# APPENDIX-I

Appendix -I

## COMMON OR TRADE NAMES, CHEMICAL DESIGNATIONS AND OTHER PROPERTIES OF SOME ORGANOPHOSPHOROUS PESTICIDES.

### CONTACT INSECTICIDES

| Common or trade name, Chemical name and Chemical designations. | Physical and biological properties. |
|---|---|
| **A. PHOSPHATES** | |
| 1. Dichloroves, DDVP, Vapona (R), Nuvan (Shell Oil Co.) $(CH_3O)_2$ P(O)-OCH = $CCl_2$ O,O-dimethyl O-(2,2 dichlorovinyl) phosphate. | Liquid; non-systemic, contact and stomach insecticide with fumigant action and low residual activity; has also acaricidal and anthelmintic property; $LD_{50}$, 80 mg/kg. |
| 2. Dibrom (R), Naled (California Spray Chemical Corporation, 1956) $(CH_3O)_2$ P(O) - OCH Br. $CBrCl_2$ O,O-dimethyl O-(1,2-dibromo-2,2-dichloro ethyl) phosphate. | Liquid (m.p. of pure compound is 26°C); Non-systemic insecticide and acaricide; $LD_{50}$, 430 mg/kg. |

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| | |
|---|---|
| 3. $(CH_3O)_2$ P(=O) – OCH = CHCl<br>O,O-dimethyl O-(2-chlorovinyl) phosphate. | Liquid; insecticide; $LD_{50}$ , 50 mg/kg. |
| 4. $(CH_3O)_2$ P(=O) – OCH = CClF<br>O,O-dimethyl O-(2,2-Chlorofluoro-vinyl) phosphate. | Liquid; low toxicity to fish. |
| 5. $(C_2H_5O)_2$ P(=O) – OCH = CHCl<br>O,O-diethyl O-(2-chlorovinyl) phosphate. | Liquid; relatively stable systemic insecticide; $LD_{50}$ , 7.4 mg/kg. |
| 6. Forestenon<br>$(C_2H_5O)_2$ P(=O) – OC(OCH$_2$CH$_2$Cl) = $CCl_2$ | Insecticide ; $LD_{50}$ , 7-10 mg/kg. |
| 7. $CH_3O$ — P(=O) – OCH = $CCl_2$ — $ClCH_2CH_2O$<br>O-methyl O-(2-chloroethyl) O-(2,2-dichlorovinyl) phosphate. | Systemic insecticide. |

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8. (a) SD - 8280

Methyl homolog of chlorfenvinphos

(b) SD - 8211

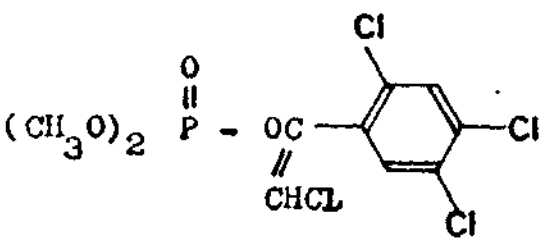
2', 5' - dichloro isomer of methyl homolog of chlorfenvinphos.

Liquid; low toxic insecticide, effective to control flies on faces of hens by feeding.

(SD - 8280 & SD - 8211 have same insecticidal and toxicological properties).

9. Tetrachlorvinphos, Gardona(R), Rabon(R)

(Shell Development CO 1966).



0,0 - dimethyl 0 - [2 - Chloro-1-(2',4',5' - trichlorophenyl) vinyl] phosphate

Solid, mp. 62°C ( -isomer) 98°C ( -isomer); non-systemic, brief persistence selective insecticide, used to control diptera, lepidoptera and Coleoptera and other pests;

$LD_{50}$ , 4,000 mg/kg.

10. Bonyl(R)

(Allied Chemical Corp., Code No - GC - 3707 1959)

1,3-di(methoxy carbonyl)-1-propen-2-yl dimethyl phosphate

Liquid; used for contact-residual treatment of insects and mites;

$LD_{50}$, 32 mg/kg (R).

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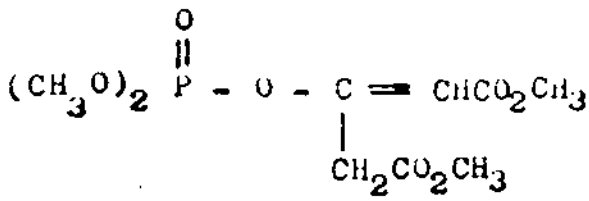
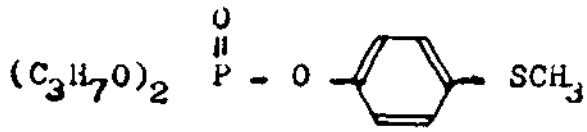


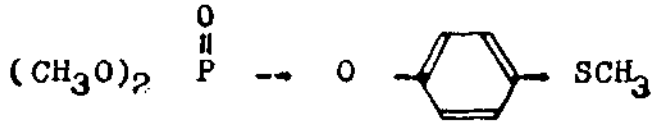
11. (a) Kayaphos (R), Propaphos

(Nippon Kayaku Co. 1968)



Liquid; selective contact insecticide for rice stem-borers and green rice leafhoppers; synergists of other organophosphorus insecticide $LD_{50}$, 70 mg/kg.

(b) GC - 6506



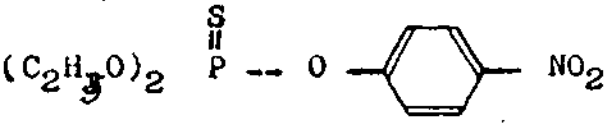
Dimethyl homolog of Propaphos

Insecticide and acaricide for use in cotton; $LD_{50}$ 7 mg/kg. Diethyl homolog is most toxic to mammals.

B. PHOSPHOROTHIONATES.

12. Parathion, Folidol (R),

(Bayer AG 1944)



Liquid; wide spectrum insecticide $LD_{50}$, 7 mg/kg.

O,O-diethyl O-paranitrophenyl phosphorothionate.

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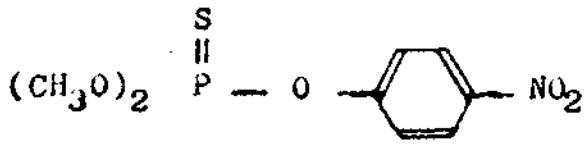
13. Methyl parathion

(Bayer AG 1949)

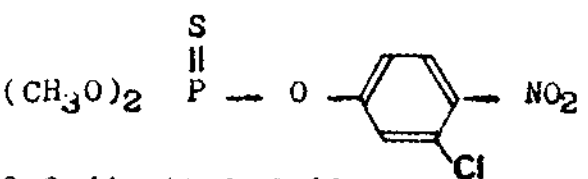


O,O-dimethyl O-paranitrophenyl

Liquid; broad-spectrum; $LD_{50}$, 25-50 mg/kg.

14. Chlorothion(R)

(Bayer AG 1952)



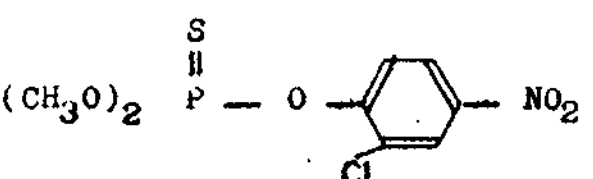
O,O-dimethyl O-(3-chloro-4-nitrophenyl).

Crystalline powder; for control of beetles, apphids, caterpillars

$LD_{50}$ 880 mg/kg.

15. Di - Captan(R), Dicapthon

(American Cyanamid Co. 1954)

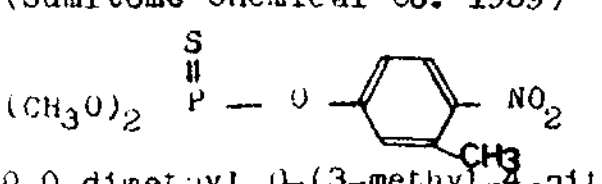


O,O-dimethyl O-(2-Chloro-4-nitrophenyl) phosphorothionate.

Crystalline powder; for controlling household insects, aphids, and boll weevils.

6. Sumithion(R), Folithion(R), Fenitrothion

(Sumitome Chemical Co. 1959)



O,O-dimethyl O-(3-methyl-4-nitrophenyl) Phosphorothionate.

Liquid; broad-spectrum (as methyl parathion), specially for rice - stem borers, flies and mosquitoes in public health programmes $LD_{50}$, 250-500 mg/kg.

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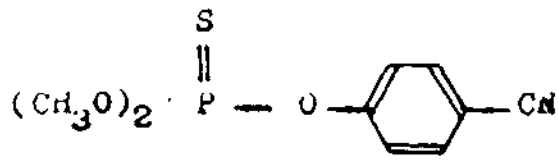
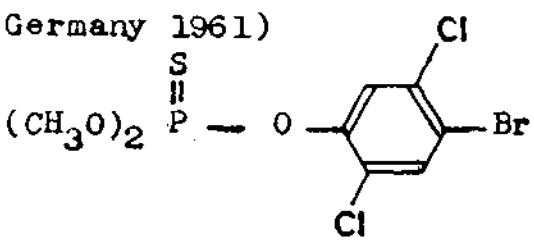
17. Cyanox (R), Cyanophos, CYAP
(Sumitomo Chemical Co. 1966)



O,O-dimethyl O-paracyanophenyl Phosphorothionate.

Liquid; effective against rice-stem borers and also useful for pests of vegetables, fruits, and ornamentals.

18. (a) Bromophos, Nexion (R), Brofene
(Boehringer Sohn and Cela Landwirtschaftliche Chemi, Germany 1961)



O,O-dimethyl O-(4-bromo-2,5-dichlorophenyl) phosphorothionate.

Crystalline solid; mp-54°C; non-systemic persistent insecticide and acariside, particularly effective against diptera; ectoparasite control in livestock; $LD_{50}$, 3750 to 6100 mg/kg.

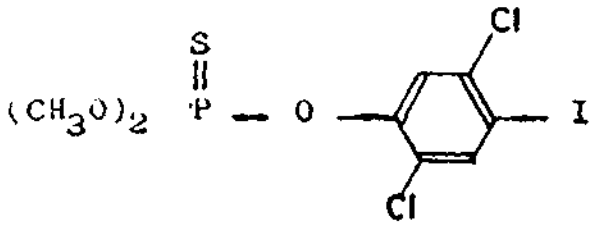
(b) Bromophos - ethyl
O,O-diethyl O-(4-bromo-2,5-dichlorophenyl) phosphorothionate.

Insecticide and acaricide; $LD_{50}$ 238 mg/kg.

(Contd.)

19. Iodofenphos, Alfacron(R), Nuvanol N(R), Elocril

(Ciba Ltd. 1966)

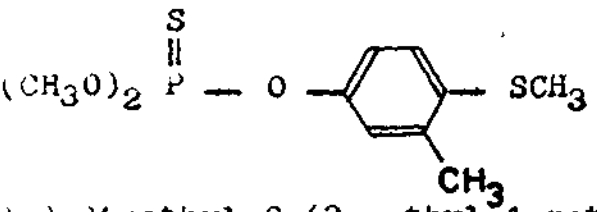


O,O-dimethyl O-(4-iodo - 2,5-dichlorophenyl) phosphorothionate.

Colourless crystalline solid; mp. 76°C; non- systemic contact and stomach insecticide and acaricide effective against a wide range of insect pests, $LD_{50}$, 2100 mg/kg.

20. Baytex(R), Lebayacid(R), Fenthion

(Bayer AG. 1958)

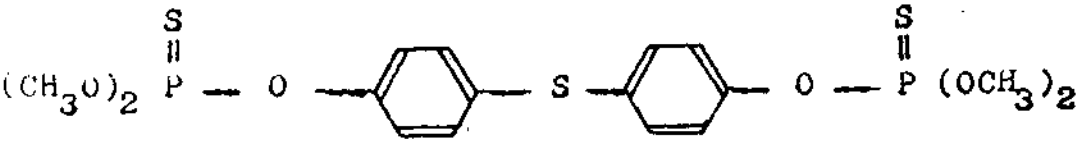


O,O-dimethyl O-(3-methyl-4-methylthiophenyl) phosphorothionate

Liquid; general purpose insecticide with systemic action; particularly for fly and mosquito;
$LD_{50}$, 215 mg/kg (Male R)
615 mg/kg (Female R).

21. Abate(R), Biothion(R)

(American Cyanamid Co. 1965)

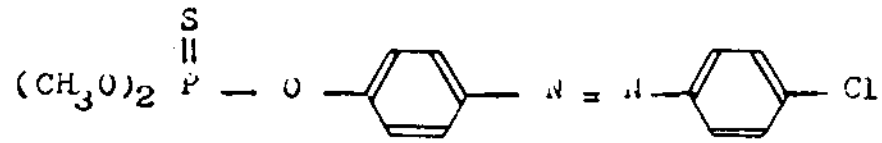


O,O, O',O' - Tetramethyl O,O'-thiodi-p-phenylene phosphorothionate.

White solid; mp - 30°C; control of mosquito larvae; $LD_{50}$, 2000-4000mg/kg

22. Alamos(R), Slam(R),
Azothoate
(Soc. Montecatini, Italy, 1964)

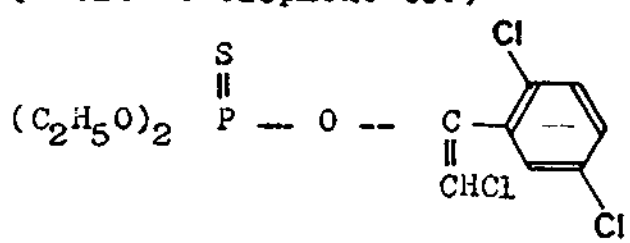
Experimental insecticide and acaricide, particularly nontoxic to mammals.



O,O-dimethyl O - [p -(p-chlorophenylazo) phenyl] phosphorothionate

23. Akton(R)
(Shell Development Co.)

Brown Liquid; non-systemic insecticide, effective particularly for soil insects such as lawn chiuch bugs;
$LD_{50}$, 146 mg/kg.

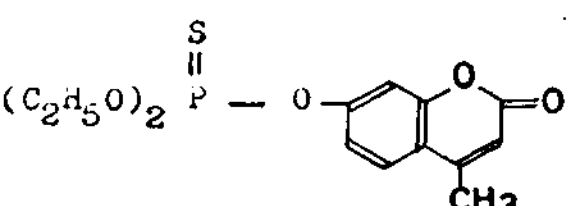


O,O - diethyl O - [2 - chloro-1-(2',5'-dichlorophenyl) vinyl] phosphorothionate

The methyl homolog and 2',4',5' - trichloro-analog of Akton are effective as house fly larvicide.

24. Potasan(R)
(1947)

Colourless crystalline solid, mp. 38°C; stomach insecticide with weak contact activity; particularly effective against Colorado potato beetles, $LD_{50}$, 42 mg/kg.



O,O-diethyl O-(4-methyl-7-coumarinyl) phosphorothionate.

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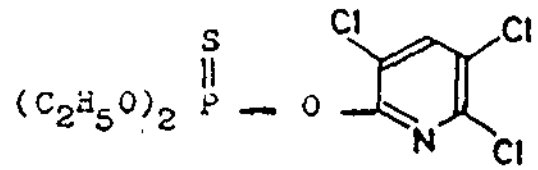
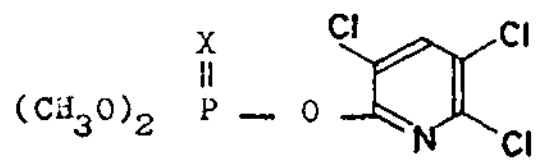
25. Dursban(R),

Chloropyrifos

(Dow Chemical Co. 1965)



O,O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothionate.

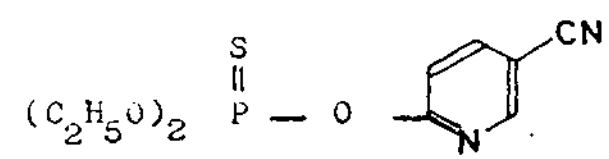


X = S Dowco 214

X = O Dowco 217

The methyl homolog (Dowco(R) 214) is more effective against adult mosquitoes but less effective against the larval than chloropyrifos; its $LD_{50}$ is 1,500 mg/kg.

White crystalline solid, mp. 43°C; moderately persistent insesticide, effective for controlling — mosquito and fly larval, sucking and chewing plant pests, and soil pests, ticks on livestock, $LD_{50}$ , 163 mg/kg.

26. 

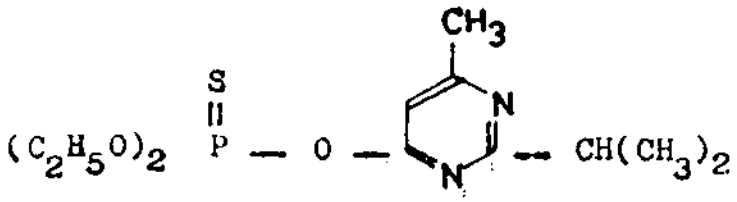
O,O-diethyl O-(5-Cyano-2-pyridyl) phosphorothionate.

Effective against various insects and mites.

(Contd.)

27. Diazinon, Basudin(R), Srolex(R)

(1952)

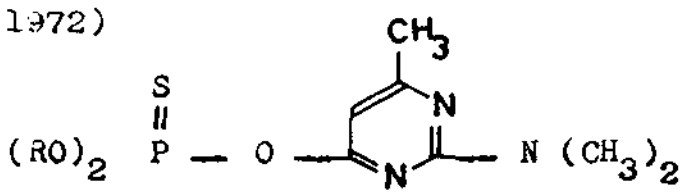


O,O-diethyl O-(2-isopropyl-4-methylpyrimidin-6-yl) phosphorothionate.

Liquid; it has long residual action and effective against soil, fruit, vegetable, and rice insects; $LD_{50}$, 108-250 mg/kg. The n-propyl isomer of diazinon (Pyrazinon) is also effective as an insecticide; $LD_{50}$, 261 mg/kg.

28. Primiphos - ethyl

(Imperial Chemical Industries 1972)



R = $C_2H_5$ primiphos - ethyl

R = $CH_3$ primiphos - methyl

O, O-diethyl O-(2-dimethylamino-4-methylpyrimidin-6-yl) phosphorothionate.

Primiphos - ethyl is a liquid, with broad insecticidal spectrum, particularly effective against diptera and colecptera; it has also fungicidal activity; $LD_{50}$, 140-200 mg/kg; Primiphos-methyl is a liquid; it is an insecticide and acaricide with contact and fumigant activity; it is also used for public health: $LD_{50}$ 2050 mg/kg.

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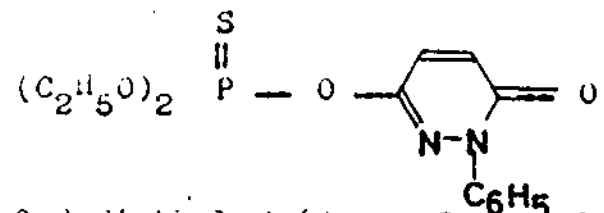
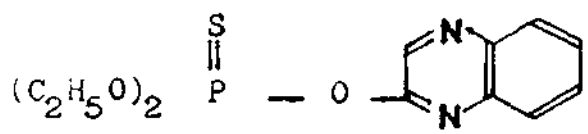
29. Pyridafenthion, Ofnack(R), AC-12, 503 (Mitsui-Toatsu Chemicals. 1973).



O,O-diethyl O-(3-oxo-2-phenyl-2H-pyridazin-6-yl) phosphorothionate.

Used for the control of rice stem borers.

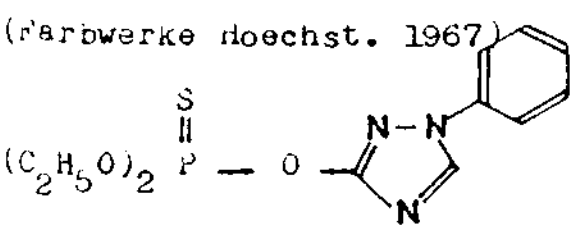
30. Quinalphos, Bayrusil(R) Diethquinalphion. (Bayer AG. 1965)



O,O-diethyl O-(2-quinoxalyl) phosphorothionate.

White crystalline powder, mp - 36°C; contact and stomach activity; effective against both biting and sucking pests, especially against diamond back moth; for control of mosquitoes and mites; $LD_{50}$ 66 mg/kg.

31. Hostathion(R), Triazophos, HOE 2960; (Farbwerke Hoechst. 1967)



O,O-diethyl O-(1-phenyl-1,2,4-triazol-3-yl) phosphorothionate.

Liquid; a non-systemic insecticide and acaricide, acting as a contact and stomach position, $LD_{50}$, 82 mg/kg.

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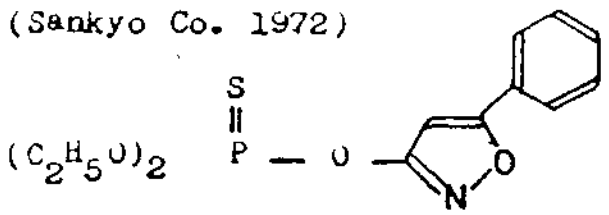
12. Isoxathion, Karphos(R)

(Sankyo Co. 1972)

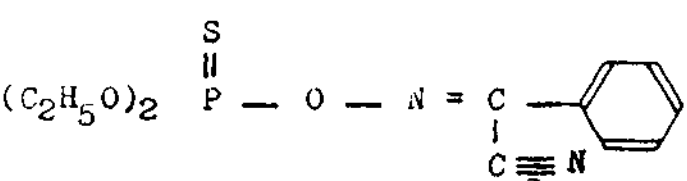


O,O-diethyl O-(5-phenyl-3-isoxazolyl) phosphorothionate. The dimethyl homolog [Dimex(R), $LD_{50}$, 593 - 697 mg/kg (M)] is less toxic.

Liquid, a broad spectrum insecticide, including scale insects and soil insects; $LD_{50}$, 112 mg/kg. The diethyl phosphorothionate ester of non-substituted 3-hydroxy isoxazole is more effective insecticide than isoxathion, but too toxic, $LD_{50}$, 5-10 mg/kg (M).

13. Phoxim, Baythion(R), Valexon

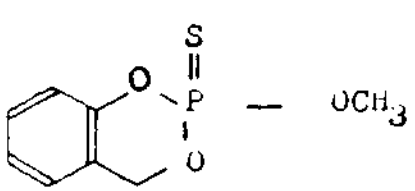
(Bayer AG. 1965)



Liquid; broad spectrum, contact and stomach poison, most useful against soil insects and stored products pests; $LD_{50}$, 2000 mg/kg

14. Salithion

(Sumitomo Chemical Co. 1968)

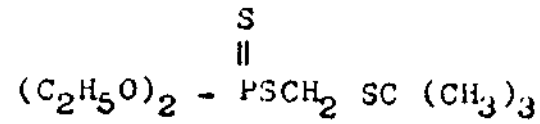


2-methoxy-4H-1,3,2-benzodioxaphosphorin-2-sulphide.

White crystalline powder, m.p. 56°C; a short-lived insecticide for protection of fruits and vegetables; $LD_{50}$, 102 mg/kg.

Other related compounds:

35. Terbufos.

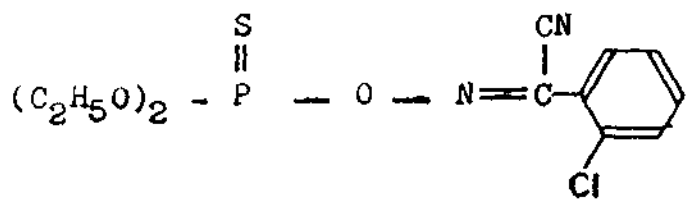


S - tert - butylthiomethyl- -O, O-diethyl phosphorodithioate.

Colourless to pale yellow liquid, has effective initial and residual activity against soil insects and other arthropods, $LD_{50}$, 1.6 mg tech/kg.

36. Chlorphoxim, Baythion C.

(Bayer AG, 1977)

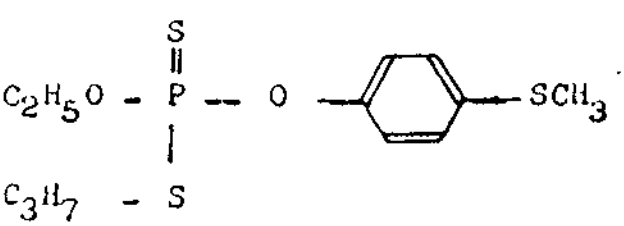


O,O-diethyl 2-Chloro- -cyano-benzylideneamino-oxyphosphonothionate.

Colourless crystalline solid, m.p. 66.5°, an insecticide used to control mosquitoes and simulium flies, $LD_{50}$ 2500 mg/kg.

37. Sulprofos, Bolstar, Helothion.

(Bayer AG, 1976)



O-ethyl O-(4-methylthiophenyl) S-propyl phosphorodithioate.

Colourless oil, b.p. 210°, has specific effect against Lepidoptera on cotton, $LD_{50}$, 304 mg/kg.

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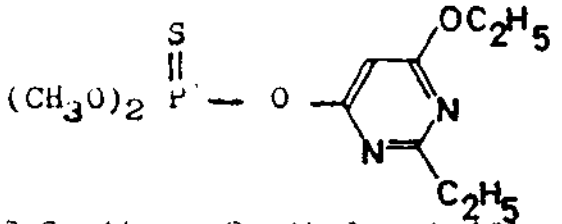
38. Etrimfos, Ekamate.

(Sandoz Ltd., 1972).



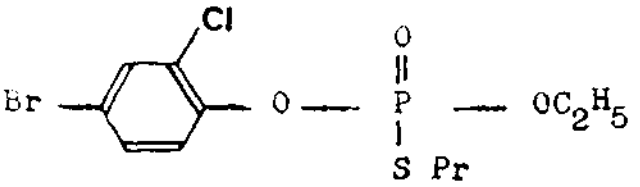
O-6-ethoxy-2-ethylpyrimidine-4-yl- O,O, -dimethyl phosphorothionate.

Colourless oil, broad-range non-systemic insecticide, effective against species of Lepidoptera, Diptera and to a variable extent Hemitera,

$LD_{50}$, 1800 mg/kg.

39. Profenofos, Curacron,

(Ciba - Geigy AG)



O-(4-bromo-2-Chlorophenyl)-O - ethyl S-propyl phosphorothioate.

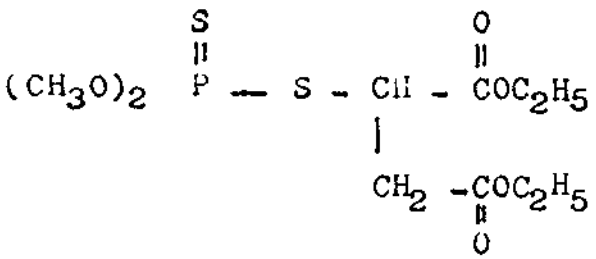
Yellow liquid, non-systemic broad - spectrum insecticide, used against insects, pests and mites on cotton and vegetables,

$LD_{50}$, 358 mg/kg.

C. PHOSPHOROTHIOLOTHIONATES.

40. Malathion, Cythion(R), Karbophos, (American Cyanamid Co. 1950).

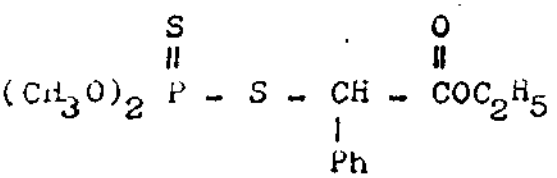
Liquid; safe general purpose insecticide with low mammalian toxicity; $LD_{50}$, 1375 mg/kg; contact and stomach poison.



O, O-dimethyl S - [1,2-di(ethoxycarbonyl) ethyl] phosphorothiolothionate.

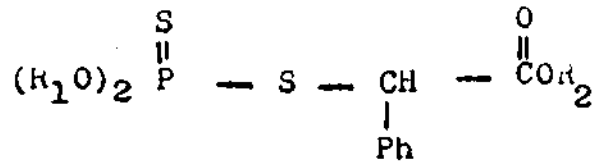
41. Phentboate, Cidial(R), dimephenthoate, Papthion(R), Elsan(R) (Soc. Montecatini, Itali. 1964)

Liquid; broad spectrum insecticide and acaricide; $LD_{50}$, 4,700 mg/kg.



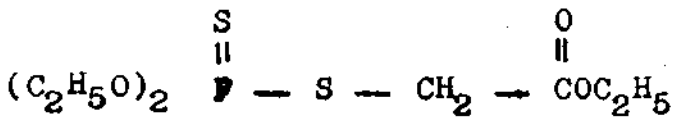
O,O-dimethyl S - [(α-ethoxycarbonyl) benzyl] phosphorothiolothionate. Some other related compounds have been tested for insecticidal and acaricidal properties.

41. (Contd.....)



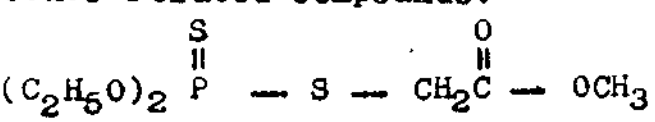
| | $R_1$ | $R_2$ | $LD_{50}$ (mg/kg) |
|---|---|---|---|
| M 1703 | $CH_3$ | $CH(CH_3)_2$ | 400 - 500 |
| M 1788 | $C_2H_5$ | $CH_2CH_2F$ | 5 |

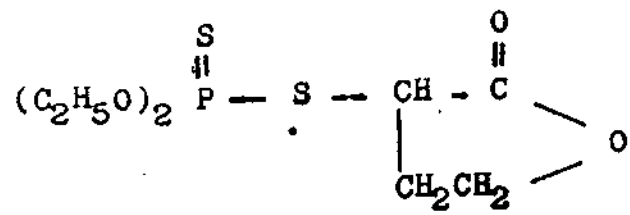
42. Acethion



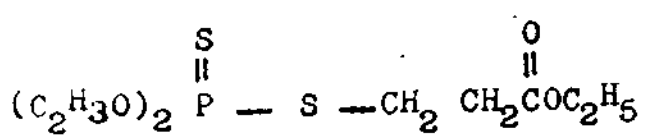
Liquid; selective insecticide; $LD_{50}$, 1100 mg/kg; it is not used practically.

Other related compounds:

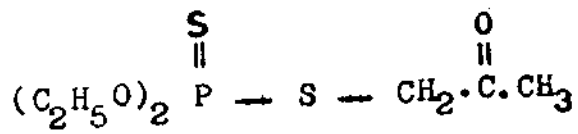




azethion



GC - 9879



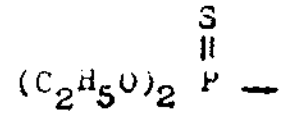
Propathion

Ketothion

(Contd.)

43. Chlormephos

(Murphy chemical Co. 1968)

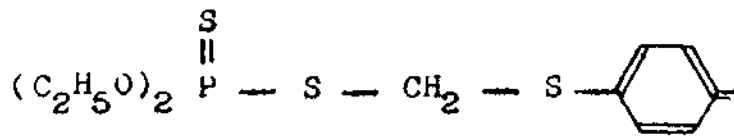


O,O-diethyl S - chloromethyl phosphorothiolothionate.

Liquid; non-systemic soil insecticide, particularly for control of larvae of coleoptera (wireworms); $LD_{50}$ , 7 mg/kg.

44. Trithion(R), Garrathion(R), Carbophenothion, Akarithion(R)

(Stanffer chemical Co. 1955).

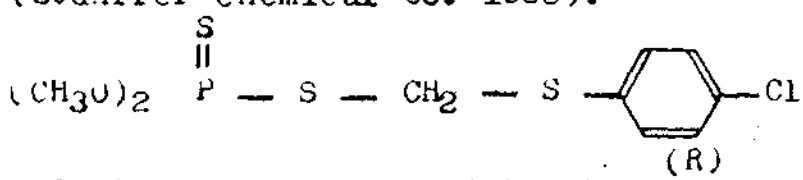


O,O-diethyl S - (p-chlorophenylthiomethyl) phosphorothiolothionate.

Liquid; insecticide and acaricide with long residual action; used for sucking plant pests, particularly mites; useful as a dip for cattle tick; $LD_{50}$, 30 mg/kg.

45. Methyl trithion(R), methyl carbophenothion

(Stanffer chemical Co. 1958).



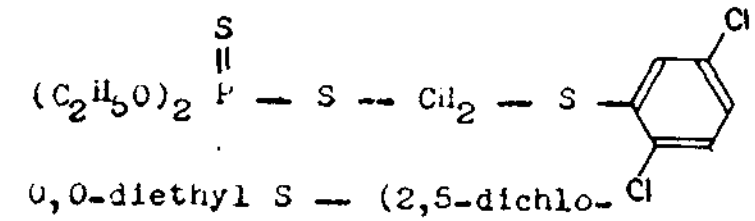
O,O-dimethyl homolog of trithion(R)

Liquid; for control of variety of insects and mites, particularly cotton boll weevil; $LD_{50}$, 150 mg/kg.

(Contd.)

46. Phenkapton, Phencapton (R)

(Geigy AG. 1956)

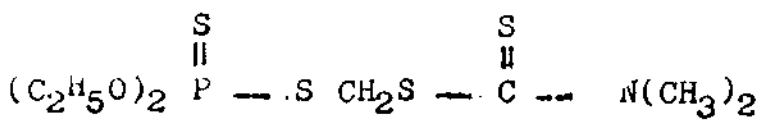


O,O-diethyl S — (2,5-dichlorophenylthiomethyl) phosphorothiolothionate.

Liquid; non-systemic, selective acaricide with prolonged action, and effective against all development stages including eggs; $LD_{50}$, 200 mg/kg.

47. Azothion

(Farbwerke hoechst. 1957)

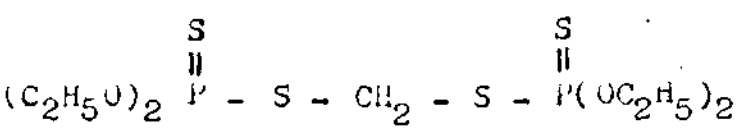


O,O-diethyl S — (N,N-dimethylthiocarbamylthiomethyl phosphorothiolothionate.

Insecticide and acaricide, $LD_{50}$, 150 mg/kg.

48. Ethion, Nialate (R)

(Food Machinery and Chemical Corp. 1956)

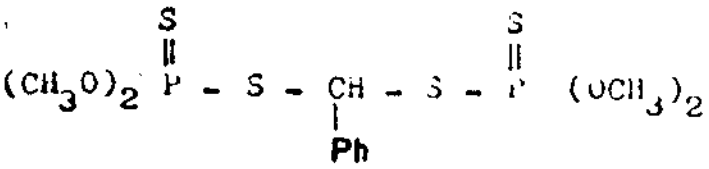


O,O,O',O' - tetraethyl S,S' - methylene. bis (phosphorothiolothionate)

Liquid; for control of aphids, scales, and mites; $LD_{50}$, 208 mg/kg.

(Contd.)

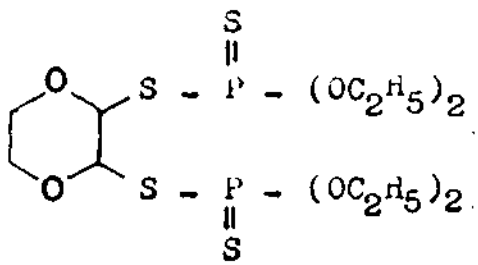
48. (Contd.)



Tetramethyl homolog is effective to bean leaf-lice and Tetranychus telarius.

The benzylidene derivative [SD-7438; tetramethyl S,S'-benzylidene bis (phosphorothilothionate)] is also an insecticide, $LD_{50}$ - 280 mg/kg.

49. Dioxathion, Delnav(R), Navadel(R) (Hercules Incorporated. 1954).



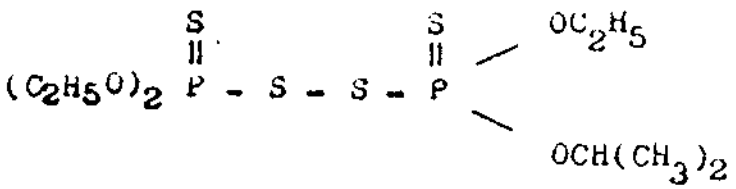
1,4 - dioxan - 2,3 - ylidene bis (O,O-diethyl phosphorothiolothionate) The methyl ester homolog has high insecticidal activity but low mammalian toxicity ($LD_{50}$, 300 mg/kg.).

Liquid; non-systemic acaricide and insecticide with a long residual effect and is particularly useful to control mites on cotton and fruits and ticks, lice, and horn fly on cattle; the cis-isomer is more toxic to both insects and mammals than the transisomer; $LD_{50}$, 65-240 mg/kg (mixture of Cis- & trans-)

(Contd.)

50. Phostex(R)

(Food Machinery and Chemical Corp. 1954).



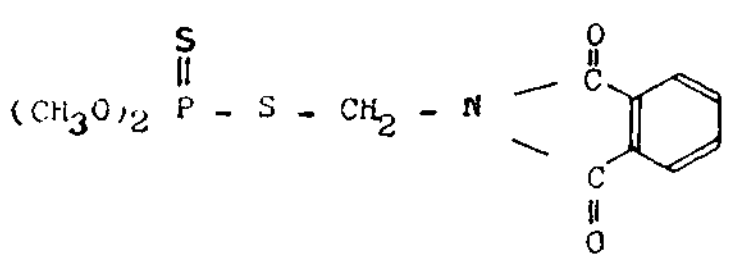
Diethoxyphosphinothionyl ethoxy-isopropoxy-phosphinothionyl disulphide.

The homologous bis(dialkyloxyphosphinothioyl) disulphides synergize the insecticidal activity of many organophosphorus insecticides.

weak contact insecticide, but a highly effective miticide with a good ovicidal activity; $LD_{50}$, 2,500 mg/kg.

51. Phosmet, Imidan(R), phthalophos, Prolate(R)

(Stauffer Chemical Co. 1966).



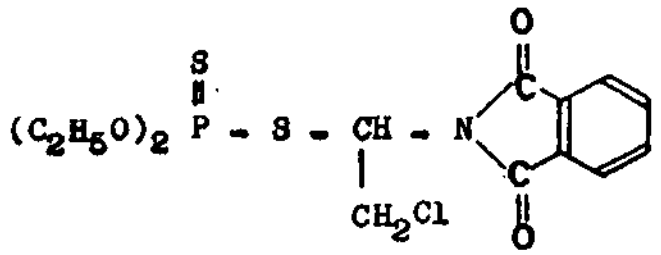
O,O-dimethyl S- (Phtnalimidomethyl) phosphorothiolothionate.

White crystalline solid, m.p. 72°C; acaricide and broad spectrum insecticide for sucking and chewing insects; $LD_{50}$, 230 mg/kg.

(contd.)

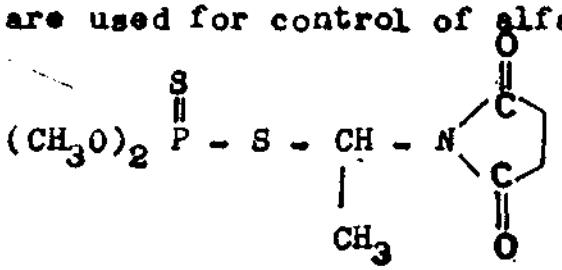
62. Dialifos, Torak(R)

(Hercules Incorporated. 1965)



O,O-diethyl S - (2-chloro-1-phtalimidoethyl) phosphorothiolothionate.

Methyl homolog as well as dialifor are used for control of alfalfa weevil.



Here - 13,462

Crystalline solid m.p. 67-69°; insecticide and acaricide; $LD_{50}$, 5-97 mg/kg. (depending on species and sex).

Succinimide derivatives (Here. 13,462) are also effective insecticides.

63. (a) Azinphosmethyl, Guthion(R), Gusathion(R)

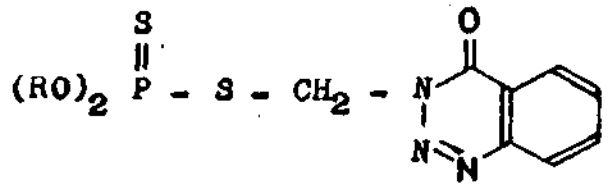
O,O-dimethyl S-4-oxobenzo-triazino-3 ylmethyl) phosphorothiolothionate.

Azinphosmethyl : white crystalline solid, m.p. 73-74°C, $LD_{50}$, 15 mg/kg.

63. Contd.

(b) Azinphosethyl, Ethyl Guthion, Gusathion A(R)

(Bayer AG. 1953)



R = $CH_3$ azinphosmethyl

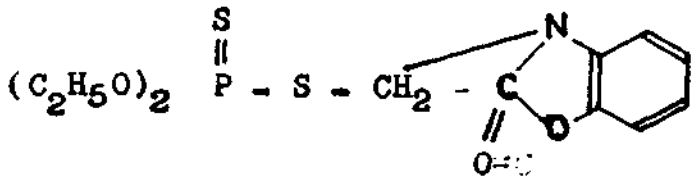
R = $C_2H_5$ azinphosethyl

Azinphosethyl; colourless needles, m.p. 53°C; $LD_{50}$ 17.5 mg/kg.

Both are non-systemic insecticides and acaricidee with long residual activity under neutral conditions.

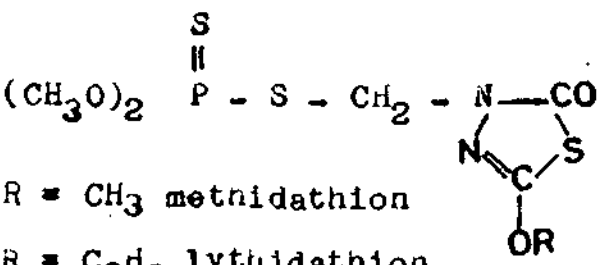
64. Zolone(R), Phosalone

(Rhone - Poulanc, France 1961).



O,O-diethyl S-(6-chloro-2-oxobenzoxazolin-3-ylmethyl) phosphorothiolothionate.

Solid; m.p. 39-40°C; non-systemic insecticide and acaricide with a wide spectrum; for controlling aphid; lepidopterous larvae (codling moth), and scales on fruit trees and cotton; $LD_{50}$, 25-48 mg/kg.

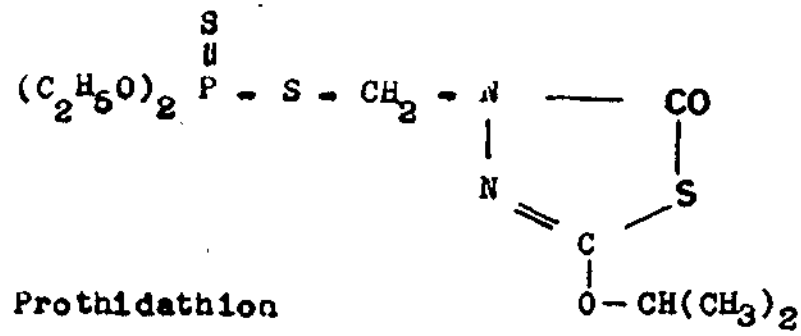


R = $CH_3$ methidathion

R = $C_2H_5$ lythidathion

Ethoxy homolog (lythidathion) ($LD_{50}$, 268-443 mg/kg) is useful specially against lepidopterous and dipterous larvae and otrhoptera.

64. Contd.

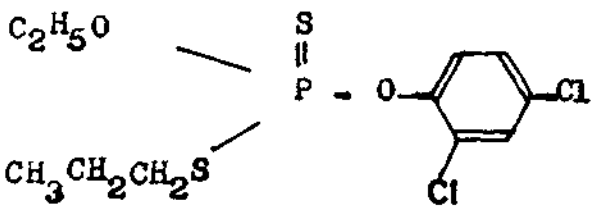


Prothidathion

Prothidathion, another homolog, is also useful as an insecticide.

65. (a) Tokuthion, Prothiofos (Bayer AG. 1975)

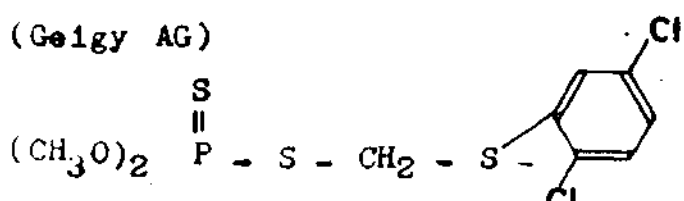
Experimental insecticide, effective to control mulbery mealybug, smaller tea tortrix, Caterpillers etc.; less toxic than the corresponding phosphorothionate.



O-ethyl S-Propyl O-(2,4-dichlorophenyl) phosphorothiolothionate.

(b) Methyl phenkapton (Geigy AG)

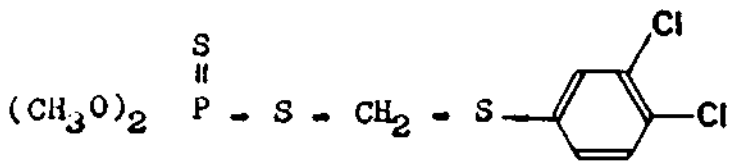
Acaricide and insecticide, $LD_{50}$, 375 mg/kg.



O,O-dimethyl S-(2,5-Dichlorophenylthiomethyl) phosphorothiolothionate.

56.(b) Contd.

The 3,4-dichloro isomer of methyl phenkapton (G-30493) is an acaricide and may be useful as a fly larvicide in manure from chicks by oral administration.



G - 34093

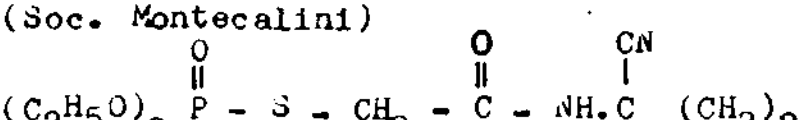
56. PHOSPHOROTHIOLATES.

Acetoxon, acetofos.

O,O-diethyl S - ethoxy carbonylmethyl phosphorothiolate.

Liquid, contact insecticide; $LD_{50}$, 300-700 mg/kg Methylacetofos (dimethyl homolog) has also insecticidal property, but degraded very quickly during storage; $LD_{50}$, 100 mg/kg.

57. Cyanthoate, Tartan (R)
(Soc. Montecalini)



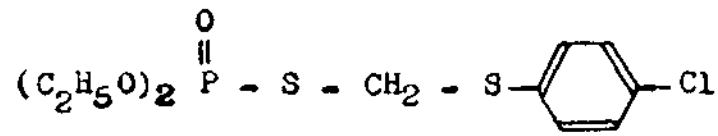
O,O-diethyl S - [N-(1-Cyano-1-methylethyl) Carbamoylmethyl] phosphorothiolate.

Liquid; insecticide and acaricide; $LD_{50}$, 3 to 4 mg/kg.

(Contd.)

58. Danifos(R), PTMD

(Kumiai Chemical Co.)

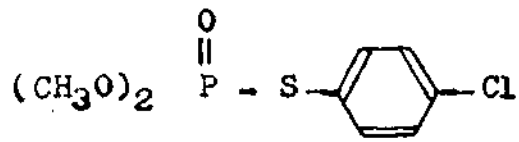


O,O-diethyl S-(p-chlorophenylthiomethyl) phosphorothiolate

Liquid; acaricide; for control of spider mites, aphids and scale on citrus; $LD_{50}$, 165 mg/kg(M)

59. Fujithion(R), DMCP

(Kumiai Chemical Co. 1968)



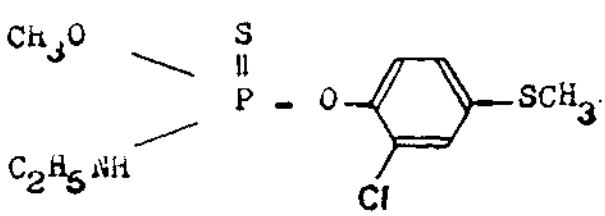
O,O-dimethyl S-(p-chlorophenyl) phosphorothiolates.

Liquid; insecticide, for control of leaf-hoppers and plant - hoppers which transmit rice virus diseases; $LD_{50}$, 100 mg/kg.

8. PHOSPHORAMIDATES

60. Amidothioate, Mitemate(R)

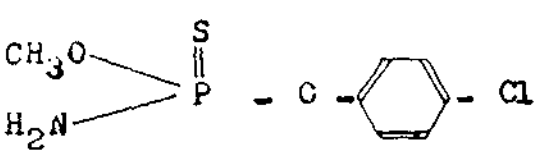
(Kippon Kayaku Co. 1965)



Yellow oil; miticide; long residual activity and can be mixed with Bordean mixture; kills both eggs and active mites; $LD_{50}$, 33 mg/kg (M)

61. Dow ET - 15

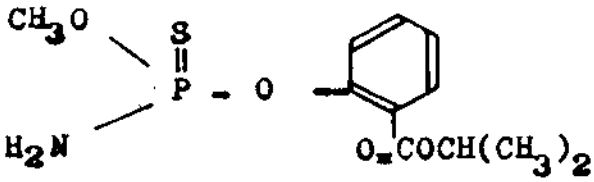
(Dow Chem. Co.)



Insecticide; $LD_{50}$, 710 mg/kg.

(Contd.)

62. Optunal(R), isocarbophos



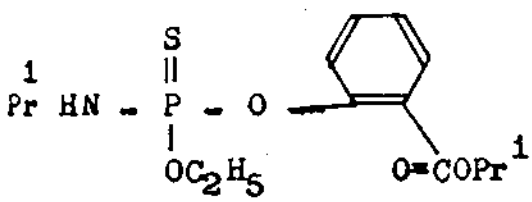
O-(Isopropoxycarbonyl) phenyl methyl phosphoramidothionate.

Effective for Colorado potato beetle and cotton insect; shows systemic activity against aphids and leaf rollers;
$LD_{50}$, 50-100 mg/kg.

Other related alkyl phenyl phosphoramidates:

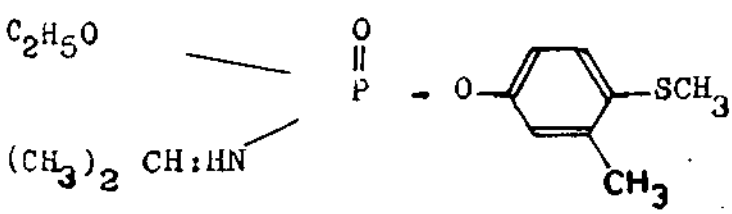
63. Isofenphos, Oftanol

(Bayer AG. 1974)



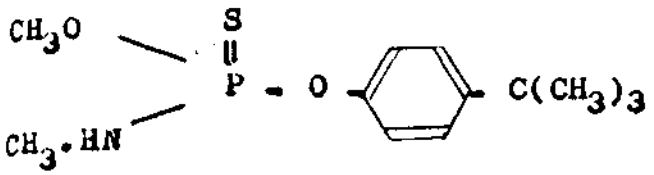
O-ethyl O-2-isopropoxycarbonyl-phenyl-isopropyl phosphoramidothioate.

Colourless oil, broad-range non-systemic insecticide, effective against species of Lepidoptera, Colioptera, Diptera and to a variable extent Hemiptera, $LD_{50}$, 1800 mg/kg.

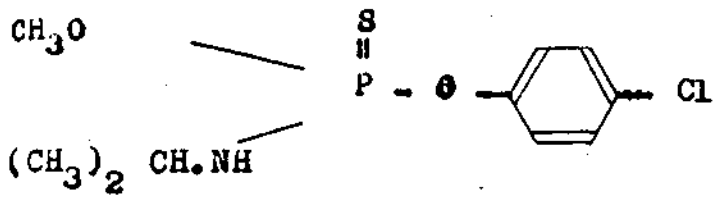


phenamiphos (nematocide)

63. Contd.... .

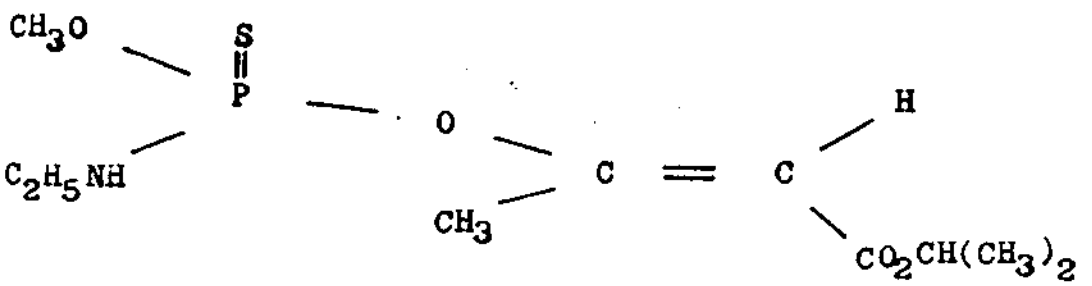


Narlene(R) (Animal systemic)



DMPA (herbicide)

64. Compound 577 (Sandoz, 1972)



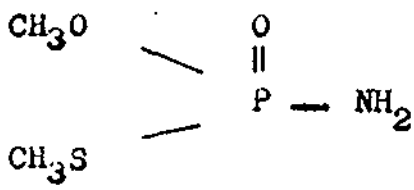
I-isopropoxycarbonyl-1-propen-2-yl methyl N-ethylphosphoramidothionate.

Experimental insecticide; trans-isomer is more toxic than cis-isomer; $LD_{50}$, 122 mg/kg (cis-isomer)

(Contd.)

64. Monitor(R), Tamaron(R), Methamidophos (Bayer AG. 1964; Chevron Research Co. 1969).

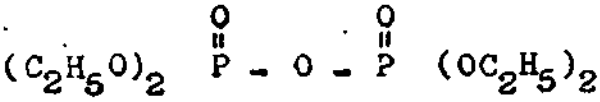
Solid, m.p. 44.5°C; acaricide and broad spectrum insecticide with contact and systemic action; $LD_{50}$ 30 mg/kg.



O,S - dimethyl phosphoramidothioate.

F. PYROPHOSPHATES.

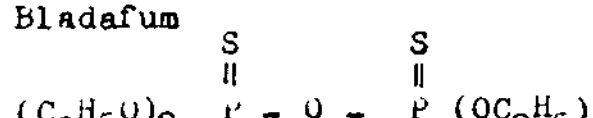
65. TEPP, Tetron(R), (Bladan(R), Nifos T, Vapotone (Bayer AG. 1943)



Tetraethyl pyrophosphate

Liquid, contact insecticide and acaricide; $LD_{50}$ 1.2-2.0 mg/kg.
For homologs, insecticidal activity decreases : ethyl methyl propyl.

66. Sulfotep, Sulfotepp, Bladafum(R)



O,O,O,O-tetra ethyl dithiopyrophosphate.

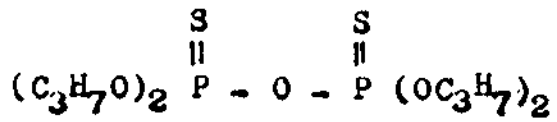
Liquid; insecticide and acaricide with high contact and fumigant activity; $LD_{50}$, 5 mg/kg.

(Contd.)

67. Aspon(R), NPD(R),

Propyl thiopyrophosphate

(Stauffer Chemical Co. 1963).



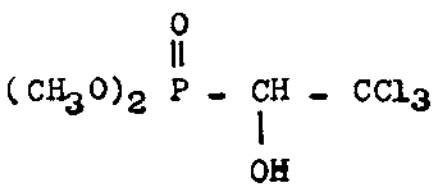
$(C_3H_7O)_2 P - O - P (OC_3H_7)_2$

O,O,O - tetra-n-propyl dithiopyrophosphate.

Liquid; insecticide with contact and fumigant action; $LD_{50}$, 900-1700 mg/kg. Tetraisopropyl isomer has higher mammalian toxicity.

## 6. PHOSPHONATES AND PHOSPHINATES

68. Trichlorfon, Dipterex(R), Neguvon(R), Tugon(R), trichlorphon, metrifonate

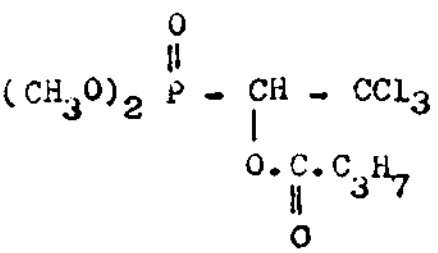


$(CH_3O)_2 P - CH(OH) - CCl_3$

Dimethyl 1-hydroxy-2,2,2-trichloroethyl phosphonate.

Crystalline powder, mp 83-84°C high insecticidal activity, particularly against Diptera; useful for sucking and chewing insects, insects of public health and animal ectoparasites; $LD_{50}$, 630 mg/kg.

69. Butonate, tribuphon



$(CH_3O)_2 P - CH(O.C.C_3H_7) - CCl_3$ (O)

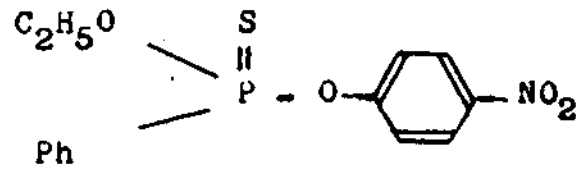
Dimethyl 1-n-butyryloxy-2,2,2-trichloroethylphosphonate.

Liquid; useful for cock-roaches, ants, flies and ectoparasites of domestic animals; $LD_{50}$, 1100 mg/kg.

(Contd.)

70. EPN

(Du Pont. 1949)

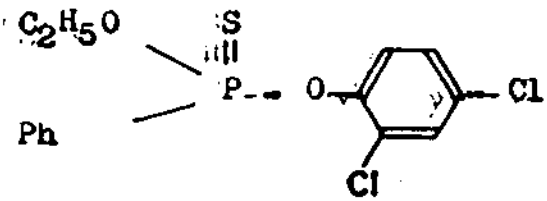


Ethyl p-nitrophenyl phenyl phosphonothionates.

Light yellow crystalline solid; mp. 36°C; insecticide and acaricide; potentiates the toxicity of malathion; shows delayed neurotoxicity; $LD_{50}$, 40 mg/kg (male rat) 12 mg/kg (female rat).

71. EPBP, S-Seven(R)

(Nissan Chemical Co. 1969).



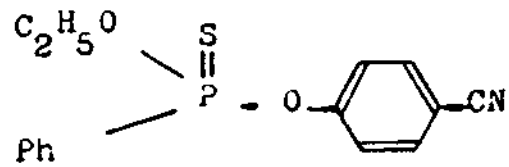
2,4-dichlorophenyl ethyl phenylphosphonothionate

Liquid; soil insecticide (onion maggot); $LD_{50}$ 274 mg/kg (M).

Methyl ester homolog is more toxic than EPBP.

72. Cyanofenphos, CYP, Surecide(R)

(Sumitomo Chemical Co. 1966)

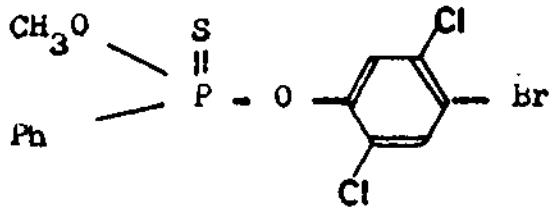


p-cyanophenyl ethyl phenylphosphonothionate.

White crystalline powder, mp. 83°C; insecticide -- rice stem borer, cotton boll worm etc., $LD_{50}$, 80 mg/kg.

(Contd.)

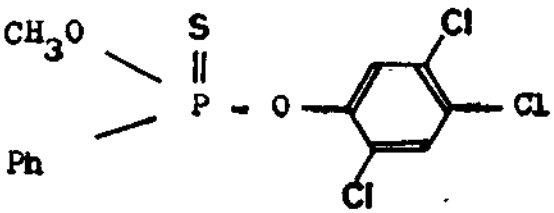
73. Phosvel(R) Leptophos,
VCS - 506
(Velsicol Chemical Corp. 1965)



4-bromo-2,5-dichlorophenyl methyl phenylphosphonothionate.

White solid, mp - 70.2°C; insecticide; controlling lepidoptoran such as tobacco budworms, cotton leafworms, rice stem borers; has also fungicidal effect.
$LD_{50}$, 90 mg/kg.
It has no mutagenic or teratogenic properties.

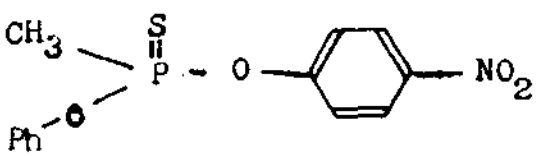
Closely related compound,
methyl 2,4,5-trichlorophenyl phenylphosphonate (H 6034), is a fungicide.



H 6034

74. Colep(R)
(Monsanto Co. 1962)

Insecticide.

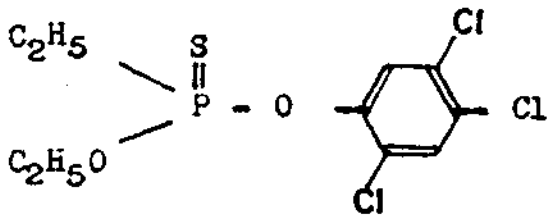


Phenyl p-nitrophenyl methylphosphonothionate.

(Contd.)

75. Trichloronate, Agritox(R), Agrisil(R), Phytosol(R), (Bayer AG. 1960)

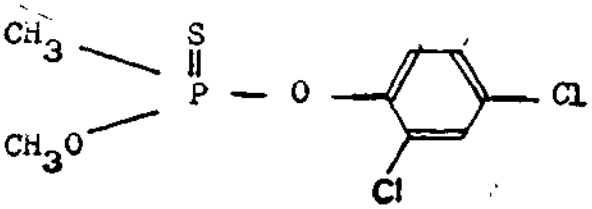
Liquid, non-systemic, persistent soil insecticide (root maggots and wireworms); $LD_{50}$, 50 mg/kg.



Ethyl 2,4,5 - trichlorophenyl ethylphosphonothionate.

76. Bay 30911

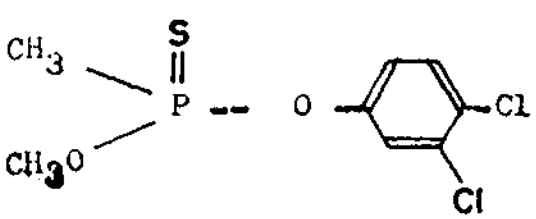
Systemic and contact insecticide with nematocidal activity; $LD_{50}$, 140 mg/kg.



Methyl 2,4-dicholorphenyl methylphosphonothionate.

7. Bay 80833

Soil insecticide.

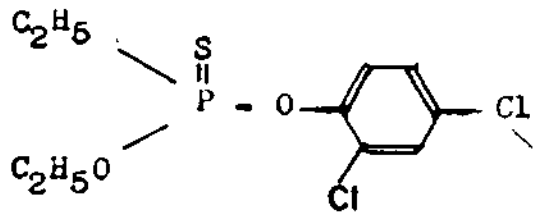


Methyl 3,4 - dichlorophenyl methylphosphonothionate.

(Contd.)

78. Stauffer N - 3054

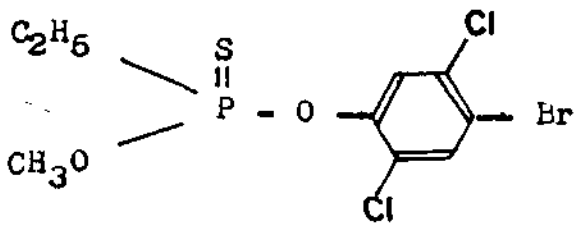
Insecticide ; $LD_{50}$, 75 mg/kg.



Ethyl 2,4-dichlorophenyl ethylphosphonothionate.

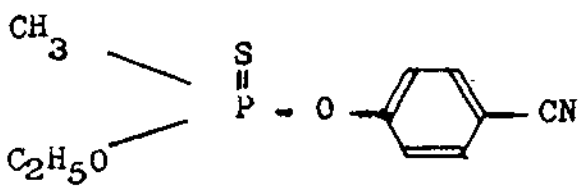
79. CELA K-41

Insecticide and acaricide, 7 times more active than trichloro analog; $LD_{50}$, 80 mg/kg.



80. Stauffer B - 10341

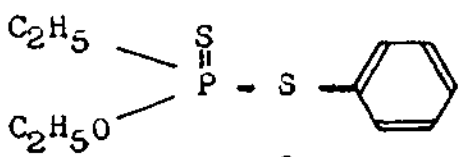
Insecticide, effective to resistant strain houseflies.



Ethyl 4-Cyanophenyl methylphosphonothionate.

81. Fonofox, Dyfonate(R)
(Stauffer Chemical Co. 1967)

Yellow liquid; non-systemic, persistent soil insecticide (corn root worms, wireworms, cutworms, maggots etc.)
$LD_{50}$, 16.5 mg/kg.

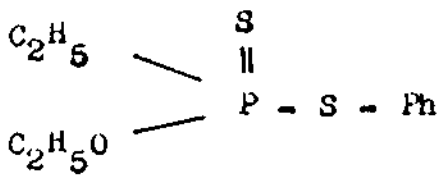
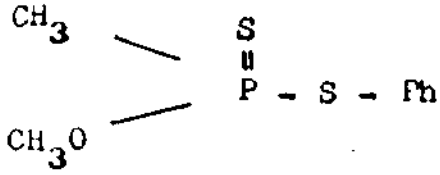
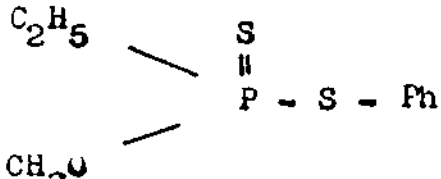
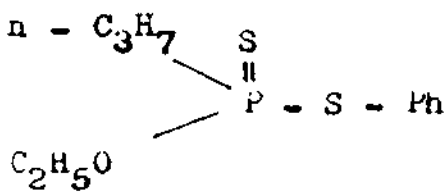
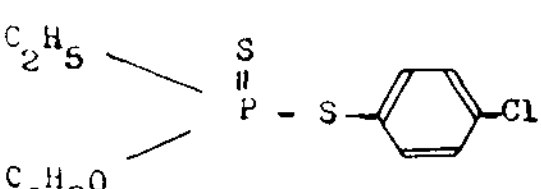


Fonofos

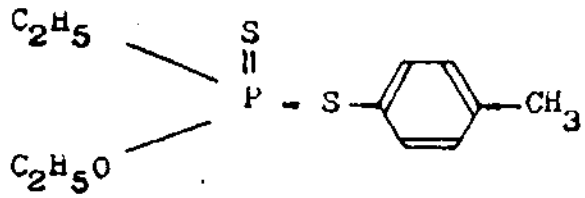
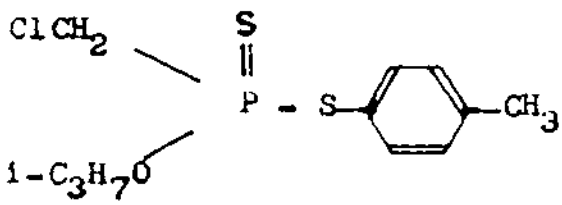
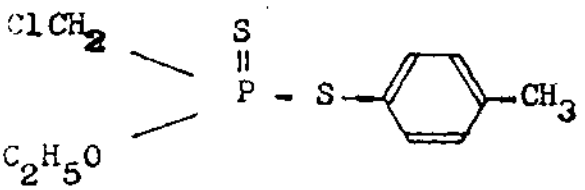
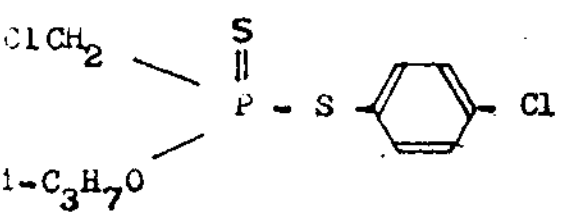
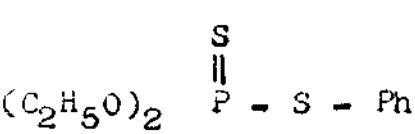
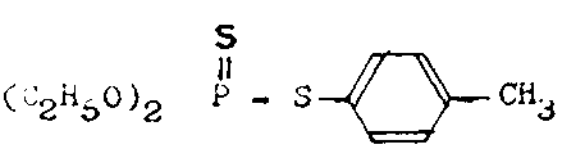
O-Etnyl S-phenyl ethylphosphonothiolothionate.

(Contd.)

Some other O-alkyl S-phenylphosphonothiolothionates:

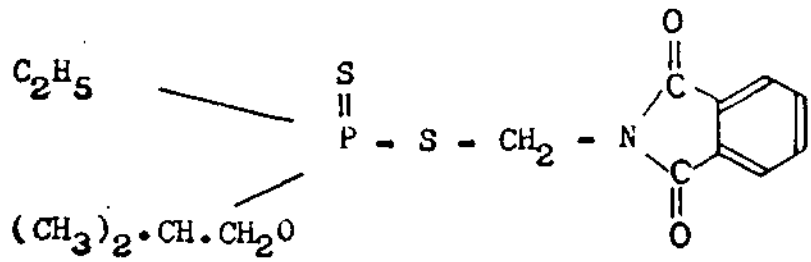
| | | $LD_{50}$ | |
|---|---|---|---|
| | | Rat mg/kg | Housefly mg/25 $\overset{0}{+}$ |
|  | | 2.7 | 4.8 |
|  | N - 3727 | 141 | 7.5 |
|  | N - 3794 | 90 | 5.8 |
|  | | 55 | 8.8 |
|  | N - 2596 | 6 | 5.0 |

81. Contd.....

| | | | | |
|---|---|---|---|---|
|  | Bay 38156 | 123 | | 4.3 |
|  | B - 10119 | 204 | | 5.7 |
|  | | 336 | | 5.4 |
|  | B - 10046 | 26 | | 5.5 |
|  | | 233 | | 56 |
|  | | 316 | | 330 |

(Contd.)

82. Stauffer N-4543

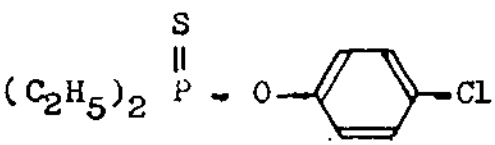


Solid, mp. 58-60°C, promising non-systemic insecticide and acaricide; $LD_{50}$, 75 mg/kg.

O - isobutyl S-(phthalimidomethyl) ethylphosphonothiolothionate.

83. Agvitor

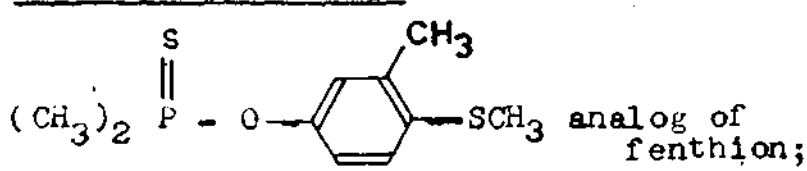
(Bayer AG. 1958)



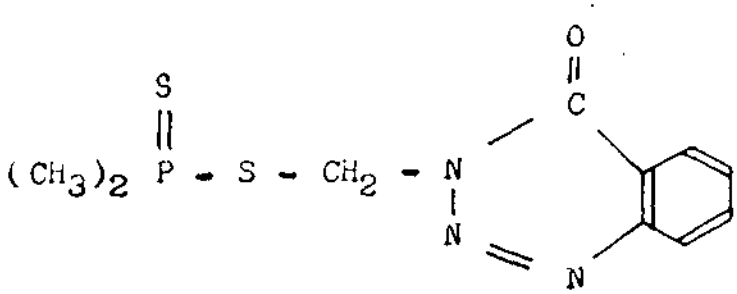
O-(2,4,5-trichlorophenyl) diethylphosphinothionate.

Liquid; soil insecticide (carrot and onion fly); $LD_{50}$, 100 mg/kg; (it is the phosphinate analog of ronnel).

<u>Other phosphinates:</u>

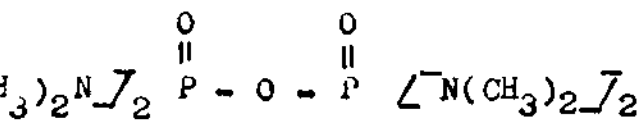
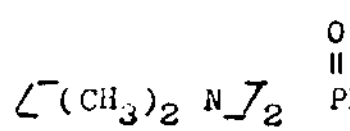


analog of fenthion; insecticide $LD_{50}$, 175 mg/kg



analog of azinphos-methyl. insecticide $LD_{50}$, 1000 mg/kg.

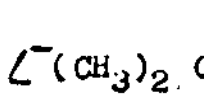
# PLANT SYSTEMIC INSECTICIDES

| Common or trade name, Chemical name and Chemical designations. | Physical and biological properties. |
|---|---|
| **A: PHOSPHORAMIDES** | |
| 1. Schradan, OMPA, System$^{(R)}$<br>  <br>N,N,N',N' - tetramethylphosphorodiamidie anhydride<br>or<br>Octamethyl pyrophosphoramide. | Liquid; effective against aphids and mites; biotransformed in vivo into toxic monomide oxide; weak contact action;<br>$LD_{50}$, 13.5 to 35.5 mg/kg. |
| 2. Dimefox, Hanane$^{(R)}$, Terra-System$^{(R)}$.<br>(Fisons Pest Control Ltd. 1949).<br>  <br>N,N,N',N' - tetramethylphosphorodiamidic fluoride | Liquid; extremely toxic;<br>$LD_{50}$ 1 to 5 mg/kg;<br>formulated as gelaline ampoules for safe application in soil. |

(Contd.)

3. Mipafox, Isopestox$^{(R)}$, Pestox 15.

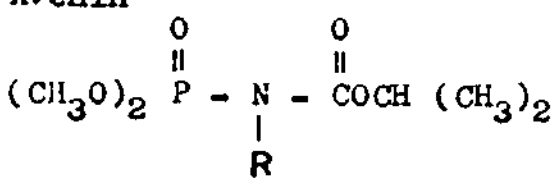
(Fisons Pest Control. 1950).



N, N - di-isopropylphosphorodiamidic fluoride.

Solid, mp. 61-62°C, not used now because of the delayed neurotoxicity.

4. Avenin

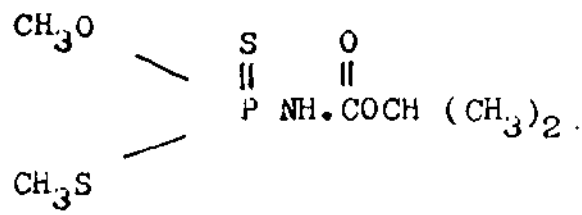


R = H avenin

R = $CH_3$ demuphos

Dimetnyl N-(isopropoxycarbonyl) phosphoramidiate.

Another phosphoryl urethan which has insecticidal activity is:



Undistillable oil; insecticide, selective to sugar beet weevil and sensitive to bean aphids;

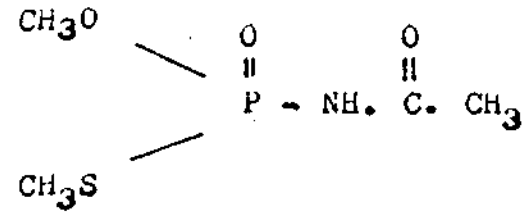
$LD_{50}$, 5000 mg/kg.

Demuphos is more effective and persistent than avenin; can control sugar beet weevils for 20 - 25 days.

(Contd.)

5. Acephate, Orthene(R), Ortran(R)

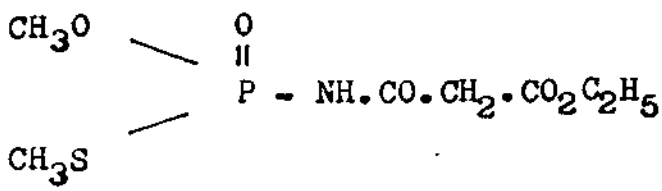
(Chevron Chemical Co. 1971).



O,S - dimethyl N-acetylphosphoramidothiolate.

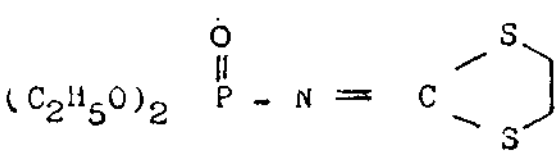
It is the N-acetyl derivative of Monitor(R); solid, mp. 91-92°C; systemic insecticide; moderate persistence; used for sucking and chewing pests.
$LD_{50}$, 945 mg/kg (R), 361 mg/kg (M).

The N-malonyl ethyl ester derivative of Monitor(R) has a very good cuticular penetrating property:



6. Phosfolan, Cyolane(R)

(American Cyanamid Co. 1963).



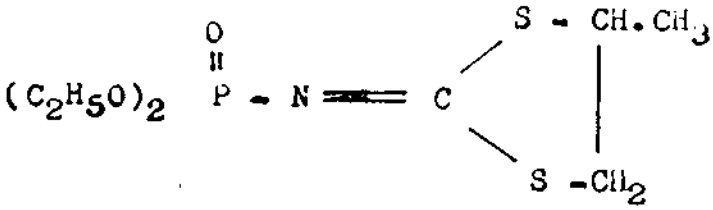
2-(diethoxyphosphinylimino)-1-3-dithiolene.

Liquid; insecticide - cotton leafworms, sucking insects and mites; use also for soil insects, relatively long persistence in soil.
$LD_{50}$, 9 mg/kg.

(Contd.)

7. Mephosfolan, Cytrolane (R)

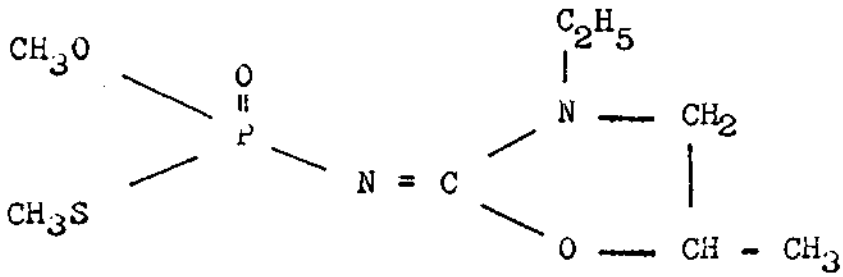
(American Cyanamid Co.)



Liquid; systemic insecticide and miticide; soil use against rice pests hopaphid etc.
$LD_{50}$, 3 to 9 mg/kg.

0,0 - diethyl (4-methyl - 1,3-dithiolan-2 ylidene) phosphoramidate.

8. Stauffer R - 16,661



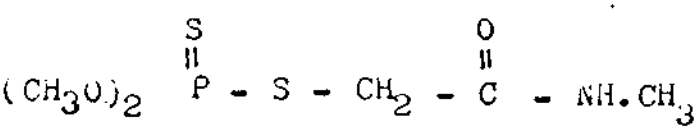
Systemic insecticide for sucking and chewing pests of cotton;
$LD_{50}$, 0.1 to 0.2 mg/kg (M)

2-(methoxymethylthiophosphinylimino)-3-ethyl-5-methyl-1,3-oxazoline.

B: CARBOXYAMIDES AND RELATED COMPOUNDS:

9. Dimethoate, Roger (R)

Cygon (R),



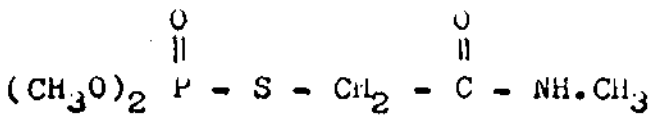
Solid, mp. 51-52°C; systemic and contact broad-range insecticide and acaricide, $LD_{50}$, 600 mg/kg (pure compound) 150 - 300 mg/kg (Technical product.).

0,0 - dimethyl S - (N-methylcarbomoylmetnyl) phosphorothiolothionate.

(Contd.)

10. Folimat(R) Omethoate

(bayer AG. 1965)

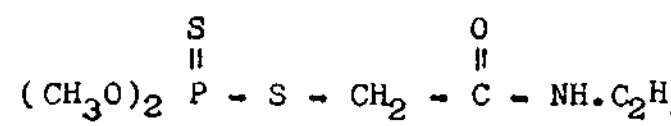


O,O - dimethyl S-(N-methylcarbamoyl-methyl) phosphorothiolate.

Undistillable oil; systemic insecticide and acaricide with a broad-range of action hopaphid and wheat bulb fly; $LD_{50}$, 50 mg/kg.

11. Ethoate-methyl, Fitios B/77

(Bombrini Parodi-Delfino, Italy).

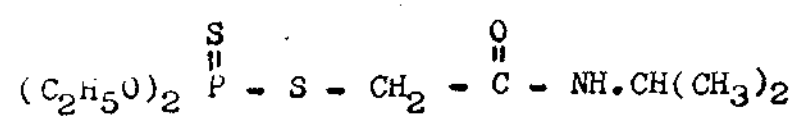


O, O - dimethyl S - (N-ethylcarbamoyl-methyl) phosphorothiolothionate.

Solid; m.p. 67-68°C; insecticide and acaricide with contact action, particularly effective against fruit fly; $LD_{50}$, 340 mg/kg.

12. Prothoate, Fostion(R),
Fac 20(R)

(Soc. Montecatini. 1956).



O, O - diethyl S-(N-isopropylcarbamoyl-methyl) phosphorothiolothionate.

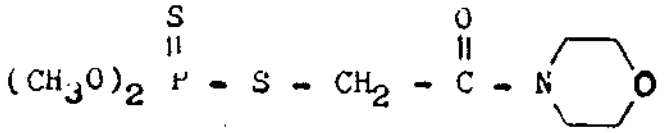
The O - methyl homolog (m.p. 77-78°C) has also insecticidal property; $LD_{50}$, 250 mg/kg.

Crystalline solid, m.p. 28.5°C; acaricide and insecticide with systemic action, used mainly against phytophagous mites and some sap-sucking insects; olive fly, cherry maggot;

(Contd.)

13. Morphothion, Ekatin F(R), Morphotox(R)

(Sandoz Ltd., 1956)



O, O-dimethyl S-(morpholinocarbonylmethyl) phosphorothiolothionate.

Crystalline solid, m.p. 63-64°C; a systemic and contact insecticide; $LD_{50}$, 190 mg/kg.

14. Amidothion, Thiocron(R), Medithionate

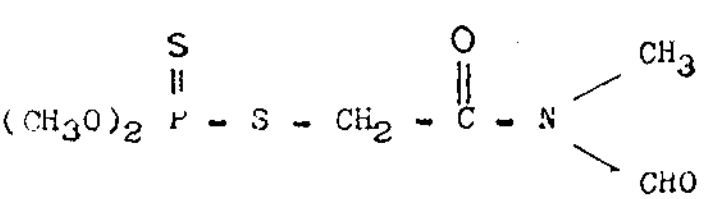
(Ciba Ltd., 1963)

O, O-dimethyl S-(N-methoxyethylcarbamoylmethyl phosphorothiolothionate.

Solid, m.p. 46°C; insecticide, sucking pests on cherries and vegetables; $LD_{50}$, 600-660 mg/kg.

15. Formothion, Anthio(R), Aflix(R)

(Sandoz Ltd., 1963)

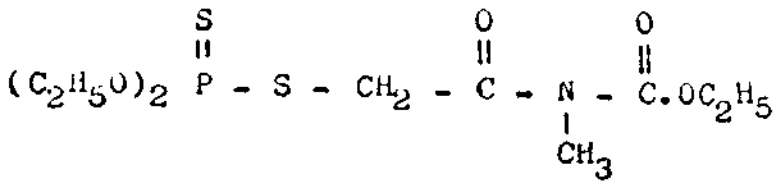


O,O-dimethyl S-(N-formyl-N-methylcarbamoylmethyl) phosphorothiolothionate.

Liquid; contact and systemic acaricide and insecticide, effective against both sucking and chewing pests; $LD_{50}$, 375 - 535 mg/kg.

16. Mecarbam, Pestan,(R) Murfotox(R), Afos(R)

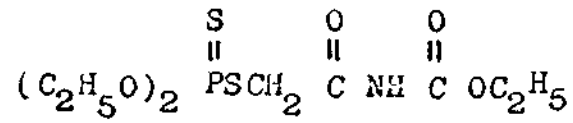
(Murphy Chemical Ltd., 1961)



O, O-diethyl S-(N-ethoxycarbonyl-N-methyl-carbamoylmethyl) phosphorothiolothionate.

Liquid; contact insecticide and acaricide with slight systemic action; persists in soil for several weeks; useful for control of sucking and chewing pests and root maggots of vegetables; $LD_{50}$, 36 mg/kg.

17. Bay 19596

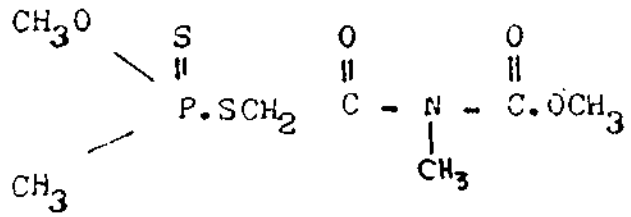


N-desmethyl homolog of Mecarbam

Insecticide, effective against the oriental fruit fly and the melonfly.

18. Mecarphos, Mecarphon

(Murphy Chemical Ltd.,)



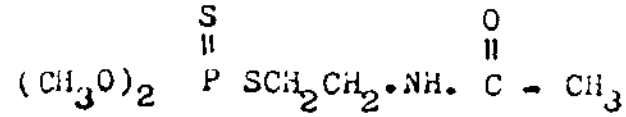
[S - (N - methoxycarbonyl - N - methylcarbamoylmethyl)] methyl methylphosphorothiolothionate.

Systemic insecticide; $LD_{50}$, 57 mg/kg.

(Contd.)

19. DAEP, Amiphos(R)

(Nippon Soda Co. 1966)

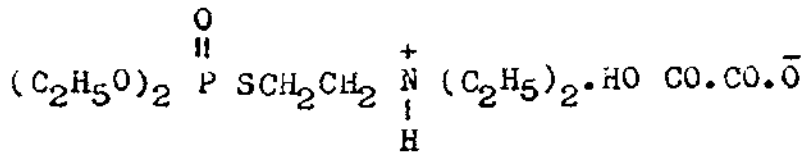


Dimethyl S-(2-acetamidoethyl) phosphorothiolothionate.

Solid, m.p. 22-23°C; systemic acaricide and insecticide, useful to control sucking pests on fruits, vegetables, and ornamentals; $LD_{50}$, 400 mg/kg.

20. Amiton, Tetram(R), Citram(R).

(Imperial Chemical Industries)

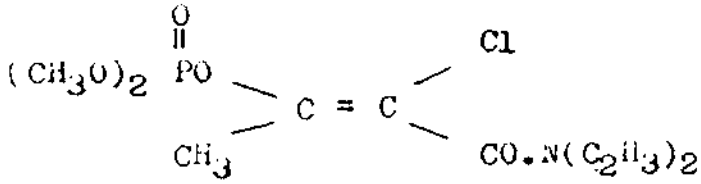


Diethyl S - (2-diethylaminoethyl) phosphorothiolate hydrogen oxalate

Solid, mp. 100-101°C (Free base liquid); long acting systemic insecticide and acaricide; $LD_{50}$, 0.5 - 7 mg/kg (free base, for various animals).

21. Phosphamidon, Dimecron(R), Dicron(R)

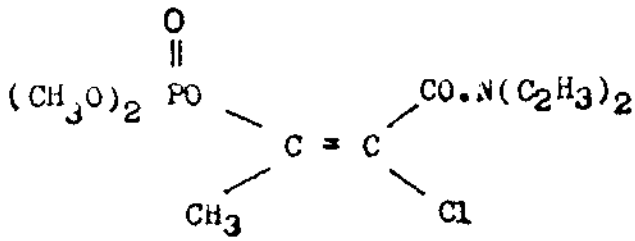
(Ciba Ltd.)



Cis(β-) -isomer

Liquid; systemic insecticide and acaricide with a little contact action; useful against sap-feeding and leaf-eating insects, particularly aphids, bugs, caterpillars (not Noctuidae), thrips rice stem borers etc. $LD_{50}$, 15-28 mg/kg.

21. Contd.....



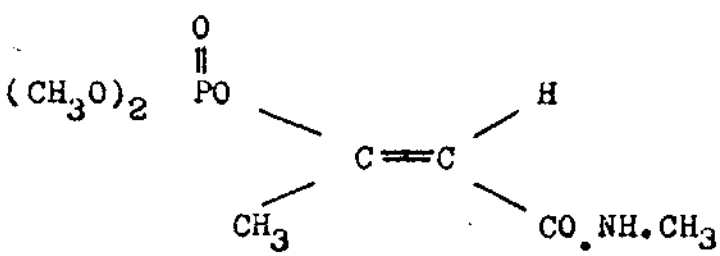
0,0-dimethyl O-(2-methyl-2-chloro-2-diethylcarbamoyl vinyl) phosphate

The cis - isomer is more biologically active than trans - isomer.

tans (∝-) - isomer

22. Monocrotophos, Azodrin(R), Nuvacron(R)

(Ciba AG. 1965)



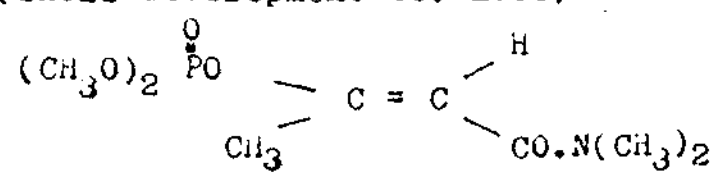
3- (dimethoxyphosphinyloxy) - N - methyl-cis-crotonamide.

Solid, mp. 53-55; a fast-acting insecticide with systemic, stomach and contact action, used against a wide range of pests; $LD_{50}$, 21 mg/kg.

23. Dicrotophos, Bidrin(R), Ektafos(R), Carbicron(R).

(Ciba AG. 1963)

(Shell Development Co. 1965)



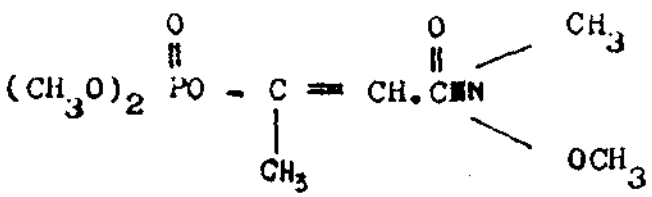
3-(dimethoxyphosphinyloxy)-N,N-dimethyl-cis-crotonamide.

Liquid; moderately persistent systemic insecticide with stomach and contact poison and useful for controlling sucking, chewing, and mining insects and certain mites; $LD_{50}$, 22 mg/kg.

(Contd.)

24. C - 2307 — Insecticide; $LD_{50}$, 2 mg/kg.

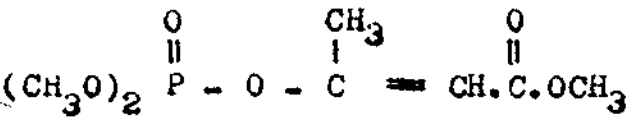
(CIBA AG)



3-(dimethoxyphosphinyloxy)-N-methoxy-N-methyl-crotonamide.

25. Phosdrin(R), Mevinphos — Liquid; a contact and systemic insecticide and acaricide of short persistence, effective against sucking and chewing insects and mites; $LD_{50}$, 4-7 mg/kg.

(Shell Development Co. 1953)

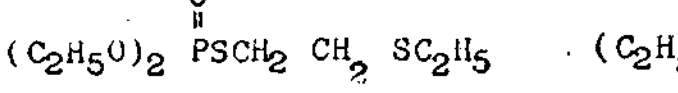


2-methoxycarbonyl-1-methylvinyl dimethyl phosphate.

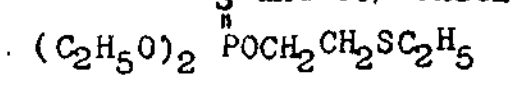
C: SULPHIDES AND RELATED COMPOUNDS.

26. Demeton, Systox(R), mercaptophos — Liquid; technical product contains 70% thiono-isomer and 30% thiolo-isomer; $LD_{50}$ 30 mg/kg (demeton-O) and $LD_{50}$, 1.5 mg/kg (demeton-S); it is a systemic and acaricide with some

(Bayer AG. 1951)



demeton - S



demeton - O

(Contd.)

26. Contd.....

or

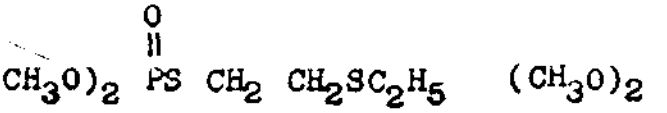
Isosystox(R)

(Thiolo-isomer)

O,O-diethyl 2-ethylthioethyl phosphorothioate.

fumigant action, effective especially against sap-sucking insects and mites.

27. Demeton-methyl, Metasystox(R), (Bayer AG. 1954)



or

Metasystox 55

or

Isometasystox

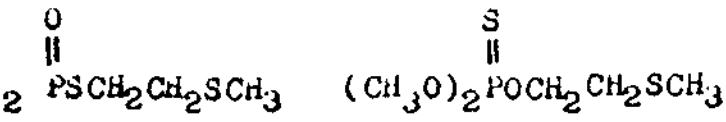
O,O-dimethyl 2-ethylthoethyl phosphorothioate.

Liquid, technical product contains 70:30 mixture of thiono-isomer and thiolo-isomer; $LD_{50}$, 40 mg/kg (thiolo-isomer); it is a systemic and contact insecticide and acaricide, rapid in action, moderate persistence, effective against sap-sucking pests, sawflies, red spider mites etc.

(Contd.)

28. Demephion, methyldemeton-methyl, Tinox(R), Cymetox(R)

(Farbenfabriken Wolfen, East Germany).



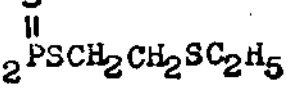
demephion - S (thiolo-isomer) demephion - O (thiono-isomer)

O,O-dimethyl 2-methylthioethyl phosphorothioate.

Liquid; technical product is a mixture of thiono-isomer (30 to 40%) and thiolo-isomer (60 to 70%); $LD_{50}$, 750 mg/kg (thiono-isomer), $LD_{50}$, 40 mg/kg (thiolo-isomer); systemic insecticide and acaricide; sap-feeding insects.

29. Thiometon, Ekatin(R), Dithoometasystox(R)

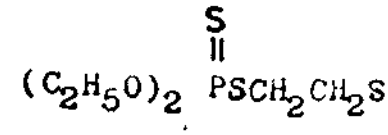
(Sandoz Ltd.).



O,O-dimethyl S-(2-ethylthioethyl) phosphorothiolothionate.

Liquid; a systemic insecticide and acaricide with contact action; effective against aphids, sawflies, thripe, and mites; $LD_{50}$, 70-120 mg/kg.

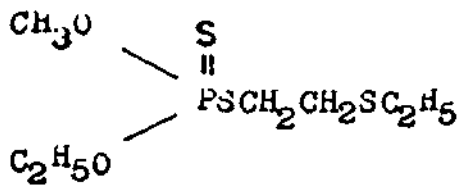
30. Disulfoton, thiodemeton, Disyston (R), Dithiosystox (Bayer AG. 1956)



O,O-diethyl S-(2-ethylthioethyl) phosphorothiolothionate.

Liquid; a systemic insecticide and acaricide, used mainly for soil pests; seed dressing or granules to protect seedlings; effective against aphids on vegetables and fruits and carrot fly, leafhoppers on rice, vegetables, cotton and for some other pests.

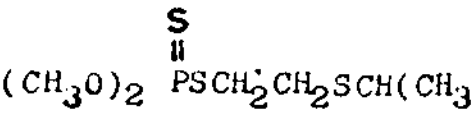
31. Tetrathion (in Czechoslovakia)



O - methyl O-ethyl S-(2-ethylthioethyl) phosphorothiolothionate.

Liquid; a systemic insecticide and acaricide, used mainly for soil pests; chemical and insecticidal properties are similar to thiometon and disulfoton; $LD_{50}$, 1.2 - 22.3 mg/kg (various animals).

32. Isothioate, Hosdon (R) (Nihon Noyaku Co. 1972)



O,O-dimethyl S-(2-isopropylthioethyl) phosphorothiolothionate.

Liquid; a systemic insecticide and acaricide, effective against sucking plant pests by soil treatment or foliage spray; $LD_{50}$, 200 mg/kg.

(Contd.)

33. Phorate, Thimet(R), timet (American Cyanamid Co. 1954).

$(C_2H_5O)_2\ PSCH_2SC_2H_5$

O,O-diethyl S-(ethylthiomethyl) phosphorothiolothionate.

Liquid; a persistent systemic insecticide, used for the protection seedlings from sap-feeding and soil insects; it has also some contact and fumigant action; $LD_{50}$, 2-4 mg/kg.

34. Am. Cy. 12008 (American Cyanamid Co. 1954)

$(C_2H_5O)_2\ PSCH_2S\ CH(CH_3)_2$

O, O - diethyl S-(isopropylthiomethyl) phosphorothiolothionate.

Liquid; systemic insecticide with some contact activity, $LD_{50}$, 14 to 16 mg/kg (M).

35. Aphidan, IPSP, PSP - 204 (Hokko Chemical Co. 1964)



$[(CH_3)_2\ CHO]_2\ PSCH_2\ SC_2H_5$

O,O-di-isopropyl S-(ethylsulfinylmethyl) phosphorothiolothionate.

Liquid; a systemic insecticide, applied in soils to protect the plant from the attack of aphid; potatoes can be protected from the aphid vector of virus diseases by treating the seed potatoes; $LD_{50}$, 84.5 mg/kg.

36. Oxydisulfoton, Disystons(R), Disyston-sulfoxide(R) (Bayer AG. 1965)

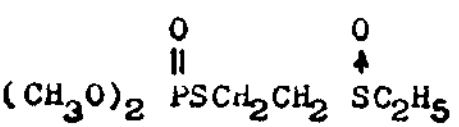
$(C_2H_5O)_2\ PSCH_2CH_2\ SC_2H_5$

O,O-diethyl S-(2-ethylsulfinylethyl) phosphorothiolothionate.

Liquid; a persistent, systemic insecticide and acaricide particularly suitable for seed treatment against virus vectors (sap-sucking insect); $LD_{50}$, 3.5 mg/kg.

(Contd.)

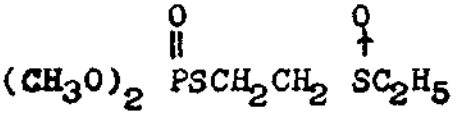
37. Oxydemeton-methyl, Metasystox - R$^{(R)}$
Isometasystox-sulfoxide, demeton-S-methyl-sulfoxide.
(Bayer AG. 1960).



O,O-dimethyl S-(2-ethylsulfinylethyl) phosphorothiolate.

Liquid; a systemic and contact insecticide, used against sap-sucking insects and mites, with a fast kill and moderate persistence;
$LD_{50}$, 70 mg/kg.

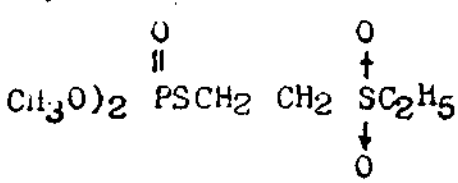
38. Metasystox - S$^{(R)}$, Estox$^{(R)}$
(Bayer AG. 1955)



O, O-dimethyl S-(2-ethylsulfinylisopropyl) phosphorothiolate.

Liquid; a systemic and contact insecticide, like oxydemetonmethyl,
$LD_{50}$, 105 mg/kg.

39. Dioxydemeton - S - methul,
Demeton - S - methyl - sulfone,
Metaisosystox - sulfon.
(Bayer AG. 1965)



O, O-dimethyl S-(2-ethylsulfonylethyl) phosphorothiolate.

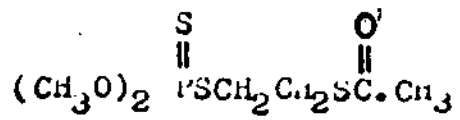
Solid, mp. 60°C; a systemic insecticide;
$LD_{50}$, 37.5 mg/kg.

(Contd.)

40. Intration

(in Czechoslovakia, 1967)

Systemic insecticide for aphid control on hop.

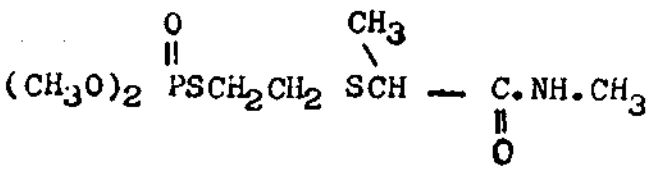


0,0-dimethyl S-(2-acetylthioethyl) phosphorothiolothionate.

41. Vamidothion, Kilval(R)

(Rhone - Poulenc, France. 1962).

Solid, mp. 46 to 48°C; a systemic insecticide and acaricide of high persistence of particular value against wooly aphid; the sulfoxide has similar biological activity but greater persistence; $LD_{50}$, 64 to 100 mg/kg.



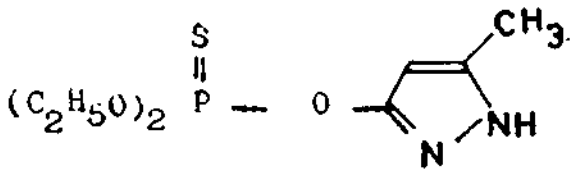
0,0-dimethyl S-[2-(1-methylcarbamoyl-ethylthio) ethyl] phosphorothiolate.

D: PHOSPHORUS ESTER CONTAINING HETERO AROMATIC RING:

42. Pyrazothion(R)

(Geigy Chem. Corp. 1952)

Liquid; systemic insecticide, effective against aphids and spider mites; $LD_{50}$, 36 mg/kg.

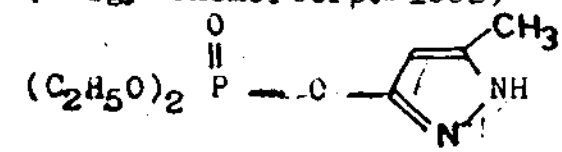


0,0-diethyl 3-methylpyrazol-5-yl phosphorothionate.

(Contd.)

43. Pyrazoxon(R)

(Geigy Chem. Corp. 1952)

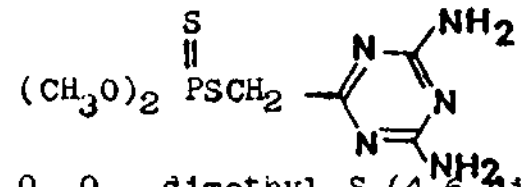


Liquid; systemic insecticide; $LD_{50}$, 4 mg/kg.

O, O - diethyl 3-methylpyrazol-5-yl phosphate.

44. Menazon, azidithion,
Saphizon(R), Sayfos(R)

(Plant Protection Ltd. 1959)

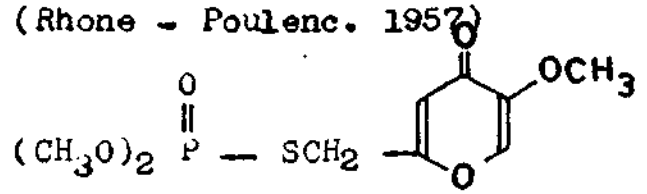


Crystalline solid, mp. 166°C; ystemic aphicide, used by foliar spray, soil treatment, seed dressing, and root dip; $LD_{50}$, 900 to 1,950 mg/kg.

O, O - dimethyl S-(4,6-diamino-1,3,5-triazin-2-ylmethyl phosphorothiolothionate.

45. Endothion, Exothion(R),
Endocide(R), Phosphopyron(R)

(Rhone - Poulenc. 1957)



Solid, mp. 90 to 91°C; systemic insecticide and acaricide;
$LD_{50}$, 30 - 50 mg/kg.

O, O - dimethyl S - (5-methoxy-4-oxo-4H-pyran-2-ylmethyl) phosphorothiolate.

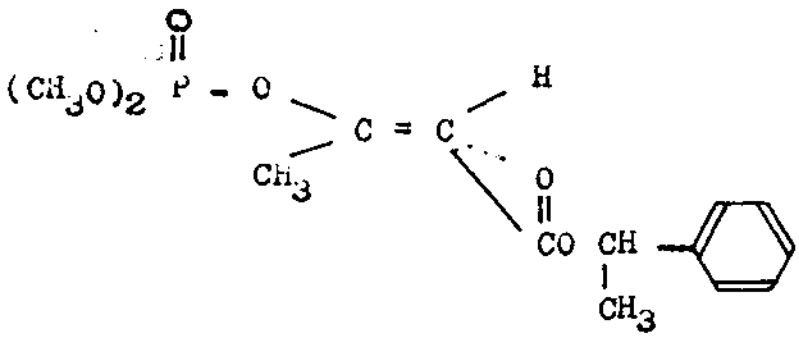
## ANIMAL SYSTEMIC INSECTICIDE AND VETERINARY PESTICIDES.

| Common or trade name, Chemical name and Chemical designations. | Physical and biological properties. |
|---|---|

A: PHOSPHATES:

1. Crotoxyphos, Ciordrin(R)

(Shell Development Co. 1962).

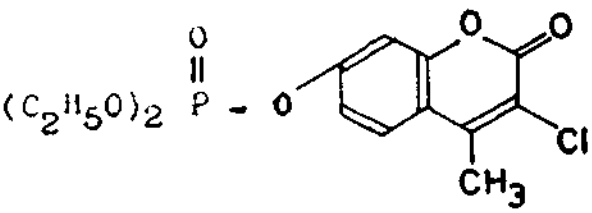


Dimethyl cis -1-methyl-2-(1-phenyle-thoxy-carbonyl) vinyl phosphate.

Liquid; insecticide with no systemic activity, effective against ecto-parasites on livestock by spray (for the con-trol of flies, lice, mites, and ticks on cattle and pigs by spray); $LD_{50}$, 125 mg/kg.

2. Coroxon

(Cooper Technical Bureau. 1961)



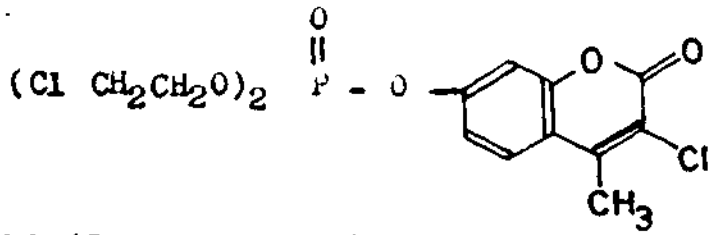
Diethyl 3-chloro-4-methylcoumarin-7-yl phosphate.

Solid, mp. 72°C; animal systemic insecticide; $LD_{50}$, 12 mg/kg.

(Contd.)

3. Haloxon

(Cooper Tech. Bureau. 1962)

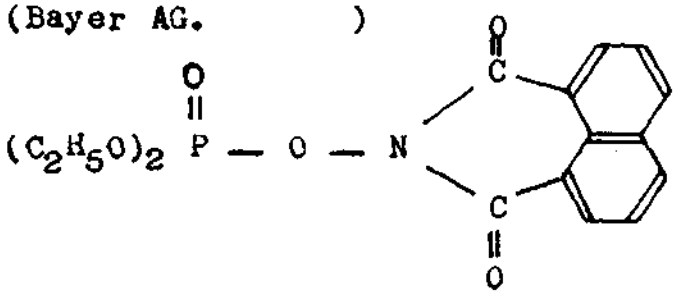


Bis(2-chloroethyl) 3-chloro-4-methyl-coumarin-7-yl phosphate.

Solid, mp. 92°C; has high anthelmintic properties, but has no useful insecticidal properties; $LD_{50}$, 900 mg/kg.

4. Maretin (R), Rametin (R),

(Bayer AG. )

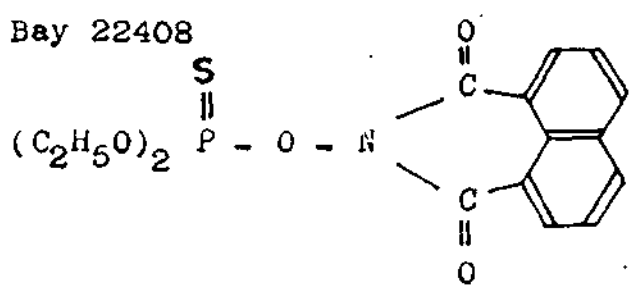


N-(diethoxyphosphinyloxy)-naphthalimide

Solid, mp. 196°C; has anthelmintic and insecticidal properties; $LD_{50}$, 75 mg/kg.

B: PHOSPHOROTHIONATES.

5. Bay 22408



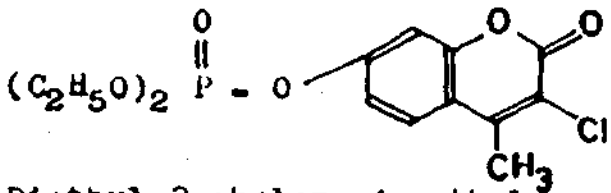
N-(diethoxyphosphinothioyloxy)-naphthalimide.

Solid; insecticide, effective against Mediterranean fruit flies; $LD_{50}$, 500 mg/kg.

(Contd.)

6. Coumaphos, Co-Ral(R), Asuntol(R), Muscatox(R)

(Montecatini. 1956)

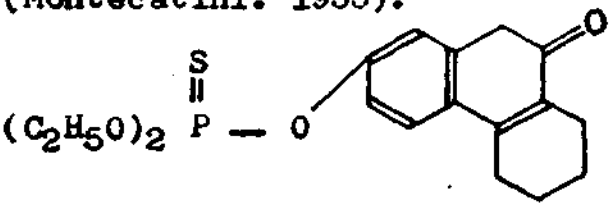


Diethyl 3-choloro-4-methylcoumairn-7-yl phosphorothionate.

Solid, mp. 95°C; insecticide, useful to control ectoparasites on cattle, goats, etc. by feed or spray; also effective against flies, mosquitp larvae; active against gastrointestinal nematodes and has synergistic activity with the anthelmintic agent phenothiazine; $LD_{50}$, 90 to 110 mg/kg.

7. Coumithoate, Dition(R)

(Montecatini. 1955).

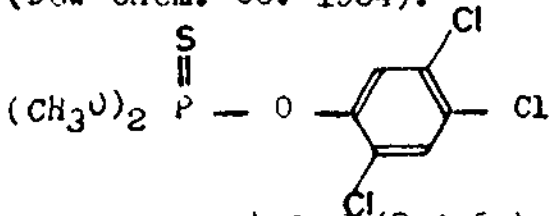


O,O-diethyl O-(3,4-tetramethylene-7-coumarinyl) phosphorothionate.

Solid, mp. 88-89°C; insecticide and meticide, useful for livestock pest control and for public health; $LD_{50}$, 150 mg/kg.

8. Nonnel, Trolene(R), Fenchlorphos, Nankor(R), Korlan(R)

(Dow Chem. Co. 1954).

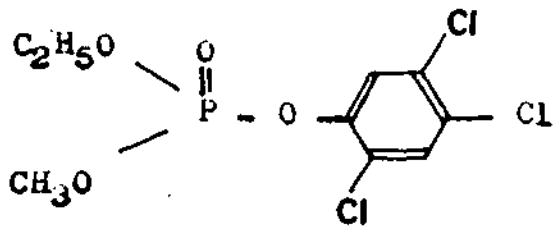


O, O - dimethyl O-(2,4,5-trichlorophenyl) phosphorothionate.

Solid, mp. 40-42°C; animal systemic insecticide, effective to control cattle grub, lice, hornfly, screwworm, and ticks on livestock by oral administration: $LD_{50}$, 1250-1750 mg/kg

(Contd.)

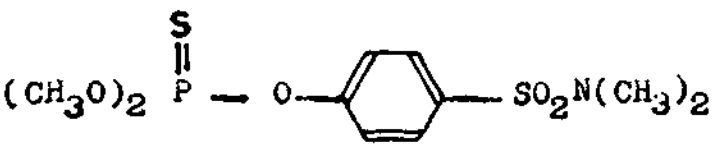
9. Trichlormetaphos - (USSR)



Liquid; insecticide, effective to control warble flies on cattle; useful against sucking insects, mites and midge larvae; $LD_{50}$, 330 - 800 mg/kg.

O-ethyl O-methyl O-(2,4,5-trichlorophenyl) phosphorothionate.

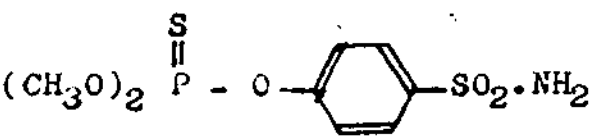
10. Famophos(R), Famphur (American Cyanamid Co.)



Solid, mp. 55°C; systemic insecticide for cattle grubs; $LD_{50}$, 35 mg/kg.

O,O - dimethyl O - [p-(dimethylsulfamoyl) phenyl] - phosphorothionate.

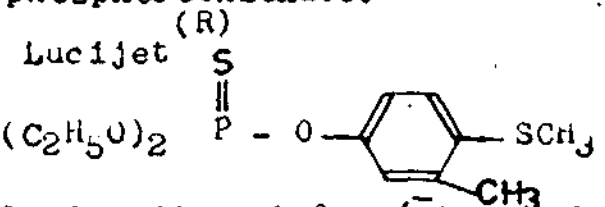
11. Proban(R), Cythioate



Solid, mp. 43-44°C; useful for the control of ticks; $LD_{50}$, 160 mg/kg.

O,O - dimethyl O [p-(sulfamolyl) phenyl] phosphorothionate.

12. Lucijet(R)

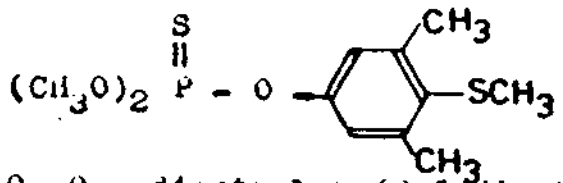


Liquids; insecticide effective against sheep blowfly larvae; $LD_{50}$, 25 to 100 mg/kg.

O, O - diethyl O - [3-methyl-4-methylthiophenyl] phosphorothionate.

(Contd.)

13. Bay 37342

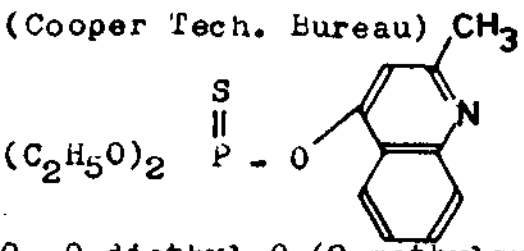


O, O - dimethyl O-(3,5-dimethyl-4-methylthiophenyl) phosphorothionate.

Liquid; animal systemic insecticide for the control of sheep botfly; $LD_{50}$, 1000 mg/kg.

14. Quinothion

(Cooper Tech. Bureau)



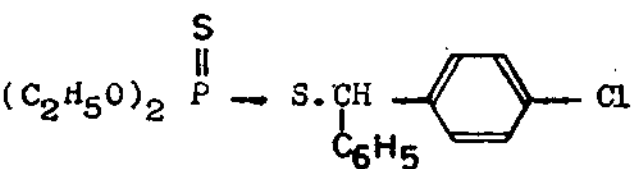
O, O-diethyl O-(2-methylquinolin-4-yl) phosphorothionate.

Liquid; insecticide effective against the sheep parasite Psoroples Communis ovis scab.

C: PHOSPHOROTHIOLOTHIONATES.

15. R - 3,828

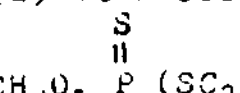
(Stauffer Chem. Co.)



O, O - diethyl S- (P-chloro -phenylbenzyl) phosphorothiolothionate.

Animal systemic insecticide; $LD_{50}$, 10,000 mg/kg.

16.(a) VC 3-668



S, S - dipropyl O - methyl phosphorothionodithiolate.

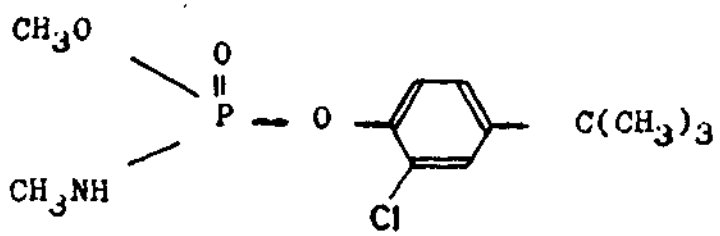
Liquid; effective as a larvicide of manure from chicks by oral administration.

(Contd.)

D: PHOSPHORAMIDATES.

17. Crufomate, Ruelene(R)
(Dow Chem. Co. 1959)

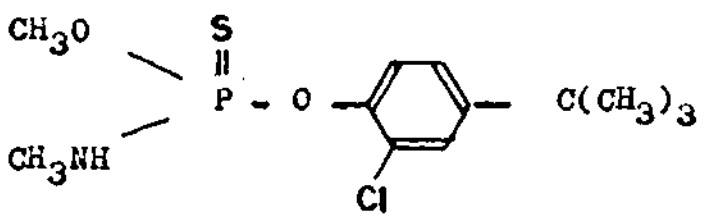
Solid, mp. 60°C; useful for the control of intestinal worms and warble flies etc;
$LD_{50}$, 770 to 1,000 mg/kg.



O - methyl O-(2-chloro-4-tert - butylphenyl)
N - methylphosphoramidate.

17. Narlene(R), Dowco 109(R)
(Dow Chem. Co. 1958)

Solid; effective to control cattle grubs and botflies on livestock and also as an anthelmintic;
$LD_{50}$, 1000 mg/kg.



O - methyl O - (2-chloro - 4 - tert-butylphenyl)
N-methylphosphoramidothionate.

E: PHOSPHONATES.

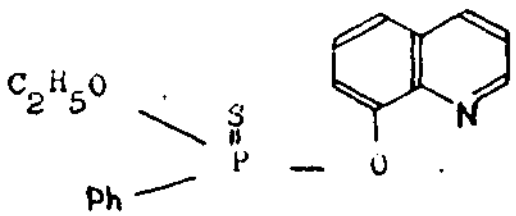
18. CELA K - 159
O - propyl O-(4-bromo - 2,5-dichlorophenyl) methylphosphonate.

Animal systemic insecticide for the control of cattle grubs; $LD_{50}$,

(Contd.)

19. Bacdip (R)

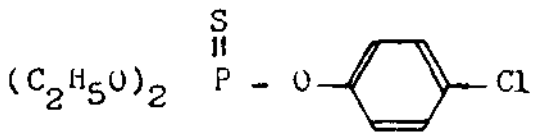
(Bayer AG.)



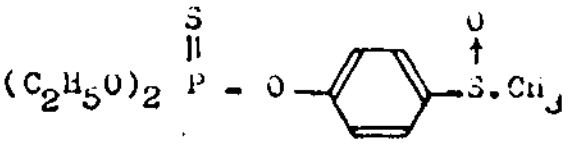
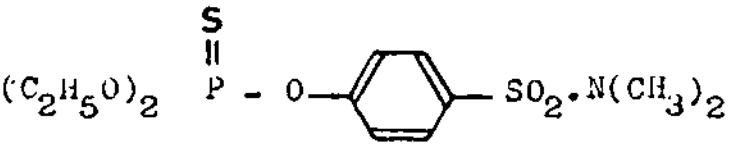
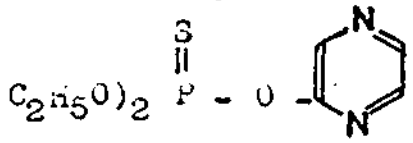
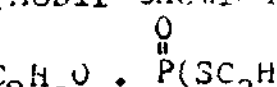
O- ethyl O-(quinolin-8-yl) phenylphosphorothionate.

Acaricide; can be used to control ticks on livestock; $LD_{50}$, 150 mg/kg.

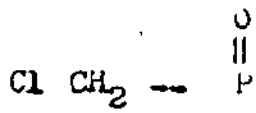
## NEMATICIDES

| Common or trade name, Chemical name and Chemical designations. | Physical and biological properties. |
|---|---|
| 1. Nemacide (R), Dichlofenthion, VC - 13. (Virginia - Carolina Chem. Corp.)  O, O - diethyl O-(2,4-dichlorophenyl) phosphorothionate. | Liquid; systemic, persistence nemalicide and soil insecticide; $LD_{50}$, 270 mg/kg. |

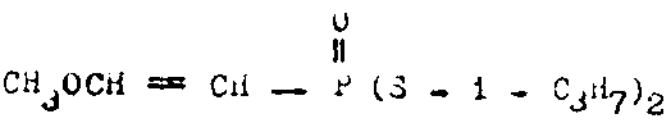
(Contd.)

| | |
|---|---|
| 2. Dasanit(R), Fensulfothion, Terracur P(R)<br>  <br>O, O - diethyl O-(p-methylsulfinyl-phenyl)-phosphorothionate. | Liquid; systemic, persistent nematicide and soil insecticide; it has also contact activity; $LD_{50}$, 4 to 10 mg/kg. |
| 3. DCP; Kaya - ace(R)<br>(Nippon Kayaku Co. 1966)<br>  <br>O, O - diethyl O - (p-dimethylsulfamoylphenyl)-phosphorothionate. | Solid, mp. 68-69°C; persistent nematicide and soil insecticide; $LD_{50}$, 65.4 mg/kg. |
| 4. Thionazin, Zinophos(R), Nemafos(R), Cynem(R)<br>(American Cyanamid Co. 1966)<br>  <br>O-ethyl S,S - dipropyl phosphorodithiolate. | Liquid; systemic soil insecticide and nematicide; persists about 4 weeks in soil; $LD_{50}$, 12 mg/kg. |
| 5. Mocap(R), Prophos<br>(Mobil Chemical Co.)<br>  <br>O-ethyl S,S - dipropyl phosphorodithiolate. | Liquid; contact soil insecticide (corn rootworms) and nematicide; $LD_{50}$, 61.5 mg/kg. |

**Other alkylphosphorodithiolate esters:**

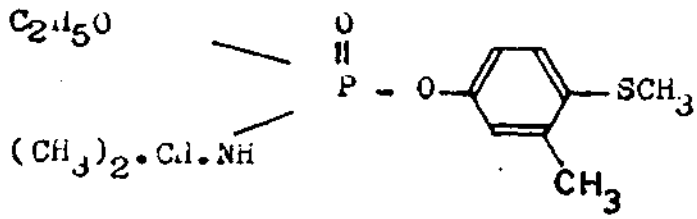


Liquid; nematicide.



Liquid; nematicide.

6. Nemacur,(R) Phenamiphos (bayer AG.)



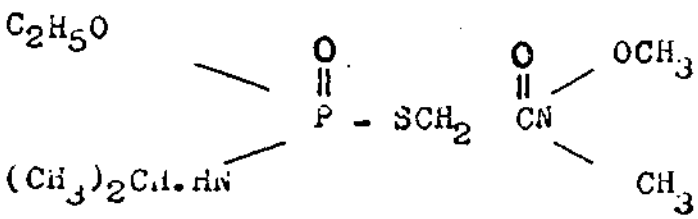
O - ethyl O-(3-methyl-4-methylthiophenyl) N-isopropylphosphoramidate.

Solid, mp. 49°C; systemic nematicide, effective against almost all nematode species below 5 ppm in soil for a long time (3 to 4 months).

$LD_{50}$, 15.3 to 19.4 mg/kg.

7. FCS 13

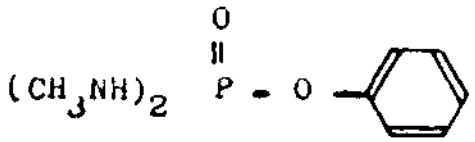
Nematicide.



O - ethyl S - (N - methoxy - N - methylcarbamoylmethyl) N-isopropylphosphoramidothiolate.

(Contd.)

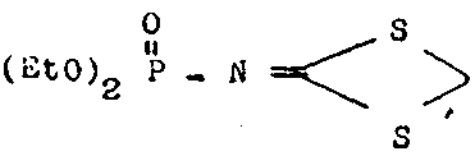
8. Nellite(R), Bowco 169
(Dow Chem. Co.)



O, - phenyl N,N' dimethyl phosphorodiamidate.

Solid, mp. 105-106°C; systemic nematicide, specifically effective against root-knot nematode larvae; $LD_{50}$, 250 mg/kg.

9. Fosthietan, Acconem, Geophos.
(American Cynamide Co. 1972)



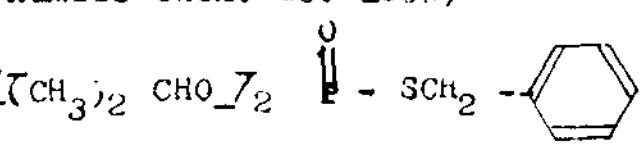
1,3 - dithietan-2-ylidene-phosphoramidate.

Liquid, broad- range nematicide and insecticide, effective in soil application.
$LD_{50}$, 5.7 mg tech/kg.

## FUNGICIDES

| Common or trade name, Chemical name and Chemical designation. | Physical and biological properties. |
|---|---|

1. Kitazin P(R), IBP
(Kumiai Chem. Co. 1965)



O, O - diisopropyl S-benzylphosphorothiolate.

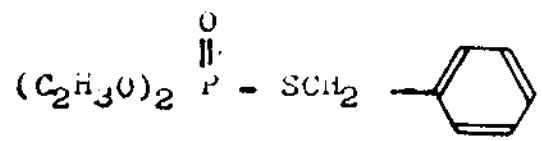
Liquid; systemic fungicide, inhibits strongly the myceliah growth and spore formation of Pericularia oryzae; has also weak insecticidal activity with fenitrothion; $LD_{50}$, 238 mg/kg (M)

(Contd.)

2. Kitazin(R)

(Kumiai Chem. Co. 1967)

Liquid; systemic fungicide; $LD_{50}$, 238 mg/kg (M)

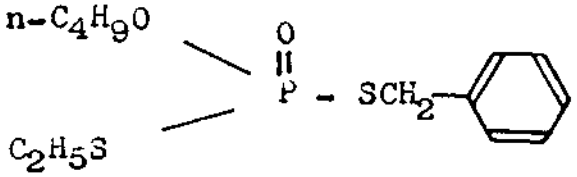


O, O - diethyl S - benzyl phosphorothiolate.

3. Conen(R) BEBP

(Sumitomo Chem. Co.)

Liquid; fungidide to control rice blast disease; $LD_{50}$, 118 mg/kg.

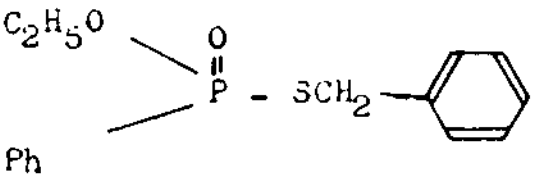


S - Benzyl S-ethyl O-(n-butyl) phosphorodithiolate.

4. Inezin(R), ESBP

(Nissan Chem. Co.)

Liquid; fungicide to control rice blast and rice sheath blight; $LD_{50}$, 720 mg/kg.

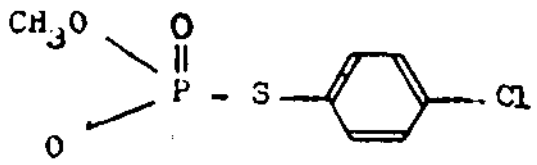


O - ethyl S - benzyl phenylphosphonothiolate.

(Contd.)

5. Cerezin(R)

(Nihon Tukushu Noyaku Seizo Co.1966)



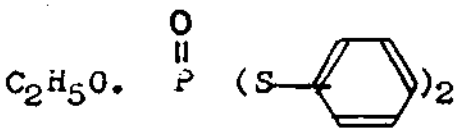
Liquid; has curative effect on rice blast disease and has also insecticidal activity;

$LD_{50}$, 160 mg/kg.

O - methyl O - Cyclohexyl S - (p-chlorophenyl) phosphorothiolate.

6. Hinosan(R), Edifenphos, EDDP

(Bayer AG; Nihon Tokushu Noyaku Seize Co.)



Liquid; fungicide, effective against rice blast disease; has prophylastic effect against P. Oryzae

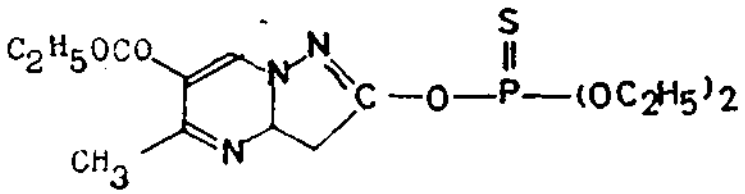
$LD_{50}$, 140 mg/kg.

O-ethyl S, S-diphenyl phosphorodithiolate.

Remarks: n-propyl and isopropyl homologs have almost the same fungicidal activity as Hinosan, but methyl and butyl homologs are much less active than the latter.

7. Pyrazophos, HOE 2873, Afugan(R)

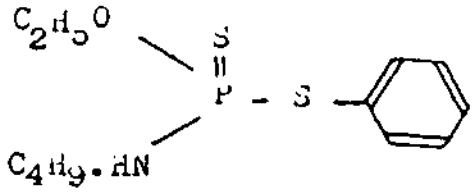
Systemic fungicide, effective against powdery mildews.



O,O- diethyl O-(6-ethoxycorbonyl-5-methylpyrazolol [1,5-a] pyrimidin-2-yl) phosphorothionate.

(Contd.)

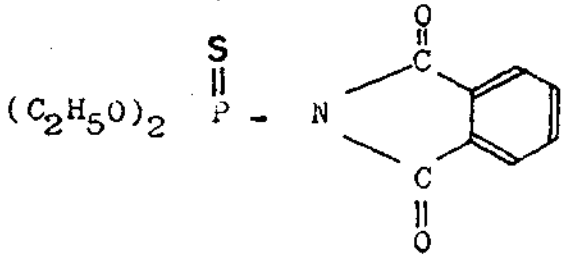
8. Phosbutyl



Liquid; fungicide, effective against mycelial cell formation, but not active against spore germination,
$LD_{50}$, 300 mg/kg.

O - ethyl S-phenyl N-butylphosphoramidothiolothionate.

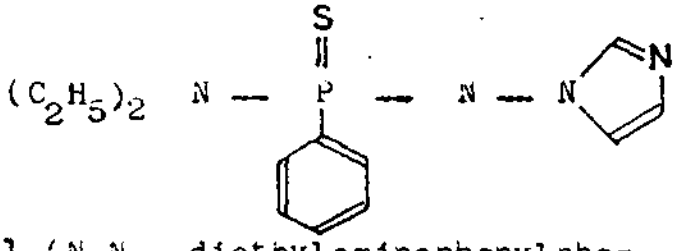
9. Ditalimfos, Dowco 199



Solid, mp. 83-84°C; fungicide, effective to control powdery mildew, shows curative and protective action;
$LD_{50}$, 5660 mg/kg.

O, O - diethyl phthalimidophosphonothionate.

10.

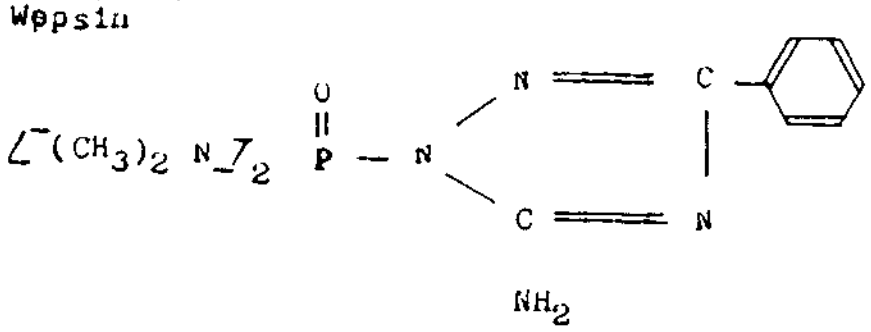


Solid, mp. 43°C; fungicide, effective against Erysiphe cichoracearum on Cucumbers and Phytophthora infestans on potato plants;
$LD_{50}$, 1000 mg/kg.

1-(N,N - diethylaminophenylphosphinothioyl) - imidazole.

(Contd.)

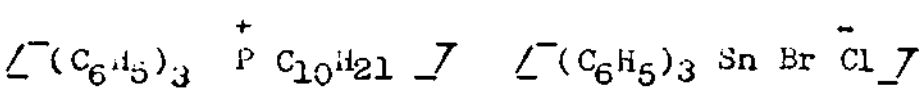
11. Triamiphos, Wepsyn (R), Wepsin (R)



5-amino-1-[bis-(dimethylamino) phosphinyl]-3-phenyl-1,2,4-triazole 5-anilino-3-alkyl analogs are also active as fungicides and insecticides.

Solid, mp. 167-168°C; insecticide and fungicide, effective against powdery mildew on apples and roses; useful as an acaricide with systemic properties; $LD_{50}$, 20 mg/kg.

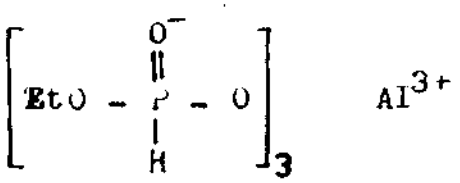
12. Decafentin



Fungicide, $LD_{50}$, 450 - 515 mg/kg.

13. Aliette, Mikal

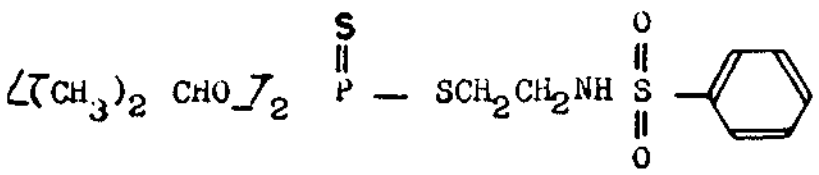
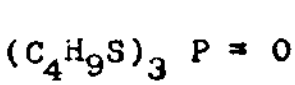
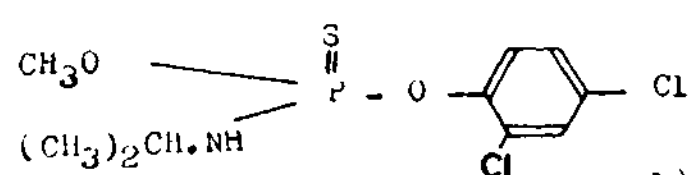
(Rhone - Poulenc Phytosanitare, 1978)



Aluminium tris (ethyl phosphonate).

Colourless powder, decomposing 200°C, systemic fungicide, effective against phycomycete diseases $LD_{50}$, 5800 mg a-1/kg.

## HERBICIDES AND PLANT GROWTH REGULATORS

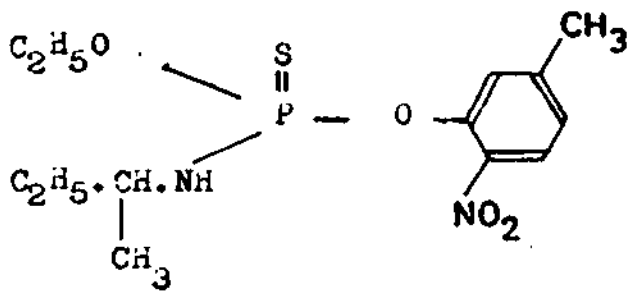
| Common or Trade name<br>Chemical name and<br>Chemical designations. | Physical and biological properties |
|---|---|
| 1. Prefar(R), Betasan(R),<br>Bensulide<br>(Stauffer Chem. Co. 1964)<br>  <br>N-(2-mercaptoethyl) benzenesulfonamides-S-(O,O-= di-isopropyl phosphorodithionate). | Super cooled liquid or solid, mp. 34.5; herbicide, effective for the pre-emergence control of weeds, principally crabgrans, with a long action, $LD_{50}$, 770 mg/kg. |
| 2. DEF(R), bulifos<br>(Ethyl Corporation. 1954).<br>  <br>S,S,S - tributyl phosphorotrithiolate. | Liquid, effective defoliant for use on cotton; it is a synergist of malathion; $LD_{50}$, 325 mg/kg. |
| 3. DMPA, Zytron(R)<br>(Dow Chem. Co. 1959).<br>  <br>O-methyl O-(2,4 - dichlorophenyl) N-isopropylphosphoramidothionate. | Solid, mp. 51°C, pre-emergence selective herbicide for control of Crabgran in turf; $LD_{50}$, 270 mg/kg, it shows delayed neurotoxicity. |

(Contd..)

4. Cremart,

S - 2846

(Sumitomo Chem. Co.)



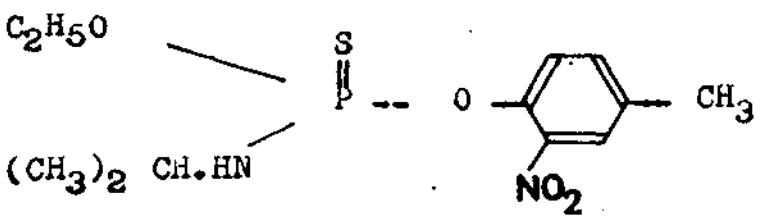
O - ethyl O-(3-methyl-6-nitrophenyl)

N-sec - butylphosphoramidothionate.

Liquid; pre-emergence herbicide, used in Cereal, beans, Carrot etc.; $LD_{50}$, 790 mg/kg (male rat).

5. Amiprophos

(Nihon Tokushu Noyaku Co. 1971)

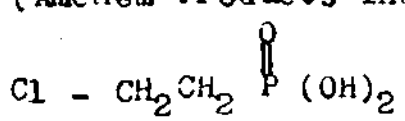


O - ethyl O-(2-nitro-4-methyl) N-isopropyl Phosphoramidothionate.

herbicide; $LD_{50}$, 720 mg/kg.

6. Ethephon, Ethrel (R)

(Amchem Products Incorporated)



2-chloroethylphosphonic acid

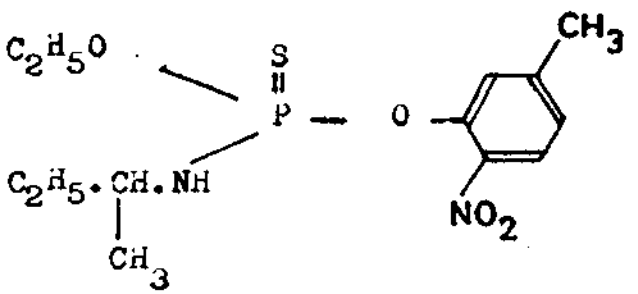
Hygroscopic solid, mp. 74-75°C; plant growth regulator;

$LD_{50}$, 4,200 mg/kg.

(Contd..)

4. **Cremart,**
S - 2846
(Sumitomo Chem. Co.)

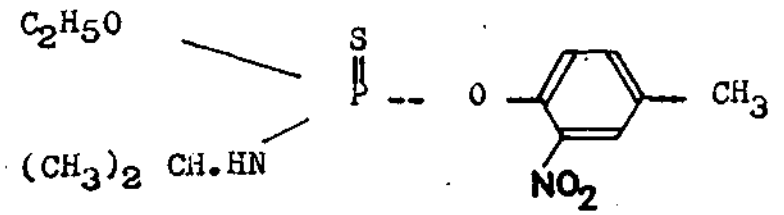
Liquid; pre-emergence herbicide, used in Cereal, beans, Carrot etc.; $LD_{50}$, 790 mg/kg (male rat).



O - ethyl O-(3-methyl-6-nitrophenyl)
N-sec - butylphosphoramidothionate.

5. Amiprophos
(Nihon Tokushu Noyaku Co. 1971)

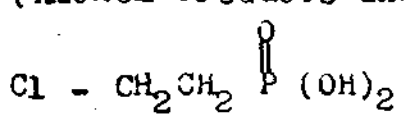
herbicide; $LD_{50}$, 720 mg/kg.



O - ethyl O-(2-nitro-4-methyl) N-isopropyl
Phosphoramidothionate.

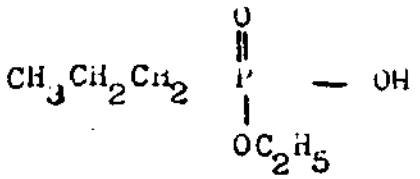
6. Ethephon, Ethrel(R)
(Amchem Products Incorporated)

Hygroscopic solid, mp. 74-75°C; plant growth regulator;
$LD_{50}$, 4,200 mg/kg.



2-chloroethylphosphonic acid

7. NIA 10637

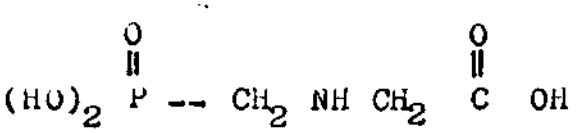


O-ethyl np-propylphosphonic acit.

Plant growth regulator, by reducing internode elongation;

8. Glyphosate

(Monsanto Co. 1971)



N-(phosphonomethyl) glycine

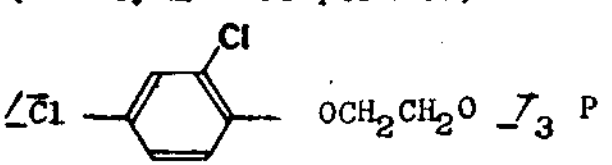
The monp-isoproypylamine salt of Glyphosate is called Roundup(R).

Solid, mp. 230°C; postemergence herbicide for broad spectrum control of both annual and perennial weeds; $LD_{50}$, 4,320 mg/kg.

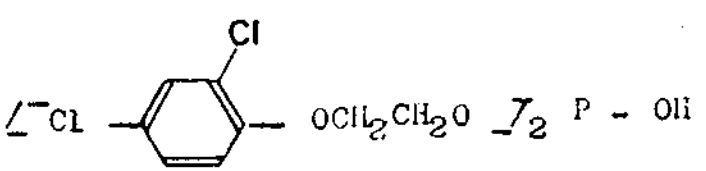
9. Falone(R), Falodin(R)

2,4-DEP

(Uniroyal Incorporated)



(tris form)



(bis form)

Useful for pre-emergence weed control;

$LD_{50}$, 850 mg/kg.

10. Folex(R),

merphos

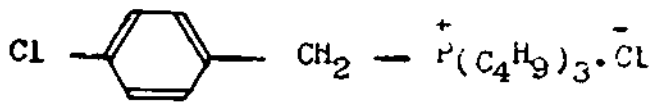
$(C_4H_9S)_3$ P

Tributyl phosphorotrithioite.

Liquid; very effective cotton defoliant; $LD_{50}$, 1,270 mg/kg.

(Contd.)

11. Phosfon (R)

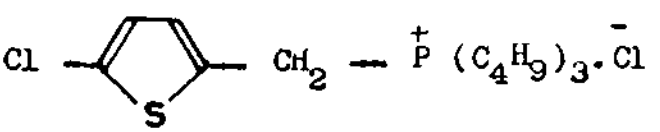


2,4-dichlorobenzyltributylphosphonium chloride

Solid, mp. 114 to 120°C; effective as height retardant;

$LD_{50}$, 173 mg/kg.

12. CTBP



5-chloro-2-thenyltributylphosphonium-chloride

The yield of snap beans (phaseolus vulgaris) is increased by a foliar spray of CTBP.

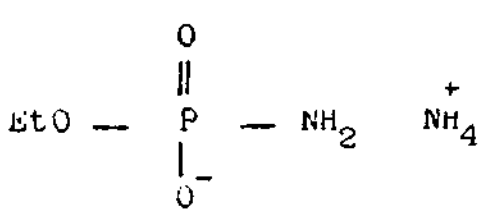
13.

$(C_4H_9)\ \overset{+}{P}\ (C_2H_5)_3.\bar{C}l$

Butyltriethylphosphoniumchloride

Defoliant.

14. Fosamine - amonium

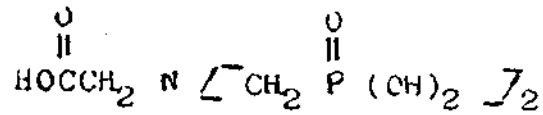


Amonium ethylcarbamoylphosphonate.

Solid, mp. - 175°C effective against woody plants.

$LD_{50}$, 24,000 mg/kg.

15. Glyphosine

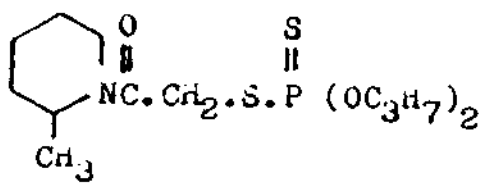


N,N- bis (phosphonomethyl) glycine.

Solid, plant growth regulator used to hasten ripening of sugarcane and to increase sucrose content.
$LD_{50}$, 3925 mg/kg.

16. Piperophos.

(Ciba - Geigy AG. 1969)

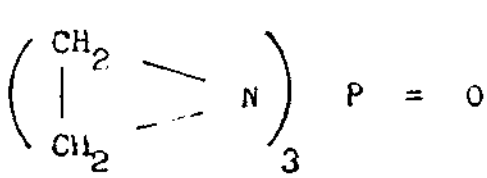


S-2-methyl piperidino carbonyl methyl
O, O - dipropyl phosphorodithioate.

Oil in room temp., but decomposes on heating, selective herbicide against annual grasses and sedges in rice, $LD_{50}$, 324 mg/kg.

## INSECT CHEMOSTERILANTS

| Common or trade name, Chemical name and Chemical designations. | Physical and biological properties. |
|---|---|
| 1. Tepa, APO, Aphoxide | Hygroscopic solid, mp.45°C, highly selective sterilant, $LD_{50}$, 37 mg/kg. |

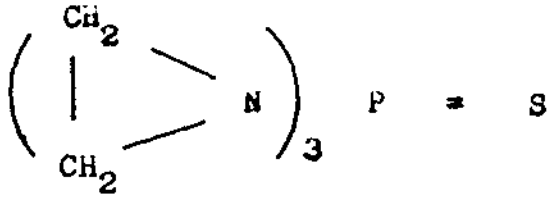


Tris-(1-aziridinyl) phosphine oxide.

(Contd.)

2. Thiotepa

Solid, mp. 51.5° ; suitable for sterilization of Culex pipiens quinquefasciatus.

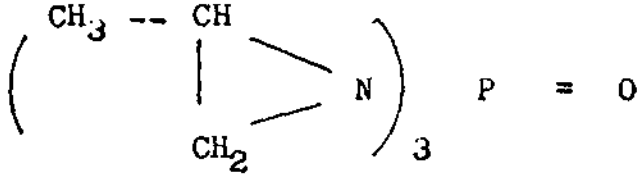


Tris - (1-aziridinyl) phosphine sulphide

3. Metapa, MAPO

Liquid; $LD_{50}$, 136 mg/kg.

Methaphoxide.



Tris (2-methyl-1-aziridinyl) phosphine oxide

4. Hempa,
HMPA, HMP

Liquid; $LD_{50}$, 2640 mg/kg.

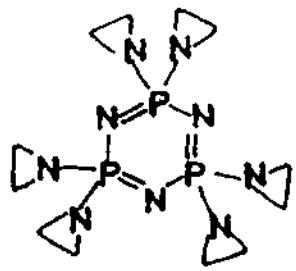
$[(CH_3)_2 N]_3 P = O$

Hexamethylphosphoric triamide

(Contd.)

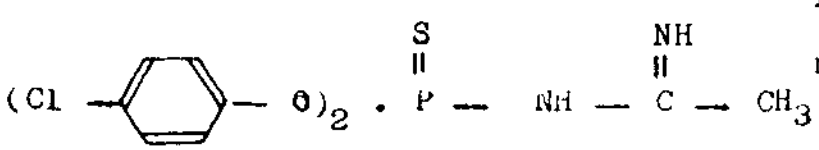
5. Apholate, Omaflora(R) — Solid, mp. 155°C.

APN



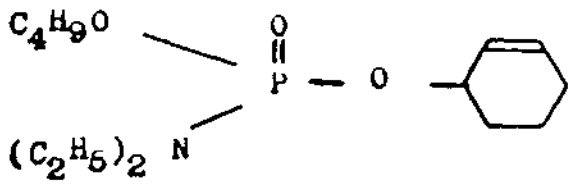
2,2,4,4,6,6 - Hexakis (1-aziridinyl)-2,2,4,4,6,6 - Hexahydro - 1,3,5,2,4,6-triazatriphosphorine.

## RODENTICIDES, INSECT RAPALLENTS AND INSECTICIDE SYNERGISTS.

| Common or trade name, Chemical name and Chemical designations. | Physical and biological properties. |
|---|---|
| 1. Gophacide(R) (Bayer AG)  O,O - di-(p-chlorophenyl) N-acetimidophosphoramidothionate. | Solid, mp. 104-106°C; rodenticide; $LD_{50}$, 7.5 mg/kg. |

(Contd.)

2. Liquid; repellents for fleas, mosquitoes and house flies.



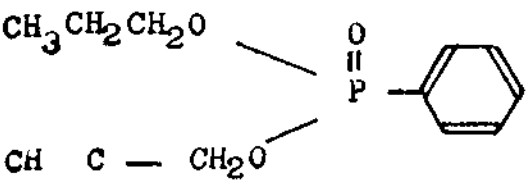
O-butyl O-cychohexenyl N,N-diethylphosphoramidate.

n-butyl isomer, b.p. 173-175°C (9 mm Hg)

Iso " " , b.p. 165-170°C (8 mg Hg)

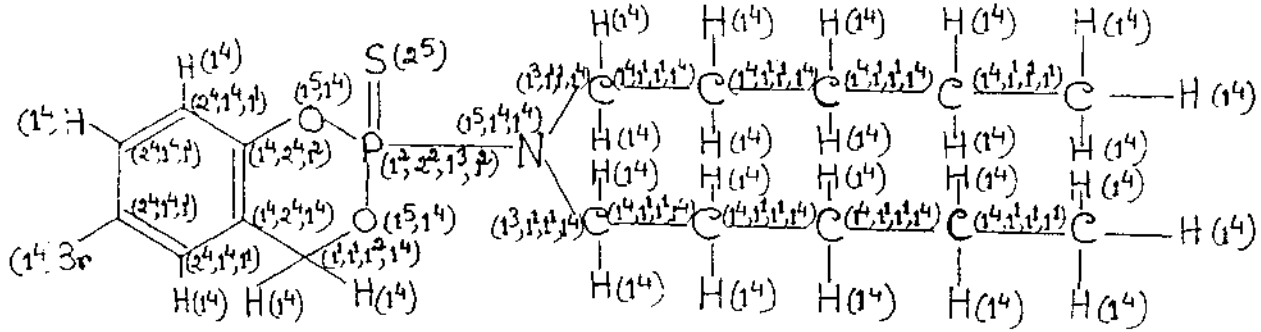
3. NIA 16388
(Niagara Chemical Division FMC)

Liquid, synergist of pyrethroids; shows juvenile hormone activity; $LD_{50}$, 362 mg/kg.



O - n - propyl O - (2-propynyl) phenyl phosphonate.

# APPENDIX - II



BR-8

$n = 50$

H : $\{(1^4) \times 27\}$ S : $\{(2^5) \times 1\}$ C : $\{(2^4,1^4,1^1) \times 4\}$ ; $\{(1^1,1^1,1^2,1^4) \times 1\}$

N : $\{(1^5,1^4,1^4) \times 1\}$ P : $\{(1^2,2^2,1^3,1^2) \times 1\}$ $\{(1^4,2^4,1^4) \times 1\}$ ; $\{(1^3,1^1,1^1,1^4) \times 2\}$

Br : $\{(1^4) \times 1\}$ O : $\{(1^5,1^4) \times 2\}$ $\{1^4,2^4,1^2) \times 1\}$ ; $\{(1^4,1^1,1^1,1^4) \times 6\}$

$\{(1^4,1^1,1^1,1^1) \times 2\}$

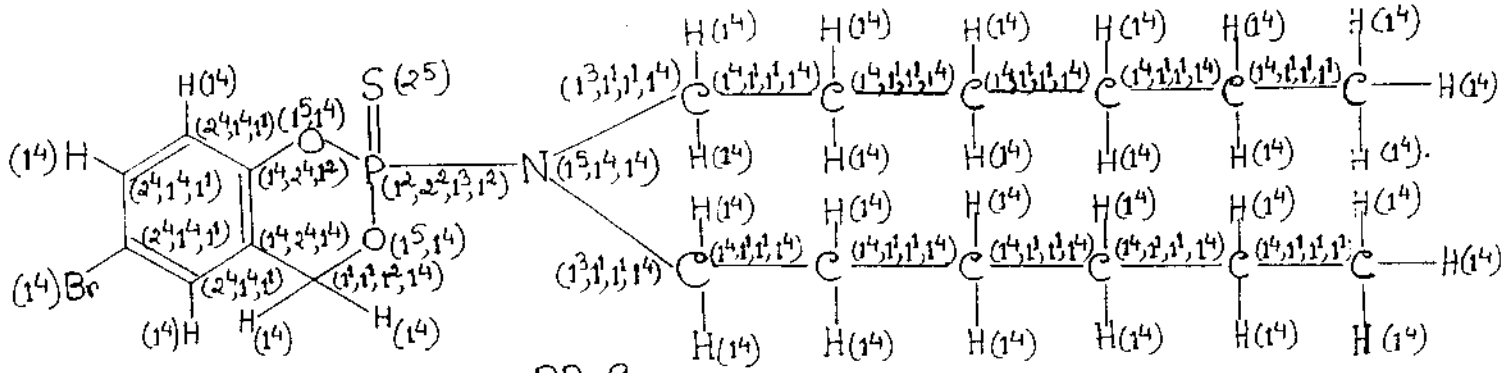
$$I'(C) = -\left\{1\times\frac{27}{50}\log_2\frac{27}{50} + 3\times\frac{2}{50}\log_2\frac{2}{50} + 1\times\frac{4}{50}\log_2\frac{4}{50} + 1\times\frac{6}{50}\log_2\frac{6}{50} + 7\times\frac{1}{50}\log_2\frac{1}{50}\right\}$$

$$= -\left\{\frac{27}{50}\log_2 27 + \frac{6}{50}\log_2 2 + \frac{4}{50}\log_2 4 + \frac{6}{50}\log_2 6 + \log_2\frac{1}{50}\right\}$$

$$= 2.4864 \text{ bits}$$

$$I(C) = -\left\{50\times\frac{1}{50}\log_2\frac{1}{50}\right\} = 5.6445 \text{ bits}$$

$$S.I.C = 2.4864/\log_2 50 = 0.4405$$



BR-9

$n = 56$

H: $\{(1^4) \times 31\}$

N: $\{(1^5, 1^4, 1^4) \times 1\}$

Br: $\{(1^4) \times 1\}$

S: $\{(1^5, 1^4) \times 1\}$

P: $\{(1^2, 2^2, 1^3, 1^2) \times 1\}$

O: $\{(1^5, 1^4) \times 2\}$

C: $\{(2^4, 1^4, 1^1) \times 4\}$ ; $\{(1^1, 1^1, 1^2, 1^4) \times 1\}$

$\{(1^4, 2^4, 1^4) \times 1\}$ ; $\{(1^3, 1^1, 1^1, 1^4) \times 2\}$

$\{(1^4, 2^4, 1^2) \times 1\}$ ; $\{(1^4, 1^1, 1^1, 1^4) \times 8\}$

$\{(1^4, 1^1, 1^1, 1^1) \times 2\}$

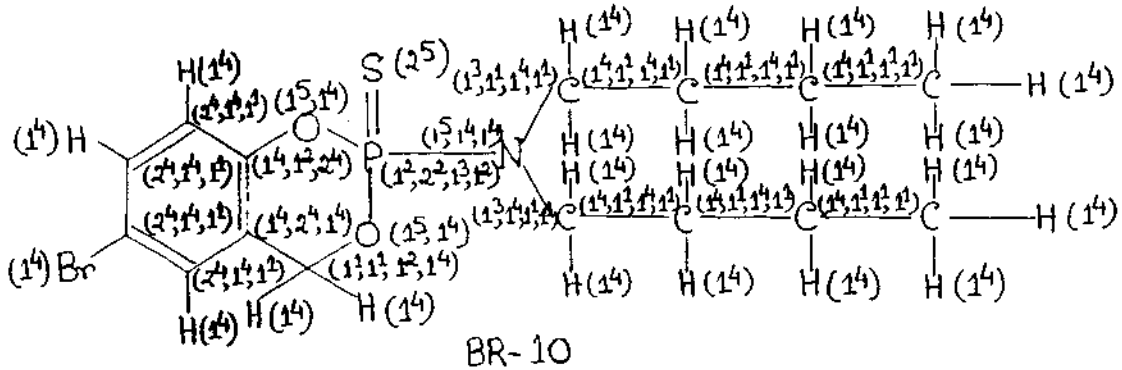
$$I'(C) = -\left\{1 \times \frac{31}{56} \log_2 \frac{31}{56} + 3 \times \frac{2}{56} \log_2 \frac{2}{56} + 1 \times \frac{4}{56} \log_2 \frac{4}{56} + 1 \times \frac{8}{56} \log_2 \frac{8}{56} + 7 \times \frac{1}{56} \log_2 \frac{1}{56}\right\}$$

$$= -\left\{\frac{31}{56} \log_2 31 + \frac{6}{56} \log_2 2 + \frac{4}{56} \log_2 4 + \frac{8}{56} \log_2 8 + \log_2 \frac{1}{56}\right\}$$

$= 2.3867$ bits

$$I(C) = -\left\{56 \times \frac{1}{56} \log_2 \frac{1}{56}\right\} = 5.8080 \text{ bits}$$

$S.I.C = 2.3867 / \log_2 56 = 0.4109$



BR-10

C: $\{(2^4,1^4,1^1)\times 4\}$; $\{(1^3,1^1,1^4,1^1)\times 2\}$; $\{(1^4,2^4,1^4)\times 1\}$; $\{(1^4,1^1,1^4,1^1)\times 4\}$; $\{(1^4,1^2,2^4)\times 1\}$; $\{(1^4,1^1,1^1,1^1)\times 2\}$; $\{(1^1,1^1,1^2,1^4)\times 1\}$;

$n = 44$

H: $\{(1^4)\times 23\}$

N: $\{(1^5,1^4,1^4)\times 1\}$

Br: $\{(1^4)\times 1\}$

S: $\{(2^5)\times 1\}$

P: $\{(1^2,2^2,1^3,1^2)\times 1\}$

O: $\{(1^5,1^4)\times 2\}$

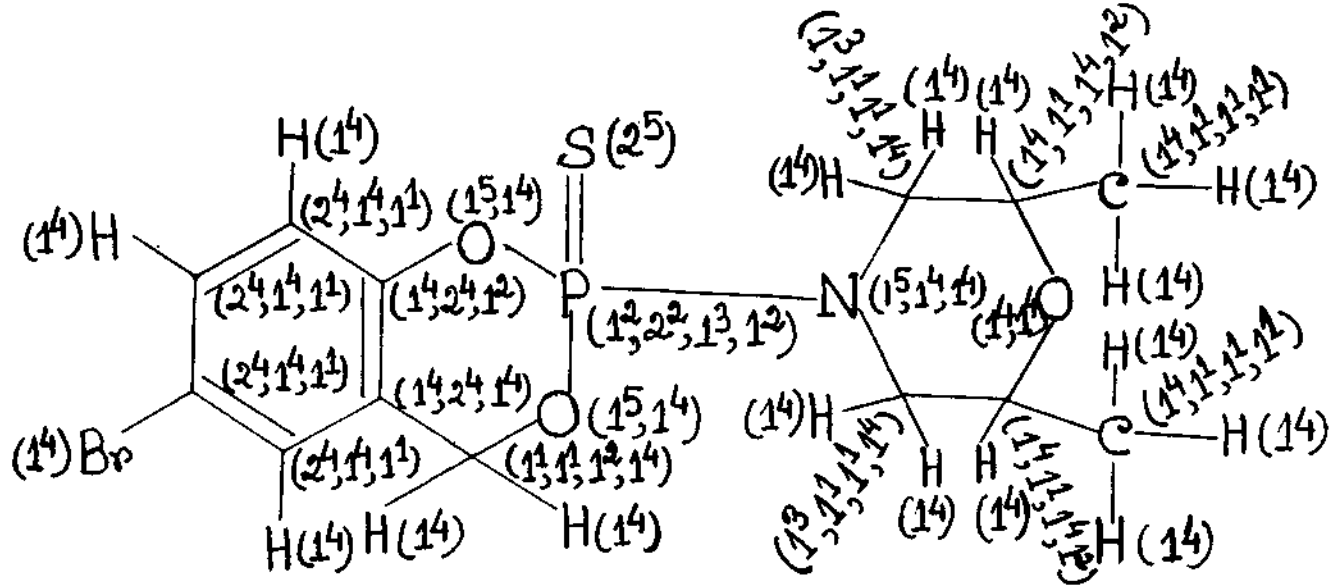
$$I'(C) = -\left\{1\times\frac{23}{44}\log_2\frac{23}{44} + 3\times\frac{2}{44}\log_2\frac{2}{44} + 2\times\frac{4}{44}\log_2\frac{4}{44} + 7\times\frac{1}{44}\log_2\frac{1}{44}\right\}$$

$$= -\left\{\frac{23}{44}\log_2 23 + \frac{6}{44}\log_2 2 + \frac{8}{44}\log_2 4 + \log_2\frac{1}{44}\right\}$$

$$= 2.5951 \text{ bits}$$

$$I(C) = -\left\{44\times\frac{1}{44}\log_2\frac{1}{44}\right\} = 5.46 \text{ bits}$$

$$S.I.C = 2.5951/\log_2 44 = 0.4753$$



BR-12

$n = 37$

H: $\{(1^4) \times 17\}$

N: $\{(1^5, 1^4, 1^4) \times 1\}$

Br: $\{(1^4) \times 1\}$

S: $\{(2^5) \times 1\}$

P: $\{(1^2, 2^2, 1^3, 1^2) \times 1\}$

O: $\{(1^5, 1^4) \times 2\}$

$\{(1^4, 1^4) \times 1\}$

C: $\{(2^4, 1^4, 1^1) \times 4\}$; $\{(1^3, 1^1, 1^1, 1^4) \times 2\}$

$\{(1^4, 2^4, 1^4) \times 1\}$; $\{(1^4, 1^1, 1^4, 1^2) \times 2\}$

$\{(1^4, 2^4, 1^2) \times 1\}$; $\{(1^4, 1^1, 1^1, 1^1) \times 2\}$

$\{(1^1, 1^1, 1^2, 1^4) \times 1\}$

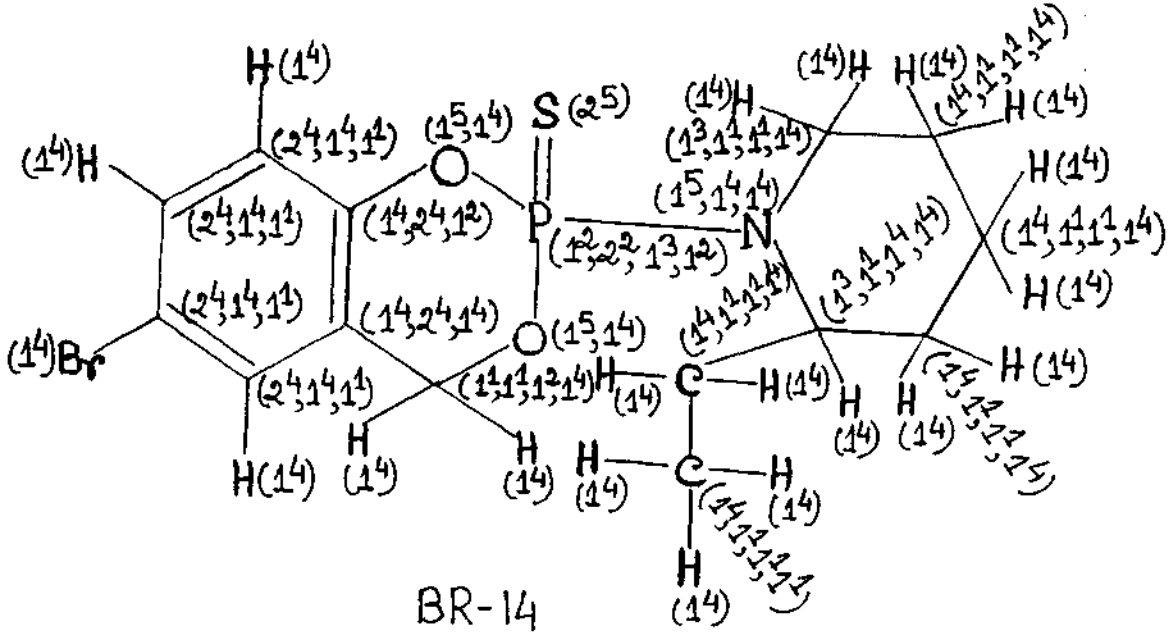
$$I'(C) = -\left\{1 \times \frac{17}{37} \log_2 \frac{17}{37} + 4 \times \frac{2}{37} \log_2 \frac{2}{37} + 1 \times \frac{4}{37} \log_2 \frac{4}{37} + 8 \times \frac{1}{37} \log_2 \frac{1}{37}\right\}$$

$$= -\left\{\frac{17}{37} \log_2 17 + \frac{8}{37} \log_2 2 + \frac{4}{37} \log_2 4 + \log_2 \frac{1}{37}\right\}$$

$$= 2.8994 \text{ bits}$$

$$I(C) = -\left\{37 \times \frac{1}{37} \log_2 \frac{1}{37}\right\} = 5.21 \text{ bits}$$

$$S.I.C = 2.8994 / \log_2 37 = 0.5565$$



BR-14

$n = 39$

H: $\{(1^4) \times 19\}$

N: $\{(1^5, 1^4, 1^4) \times 1\}$

Br: $\{(1^4) \times 1\}$

S: $\{(2^5) \times 1\}$

P: $\{(1^2, 2^2, 1^3, 1^2) \times 1\}$

O: $\{(1^5, 1^4) \times 2\}$

C: $\{(2^4, 1^4, 1^1) \times 4\}$ ; $\{(1^3, 1^1, 1^1, 1^4) \times 1\}$
$\{(1^4, 2^4, 1^4) \times 1\}$ ; $\{1^3, 1^1, 1^4, 1^4) \times 1\}$
$\{(1^4, 2^4, 1^2) \times 1\}$ ; $\{(1^4, 1^1, 1^1, 1^4) \times 4\}$
$\{(1^1, 1^1, 1^2, 1^4) \times 1\}$ ; $\{(1^4, 1^1, 1^1, 1^1) \times 1\}$

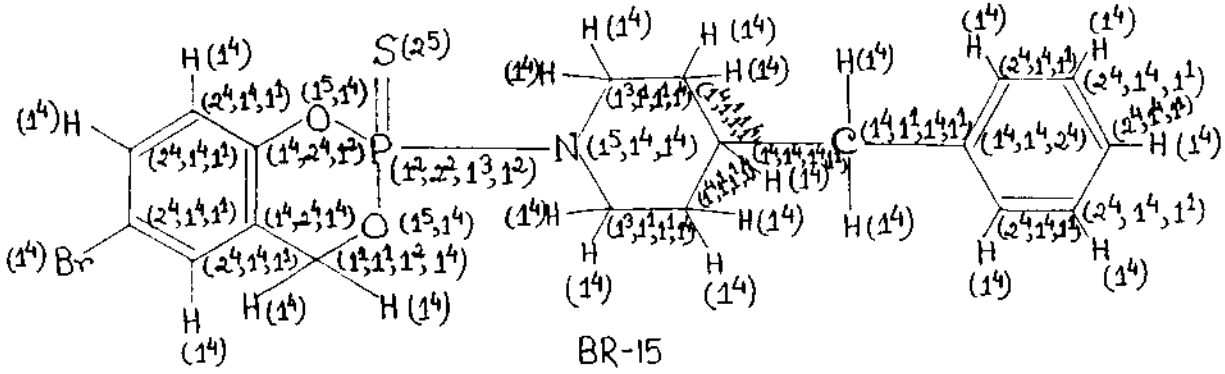
$$I'(C) = -\left\{1 \times \frac{19}{39} \log_2 \frac{19}{39} + 1 \times \frac{2}{39} \log_2 \frac{2}{39} + 2 \times \frac{4}{39} \log_2 \frac{4}{39} + 10 \times \frac{1}{39} \log_2 \frac{1}{39}\right\}$$

$$= -\left\{\frac{19}{39} \log_2 19 + \frac{2}{39} \log_2 2 + \frac{8}{39} \log_2 4 + \log_2 \frac{1}{39}\right\}$$

$= 2.7548$ bits

$$I(C) = -\left\{39 \times \frac{1}{39} \log_2 \frac{1}{39}\right\} = 5.2860 \text{ bits}$$

$$S.I.C = 2.7548 / \log_2 39 = 0.5211$$



BR-15

$n = 46$

H: $\{(1^4)\times 21\}$ S: $\{(2^5)\times 1\}$

N: $\{(1^5,1^4,1^4)\times 1\}$ P: $\{(1^2,2^2,1^3,1^2)\times 1\}$

Br: $\{(1^4)\times 1\}$ O: $\{(1^5,1^4)\times 2\}$

C: $\{(2^4,1^4,1^1)\times 9\}$ ; $\{(1^3,1^1,1^1,1^4)\times 2\}$
$\{(1^4,2^4,1^4)\times 1\}$ ; $\{(1^4,1^1,1^1,1^4)\times 3\}$
$\{(1^4,2^4,1^2)\times 1\}$ ; $\{(1^4,1^4,1^4,1^1)\times 1\}$
$\{(1^1,1^1,1^2,1^4)\times 1\}$ ; $\{(1^4,1^4,2^4)\times 1\}$

$$I'(C) = -\left\{1\times\frac{21}{46}\log_2\frac{21}{46} + 2\times\frac{2}{46}\log_2\frac{2}{46} + 1\times\frac{3}{46}\log_2\frac{3}{46} + 1\times\frac{9}{46}\log_2\frac{9}{46} + 9\times\frac{1}{46}\log_2\frac{1}{46}\right\}$$

$$= -\left\{\frac{21}{46}\log_2 21 + \frac{4}{46}\log_2 2 + \frac{3}{46}\log_2 3 + \frac{9}{46}\log_2 9 + \log_2\frac{1}{46}\right\}$$

$$= 2.7082 \text{ bits}$$

$$I(C) = -\left\{46\times\frac{1}{46}\log_2\frac{1}{46}\right\} = 5.5242 \text{ bits}$$

$$S.I.C = 2.7082/\log_2 46 = 0.4902$$

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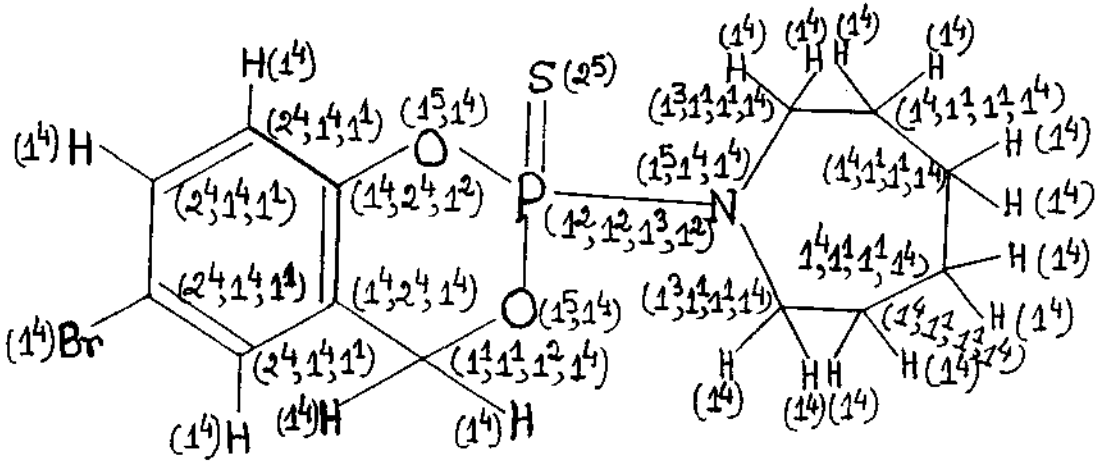

BR-17

$n = 36$

H: $\{(1^4) \times 17\}$

N: $\{(1^5, 1^4, 1^4) \times 1\}$

Br: $\{(1^4) \times 1\}$

S: $\{(2^5) \times 1\}$

P: $\{(1^2, 2^2, 1^3, 1^2) \times 1\}$

O: $\{(1^5, 1^4) \times 2\}$

C: $\{(2^4, 1^4, 1^1) \times 4\}$ ; $\{(1^1, 1^1, 1^2, 1^4) \times 1\}$

$\{(1^4, 2^4, 1^4) \times 1\}$ ; $\{(1^3, 1^1, 1^1 1^4) \times 2\}$

$\{(1^4, 2^4, 1^2) \times 1\}$ ; $\{(1^4, 1^1, 1^1, 1^4) \times 4\}$

$$I'(C) = -\left\{1 \times \frac{17}{36} \log_2 \frac{17}{36} + 2 \times \frac{2}{36} \log_2 \frac{2}{36} + 2 \times \frac{4}{36} \log_2 \frac{4}{36} + 7 \times \frac{1}{36} \log_2 \frac{1}{36}\right\}$$

$$= -\left\{\frac{17}{36} \log_2 17 + \frac{4}{36} \log_2 2 + \frac{8}{36} \log_2 4 + \log_2 \frac{1}{36}\right\}$$

$$= 2.6846 \text{ bits}$$

$$I(C) = -\left\{36 \times \frac{1}{36} \log_2 \frac{1}{36}\right\} = 5.1705 \text{ bits}$$

$$S.I.C = 2.6846 / \log_2 36 = 0.5192$$