, and XXXIII cyclopropane-^{1:1:3}III^{1:1:2}-cyclobutane.

In the following pages an attempt is made to outline a system of nomenclature applicable to practically all types of polycyclic rings, whether condensed rings or rings with bridges, whether formed from a ring and a side chain or from two or more independent rings, and including systems with spiro linking if thought desirable.

A sound system of nomenclature should fulfil the following conditions :—

1. It should be applicable to all the types of compounds with which it has to deal.
2. The rules involved should be sufficiently simple and yet rigid, so that the name can be derived with ease from the structural formula, and for a given compound there should be only one systematic name possible.
3. From the name it should be comparatively easy to write the structural formula.

The system advocated in this paper comprises many of the rules contained in other systems, but aims at avoiding some of the unsatisfactory features of these systems. The scheme is based on the following rules :—

1. *Basal ring*.—A basal ring is selected for indicating the characteristic name, and this ring is always chosen *as large as possible*, *e.g.*, compound I is regarded as a bridged *cycloheptane* and not as a bridged *cyclohexane*; similarly, II is regarded as a bridged *cyclohexane* and not a bridged *cyclopentane*, and similarly for V and VI. In other words the bridge is always selected as short as possible and the longer chain is included in the basal ring. There are no exceptions

to this rule. The name always gives the number of carbon atoms in this basal ring,¹ e.g., *cyclononane*, *cycloheptadecane*.

2. All unions between carbon atoms of the ring, with the exception of direct union between two adjacent carbon atoms, are termed bridges. Thus in the *cyclohexane* ring the bridge may be a direct meta or para linking,² or it may be through a methene, CH₂, or substituted methene group or even by means of a chain containing two or more carbon atoms; and the carbon atoms of the ring linked up by the bridge may be in the ortho-, meta- or para-position.³ No attempt is made to indicate the total number of rings formed by such bridges, as it is much simpler to indicate the number of bridges than the number of rings formed. A capital B is used to denote the presence of a bridge, and if several are present a *large* Arabic numeral is prefixed to the B in order to indicate the number of bridges.

3. *Types of bridges—*

(a) Direct or diagonal linking. The simplest type of bridge is a direct or plain linking of the two carbon atoms concerned, and such a bridge is indicated in the name for the compound by giving, immediately after the capital B, the numbers of the two carbon atoms so linked. If the direct linking is an olefine linking, this is regarded as a single bridge and the lower number is repeated twice.

(b) Bridges containing one or more carbon atoms. A bridge formed by a methene, substituted methene or polymethene group may be regarded as a bivalent substituent. If the two ends of the bridge chain terminate at the same carbon atom of the ring the substance is a spiro compound and these are referred to later.⁴ As a rule the two ends of the bridge are attached to two different carbon atoms of the ring and in the systematic name for the compound the name for the substituent is placed immediately after the capital B and is followed by the numbers of the carbon atoms which form the bridge, including the numbers of the ring carbon atoms and also of the carbon atoms in the bridge.

¹ When it is possible to select two basal rings both containing the same number of carbon atoms but one with a substituent or an olefine linking, the ring containing the olefine linking or substituent is selected and an olefine linking is given precedence (cf. vii, p. 147.)

² Logically an additional linking between adjacent carbon atoms is a 1:2-bridge, but as there is already a well known system of nomenclature for olefine linkings in cyclic compounds, the 1:2-bridge has been omitted from this scheme.

³ It should be made quite clear that any chain of carbon atoms whether normal or branching is regarded as a single bridge although it may be attached to three or more carbon atoms of the ring. The criterion is the linking of the carbon atoms in the chain. For two bridges the carbons in the bridges must not be directly united in any way.

⁴ Where it is possible to have two systems of bridges with the same basal ring, e.g., several simple bridges or one complex bridge, the latter is adopted as then the number of bridges is kept as low as possible. An example is met with on p. 161 and a second example is XLVIII, pyreneperhydryde.

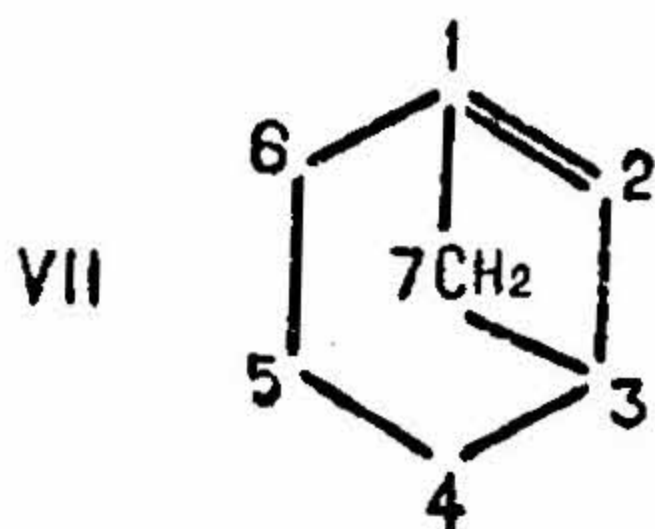
If several bridges are present these are arranged in order of increasing length or complexity. Thus a direct linking comes first, followed by a methene or substituted methene group, then chains of two carbon atoms and finally those of three.

It is necessary clearly to indicate in the name the different bridges. This may be accomplished by placing the numbers, or name and numbers, used for each bridge in brackets or separating them by well defined commas. The latter method has been adopted in order to avoid confusion with the brackets used by Baeyer for a different purpose.

The following are the bridges commonly met with in bridged compounds :—

i. Methene, $-\text{CH}_2-$, a divalent group uniting two different¹ carbon atoms of the basal ring. Various substituted methene groups are also met with, the commonest of these are methylmethene, $\text{CH}_3\cdot\text{CH}<$; dimethylmethene, $(\text{CH}_3)_2\text{C}<$; and methenone, $-\text{CO}-$.

ii. Methine, $>\text{CH}-$, a trivalent substituent uniting three carbon atoms of the ring. The methine group may also join only two carbon atoms of the ring, and in that case one of the carbon atoms will be attached to the methine by an olefine linking. In the name for such a compound the number of the carbon atom of the ring attached by an olefine linking to methine is given twice. Compound VII (p. 147) might be termed a methine-bridged *cyclohexane*; it is, however, considered advisable that, as far as possible, both substituents and olefine linkings should be placed in the ring rather than in bridges. Compound VII then becomes a methene bridged derivative of *cyclo- Δ^1 -hexene*.²

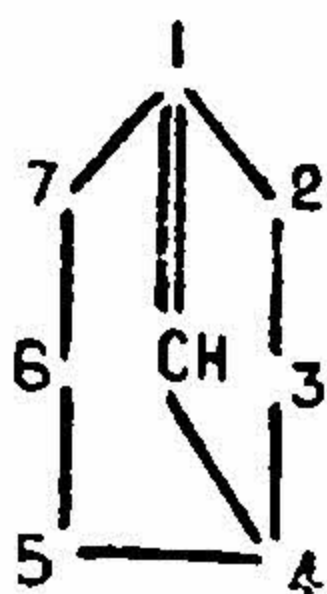


¹ If the two methene linkings are attached to the same carbon atom of the ring, the methene group is regarded as a simple substituent and is named in the usual manner, e.g.

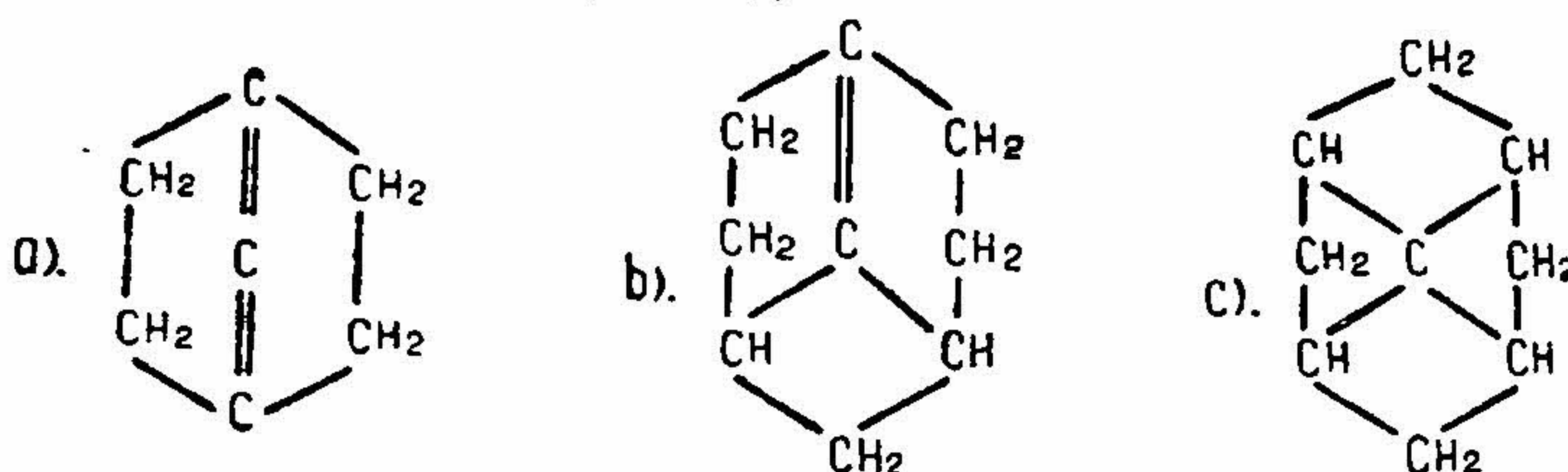
$\text{CH}_3 : \text{C} \begin{array}{l} \diagup \text{CH}_2 \cdot \text{CH}_2 \\ \diagdown \text{CH}_2 \cdot \text{CH}_2 \end{array} \text{CH} \cdot \text{CH}_3$ is 1-methyl-4-methenecyclohexane.

² Similarly compound VIII is a dimethene bridged *cyclohexadiene*.

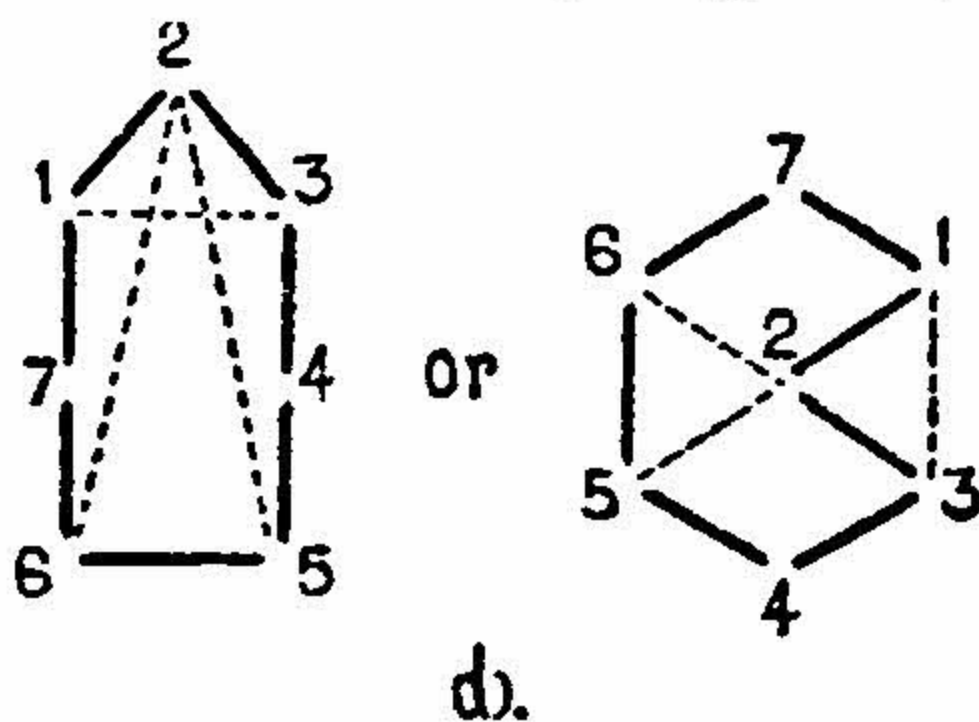
An example of a methine bridged compound is ¹



iii. Carbo, $>C<$, a quadravalent group, which can serve to attach 2, 3 or even 4 carbon atoms of the original ring. Examples are given in figures (a),² (b) and (c):—



Compound (a), i.e., a *cyclohexane* ring with a carbo attached to carbon atoms 1,2,4,5 as usually numbered has to be regarded as a three bridge-*cycloheptane*, viz., 3B-1:3, 2:5, 2:6-*cycloheptane*.



iv. Dimethene, $-CH_2-CH_2-$ and substituted dimethene groups. These are divalent groups analogous to methene. Similarly with trimethene $-CH_2-CH_2-CH_2-$.³

¹ See footnote 1, p. 147.

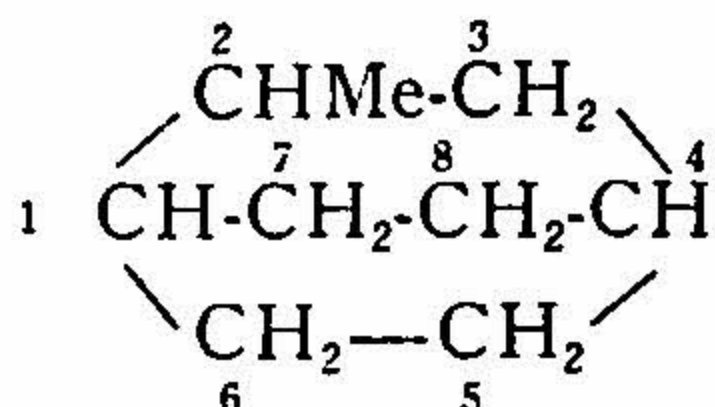
² In this case the olefine linkings must be in the bridge, as if placed in the ring this becomes reduced from a *cyclohexane* to a *cyclopentane* and rule No. 1 is not followed.

³ On the principle that the largest basal ring is always selected the bridges met with will never be very long, as of the two possible bridges the longer is always incorporated in the ring and the smaller forms the bridge. Mr. P. Ramaswami Ayyar has pointed out that if N represents the number of carbon atoms in the basal ring and n the maximum number of carbon atoms possible in a bridge then $n = \frac{N}{2} - 1$ (neglecting fractions). If attempts are made to increase n, then the bridge according to the rule, has to be incorporated in the ring and a shorter bridge selected.

In formula (a) and most subsequent formulae the basal ring is denoted by heavy lines and the bridges by dotted lines.

v. Combinations such as, $-\text{CH}_2\text{-CH}<$, methenemethine; methenecarbo, $-\text{CH}_2\text{-C}\leq$; dimethine, $>\text{CH-CH}<$ or $-\text{CH:CH-}$; dicarbo etc., and similar combinations with a three-membered bridge.

The same rule holds in all these cases that substituents and olefine linkings are placed in the ring as far as this is practicable. Examples are :—

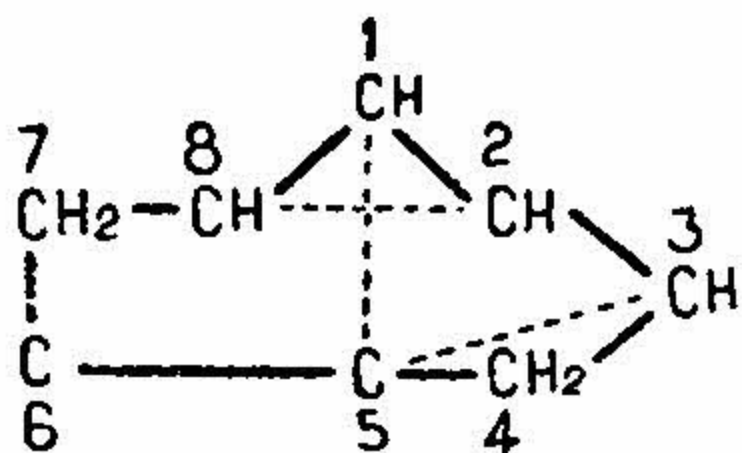


1B-dimethene-1:7:8:4,-2-methyl-cyclohexane.

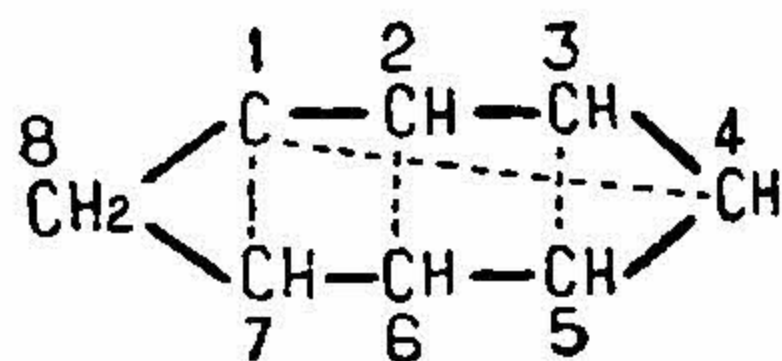
Compound VIII is 1B-dimethene-1:7:8:4,-cyclohexa- $\Delta^{2:5}$ -diene and not 1B-dicarbo-1:7:7:8:4,-cyclohex- Δ^2 -ene.

4. Numbering the carbon atoms.

(a) *Carbon atoms in the basal ring.* As already stated the carbons of the ring are numbered first and in a clockwise¹ direction. The starting point is always a tertiary, or, if possible, a quaternary carbon atom,² i.e., a carbon atom from which one or even two bridges start. When only one bridge is present the numbering is always such that the carbon atom to which the other end of the bridge is attached receives the lower of the two possible numbers, e.g., the compound represented by fig. I (page 145) is 1-B-1:3,-cyclo- not 1-B-1:6,-cycloheptane. When several bridges are present the starting point is always a tertiary or quaternary carbon atom and is so selected that the carbon atoms from which the subsequent bridges start are numbered as low as possible, e.g., XVIII (p. 152) is numbered as given in the diagram below as then the three distinct bridges start from carbons numbered 1, 2 and 3.



XVIII.



XXV.

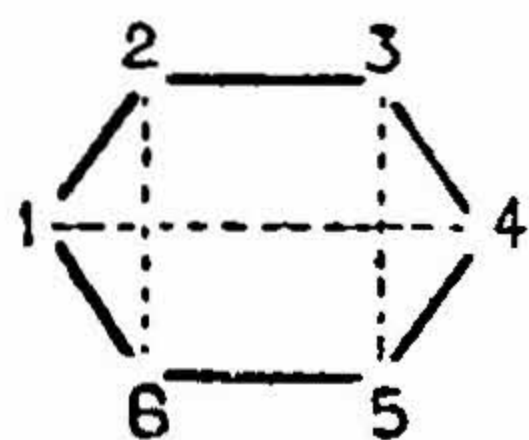
Similarly XXV is numbered as shown, as all four bridges start from the adjacent carbons numbered 1, 2 and 3, and the starting point

¹ For uniformity the numbering throughout this paper is clockwise. It is obvious that if the formulae were reversed the numbering would be anti-clockwise.

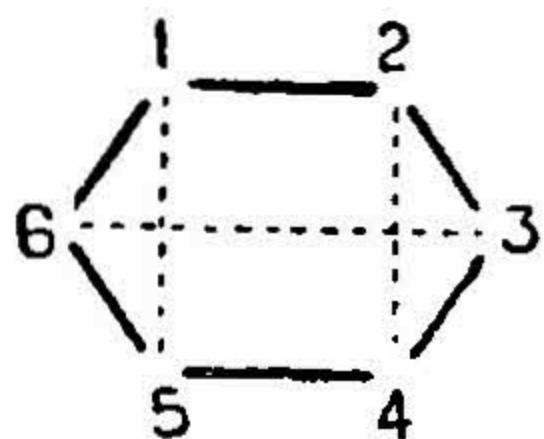
² The quaternary carbon atom formed by the replacement of the hydrogen atom attached to a tertiary carbon by an ordinary substituent is not to be confused with the quaternary carbon produced by two bridges proceeding from the same carbon atom. It is only the latter type which is referred to in this paper.

is also the only quaternary carbon present. XXVI is a similar case. In B₁₂ (Plate V) the four bridges start from carbons Nos. 1, 2, 2 and 3, No. 2 is a quaternary carbon but it is not found possible to start with this as No. 1 and get all four bridges attached to three carbon atoms with the lowest numbers.¹

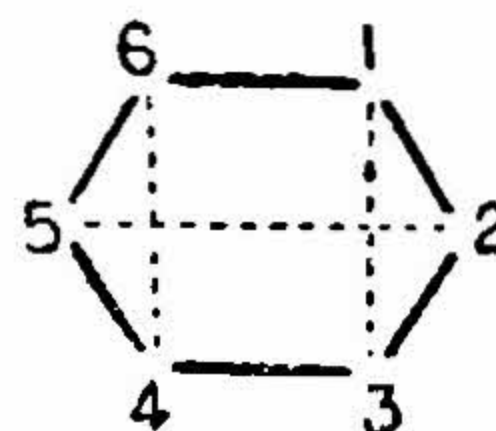
With the above rule it is sometimes possible to get two distinct systems of numbering for the same compound, e.g., XXII may be numbered as in (a) or (b)



a).



b).



c).

as in both cases the three bridges start from carbons numbered 1, 2 and 3 and the name might therefore be either 3B-1:4, 2:6, 3:5; or 3B-1:5, 2:4, 3:6, -cyclohexane. The numbering indicated in (c) is excluded as then the three bridges start from carbons numbered 1, 2 and 4.

Similarly X (p. 149) may be numbered in two different ways and be called 2B-1:3, 7:7-dimethylmethene-2:7:5, -cyclohexane or 2B-2:6, 7:7-dimethylmethene-1:7:4, -cyclohexane. D₅ (Plate VII) is also similar.

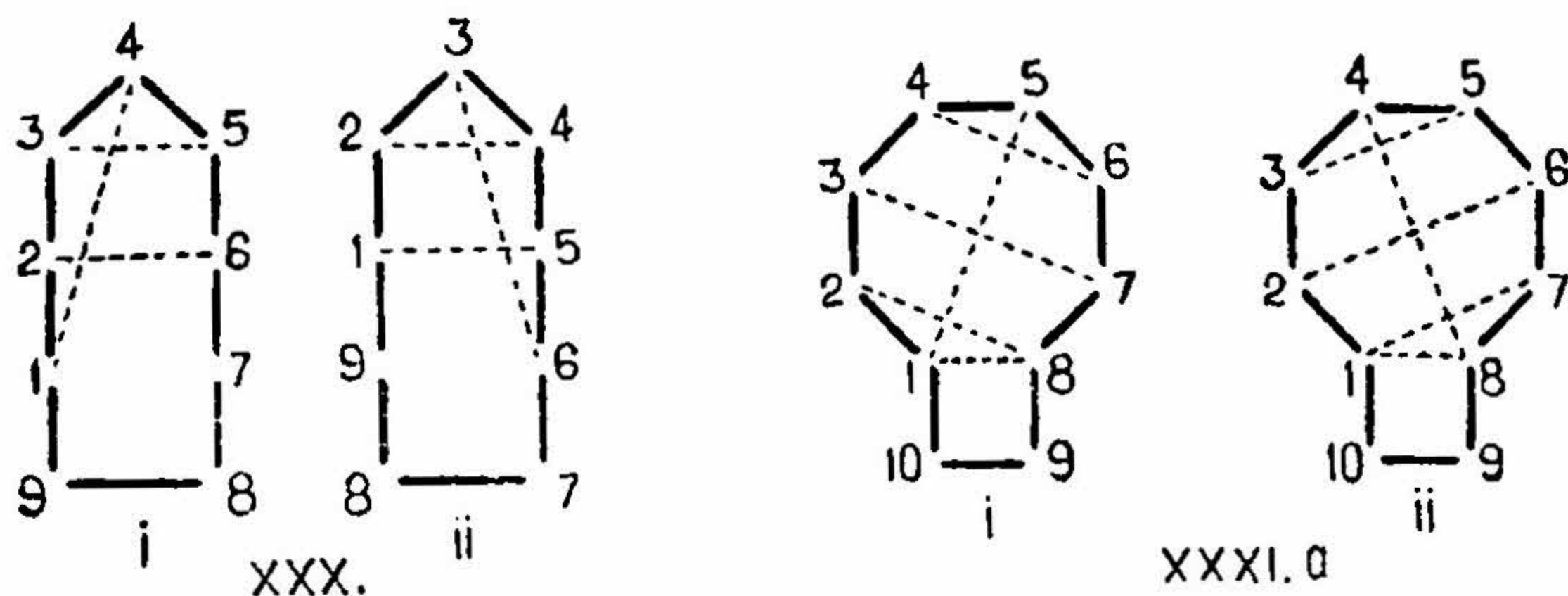
All such cases can be met by a sub-rule to the effect that when under the above main rule two or more possible systems of numbering are offered the one selected is such that the bridge proceeding from carbon atom No. 1 terminates at the carbon atom of the ring having the lower number. Thus XXII is numbered as in (a) and X is given the first of the two names mentioned.

The same sub-rule holds for the more complex cases XXX and XXXI (a).

¹ Numerous examples of this system of numbering are given in subsequent pages of this part and also in Parts II and III.

In No. XLV, the method of numbering adopted (cf. Plate II) admits of all four bridges starting from carbon atoms with numbers between one and six, whereas if No. 11 were made No. 1 the bridges would start from carbon atoms numbered one, four, five and eight. Invariably the carbon atoms from which the bridges start receive the lowest numbers possible.

If there are two methods of numbering, both of which start from atoms numbered between one and eight, but one has the numbers 1, 2, 5, 8 and the other 1, 3, 5, 8 then the former is selected. Similarly 1, 3, 5, 8 is preferred to 1, 3, 6, 8, and 1, 2, 5, 8 to 1, 3, 4, 8.



In each case the numbering (i) is selected as it gives a lower number for the termination of the bridge starting from No. 1 carbon atom.¹

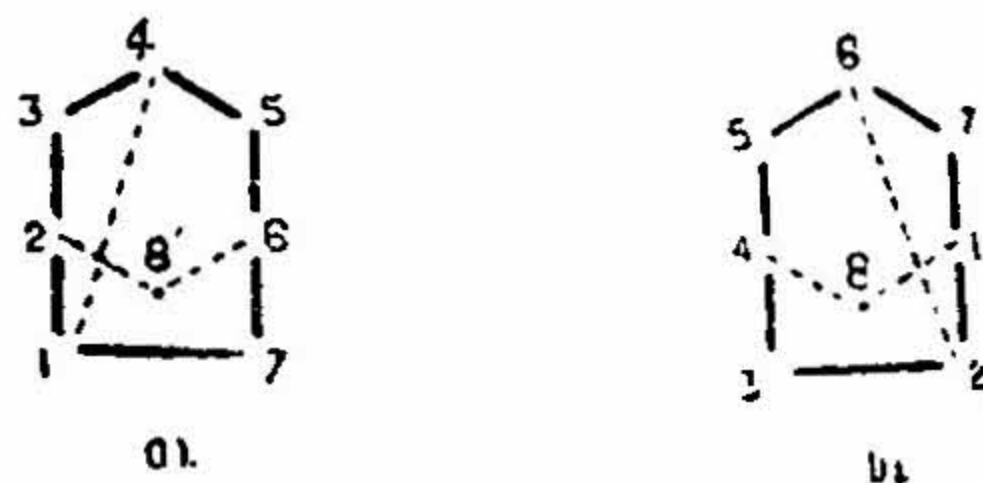
(b) *Carbon atoms in the bridges.*

The carbon atoms are numbered consecutively after the carbon atoms of the ring. Thus in a *cyclohexane* ring with several bridges but with only one carbon atom in all the bridges combined, this is numbered 7, for example figure X (page 149.)

When several bridges are present containing carbon atoms in the bridges, then the atoms in the bridge starting from carbon atom No. 1 of the ring take precedence. The length of the bridge is not considered in this connection. The system is clearly shown by reference to E₅, B₈, and B₁₂ and C₅ given on Plates IV to IX.

If it is necessary to number the carbon atoms in an alkyl group substituted in the ring, the numbering follows after the numbering of the carbon atoms in all the bridges.²

¹ In a few cases it is found that two different systems of numbering are permissible under the main rule and this sub-rule. Thus compound D 7 (Plate VII) can be numbered as indicated in (a) and (b).



Viz., (a) 2B-1:4, methene 2:8:6, -*cycloheptane*. (b) 2B-2:6, methene-1:8:4, -*cycloheptane*.

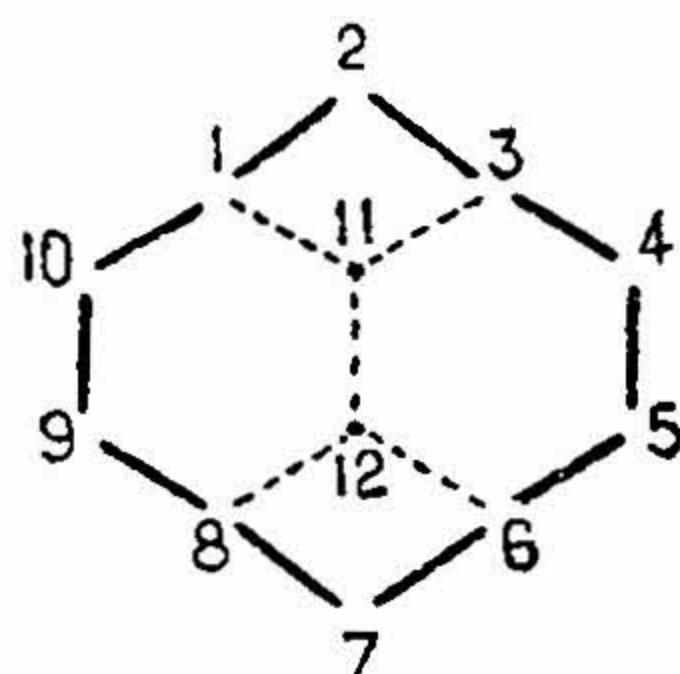
The former is selected as the bridge beginning with 1 and ending with 4 is shorter than in (b).

² The numbering is sometimes necessary in order to indicate the position of a substituent such as bromine in a side chain.

As already stated (p. 155) the systematic name gives the type of bridge and the numbers of all the carbon atoms taking part in a bridge, thus with a methene or dimethene bridge starting at 1 and terminating at 4 in a *cycloheptane* ring the bridges would be indicated as methene-1:8:4 or dimethene-1:8:9:4.

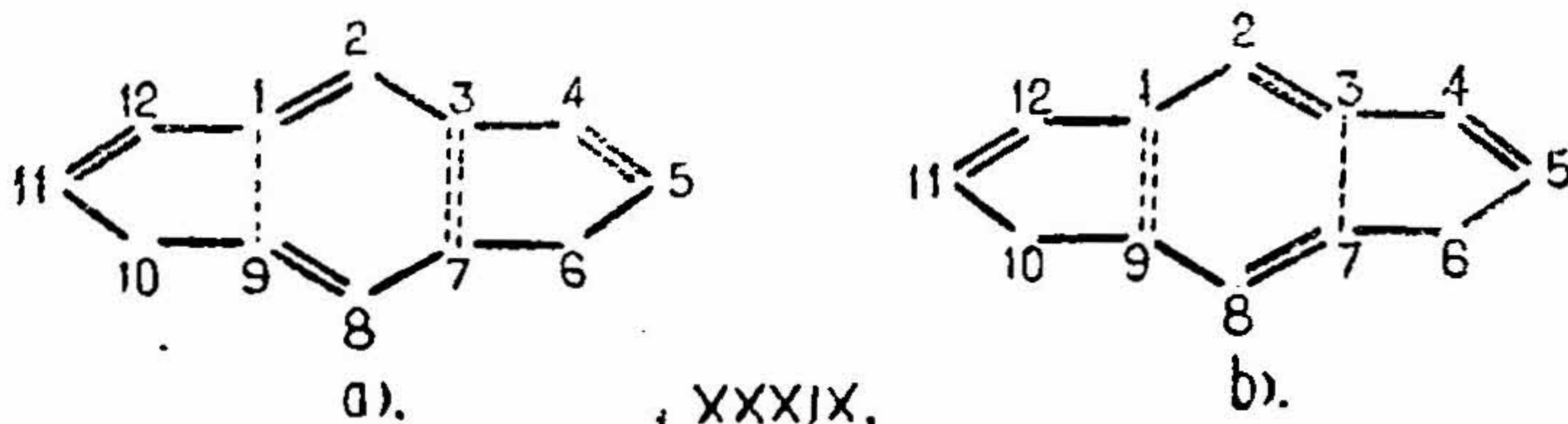
With a methine bridge the numbers are arranged in the following order:—the two lowest ring numbers to which the CH is attached, the number of the methine carbon and finally the third point of attachment to the ring. Similarly with a carbo bridge, the two lowest points of attachment to the ring, the number of the carbo-carbon atom and lastly the two highest points of attachment to the ring.

With a longer chain containing dimethene, methene and methine or methine and carbo groups the method is similar, e.g.,



for other examples see B11 and B12. (Plate V.)

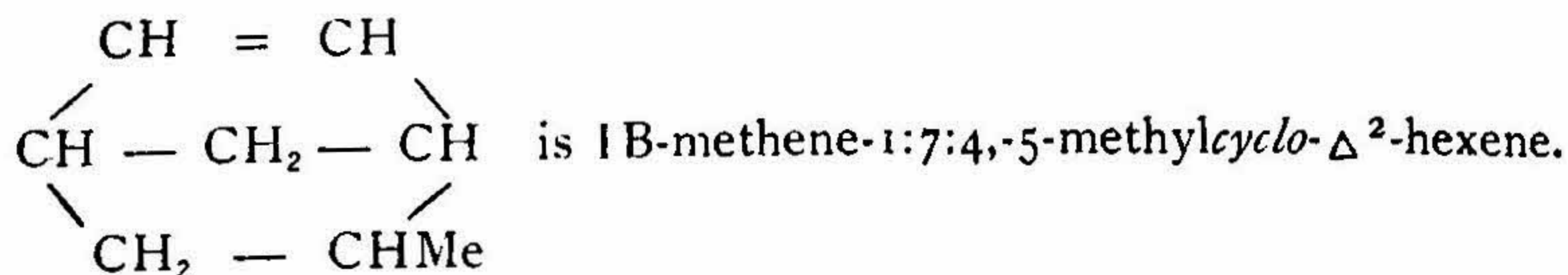
The presence of an olefine linking in a bridge and its position are denoted by the repetition of the lower of the two numbers of the carbon atoms joined by the olefine linking. In any compound where olefine linkings occur in both ring and bridges priority is given the ring linking, e.g., XXXIX



of the two modes of numbering (a) is preferred as it gives a Δ^1 -linking in the ring whereas (b) gives a Δ^2 -linking.

Substituents and olefine linkings are of importance in the case of a symmetrical parent substance. Thus in a substituted *cyclohexane* with a para-bridge—either a direct linking or a methene bridge—the

numbering would always proceed so that the olefine linking or the substituent gets the lower number and the double linking has precedence over a substituent, e.g.,



Below are given the systematic names, based on the scheme outlined above, for most of the ring compounds mentioned in the preceding pages :—

- I. 1B-1:3,-cycloheptane.
- II. 1B-methene-1:7:4,-cyclohexane.
- III. 1B-dimethene-1:7:8:4,-2:6-dimethylcyclohexane.
- IV. 1B-7:7-dimethylmethene-1:7:4,-1-methylcyclohexane.
- V. 1B-1:3,-4-methyl-1-isopropylcyclohexan-5-one.
- VI. 1B-methene-1:7:3,-2:2:4-trimethylcyclohex- Δ^4 -ene.
- VII. 1B-methene-1:7:3,-cyclohex- Δ^1 -ene.
- VIII. 1B-dimethene-1:7:8:4,-cyclohexa- $\Delta^{2:5}$ -diene.
- IX. 1B-dimethene-1:7:8:4,-cyclohexa- $\Delta^{1:4}$ -diene.
- X. 2B-3:5, methene-1:7:4,-1:2:2-trimethylcyclohexane.
- XI. 1B-methene-1:8:4,-cycloheptan-2-one.
- XII. 1B-methene-1:9:5,-cyclooctane.
- XIII. 1B-1:3,-2-ethylcyclohexane.
- XIV. 1B-1:4,-2-methylcycloheptane.
- XV. 1B-1:5,-cyclooctane.
- XVI. 2B-1:3, 2:4,-2-methylcyclohexane.
- XVII. 2B-1:3, 2:5,-4-methylcyclohexane.
- XVIII. 3B-1:5, 2:8, 3:5,-cyclooctane.
- XIX. 5B-1:6, 1:7, 2:4, 2:5, 3:8,-cyclooctane.
- XX. 2B-1:5, 2:4,-cyclooctane.
- XXI. 3B-1:4, 2:6, 3:5,-cyclooctane.
- XXII. 3B-1:4, 2:6, 3:5,-cyclohexane (cf. p. 159.)
- XXIII. Cyclopropylcyclopentane.
- XXIV. 2B-1:5, 2:4,-cyclohexane.
- XXV. 4B-1:4, 1:7, 2:6, 3:5,-cyclooctane

- XXVI. 4B-1:4, 1:6, 2:6, 3:5, -*cyclooctane*.
 XXVII. 2B-1:3, 2:5, -4-methyl*cyclooctane*.
 XXVIII. 1B-7:7-dimethylmethene-1:7:4, -1-methyl*cyclohexan-2-one*.
 XXIX. 1B-1:3, -2:2-dimethyl*cyclopentane-1-carboxylic acid*.
 XXX. 3B-1:4, 2:6, 3:5, -*cyclononane*.¹
 XXXI. 5B-1:4, 1:8, 2:8, 3:7, 4:6, -*cyclodecane*.
 XXXII. 1B-1:4, -2-methyl*cyclohex-Δ¹-ene*.
 XXXIII. 2B-1:5, 2:4, -*cyclohex-Δ¹-ene*.

In Part II will be found further examples of polycyclic and cage compounds named according to this system, and below, its application in naming a number of common compounds formed of condensed benzene and other *isocyclic* nuclei is illustrated.

<i>Common name.</i>	<i>Systematic name.</i>
XXXIV ² . Norcarane	.... 1B-1:3, - <i>cycloheptane</i> .
XXXV. Hexahydroindane	.... 1B-1:5, - <i>cyclononane</i> .
XXXVI. β-Phenylhydrindone....	1B-1:5, -3-phenyl <i>cyclonona-Δ^{5:7:9}-triene-2-one</i> . ³
XXXVII. Naphthalene	.... 1B-1:1:6, - <i>cyclodeca-Δ^{2:4:7:9}tetrene</i> .
Decahydronaphthalene...	1B-1:6, - <i>cyclodecane</i> .
Hexahydrophenheptamethylene	.... 1B-1:6, - <i>cycloundecane</i> .
Acenaphthene	.... 1B-carbo-1:4:12:8:8, - <i>cycloundeca-Δ^{4:6:9:11}-tetrene</i> .
XXXVIII. Acenaphthylene	.... 1B-carbo-1:4:12:8:8, - <i>cycloundeca-Δ^{2:4:6:9:11}-pentene</i> .
XXXIX. Indacene	.... 2B-1:9, 3:3:7, - <i>cyclododeca-Δ^{1:4:8:11}-tetrene</i> . ⁴
Dodecahydrofluorene.	2B-1:9, 2:7, - <i>cyclotridecane</i> .
XL. Fluorene	.... 2B-1:9, 2:7, - <i>cyclotrideca-Δ^{2:4:6:9:11:13}-hexene</i> .
Tetradecahydroanthracene.	2B-1:10, 3:8, - <i>cyclotetradecane</i> .

¹ Cf. p. 160.

² These numbers refer to the formulae given on Plates I and II.

³ Δ^{5:7:9} indicates that the double linkings are between carbon atoms Nos. 5 and 6, 7 and 8, and 9 and 1. As there are only 9 atoms in the ring the next one to 9 is 1.

⁴ The olefine linking in the ring has precedence over that in the bridge (cf. p. 161).

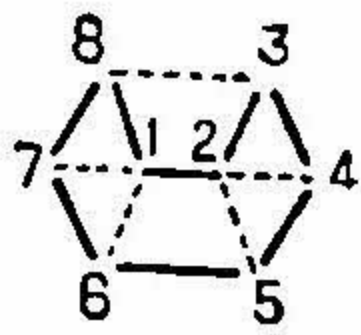
XL I. Anthracene	....	3B-1:1:10, 2:9, 3:3:8-, <i>cyclotetradeca-</i> $\Delta^{4:6:11:13}$ -tetrene.
Tetradecahydrophenanthrene.		2B-1:10, 2:7-, <i>cyclotetradecane</i> .
XL II. Octahydrofluoranthrene.		2B-1:10, methine-2:5:15:9-, <i>cyclotetradecane</i> .
XL III. Triscyclo trimethylenebenzene.		3B-1:12, 2:6, 7:11-, <i>cyclopentadeca-</i> $\Delta^{1:6:11}$ -triene.
XL IV. Dinaphanthraquinone.		4B- 1:1:18, 2:2:15, 4:4:13, 5:5:10, - <i>cyclodocosa-</i> $\Delta^{6:8:11:16:19:21}$ -hexene-3:14-dione.
XL V. Picene perhydride	....	4B-1:18, 2:15, 5:14, 6:11-, <i>cyclodocosane</i> .
XL VI. Diphensuccindone	....	3B-1:12, 2:10, 4:9-, <i>cyclohexadeca-</i> $\Delta^{4:6:8:12:14:16}$ -hexene-3:11-dione.
XL VII. Dinaphthfluorene perhydride.		4B-1:17, 2:14, 4:13, 5:10, - <i>cycloheneicosane</i> .
XL VIII. Pyrene perhydride	....	1B-dimethine-1:11:15:16:4:8-, <i>cyclotetradecane</i> . ¹
XL IX. Acenaphanthraquinone.		3B-2:2:11, 4:4:9, carbo-1:1:20:13:16, - <i>cyclononadeca-</i> $\Delta^{5:7:12:16:18}$ -pentene-3:10-dione.
L. Truxene	....	6B- 1:23, 2:2:21, 3:3:11, 5:10, 12:12:20, 14:19-, <i>cycloheptacosae-</i> $\Delta^{5:7:9:14:16:18:23:25:27}$ -nonene.
LI. 3:6'-Dihydroxymesonaphthodianthrone ²		7B-2:23, 3:3:16, 4:9, 10:15, 17:22, methenone-1:27:5, 14:28:18-, <i>cyclohexacosae-</i> $\Delta^{1:4:6:8:10:12:14:17:19:21:23:25}$ -dodecene-8:21-diol.
LII. Amphidihydroxy-dihydropyranthrene. ³		6B-2:15, 3:12, 5:10, 18:23, methinol-4:4:30:28, carbo- 1:1:29:17:25-, <i>cyclo-octacosae-</i> $\Delta^{2:5:7:9:12:14:16:18:20:22:25:27}$ -dodecen-16-ol.
LIII. Indanthrene golden orange.		6B- 1:1:24, 4:4:17, 7:7:16, 9:9:14, methine- 15:15:30:19, carbo-2:18:29:22:22, - <i>cyclo-octacosae-</i> $\Delta^{2:5:10:12:18:20:25:27}$ -octene-8:23-dione.

¹ This name is selected as it gives only one bridge, the alternative necessitates three bridges. (cf. footnote 4, p. 155.)

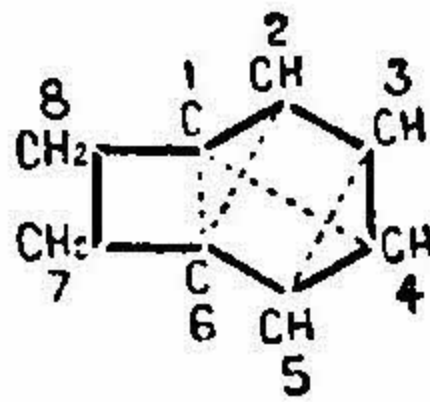
² Haller and Perkin, *J. Chem. Soc.*, 1924, 125, 233.

³ Scholl and Tanzer, *Annalen*, 1923, 433, 168.

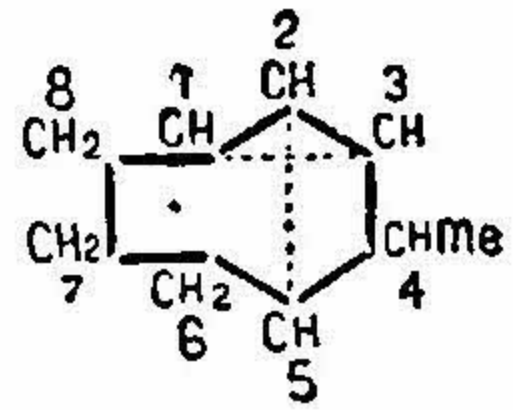
PLATE I.



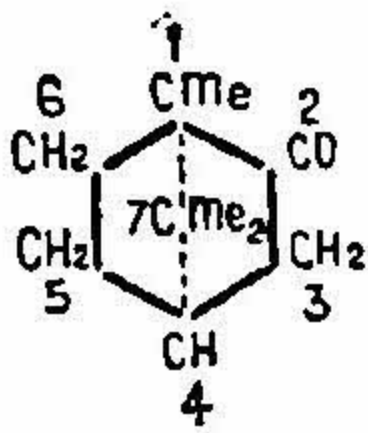
XIX.



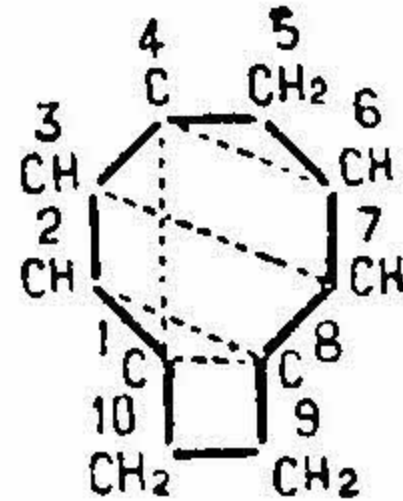
XXVI



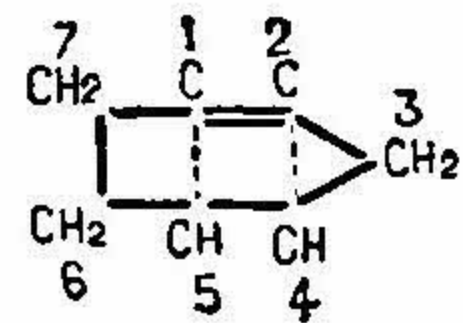
XXVII



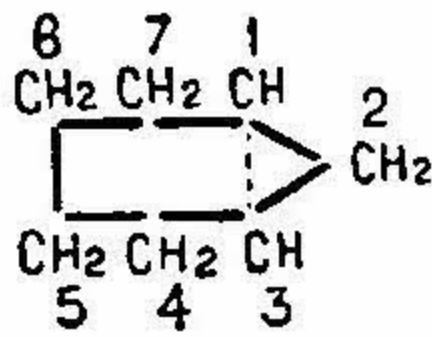
XXVIII



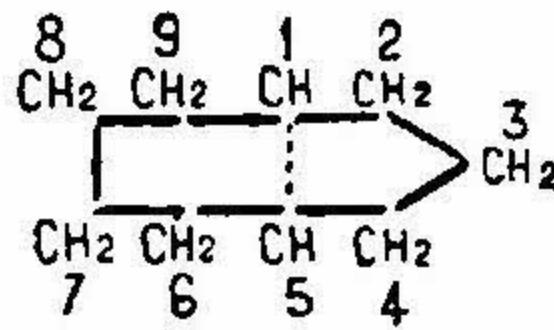
XXXI



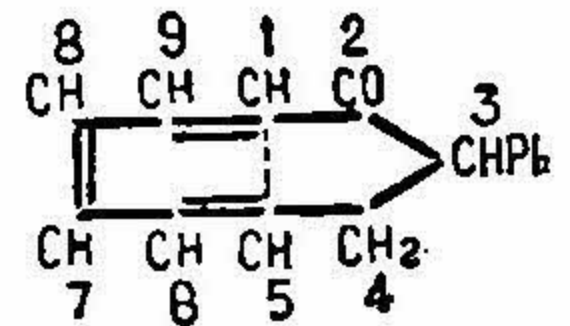
XXXIII



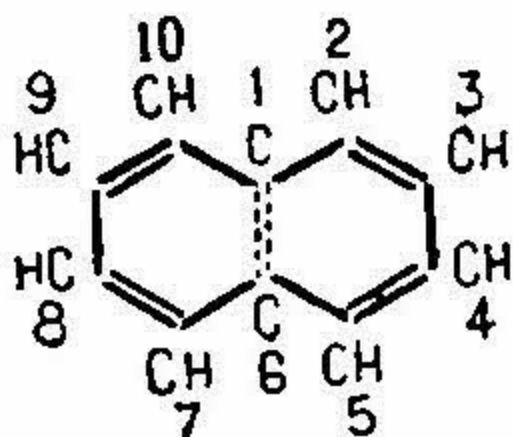
XXXIV



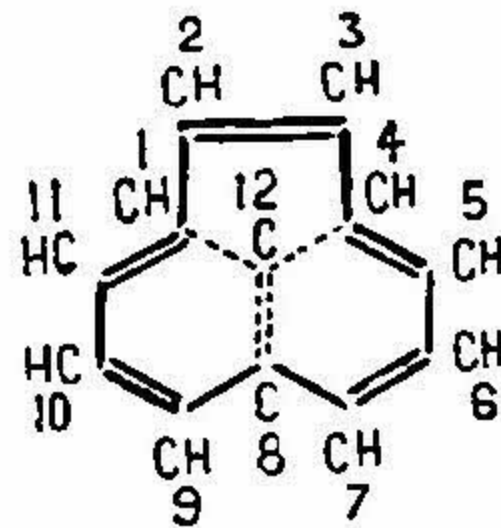
XXXV



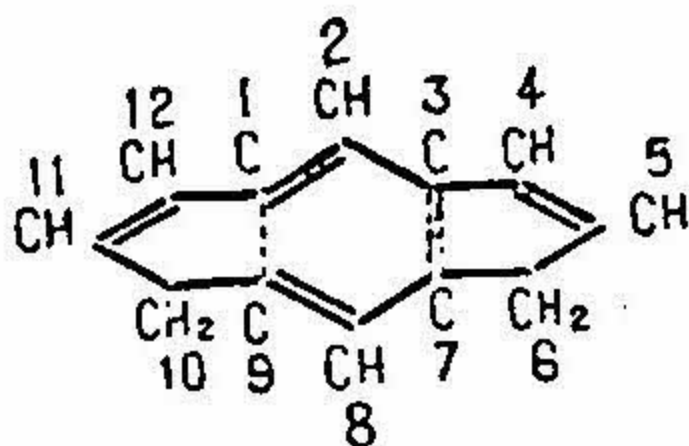
XXXVI



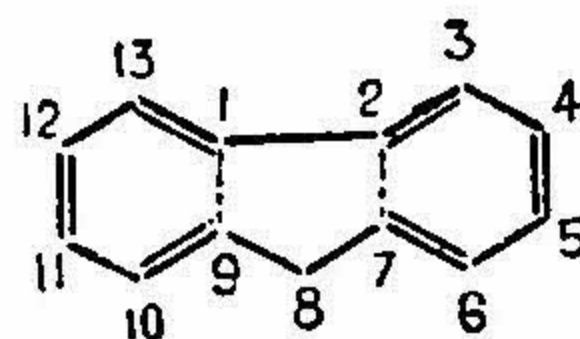
XXXVII



XXXVIII

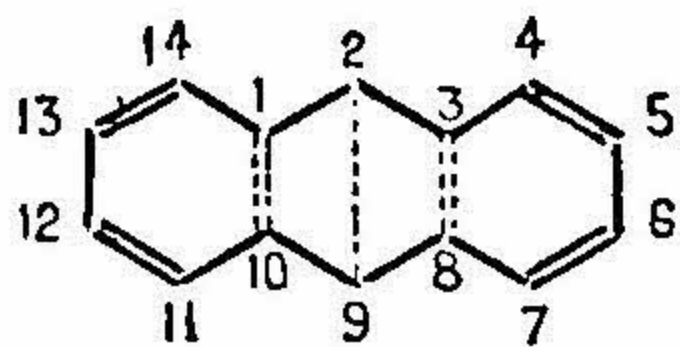


XXXIX

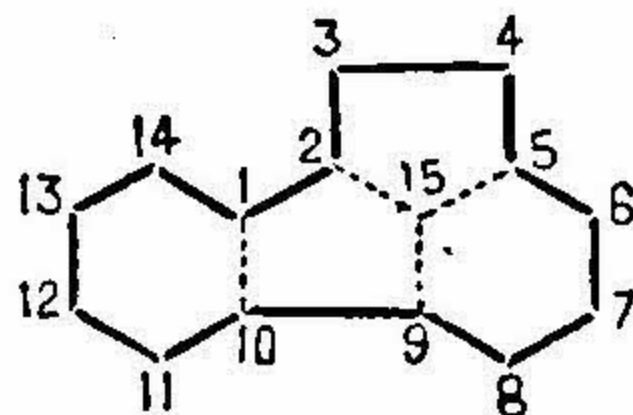


XL

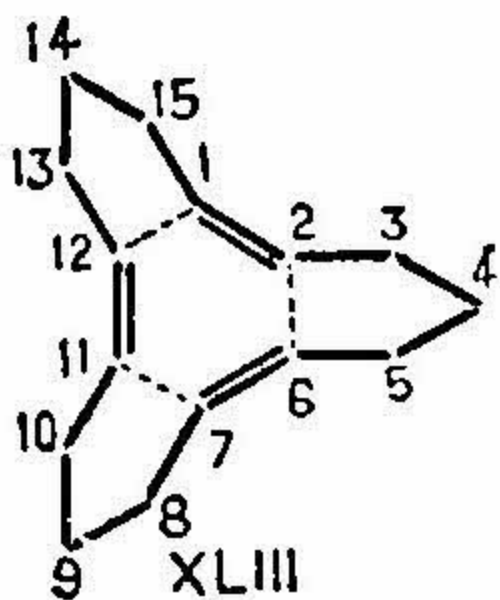
PLATE II.



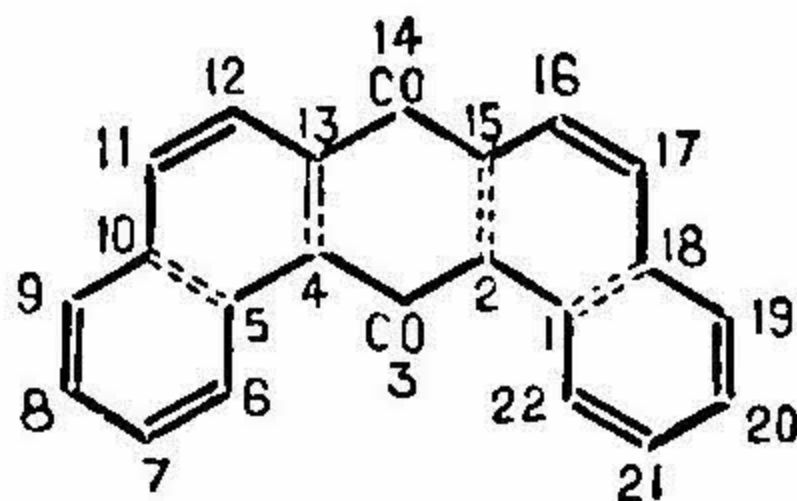
XLI



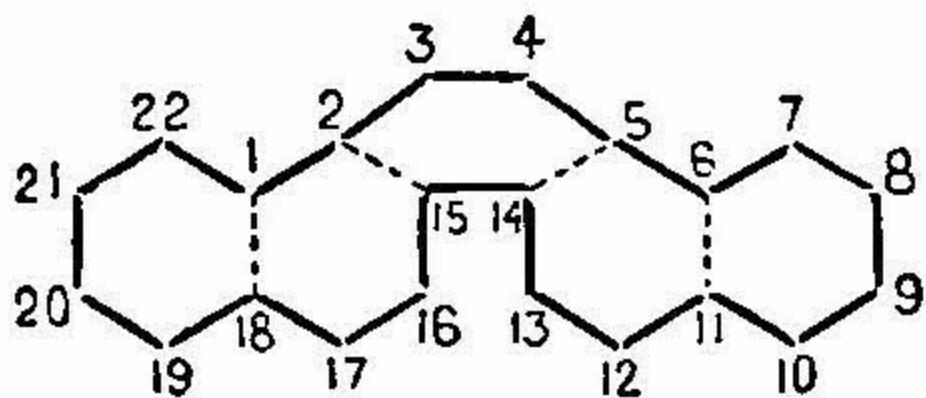
XLII



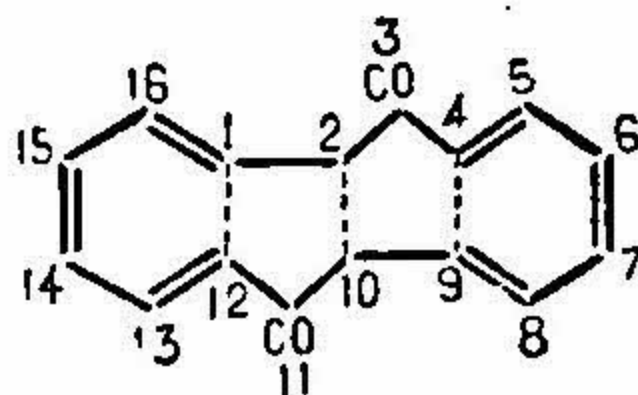
XLIII



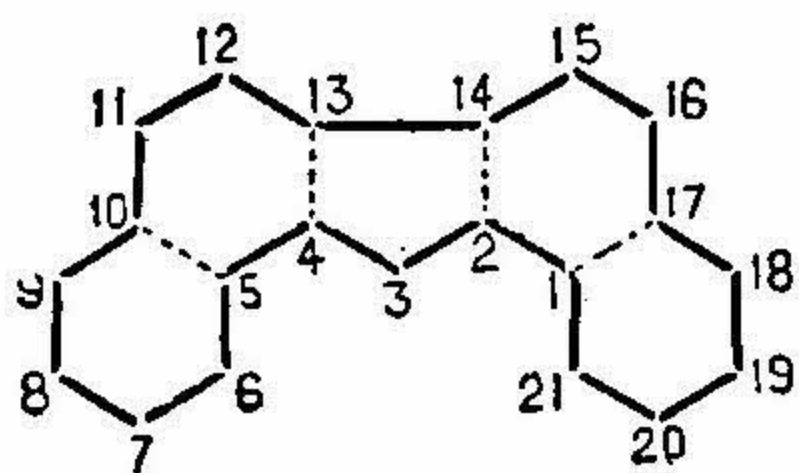
XLIV



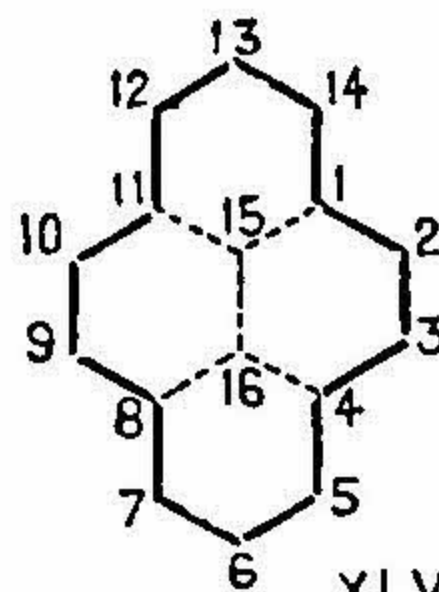
XLV



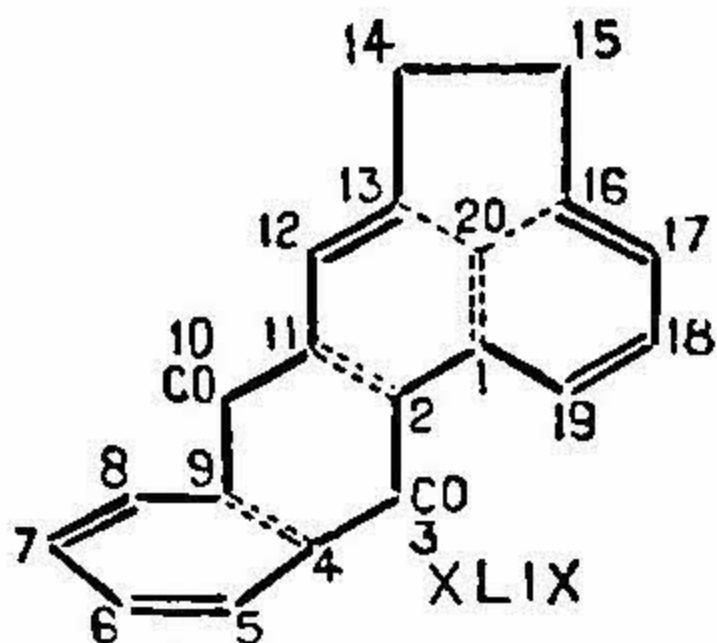
XLVI



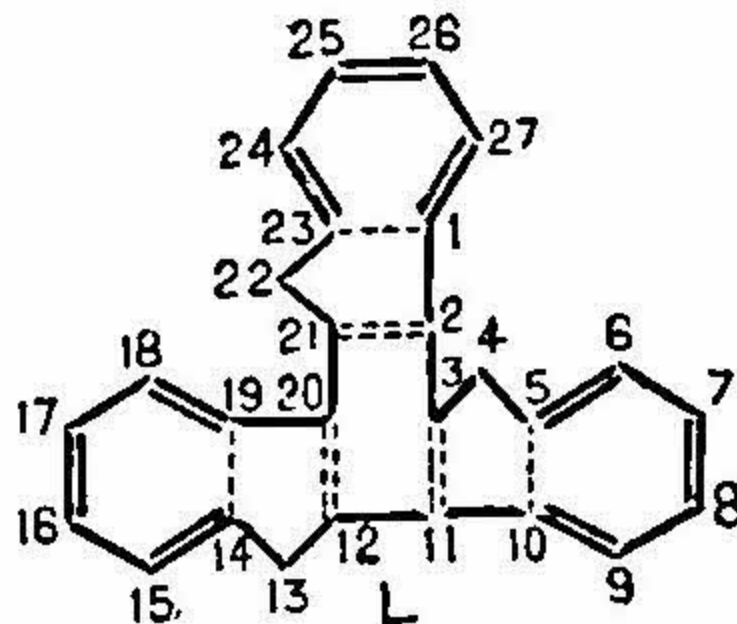
XLVII



XLVIII

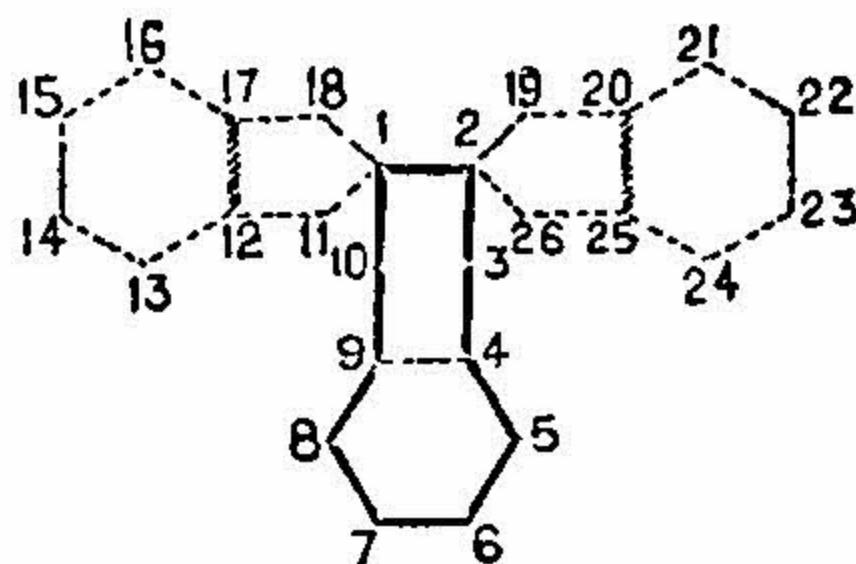
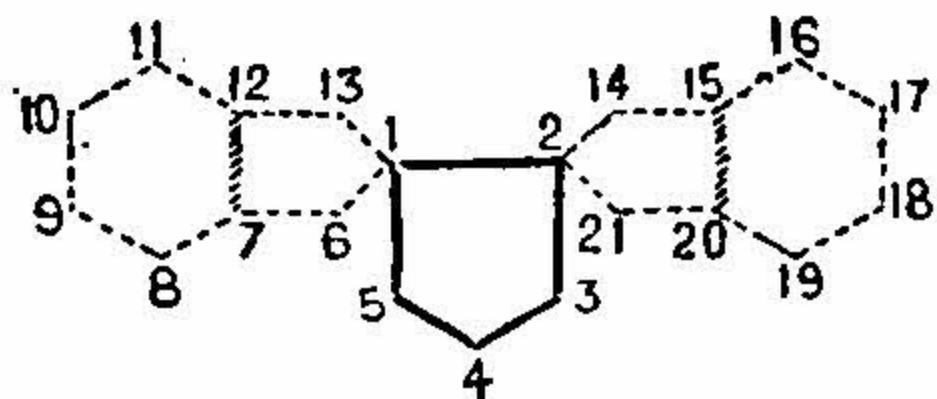
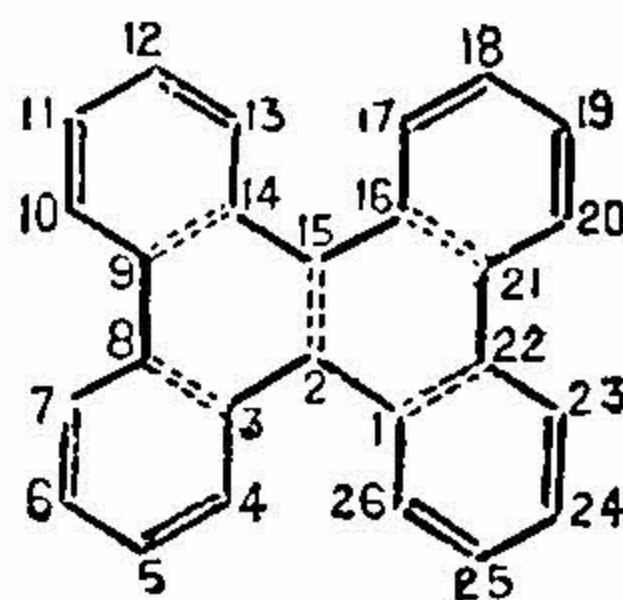
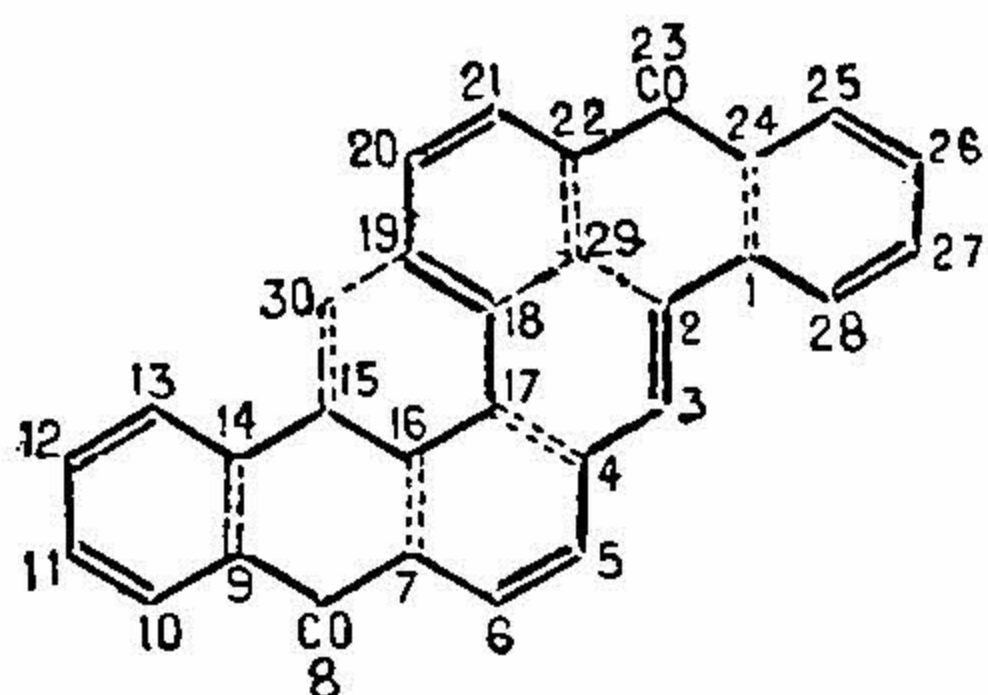
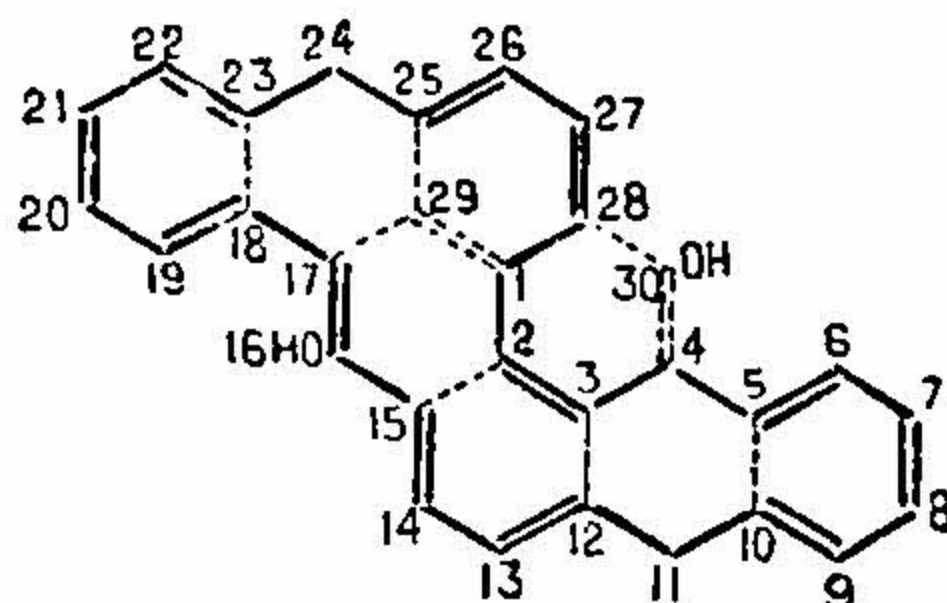
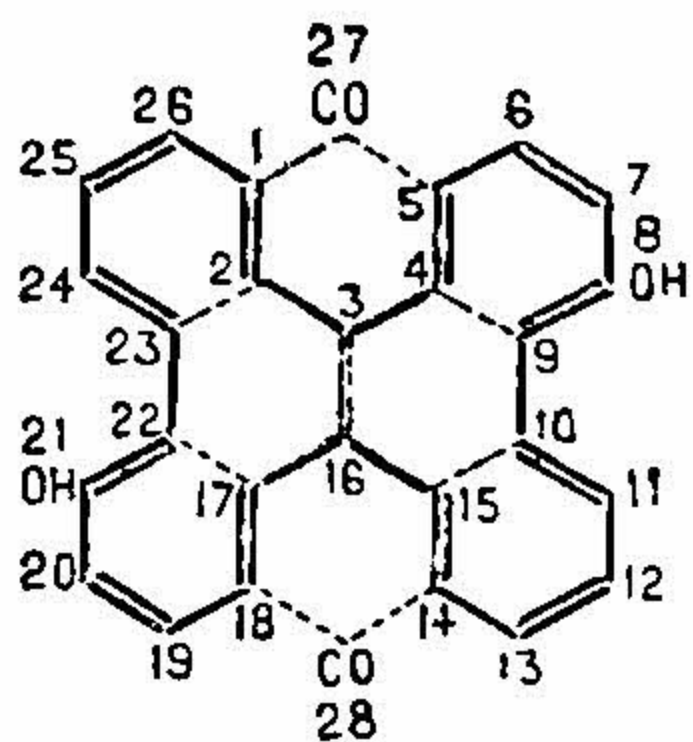


XLIX



L

PLATE III.

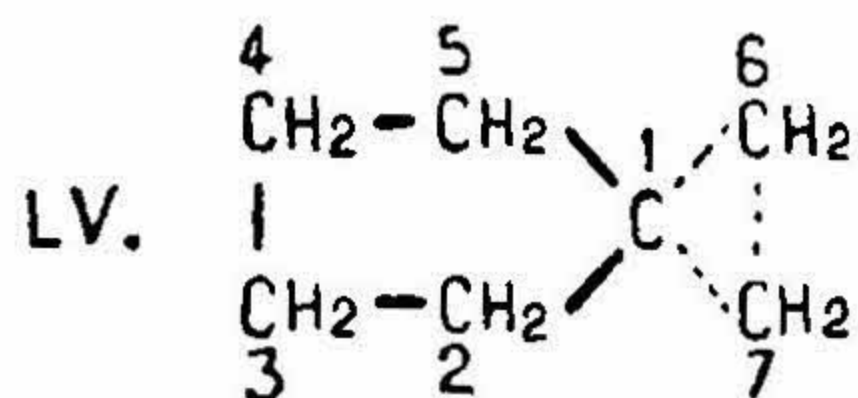


LIV. 9:10-Diphenylene-
phenanthrene.

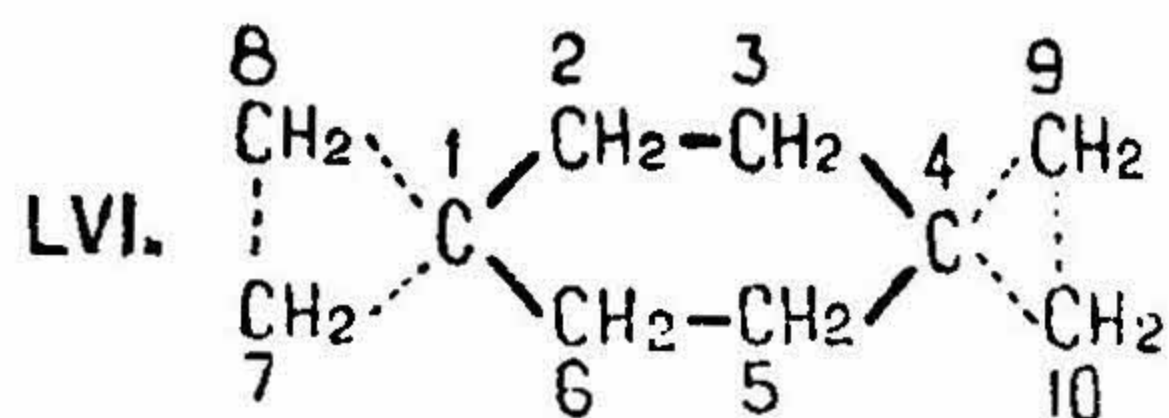
5B-1:1:22, 2:2:15, 3:3:8, 9:9:14,
16:16:21, -*cyclo*-hexacos- $\Delta^{4:6:10}$:
12:17:19:23:25-octene.

SPIRO-COMPOUNDS.

As already stated (p. 155) spiro-compounds may readily be included in this system of nomenclature. Two examples are compounds numbered LV and LVI.



1B-Dimethene-1:6:7:1,-*cyclo*-
pentane.¹



2B-Dimethene-1:7:8:1,4:9:10:4,
-*cyclo*hexane.

In both cases the larger ring is taken as the basal ring, and the smaller rings are regarded as divalent substituents with the two linkings attached to the same carbon atom of the ring.

The dispirans, LVII and LVIII, the parent substances of compounds recently prepared by Radulescu,² are interesting. In the more complex compound LVIII the largest of the three rings can still be taken as the basal ring, but in LVII it is the smallest ring, viz., the 5 membered ring which has to be taken as the basal ring, and a rule which applies generally to di- and poly-spirans is that the ring which is spiro to two or more rings must always be selected as the basal ring irrespective of the relative lengths of the rings. In each cyclic bridge a secondary bridge is present and this complicates the nomenclature.

The names would be :—

LVII. 2B- (1B-7:12) octamethene- 1:6 . . . 13:1, (1B-15:20)
octamethene- 2:14 . . . 21:2, -*cyclo*pentane.

LVIII. 3B- 4:9, (1B-12:17) octamethene-, 1:11 . . . 18:1,
(1B-20:25) octamethene- 2:19 . . . 26:2, *cyclo*decane.

In conclusion I desire to thank Dr. H. E. Watson for valuable suggestions and Mr. P. Ramaswami Ayyar for unstinted assistance in connection with correcting the manuscript.

¹ The name shows that the bridge starts and ends on the same carbon atom and hence the compound must be a spiran derivative.

² Radulescu, *Bull. Soc. Stiinta Cluj.*, 1922; 1, 335.