DEPARTMENT OF CHEMISTRY

UNIVERSITY OF SWAZILAND

C304 **ANALYTICAL CHEMISTRY 1**

DECEMBER 2009 FINAL EXAMINATION

Time Allowed: Three (3) Hours

Instructions:

1. **This examination has six (6) questions and one (1) data sheets. The total number of pages is four (4) including this page.**
2. **Answer any four (4) questions fully; diagrams should be clear, large and properly labeled. Marks will be deducted for improper units and lack of procedural steps in calculations.**
3. **Each question is worth 25 marks.**

Special Requirements

1. **Data sheets.**
2. **Graph paper.**

YOU ARE NOT SUPPOSED TO OPEN THIS PAPER UNTIL PERMISSION TO DO SO HAS BEEN GIVEN BY THE CHIEF INVIGILATOR.

QUESTION 1 [25]

a. i) What does the acronym "emr" stand for? (1)

ii) Draw the blackbody radiation plot showing temperatures at 600K and 10,000K (2)

iii) Calculate the wavelength of maximum emission, in cm^{-1}, of the blackbody in (ii) above at the two temperatures given the Wien's Displacement constant of 2.9×10^{-3} mK. (4)

iv) Explain using examples what is meant by
a chromophore (2)
a bathochromic shift (2)

b. i) Chromotography is a "semi-batch, differential migration, thermodynamic technique". Use diagrams to explain what is meant by this statement. (3)

ii) Use diagrams and equations to explain the concept of "resistance to mass transfer in the stationary phase", and how it causes band broadening. (3)

c. i) Describe each of four (4) properties of the stationery phase in chromatography. (4)

ii) Use chemical equations to explain the concept of "reverse phase bonded phase" and "normal phase bonded phase". (4)

QUESTION 2 [25]

a. i) Use a diagram to explain how a band reject filter works (2)

ii) Gratings are one of the widely used monochromators in analytical instrumentation today. Given a grating that is 4.6cm wide with 1000 lines/mm, calculate the first order resolving power of the grating, and the resolution at 750nm. (3)

iii) Prisms are one of the widely used monochromators in analytical instrumentation today. Given a prism length of 5cm and a dispersion of 2.7×10^{-5}, calculate the resolving power of the prism, and the resolution at 5268 angstroms. (3)

b. i) What is meant by "efficiency" of a column in liquid chromatography? (2)

ii) How does efficiency affect the height equivalent to a theoretical plate in liquid chromatography? (2)

c. i) Use diagrams to explain the effect of stationery liquid loading on resolution in gas chromatography. (4)

ii) Use diagrams to explain the effect of choice of carrier gas between He and N_2 in gas chromatography. (4)

iii) What are "silanol" groups in gas chromatography? Why are they not desired in gas chromatography? How are they masked in gas chromatography? (5)

QUESTION 3 [25]

a. i) Use diagrams to explain how a photovoltaic cell and a PMT work. (7)

ii) Explain why the PMT is the most sensitive of the two. (2)

iii) Explain why:

There is a difference in sample placement between UV-Visible and IR spectroscopy (2)
IR bands are much broader than UV-Visible bands (2)

b. i) Explain why H_2 and O_2 do not show infrared bands, yet HCl and CO do. (2)

ii) Explain why dispersive infra-red spectroscopy has poor resolution. (2)

iii) What causes "atmospheric absorption bands" in infra-red spectroscopy? Why are they not desired? How are they eliminated? (3)

c. Draw the bolometer used as a thermal detector in infra-red spectroscopy and explain how it works. (5)

QUESTION 4 [25]

a. i) Use a diagram to illustrate how the stoichiometry of the complex Fe $(bipyridine)_3^{2+}$ is determined by the Job's Method of Continuous Variation (3)

b. In the determination of trace iron in water by spectrophotometry,

i) Explain the role of bipyridine. (1)
ii) Why is a pH=4.5 buffer added? (1)
iii) Why is hydroxylamine hydrochloride added? (1)
iv) Sketch the spectrum expected and indicate λ_{max} given that the ε at λ_{max} is 520 nm. (2)

c. Draw the thermocouple used as a detector in infra-red spectroscopy and explain how it works. (4)

d. What is meant by "resistance to mass transfer in the mobile phase" in chromatography? Write down the equation relating HETP to resistance to mass transfer in the mobile phase in chromatography. (3)

e. List and describe any of three (3) desirable properties of a solid support in chromatography. (3)

f. Describe each of the two ways of eluting compounds in liquid chromatography, and explain why one would be preferred over the other. (3)

g. Use a drawing to explain how a thermal conductivity detector works in chromatography. (4)

QUESTION 5 [25]

a. i) Explain the difference between AA and AE spectroscopy. (1)

ii) "Nebulization is a very inefficient approach to atomization". Explain the meaning and significance of this phase. (2)

iv) Explain how nebulisation is bypassed altogether in GFAAS. (3)

v) Outline the three (3) major cycles that lead to atomization in GFAAS. (3)

vi) List and describe each of two (2) advantages that GFAAS has over flame methods of atomic spectroscopy. (2)

b. What is meant by "Eddy Diffusion" in chromatography? Write down the "Eddy Diffusion" term in the Van Deempter equation, and explain how it could experimentally be manipulated to improve resolution. (4)

c. List and describe any three (3) desirable properties of a stationery phase in gas chromatography (3)

d. Describe each of the two ways of eluting compounds in gas chromatography, and explain why one would be preferred over the other. (3)

e. Use a diagram to explain how a flame ionization detector works in gas chromatography. (4)

QUESTION 6 [25]

a. i) What is a plasma, as applied in ICP-OES? (1)

ii) Draw the cross flow nebulizer, explain its role in ICP OES, and how it works. (3)

b. i) Using $CaCl_2$ solution as an example, describe the steps involved in the formation of excited state atoms, ions and molecular species in the flame in atomic absorption spectroscopy, and explain how this is different in the case of ICP. (4)

ii)List and describe each of three (3) advantages that ICP has over flame atomic absorption spectroscopy. (3)

c. i) Use diagrams to illustrate the effect of slit width on resolution. (3)
ii) Physically what does a grating look like? (1)
iii)State Bragg's Law as applied to a grating (2)

d. What is meant by "Longitudinal Diffusion" in chromatography? Write down the "Longitudinal Diffusion" term in the Van Deempter equation, and explain how it could experimentally be manipulated to improve resolution. (4)

e. Draw the "flow through" cell used in HPLC, and explain how using this cell makes UV-Visible detection of ortho-and para-nitroanilines possible in HPLC. (4)

1. PERIODIC CHART OF THE ELEMENTS

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18
								1 H 1.00794									2 He 4.00260
3 Li 6.941	4 Be 9.01218											5 B 10.8	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.99840	10 Ne 20.179
11 Na 22.98977	12 Mg 24.305											13 Al 26.98154	14 Si 28.0855	15 P 30.97376	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.0983	20 Ca 40.08	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.69	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.22	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.9055	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.9045	54 Xe 131.29
55 Cs 132.9055	56 Ba 137.33	57 ★ La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.9665	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.9804	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0254	89 ▲ Ac 227.0278	104 Unq (261)	105 Unp (262)	106 Unh (263)	107 Uns (262)	108 Uno (265)	109 Une (266)									

A value in brackets denotes the mass number of the longest lived or best known isotope.

★ Lanthanide series	58 Ce 140.12	59 Pr 140.9077	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.9254	66 Dy 162.50	67 Ho 164.9304	68 Er 167.26	69 Tm 168.9342	70 Yb 173.04	71 Lu 174.967
▲ Actinide series	90 Th 232.0381	91 Pa 231.0359	92 U 238.0289	93 Np 237.0482	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

4. NET STABILITY CONSTANTS

$Ag(CN)_2^-$	5×10^{20}
$Ag(NH_3)_2^+$	1.6×10^{7}
$Ag(S_2O_3)_2^{-3}$	4.7×10^{13}
$Al(OH)_4^-$	1.0×10^{33}
$Ca(EDTA)^=$	1.0×10^{11}
$Cd(CN)_4^=$	8.3×10^{17}
$Cd(NH_3)_4^{++}$	5.5×10^{6}
$Co(NH_3)_6^{+3}$	2×10^{35}
$Cr(OH)_4^-$	4×10^{28}
$Cu(CN)_4^{-3}$	1×10^{28}
$Cu(NH_3)_4^{++}$	1.2×10^{11}
$Fe(CN)_6^{-3}$	4.0×10^{43}
$Fe(CN)_6^{-4}$	2.5×10^{35}
$Fe(SCN)^{++}$	1.0×10^{3}
$HgCl_4^=$	1.3×10^{15}
$Hg(CN)_4^=$	8.3×10^{38}
$Hg(SCN)_4^=$	5.0×10^{20}
$HgI_4^=$	6.3×10^{29}
$Mg(EDTA)^=$	1.3×10^{9}
$Ni(NH_3)_4^{++}$	4.7×10^{7}
$Pb(OH)_3^-$	7.9×10^{13}
$Zn(CN)_4^=$	4.2×10^{16}
$Zn(NH_3)_4^{++}$	7.8×10^{8}
$Zn(OH)_4^=$	6.3×10^{14}

2. IONIZATION CONSTANTS (K_A) FOR WEAK ACIDS

Acetic		1.9×10^{-5}
2-Amino-pyridinium Ion		2×10^{-7}
Ammonium Ion		5.6×10^{-10}
Anilinium Ion		2.3×10^{-5}
Arsenic	K_1	5.6×10^{-3}
Benzoic		6.7×10^{-5}
Boric	K_1	5×10^{-10}
Carbonic	K_1	4.3×10^{-7}
	K_2	5.6×10^{-11}
Chloroacetic		1.5×10^{-3}
Chromic	K_2	3.2×10^{-7}
Citric	K_1	8.7×10^{-4}
	K_2	1.8×10^{-5}
	K_3	4×10^{-6}
Dichloroacetic		5×10^{-2}
EDTA	K_1	7×10^{-3}
	K_2	2×10^{-3}
	K_3	7×10^{-7}
	K_4	6×10^{-11}
Formic		2×10^{-4}
α-D(+)-Glucose		5.2×10^{-13}
Glycinium Ion	K_1	4.6×10^{-3}
	K_2	2.5×10^{-10}
Hydrazinium Ion		5.9×10^{-9}
Hydrocyanic		7×10^{-10}
Hydrofluoric		7×10^{-4}
Hydroxylammonium Ion		9.1×10^{-7}
Hypochlorous		3.7×10^{-8}
H_2S	K_1	9×10^{-8}
	K_2	1×10^{-15}
Imidazolium Ion		1.1×10^{-7}
Lactic		1.4×10^{-4}
Methylammonium Ion		2.7×10^{-11}
Monoethanolammonium Ion		3×10^{-10}
Nicotinium Ion		9.6×10^{-9}
Oxalic	K_1	6×10^{-2}
	K_2	6×10^{-5}
Phenol		1.3×10^{-10}
Phthalic	K_2	4×10^{-6}
Phosphoric	K_1	7.5×10^{-3}
	K_2	6.2×10^{-8}
	K_3	4.7×10^{-13}
Phosphorous	K_1	1.0×10^{-2}
	K_2	2.6×10^{-7}
Pyridinium Ion		1×10^{-5}
Succinic	K_1	7×10^{-5}
	K_2	2.5×10^{-6}
Sulfuric	K_2	1.2×10^{-2}
Sulfurous	K_1	2×10^{-2}
	K_2	6×10^{-8}
Trimethylammonium Ion		1.6×10^{-10}
Uric		1.3×10^{-4}
Water, K_w, 24°C		1.0×10^{-14}

3. SOLUBILITY PRODUCT CONSTANTS

$AgBr$	4×10^{-13}	BaC_2O_4	2×10^{-8}	$KClO_4$	2×10^{-2}
Ag_2CO_3	6×10^{-12}	$BaSO_4$	1×10^{-10}	$MgCO_3$	1×10^{-5}
$AgCl$	1×10^{-10}	$CaCO_3$	5×10^{-9}	MgC_2O_4	9×10^{-5}
Ag_2CrO_4	2×10^{-12}	CaF_2	4×10^{-11}	$MgNH_4PO_4$	2×10^{-13}
$Ag[Ag(CN)_2]$	4×10^{-12}	CaC_2O_4	2×10^{-9}	$Mg(OH)_2$	1×10^{-11}
AgI	1×10^{-16}	CdS	1×10^{-28}	MnS	1×10^{-15}
Ag_3PO_4	1×10^{-19}	$Cu(OH)_2$	2×10^{-20}	$PbCrO_4$	2×10^{-14}
Ag_2S	1×10^{-50}	CuS	1×10^{-36}	PbS	1×10^{-28}
$AgCNS$	1×10^{-12}	$Fe(OH)_3$	1×10^{-36}	$PbSO_4$	2×10^{-8}
$Al(OH)_3$	2×10^{-32}	Hg_2Br_2	3×10^{-23}	$SrCrO_4$	4×10^{-5}
$BaCO_3$	5×10^{-9}	Hg_2Cl_2	6×10^{-19}	$Zn(OH)_2$	3.6×10^{-16}
$BaCrO_4$	1×10^{-10}	HgS	1×10^{-52}	ZnS	1×10^{-24}

5. FIRST IONIZATION ENERGIES, e.v.

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	
								14									25
5.4	9.3											8.3	11	15	14	17	22
5.1	7.6											6.0	8.1	11	10	13	16
4.3	6.1	6.6	6.8	6.7	6.8	7.4	7.9	7.9	7.6	7.7	9.4	6.0	8.1	10	9.8	12	14
4.2	5.7	6.6	7.0	6.8	7.2		7.5	7.7	8.3	7.6	9.0	5.8	7.3	8.6	9.0	10	12
3.9	5.2	5.0 6.9	5.5	6	8.0	7.9	8.7	9.2	9.0	9.2	10	6.1	7.4	8			11

6. ELECTRONEGATIVITIES, Pauling

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	
								2.1									
1.0	1.5											2.0	2.5	3.0	3.5	4.0	
0.9	1.2											1.5	1.8	2.1	2.5	3.0	
0.8	1.0	1.3	1.5	1.6	1.6	1.5	1.8	1.8	1.8	1.9	1.6	1.6	1.8	2.0	2.4	2.8	
0.8	1.0	1.2	1.4	1.6	1.8	1.9	2.2	2.2	2.2	1.9	1.7	1.7	1.8	1.9	2.1	2.5	
0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.2	2.2	2.2	2.4	1.9	1.8	1.8	1.9	2.0	2.2	

7. ATOMIC RADII picometers

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	
								37									32
155	112											98	91	92	73	71	69
190	160											143	132	128	127	99	97
235	197	162	147	134	130	135	126	125	124	128	138	141	137	139	140	114	[illegible]
248	215	178	160	146	139	136	134	134	137	144	154	166	162	159	[illegible]	133	130
267	222	187	167	149	141	137	135	136	139	146	157	171	175	170	[illegible]		145

8. IONIC RADII pm

Li^+	60	Sr^{+2}	113	S^{-2}	184
Na^+	95	Ba^{+2}	135	Se^{-2}	198
K^+	133	B^{+3}	20	Te^{-2}	221
Rb^+	148	Al^{+3}	50	F^-	136
Be^{+2}	31	N^{+3}	171	Cl^-	181
Mg^{+2}	65	P^{+3}	212	Br^-	195
Ca^{+2}	99	O^{-2}	140	I^-	216

9. LATTICE ENERGIES

(All negative) kJ/mol

	F	Cl	Br	I
Li	1030	840	781	718
Na	914	770	728	681
K	812	701	671	632
Rb	[illegible]	682	654	617
Cs	744	630	613	585

10. HALF LIVES

H^3	12.3 years	K^{40}	1.28×10^9 y	I^{131}	8.1 days
F^{20}	11.4 secs	Ca^{45}	165 days	Cs^{137}	30 years
C^{14}	5730 years	Fe^{59}	45 days	Au^{198}	2.69 days
Na^{24}	15.0 hours	Co^{60}	5.26 y	Ra^{226}	1620 yrs.
P^{32}	14.3 days	Br^{82}	35.5 hours	U^{235}	7.1×10^8 y
S^{35}	88 days	Sr^{90}	28 years	U^{238}	4.51×10^9 y
Cl^{36}	3.1×10^5 y	I^{129}	1.7×10^7 y	Pu^{239}	24,400 y

…or	pH range	pKin	Acid	Base
…blue	1.2 – 2.8	1.6	red	yellow
… yellow	2.9 – 4.0	3.3	red	yellow
…yl orange	3.1 – 4.4	4.2	red	yellow
…omocresol green	3.8 – 5.4	4.7	yellow	blue
…thyl red	4.2 – 6.2	5.0	red	yellow
…lorophenol red	4.8 – 6.4	6.0	yellow	red
…omothymol blue	6.0 – 7.6	7.1	yellow	blue
…enol red	6.4 – 8.0	7.4	yellow	red
…esol purple	7.4 – 9.0	8.3	yellow	purple
…ymol blue	8.0 – 9.6	8.9	yellow	blue
…enolphthalein	8.0 – 9.8	9.7	colorless	red
…ymolphthalein	9.3 – 10.5	9.9	colorless	blue

n	Q_{90}	n	Q_{90}	n	Q_{90}
3	0.94	6	0.56	9	0.44
4	0.76	7	0.51	10	0.41
5	0.64	8	0.47		

15. Bond Enthalpies

kJ mol^{-1} at 25°C (i.e. Bond Energies)

Single	O	N	C	S	F	Cl
H	463	391	413	368	563	432
C	358	305	346	272	489	328
N	222	163	MISC.		275	192

S—S	251	H—H	436	C=C	615
S—F	327	N≡N	946	C≡C	812
S—Cl	271	N=O	607	C=O	749

D.F.	t_{50}	t_{90}	t_{95}	$t_{9…}$
1	1.0	6.3	13	64
2	0.82	2.9	4.3	9.
3	0.76	2.35	3.2	5.
4	0.74	2.13	2.8	4.
5	0.73	2.02	2.57	4.
6	0.72	1.94	2.45	3.
7	0.71	1.90	2.36	3.
8	0.71	1.86	2.31	3.
9	0.70	1.83	2.26	3.
10	0.70	1.81	2.23	3.
20	0.69	1.72	2.09	2.
30	0.68	1.70	2.04	2.
∞	0.67	1.64	1.96	2.

12. ELECTRODE POTENTIALS, $\mathcal{E}°$

Reaction	$\mathcal{E}°$
$…^{+} + e \rightleftharpoons Na$	– 2.713
$…g^{++} + 2e \rightleftharpoons Mg$	– 2.37
$…^{+++} + 3e \rightleftharpoons Al$	– 1.66
$…^{++} + 2e \rightleftharpoons Zn$	– 0.763
$…^{++} + 2e \rightleftharpoons Fe$	– 0.44
$…^{++} + 2e \rightleftharpoons Cd$	– 0.403
$…^{+++} + e \rightleftharpoons Cr^{++}$	– 0.38
$…^{+} + e \rightleftharpoons Tl$	– 0.336
$…^{+++} + e \rightleftharpoons V^{++}$	– 0.255
$…^{++} + 2e \rightleftharpoons Sn$	– 0.14
$…^{++} + 2e \rightleftharpoons Pb$	– 0.126
$…^{+} + 2e \rightleftharpoons H_2$	0.000
$…O_6^{=} + 2e \rightleftharpoons 2S_2O_3^{=}$	0.09
$…O^{++} + 2H^{+} + e \rightleftharpoons Ti^{+++} + H_2O$	0.10
$… + 2H^{+} + 2e \rightleftharpoons H_2S$	0.14
$…^{+4} + 2e \rightleftharpoons Sn^{++}$	0.14
$…u^{++} + e \rightleftharpoons Cu^{+}$	0.17
$…O_4^{=} + 4H^{+} + 2e \rightleftharpoons H_2O + H_2SO_3$	0.17
$…gCl + e \rightleftharpoons Cl^{-} + Ag$	0.222
…turated calomel	(0.244)
$…g_2Cl_2 + 2e \rightleftharpoons 2Cl^{-} + 2Hg$	0.268
$…i^{+++} + 3e \rightleftharpoons Bi$	0.293
$…O_2^{++} + 4H^{+} + 2e \rightleftharpoons U^{+4} + 2H_2O$	0.33
$…O^{++} + 2H^{+} + e \rightleftharpoons V^{+++} + H_2O$	0.34
$…u^{++} + 2e \rightleftharpoons Cu$	0.34
$…e(CN)_6^{-3} + e \rightleftharpoons Fe(CN)_6^{-4}$	0.355
$…u^{+} + e \rightleftharpoons Cu$	0.52
$…^{-} + 2e \rightleftharpoons 3I^{-}$	0.545
$…_3AsO_4 + 2H^{+} + 2e \rightleftharpoons H_3AsO_3 + H_2O$	0.56
$…_2 + 2e \rightleftharpoons 2I^{-}$	0.621
$…HgCl_2 + 2e \rightleftharpoons Hg_2Cl_2 + 2Cl^{-}$	0.63
$…_2 + 2H^{+} + 2e \rightleftharpoons H_2O_2$	0.69
…uinone + $2H^{+} + 2e \rightleftharpoons$ Hydroquinone	0.70
$…e^{+++} + e \rightleftharpoons Fe^{++}$	0.771
$…g_2^{++} + 2e \rightleftharpoons 2Hg$	0.792
$…g^{+} + e \rightleftharpoons Ag$	0.799
$…Hg^{++} + 2e \rightleftharpoons Hg$	0.851
$…Hg^{++} + 2e \rightleftharpoons Hg_2^{++}$	0.907
$…O_3^{-} + 3H^{+} + 2e \rightleftharpoons HNO_2 + H_2O$	0.94
$…NO_2 + H^{+} + e \rightleftharpoons NO + H_2O$	0.98
$…O_2^{+} + 2H^{+} + e \rightleftharpoons VO^{++} + H_2O$	0.999
$…Br_2 + 2e \rightleftharpoons 2Br^{-}$	1.08
$…O_3^{-} + 12H^{+} + 10e \rightleftharpoons 6H_2O + I_2$	1.19
$…O_2 + 4H^{+} + 4e \rightleftharpoons 2H_2O$	1.229
$…MnO_2 + 4H^{+} + 2e \rightleftharpoons Mn^{++} + 2H_2O$	1.23
$…Cr_2O_7^{=} + 14H^{+} + 6e \rightleftharpoons 7H_2O + 2Cr^{+++}$	1.33
$…Cl_2 + 2e \rightleftharpoons 2Cl^{-}$	1.358
$…BrO_3^{-} + 12H^{+} + 10e \rightleftharpoons 6H_2O + Br_2$	1.50
$…MnO_4^{-} + 8H^{+} + 5e \rightleftharpoons 4H_2O + Mn^{++}$	1.51
$…Ce^{+4} + e \rightleftharpoons Ce^{+3}$	1.61

13. MEAN ACTIVITY COEFFICIENTS

M	KCl	Na_2SO_4	$ZnSO_4$
0.001	0.965	0.89	0.70
0.01	0.901	0.72	0.39
0.1	0.769	0.45	0.15

16. HEATS OF FORMATION

$\Delta H°$ in kJ mol^{-1} at 25°C

All ions in H_2O solution except as noted

All Elements = 0

H_g	218	H^{+}	0.0	H_2O_g	—242
O_g	249	Na^{+}	—240	H_2O_l	—286
C_g	717	Ag^{+}	106	CO_g	—111
N_g	473	NH_4^{+}	—133	CO_{2g}	—394
F_g	79	OH^{-}	—230	NH_{3g}	—46
Cl_g	122	F^{-}	—333	NO_g	90
Br_g	112	Cl^{-}	—167	NO_{2g}	33
I_g	107	Br^{-}	—122	N_2O_{4g}	9
S_g	279	I^{-}	—55	SO_{2g}	—297
P_g	315	$S^{=}$	33	SO_{3g}	—396
Na_g	107	$SO_4^{=}$	—909	H_2S_g	—21
K_g	88	$CO_3^{=}$	—677	NaF_s	—574
Na^{+}_g	609	HF_g	—271	$NaCl_s$	—411
K^{+}_g	514	HCl_g	—92	KF_s	—567
F^{-}_g	—255	HBr_g	—36	KCL_s	—437
Cl^{-}_g	—233	HI_g	26	$AgCl_s$	—127
CH_{4g}	—75	HCN_g	135	$AgBr_s$	—100
C_2H_{2g}	227	PH_{3g}	5	PCl_{3g}	—287
C_2H_{4g}	52	C_6H_{6l}	49	PCl_{5g}	—375
		C_2H_{6g}	—85	CH_3OH_l	—238
		C_3H_{8g}	—105	$C_2H_5OH_g$	—235
		nC_4H_{10g}	—127	$C_2H_5OH_l$	—278
		nC_8H_{18g}	—209	$COCl_{2g}$	—219
		CCl_{4l}	—135	CH_2Cl_g	—81

17. ABS. ENTROPY S°

J mol^{-1} K^{-1}, at 25°C

H_{2g}	131	P_{4wh}	164	SF_{6g}	292
N_{2g}	192	HF_g	174	NO_g	211
O_{2g}	205	HCl_g	187	NO_{2g}	240
Cl_{2g}	223	H_2O_g	189	N_2O_{4g}	304
F_{2g}	203	CO_g	198	NH_{3g}	192
Cgra	5.7	CO_{2g}	214	PCl_{3g}	312
S_{8r}	254	SO_{2g}	248	PCl_{5g}	365
CH_{4g}	186	SO_{3g}	256	BF_{3g}	254
		C_2H_{6g}	229	CH_3OH_l	127
		C_3H_{8g}	270	$C_2H_5OH_g$	283
		C_2H_{2g}	201	$C_2H_5OH_l$	161
		C_2H_{4g}	219	$(CH_3)_2O_g$	266
		C_6H_{6g}	269	CH_3COOH_g	282

18. ΔG° FORMATION

kJ mol^{-1} at 25°C

H_g	203	HF_g	—273	H_2O_g	—229
F_g	62	HCl_g	—95	H_2O_l	—237
Cl_g	106	HBr_g	—54	SO_{2g}	—300
O_g	232	HI_g	1.7	SO_{3g}	—371
NO_g	87	NH_{3g}	—16	PCl_{3g}	—268
NO_{2g}	51	CO_g	—137	PCl_{5g}	—305
N_2O_{4g}	98	CO_{2g}	—394	CH_{4g}	—51
C_2H_{4g}	68	C_2H_{2g}	209	C_2H_{6g}	—33
C_6H_{6l}			125	CH_3OH_l	—162
CCl_{4l}			—65	$C_2H_5OH_l$	—175
BF_{3g}			—1120	$CHCl_{3g}$	—70
SF_{6g}			—1105	CH_3COOH_g	—374

20. CONC. ACIDS AND BAS…

	M.W.	Density	Wt. %	Mol… it…
Acetic	60.05	1.05	99.5	1…
H_2SO_4	98.07	1.83	94	1…
HF	20.01	1.14	45	2…
HCl	36.46	1.19	38	1…
HBr	80.91	1.52	48	
HNO_3	63.01	1.41	69	1…
$HClO_4$	100.46	1.67	70	1
H_3PO_4	98.00	1.69	85	1
NaOH	40.00	1.53	50	1
NH_3	17.03	0.90	28	1

21. DENSITIES (g cm^{-3})

Water at			
0.°C	0.9168	Air (70 cm)	0.0…
10°	0.9997	Glass	2.7
20°	0.9982	Na_2CO_3	2.5
22°	0.9978	NaCl	2.2
24°	0.9973	$BaSO_4$	4.5
26°	0.9968	AgCl	5.6
28°	0.9963	Aluminum	2.7
30°	0.9956	Iron	7.9
90°	0.9653	Brass	8.4
100°	0.0006	Mercury	13.6
		Platinum	21.4

22. MOBILITIES ($m^2V^{-1}s^{-1}$ × 1…

Li^{+}	39	H_3O^{+}	350	$\frac{1}{2}Ba^{++}$	
Na^{+}	50	NH_4^{+}	73	$\frac{1}{3}La^{+3}$	
K^{+}	74	Ag^{+}	62	$\frac{1}{2}SO_4^{=}$	
Cl^{-}	76	OH^{-}	198	$\frac{1}{3}PO_4^{-3}$	
Br^{-}	78	I^{-}	77	NO_3^{-}	

23. WATER V.P. (torr)

0°C	4.6	25°	…
15°	12.8	30°	…
20°	17.5	50°	…

24. MISCELLANEOUS

Std. dev. = $\sqrt{\Sigma (X_i - \bar{X})^2/(n-1)}$

Conf. limits = $\bar{X} \pm ts/\sqrt{n}$

$E = E° - (0.0592/n)\log([Red]/[Ox])$

$\log I_o/I_t = abc = A = \log 1/T$

$\log N_T = \log N_0 - 0.301T/T_{\frac{1}{2}}$

$x = (-b \pm \sqrt{b^2 - 4ac})/2a$

$n\lambda = 2d \sin \theta$

$2.303 \log_{10} a = \log_e a$

$h = 6.626 \times 10^{-34}$ J s

$e = 1.602 \times 10^{-19}$ C

$N_A = 6.022 \times 10^{23}$ mol^{-1}

F = 96487 C

$g = 9.807$ m s^{-2}

$c = 2.998 \times 10^{8}$ m s^{-1}

1 amu = 1.661×10^{-27} kg

R = 1.987 cals mol^{-1} K^{-1}

= 0.08206 litre atm mol^{-1} K^{-1}

= 8.314 J mol^{-1} K^{-1}

= 8.314 kPa dm^3 mol^{-1} K^{-1}

0 °C = 273.15 K

1 eV = 1.602×10^{-19} J

1 cal = 4.1840 J