

Table C –Solute Unreactive Towards Muonium Atoms in Aqueous Solutions

A record of inorganic and organic solutes in water which react too slowly with Mu to measure

The data presented refers to ambient temperatures (293-298K) and normal pressure unless otherwise specified.

k_M values represent upper limit

INORGANIC SOLUTES

Code	Ion	Reaction	Type of Reaction	k_M (in $\text{dm}^3\text{mol}^{-1}\text{s}^{-1}$)	Notes about measurement	Reference	k_H (in $\text{dm}^3\text{mol}^{-1}\text{s}^{-1}$)	Notes about measurement	Reference	$KIE = k_M / k_H$
C1	Bromide ion – Br^- as KBr	$\text{Br}^- + \text{Mu} \leftrightarrow \text{Mu Br}^-$	addition (as proposed for H atom reaction)	$< 10^6$	N/A	Venkatesvaran, K., Barnabas, M.V., Ng, B.W. and Walker, D.C. <i>Can. J. Chem.</i> , 1988, 66 , 1979.	$(1.7 \pm 0.3) \times 10^6$	$E_a \approx 0$ (6.3 ± 6.2) kJ/mol^{-1} for T = 283 K to 331 K	Bartels, D.M. and Mezyk, S.P. <i>J. Phys. Chem.</i> , 1993, 97 , 4101.	< 0.6
C2	Cadmium (II) ion – Cd^{+2} as CdSO_4	$\text{Cd}^{+2} + \text{Mu} \rightarrow$ no reaction detected	reduction	8×10^5	N/A	Walker, D.C., Jean, Y.C. and Fleming, D.G. <i>J. Phys. Chem.</i> 1979, 70 , 4534.	$< 3 \times 10^5$	pH \sim 7.0	www.rcdc.nd.edu/compilations/HAtom/H.htm	N/A
C3	Chloride ion - Cl^- as NaCl	$\text{Cl}^- + \text{Mu} \rightarrow$ no reaction detected	addition (probably)	$< 2 \times 10^5$	N/A	Percival, P.W., Roduner, E., Fischer, H., Camani, M., Gygax, F.N. and Schenck, A. <i>Chem. Phys. Lett.</i> , 1973, 47 , 11.	$< 1 \times 10^5$	pH \sim 7.0	www.rcdc.nd.edu/compilations/Hatom/H.HTM	N/A
C4	Fluoride ion – F^- as KF	N/A	N/A	$< 3 \times 10^5$	N/A	Roduner, E., Ph.D. Thesis, University of Zurich, 1974.	1×10^4	pH = 8.3	www.rcdc.nd.edu/compilations/Hatom/H.HTM	N/A
C5	Perchlorate ion – ClO_4^- as HClO_4 or NaClO_4	$\text{ClO}_4^- + \text{Mu} \rightarrow$ no reaction detected	?	$< 1 \times 10^7$	pH = 1	Percival, P.W., Roduner, E., Fischer, H., Camani, M., Gygax, F.N. and Schenck, A. <i>Chem. Phys. Lett.</i> , 1973, 47 , 11.	Unknown	N/A	N/A	N/A
C6	Hydrogen ion – H^+ as HClO_4	$\text{H}^+ + \text{Mu} \rightarrow \text{MuH}^+$ or $\text{H} + \mu^+$	addition or reduction (electron transfer)	$< 2 \times 10^5$	pH = 1.0	Percival, P.W., Roduner, E., Fischer, H., Camani, M., Gygax, F.N. and Schenck, A. <i>Chem. Phys. Lett.</i> , 1973, 47 , 11.	k_H ($\text{H} + \text{H}^+$) from 2.5×10^4 to 5×10^6	N/A	Anbar, M., Farhataziz and Ross, A.B. NSRDS-NBS 51 Washington, 1975.	N/A

C7	Ammonium ion – NH ₄ ⁺ as (NH ₄) ₂ SO ₄	NH ₄ ⁺ + Mu → no reaction detected	?	< 10 ⁷	N/A	Jean, Y.C., Brewer, J.H., Fleming, D.G. and Walker, D.C. <i>Chem. Phys. Lett.</i> , 1978, 60 , 125.	< 4 x 10 ⁴	pH= 7.0	www.rcdc.nd.edu/compilations/HAtom/H.htm	N/A
C8	Hydrogen phosphate ion – HPO ₄ ²⁻ as Na ₂ HPO ₄	Mu + HPO ₄ ²⁻ → MuH + PO ₄ ³⁻ <i>(reaction scheme inferred by analogy to H-atoms)</i>	abstraction	< 10 ⁵	N/A	Barnabas, M. and Walker, D.C. <i>Can. J. Chem.</i> , 1991, 69 , 1252.	< 5 x 10 ⁴	pH = 9 -12.3	www.rcdc.nd.edu/compilations/HAtom/H.htm	N/A
C9	Potassium ion – K ⁺ as K ₂ SO ₄	K ⁺ + Mu → no reaction detected	?	< 10 ⁷	N/A	Jean, Y.C., Brewer, J.H., Fleming, D.G., Garner, D.M., Mikula, R.J., Vaz, L.C. and Walker, D.C. <i>Chem. Phys. Lett.</i> , 1978, 57 , 293.	unknown	N/A	N/A	N/A
C10	Sodium ion – Na ⁺ as Na ₂ SO ₄	Na ⁺ + Mu → no reaction detected	?	< 2 x 10 ⁵	N/A	Percival, P.W., Roduner, E., Fischer, H., Camani, M., Gygax, F.N. and Schenck, A. <i>Chem. Phys. Lett.</i> , 1973, 47 , 11.	unknown	N/A	N/A	N/A
C11	Water – H ₂ O	H ₂ O + Mu → H + MuHO H ₂ O + Mu → MuH + OH no reaction detected	a) atom exchange and/or abstraction b) high temperature reaction	a) < 9 x 10 ² b) < 2 x 10 ⁴	a) N/A b) upper limit at 400 ° C	a) Nagamine, K., Nishiyama, K., Imazato, I., Nakayama, H., Yoshida, M., Sakai, Y., Sato, H. and Tominaya, T. <i>Chem. Phys. Lett.</i> , 1982, 87 , 186. b) Percival, P.W., Brodovitch, J-C., Ghandi, K., Addison-Jones, B., Schutch, J. and Bartels, M. <i>Phys. Chem. Chem. Phys.</i> 1999, 1 , 4999.	≈ 1 x 10 ¹ <i>(value too low to measure reliably)</i>	pH = 10 – 13	www.rcdc.nd.edu/compilations/HAtom/H.htm	N/A

C12	Sulphate ion – SO ₄ ²⁻ as Na ₂ SO ₄	SO ₄ ²⁻ + Mu → no reaction detected	?	< 10 ⁶	N/A	Venkateswaran, K., Barnabas, M.V., Ng, B.W. and Walker, D.C. <i>Can. J. Chem.</i> , 1988, 66 , 1979.	unknown	N/A	N/A	N/A
C13	Zinc (II) ion – Zn ²⁺ as ZnSO ₄	Zn ²⁺ + Mu → Zn ⁺ + μ ⁺ (<i>proposed</i>)	reduction	< 10 ⁷	N/A	Jean, Y.C., Brewer, J.H., Fleming, D.G., Garner, D.M., Mikula, R.J., Vaz, L.C. and Walker, D.C. <i>Chem. Phys. Lett.</i> , 1978, 57 , 293.	< 3 x 10 ⁵	pH ~ 7	www.rcdc.nd.edu/c ompilations/HAtom /H.htm	N/A

ORGANIC SOLUTES

Code	Ion	Reaction	Type of Reaction	k_M (in $\text{dm}^3\text{mol}^{-1}\text{s}^{-1}$)	Notes about measurement	Reference	k_H (in $\text{dm}^3\text{mol}^{-1}\text{s}^{-1}$)	Notes about measurement	Reference	$KIE = k_M / k_H$
C14	Acetamide	$\text{CH}_3\text{CO NH}_2 + \text{Mu} \rightarrow$ no reaction detected	abstraction (proposed)	a) $< 10^5$ b) MRMS*: 1×10^{10} in the CTAB micelles	N/A	a) Barnabas, M.V., Venkateswaran, K. and Walker, D.C. b) Barnabas, M.V. and Walker, D.C., Can. J. Chem. 1999, 69, 1252	1.5×10^5 (average of 2 values)	N/A	www.rcdc.nd.edu/com-pilations/HAtom/H.htm	< 0.7
C15	Acetic acid	$\text{CH}_3\text{COOH} + \text{Mu} \rightarrow \text{CH}_2\text{COOH} + \text{MuH}$	abstraction (proposed)	$< 10^5$	N/A	Barnabas, M.V. and Walker, D.C., Can. J. Chem. 1999, 69, 1252	1.0×10^5 (average of 2 values)	pH = 7 – 8	www.rcdc.nd.edu/com-pilations/HAtom/H.htm	< 1
C16	Cyclam-1,4,8,11-Tetraazacyclotetradecane (ligand for Ni^{+2} ions)	Cyclam + Mu $\rightarrow ?$	abstraction (?)	$< 10^7$	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
C17	N,N-Dimethylacetamide	$\text{CH}_3\text{CO N}(\text{CH}_3)_2 + \text{Mu} \rightarrow$ no reaction detected	abstraction (proposed)	a) $< 10^5$ b) MRMS*: $\approx 2 \times 10^7$ in the SOS micelles	N/A	a) Barnabas, M.V., Venkateswaran, K. and Walker, D.C. Can. J. Chem., 1989, 67 , 120. b) Barnabas, M.V. and Walker, D.C., Can. J. Chem. 1999, 69, 1252.	unknown	N/A	N/A	N/A
C18	Formamide	$\text{HCONH}_2 + \text{Mu} \rightarrow$ no reaction detected	abstraction (proposed)	a) $< 10^5$ b) MRMS*: $\approx 7 \times 10^6$ in the SOS micelles	N/A	a) Barnabas, M.V., Venkateswaran, K. and Walker, D.C. Can. J. Chem., 1989, 67 , 120. b) Barnabas, M.V. and Walker, D.C., Can. J. Chem. 1999, 69, 1252.	Unknown	N/A	N/A	N/A

C19	Formic acid – HCOOH	HCOOH + Mu → MuH + COOH	abstraction	< 1 x 10 ⁵	N/A	Roduner, E. Ph.D. Thesis, University of Zurich, 1979.	a) 4.4 x 10 ⁵ <i>in good agreement with</i> b) (4.2 ± 0.6) x 10 ⁵	N/A	a) www.rcdc.nd.edu/com pilations/HAtom/H.htm b) Lossack, A.M., Bartels, D.M. and Roduner, E. <i>Res. Chem. Intermed.</i> 2002, 27 , 475.	<0.25 (with $k_H =$ 4.2×10^5)
C20	Guanidine	H ₂ NC(=NH)NH ₂ + Mu → no reaction detected	abstraction <i>(proposed)</i>	a) ≈ 3 x 10 ⁵ b) MRMS*: ≈ 9 x 10 ⁸ <i>in the CTAB micelles</i>	N/A	a) Barnabas, M.V., Venkateswaran, K. and Walker, D.C. <i>Can. J. Chem.</i> , 1989, 67 , 120. b) Barnabas, M.V. and Walker, D.C., <i>Can. J. Chem.</i> 1999, 69, 1252.	1.2 x 10 ⁶	pH = 1.0 <i>guanidine as conjugated acid</i>	www.rcdc.nd.edu/com pilations/HAtom/H.htm	≈ 0.25
C21	N-Methylacetamide	CH ₃ CONHCH ₃ + Mu → no reaction detected	abstraction <i>(proposed)</i>	a) < 10 ⁵ b) MRMS*: ≈ 10 ¹⁰ <i>in the CTAB micelles</i>	N/A	a) Barnabas, M.V., Venkateswaran, K. and Walker, D.C. <i>Can. J. Chem.</i> , 1989, 67 , 120. b) Barnabas, M.V. and Walker, D.C., <i>Can. J. Chem.</i> 1999, 69, 1252.	unknown	N/A	N/A	N/A
C22	Surfactants: a. Cetyltrimethylammonium bromide CTAB b. Dodecyltrimethylammonium bromide DDTAB c. Dodecylsulfate sodium salt SDDS (NaLS) d. Hexylsulfate sodium salt NaHS e. Octylsulfate sodium salt NaOSA(SOS) f. Polyethylene oxide lauryl ether pEO	Surfactant molecule + Mu → ?	abstraction ?	~ 10 ⁷ <i>(average value)</i>	N/A	N/A	~ 10 ⁸ <i>(average value)</i>	N/A	N/A	N/A

C23	Tetramethylurea	$[(\text{CH}_3)_2\text{N}]_2\text{C}=\text{O} + \text{Mu} \rightarrow ?$	abstraction (proposed)	a) $\approx 4 \times 10^5$ b) MRMS*: $\approx 2 \times 10^9$ in the CTAB micelles	N/A	a) Barnabas, M.V., Venkateswaran, K. and Walker, D.C. <i>Can. J. Chem.</i> , 1989, 67 , 120. b) Barnabas, M.V. and Walker, D.C., <i>Can. J. Chem.</i> 1999, 69, 1252.	unknown	N/A	N/A	N/A
C24	Urea	$\text{H}_2\text{NCONH}_2 + \text{Mu} \rightarrow$ no reaction detected	H-abstraction (proposed)	a) $< 10^5$ b) $< 10^6$ c) MRMS*: $\approx 10^9$ in the CTAB micelles	a) pH = 7.0 b) pH = 1.0 c) N/A	a) Barnabas, M.V., Venkateswaran, K. and Walker, D.C. <i>Can. J. Chem.</i> , 1989, 67 , 120. b) & c) Barnabas, M.V. and Walker, D.C., <i>Can. J. Chem.</i> 1999, 69, 1252.	$< 3 \times 10^4$	N/A	www.rcdc.nd.edu/compilations/HAtom/H.htm	N/A

MRMS* = Muonium reactions in the micellar systems