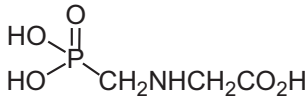
# 445 glyphosate *Herbicide*

**HRAC** G **WSSA** 9; glycine derivative



For a general review, see *Glyphosate*. For glyphosate-trimesium, see Superseded Entries.

**NOMENCLATURE:** *glyphosate*
**Common name** glyphosate (BSI, E-ISO, (*m*) F-ISO, ANSI, WSSA, JMAF)
**IUPAC name** *N*-(phosphonomethyl)glycine
**Chemical Abstracts name** *N*-(phosphonomethyl)glycine
**Other names** sulfosate* (for discontinued dimethylsulfonium salt) **CAS RN** *[1071–83–6]*
**EC no.** 213–997–4 **Development codes** MON-0573 (Monsanto); CP 67573 (Monsanto)

*glyphosate-ammonium*
**CAS RN** *[40465–66–5]* monoammonium salt; *[114370–14–8]* mono- or di- ammonium salt (unspecified) **Development codes** MON 8750 (Monsanto)

*glyphosate-diammonium*
**CAS RN** *[69254–40–6]*; *[114370–14–8]* mono- or di- ammonium salt (unspecified)

*glyphosate-dimethylammonium*
**CAS RN** *[34494–04–7]*

*glyphosate-isopropylammonium*
**CAS RN** *[38641–94–0]* **EC no.** 254–056–8 **Development codes** MON 0139 (Monsanto); MON 77209 (Monsanto)

*glyphosate-potassium*
**CAS RN** *[39600–42–5]* monopotassium salt; *[70901–12–1]* unspecified potassium salt

*glyphosate-sesquisodium*
**CAS RN** *[70393–85–0],* formerly *[68822–12–8]*; *[34494–03–6]* monosodium salt
**Development codes** MON 8000; MON 8722 for glyphosate-sodium (both Monsanto)

**PHYSICAL CHEMISTRY:** *glyphosate*
**Composition** Tech. is ≥95% pure. Zwitterion structure (P. Knuuttila & H. Knuuttila, *Acta Chem. Scand.,* 1979, **33,** 623). **Mol. wt.** 169.1 **M.f.** $C_3H_8NO_5P$ **Form** Odourless, white crystals. **M.p.** Decomp. 200 °C **V.p.** $1.31 \times 10^{-2}$ mPa (25 °C) **$K_{ow}$** logP <–3.2 (pH 2–5, 20 °C) (OECD 107; EEC A8) **Henry** $<2.1 \times 10^{-7}$ Pa $m^3$ $mol^{-1}$ (calc.) **S.g./density** 1.705 (20 °C) **Solubility** In water 10.5 g/l (pH 1.9, 20 °C). Practically insoluble in common organic solvents, e.g. acetone, ethanol and xylene. The alkali-metal and amine salts are readily soluble in water.
**Stability** Glyphosate and all its salts are non-volatile, do not photochemically degrade in buffered water and are stable in air. Glyphosate is stable to hydrolysis at pH 3, 6 and 9 (5–35 °C). **pKa** 2.34 (20 °C), 5.73 (20 °C), 10.2 (25 °C) **F.p.** Not flammable

*glyphosate-ammonium*
**Composition** Tech. is 95.2% pure. **Mol. wt.** 186.1 **M.f.** $C_3H_{11}N_2O_5P$ **Form** Odourless, white powder. **M.p.** Decomp. >190 °C, without melting **V.p.** $9 \times 10^{-3}$ mPa (25 °C)
**$K_{ow}$** logP <–3.7 **Henry** $1.16 \times 10^{-8}$ Pa $m^3$ $mol^{-1}$ (calc.) **S.g./density** 1.433 (22 °C) **Solubility** In

water 144±19 g/l (pH 3.2). Essentially insoluble in organic solvents. **Stability** Stable over 5 days at 50 °C (pH 4, 7 and 9). **pKa** See isopropylammonium salt **F.p.** Not flammable

*glyphosate-diammonium*
**Mol. wt.** 203.1 **M.f.** $C_3H_{14}N_3O_5P$

*glyphosate-dimethylammonium*
**Mol. wt.** 214.2 **M.f.** $C_5H_{15}N_2O_5P$

*glyphosate-isopropylammonium*
**Composition** As a wet cake, contains *c.* 62% *w/w* isopropylammonium salt, *c.* 35% water. **Mol. wt.** 228.2 **M.f.** $C_6H_{17}N_2O_5P$ **Form** Odourless, white powder. **M.p.** Occurs in 2 steps, 143–164 °C and 189–223 °C **B.p.** Decomposes without boiling **V.p.** $2.1 \times 10^{-3}$ mPa (25 °C) $K_{ow}$ logP = –5.4 **Henry** $4.6 \times 10^{-10}$ Pa $m^3$ $mol^{-1}$ (25 °C, calc.) **S.g./density** 1.482 (20 °C) **Solubility** In water 1050 g/l (25 °C, pH 4.3). In dichloromethane <0.5, methanol 19.86 (both in g/l, 20 °C). **Stability** Stable 5 days at pH 4, 5 and 9 (50 °C). **pKa** 5.77±0.03, 2.18±0.02 (20±2 °C) (OECD 112)

*glyphosate-potassium*
**Composition** In products described as containing glyphosate-potassium, the CAS Registry Number for the salt with unspecified potassium content is usually quoted. **Mol. wt.** 207.2 (monopotassium salt) **M.f.** $C_3H_7KNO_5P$ (monopotassium salt)

*glyphosate-sesquisodium*
**Mol. wt.** 405.2; 191.1 glyphosate-sodium **M.f.** $C_6H_{14}N_2Na_3O_{10}P_2$; $C_3H_7NNaO_5P$ (glyphosate-sodium) **Form** Odourless, white powder. **M.p.** Decomp. >260 °C **V.p.** $7.56 \times 10^{-3}$ mPa (25 °C) $K_{ow}$ logP = –4.58 (tech., 25 °C) **Henry** $4.27 \times 10^{-9}$ Pa $m^3$ $mol^{-1}$ (glyphosate-sodium, calc.) **S.g./density** 1.622 (20 °C) (glyphosate-sodium) **Solubility** In water 335±31.5 g glyphosate-sodium/l of solution (or 414±51.8 g glyphosate-sodium/l of water) (pH 4.2, 20 °C). **Stability** Stable over 5 days (pH 4, 7 and 9, 50 °C).

**COMMERCIALISATION:** **History** Herbicidal activity reported by D. D. Baird *et al.* (*Proc. North Cent. Weed Control Conf.*, 1971, **26,** 64). The isopropylammonium, sodium and ammonium salts introduced by Monsanto Co. in 1974. The trimesium salt (*q.v.*, in Superseded Entries) introduced in 1989; the potassium salt introduced in 2002. The diammonium salt introduced by Syngenta AG. **Patents** US 3799758 (to Monsanto); EP 53871; US 4315765 (both to ICI) **Manufacturers** Monsanto; ACA; Agrochem; AgroDragon; Ancom; Anhui Huaxing; Anpon; Aragro; Atanor; Baocheng; Binnong; CAC; Cheminova; Chongqing Shuangfeng; Comlets; Dow AgroSciences; Drexel; Excel; Feinchemie Schwebda; Fertiagro; Guangxin Agrochemical; Hebei Golhil; Herbex; High Kite; Hubei Sanonda; Hui Kwang; Huifeng Agrochemical; Iprochem; Jiangsu Good Harvest; Jiangsu Kuaida; Jiangsu Yangnong; Jinfanda; Jingma; KSA; Makhteshim-Agan; Nantong Jiangshan; Nortox; Nufarm China; Pyosa; Qingdao Kyx; Rainbow; Red Sun; Reposo; Sabero; Sannong; Sanonda Zhengzhou; Shandong Qiaochang; Shanghai Kaipu; Sharda; Sinon; Sundat; Xinan; Zhejiang Linghua

**APPLICATIONS:** **Biochemistry** Inhibits 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), an enzyme of the aromatic acid biosynthetic pathway. This prevents synthesis of essential aromatic amino acids needed for protein biosynthesis. **Mode of action** Non-selective systemic herbicide, absorbed by the foliage, with rapid translocation throughout the plant. Inactivated on contact with soil.

*glyphosate*
**Uses** Control of annual and perennial grasses and broad-leaved weeds, pre-harvest, in cereals, peas, beans, oilseed rape, flax and mustard, at *c.* 1.5–2 kg/ha; control of annual and perennial grasses and

broad-leaved weeds in stubble and post-planting/pre-emergence of many crops; as a directed spray in vines and olives, at up to 4.3 kg/ha; in orchards, pasture, forestry and industrial weed control, at up to 4.3 kg/ha. As an aquatic herbicide, at *c.* 2 kg/ha. **Formulation types** SG; SL.
**Compatibility** Mixing with other herbicides may reduce the activity of glyphosate.
**Selected products** 'Gladiator' (Devidayal); 'Glyfall' (Hermoo); 'Karda' (Lainco); 'Maxweed' (Crop Health); 'Nasa' (Agria); 'Pilarsato' (Pilarquim); 'Rinder' (Inquiport); 'Rophosate' (Rotam); 'Seccherba' (Agrimix); 'Sharp' (Baocheng); **mixtures** 'Folar' (+ terbuthylazine) (Syngenta).

*glyphosate-diammonium*
**Selected products** 'Touchdown' (some Touchdown products contain glyphosate-potassium) (Syngenta).

*glyphosate-isopropylammonium*
**Selected products** 'Roundup' (Monsanto); 'Asset' (Ancom); 'Cosmic' (Arysta LifeScience EAME); 'Fozat' (Agro-Chemie); 'Gallup' (Barclay); 'Glycel' (Excel); 'Glyfos' (Cheminova); 'Glyphogan' (Makhteshim-Agan); 'Glyphomax' (Dow AgroSciences); 'Glyphotox' (Aimco); 'Glysate' (Mobedco); 'Ground-Up' (Vapco); 'Nufosate' (Nufarm UK); 'Oxalis' (Arysta LifeScience EAME); 'Rodeo' (Dow AgroSciences); 'Rondo' (Reposo); 'Sanos' (Hubei Sanonda); 'Vifosat' (Vipesco); 'Yerbimat' (Ingeniería Industrial); **mixtures** 'PrePass' (+ florasulam) (Dow AgroSciences).

*glyphosate-sesquisodium*
**Uses** A sugar cane ripener. Sodium salts, with unspecified stoichiometry, also used as a non-selective herbicide.

**ANALYSIS:** **Product** analysis by hplc with uv detection (*AOAC Methods,* 18th Ed., 983.10; *CIPAC Handbook,* 1985, **1C,** 2132; *ibid*., 1998, **H**, 182), or by ion-exchange lc with uv detection (*AOAC Methods,* 18th Ed., 996.12). **Residues** determined by gc with MSD (also applicable to aminomethylphosphonic acid, *AOAC Methods*, 18th Ed., 2000.05), by hplc with *o*-phthalaldehyde post-column reaction specific for primary amines (*J. Agric. Food Chem*., 1986, **34**(6), 955–960), or by gc/FPD (*Resid. Anal. Methods*). See also *Pestic. Anal. Man.,* **II**, 180.364. In **water** by hplc determination by *o*-phthalaldehyde post-column reaction system (*AOAC Methods*, 18th Ed., 991.08), by hplc/FLD (*Environ. Chem. Methods*), or by gc/FPD (*ibid*.). In **soil** by gc/FPD or gc/ms (*ibid*.).

**TOXICOLOGICAL & ENVIRONMENTAL REVIEWS:** *EHC* 159 (1994). *JMPR Mtg.* 104 (2005); *JMPR Evaln. I* 72 (1994), 81 (1997), 105 (2005); *JMPR Evaln. II* 49 (1986), 103 (2004); *JMPR Evaln. I* 81 (1997); *JMPR Evaln. II* 82 (1997) (for degradation product aminomethylphosphonic acid). *PDS* 91 (1996). *ICSC* 0160 (2005). **91/414/EC Annex I status** Included, 2001/99/EC.

**MAMMALIAN TOXICOLOGY:** *glyphosate*
**Oral** Acute oral $LD_{50}$ for rats >5000, mice >10 000, goats 3530 mg/kg. **Skin and eye** Acute percutaneous $LD_{50}$ for rabbits >5000 mg/kg. Eye irritant; non-irritating to skin (rabbits). Not a skin sensitiser (guinea pigs). **Inhalation** $LC_{50}$ (4 h) for rats >4.98 mg/l air. **NOEL** In 2 y feeding trials, no ill-effects were observed in rats receiving 410 mg/kg diet daily (ave.) and, in 1 y feeding trials, no ill-effects were observed in dogs receiving 500 mg/kg daily (highest dose treated). Lowest relevant NOAEL (2 y) for rats 31 mg/kg b.w. daily (EU). **ADI/RfD** (JMPR) 1 mg/kg b.w. [2004]; (EC) 0.3 mg/kg b.w. [2001]; (EPA) proposed RfD 2 mg/kg b.w. [1993]. **Water GV** GV not established (O). **Other** Not mutagenic, not carcinogenic, not teratogenic, not neurotoxic. No adverse effects on reproduction. **Toxicity class** WHO (a.i.) U; EPA (formulation) III. **EC classification** Xi; R41| N; R51, R53.

*glyphosate-ammonium*
**Oral** Acute oral $LD_{50}$ for rats 4613 mg/kg. **Skin and eye** Acute percutaneous $LD_{50}$ for rabbits >5000 mg/kg. Slight eye irritant; not a skin irritant (rabbits). **Inhalation** $LC_{50}$ for rats (whole body)

>1.9 mg/l air. **ADI/RfD** See glyphosate. **Toxicity class** EPA (formulation) III.
**EC classification** N; R51, R53.

*glyphosate-diammonium*
**EC classification** N; R51, R53.

*glyphosate-isopropylammonium*
**Oral** Acute oral $LD_{50}$ for rats >5000, goats 5700 mg/kg. **Skin and eye** Acute percutaneous $LD_{50}$ for rabbits >5000 mg/kg. Slight eye irritant; not a skin irritant (rabbits). **Inhalation** $LC_{50}$ (4 h) for rats >1.3 mg/l air. **NOEL** In a 6 mo capsule trial, no ill-effects were observed in dogs receiving 300 mg/kg daily (highest dose treated). **ADI/RfD** See glyphosate.
**Toxicity class** EPA (formulation) III. **EC classification** N; R51, R53.

*glyphosate-potassium*
**Oral** Acute oral $LD_{50}$ for rats >5000 mg/kg. **Skin and eye** Acute percutaneous $LD_{50}$ for rats >5000 mg/kg. Moderate eye irritant; not a skin irritant (rabbits). **Inhalation** $LC_{50}$ (4 h) for rats >5.27 mg/l air. **ADI/RfD** See glyphosate. **Toxicity class** EPA (formulation) III.
**EC classification** N; R51, R53.

*glyphosate-sesquisodium*
**Skin and eye** Acute oral $LD_{50}$ for rats >5000 mg/kg. Slight eye irritant; not a skin irritant (rabbits). **Toxicity class** EPA (formulation) IV. **EC classification** N; R51, R53.

ECOTOXICOLOGY: *glyphosate*
**Birds** Acute oral $LD_{50}$ for bobwhite quail >3851 mg/kg. Dietary $LC_{50}$ (5 d) for quail and ducks >4640 mg/kg diet. **Fish** $LC_{50}$ (96 h) for trout 86, bluegill sunfish 120, harlequin fish 168, sheepshead minnows >1000 mg/l. **Daphnia** $LC_{50}$ (48 h) 780 mg/l. **Algae** $E_bC_{50}$ (72 h) for green algae (*Selenastrum capricornutum*) 485 mg/l, (7 d) 13.8 mg/l, $E_rC_{50}$ (72 h) 460 mg/l; $EC_{50}$ (96 h) for marine algae (*Skeletonema costatum*) 1.3 mg/l, (7 d) 0.64 mg/l; $EC_{50}$ (7 d) for diatom (*Navicula pelliculosa*) 42, blue-green algae (*Anabaena flos-aquae*) 15 mg/l. **Other aquatic spp.** $LC_{50}$ (96 h) for mysid shrimps (*Mysidopsis bahia*) >1000, grass shrimps 281, fiddler crabs 934 mg/l. $EC_{50}$ (96 h) for sea urchins >1000 mg/l; (14 d) for *Lemna gibba* 25.5 mg/l; (48 h) for *Litoria moorei* tadpoles 111 mg/l. **Bees** $LD_{50}$ (48 h) (contact) >100 μg/bee; (oral) 100 μg/bee.
**Other beneficial spp.** Formulation of glyphosate had no effects on carabid beetles; harmless to slightly harmful to green lacewing, parasite species, mites/spiders and insects, except moderately harmful to *Bembidion lampros* (EU Guidelines).

*glyphosate-isopropylammonium*
**Fish** $LC_{50}$ (96 h) for trout and bluegill sunfish >1000, fathead minnows 97, channel catfish 130 mg/l. **Daphnia** $LC_{50}$ (48 h) 930 mg/l. **Algae** $E_bC_{50}$ (72 h) for *Scenedesmus subspicatus* 72.9 mg/l, $E_rC_{50}$ (72 h) 166 mg/l. **Other aquatic spp.** $EC_{50}$ (48 h) for midge larvae 5600, *Litoria moorei* tadpoles >343 mg/l. **Worms** $LC_{50}$ (14 d) for earthworms (*Eisenia foetida*) >5000 mg/kg soil. Reproductive toxicity NOEC (56 d) 28.79 mg/kg.

*glyphosate-potassium*
**Birds** Acute oral $LD_{50}$ for bobwhite quail >2241 mg a.e./kg. **Fish** $LC_{50}$ (96 h) for trout >1227 mg a.e./l. **Daphnia** $LC_{50}$ (48 h) >1227 mg a.e./l. **Algae** $E_bC_{50}$ (72 h) for green algae (*Selenastrum capricornutum*) 35 mg a.e./l, $E_rC_{50}$ (72 h) 54 mg a.e./l. **Bees** $LD_{50}$ (48 h) (contact and oral) >100 g a.e./bee.

ENVIRONMENTAL FATE: **Animals** In mammals, following oral administration, glyphosate is very rapidly excreted unchanged and does not bioaccumulate. **Plants** Slowly metabolised to aminomethylphosphonic acid (*[1066–51–9]*), which is the major plant metabolite.
**Soil/Environment** In soil (field), $DT_{50}$ 1–130 d, depending on edaphic and climatic conditions. In

water, $DT_{50}$ varies from a few to 91 d. Photodegradation in natural water occurs, $DT_{50}$ 33–77 d; no substantial photodegradation in soil was recorded over 31 d. In a lab. whole system with water and sediment, $DT_{50}$ 27–146 d (aerobic), 14–22 d (anaerobic). The major metabolite in soil and water is aminomethylphosphonic acid.