Table A – Inorganic Solutes in Aqueous Solutions

A record of reactions of Mu with inorganic solutes in water

This compilation is aimed at presenting data on reactions of muonioum and hydrogen atoms at ambient temperatures (293-298K) and normal pressure unless otherwise specified.

code	Ion	Reaction	Type of reaction	k_M (in $dm^3mol^{-1}s^{-1}$)	Notes about measurement	Reference	k_H (in $dm^3mol^{-1}s^{-1}$)	Notes about measurement	Reference	KIE = k_M / k_H
A1	Silver (I) ion – Ag^+ as $AgClO_4$	Ag^+ + Mu → Ag^o + μ^+	reduction – inferred by analogy with H atom	1.6×10^{10}	pH= 1.0	Percival, P.W., Roduner, E. and Fischer, H. in *Adv. Chem. Ser*. 1979, **175**, 335; ed. by H.J. Ache, ACS, Washington DC, 1979.	$(2.0 \pm 0.8) \times 10^{10}$ *(average of 2 values)*	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	0.8
A2	Cyanide ion – CN^- as KCN	CN^- + Mu → $MuCN^-$	addition to CN bond	3×10^9	pH = 1.0	Stadlbauer, J.M., Ng, B.W., Jean, Y.C. and Walker, D.C. *J. Phys. Chem.*, 1983, **87**, 841.	4.1×10^9	pH= 7.0	Anbar, M., Farhataziz and Ross, A.B. NSRDS-NBS 51 Washington, 1975	0.75
A3	Thiocyanate ion – SCN^- as NaSCN	SCN^- + Mu → $MuSCN^-$	addition	6×10^7	pH = 1.0	Jean, Y.C., Brewer, J.H., Fleming, D.G., Garner, D.M., Mikula, R.J., Vaz, L.C. and Walker, D.C. *Chem. Phys. Lett.*, 1978, **57**, 293.	2.3×10^8	pH = 1.0	www.rcdc.nd.edu/compilations/Hatom/H.HTM	0.25
A4	Tetracyanocadmate (II) ion $[Cd(CN)_4]^{2-}$ as $K_2Cd(CN)_4$	$[Cd(CN)_4]^{2-}$ + Mu → ?	addition to CN	1.7×10^{10}	$E_a = (15 \pm 2)$ kJ mol^{-1} for T = 273 K to 353 K	Stadlbauer, J.M., Ng, B.W., Jean, Y.C. and Walker, D.C. *J. Phys. Chem.*, 1983, **87**, 841.	$> 2.4 \times 10^9$	pH = 5.0	Anbar, M., Farhataziz and Ross, A.B NSRDS-NBS 51 Washington, 1975.	< 7
A5	Chromate (VI) ion – CrO_4^{2-} as K_2CrO_4	CrO_4^{2-} + Mu → CrO_4^{3-} + μ^+ ?	reduction	$(2.4 \pm 0.3) \times 10^{10}$	N/A	Percival, P.W. *Hyperfine Interact.*, 1981, **8**, 315.	8.2×10^9 *(average of 2 value)*	pH = 7.0	www.rcdc.nd.edu/compilations/Hatom/H.HTM	3
A6	Chromium (III) ion – Cr^{3+} as $CrCl_3$	Cr^{3+} + Mu (↑↑) → Cr^{3+} + Mu(↑↓)	presumed largely spin exchange	5.3×10^9	N/A	Jean, Y.C., Brewer, J.H., Fleming, D.G. and Walker, D.C. *Chem. Phys. Lett.*, 1978, **60**, 125.	2×10^7 *(average of 2 value)*	pH = 3.5-5	Anbar, M., Farhataziz and Ross, A.B. NSRDS-NBS 51 Washington, 1975.	KIE_{obs} = 260 *(indicates different type of reaction for Mu and H atoms)*
A7	Hexaaquachromium (III) ion – $[Cr(H_2O)_6]^{3+}$	$[Cr(H_2O)_6]^{3+}$ + Mu (↑↑) → $[Cr(H_2O)_6]^{3+}$ + Mu (↑↓)	spin exchange	$(8 \pm 1) \times 10^9$	N/A	Lazzarini, E., Stadlbauer, J.M., Venkateswaran, K., Gillis, H.A., Porter, G.B. and Walker, D.C. *J. Phys. Chem.*, 1994, **98**, 8050.	unknown	N/A	N/A	N/A

A8	Pentaaquachlorochromium (III) ion – $[Cr(H_2O)_5Cl]^{2+}$	$[Cr(H_2O)_5Cl]^{2+}$ + Mu ($\uparrow\uparrow$) $\rightarrow$ $[Cr(H_2O)_5Cl]^{2+}$ + Mu ($\uparrow\downarrow$)	spin exchange	$(7.5 \pm 1.5) \times 10^9$	N/A	Lazzarini, E., Stadlbauer, J.M., Venkateswaran, K., Gillis, H.A., Porter, G.B. and Walker, D.C. *J. Phys. Chem.*, 1994, **98**, 8050.	unknown	N/A	N/A	N/A
A9	Aqua(ethylenediaminetetracetate)chromium (III) ion – $[Cr(EDTA)H_2O]^-$	$[Cr(EDTA)H_2O)]^-$ + Mu ($\uparrow\uparrow$) $\rightarrow$ $[Cr(EDTA)H_2O]^-$ + Mu ($\uparrow\downarrow$)	spin exchange	$(1.2 \pm 0.4) \times 10^{10}$	N/A	Lazzarini, E., Stadlbauer, J.M., Venkateswaran, K., Gillis, H.A., Porter, G.B. and Walker, D.C. *J. Phys. Chem.*, 1994, **98**, 8050.	unknown	N/A	N/A	N/A
A10	Hexaamminechromium (III) ion – $[Cr(NH_3)_6]^{3+}$	$[Cr(NH_3)_6]^{3+}$ + Mu ($\uparrow\uparrow$) $\rightarrow$ $[Cr(NH_3)_6]^{3+}$ + Mu ($\uparrow\downarrow$)	spin exchange	$(9 \pm 1) \times 10^9$	N/A	Lazzarini, E., Stadlbauer, J.M., Venkateswaran, K., Gillis, H.A., Porter, G.B. and Walker, D.C. *J. Phys. Chem.*, 1994, **98**, 8050.	unknown	N/A	N/A	N/A
A11	Diaquabis(ethylenediamine) chromium (III) ion as $[Cr(en)_2(H_2O)_2]_2(S_2O_6)_3$	$[Cr(en)(H_2O)_2]^{3+}$ + Mu ($\uparrow\uparrow$) $\rightarrow$ $[Cr(en)_2(H_2O)_2]^{3+}$ + Mu ($\uparrow\downarrow$)	spin exchange	1.05×10^{10} *(Anion $S_2O_6^{2-}$ present in this complex could possibly react with Mu therefore k_M observed might be the upper limit)*	N/A	Lazzarini, E., Stadlbauer, J.M., Venkateswaran, K., Gillis, H.A., Porter, G.B. and Walker, D.C. *J. Phys. Chem.*, 1994, **98**, 8050.	unknown	N/A	N/A	N/A
A12	Tris (ethylenediamine) chromium (III) ion – $[Cr(en)_3]^{3+}$	$[Cr(en)_3]^{3+}$ + Mu ($\uparrow\uparrow$) $\rightarrow$ $[Cr(en)_3]^{3+}$ + Mu ($\uparrow\downarrow$)	spin exchange	$(7.3 \pm 2) \times 10^9$	N/A	Lazzarini, E., Stadlbauer, J.M., Venkateswaran, K., Gillis, H.A., Porter, G.B. and Walker, D.C. *J. Phys. Chem.*, 1994, **98**, 8050.	unknown	N/A	N/A	N/A
A13	Diamminetetra(thiocyanato-N) chromium (III) ion – $[Cr(NCS)_4(NH_3)_2]^-$	$[Cr(NCS)_4(NH_3)_2]^-$ + Mu ($\uparrow\uparrow$) $\rightarrow$ $[Cr(NCS)_4(NH_3)_2]^-$ + Mu ($\uparrow\downarrow$)	spin exchange	$(2.7 \pm 0.5) \times 10^{10}$	N/A	Lazzarini, E., Stadlbauer, J.M., Venkateswaran, K., Gillis, H.A., Porter, G.B. and Walker, D.C. *J. Phys. Chem.*, 1994, **98**, 8050.	unknown	N/A	N/A	N/A

A14	Hexa(thiocyanato-N)chromium (III) ion $[Cr(NCS)_6]^{3-}$ as $K_3[Cr(NCS)_6]$	$[Cr(NCS)_6]^{3-}$ + Mu (↑↑) → $[Cr(NCS)_6]^{3-}$ + Mu (↑↓)	spin exchange	$(3.1 \pm 0.4) \times 10^{10}$	N/A	Stadlbauer, J.M., Venkateswaran, K., Porter, G.B. and Walker, D.C. *J. Phys. Chem.*, 1997, **101**, 4741.	unknown	N/A	N/A	N/A
A15	Copper (II) ion – Cu^{2+} as $CuSO_4$	Cu^{2+} + Mu (↑↑)→ Cu^{2+} + Mu (↑↓) Cu^{2+} + Mu → Cu^{+} + μ^{+}	spin exchange and possibly also reduction	$k_M^{obs} = (6.5 \pm 1.0) \times 10^9$	N/A	Jean, Y.C., Brewer, J.H., Fleming, D.G. and Walker, D.C. *Chem. Phys. Lett.*, 1978, **60**, 125.	9.1×10^7 *(average of 3 values)*	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	70
A16	Iron (II) ion – Fe^{2+} as $(NH_4)_2Fe_2(SO_4)_3$	Fe^{2+} + Mu (↑↑) → Fe^{2+} + Mu (↑↓) Fe^{2+} + Mu → Fe^{+} + μ^{+} or ($FeMu^{2+}$)	predominantly spin exchange and possibly (?) also reduction	1.2×10^{10}	N/A	Jean, Y.C., Brewer, J.H., Fleming, D.G. and Walker, D.C. *Chem. Phys. Lett.*, 1978, **60**, 125.	7.5×10^6	pH = 0	www.rcdc.nd.edu/compilations/Hatom/H.HTM	1600 *(indicates different type of reactions for Mu and H atoms)*
A17	Ferrocyanide ion $[Fe(CN)_6]^{4-}$, hexacyanoferrate (II) as $K_4Fe(CN)_6$	$[Fe(CN)_6]^{4-}$ + Mu → ?	reduction or addition to CN^-	3.05×10^8	N/A	Jean, Y.C., Brewer, J.H., Fleming, D.G. and Walker, D.C. *Chem. Phys. Lett.*, 1978, **60**, 125.	3.9×10^7	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	≈ 8
A18	Iron (III) ion – Fe^{+3} as $Fe(NH_4)(SO_4)_2$	Fe^{+3} + Mu (↑↑) → Fe^{+3} + Mu (↑↓)	predominantly spin exchange with small contribution of reduction	$k_M^{obs} = 5.5 \times 10^9$	N/A	Jean, Y.C., Brewer, J.H., Fleming, D.G. and Walker, D.C. *Chem. Phys. Lett.*, 1978, **60**, 125.	1.4×10^6 *(average of 2 values)*	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	≈4000 *(indicates different type of reactions for Mu and H atoms)*

A19	Ferricyanide ion, hexacyanoferrate (III) ion – $[Fe(CN)_6]^{3-}$	$[Fe(CN)_6]^{3-}$ + Mu → ?	reduction with small contribution of spin exchange (?)	**a)** 2 x 10^{10} **b)** 3.2 x 10^{10} **c)** MRMS*: 2 x 10^{10} *in the NaOSA micelles*	**a)** pH = 7 **b)** pH = 1 *(small pH effect)*	**a)** Jean, Y.C., Brewer, J.H., Fleming, D.G. and Walker, D.C. *Chem. Phys. Lett.,* 1978, 60, 125 **b)** Venkateswaran, K., Barnabas, M.V., Ng, B.W. and Walker, D.C., Can. J. Chem., 1988, 66, 1979. **c)** Jean, Y.C., Ng, B.W., Stadlbauer, I.M. and Walker, D.C., J. Chem. Phys., 1981, 75, 2879.	6.3 x 10^9	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	**a)** ≈ 3 **b)** ≈ 5
A20	Mercury (II) chloride – $HgCl_2$	$HgCl_2$ + Mu → HgCl + μ^+ + Cl^- *(as proposed for HA atom reaction)*	reduction ?	2.0 x 10^9	N/A	Jean, Y.C., Brewer, J.H., Fleming, D.G. and Walker, D.C. *Chem. Phys. Lett.,* 1978, **60**, 125.	(1 ± 0.5) x 10^{10}	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	0.2
A21	Iodine – I_2	I_2 + Mu → MuI + I I_2 + Mu → μ^+ + I_2^-	abstraction or reduction	**a)** (1.7 ± 0.3) x 10^{10} **b)** MRMS* k_M = (4.1 ± 1.0) x 10^{10} *in the NaOSA micelles* k_M = (4.0 ± 0.9) x 10^{10} *in the NaHS micelles* k_M = (5.0 ± 0.8) x 10^{10} *in the NaLS micelles*	N/A	**a)** Jean, Y.C., Ng, B.W., Ito, Y., Nguyen, T.G. and Walker, D.C. *Hyperfine Interact.,* 1981, 8, 351. **b)** Jean, Y.C., Ng, B.W., Stadlbauer, I.M. and Walker, D.C., *J. Chem. Phys.*, 1981, 75, 2879.	3.5 x 10^{10}	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	**a)** 0.5 **b)** N.A.
A22	Triiodine ion – I_3^- as KI_3	I_3^- + Mu → I^- + I_2^- + μ^+	?	(5.9 ± 1.2) x 10^{10}	N/A	Jean, Y.C., Ng, B.W., Ito, Y., Nguyen, T.G. and Walker, D.C. *Hyperfine Interact.,* 1981, **8**, 351.	2.2 x 10^{10} *(average from all values)*	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	2.7

A23	Iodide ion – I^- as KI or NaI	$I^- + Mu \leftrightarrow MuI^-$	addition *(based on H-atom scheme)*	**a)** 5.3×10^{7} **b)** $(7 \pm 1) \times 10^{7}$	**a)** $E_a \approx 0$ kJ/mol^{-1} ($E_A = -5.6 \pm 1.8$ kJ/mol) for T=278 to 363K **b)** N/A	**a)** Bartels, D.M. and Roduner, E. *Chem. Phys.*, 1996, **203**, 339. **b)** Jean, Y.C., Ng, B.W., Ito, Y., Nguyen, T.G. and Walker, D.C. *Hyperfine Interact.*, 1981, **8**, 351.	$k_H = (2.8 \pm 0.4) \times 10^{8}$ $k_D = 3.2 \times 10^{8}$	N/A	k_H from: www.rcdc.nd.edu/compilations/Hatom/H.HTM k_D from:Bartels, D.M. and Roduner, E. *Chem. Phys.*, 1996, 203, 339.	**a)** $KIE_{M/H} = k_M / k_H = 0.20$ $KIE_{M/D} = k_M/k_D = 0.16$ **b)** KIE = 0.25
A24	Permanganate ion – MnO_4^- as $KMnO_4$	$MnO_4^- + Mu \rightarrow [MnO_4]^{2-} + \mu^+$	electron transfer reduction	**a)** 2.5×10^{10} **b)** 2.5×10^{10} **c)** 1.7×10^{10} Muonium reactions at high pressures (see ANNEX 1)	**a)** pH =7.0 **b) pH** =7.0 **A** = $(3.5 \pm 0.3) \times 10^{13}$ $\mathbf{E_a}$ = (18.4 ± 1.7) kJ mol^{-1} for: **T** = 276 K to 361 K **c) pH** =1.0	**a)** Percival, P.W., Roduner, E. and Fischer, H. in *Adv. Chem. Ser.* 1979, **175**, 335; ed. by H.J. Ache, ACS, Washington DC, 1979. **b)** Ng, B.W., Jean, Y.C., Ito, Y., Suzuki, T., Brewer, J.H., Fleming, D.G. and Walker, D.C. *J. Phys. Chem.*, 1981, **85**, 454. **c)** Barnabas, M.V. and Walker, D.C. *Can. J. Chem.*, 1991, **69**, 1252	$\leq 2.4 \times 10^{10}$	pH = 3	k_H from: www.rcdc.nd.edu/compilations/Hatom/H.HTM	**a)** 1.0 **b)** 1.0 **c)** 0.7
A25	Nitrous oxide	$N_2O + Mu \rightarrow N_2 + MuO$	abstraction of O *(by analogy to H atom reaction)*	6.5×10^{7}	N/A	Venkateswaran, K., Barnabas, M., Wu, Z. and Walker, D.C. *Radiat. Phys. Chem.*, 1988, **32**, 65.	2.1×10^{6}	In alkaline solution	www.rcdc.nd.edu/compilations/Hatom/H.HTM	30

A26	Nitrate ion NO_3^- as $NaNO_3$	NO_3^- + Mu → [$MuNO_3^-$] → (?) NO_3^- + Mu → NO_2 + MuO^- (?)	?	**a)** 1.5 x 10^9 **b)** 1.5 x 10^9 **c)** 1.9 x 10^9 **d)** MRMS *: 0.8 x 10^9 *in the SDDS micelles* 3.7 x 10^9 *in the DDTAB micelles* 1.5 x 10^9 *in the pEO micelles*	**a)** N/A **b) pH** = 7 E_a = (6.3 ± 1.2) kJ mol^{-1} for T = 274 K to 365 K **A** = (2.1 ± 0.2) x 10^{10} $dm^3 mol^{-1} s^{-1}$ **c) pH =** 1.0 *(no effect of pH)* **log(A**/$dm^3 mol^{-1} s^{-1}$) = 15.28 ± 0.16 E_a = (48.7 ± 1.0) kJ mol^{-1} for T = 288 to 358 K	**a)** Percival, P.W., Roduner, E., Fischer, H., Camani, M., Gygax, F.N. and Schenk, A. *Chem. Phys. Lett.*, 1973, 47, 11. **b)** Ng, B.W., Jean, Y.C., Ito, Y., Suzuki, T., Brewer, J.H., Fleming, D.G. and Walker, D.C. *J. Phys. Chem.*, 1988, 85, 454. **c)** Barnabas, M.V. and Walker, D.C. *Can. J. Chem.*, 1991, **69**, 1252. **d)** Venkateswaran, K., Barnabas, M.V., Ng, B.W. and Walker, D.C., *Can. J. Chem.*, 1988, **66**, 1979.	5.6 x 10^6	**pH** = 1.0 **log**(A/$dm^3 mol^{-1} s^{-1}$) = 15.28 ± 0.16 $\mathbf{E_a}$ **=** (48.7 ± 1.0) kJ mol^{-1} for T = 288 to 358 K	Mezyk, S.P. and Bartels, D.M. *J. Phys. Chem.*, 1997, **101**, 6233.	**a) & b)** 270 at pH = 1.0 & pH = 7.0 **c)** N/A **d)** N/A
A27	Nitrite ion – NO_2^-	NO_2^-+ Mu → Mu NO_2^- *(as proposed for H atoms)*	addition *(combination)*	(8 ± 1.5) x 10^9	N/A	Karolczak, S., Gillis, H.A., Porter, G.B. and Walker, D.C. *Can. J. Chem*, 2003, **81**, 175	1.6 x $10^9 dm^3 mol^{-1} s^{-1}$	E_a = (15.59 ± 0.36) kJ/mol^{-1} for T = 280 K to 360 K **log[A($dm^3 mol^{-1} s^{-1}$)]** = 11.94 ± 0.06	www.rcdc.nd.edu/compilations/Hatom/H.HTM	(5 ± 1)

A28	Nickel (II) ion Ni^{2+} as $NiSO_4$	Ni^{2+} + Mu (↑↑)→ Ni^{2+} + Mu (↑↓)	spin conversion	**a)** k_M^{obs} = 1.7 x 10^{10} **b)** N/A **c)** MRMS*: k_M = 1.4 x 10^{10} *in the NaOSA micelles* Muonium reactions at high tempera-tures and pressures (see ANNEX 2)	**a)** N/A **b) A =** (0.9 ± 0.2) x 10^{13} $dm^3mol^{-1}s^{-1}$ **E_A** = 16.0 ± 2.5 kJ mol^{-1}	**a)** Jean, Y.C., Brewer, J.H., Fleming, D.G. and Walker, D.C. *Chem. Phys. Lett.*, 1978, 60, 125. **b)** Ng, B.W., Jean, Y.C., Ito, Y., Suzuki, T., Brewer, J.H., Fleming, D.G. and Walker, D.C. *J. Phys. Chem.*, 1981, 85, 454. **c)** Jean, Y.C., Ng, B.W., Stadlbauer, I.M. and Walker, D.C., *J. Chem. Phys.*, 1981, **75**, 2879.	< 3 x 10^5	pH natural, *(limiting value)*	www.rcdc.nd.edu/compilations/Hatom/H.HTM	**a)** > 5 x 10^4 *(KIE do indicate different type of reactions)* **b) & c)** N/A
A29	Tetraamminenickel (II) ion – $[Ni(NH_3)_4]^{2+}$	$[Ni(NH_3)_4]^{2+}$ + Mu (↑↑) → $[Ni(NH_3)_4]^{2+}$ + Mu (↑↓) *(Ni^{2+} ion in the form of paramagnetic tetrahedral complex)*	spin exchange	1.5 x 10^{10}	in 1M NH_3 solution	N/A	unknown	N/A	N/A	N/A

A30	1,4,8,11-Tetraazacyclotetradecanenickel (II) ion, cyclamnickel (II) ion – $[Ni(cyclam)]^{2+}$ as $[Ni(cyclam)]_2PF_6$	$[Ni(cyclam)]^{2+}$ + Mu → $Ni[(cyclam)]^{+} + \mu^{+}$ *(Ni^{2+} ion in the form of diamagnetic planar complex)*	reduction *(electron transfer by analogy to H-atom reaction)*	5 x 10^{8}	N/A	Stadlbauer, J.M., Ng, B.W., Jean,Y.C. and Walker, D.C J.Am.Chem.Soc. 1983, **105**, 752	*unknown for this specific complex but determined for similar solute 5,7,7,12,14,14-Hexamethyl-1,4,8,11-tetraazacyclo-tetradecane nickel (II) ion* k_H = 3.2 x 10^{8}	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	1.5
A31	1,4,8,12-Tetraazacyclotetradecanediamminonickel (II) ion – Diamminocyclamnickel (II) ion – $[Ni(cyclam)(NH_3)_2]^{2+}$	$[Ni(cyclam)(NH_3)_2]^{2+}$ + Mu (↑↑) → $[Ni(cyclam)(NH_3)_2]^{2+}$ + Mu (↑↓) *(Ni^{2+} ion in the form of paramagnetic octahedral complex)*	spin exchange	2 x 10^{10}	N/A	Stadlbauer, J.M., Ng, B.W., Jean,Y.C. and Walker, D.C J.Am.Chem.Soc. 1983, **105**, 752	unknown	N/A	N/A	N/A
A32	1,4,8,12-Tetraazacyclotetradecanediaquanickel (II) ion, cyclamdiaquanickel (II) ion – $[Ni(cyclam)(H_2O)_2]^{2+}$	$Ni[(cyclam)(H_2O)_2]^{2+}$ + Mu (↑↑) → $Ni[(cyclam)(H_2O)_2]^{2+}$ + Mu (↑↓) *(Ni^{2+} ion in the form of paramagnetic octahedral complex)*	spin exchange	4.5 x 10^{10}	N/A	Stadlbauer, J.M., Ng, B.W., Jean,Y.C. and Walker, D.C J.Am.Chem.Soc. 1983, **105**, 752	k (H + Ni^{2+}) < 3 x 10^{5}	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	> 10^{5} *(this manifests different type of reactions)*

A33	Hydroxide ion - OH_{aq}^- as NaOH or KOH	OH_{aq}^- + Mu → MuOH + e_{aq}^-	acid, μ^+ transfer	**a)** (9.1 ± 1.2) x 10^6 *(calculated on the basis of activities rather than molar concentration)* **b)** 1.7 x 10^7 **c)** 1.7 x 10^7 Muonium reactions at high tempera - tures and pressures: see ANNEX 3	**a) [OH$^-$]$_{max}$** = 0.38 M **b) pH** range not stated **c) [OH$^-$]$_{max}$** = 0.08 M **A** = (2.4 ± 0.1) x 10^{14} $dm^3mol^{-1}s^{-1}$ **E$_A$** = (40 ± 5) kJ mol^{-1} for T = 247 K to 357 K	**a)** Percival, P.W., Roduner, E., Fischer, H., Camani, M., Gygax, F.N.and Schenck, A. *Chem. Phys. Lett.,* 1973, **47**, 11. **b)** Percival, P.W., Roduner, E. and Fischer, H. in *Adv. Chem. Ser.* 1979, **175**, 335; ed. by H.J. Ache, ACS, Washington DC, 1979. **c)** Ng, B.W., Stadlbauer, J.M. and Walker, D.C *J. Phys. Chem.,* 1984, **88**, 857.	(2.51 ± 0.44) x 10^7	**E$_A$** = (38.38 ± 0.31) kJ mol^{-1} for T ~ 286 K to 345 K **A** = (1.33 ± 0.16) x 10^{14} $dm^3mol^{-1}s^{-1}$)	Han, P. and Bartels, D.M., *J. Phys. Chem.,* 1992, 96, 4899. latest entry to: www.rcdc.nd.edu/compilations/Hatom/H.HTM	**a)** N/A **b) & c)** 0.7 *(with k_H = 2.5 x 10^7)*
A34	Deuterium peroxide – D_2O_2	D_2O_2 + Mu → MuD + DO_2 D_2O_2 + Mu → MuO + D_2O_2	abstraction of D or O (abstraction of D proposed to D atom reaction)	1.4 x 10^9	pH = 2.6 E_a ≈ 11kJ mol^{-1}	Percival, P.W., Brodovitch, J.C. and Newman, K.E. NBS Special Publication (US) 1986, **716**, 547.	k_D = (2.30 ± 0.10) x 10^7 $dm^3mol^{-1}s^{-1}$	**E$_a$** = 25.6 kJ mol^{-1} for T = 283 K to 343 K **log** ($A/dm^3mol^{-1}s^{-1}$) = 10.37 ± 0.10	k_D, A and E_a from: Mezyk, S.P., and Bartels, D.M. *J. Chem. Soc.Faraday Trans.,* 1995, **91**, 3127.	60 *(with k_D = 2.3 x 10^7)*
A35	Deuteroperoxyanion - DO_2^-	DO_2^- + Mu → MuD + O_2^- DO_2^- + Mu → MυO + OΔ$^-$	D or O abstraction (D abstraction proposed for D atom reaction)	4.5 x 10^9	pH = 12.6 E_a = 10.5 kJ mol^{-1}	Percival, P.W., Brodovitch, J.C. and Newman, K.E. NBS Special Publication (US) 1986, **716**, 547.	k_D = 2.12 x 10^9	N/A	k_D from: Mezyk, S.P., and Bartels, D.M. *J. Chem. Soc.Faraday Trans.,* 1995, **91**, 3127.	2 *(with k_D = 2.1 x 10^9)*

A36	Hydrogen peroxide – H_2O_2	H_2O_2 + Mu → MuH + HO_2 H_2O_2 + Mu → MuO + D_2O	abstraction of H or O (H atom abstraction proposed for H atom reaction)	1.65 x 10^9	pH ~ 3.0 E_a = 5.8 kJ mol^{-1} for T = 275K to 322K	Percival, P.W., Brodovitch, J.C. and Newman, K.E. NBS Special Publication (US) 1986, **716**, 547.	(4.6 ± 0.1) x 10^7 *(average of the 3 latest values)*	E_a: given in the Notre Dame Data Base varies from 11 kJ mol^{-1} to 21 kJ mol^{-1}	www.rcdc.nd.edu/compilations/Hatom/H.HTM	≈36
A37	Hydroperoxyanion – HO_2^-	HO_2^- + Mu → MuH + O_2^- HO_2^- + Mu → MuO + OH^-	abstraction of H or O	5.0 x 10^9	pH_{max} = 12.4 E_a = 10.5 kJ mol^{-2}	Percival, P.W., Brodovitch, J.C. and Newman, K.E. NBS Special Publication (US) 1986, **716**, 547.	(1.24 ± 0.14) x 10^9	pH = 11.5 log A ($dm^3mol^{-1}s^{-1}$) = 13.65 ± 0.30 E_A = (17.3 ± 0.6) kJ mol^{-1} for T = 280 K to 315 K	Mezyk, S.P. and Bartels, D.M. *J. Chem. Soc. Faraday Trans.*, 1995, **91**, 3127.	4
A38	Oxygen – O_2	a) O_2 + Mu + (↑↑) → Mu (↑↓)+ O_2 (k_{SE}) O_2 + Mu → MuO_2 (k_{CR}) b) O_2 + Mu (↑↑)→ Mu (↑↓)+ O_2 (k_{SE}) Mu + O_2 → MuO_2 (or m^+ + O^-_2, or MuO + O) (k_{CR})	spin exchange (SE) chemical reaction (CR)	**a)** k_M^{obs} **i)** (1.8 ± 0.1) x 10^{10} **ii)** (3.3 ± 0.3) x 10^{10} **iii)** (4.8 ± 0.6) x 10^{10} **iv)** (4.3 ± 0.9) x 10^{10} **b)** k_M^{obs}= (2.4 ± 0.5) x 10^{10} Average from a) and b): (2.1 ± 0.5) x $10^{10]}$	**a)** E_a ≈ 2.6 kJ mol^{-1} *(calculated on the basis of authors's data (4 points))* **i)** T = 297 K **ii)** T = 318 K **ii)** T = 343 K **iv)** T = 358 K *(Experimental method: MSR in transverse and longtidual fields for separation chemical process and spin exchange)*	**a)** Roduner, E., Tregenna-Pigott, P.L.W., Digler, H., Ehrensberger, K. and Senba, M. *J. Chem. Soc., Faraday Trans.*, 1995, **91**, 1935. **b)** Jean, Y.C., Fleming, D.G., Ng, B.W. and Walker, D.C. *Chem. Phys. Lett.*, 1979, **66**, 187	●2.0 x 10^{10} ○1.2 x 10^{10}	N/A	● Han, P. and Bartels, D.M. in *Ultrafast Reaction Dynamics* ed. Gauduel, Y. and Rossky, P.J., AIP Conference Proceedings 298, American Institute of Physics, N.Y. 1991.(latest value published) ○ www.rcdc.nd.edu/compilations/Hatom/H.HTM	● ≈ 1 ○ 1.8 *(both using the average value of k_M^{obs})*

A39	Thiosulphate ion – $S_2O_3^{2-}$ as $Na_2S_2O_3$	$S_2O_3^{2-}$ + Mu → ?	?	**a)** 2.6 x 10^{10} **b)** MRMS*: k_M = 2.1 x 10^{10} *in the SDDS micelles; (average of 3 values)*	N/A	**a) & b)** Venkateswaran, K., Barnabas, M.V., Ng, B.W. and Walker, D.C. *Can. J. Chem.,* 1988, 66, 1979.	Unknown	N/A	N/A	N/A
A40	Thallium (I) ion – Tl^+ as Tl_2SO_4	Tl^+ + Mu → Tl° + μ^+	reduction (electron transfer)	**a)** 8 x 10^8 **b)** MRMS*: k_M = 3.2 x 10^9 *in the SDDS micelles*	**a)** N/A **b)** MRMS*: $[Tl^+]$ = 0.4 mM [SDDS] = 0.5 mM	**a)** Jean, Y.C., Brewer, J.H., Fleming, D.G., Garner, D.M., Mikula, R.J., Vaz, L.C. and Walker, D.C. *Chem. Phys. Lett.,* 1978, **57**, 293. **b)** Venkateswaran, K., Barnabas, M.V., Ng, B.W. and Walker, D.C., *Can. J. Chem.*, 1988, 66, 1979.	4.1 x 10^7 *(average of 2 values)*	N/A	www.rcdc.nd.edu/compilations/Hatom/H.HTM	20

* MRMS = Muonium reactions in the micellar systems

ANNEX 1: A24 - Permanganate ion - Muonium reactions at high pressures

k_M values decrease with pressure applied (up to 2 kbars)

activation volume calculated: $DV^{'} = 3.1 \pm 1.6\ cm^3mol^{-1}$ for Mu + $KMnO_4$

$DV^{'} = 2\ cm^3mol^{-1}$ for H + $KMnO_4$

from: Brodovitch, J-C., Leung, S-K., Percival, P.W., Dake Yu. and Newman, K.E. *Radiat. Phys. Chem.*, 1988, **1**, 105.

ANNEX 2: A28 – Nickel (II) ion - Muonium reactions at high temperatures and pressures

Ghandi,K.,Addison-Jones,B.,Brodovitch,J-C.,McKenzie,I.,Percival,P.W. and Schueth,J, Phys.Chem.Chem.Phys,2002, **4**, 586.

T/℃	P/bar	$k_{Mu}/10^{10}$ dm^3 mol^{-1} s^{-1}
26	4	1.32(22)
205	48	1.93(33)
205	244	2.72(34)
205	390	2.42(50)
231	247	2.06(24)
257	258	1.48(22)
310	253	0.72(17)
359	250	0.24(10)
359	304	0.52(13)
359	350	1.07(22)
359	402	0.34(18)
388	249	1.47(26)
75	250	2.42(41)
100	242	3.98(58)
131	250	3.46(52)
163	250	2.94(36)
26	4	1.16(12)
91	235	2.58(45)
122	260	3.82(69)
310	96	1.24(28)
310	220	1.72(25)
310	250	1.54(28)
310	318	1.74(25)
310	400	2.05(26)
388	253	1.53(13)
415	242	0.21(21)

Activation volumes $\Delta V^{\neq}$ calculated from the rate constants at various temperatures.

Temperature / °C	*$\Delta V^{\neq}$ /cm^{3}mol^{-1}*
205	-16 ± -15
310	-42 ± -11
359	-280 ± -230
257	-5 ± -10
331	-70 ± -20
362	-260 ± -100

ANNEX 3: A33 - Hydroxide ion - Muonium reactions at high temperatures and pressures

Ghandi,K., Addison-Jones,B., Brodovitch, McKenzie,I., Kecman,S. and Percival,P.W. Physica B ,2003**, 326**,55

T/°C	P/bar	$k_{Mu}/10^{10}$ dm^3 mol^{-1} s^{-1}
270	245	1.45(23)
270	245	1.22(10)
310	202	1.33(11)
310	302	1.46(10)
310	348	1.66(14)
310	348	1.67(14)
315	245	1.54(14)
335	245	2.01(10)
370	257	0.55(12)
378	245	0.40(12)
382	245	0.16(15)
382	245	0.30(15)
394	380	2.20(13)
404	375	1.29(3)
149	245	0.18(3)
205	190	0.38(5)
205	240	0.52(6)
205	270	0.39(4)
206	350	0.34(4)
250	170	0.52(5)
250	200	0.66(5)
257	260	0.87(8)
250	300	0.68(6)
250	360	0.59(4)
300	174	0.92(9)
300	220	1.17(9)
300	224	1.08(9)
300	260	0.98(7)
301	243	1.16(11)
315	200	1.02(8)
330	200	1.10(9)
330	260	1.28(10)
362	188	0.15(6)

362	225	0.62(5)
362	250	1.20(7)
350	262	1.37(8)
362	295	1.43(8)
362	325	1.50(9)
365	350	1.20(8)
388	264	0.49(7)
394	244	0.49(22)
394	317	0.65(6)
394	344	1.32(8)
83	245	0.02(1)
115	245	0.09(1)
115	245	0.10(1)
135	245	0.12(2)
170	245	0.34(3)
373	245	0.14(1)
383	245	0.06(3)
383	245	0.07(2)