



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁴ : C07C 149/36, A61K 31/10		A1	(11) International Publication Number: WO 89/ 03822
			(43) International Publication Date: 5 May 1989 (05.05.89)
(21) International Application Number: PCT/GB88/00912 (22) International Filing Date: 21 October 1988 (21.10.88) (31) Priority Application Numbers: 8724799 8724800 (32) Priority Dates: 22 October 1987 (22.10.87) 22 October 1987 (22.10.87) (33) Priority Country: GB (71) Applicant (for all designated States except US): THE VICTORIA UNIVERSITY OF MANCHESTER [GB/GB]; Oxford Road, Manchester M13 9PL (GB). (72) Inventor; and (75) Inventor/Applicant (for US only) : BRUCE, John, Malcolm [GB/GB]; 9 Westward Road, Wilmslow, Cheshire SK9 5JY (GB).		(74) Agent: TUNNICLIFFE, Peter, Barry; Westfields House, 5 Vincent Drive, Lache Lane, Chester CH4 7RQ (GB). (81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BG, BJ (OAPI patent), BR, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE, DE (European patent), DK, FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US. Published With international search report.	
(54) Title: NEW COMPOUNDS OF THE ANTHRAQUINONE SERIES			
(57) Abstract			
<p>Anthralin analogues containing a thio-substituent, especially in one or more of the positions 2-, 7- and 10- of the anthralin ring. They may be made by reacting an anthralin derivative (e.g. 10-bromoanthralin) with a thiol or a compound containing a group convertible to a thio-group. Alternatively, a 1,8-dihydroxy anthraquinone containing a thio-substituent may be reduced. Reactive intermediates may be made by introducing one or more nuclear allylic groups into a 1,8-dihydroxy anthraquinone and then converting them into a reactive form, e.g. by epoxidation or halide addition. The intermediate can then be reduced to the oxidation state corresponding to anthralin. Additional products having the 10-carbon atom of the anthralin ring as part of a heterocyclic ring, may be made by anthralins containing various substitutes thioalkyl groups as the 10-substituent. The compounds are useful for treatment of psoriasis, and may be formulated in the conventional vehicles for topical application, for example petrolatum.</p>			

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TITLE: NEW COMPOUNDS OF THE ANTHRAQUINONE SERIES.

This invention relates to new compounds of the anthraquinone series which are useful in the treatment of psoriasis.

5 It has been well known for many years that the compound known as anthralin (dithranol, or 1,8-dihydroxy-9-anthrone) is useful for the topical treatment of psoriasis. While this compound is effective, however, it has the strong disadvantages of also causing staining and irritation. Staining of the skin
10 normally clears within about four weeks after treatment ceases, but the staining also affects bed linen, clothing, and equipment, and so is a major drawback in practical use in many senses, especially to out-patients.

Irritation is a major drawback which can be sufficiently
15 severe as to require treatment to be discontinued for about 10% of patients for whom anthralin therapy would otherwise be appropriate. The staining is not only objectionable to the patients, but also is difficult to remove from fabrics and bathroom fittings.

20 Accordingly, there is a great need for a treatment agent which does not have these disadvantages.

We have now found that these disadvantages can be reduced by a modification of the structure of the anthralin molecule.

Thus according to our invention we provide new organic
25 compounds, useful for the treatment of psoriasis, which are analogues of anthralin having a thio substituent in the molecule.

Alternatively, these compounds can be described as 1,8-dihydroxy-9-anthrone having a thio substituent in the molecule.

The thio substituent may be present in any position in the
30 anthralin molecule, but it is easier to establish it in some positions than in others. Thus, the positions in which it can be built into the molecule are mainly determined by the ease of providing a reactive centre through which the thio substituent can be attached, and consequently it is preferred that it be
35 attached in one or more of the positions 2, 7 and 10 in the anthralin ring system, and especially in position 10.

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The term "thio substituent" is used herein to mean a substituent containing a sulphide linkage (i.e. a C-S linkage, especially a C-S-C or a C-SH linkage) and does not include substituents in which the sulphur is in an oxidised state, as for
5 example in sulfoxides, sulphones or sulphonic acids.

Such thio substituents may take a wide variety of different forms. Most conveniently, it may be part of a larger group containing the sulphur bound in as indicated above but as a small part of the structure. This allows for adjusting the properties
10 of the molecule as a whole and, in some instances, better stability or ease of manufacture.

In general it is possible to make the products of the invention by various routes, according to the ease of obtaining the desired starting materials.

15 According to the invention we provide a method for the manufacture of analogues of anthralin having a thio substituent in the molecule, which comprises interaction between a thiol and an anthralin containing a substituent which is reactive towards the thiol to form a sulphur-containing molecular link.

20 The substituent which is reactive towards the thiol to form a thio (i.e. sulphur-containing) link may be especially in one or more of the positions 2, 7 and 10 in the anthralin ring system, and especially in the 10-position.

There are two main variants of this method. One starts from
25 the thiol and a derivative of anthralin containing a substituent which is reactive towards the thiol, so that the desired product containing a sulphide (C-S-C) bond is obtained directly. The other is to use a derivative of anthralin containing a reactive group and react this with a compound which, though not itself
30 containing a thiol group, contains a group which is convertible to a thio group.

When the reactive group is attached directly to a carbon atom of the anthralin ring system, this method is applicable to making 10-substituted anthralin derivatives, because nucleophilic
35 substitution of the anthralin ring can be made to take place most readily in the 10-position. Thus, the procedure may start from a

10-halogenated anthralin (a 10-halogenated 1,8-dihydroxy-9-anthrone). The halogen atom may be any which imparts an appropriate degree of reactivity, consistent with reasonable stability; it is preferably bromine, as in 10-bromoanthralin,
5 but other halogens may be used if desirable.

This halogen atom may then be used for reaction with either a thiol (i.e. to form a sulphide link directly) or with another compound which, though not itself containing a sulphide link can be converted by a further stage of reaction into such a compound
10 (i.e. to form a sulphide link indirectly). The reaction of the 10-halogenated anthralin with a compound containing a thiol group gives a product containing the sulphur atom attached to the 10-position of the anthralin ring.

When the sulphur-containing part of the molecule is
15 introduced by building on to reactive groups present in the substituents and is not attached directly by a C-S bond to a carbon atom of the anthralin ring system, this method may be employed regardless of the particular position the substituent occupies in the anthralin ring system. It is especially useful
20 for making products substituted in the 2-position or in the 2- and 7-positions of the anthralin ring system, but can also be used to make products substituted in the 10-position of the anthralin ring system.

The reaction may be carried out in the manner conventional
25 for the reaction of thiols with reactive halogen-containing compounds. It is particularly convenient to carry it out in the presence of a solvent, for example a halogenated hydrocarbon solvent. A very suitable and convenient solvent is dichloromethane, especially as this is a good solvent for 10-
30 bromo-anthralin. The reaction is usually carried out easily by mixing the reactants and stirring them together at ambient temperature, though the reaction may in some cases be assisted by heating.

According to the invention we also provide a method for the
35 manufacture of analogues of anthralin having a thio substituent in the molecule, which comprises reducing a 1,8-dihydroxy-9,10-

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anthraquinone which contains a thio substituent in the molecule.

The reducing agent for this purpose may be any which will reduce the 10-carbonyl group to methylene, so reducing the 9,10-anthraquinone structure to the corresponding 9-anthrone structure, without adversely affecting the rest of the molecule and especially without removing the sulphur of the thio group.

Examples of suitable reagents include tin and hydrochloric acid, aluminium and sulphuric acid, and other dissolving metal systems.

10 The method is especially applicable to the production of compounds having substituents in the 2-position or the 2- and 7-positions of the anthralin ring system, and the main step is that of introducing the substituent into the ring system.

This can be carried out very conveniently in two stages comprising:-

- (1) introducing an allylic substituent into a compound having the carbon ring system of anthraquinone, and
- (2) subjecting this allylated compound to chemical reaction which converts the allylic substituent into a thio-bearing substituent, and converting the anthraquinone ring system to the oxidation state appropriate for the anthralin system.

20 This uses the reactivity of the allylic double bond to provide the point of attachment or formation of the sulphur linkage required for the thio substituent, and the greater suitability of the hydroxyanthraquinone for the introduction of a substituent.

The sequence of the two parts of stage (2) above is most conveniently as mentioned above, to avoid carrying them out in a way which results in one stage destroying the results of a previous one.

30 This method based on allylation forms those anthralin derivatives containing at least three carbon atoms in the substituent, and having the sulphur atom of the thio group attached to a carbon atom of the side-chain.

The 2-substituted and 2,7-di-substituted 1,8-dihydroxy anthraquinones required for this process may be made by allylating a 1,8-dihydroxy 9,10-anthraquinone. This may be

achieved by treating the 1,8-dihydroxy 9,10-anthraquinone with an allylating agent.

This process results overall in allylation of the anthraquinone structure in positions adjacent to the hydroxyl substituents. The allylation reaction leads first to a product in which one or both of the 1- and 8-hydroxy groups are converted to allylic ether groups. The transfer of the allylic group from the ether oxygen to the adjacent carbon atom (the 2- and 7-carbon atoms respectively) of the anthraquinone ring structure can then be achieved by the reaction known as a reductive Claisen rearrangement.

The allylating agents which may be used for this purpose are compounds containing the carbon structure of the allyl group, i.e. $C=C-C-$. These agents have the structure $C=C-C-X$, wherein X represents a reactive atom or group, especially a halogen atom. The halogen atom may be any which imparts an appropriate degree of reactivity to the allylating agent, consistent with reasonable stability; usually it is preferably bromine, but if desired it may chlorine or iodine.

The simplest allylating agent compound is an allyl halide, for example allyl bromide. Substituted derivatives of the simple allyl compounds can also be used, for example those wherein one or more of the valence positions in the allylic group ($C=C-C-$) are hydrocarbon groups. Examples of these include methallyl halides, which have the structure $CH_2=CH(CH_3)-CH_2-Halogen$.

The reaction conditions for the allylation are those conventional for ether formation from phenolic hydroxy compounds, for example reaction between the hydroxy compound and the allylating agent in the presence of a base, and preferably also in the presence of a solvent or diluent. The reductive Claisen rearrangement, to convert the allylic ether to the derivative with the allylic substituent in the anthraquinone ring, may be carried out by treatment of the allylic ether derivative with an aqueous solution of alkaline dithionite (for example alkaline sodium dithionite).

Direct allylation of the 1,8-dihydroxy-9,10-anthraquinone

leads to a product which contains the di-ether and the mono-ether in proportions which depend upon the reaction conditions used, and the mono and di ethers may be separated if desired. This route, using an excess of allylating agent, is therefore preferred for making the 2,7-di-allylated product.

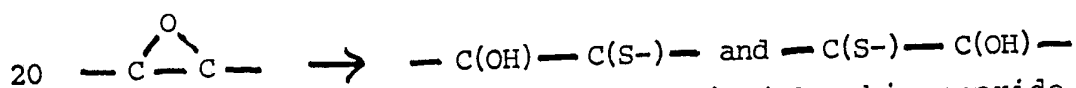
When the mono-allylated product is desired as the principal product, the preferred procedure is to allylate a 1,8-dihydroxy-anthraquinone in which one hydroxyl group is protected, for example by etherification. This protection is achieved by a group which can be removed easily after the allylation of the other hydroxyl group has been carried out. Conveniently, for example, this may be done by using a derivative of 1,8-dihydroxy anthraquinone in which one of the hydroxyls is replaced by an alkoxy group, most conveniently a methoxy group. Thus, a 2-allylated 1-hydroxy-8-alkoxy-9,10-anthraquinone required as starting material for making a 2-substituted anthralin may be made by allylating the corresponding 1-hydroxy-8-alkoxy-9,10-anthraquinone in a manner analogous to that described above for allylating a 1,8-dihydroxy-9,10-anthraquinone. The allylated product (a 2-allylated 1-hydroxy-8-alkoxy-9,10-anthraquinone) can then be de-alkylated to free the 8-hydroxy group and form a 2-allylated 1,8-di-hydroxy-9,10-anthraquinone. For this purpose, convenient de-alkylating reagents include hydrogen bromide in acetic acid, and a thiolate (especially an alkyl thiolate, for example sodium ethyl thiolate), conveniently in a dipolar aprotic solvent, for example dimethylformamide.

It is very convenient to have the reactive group situated in a larger substituent in the anthralin ring system, as this allows a greater range of structures to be formed. For example, a variety of reactive groups may be introduced by first forming an anthralin ring structure containing an allylic substituent, and then using this allylic substituent to form the desired reactive group. An example of this is the treatment of the compound containing the allylic group with a reagent which converts the ethylenic double bond into a group reactive towards thiols.

In particular, the ethylenic double bond may be reacted with

a halogen or a hydrogen halide so as to introduce a halogen atom, which can then be used to react with a thiol. This addition may be carried out in any manner known in the art, for example the hydrogen bromide addition can be carried out in solution in acetic acid. The reaction with hydrogen bromide is especially convenient as it can be carried out on a 2-allylated 1-hydroxy-8-alkoxy-9,10-anthraquinone (mentioned above as a convenient intermediate for making a mono-allylated product) to bring about both the de-alkylation and the addition at the ethylenic double bond.

Another method is to convert the ethylenic double bond into an epoxy group (by treatment with a reagent known for this purpose) and then using this epoxy group to react with a thiol, thus forming thioether alcohols. The epoxidation can be carried out in the manner known in the art, for example by the action of per-acids. Epoxy compounds react with a thiol (RSH) to form a hydroxylated sulphide substituent, of which two isomers are obtainable - and usually a mixture of both is obtained.



Similarly, reaction of a thiol (RSH) with a bis-epoxide - for example that obtained by epoxidation of 2,7-bis-allyl 1,8-dihydroxy anthraquinone - can lead to three isomeric hydroxy-thio products.

For any of the reactions indicated above as requiring a thiol, the thiol can be any thiol. It may be for example a thiol of the formula R - SH, wherein R represents a hydrocarbon group or substituted hydrocarbon group, which may be either a saturated or unsaturated hydrocarbon group, especially an alkyl or alkenyl group or a substituted alkyl or alkenyl group. Such hydrocarbon groups may be straight-chain, branched, cyclic, and aliphatic, alicyclic or aromatic in nature. Examples include methyl, ethyl, propyl, phenyl, benzyl, allyl, methallyl, and their derivatives and analogues. Likewise, R may represent a heterocyclic group or a substituted heterocyclic group. Any of these may be substituted, for example by halogen, hydroxyl, etc..

Alternative forms of thiol are those compounds which contain the thiol group (-SH) and also further functional or reactive groups.

Examples of such compounds include:-

- 5 (a) mercapto-alkanoic acids and their esters;
 - (b) mercapto-alkanols and mercapto-phenols;
 - (c) poly-mercapto compounds, e.g. bis-mercapto alkanes;
 - (d) thiols containing a basic substituent, for example amino, alkylamino or heterocyclic substituents.
- 10 These further functional groups (amino, carboxylic, hydroxyl, etc.,) present in the molecule offer the advantage of contributing to the control or manipulation of the properties of the compound, especially its ionic character, solubility and the like, which can then contribute to its formulation and
- 15 therapeutic effectiveness. Thus, mercapto-alkanoic esters can be hydrolysed and provide an alternative route to the free carboxylic acid form, and mercapto-alkanols and mercapto-alkanoic acids (and their esters) can provide a site for further reaction. For example, a carboxylic group can be converted to the acid
- 20 halide to enhance its reactivity for binding on any further desired structural elements. Conventional reagents may be used, for example oxalyl chloride can convert a carboxylic acid group to the acid chloride.

The product may contain more than one sulphur linkage if

25 desired, for example by using a polythiol [(c) above] or by using a reactive group in the thio substituent to build in a further sulphur-containing structure, or by using a bis-allylated derivative and developing both allylic groups into thio substituents. Similarly, the molecule may contain more than one

30 anthralin ring system, as for example by linking two (or more) anthralin rings by way of a thio linkage, or by linking two (or more) anthralin rings each containing the desired thio substituents.

An especially desirable form of thio substituent is one

35 which contains latent basic properties, i.e. the ability to liberate a base by decomposition or hydrolytic cleavage,

especially if this can occur in vivo. This is because the anthralin radical moiety is believed to be the effective agent in the therapeutic activity of anthralins, and the formation of the enolate form of the anthralin moiety is believed to be a more facile source of the corresponding anthralin radical. One example of this is the use of an amino thiol [(d) above], as the reaction to the initial formation of the anthralin derivative as a salt of the basic form, which is more stable than the free base form. Another example is a compound containing a thiocarbamate group, which can break down to liberate the thiol and also free amine (derived from the isocyanate used for preparing the thiocarbamate from the corresponding thiol). The amine, by producing basic conditions, can thus provide a built-in source of basic activation for the anthralin moiety. A thiocarbamate may be made by treating a compound containing a free thiol group with an isocyanate.

According to a further feature of our invention we provide new organic compounds, useful for the treatment of psoriasis, which are analogues of anthralin containing a structure at the 10-position of the anthralin ring system which locks the structure of the molecule in the non-enolic form and does not permit isomerisation to the enolic form.

Especially, such compounds contain the sulphur atom of the thio-substituent attached to the 10-carbon atom of the anthralin ring, as part of a heterocyclic ring.

This fixation of the molecular structure can be achieved by forming a "spiro" derivative in which the 10-carbon atom of the anthralin ring system becomes part of a heterocyclic ring by utilising both valencies of the 10-carbon atom which are not taken up in the anthralin ring formation.

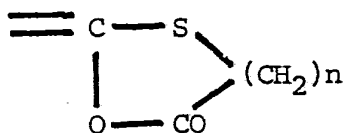
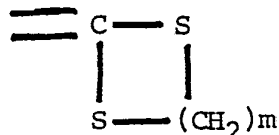
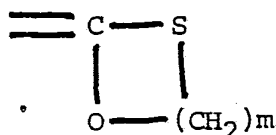
Such new compounds can be made by oxidising anthralin derivatives containing one hydrogen atom and a substituent R at the 10-position of the anthralin ring system, wherein R represents a substituent which can cyclise back on to the 10-carbon atom to form a stable ring system incorporating the 10-carbon atom of the anthralin structure.

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Examples of the substituent R include:-

- S - (CH₂)_n - CH₂OH, - S - (CH₂)_n - CH₂SH and
- S - (CH₂)_n - COOH.

By oxidation, the compounds containing these substituents
5 cyclise to form ring systems, as follows:-



wherein n represent an integer (for example 2) and m represents
15 an integer equal to n + 1.

These compounds contain a sulphur atom attached to the 10-carbon of the anthralin ring system.

The thiol, as required for the purposes of this process, is a compound of the structure HS-X-Y, wherein Y represents a
20 reactive group capable of effecting the desired ring closure and X represents a divalent linking group.

The reactive group Y may conveniently be a hydroxymethyl group (CH₂OH), a mercapto group (SH) or a carboxylic group (COOH) or a functional derivative thereof.

25 Examples of such compounds include:-

- (a) mercapto-alkanoic acids and their esters;
- (b) mercapto-alkanols;
- (c) poly-mercapto compounds, e.g. bis-mercapto alkanes.

The linking group X should be one which facilitates the
30 formation of the desired second ring system, and is preferably a polymethylene group, for example an ethylene or a trimethylene group.

The oxidising agent may be one which acts by single electron transfer, and may be an organic oxidant, for example a quinone
35 (especially 2,3-dichloro-5,6-dicyano-1,4-benzoquinone) or an inorganic oxidant for example tetravalent cerium (Ce^{IV}).

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The compounds required for use as starting materials for this process may be made by interaction between a thiol (as defined above) and an anthralin containing a substituent in the 10-position which is reactive towards the thiol to form a sulphur-containing molecular link.

Thus, the procedure may start from a 10-halogenated anthralin (a 10-halogenated 1,8-dihydroxy-9-anthrone). The halogen atom may be any which imparts an appropriate degree of reactivity, consistent with reasonable stability; it is preferably bromine, but other halogens may be used if desired.

The reaction may be carried out in the manner conventional for the reaction of thiols with reactive halogen-containing compounds. It is particularly convenient to carry it out in the presence of a solvent, for example a halogenated hydrocarbon solvent. A very suitable and convenient solvent is dichloromethane, especially as this is a good solvent for 10-bromo-anthralin. The reaction is usually carried out easily by mixing the reactants and stirring them together at ambient temperature.

In use, the compounds of the invention may be formulated most conveniently in any form which is appropriate for topical application, for example into ointment form, for example in petrolatum -- alone or in conjunction with adjuvants which enhance their stability or assist their absorption into skin tissue.

The invention is illustrated but not limited by the following Examples in which the parts and percentages are by weight unless otherwise stated.

EXAMPLE 1.

Preparation of 1,8-Dihydroxy-10-Phenylthio-9-Anthrone.

10-Bromo-1,8-dihydroxy-9-anthrone (3.05 g) was dissolved in dichloromethane (100 ml) and thiophenol (1.1 ml) was added. The red-brown solution became yellow-green, and was then left, with stirring, at room temperature for 5 hours. Removal of the solvent gave a yellow solid which, after recrystallisation from a hexane/chloroform mixture (10:1), afforded 1,8-dihydroxy-10-

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phenylthio-9-anthrone (2.89 g, 87%) as pale yellow needles, melting point 156-157°C. (Found: C 71.8, H 4.2, S 9.95;

$C_{20}H_{14}O_3S$ requires C 71.85, H 4.2, S 9.6%.)

Physical properties measured:-

- 5 δ ($CDCl_3$, 220 MHz) 5.43 (s, H-10); 6.75 (dd, $J_1=7.5$, $J_2=1.5$, H-2' + H-6'), 6.90 (d, $J=7.5$, H-2 + H-7), 7.02 (d, $J=7$, H-4 + H-5), 7.13 (t, $J=7$, H-3' + H-5'), 7.34 (bt, $J=7$, H-4'), 7.51 (t, $J=7$, H-3 + H-6), 11.83 (s, 1-OH + 8-OH);
- 10 ν max. (film), 1629s, 1598vs, 1483m, 1448m, 1273vs, 1215s, 750vs cm^{-1} ; and
- m/z EI 334 (M^+ , 3.3), 333 [$(M-1)^+$, 5.1], 300 [$(M-34)^+$, 3.7], 226 [(Anthralin) $^+$, 30.7], 225 [(M-SPh) $^+$, 100], 198 [(Anthralin-CO) $^+$, 7.3], 197 [$(M-SPh-CO)^+$, 38],
- 15 110 (PhSH $^+$, 14.6), 109 (PhS $^+$, 7.9).

EXAMPLE 2.

Preparation of 1,8-Dihydroxy-10-Ethylthio-9-Anthrone.

- 10-Bromo-1,8-dihydroxy-9-anthrone (3.05 g) was dissolved in 20 dichloromethane (100 ml) and ethanethiol (1 ml) was added. The solution was left stirring at room temperature for 6 hours, during which time the red-brown solution became yellow-green. Removal of the solvent gave a yellow solid which, recrystallised from hexane, gave 1,8-dihydroxy-10-ethylthio-9-anthrone (2.63 g, 25 91%) as bright yellow needles, melting point 117-118°C.

(Found: C 67.3, H 5.1, S 11.1;

$C_{16}H_{14}O_3S$ requires C 67.1, H 4.93, S 11.2%.)

Physical properties measured:-

- δ ($CDCl_3$, 220 MHz) 1.01 (t, $J=7.5$, Me),
- 30 2.21 (q, $J=7.5$, $-CH_2-$), 5.19 (s, H-10), 6.95 (d, $J=8.5$, H-2 + H-7), 7.13 (d, $J=7.8$, H-4 + H-5), 7.53 (t, $J=8$, H-3 + H-6), 12.13 (s, 1-OH + 8-OH);
- ν max. (film), 1628s, 1600vs, 1482s, 1448s, 1274vs, 1213s, 1154m, 1072m, 836sh, 752vs, 736s, 718s cm^{-1} ; and
- 35 m/z EI 286 (M^+ , 4.7), 257 [$(M-Et)^+$, 1.9], 256 [$(M-1-Et)^+$, 1.9], 226 [(Anthralin) $^+$, 64.1], 225 [$(M-SEt)^+$, 100],

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198 [(Anthralin-CO)⁺, 15.2], 197[(M-SEt-CO)⁺, 47.4],
62 (EtSH⁺, 37.9].

EXAMPLE 3.

5 Preparation of 1,8-Dihydroxy-10-Hexylthio-9-Anthrone.

10-Bromo-1,8-dihydroxy-9-anthrone (91.5 mg) was dissolved in dichloromethane (10 ml) and the solution was purged with nitrogen for 10 minutes. 1-Hexanethiol (0.05 ml) was then added and the solution was stirred at room temperature for 3 days under
10 nitrogen. Removal of the solvent gave a yellow sticky solid which was a mixture of 1,8-dihydroxy-10-hexylthio-9-anthrone, 1,8-dihydroxy-10,10-dihexylthio-9-anthrone, anthralin and tetrahydroxy-dianthrone in the ratio 13:1.5:1:1.3 respectively, from the integrals of the four different hydroxyl group
15 resonances in the nmr spectrum.

The mixture (60 mg) was separated by silica gel plc using a mixture of petroleum ether (boiling point 40-60°C) and ethyl acetate (4:1).

The first band was isolated as a yellow oil (7 mg) which may
20 be 1,8-dihydroxy-10,10-dihexylthio-9-anthrone.

Physical properties measured:-

delta (CDCl₃, 60 MHz), 0.7-1.5 [m, 2x-(CH₂)₄-CH₃],
2.0-2.3 (m, 2x-SCH₂-), 6.27 (dd, $\underline{J}_1=8$, $\underline{J}_2=1.5$, H-2 + H-7 or
H-4 + H-5), 7.5 (t, $\underline{J}=8$, H-3 + H-6), 7.77 (dd, $\underline{J}_1=8$, $\underline{J}_2=1.5$,
25 H-4 + H-5 or H-2 + H-7), 12.38 (s, 1-OH + 8-OH); and
 $\underline{m}/\underline{z}$ EI 458 (M⁺, very small), 341 [(M-S(C₆H₁₃))⁺, 56.3],
257(66.5), 256[(M-SC₆H₁₃)⁺, 26.4], 226 [(Anthralin)⁺, 24],
225 [(Anthralin-1)⁺, 80], 19.7 [(Anthralin-1-CO)⁺, 42.2],
117 [(HSC₆H₁₃)⁺, 5.6].

30 The second band was isolated and recrystallised from hexane to give the major component, 1,8-dihydroxy-10-hexylthio-9-anthrone (41 mg, 61%) as pale yellow needles, melting point 49-50°C.

(Found: C 70.4, H 6.7, S 9.3;

35 C₂₀H₂₂O₃S requires C 70.1, H 6.5, S 9.35%).

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Physical properties measured:-

delta (CDCl₃, 220 MHz) 0.79 (t, \underline{J} =7, CH₃),1-1.35 [m, -(CH₂)₄-], 2.14 (t, \underline{J} =7, -SCH₂-), 5.17 (s, H-10),6.93 (d, \underline{J} =8.3, H-2 + H-7), 7.12 (d, \underline{J} =7.5, H-4 + H-5),5 7.53 (t, \underline{J} =8, H-3 + H-6), 12.14 (s, 1-OH + 8-OH);

nu max. (film), 2956m, 2926s, 2855m, 1632s, 1613vs, 1600vs,

1485s, 1448vs, 1293s, 1279vs, 1221s, 1185m, 1073w, 921w,

838sh, 744s cm⁻¹; and $\underline{m}/\underline{z}$ EI 342 (\underline{M}^+ , 1.3), 341 [$(\underline{M}-1)^+$, 1], 257 [$(\underline{M}-\text{C}_6\text{H}_{13})^+$, 5.5],10 256(5.5), 226 [(Anthralin)⁺, 52.3], 225 [$(\underline{M}-\text{SC}_6\text{H}_{13})^+$, 100],197 [$(\underline{M}-\text{SC}_6\text{H}_{13}-\text{CO})^+$, 68.2], 118(6.2), 117(3.4), 85(18.7),

84(12.6).

The third band was isolated to give 1,8-dihydroxy-9-anthrone
15 (5 mg) as a yellow solid.

Physical properties measured:-

delta (CDCl₃, 60 MHz) 4.24 (s, 2xH-10),

6.83 (bd, H-2 + H-4 + H-5 + H-8), 7.45 (dd, H-3 + H-6),

12.19 (s, 1-OH + 8-OH).

20

EXAMPLE 4.

Preparation of 1,8-Dihydroxy-10-Dodecylthio-9-Anthrone.

10-Bromo-1,8-dihydroxy-9-anthrone (75 mg) was dissolved in
dichloromethane (5 ml) and 1-dodecanethiol (0.06 ml) was added.

25 The solution was stirred at room temperature for 7 hours.

Removal of the solvent gave a yellow solid which was then
recrystallised from absolute ethanol to give 1,8-dihydroxy-10-
dodecylthio-9-anthrone (89 mg, 85%) as pale yellow needles,
melting point 76°C.

30

(Found: C 73.3, H 8.2, S 7.9;

C₂₆H₃₄O₃S requires C 73.2, H 8.05, S 7.5%).

Physical properties measured:-

delta (CDCl₃, 220 MHz) 0.83 (t, \underline{J} =7, -CH₃),35 1-1.35 (m, -(CH₂)₁₀-), 2.13 (t, \underline{J} =7, -SCH₂-), 5.14 (s, H-10),6.90 (d, \underline{J} =8.3, H-2 + H-7), 7.09 (d, \underline{J} =7.5, H-4 + H-5),

- 7.49 (t, $J=8$, H-3 + H-6), 12.1 (s, 1-OH + 8-OH);
nu max. (film), 2919s, 2848s, 1629vs, 1610vs, 1601vs, 1484s,
1468s, 1448s, 1367m, 1277vs, 1217s, 1069w, 836sh, 750vs cm^{-1} ;
and
5 m/z EI 426 (M^+ , 1.8), 402(1.3), 256(3.4), 226(49.7), 225(100),
198(9.5), 197(29.1).

EXAMPLE 5.

Preparation of 10-(Carboxymethylthio)-1,8-Dihydroxy-9-Anthrone.

- 10 (a) 10-Bromo-1,8-dihydroxy-9-anthrone (305 mg) was dissolved in
dichloromethane (10 ml) and mercaptoacetic acid (0.07 ml) was
added. The solution was stirred at room temperature for 3 days,
during which time a yellow precipitate was formed, which was
filtered off and recrystallised from absolute ethanol to give 10-
15 (carboxymethylthio)-1,8-dihydroxy-9-anthrone (237 mg, 75%) as
yellow needles, melting point 151-152°C.

(Found: C 60.9, H 3.8, S 10.1%; $M=316.0410$;

$\text{C}_{16}\text{H}_{12}\text{O}_5\text{S}$ requires C 60.75, H 3.8, S 10.1%, $M=316.0405$).

Physical properties measured:-

- 20 δ (CDCl_3 , 220 MHz) 3.1 (s, $-\text{SCH}_2-$), 5.42 (s, H-10),
7.01 (d, $J=8.5$, H-2 + H-7), 7.14 (d, $J=7.5$, H-4 + H-5),
7.57 (t, $J=8$, H-3 + H-6), 12.12 (s, 1-OH + 8-OH);
nu max. (film), 2960b, 1702s, 1629sh, 1615s, 1602vs, 1481m,
1446s, 1367s, 1274vs, 1218vs, 1185s, 1071m, 919m, 834sh,
25 779sh, 728vs cm^{-1} ; and
 m/z EI 316 (M^+ , 4.1), 256(14), 241(15), 240(10.8), 238(9.7),
227(15.8), 226(100), 225(82.2), 198(16.5), 197(47.4),
169(6.6), 92(28.2).

- (b) A 5% sodium hydroxide solution (6 ml) was purged with
30 nitrogen for 10 minutes, 10-(methoxycarbonylmethylthio)-1,8-
dihydroxy-9-anthrone (60 mg) was then added. The solution was
stirred at room temperature for 10 minutes under nitrogen. The
red-brown solution was then diluted with water (10 ml) and
neutralised with 10% hydrochloric acid to form the product as a
35 pale brown precipitate, which was extracted with chloroform (15
ml). The organic layer was then washed with water and dried over

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sodium sulphate. Removal of the solvent and recrystallisation of the residue from ethanol gave 10-(carboxymethylthio)-1,8-dihydroxy-9-anthrone (41.3 mg, 72%) as yellow needles, melting point 150-152°C.

5

EXAMPLE 6.

Preparation of 10-(Carboxyethylthio)-1,8-Dihydroxy-9-Anthrone.

(a) 10-Bromo-1,8-dihydroxy-9-anthrone (305 mg) was dissolved in dichloromethane (10 ml) and 3-mercaptopropionic acid (0.09 ml) was added. The solution was stirred at room temperature for 3 days, during which time a yellow precipitate was formed. This precipitate was filtered off and recrystallised from absolute ethanol to give 10-(carboxyethylthio)-1,8-dihydroxy-9-anthrone (240 mg, 72.7%) as pale yellow needles, melting point 152-153°C.

15 (Found: C 61.5, H 4.3, S 9.8%; $M = 330.0548$;

$C_{17}H_{14}O_5S$ requires C 61.8, H 4.3, S 9.7%; $M = 330.0562$).

Physical properties measured:-

delta ($CDCl_3$, 220 MHz) 2.27 (t, $J = 7.2$, $1 \times CH_2$),
2.48 (t, $J = 7.2$, $1 \times CH_2$), 5.24 (s, H-10),
20 6.97 (d, $J = 8.2$, H-2 + H-7), 7.13 (d, $J = 7.8$, H-4 + H-5),
7.54 (t, $J = 8$, H-3 + H-6), 12.13 (s, 1-OH + 8-OH);
nu max. (film), 2933b, 1694m, 1659w, 1626s, 1598vs, 1482m,
1448m, 1412m, 1366sh, 1273s, 1214vs, 1155s, 1070m, 921w,
836sh, 755vs, 736s cm^{-1} ; and
25 m/z EI 330 (M^+ , 6.5), 256(5.8), 240(1.6), 227(7.9), 226(51.3),
225(100), 198(17.9), 197(70.6), 169(9.3), 106(27.3).

(b) A 5% sodium hydroxide solution (5 ml) was purged with nitrogen for 10 minutes, and 10-(methoxycarbonylethylthio)-1,8-dihydroxy-9-anthrone (50 mg) was then dissolved in it at room temperature under nitrogen. The red-brown solution was then immediately diluted with water (10 ml) and neutralised with 10% hydrochloric acid to form the desired acid as a pale brown precipitate. The product was then extracted with chloroform
35 (15 ml), washed with water and dried over anhydrous sodium sulphate. Removal of the solvent and recrystallisation of the

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residue from ethanol gave 10-(carboxyethylthio)-1,8-dihydroxy-9-anthrone (33 mg, 69%) as yellow needles, melting point 150-152°C.

EXAMPLE 7.

5 Preparation of 10-(Methoxycarbonylmethylthio)-1,8-Dihydroxy-9-Anthrone.

10-Bromo-1,8-dihydroxy-9-anthrone (100 mg) was dissolved in dichloromethane (7 ml) and methyl thioglycollate (0.03 ml) was added. The red-brown solution became yellow-green on addition of
10 the thiol. The solution was stirred at room temperature for 4 hours, after which time the solvent was removed to give a pale green solid (110 mg) which, by recrystallisation from hexane, gave 10-(methoxycarbonylmethylthio)-1,8-dihydroxy-9-anthrone (92 mg, 85%) as yellow needles, melting point 120-122°C (with
15 decomposition).

(Found: C 61.9, H 4.3, S 9.5%;

C₁₇H₁₄O₅S requires C 61.8, H 4.3, S 9.7%).

Physical properties measured:-

delta (CDCl₃, 220 MHz) 2.99 (s, -SCH₂-), 3.59 (s, OMe),
20 5.35 (s, H-10), 6.95 (d, \underline{J} =8.5, H-2 + H-7),
7.09 (d, \underline{J} =7.5, H-4 + H-5), 7.51 (t, \underline{J} =8, H-3 + H-6),
12.08 (s, 1-OH + 8-OH);
nu max. (film), 3040b, 1736s, 1631s, 1612vs, 1601vs, 1484s,
1448vs, 1369m, 1278w, 1222s, 1166m, 1073sh, 922w, 837sh, 741s
25 cm⁻¹; and
 $\underline{m/z}$ EI 330 (\underline{M}^+ , 10.3), 257(2.8), 256(7.6), 226(41.4), 225(100),
197(30.5), 169(3.7), 151(10.7), 106(12.3).

EXAMPLE 8.

30 Preparation of 10-(Methoxycarbonylethylthio)-1,8-Dihydroxy-9-Anthrone.

10-Bromo-1,8-dihydroxy-9-anthrone (122 mg) was dissolved in dichloromethane (8 ml) and then methyl 3-mercaptopropionate (0.05 ml) was added. The red-brown solution became yellow-green
35 immediately after addition of the thiol. The solution was stirred at room temperature for 5 hours. Removal of the solvent

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and recrystallisation of the residue from hexane gave the product (107.5 mg, 78%) as yellow needles, melting point 92-94°C (with decomposition).

(Found: C 62.9, H 4.7, S 9.4%;

5 $C_{18}H_{16}O_5S$ requires C 62.8, H 4.7, S 9.3%).

Physical properties measured:-

delta ($CDCl_3$, 220 MHz) 2.23 (t, $J=7$, $1 \times CH_2$),

2.50 (t, $J=7$, $1 \times CH_2$), 3.62 (s, OMe), 5.23 (s, H-10),

6.97 (d, $J=8.5$, H-2 + H-7), 7.13 (d, $J=7.5$, H-4 + H-5),

10 7.55 (t, $J=8$, H-3 + H-6), 12.12 (s, 1-OH + 8-OH);

nu max. (film), 2997b, 1735vs, 1629s, 1612s, 1600vs, 1483s,

1450s, 1369s, 1274vs, 1213vs, 1153m, 1073sh, 838sh, 762vs,

737s cm^{-1} ; and

m/z EI 344 (M^+ , 5.4), 257(2.5), 256(2), 226(33), 225(100),

15 198(17.3), 197(79), 169(12.2), 168(10.4), 151(36.9),

120(3.4), 119(3.8), 88(8.5), 87(12.5).

EXAMPLE 9.

Preparation of 10-(2,3-Dihydroxypropylthio)-1,8-Dihydroxy-9-

20 Anthrone.

10-Bromo-1,8-dihydroxy-9-anthrone (122 mg) was dissolved in dichloromethane (10 ml) and then 3-mercapto-1,2-propanediol (0.04 ml) was added. The solution was stirred at room temperature for 24 hours, during which time a pale yellow
25 precipitate was formed.

Removal of the solvent and recrystallisation of the residue from ethanol gave 10-(2,3-dihydroxypropylthio)-1,8-dihydroxy-9-anthrone (104 mg, 78%) as light yellow needles, melting point 154-155°C.

30 (Found: $M=332.0707$; $C_{17}H_{16}O_5S$ requires $M=332.0718$.)

Physical properties measured:-

delta ($CDCl_3$, 220 MHz) 1.45-1.90 (bs, 2'-OH + 3'-OH),

2.46 (bd, $J=5$, $2 \times H-3'$), 3.30-3.75 (m, $2 \times H-1' + H-2'$),

5.28 (s, H-10), 6.94 (d, $J=8.3$, H-2 + H-7),

35 7.13 (d, $J=7.7$, H-4 + H-5), 7.58 (t, $J=8$, H-3 + H-6),

12.1 (s, 1-OH + 8-OH);

nu max. (film), 3358b, 2921b, 1629s, 1609vs, 1600vs, 1484m, 1449s, 1278vs, 1219s, 1165m, 1073m, 1026w, 924sh, 838sh, 744s cm^{-1} ; and

$\underline{m/z}$ EI 332 (\underline{M}^+ , 1.3), 257(1), 256(2.6), 240(3), 227(15.1),
 5 226(93.3), 225(39), 198(21.4), 197(37.5), 180(8.9),
 152(15.8), 151(14.3), 77(25.6), 76(16.1), 75(18.3), 63(10.7),
 61(41), 59(54.2), 58(18.3), 57(100).

EXAMPLE 10.

10 Preparation of 10-(2-Mercaptoethylthio)-1,8-Dihydroxy-9-Anthrone.

10-Bromo-1,8-dihydroxy-9-anthrone (75 mg) was dissolved in dichloromethane (5 ml) and 1,2-ethanedithiol (0.05 ml, 1.1 equivs.) was added. The solution was stirred at room temperature for 6 hours. Removal of the solvent gave a pale green solid
 15 (80 mg) which was then recrystallised from ethanol to give 10-(2-mercaptoethylthio)-1,8-dihydroxy-9-anthrone (67 mg, 86%) as pale yellow needles, melting point 133-134°C.

(Found: C 59.7, H 4.4, S 19.6%; \underline{M} =318.0369;

$\text{C}_{16}\text{H}_{14}\text{O}_2\text{S}_2$ requires C 60.3, H 4.4, S 20.1%; \underline{M} =318.0384).

20 Physical properties measured:-

delta (CDCl_3 , 220 MHz) 1.46 (t, \underline{J} =8.2, -SH), 2.30 (dt, \underline{J}_1 =8.2, \underline{J}_2 =7.5, -CH₂SH), 2.46 (t, \underline{J} =7.5, -SCH₂-), 5.24 (s, H-10),
 6.97 (d, \underline{J} =8.5, H-2 + H-7), 7.13 (d, \underline{J} =7.8, H-4 + H-5),
 7.54 (t, \underline{J} =7.8, H-3 + H-6), 12.12 (s, 1-OH + 8-OH):

25 nu max. (film), 3031b, 2562b, 1628s, 1597vs, 1483s, 1447s, 1365m, 1274vs, 1205vs, 1158s, 1073sh, 833sh, 761vs cm^{-1} ; and
 $\underline{m/z}$ EI 308 (\underline{M}^+ , 6), 316(3.7), 288(2.9), 287(2.7), 258(1.5),
 257(3.3), 256(5.3), 227(8.3), 226(58.2), 225(100), 198(11.4),
 197(39.8), 181(2.5), 180(3), 169(5.3), 168(4.5), 152(8.3),
 30 151(15.2), 141(8.4), 61(12.7), 60(10.8), 49(19.1), 47(13.8).

EXAMPLE 11.

Preparation of 10-(2-Hydroxyethylthio)-1,8-Dihydroxy-9-Anthrone.

10-Bromo-1,8-dihydroxy-9-anthrone (100 mg) was dissolved in
 35 dichloromethane (7 ml) and 2-mercaptoethanol (0.03 ml) was added. The solution was stirred at room temperature for 7 hours, during

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which time the light brown solution became pale green. Removal of the solvent and recrystallisation of the residue from a hexane/chloroform mixture (5:1) gave 10-(2-hydroxyethylthio)-1,8-dihydroxy-9-anthrone (89 mg, 90%) as pale yellow needles, melting point 146-147°C.

(Found: C 63.1, H 4.75, S 10.7;

C₁₆H₁₄O₄S requires C 63.55, H 4.7, S 10.6%).

Physical properties measured:-

delta (CDCl₃, 220 MHz) 1.68 (bs, 2'-OH), 2.42 (t, \underline{J} =6, 1xCH₂),
10 3.38 (t, \underline{J} =6, 1xCH₂), 5.26 (s, H-10),
6.95 (d, \underline{J} =8.5, H-2 + H-7), 7.14 (d, \underline{J} =7.8, H-4 + H-5),
7.53 (t, \underline{J} =8, H-3 + H-6), 12.11 (s, 1-OH + 8-OH):
nu max. (film), 3364b, 1627s, 1598vs, 1481s, 1448s, 1365m,
1334m, 1272vs, 1214vs, 1155s, 1072s, 1026m, 922sh, 837sh,
15 804w, 752vs cm⁻¹; and
 $\underline{m/z}$ EI 302 (\underline{M}^+ , 7.4), 257(2), 256(3.1), 240(2.9), 227(6.7),
226(48), 225(100), 198(9.2), 197(35), 169(4.3), 168(3.30),
152(6.5), 151(11.7), 78(6.9), 76(6.5), 48(10.8), 47(15.6),
46(4).

20

EXAMPLE 12.

Preparation of 1,2-Bis-(1,8-Dihydroxy-9-Anthron-10-ylthio)-Ethane.

10-Bromo-1,8-dihydroxy-9-anthrone (122 mg) was dissolved in dichloromethane (10 ml) and 1,2-ethanedithiol (0.017 ml) was
25 added. The solution was stirred at room temperature for 24 hours, during which time the product precipitated out. Filtration and recrystallisation of the residue from diethyl ether gave 1,2-bis-(1,8-dihydroxy-9-anthron-10-ylthio)-ethane (113 mg, 80%) as pale yellow needles, melting point 186-187°C.

30 Physical properties measured:-

delta (CDCl₃, 300 MHz) 2.05 (s, -SCH₂CH₂S-), 5.12 (s, 2xH-10),
6.95 [d, \underline{J} =8.4, 2x(H-2 + H-7) or 2x(H-4 + H-5)],
7.03 [d, \underline{J} =7.5, 2x(H-4 + H-5) or 2x(H-2 + H-7)],
7.50 [t, \underline{J} =8, 2x(H-3 + H-6)], 12.13 (s, 2x1-OH + 2x8-OH);
35 nu max. (film), 3340b, 1625s, 1597vs, 1479s, 1447s, 1418m,
1333m, 1269vs, 1215vs, 1153s, 1069s, 921sh, 754vs, 711s cm⁻¹;

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and

m/z EI 316 [(M-Anthralin)⁺, 13], 288(10.5), 287(14.5), 256(17),
240(17), 228(6), 227(15.5), 226(100), 198(14), 197(19.5),
180(6), 152(16.5), 139(12.5), 115(12.5), 84(20.5), 76(16),
5 60(24), 59(25.5), 58(23), 57(9), 46(8.5), 45(31.5).

EXAMPLE 13.

Addition of Phenyl Isocyanate to 10-(2-Mercaptoethylthio)-8-Dihydroxy-9-Anthrone.

10 10-(2'-Mercaptoethylthio)-1,8-dihydroxy-9-anthrone (30 mg) was dissolved in dichloromethane (10 ml), and then silica gel powder (0.5 g) and phenyl isocyanate (8 drops) were added. The mixture was stirred at room temperature overnight. Filtration and removal of the solvent gave an orange yellow solid (40 mg).
15 Washing this with a hexane/chloroform mixture (1:1, 2 ml) gave N-phenyl-S-(1,8-dihydroxy-9-anthron-10-ylthioethyl)thiocarbamate (33.8 mg, 82%) as yellow needles, melting point 144-146°C. (Found: C 62.3, H 4.4, S 14.25;

$C_{23}H_{19}NO_4S_2$ requires C 63.15, H 4.4, S 14.6%).

20 Physical properties measured:-

delta (CDCl₃, 220 MHz) 2.50-2.62 (m, part of AA'BB' system³,
 $J_{AB} + J_{AB'} = 15$, 1xCH₂), 2.80-2.93 (m, part of AA'BB' system,
 $J_{BA} + J_{BA'} = 15$, 1xCH₂), 5.28 (s, H-10), 6.95 (d, $J = 8.3$,
H-2 + H-7 or H-4 + H-5), 7.02 (bs, removed with D₂O, NH),
25 7.15 (d, $J = 7.7$, H-4 + H-5 or H-2 + H-7), 7.28-7.45 (m, -Ph),
7.52 (t, $J = 7.9$, H-3 + H-6), 12.14 (s, 1-OH + 8-OH);

delta (CDCl₃, 300 MHz) 2.54-2.64 (m, $J_{AB} + J_{AB'} = 15$, 1xCH₂),
2.85-2.95 (m, $J_{BA} + J_{BA'} = 15$, 1xCH₂), 5.29 (s, H-10),
6.97 (d, $J = 8.5$, H-2 + H-7 or H-4 + H-5), 6.99 (bs, removed by
30 D₂O, NH), 7.17 (d, $J = 7.5$, H-4 + H-5 or H-2 + H-7),
7.32-7.48 (m, -Ph), 7.53 (t, $J = 8$, H-3 + H-6),
12.20 (s, 1-OH + 8-OH); and

nu max. (film), 3308b, 3040b, 1631s, 1599vs, 1535s, 1485s,
1445vs, 1369w, 1279s, 1225s, 1157s, 1074w, 881w, 837sh, 751s,
35 693sh cm⁻¹; and

m/z EI 437 (M^+ , 0.5), 318(0.8), 317(0.8), 316(4), 288(2.7),

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287(2.9), 256(11), 227(33), 226(82.5), 225(62.5), 198(38),
197(64.5), 152(34), 151(32.5), 120(49), 119(100), 93(15),
92(31), 91(87), 77(22), 65(50), 64(92), 63(67).

5 The 10-bromo-1,8-dihydroxy-9-anthrone required for the above
precedures may be made as follows:-

1,8-Dihydroxy-9-anthrone (17.3 g) was dissolved in carbon
disulphide (1.25 litre) by heating, and the solution was treated
dropwise with 18.5 g of bromine with stirring at 50°C. The
10 solution was left stirring at that temperature overnight, then
cooled to room temperature and concentrated to one tenth of its
volume by removal of the solvent under reduced pressure. The
yellow precipitate was filtered off, dried and recrystallised
from a petroleum ether (boiling point 40-60°C)/chloroform mixture
15 (1:1) to give 10-bromo-1,8-dihydroxy-9-anthrone (18.1 g, 77.5%),
melting point 149-151°C (with decomposition).

[Literature reference, O.E. Schultz and H.-H. Schultze-Mosgau,
Arch. Pharm. (Weinheim, Ger.), 1965, 298, 273, gives melting
point 148-150°C (with decomposition)].

20

EXAMPLE 14.

Preparation of 1,8-Dihydroxy-9,10-Anthracenedione-
10-Ethylenethioketal.

10-(2-Mercaptoethylthio)-1,8-dihydroxy-9-anthrone (48.7 mg)
25 was dissolved in dichloromethane (10 ml) and the solution was
purged with nitrogen for 10 minutes. 2,3-Dichloro-5,6-dicyano-
1,4-benzoquinone (34.05 mg) was then added and the solution was
stirred at room temperature for 17 hours under nitrogen, during
which time a white precipitate of 2,3-dichloro-5,6-dicyano-1,4-
30 hydroquinone was formed.

Filtration and removal of the solvent gave a dark green
solid, which was shown by pmr spectroscopy in CDCl₃ to be a
mixture (approx. 3:1) of 1,8-dihydroxy-9,10-anthracenedione-10-
ethylenethioketal (delta 12.29, 2xOH) and 1,1',8,8'-tetrahydroxy-
35 10,10'-dianthrone (delta 11.57, 4xOH). The mixture was extracted
with hot hexane (20 ml). Removal of the solvent gave a yellow

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solid (33 mg) which was then recrystallised from hexane to give 1,8-dihydroxy-9,10-anthracenedione-10-ethylenethioketal (24.8 mg, 51.5%) as yellow needles, melting point 197-199°C.

(Found: C 60.65, H 3.8, S 20.5%;

5 $C_{16}H_{12}O_3S_2$ requires C 60.7, H 3.8, S 20.3%).

Physical properties measured:-

delta ($CDCl_3$, 220 MHz) 3.74 (s, $2 \times CH_2$), 6.94 (dd, $J_1=8.2$, $J_2=1.1$, H-2 + H-7 or H-4 + H-5), 7.51 (t, $J=8.2$, H-3 + H-6), 7.72 (dd, $J_1=7.9$, $J_2=1.1$, H-4 + H-5 or H-2 + H-7),

10 12.57 (s, 1-OH + 8-OH);

nu max. (film), 2850b, 1631vs, 1596vs, 1570m, 1478s, 1441s, 1376m, 1332m, 1296s, 1274s, 1256s, 1208s, 1168m, 1156m, 1079w, 849sh, 796sh, 750vs, 718s cm^{-1} ; and

m/z EI 316 (M^+ , 100), 289(15.7), 288(64.9), 287(65.6), 271(21),

15 257(16.9), 256(78.1), 228(17.1), 226(8.3), 200(4.9), 182(5.3), 171(7.9), 139(6.3).

EXAMPLE 15.

Preparation of 1,8-Dihydroxy-9,10-Anthracenedione-10-

20 Ethylenehemithioketal.

10-(2-Hydroxyethylthio)-1,8-dihydroxy-9-anthrone (30.2 mg) was dissolved in dichloromethane (5 ml) and the solution was purged with nitrogen for 10 minutes. 2,3-Dichloro-5,6-dicyano-1,4-benzoquinone (22.7 mg) was then added and the solution was stirred at room temperature for 15 hours under nitrogen, during which time a white precipitate of 2,3-dichloro-5,6-dicyano-1,4-hydroquinone was formed.

Filtration and removal of solvent gave an orange-brown solid, which was recrystallised from hexane to give 1,8-dihydroxy-9,10-anthracenedione-10-ethylenehemithioketal (25 mg, 75%) as orange-yellow needles, melting point 165-166°C.

(Found: C 64.2, H 4.05, S 10.7%;

$C_{16}H_{12}O_4S$ requires C 64, H 4, S 10.7%).

35 Physical properties measured:-

delta ($CDCl_3$, 220 MHz) 3.37 (t, $J=5.7$, $-OCH_2-$), 4.79 (t, $J=5.7$,

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-SCH₂-), 6.96 (dd, $J_1=8.5$, $J_2=1.2$, H-2 + H-7 or H-4 + H-5),
 7.16 (dd, $J_1=8$, $J_2=1.2$, H-4 + H-5 or H-2 + H-7),
 7.52 (t, $J=8.2$, H-3 + H-6), 12.01 (s, 1-OH + 8-OH);
 nu max. (film), 3072b, 1631s, 1608vs, 1601vs, 1573m, 1476s,
 5 1445s, 1361w, 1265vs, 1215s, 1164s, 1077sh, 816m, 766m, 745m
 cm⁻¹; and
 m/z EI 300 (M⁺, 8.5), 241(16.2), 240(100), 223(5.2), 212(16.5),
 184(13.8), 155(4.2), 138(6.4).

10 EXAMPLE 16.

Cyclisation of 10-(Carboxymethylthio)-1,8-Dihydroxy-9-Anthrone.

10-(Carboxymethylthio)-1,8-dihydroxy-9-anthrone (55 mg) was
 dissolved in dichloromethane (8 ml) and the solution was purged
 with nitrogen for 10 minutes. 2,3-Dichloro-5,6-dicyano-1,4-
 15 benzoquinone (39.5 mg) was then added and the solution was
 stirred at room temperature overnight under nitrogen, during
 which time a white precipitate of 2,3-dichloro-5,6-dicyano-1,4-
 hydroquinone was formed.

The solution was filtered and the solvent was removed from
 20 the filtrate to give a brown solid, which was extracted with
 chloroform (3 ml). Filtration and removal of the solvent was
 followed by extraction of the solid with hot hexane (3 x 2 ml
 portions) to give, after crystallisation from hexane, the
 cyclised product (46 mg, 83%) as a pale brown solid, melting
 25 point 140-155°C (with decomposition).

(Found: $M=314.0276$; C₁₆H₁₀O₅S requires $M=314.0249$).

Physical properties measured:-

delta (CDCl₃, 220 MHz) 4.05 (s, CH₂), 7.02 (dd, $J_1=8.5$, $J_2=1$,
 H-2 + H-7), 7.10 (dd, $J_1=7.5$, $J_2=1$, H-4 + H-5),
 30 7.57 (t, $J=8$, H-3 + H-6), 11.98 (s, 1-OH + 8-OH);
 nu max. (film), 3583b, 2250b, 1766s, 1630s, 1599vs, 1573s,
 1445vs, 1413s, 1275vs, 1190vs, 1168vs, 1057m, 966s, 811sh,
 780sh, 723vs cm⁻¹; and
 m/z EI 314 (M⁺, 14.3), 268(11.1), 256(10.8), 242(14.4),
 35 241(100), 240(65.8), 239(7.2), 238(23.9), 228(12.2),
 212(8.7), 184(8.2).

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EXAMPLE 17.

Cyclisation of 10-(Carboxyethylthio)-1,8-Dihydroxy-9-Anthrone.

10-(Carboxyethylthio)-1,8-dihydroxy-9-anthrone (40 mg) was dissolved in dichloromethane (7 ml) and the solution was purged with nitrogen for 10 minutes. 2,3-Dichloro-5,6-dicyano-1,4-benzoquinone (27.5 mg) was then added and the solution was stirred at room temperature overnight under nitrogen, during which time a white precipitate of 2,3-dichloro-5,6-dicyano-1,4-hydroquinone was formed.

10 The solution was filtered and the solvent was removed from the filtrate to give a brown solid which, by extraction with chloroform (2 ml), filtration and removal of the solvent gave a solid which was washed with hexane (3 x 2 ml portions) to give the cyclised product (32 mg, 80%) as a pale brown solid, melting point 150-155°C (with decomposition).

Physical properties measured:-

delta (CDCl₃, 220 MHz) 2.35 (t, \underline{J} =6, 1xCH₂), 3.08 (t, \underline{J} =6, 1xCH₂), 7.01 (d, \underline{J} =8.3, H-2 + H-7 or H-4 + H-5),
20 7.06 (d, \underline{J} =8.5, H-4 + H-5 or H-2 + H-7),
7.57 (t, \underline{J} =8.3, H-3 + H-6), 11.95 (s, 1-OH + 8-OH);
nu max. (film), 2915b, 2850b, 1710s, 1670vs, 1601vs, 1574s,
1463s, 1445s, 1274vs, 1208s, 1161s, 843sh, 720vs cm⁻¹; and
 $\underline{m/z}$ EI 328 (M⁺, 2.1), 257(1.6), 256(8), 241(19.8), 240(100),
25 228(4.9), 212(7.4), 184(7.2).

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CLAIMS:-

- (1) New organic compounds, useful for the treatment of psoriasis, which are analogues of anthralin containing a thio-substituent in the molecule.
- 5 (2) New organic compounds as claimed in Claim 1 wherein the thio-substituent is in one or more of the positions 2-, 7- and 10- of the anthralin ring system, and preferably in the 10-position.
- (3) New organic compounds, as claimed in Claim 1 or Claim 2,
10 which contain a structure at the 10-position of the anthralin ring system which locks the structure of the molecule into the non-enolic form.
- (4) New organic compounds as claimed in Claim 3, wherein the
15 compound is a "spiro" derivative in which the 10-carbon atom of the anthralin ring is part of a heterocyclic ring formed by utilising both valencies of the 10-carbon atom which are not taken up in the anthralin ring system and a sulphur atom attached to the 10-carbon atom of the anthralin ring.
- (5) Process for the manufacture of a compound as claimed in
20 Claim 1 or Claim 2, which comprises reaction between a thiol and an anthralin containing a substituent which is reactive with a thiol to form a thio (i.e. sulphur-containing) linkage.
- (6) Process for the manufacture of a compound as claimed in
25 Claim 1 or 2 which comprises interacting a reactive derivative of anthralin and a compound which contains a group which is convertible to a thio-substituent, and converting that group into a thio-substituent.
- (7) Process as claimed in Claim 5 or Claim 6, wherein the
30 product is a 10-substituted anthralin, and the reaction comprises interacting a 10-halogenated anthralin (especially 10-bromoanthralin) and a thiol or a compound which contains a group which is convertible to a thio-group.
- (8) Process for the manufacture of a compound as claimed in
35 Claim 1 or Claim 2, which comprises reducing a 1,8-dihydroxy anthraquinone which contains a thio-substituent in the molecule.
- (9) Process as claimed in Claim 8 wherein the 1,8-dihydroxy

- anthraquinone which contains a thio-substituent in the molecule is made from a 1,8-dihydroxy anthraquinone containing an allylic substituent attached to a carbon of the anthraquinone ring, by converting the allylic group into a reactive form (e.g. by addition of halogen, hydrogen halide, or epoxydation), and then reacting with a thiol or a compound containing a group which is convertible to a thio-substituent, and reacting the product to convert the anthraquinone ring system into the oxidation state corresponding to the anthralin system.
- 5 (10) Process as claimed in Claim 9 wherein the 1,8-dihydroxy-anthraquinone containing an allyl substituent is made by allylating a 1,8-dihydroxy anthraquinone, whereby one or both of the hydroxy groups are converted to allylic ether groups, and the allylic substituent is then transferred to the carbon of the anthraquinone ring, for example by a reductive Claisen rearrangement.
- 15 (11) Process as claimed in Claim 9 or claim 10 wherein the 1,8 dihydroxy anthraquinone is used in a form in which one hydroxyl is protected by a group which can be removed easily after allylation of the other hydroxy group has been carried out, for example by using a 1-hydroxy-8-alkoxy anthraquinone and de-alkylating the resulting alkoxy compound.
- 20 (12) Process for the manufacture of a compound as claimed in Claim 3 or Claim 4 which comprises oxidising an anthralin derivative containing one hydrogen atom and one substituent R at the 10-position of the anthralin ring system, wherein R represents a substituent which can cyclise back on to the 10-carbon atom and form a stable ring system incorporating the 10-carbon atom of the anthralin ring structure, for example one of the substituents:-
- 30 - S - (CH₂)_n - CH₂OH, - S - (CH₂)_n - CH₂SH or
- S - (CH₂)_n - COOH.
- (13) Anthralin derivatives containing thio-substituents, substantially as described.
- 35 (14) Process for making anthralin derivatives containing thio-substituents, substantially as described.

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- (15) Pharmaceutical compositions, useful for the treatment of psoriasis, comprising comprising a thio-substituted anthralin as claimed in any one of Claims 1 to 4 and Claim 13, in conjunction with a pharmaceutically acceptable excipient.
- 5 (16) Procedure for treatment of psoriasis in which a thio-substituted anthralin is the treatment agent.

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INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 88/00912

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁴ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ⁴ : C 07 C 149/36; A 61 K 31/10											
II. FIELDS SEARCHED <div style="text-align: center; margin-top: 10px;">Minimum Documentation Searched ⁷</div> <table style="width: 100%; border: none;"> <tr> <td style="width: 30%; border: none;">Classification System</td> <td style="border: none;">Classification Symbols</td> </tr> <tr> <td style="border: none; padding-top: 10px;">IPC⁴</td> <td style="border: none; padding-top: 10px;">C 07 C 149/00</td> </tr> </table> <div style="text-align: center; margin-top: 10px; font-size: small;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸</div>			Classification System	Classification Symbols	IPC ⁴	C 07 C 149/00					
Classification System	Classification Symbols										
IPC ⁴	C 07 C 149/00										
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹ <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%; padding: 5px;">Category ⁹</th> <th style="width: 70%; padding: 5px;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 20%; padding: 5px;">Relevant to Claim No. ¹³</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;"> Synthesis, Journal of Synthetic Organic Chemistry, no. 5, May 1986, (Stuttgart, DE), M. d'Ischia et al.: "Synthesis of 10-alkylthio- and arylthio-1,8-dihydroxy-9-anthrones, a new class of anthracene derivatives of potential pharmacological interest", pages 430-431 <div style="text-align: center;">--</div> </td> <td style="text-align: center; vertical-align: top; padding: 5px;">1,2</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;"> FR, A, 2495934 (CENTRE INTERNATIONAL DE RECHERCHES DERMATOLOGIQUES CIRD) 18 June 1982 <div style="text-align: center;">-----</div> </td> <td></td> </tr> </tbody> </table>			Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	X	Synthesis, Journal of Synthetic Organic Chemistry, no. 5, May 1986, (Stuttgart, DE), M. d'Ischia et al.: "Synthesis of 10-alkylthio- and arylthio-1,8-dihydroxy-9-anthrones, a new class of anthracene derivatives of potential pharmacological interest", pages 430-431 <div style="text-align: center;">--</div>	1,2	A	FR, A, 2495934 (CENTRE INTERNATIONAL DE RECHERCHES DERMATOLOGIQUES CIRD) 18 June 1982 <div style="text-align: center;">-----</div>	
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A	FR, A, 2495934 (CENTRE INTERNATIONAL DE RECHERCHES DERMATOLOGIQUES CIRD) 18 June 1982 <div style="text-align: center;">-----</div>										
<div style="display: flex; justify-content: space-between; font-size: x-small;"> <div style="width: 45%;"> <p>* Special categories of cited documents: ¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>											
IV. CERTIFICATION <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;"> Date of the Actual Completion of the International Search 10th January 1989 International Searching Authority EUROPEAN PATENT OFFICE </td> <td style="width: 50%; border: none; vertical-align: top;"> Date of Mailing of this International Search Report 15 FEB 1989 <div style="text-align: right; font-size: large; font-weight: bold;">15 FEB 1989</div> Signature of Authorized Officer <div style="text-align: right;"> P.C.G. VAN DER PUTTEN </div> </td> </tr> </table>			Date of the Actual Completion of the International Search 10th January 1989 International Searching Authority EUROPEAN PATENT OFFICE	Date of Mailing of this International Search Report 15 FEB 1989 <div style="text-align: right; font-size: large; font-weight: bold;">15 FEB 1989</div> Signature of Authorized Officer <div style="text-align: right;"> P.C.G. VAN DER PUTTEN </div>							
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FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☒ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND ^{incompletely} / UNSEARCHABLE

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☒ Claim numbers 16, because they relate to subject matter not required to be searched by this Authority, namely:

See PCT Rule 39.1(iv)

Methods for treatment of the human or animal body by means of surgery or therapy, as well as diagnostic methods.

Please see additional sheet for further notes.

2. ☐ Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers , because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING ²

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM

PCT/ISA/210 supplementary sheet

1. The claims as drafted do not comply with the requirements of Art. 6 PCT:
 - a) They are not clear as they contain a lot of undefined concepts.
 - b) They are not concise as they are imprecise.
 - c) They are not based on the description as the description contains only a few clear and explicit examples of compounds, far less than the possibilities opened in Claim 1.
2. A search as defined in Art. 15.3 PCT is impossible. However, a search restricted to the compounds of examples 1 to 12 was made. The compounds of examples 13 to 17 are not always defined conversion products of the former. They probably form other subjects, not necessarily covered by the claims.
3. Unity in the claims cannot be evaluated at this moment, as their scope is not clear. However as a few of the compounds are not novel and as several apparently obvious preparation methods are claimed, several subjects dealing with these obvious processes can be discerned. They were considered as unimportant and therefore no objections are made.
4. Claims 13 and 14 do not comply with PCT Rule 6.2(a).

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.**

GB 8800912

SA 24973

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 03/02/89
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR-A- 2495934	18-06-82	BE-A- 891467	14-06-82
		GB-A, B 2091999	11-08-82
		NL-A- 8105618	01-07-82
		DE-A, C 3149528	19-08-82
		SE-A- 8107468	16-06-82
		JP-A- 57163311	07-10-82
		US-A- 4405615	20-09-83
		CA-A- 1186228	30-04-85
		CH-B- 649708	14-06-85
		SE-B- 453961	21-03-88
