Environmental Science & Technology

Supporting information for *Environ. Sci. Technol.*, **1981**, 15(3), 345 – 353, DOI: 10.1021/es00085a012

HOFFMANN

PP 345-353

E-353-H1

TABLE I

FIRST-ORDER REACTION RATE CONSTANTS FOR AQUATION; $ML + H_2O \rightarrow MH_2O + L$

Metal Complex	k_1 (sec^{-1})	μ (M)	T (°C)	pH	Reference
$Mn(CN)_6^{-3}$	4.4×10^{-4}	---	8	9-8	1
$Fe(H_2O)_5NCS^{+}$	8.8×10^{-1}	0.4	14.5	1.5	2
$Fe(H_2O)_5SO_3^{+}$	1.1	1.0	8.4	1.7	3
$Cr(OX)_2(AC)H_2O^{-2}$	6.2×10^{-4}	0.1	16.3	2-5	4
$Cr(OX)_2(AC)OH^{-3}$	2.7×10^{-2}	0.1	8.4	9-12	4
$Co(en)_2(H_2O)Cl^{+2}$	1.6×10^{-6}	---	---	2-3	5
$Co(en)_2(OH)Cl^{+}$	1.3×10^{-2}	---	---	7-9	6
$Mn(H_2O)_6^{+2}$	3.1×10^{7}	0.1	25	1	7
$Fe(H_2O)_6^{+2}$	3.2×10^{6}	0.1	25	1	7
$Ni(H_2O)_6^{+2}$	3.0×10^{4}	0.1	25	1	7
$Cu(H_2O)_6^{+2}$	8.0×10^{9}	0.1	25	1	8
$Fe(H_2O)_6^{+3}$	3.0×10^{3}	0.1	25	1	8
$Co(cyclam)(OH)Cl^{+}$	1.2×10^{-2}	0.1	18.8	7-12	9
$CaEDTA^{-2}$	1.3	0.5	25	6-8	10
$Ca(PDTA)^{-2}$	6.6×10^{-2}	0.5	25	7-8	10
$Ni(dipy)^{+2}$	5.3×10^{-5}	---	25	7	11
$Ni(AC)^{+}$	1.0×10^{3}	1.0	20	5	12
$CO_2(aq) + H_2O$ —— $HCO_3^{-} + H^{+}$	2.6×10^{-2}	0.1	25	8.7	13
$H^{+} + FeS + 2.25\ O_2$—— $Fe^{+3} + SO_4^{=} + H_2O$	3.0×10^{-3}*	.001	20	7.0	14

*pseudo first-order constant

TABLE II

SECOND-ORDER REACTION RATE CONSTANTS FOR REDOX PROCESSES/ELECTRON TRANSFERS

REACTION	k_2 ($M^{-1}sec^{-1}$)	μ (M)	T (°C)	pH	Reference
$Fe^{+2} + Mn^{+3}$	$1.7x10^4$	3.1	25	0	15
$MnTPP^{-3}$ + HO-quinoline	$7.9x10^5$	0.1	16	8	16
$FeEDTA^{-2} + ClO_2^-$	$3.0x10^4$	1.0	20	9	17
$Fe(phen)_3^{+2} + ClO_2^-$	$3.0x10^5$	1.0	20	9	17
$Fe(CN)_6^{-3}$ + ascorbate	$1.3x10^2$	0.24	25	2.0	18
$Fe(CN)_6^{-3}$ $p\text{-}NH_2\text{-}\phi\text{-}NH_2$	$4.0x10^1$	000	30	7.5	19
$MnNTA^-$ + HO-quinoline	$1.9x10^7$	0.1	16	8	16
$MnATP^{-2}$ + HO-quinoline	$1.0x10^6$	0.1	16	8	16
$Fe(phen)^{+2} + MnO_4^-$	$6.0x10^3$	0.45	25	1	20
Fe^{+3} + penicillamine	$4.5x10^{-1}$	0.1	20	9	21
$Fe(phen)_3^{+2} + HOCl$	$2.2x10^{-2}$	1.0	25	7.2	22
Fe^{+3} + ascorbate	30	1.0	0	1	23
$Fe^{+3} + I^-$	16	0.2	25	1	24
$Fe(phen)^{+3} + S_2O_5^{-2}$	$7.2x10^3$	0.5	25	1	25
$Fe(phen)_3^{+3} + SO_3^{-2}$	4.2	0.5	25	1	25
Cytochrome C + $FeEDTA^{-2}$	$2.6x10^4$	0.1	25	6-9	26
Fe^{+3} + HS-succinnic acid	1.0	1.0	25	1	27
Mn^{+3} + 1,2-$(pH)_2$-benzene	$6.5x10^3$	3.0	25	0	28
Cu^{+2} + ascorbate	$3.1x10^4$	0.1	30	4-6	29
Mn^{+3} + thiourea	$2.6x10^4$	---	25	0	30
$Cu(DMP)_2^{+2} + H_2O_2$	$1.2x10^6$	0.1	25	6-9	31
Fe^{+2} + benzoquinone	$9.1x10^{-4}$	0.5	25	0	32
Cytochrome C + $Fe(CN)_6^{-4}$	$1.3x10^4$	0.2	12	7	33

TABLE III

SECOND-ORDER REACTION RATE CONSTANTS FOR COMPLEXATION

REACTION	k_2 ($M^{-1}sec^{-1}$)	μ (M)	T (°C)	pH	Reference
$Fe(OH)^{+}$ + chloride	$1.1x10^{4}$	1.0	25	1.2	34
$Fe(OH)^{+}$ + thiocyanate	$1.1x10^{4}$	0.4	25	1.5	34
$Fe(OH)^{+}$ + acetate	$2.8x10^{3}$	0.5	25	1.5	35
$Fe(OH)^{+2}$ + H_2-salicylate	$5.5x10^{3}$	1.0	25	2.0	36
$Fe(OH)^{+2}$ + H-salicylate	$1.4x10^{4}$	1.0	25	2.0	36
Fe^{+3} + oxalate	$1.4x10^{2}$	0.5	25	0.5	37
Fe^{+3} + sulfate	$6.4x10^{3}$	0.5	25	1.3	38
Fe^{+3} + sulphosalicylate	$1.2x10^{4}$	1.0	25	2	39
Fe^{+3} + salicylate	$1.4x10^{4}$	1.0	25	2	39
$Fe(OH)^{+}$ + $HIDA^{-}$	$8.8x10^{3}$	1.0	25	2	40
$Fe(OH)^{+}$ + H_2NTA^{-}	$5.6x10^{4}$	1.0	25	2	40
$Fe(OH)^{+}$ + H_3EDTA^{-}	$1.1x10^{5}$	1.0	25	2	41
Fe^{+2} + sulfate	$1.0x10^{6}$	0.1	20	1	42
Fe^{+2} + phen	$7.9x10^{5}$	1.0	25	1	43
$Fe(dipy)_2^{+2}$ + dipy	$4.0x10^{5}$		25		44
Mn^{+2} + NTA^{-3}	$5.0x10^{8}$		25		45
Mn^{+2} + $HNTA^{-2}$	$2.0x10^{5}$		25		45
Mn^{+2} + sulfate	$4.0x10^{6}$	0.1	20	1	42
Mn^{+2} + chloride	$1.6x10^{7}$	0.1	20	1	46
Cu^{+2} + H_2ATP^{-2}	$8.8x10^{8}$	0.1	25	1-5	47
Cu^{+2} + serinate	$1.8x10^{9}$	0.1	25	1-5	48
Co^{+2} + α-alanine	$1.3x10^{9}$	0.1	20	9	49
Co^{+2} + histidine	$1.3x10^{7}$	0.1	20	9	49

TABLE IV

SECOND-ORDER REACTION RATE CONSTANTS FOR AUTOXIDATIONS

REACTION	k_2 (M^{-1} sec^{-1})	T (°C)	pH	Reference
$H^+ + Fe^{+2} + 1/4\ O_2 \rightarrow Fe^{+3} + 1/2 H_2O$	9.6×10^{-1} *	20	7	50
$Mn^{+2} + H_2O + 1/2\ O_2 \rightarrow MnO_2 + 2H^+$	9.1×10^{-2} *	25	9	51
$Fe^{+2} + O_2$	2.0×10^{-4}	25	5	52
$Fe^{+2} + O_2$	7.9×10^{-4}	30	2-3	53
(M^{-2} atm^{-1} sec^{-1})				
$Fe^{+2} + O_2$ (M^{-2} sec^{-1})	7.1×10^{-1}	30	2-3	54
$Co(hist)_2^{-2} + O_2$	3.5×10^3	25	8-11	55
$Co(glygly)_2(OH)_2^{-2} + O_2$	1.0×10^3	25	8-12	56
$Cu(dipy)_2^+ + O_2$	6.5×10^3	25	5	57
$Fe(HTPP)_2^{-2}$	4.0×10^1	25	4.5	58
$Fe(cyst) + O_2$	5.0×10^3	25	6	59
$Fe(cyst)_2^{-2} + O_2$	2.0×10^4	25	9.7	59
$Co(trien)(H_2O)_2^{+2}$	2.5×10^4	25	7-12	60
$Co(trien)(OH)(H_2O)^+ + O_2$	2.8×10^5	25	7-12	60

* Calculated from data presented in reference.

TABLE V

SECOND-ORDER REACTION RATE CONSTANTS FOR PROTON TRANSFER

REACTION	k_2 (M^{-1} sec^{-1})	μ (M)	T (°C)	pH	Reference
$H_3O^+ + OH^-$	1.4×10^{11}	0	25	15.75	61
$NH_4^+ + OH^-$	3.4×10^{10}	0	20	9.25	61
$imidazole^+ + OH^-$	1.3×10^{10}	0	25	6.95	61
$C_6H_5OH + OH^-$	1.3×10^{10}	0	25	4.20	61
$H_3O^+ + HS^-$	7.5×10^{10}	0	25	7.24	61
$H_3O^+ + NH_3$	4.0×10^{10}	0	25	9.25	61
$H_3O^+ + HCO_3^-$	5.0×10^{10}	0	25	3.77	61
$H_3O^+ + CH_3CO_2^-$	3.2×10^{10}	0	25	4.20	61
CH_3CO_2H + formate	5.0×10^{8}	1	20	3.75	62
CH_3CO_2H + propionate	4.0×10^{8}	1	20	4.87	62
CH_3CO_2H + malonate	5.6×10^{8}	1	20	5.70	62
CH_3CO_2H + imidazole	1.3×10^{9}	1	20	7.0	62
$CH_3CO_2H + HPO_4^-$	4.8×10^{9}	1	20	7.2	62
$HCO_3^- + H_3O^+ \rightarrow CO_2(H_2O)$	5.6×10^{4}	0	25	6.35	62

TABLE VI

SECOND-ORDER RATE CONSTANTS FOR Ni(II) COMPLEXATION

LIGAND	$k_2(M^{-1}sec^{-1})$	log K	μ(M)	T(°C)	pH	Reference
histidine	$2.2x10^3$	8.7	0.1	24	5-7	63
phenanthroline	$4.1x10^3$	8.6	0.1	25	6-8	64
dipyridyl	$1.6x10^3$	7.0	---	---	---	65
salicylicate	$5.3x10^3$	7.0	0.1			66
sulfosalylicate	$4.7x10^3$	6.4	0.1			66
proline	$3.4x10^4$	5.9	0.1	25	6-8	67
α-alanine	$2.0x10^4$	5.4	0.1	20	9	68
ethylmalonate	$7.6x10^3$	3.2	0.1	25	3-5	69
$HEDTA^{-3}$	$2.0x10^5$	3.2	0.1	25		70
phthalate	$2.6x10^5$	2.2	0.1	25	4-5	69
lactate	$2.6x10^4$	1.6	0	25	5.8	71
acetate	$2.7x10^4$	1.5	0	25	3-7	72
sulfate	$1.6x10^4$	1.0		25		42
oxalate	$7.9x10^4$	52	0.1	25	7	73
imidazole	$3.2x10^3$	3.0	0.1	24	6	74
pyridine	$4.6x10^3$	1.9	---	25	7	75
thiocyanate	$5.0x10^3$	1.2	0.1	25	7	76
methionine	$\sim 1x10^{-3}$	5.2	0.15	24	6-7	77
glutathione	$\sim 1x10^{-3}$		0.15	24	6-7	77
m-tyrosine	$1.2x10^{-1}$	5.1	0.15	24	6-7	77
cysteine	$8.5x10^2$	9.8	0.15	24	6-7	77

TABLE VII

KINETIC DATA FOR AUTOXIDATION OF SULFIDE; COMPARISON OF RESULTS

#	REACTION	WATER	pH	$t_{1/2(min)}$**	T(°C)	$[HS^-]^n$	$[O_2]^m$	pH Range	R
1	$HS^- + O_2$	sea water	8.0	280	23.0	1	---	8-8.5	78
2	$HS^- + O_2$	distilled†	7.9	3,000	25.0	1.34	0.56	6-12	79
3	$HS^- + O_2$	sea water	8.2	24	25.0	1	1	---	80
4	$HS^- + O_2$	sea water	7.8	175	9.8	1	---	---	81
5	$HS^- + O_2$	fresh††	7.6	880	25.0	1	1	4-10	82
6	$HS^- + O_2$	distilled	11.0	130	---	1	---	11-14	83
7	$HS^- + O_2$	fresh	8.6	2,200	25.0	1	1	7-8.6	84
8	$HS^- + O_2$	fresh	8.0	114	25.0	1	---	6-10	85
9	$HS^- + O_2$	sea water	7.7	600	9.0	---	---	7-8	86
10	$HS^- + O_2$	distilled†	8.3	816	25.0	1	1	5-12	87
11	$HS^- + O_2$ + CoTSP*	distilled	8.3	7	25.0	1	1	5-12	88

** Calculated from reported data
† EDTA added
†† simulated
* CoTSP = Co(II)-4,4',4",4'''-tetrasulphophthalocyanine, [CoTSP] = 2×10^{-9}M

TABLE VIII: KINETIC AND EQUILIBRIUM DATA FOR Fe(II) OXIDATIONS

#	OXIDANT	$k_2(M^{-1}sec^{-1})$[a]	$\Delta G^{\ddagger}$ [b]	ΔG^{o} [b]	$\mu(M)$	T(°C)	R
1	Fe^{+3}	4.0	69.7	0	0.5	25	89
2	$Fe(EDTA)^{-}$	4.0×10^{-4}	92.5	61.3	0.5	25	90
3	$FeCl^{+2}$	3.73×10^{1}	64.1	- 2.5	0.5	25	89
4	$Fe(terpy)_3^{+3}$	8.5×10^{4}	44.9	-18.3	0.5	25	91
5	$Fe(dipy)_3^{+3}$	2.7×10^{4}	47.7	-22.2	0.5	25	91
6	$Fe(5\text{-nitrophen})_3^{+3}$	1.1×10^{5}	38.5	-49.2	0.5	25	91
7	$Fe(5\text{-chlorophen})_3^{+3}$	2.1×10^{5}	42.7	-36.7	0.5	25	91
8	$Fe(2,5\text{-dimethylphen})_3^{+3}$	7.8×10^{3}	50.8	-22.2	0.5	25	91
9	$Fe(tetramethylphen)_3^{+3}$	2.3×10^{2}	59.5	- 6.7	0.5	25	91
10	benzosemiquinone[c]	7.19×10^{-1}	73.9	52.3	0.5	25	92
11	tolusemiquinone[c]	2.98×10^{-1}	76.1	62.3	0.5	25	92
12	durosemiquinone[c]	2.66×10^{-4}	93.6	85.8	0.5	25	92
13	2,6-dichlorosemiquinone[c]	3.58	70.0	38.9	0.5	25	92
14	$FeSO_4^{+}$	6.77×10^{2}	56.9	6.5	0.5	25	93

a. $[H^{+}]$ = 1.0 M

b. ΔG in kJ/mole

c. Calculated from K and k_f (Marcus, R. A., J. Chem. Phys., 26, 872 (1957).

References

1. Adamson, A. W., Welker, J. P., Wright, W. B., J. Am. Chem. Soc., 73, 4786 (1951).
2. Below, J. F., Connick, R. E., Coppel, C. P., J. Am. Chem. Soc., 80, 2961 (1958).
3. Carlyle, D. W., Inorg. Chem., 10, 761 (1971).
4. Casula, M., Illuminati, G., Ortaggi, G., Inorg. Chem., 11, 1062 (1972).
5. Chan, S. C., J. Chem. Soc., 5137 (1963).
6. Pearson, R. G., Meeker, R. E., Basolo, F., J. Am. Chem. Soc., 78, 2673 (1956).
7. Swift, T. J., R. E. Connick, J. Chem. Phys., 37, 307 (1962).
8. Connick, R. L., "Symposium on Relaxation Techniques," Buffalo, N.Y. June (1965).
9. Poon, C. K., Tobe, M. L., J. Chem. Soc. (A) 2069 (1967).
10. Carr, J. D., Swartzfager, J. Am. Chem., Soc., 97, 315 (1975).
11. Melson, G. A., Wilkins, R. G., J. Chem. Soc., 4208 (1962).
12. Fronaeus, S., Acta Chem. Scand., 6, 1200 (1952).
13. Pinsent, B. R. W., Pearson, L., Roughton, F. J. W., Trans. Faraday Soc., 52, 512 (1956).
14. Nelson, M. B., Davis, J. A., Benjamin, M. M., Leckie, J. O., "The Role of Iron Sulfides in Controlling Trace Metals in Anaerobic Sediments," AFOSR report No. CEEDO-TR-77-13, Environ. Sci. Res. Div., Tyndall AFB, FL, 398 pages (1977).
15. Sutin, N., J. Phys. Chem., 68, 174 (1964).
16. Hague, D. N., Zetter, M. S., Trans. Faraday Soc., 66, 1176 (1970).
17. Burke, R. L., Marzluff, W. L., J. Am. Chem. Soc., 91, 3481 (1969).
18. Mehrota, U.S., Agrawal, M. C., Mushran, S. P., J. Phys. Chem., 73, 1996 (1969).
19. Corbett, J. F., J. Chem. Soc. (B), 207, 213, 818 (1969).
20. Hicks, K. W., Sutter, J. R., J. Phys. Chem., 75, 1107 (1971).
21. Bell, C. M., McKenzie, E. D., Orton, J., Inorg. Chimica Acta, 5, 109 (1971).

22. Ondrus, M. G., Gordon, G., Inorg. Chem., 10, 474 (1971).

23. Lawrence, G. S., Ellis, K. J., J. C. S. Dalton 1667 (1972).

24. ibid., 2229 (1972).

25. Carlyle, D. W., J. Am. Chem. Soc., 94, 4525 (1972).

26. Hodges, H. L., Holwerda, R. A., Gray, H. B., J. Am. Chem. Soc., 96, 3132 (1974).

27. Ellis, K. J., McAuley, A., J. C. S. Dalton, 1533 (1973).

28. Mentasti, E., Pelizzetti, Pramanro, E., Giraudi, Inorg. Chim. Acta, 12, 61 (1975); Gazzetha 105, 551 (1975); Inorg. Chim. Acta, 15, L1 (1975).

29. Hayakawa, K., Minami, Nakamura, S., Bull. Chem. Soc. Japan, 46, 2788 (1973).

30. Davies, G., Inorg. Chim. Acta, 14, L13-14 (1975).

31. Davies, G., Higgins, R., Loose, D. J., Inorg. Chem., 15, 700 (1976).

32. Baxendale, J. H., Hardy, H. R., Trans. Faraday Soc., 50, 808 (1964).

33. Sutin, N., Christman, R., J. Am. Chem. Soc., 83, 1773 (1961).

34. Connick, R. E., Coppel, C. P., J. Am. Chem. Soc., 81, 6389 (1959).

35. Pandey, R. N., Smith, W. F., Can. J. Chem., 50, 194 (1972).

36. Saini, G., Mentasti, E., Inorg. Chim. Acta, 4, 585 (1970).

37. Bauer, R. F., Smith, W. F., Can. J. Chem., 43, 2763 (1965).

38. Davis, G. G., Smith, W. F., Can. J. Chem., 40, 1836 (1962).

39. Gonger, S., Stueher, J., Inorg. Chem., 13, 379 (1974).

40. Mentasti, E., Pellizzetta, E., Saini, Gazzetta, 104, 201 (1974).

41. ibid, J. C. S. Dalton, 1944 (1974).

42. Eigen, M., Tamm, K. Z., Electrochem., 66, 107 (1962).

43. Bell, R. S., Sutin, N., Inorg. Chem., 1, 359 (1962).

44. Irving, H., Mellor, D. H., J. Chem. Soc., 5222 (1962).

45. Koryta, J., Z. Electrochem., 61, 423 (1957).

46. Hayes, R. G., Myers, R. J., J. Chem. Phys., 40, 877 (1964).

47. Brundage, R. S., Karpel, R. L., Kuotin, K., Weisel, J., Biochim. Biophys. Acta, 267, 258 (1972).

48. Cobb, M. A., Hague, D. N., J. C. S. Faraday (I) 68, 932 (1972).

49. Pasternak, R. F., Justin, K., Weinstock, E. I., J. Am. Chem. Soc., 88, 4610 (1966).

50. Stumm, W., Lee, G. F., Ind. Eng. Chem., 53, 143 (1961).

51. Morgan, J. J., "Chemical Equilibria and Kinetic Properties of Manganese in Natural Waters," in Principles and Applications in Water Chemistry, S. D. Faust and J. V. Hunter, eds., Wiley, N.Y., p. 561 (1967).

52. Tamura, H., Goto, K., Nagayama, M., J. Inorg. Nucl. Chem., 38, 113 (1976).

53. Cher, M., Davidson, N., J. Am. Chem. Soc., 77, 793 (1955).

54. Utsumi, S., Murosima, K., J. Chem. Soc., Japan, Pure Chem. Sect., 86, 593 (1965).

55. Simplicio , J., Wilkins, R. G., J. Am. Chem. Soc., 84, 6092 (1967).

56. Tanford, C., Kirk, D. C., Chantooni, M. K., J. Am. Chem. Soc., 76, 5325 (1954).

57. Pecht, J., Anbar, M., J. Chem. Soc., A, 1902 (1968).

58. Kurimura, Y., Kuriyama, H., Bull. Chem. Soc. 42, 2239 (1969).

59. Gilmour, A. D., McAuley, J. Chem. Soc. (A), 1006 (1970).

60. Miller, F., Wilkins, R. G., J. Am. Chem. Soc., 92, 2687 (1970).

61. Eigen, M., Angew. Chem., 75, 489 (1963); Internat. Edt., 3, 1 (1964); Pure Appl. Chem., 6, 97 (1963).

62. Ahrens, M. L. Maass, G., Angew, Chem., Internat. Edt., 7, 818 (1968).

63. Letter, J. E., Jordan, R. B., Inorg. Chem., 10, 2692 (1971).

64. Kustin, K., Liu, S. T., J. C. S. Dalton, 278 (1973).

65. Bennetto, H. P., Caldin, E. F., Chem. Comm., 599 (1969).

66. Williams, J., Petrucci, S., J. Am. Chem. Soc., 95, 7619 (1973).

67. Wilkins, R. G., J. Am. Chem. Soc., 94, 8399 (1972).

68. Pasternak, R. F., Kustin, K., Weinstock, E. M., J. Am. Chem. Soc., 88, 4610 (1966).

69. Cavasino, F. P., Di Dio, E., Locanto, G., J. C. S. Dalton, 2419 (1973).

70. Margerum, D. W., Zabin, B. A., J. Phys. Chem., 66, 2214 (1962).

71. Harada, S., Tanabe, H., Yasunaga, T., Bull. Chem. Soc. Japan, 46, 3125 (1973).

72. Harada, S., Yasunaga, T., Tamura, K., Tatsumoto, N., J. Phys. Chem., 80, 313 (1976).

73. Nancollas, G. H., Sutin, N., Inorg. Chem., 3, 360 (1964).

74. Hammes, G. G., Stinfeld, J. I., J. Phys. Chem., 67, 528 (1963).

75. Melson, G. A., Wilkins, R. G., J. Chem. Soc., 4208 (1962).

76. Davies, A. G., Mac F. Smith, W., Proc. Chem. Soc., 380 (1961).

77. Letter, J. E., Jordan, R. B., J. Am. Chem. Soc., 97, 2381 (1975).

78. Almgren, T., Hagstrom, I., Water Res., 8, 395 (1974).

79. Chen, K. Y., Morris, J. C., Environ. Sci. Tech., 6, 529 (1972).

80. Östlund, H. G., Alexander, J., J. Geophys. Res., 68, 3395 (1963).

81. Cline, J. D., Richards, F. A., Environ. Sci. Tech., 3, 838 (1969).

82. O'Brien, D. J., Birkner, F. B., Environ. Sci., Tech., 12, 1114 (1977).

83. Avrahami, M., Golding, R. M., J. Chem. Soc., (A), 647 (1968).

84. Demirjian, Y. A., "The Electrochemical Characterization of the Rates of Oxidation of Soluble Sulfides by Molecular Oxygen," Ph.D. Thesis, University of Michigan, Ann Arbor, 1971.

85. Moussavi, M., "Autoxidation of Aqueous Sulfide in the Presence of Phenols-Kinetics and Products," Ph.D. Thesis, University of Southern California, Los Angeles, 1974.

86. Sorokin, Y. I., Okeanologiya, 11, 423 (1971).

87. Lim, B. C. H., "Kinetics and Mechanism of the Oxidation of Sulfide by Oxygen Catalyzed by Homogeneous Organometallic Complexes," M.S. Thesis, University of Minnesota (1978).

88. Hoffmann, M. R., Lim, B. C. H., (1979) to appear, Environ. Sci. Tech., 14, 1406.

89. Silverman, J., Dodson, R. W., J. Phys. Chem., 56, 846 (1952).

90. Reynolds, W. L., J. Am. Chem. Soc., 83, 1078 (1961).

91. Ford-Smith, M. H., Sutin, N., J. Am. Chem. Soc., 83, 1830 (1961).

92. Baxendale, J. H., Hardy, H. R., Trans. Faraday Soc., 50, 808 (1954).

93. Reynolds, W. L., Fukushima, S., Inorg. Chem., 2, 176 (1963).