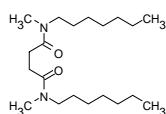


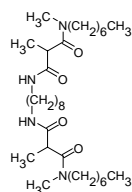
## Magnesium



### Magnesium Ionophore I

(ETH 1117; N,N'-Diheptyl-N,N'-dimethyl-1,4-butanediamide)  
 $C_{20}H_{40}N_2O_2$   $M_r$  340.55 [75513-72-3]

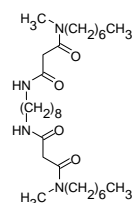
[63082](#) **Selectophore<sup>®</sup>, function tested** 50 mg, 250 mg



### Magnesium Ionophore II

(ETH 5214; N,N''-Octamethylenebis(N'-heptyl-N'-methyl-methylmalonamide)  
 $C_{32}H_{62}N_4O_4$   $M_r$  566.87 [119110-37-1]

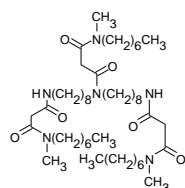
[63083](#) **Selectophore<sup>®</sup>, function tested** 50 mg



### Magnesium Ionophore III

(ETH 4030; N,N''-Octamethylenebis(N'-heptyl-N'-methylmalonamide)  
 $C_{30}H_{58}N_4O_4$   $M_r$  538.82 [119110-38-2]

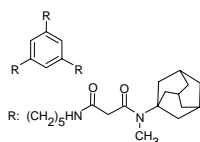
[63086](#) **Selectophore<sup>®</sup>, function tested** 50 mg, 250 mg



### Magnesium Ionophore IV

(ETH 7025; N-Heptyl-N',N'-bis{8-[[3-(heptylmethylamino)-1,3-dioxopropyl]amino]octyl}-N-methyl-propanediamide; N,N',N''-Tris[3-(heptylmethylamino)-3-oxopropionyl]8,8'-iminodioctylamine)  
 $C_{49}H_{94}N_6O_6$   $M_r$  863.32 [135734-39-3]

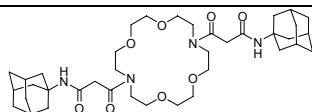
[63088](#) **Selectophore<sup>®</sup>, function tested** 50 mg solution in 0.5 ml tetrahydrofuran



### Magnesium Ionophore VI

(ETH 5506; 1,3,5-Tris[10-(1-adamantyl)-7,9-dioxo-6,10-diazaundecyl]benzene)  
 $C_{63}H_{96}N_6O_6$   $M_r$  1033.47 [151058-38-7]

[63112](#) **Selectophore<sup>®</sup>, function tested** 10 mg, 100mg



### Magnesium Ionophore VII

(K22B5; 4,13-Bis(N-adamantylcarbamoyl)acetyl]-1,7,10,16,tetraoxa-4,13-diazacyclooctadecane)  
 $C_{38}H_{60}N_4O_8$   $M_r$  700.91 [156210-12-7]

[00744](#) **Selectophore<sup>®</sup>, function tested** 10 mg, 100 mg

---

**Magnesium Ionophore I - Cocktail A**

Magnesium-selective membrane solution for microelectrodes

[63048](#) **Selectophore®** package with 0.1 mL

---

**Magnesium Ionophore II - Cocktail A**

Magnesium-selective membrane solution for microelectrodes

[63085](#) **Selectophore®** package with 0.1 mL

---

**Magnesium Ionophore III – Membrane A**[63098](#) **Selectophore®** package with 5 PVC membranes (diameter 7 mm)

---

**Magnesium Ionophore IV – Membrane A**[63099](#) **Selectophore®** package with 5 PVC membranes (diameter 7 mm)

---

**Electrochemical Transduction**

- Ion-Selective Electrodes
- Microelectrodes

## Electrochemical Transduction

### Ion-Selective Electrodes

#### Application 1 and Sensor Type <sup>1</sup>

Assay of  $Mg^{2+}$  activity with solvent polymeric membrane electrodes based on Magnesium Ionophore I.

#### Recommended Cell Assembly

Reference || sample solution || ion-selective membrane | 0.1 M  $MgCl_2$  + 0.025 M  $Na_2B_4O_7$  | AgCl, Ag

#### Recommended Membrane Composition

1.40	wt%	Magnesium Ionophore I ( <a href="#">63082</a> )
1.00	wt%	Potassium tetrakis(4-chlorophenyl)borate ( <a href="#">60591</a> )
64.50	wt%	2-Nitrophenyl octyl ether (NPOE) ( <a href="#">73732</a> )
33.10	wt%	Poly(vinyl chloride) high molecular weight ( <a href="#">81392</a> )

#### Electrode Characteristics and Function

Selectivity coefficients  $\log K_{Mg, M}^{Pot}$  as obtained by the separate solution method (0.1 M solutions of the chlorides)

$\log K_{Mg, Li}^{Pot}$	-1.4	$\log K_{Mg, NH_4}^{Pot}$	-1.2
$\log K_{Mg, Na}^{Pot}$	-2.1	$\log K_{Mg, Ca}^{Pot}$	-1.3
$\log K_{Mg, K}^{Pot}$	-1.1		

Detection limit ( $MgCl_2$  solution without interfering ions):  $\log a_{Mg} \sim -5.0$

#### Application 2 and Sensor Type <sup>2,3</sup>

Assay of  $Mg^{2+}$  activity in blood by chemometric procedures and determination of water hardness with solvent polymeric membrane electrodes based on Magnesium Ionophore III.

#### Recommended Cell Assembly

Reference || sample solution || ion-selective membrane | 0.01 M  $MgCl_2$  | Ag, AgCl

#### Recommended Membrane Composition

0.99	wt%	Magnesium Ionophore III (63086)
0.64	wt%	Potassium tetrakis(4-chlorophenyl)borate (60591)
65.58	wt%	Chloroparaffin (60% Chlorine) (25720)
32.79	wt%	Poly(vinyl chloride) high molecular weight (81392)

#### Electrode Characteristics and Function

Selectivity coefficients  $\log K_{Mg, M}^{Pot}$  as obtained by the separate solution method (0.1 M solutions of the chlorides)

$\log K_{Mg, H}^{Pot}$	1.7	$\log K_{Mg, K}^{Pot}$	- 3.7
$\log K_{Mg, Li}^{Pot}$	- 3.1	$\log K_{Mg, Ca}^{Pot}$	0
$\log K_{Mg, Na}^{Pot}$	- 3.8		

Slope of linear regression: 28.0 mV for  $Mg^{2+}$  and 28.3 mV for  $Ca^{2+}$  at 21° ( $10^{-3}$  to  $10^{-1}$  M chlorides)

Detection limit:  $\log a_{Mg}$ ,  $\log a_{Ca} \sim -6.0$

Response time: 95% response time 0.9 s

<sup>1</sup> D. Erne, N. Stojanac, D. Ammann, P. Hofstetter, E. Pretsch, W. Simon, Lipophilic Di- and Triamides as Ionophores for Alkaline Earth Metal Cations, *Helv. Chim. Acta* **63**, 2271 (1980).

<sup>2</sup> M. Müller, M. Rouilly, B. Rusterholz, M. Maj-Zurawska, Z. Hu, W. Simon, Magnesium Selective Electrodes for Blood Serum Studies and Water Hardness Measurement, *Mikrochim. Acta* **III**, 283 (1988).

<sup>3</sup> M. Maj-Zurawska, M. Rouilly, W.E. Morf, W. Simon, Determination of Magnesium and Calcium in Water with Ion-selective Electrodes, *Anal. Chim. Acta* **218**, 47 (1989).

### Application 3 and Sensor Type <sup>4</sup>

Assay of Mg<sup>2+</sup> activity in blood serum with solvent polymeric membrane electrodes based on Magnesium Ionophore IV.

#### Recommended Membrane Composition

1.00	wt%	Magnesium Ionophore IV ( <a href="#">63088</a> )
0.90	wt%	Potassium tetrakis(4-chlorophenyl)borate ( <a href="#">60591</a> )
3.00	wt%	Tetradodecylammonium tetrakis(4-chlorophenyl)borate ( <a href="#">87255</a> )
65.07	wt	2-Nitrophenyl octyl ether ( <a href="#">73732</a> )
32.79	wt%	Poly(vinyl chloride) high molecular weight ( <a href="#">81392</a> )

#### Recommended Cell Assembly

Reference || sample solution | liquid membrane | 0.1 M MgCl<sub>2</sub> or 0.0071 M MgCl<sub>2</sub> + 0.00122 M CaCl<sub>2</sub> + 0.004 M KCl + 0.14 M NaCl | AgCl, Ag

#### Electrode Characteristics and Function

Selectivity Coefficients  $\log K_{Mg, M}^{Pot}$  as obtained by the separate solution method (0.1 M solutions of the chlorides).

$\log K_{Mg, H}^{Pot}$	1.0	$\log K_{Mg, K}^{Pot}$	- 2.9
$\log K_{Mg, Na}^{Pot}$	- 4.7	$\log K_{Mg, Ca}^{Pot}$	- 1.2

Slope of linear regression: 29.5 ± 0.3 mV (10<sup>-4</sup> to 10<sup>-1</sup> MgCl<sub>2</sub>)

Detection limit (MgCl<sub>2</sub>, no ion background): log aMg ~-5.0

Electrical resistance: 10<sup>5</sup> to 10<sup>6</sup> Ω

Response time: 90 % response time ≤ 30 s

Lifetime: log P<sub>TLC</sub><sup>1)</sup> ionophore : 6.9 ± 0.6

<sup>1)</sup> lipophilicity, determined by thin layer chromatography <sup>5</sup>

### Application 4 and Sensor Type <sup>6</sup>

Assay of Mg<sup>2+</sup> activity in blood serum with solvent polymeric membrane electrode based on Magnesium Ionophore IV with chemometrical correction for Ca<sup>2+</sup>.

#### Recommended Membrane Composition

1.00	wt%	Magnesium Ionophore IV ( <a href="#">63088</a> )
1.24	wt%	Potassium tetrakis(4-chlorophenyl)borate ( <a href="#">60591</a> )
33.00	wt%	Poly(vinyl chloride) high molecular weight ( <a href="#">81392</a> )
67.76	wt%	[12-(4-Ethylphenyl)dodecyl-2-nitrophenyl ether ( <a href="#">46092</a> )

#### Recommended Cell Assembly

Reference || sample solution || ion-selective electrode | 0.1 M MgCl<sub>2</sub> | AgCl, Ag

#### Electrode Characteristics and Function

Selectivity Coefficients  $\log K_{Mg, M}^{Pot}$  as obtained by the separate solution method (0.1 M solutions of the chlorides).

	required <sup>1)</sup>	found
$\log K_{Mg, Ca}^{Pot}$	-2.3	-1.3
$\log K_{Mg, Na}^{Pot}$	-3.7	-4.5
$\log K_{Mg, K}^{Pot}$	-1.0	-3.3

<sup>1)</sup> for measurements in human blood serum

<sup>4</sup> T. Maruizumi, D. Wegmann, G. Suter, D. Ammann, W. Simon, Na<sup>+</sup>-Selective Electrode for Application in Blood Serum, **Mikrochim. Acta** **88**, 331 (1986).

<sup>5</sup> O. Dinten, U.E. Spichiger, N. Chaniotakis, P. Gehrig, B. Rusterholz, W.E. Morf, W. Simon, Lifetime of neutral-carrier-based liquid membranes in aqueous samples and blood and the lipophilicity of membrane components, **Anal. Chem.** **63**, 596 (1991).

<sup>6</sup> R. Eugster, T. Rosatzin, B. Rusterholz, B. Aebersold, U. Pedrazza, D. Rüegg, A. Schmid, U.E. Spichiger, W. Simon, **Anal. Chim. Acta** **289**, 1 (1994).

Lifetime: log P <sub>TLC</sub>	ionophore	6.9 ± 0.6
	plasticizer	12.8 ± 2.0

#### Application 5 and Sensor Type <sup>7,8,9,10</sup>

Assay of Mg<sup>2+</sup> activity in extracellular fluid with solvent polymeric membrane electrodes based on Magnesium Ionophore VI.

##### Recommended Membrane Composition

1.00	wt%	Magnesium Ionophore VI ( <a href="#">63112</a> )
0.74	wt%	Potassium tetrakis(4-chlorophenyl)borate ( <a href="#">60591</a> )
65.26	wt%	[12-(4-Ethylphenyl)dodecyl] 2-nitrophenyl ether ( <a href="#">46092</a> )
30.00	wt%	Poly(vinyl chloride) high molecular weight ( <a href="#">81392</a> )

##### Recommended Cell Assembly

Reference || sample solution || sample solution || liquid membrane | 0.01 M MgCl<sub>2</sub> | AgCl,Ag

##### Electrode Characteristics and Function

Selectivity Coefficients logK<sub>Mg, M</sub><sup>Pot</sup> as obtained by the mixed solution method.

logK<sub>Mg, Na</sub><sup>Pot</sup> -3.9                      logK<sub>Mg, Ca</sub><sup>Pot</sup> -1.9

logK<sub>Mg, K</sub><sup>Pot</sup> -3.3

Slope of linear regression: 31.4 ± 0.7 mV/dec

Lifetime: log P <sub>TLC</sub>	ionophore	8.48 ± 0.98
	plasticizer	12.8

#### Application 6 and Sensor Type <sup>11,12</sup>

Assay of Mg<sup>2+</sup> activity in extracellular fluid with solvent polymeric membrane electrodes based on Magnesium Ionophore VI.

##### Recommended Membrane Composition

1.00	wt%	Magnesium Ionophore VII ( <a href="#">00744</a> )
0.71	wt%	Potassium tetrakis(4-chlorophenyl)borate ( <a href="#">60591</a> )
32.00	wt%	Poly(vinyl chloride) high molecular weight ( <a href="#">81392</a> )
66.29	wt%	2-Nitrophenyl octyl ether ( <a href="#">73732</a> )

##### Recommended Cell Assembly

Ag, AgCl, 3M KCl | 0.3 M NH<sub>4</sub>NO<sub>3</sub> || sample solution || liquid membrane | 0.1 M MgCl<sub>2</sub> | AgCl,Ag

##### Electrode Characteristics and Function

Selectivity Coefficients logK<sub>Mg, M</sub><sup>Pot</sup> as obtained by the mixed solution method.

logK<sub>Mg, Na</sub><sup>Pot</sup> -3.0                      logK<sub>Mg, Li</sub><sup>Pot</sup> -3.8

logK<sub>Mg, K</sub><sup>Pot</sup> -2.1                      logK<sub>Mg, Ca</sub><sup>Pot</sup> -2.6

Lifetime: log P <sub>TLC</sub>	ionophore	4.0 ± 0.6
--------------------------------	-----------	-----------

<sup>7</sup> J. O'Donnell, H. Li, B. Rusterholz, U. Pedrazza, W. Simon, Development of magnesium-selective ionophores *Anal. Chim. Acta* **281**, 129 (1993).

<sup>8</sup> W. Zhang, L. Jenny, U.E. Spichiger, A Comparison of Neutral Mg<sup>2+</sup>-Selective Ionophores in Solvents Polymeric Membranes: Complex Stoichiometry and Lipophilicity *Anal. Sci.* **16**, 11 (2000).

<sup>9</sup> U.E. Spichiger, A. Fakler, Potentiometric microelectrodes as sensor and detectors. Magnesium-selective electrodes as sensors, and hofmeister electrodes as detectors for histamine in capillary electrophoresis. *Electrochim. Acta* **42**, 3137 (1997).

<sup>10</sup> D. Gunzel, W.R. Schlue, Determination of [Mg(2+)]<sub>i</sub> - an update on the use of Mg(2+)-selective electrodes, *Biometals.* **15(3)**, 237 (2002).

<sup>11</sup> K. Suzuki, K. Watanabe, Y. Matsumoto, M. Kobayashi, S. Sato, D. Siswanta, H. Hisamoto, Design and Synthesis of Calcium and Magnesium Ionophores Based on Double-Armed Diazacrown Ether Compounds and Their Application to an Ion-Sensing Component for an Ion-Selective Electrode, *Anal. Chem.* **67**, 324, (1995).

<sup>12</sup> W. Zhang, L. Jenny, U.E. Spichiger, A Comparison of Neutral Mg<sup>2+</sup>-Selective Ionophores in Solvent Polymeric Membranes: Complex Stoichiometry and Lipophilicity, *Anal. Sci.* **16**, 11 (2000).

## Microelectrodes

### Application 1 and Sensor Type general 13, application 14, 15, 16, 17, 18, 19

Assay of  $Mg^{2+}$  activity in intracellular (single cell) liquids with  $Mg^{2+}$  microelectrodes based on Magnesium Ionophore I.

Magnesium Ionophore I - Cocktail A ([63048](#))

Cocktail Composition:

20.0	wt%	Magnesium Ionophore I ( <a href="#">63082</a> )
79.0	wt%	Propylene carbonate ( <a href="#">82227</a> )
1.0	wt%	Sodium tetrphenylborate ( <a href="#">72018</a> )

Electrode Characteristics and Function

Selectivity Coefficients  $\log K_{Mg, M}^{Pot}$  as obtained by the separate solution method (0.1M solutions of the chlorides) :

$\log K_{Mg, Na}^{Pot}$	- 1.1	$\log K_{Mg, Ca}^{Pot}$	- 1.1
$\log K_{Mg, K}^{Pot}$	- 1.4		

Slope of linear regression:  $28.0 \pm 0.7$  mV/dec ( $10^{-5}$  to  $10^{-1}$  M  $MgCl_2$ )

Detection limit ( $MgCl_2$ , ion background of 10 mM  $Na^+$ , 100 mM  $K^+$ , 0.001 mM  $Ca^{2+}$ ):

$\log a_{Mg} \sim -3.5$

Electrical Resistance Tip diameter ~1 mm:  $\sim 3 \cdot 10^{10} \Omega$

Response Time 90% response time:  $\leq 5$  s

### Application 2 and Sensor Type 19, 20, 21, 22, 23

Assay of  $Mg^{2+}$  activity in intracellular (single cell) liquids with microelectrodes based on Magnesium Ionophore II.

Magnesium Ionophore II - Cocktail A

Cocktail Composition

10.0	wt%	Magnesium Ionophore II ( <a href="#">63083</a> )
87.0	wt%	2-Nitrophenyl octyl ether (o-NPOE) ( <a href="#">73732</a> )
3.0	wt%	Potassium tetrakis(4-chlorophenyl)borate ( <a href="#">60591</a> )

Recommended Cell Assembly

Reference | sample solution | | cocktail | 0.001 M  $MgCl_2$ , 0.01 M  $NaCl$ , 0.1 M  $KCl$ , 0.001 M  $CaCl_2$  |  $AgCl$ ,  $Ag$

<sup>13</sup> F. Lanter, D. Erne, D. Ammann, W. Simon, Neutral carrier based ion-selective electrode for intracellular magnesium activity studies, **Anal. Chem.** **52**, 2400 (1980).

<sup>14</sup> P. Hess, P. Metzger, R. Weingart, Free magnesium in sheep, ferret and frog striated muscle at rest measured with ion-selective micro-electrodes, **J. Physiol.** **333**, 173 (1982).

<sup>15</sup> F.J. Alvarez-Leefmans, S.M. Gamiño, T.J. Rink, Intracellular free magnesium in neurones of *Helix aspersa* measured with ion-selective micro-electrodes, **J. Physiol.** **354**, 303 (1984).

<sup>16</sup> J.R. Lopez, L. Alamo, C. Caputo, J. Vergara, R. DiPolo, Direct measurement of intracellular free magnesium in frog skeletal muscle using magnesium-selective microelectrodes, **Biochim. Biophys. Acta** **804**, 1 (1984).

<sup>17</sup> L.A. Blatter, J.A.S. McGuigan, Free intracellular magnesium concentration in ferret ventricular muscle measured with ion selective micro-electrodes, **Quart. J. Exp. Physiol.** **71**, 467 (1986).

<sup>18</sup> F.J. Alvarez-Leefmans, S.M. Gamiño, F. Giraldez, H. Gonzáles-Serratos, Intracellular free magnesium in frog skeletal muscle fibres measured with ion-selective micro-electrodes, **J. Physiol.** **378**, 461 (1986).

<sup>19</sup> D. Ammann, P. Caroni, Preparation and use of micro- and macroelectrodes for measurement of transmembrane potentials and ion activities, **Methods in Enzymol.** **172**, 136 (1989).

<sup>20</sup> Z. Hu, T. Bühner, M. Müller, B. Rusterholz, M. Rouilly, W. Simon, Intracellular Magnesium Ion Selective Microelectrode Based on a Neutral Carrier, **Anal. Chem.** **61**, 574 (1989).

<sup>21</sup> D. Gunzel, S. Galler, Intracellular free  $Mg^{2+}$  concentration in skeletal muscle fibres of frog and crayfish, **Pflugers Arch.** **417(5)**, 446 (1991).

<sup>22</sup> L.A. Blatter, Estimation of intracellular free magnesium using ion-selective microelectrodes: evidence for an  $Na/Mg$  exchange mechanism in skeletal muscle, **Magnes Trace Elem.** **10 (2-4)**, 67 (1991-92).

<sup>23</sup> A. Buri, J.A.S. McGuigan, Intracellular free magnesium and its regulation, studied in isolated ferret ventricular muscle with ion-selective microelectrodes, **Exp Physiol.** **75(6)**, 751 (1990).

### Electrode Characteristics and Function

Selectivity Coefficients  $\log K_{Mg, M}^{Pot}$  as obtained by the separate solution method (0.1M solutions of the chlorides)

$\log K_{Mg, H}^{Pot}$	1.5	$\log K_{Mg, K}^{Pot}$	- 2.3
$\log K_{Mg, Li}^{Pot}$	- 1.2	$\log K_{Mg, Ca}^{Pot}$	0.8
$\log K_{Mg, Na}^{Pot}$	- 2.2		

Slope of linear regression:  $29.4 \pm 0.2$  mV/dec at 25°C ( $10^{-4}$  to  $10^{-1}$  M  $MgCl_2$ )

Detection limit for solutions with intracellular ion background

(ion background of 10 mM  $Na^+$ , 100 mM  $K^+$ , 0.001 mM  $Ca^{2+}$ ):  $\log a_{Mg} \sim -4.3$

Electrical Resistance Tip diameter  $\sim 1 \mu m$ :  $\sim 5 \cdot 10^{10} \Omega$

Response Time 90% response time:  $\leq 3$  s

### Application 3 and Sensor Type <sup>19,20</sup>

Assay of  $Mg^{2+}$  activity in intracellular liquids with microelectrodes based on Magnesium Ionophore II.

Magnesium Ionophore II - Cocktail A

#### Cocktail Composition

10.0	wt%	Magnesium Ionophore II ( <a href="#">63083</a> )
62.0	wt%	2-Nitrophenyl octyl ether (o-NPOE) ( <a href="#">73732</a> )
25.0	wt%	Chloroparaffin (60% chlorine) ( <a href="#">25720</a> )
3.0	wt%	Potassium tetrakis(4-chlorophenyl)borate ( <a href="#">60591</a> )

#### Recommended Cell Assembly

Reference | sample solution | | cocktail | 0.01 M  $MgCl_2$  | AgCl. Ag

### Electrode Characteristics and Function

Selectivity Coefficients  $\log K_{Mg, M}^{Pot}$  as obtained by the separate solution method (0.1M solutions of the chlorides)

$\log K_{Mg, H}^{Pot}$	0.3	$\log K_{Mg, K}^{Pot}$	- 3.2
$\log K_{Mg, Li}^{Pot}$	- 2.0	$\log K_{Mg, NH_4}^{Pot}$	- 2.7
$\log K_{Mg, Na}^{Pot}$	- 3.1	$\log K_{Mg, Ca}^{Pot}$	0.6

Slope of linear regression:  $29.7 \pm 0.2$  mV/dec at 25° ( $10^{-4}$  to  $10^{-1}$  M  $MgCl_2$ )

Detection limit ( $MgCl_2$ , no ion background):  $\log \log a_{Mg} \sim -6.4$

Detection limit (ion background of 10 mM NaCl, 100 mM KCl, 0.001 mM  $CaCl_2$ ):  $\log a_{Mg} \sim -4.8$

Electrical Resistance Tip diameter  $\sim 5 \mu m$ :  $\sim 10^{10} \Omega$

Practical pH measuring range: 3.5-9.5

Response Time 95% response time:  $\leq 3$  s