DEPARTMENT OF CHEMISTRY

UNIVERSITY OF SWAZILAND

C304 **ANALYTICAL CHEMISTRY I I**

DECEMBER 2013 **FINAL EXAMINATION**

Time Allowed: **Three (3) Hours**

Instructions:

1. **This examination has six (6) questions and one (1) data sheet. The total number of pages is five (5), 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 sheet.**
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) A spectroscopy source emits 1500cm^{-1} radiation.

i) What type of transition would it induce in a sample? [1]

ii) What is its wavelength in µm? [1]

iii) What is its energy in J? [1]

iv) What is its frequency in Hz? [1]

v) What is its energy in eV? [1]

b) Explain the difference in sample placement between IR and uv-visible spectroscopy [4]

c) Gratings have a very good resolving power in spectroscopy.

i) Physically, how does a grating look like (2)
ii) Use equations to explain how a grating works (3)
iii) Calculate the second order resolving power of a grating which is 5cm long with 1180 lines per mm (3)

d) One of the applications of GC is the separation of benzene from its mixture with cyclohexane, followed by quantification of the benzene.

(i) In GC, use diagrams to explain what is meant by longitudinal diffusion [2]
(ii) State the equation that relates longitudinal diffusion in a packed chromatographic bed, to linear velocity [2]
(iii) In GC, use diagrams to explain what is meant by Eddy diffusion [2]
(iv) State the equation that relates bandbroadening due to Eddy Diffusion, to linear velocity [2]

QUESTION 2 [25]

a) State Beer's Law as applied to spectroscopy, and explain all terms appearing in it [3]

b) Stray light is problematic in spectroscopy

i) What is meant by "stray light" in spectroscopy? [1]
ii) Use equations to explain why stray light leads to negative deviations from Beer's Law [3]
iii) How is stray light eliminated in spectroscopy? [1]

c) Draw and label a vacuum phototube and explain how it works. [3]

d) The mobile phase is a critical component in chromatography.

i) Explain the role of the mobile phase in gas chromatography [1]
ii) List and discuss any two (2) desirable properties of a mobile phase in gas chromatography [4]
iii) Explain how silanol groups are deactivated in chromatography [4]

e) Use diagrams to explain how UV-visible detection of ink isomers is carried out after separation in an HPLC instrument.[5]

Question 3 [25]

a) Use diagrams to explain why it was not possible to perform atomic absorption spectroscopy using traditional broadband sources prior to the invention of the hollow cathode lamp [4]

b) Explain why in atomic absorption spectroscopy

(i) 1000 ppm La is added to all solutions in the analysis of Pb [2]
(ii) Excess EDTA is added to all solutions in the analysis of Ca [2]

c) Explain the role of background correction in flame atomic absorption spectroscopy, and explain using diagrams how this is achieved [4]

d) Chromatography is semi-batch differential migration, phase distribution technique. Explain the meaning of this phrase. [3]

e) Draw the Van Deempter Plot for gas chromatography and explain how it is used to optimize linear velocity of the carrier gas. [3]

f) What is the major difference between a typical Gc Van Deempter Plot and a typical LC one ? [2]

g) Use diagrams to explain

(i) Why N_2 is preferred over He as carrier gas in chromatography [2]
(ii) The effect liquid loading of stationary phase on bandbroadening [3]

Question 4 [25]

a) With the aid of a diagram briefly describe the IPC torch [3]

b) Describe the path taken by a Ca atom in a sample containing $CaCl_2$ solution from aspiration stage to atomization stage in ICP [4]

c) Discuss two major advantages of ICP over flame or graphite furnace atomic absorption. [2]

d) The ICP has many excitation lines which must be resolved using a grating.

i) Physically, how does a grating look like? [1]
ii) Use equations to explain how it works as a monochromator [3]

e) With the aid of a diagram, briefly but informatively explain the function of each of the following detectors

i) Electron Capture Detector [4]

ii) Flame Ionization Detector. [4]

iii) Thermal Conductivity Detector [4]

Question 5 [25]

a) State Beer's Law and explain all terms appearing in it [3]

b) Explain how an unstable power supply gives rise to deviation in Beer's Law, and use a diagram to explain how this deviation is eliminated [3]

c). Use diagrams to explain how UV-visible spectroscopy is used to determine stoichiometry by the Job's Method [3]

d) In liquid chromatography, two solvent reservoirs are usually used. Explain the reason for this. [2]

e) In gas chromatography, dual columns are often used simultaneously. Explain the reason for this. [2]

f) One of the applications of GC is the separation of benzene from its mixture with cyclohexane, followed by quantification of the benzene.

(i) In GC, what is meant by lateral diffusion? [3]
(ii) State the equation that relates resistance to mass transfer in the mobile phase to bandbroadening [3]
(iii) In GC, what is meant by resistance to mass transfer in the stationery phase? [3]
(iv) State the equation that relates resistance to mass transfer in the stationery phase to bandbroadening [3]

Question 6 [25]

a) Prisms are used as monochromatours for spectroscopy

i) Draw the prism (1)
ii)Use equations to explain how the prism works (3)
iii)Draw and label the Bunsen arrangement of optical components in a spectrometer(3)

b) The Nernst Glower is a useful source of radiation in infrared spectroscopy.

i) Describe the Nernst Glower as used in IR spectroscopy. [1]
ii) Which of the molecules oxygen and hydrogen chloride is IR active and why? [2]
iii) Why is it not possible to carry out quantitative analyses on dispersive IR? [3]

c) Nebulization is a very wasteful approach to atomization.

i) What does the term "nebulization" mean? [1]
ii) Use diagrams to explain how nebulization is carried out in atomic spectroscopy [3]
iii) Use your answer in (c) ii above to explain why nebulization is considered inefficient [2]

d) Bandbroadening is important for peak resolution in HPLC.

i) Use a drawing to explain the importance of linear velocity on HETP [2]
ii) On this drawing, indicate the optimum linear velocity [1]
iii) Use diagrams to explain the phenomenon of "race track effect", how it affects bandbroadening, and how it is eliminated. [3]

CHEMISTRY DATA SHEET

1. PERIODIC CHART OF THE ELEMENTS

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	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 10.81	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 228.0254	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^{23}
$Cu(NH_3)_4^{++}$	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.

14

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	
																	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

2.1

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	
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	1.8	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

37

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	
																	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	110
248	215	178	160	146	139	136	134	134	137	144	154	166	162	159	160	133	130
267	222	187	167	149	141	137	135	136	139	146	157	171	175	170	176		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	780	682	654	617
Cs	744	630	613	585

10. HALF LIVES

H^3	12.3 years	K^{40}	1.28×10^9y	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}	7.1×10^8y
S^{35}	88 days	Sr^{90}	28 years	U^{238}	4.51×10^9y
Cl^{36}	3.1×10^5y	I^{129}	1.7×10^7y	Pu^{230}	24,400 y

11. ACID-BASE INDICATORS AT 25°C

Indicator	pH range	pKin	Acid	Base
Thymol blue	1.2 – 2.8	1.6	red	yellow
Methyl yellow	2.9 – 4.0	3.3	red	yellow
Methyl orange	3.1 – 4.4	4.2	red	yellow
Bromocresol green	3.8 – 5.4	4.7	yellow	blue
Methyl red	4.2 – 6.2	5.0	red	yellow
Chlorophenol red	4.8 – 6.4	6.0	yellow	red
Bromothymol blue	6.0 – 7.6	7.1	yellow	blue
Phenol red	6.4 – 8.0	7.4	yellow	red
Cresol purple	7.4 – 9.0	8.3	yellow	purple
Thymol blue	8.0 – 9.6	8.9	yellow	blue
Phenolphthalein	8.0 – 9.8	9.7	colorless	red
Thymolphthalein	9.3 – 10.5	9.9	colorless	blue

14. DATA REJECTION—Q TABLE

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			275	192

MISC.

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

19. t TABLE

D.F.	t_{50}	t_{90}	t_{95}	t_{99}
1	1.0	6.3	13	64
2	0.82	2.9	4.3	9.9
3	0.76	2.35	3.2	5.8
4	0.74	2.13	2.8	4.6
5	0.73	2.02	2.57	4.0
6	0.72	1.94	2.45	3.7
7	0.71	1.90	2.36	3.5
8	0.71	1.86	2.31	3.36
9	0.70	1.83	2.26	3.25
10	0.70	1.81	2.23	3.17
20	0.69	1.72	2.09	2.84
30	0.68	1.70	2.04	2.75
∞	0.67	1.64	1.96	2.58

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

$Na^+ + e \rightleftarrows Na$	– 2.713
$Mg^{++} + 2e \rightleftarrows Mg$	– 2.37
$Al^{+++} + 3e \rightleftarrows Al$	– 1.66
$Zn^{++} + 2e \rightleftarrows Zn$	– 0.763
$Fe^{++} + 2e \rightleftarrows Fe$	– 0.44
$Cd^{++} + 2e \rightleftarrows Cd$	– 0.403
$Cr^{+++} + e \rightleftarrows Cr^{++}$	– 0.38
$Tl^+ + e \rightleftarrows Tl$	– 0.336
$V^{+++} + e \rightleftarrows V^{++}$	– 0.255
$Sn^{++} + 2e \rightleftarrows Sn$	– 0.14
$Pb^{++} + 2e \rightleftarrows Pb$	– 0.126
$2H^+ + 2e \rightleftarrows H_2$	0.000
$S_4O_6^= + 2e \rightleftarrows 2S_2O_3^=$	0.09
$TiO^{++} + 2H^+ + e \rightleftarrows Ti^{+++} + H_2O$	0.10
$S + 2H^+ + 2e \rightleftarrows H_2S$	0.14
$Sn^{+4} + 2e \rightleftarrows Sn^{++}$	0.14
$Cu^{++} + e \rightleftarrows Cu^+$	0.17
$SO_4^= + 4H^+ + 2e \rightleftarrows H_2O + H_2SO_3$	0.17
$AgCl + e \rightleftarrows Cl^- + Ag$	0.222
Saturated calomel	(0.244)
$Hg_2Cl_2 + 2e \rightleftarrows 2Cl^- + 2Hg$	0.268
$Bi^{+++} + 3e \rightleftarrows Bi$	0.293
$UO_2^{++} + 4H^+ + 2e \rightleftarrows U^{+4} + 2H_2O$	0.33
$VO^{++} + 2H^+ + e \rightleftarrows V^{+++} + H_2O$	0.34
$Cu^{++} + 2e \rightleftarrows Cu$	0.34
$Fe(CN)_6^{-3} + e \rightleftarrows Fe(CN)_6^{-4}$	0.355
$Cu^+ + e \rightleftarrows Cu$	0.52
$I_3^- + 2e \rightleftarrows 3I^-$	0.545
$H_3AsO_4 + 2H^+ + 2e \rightleftarrows H_3AsO_3 + H_2O$	0.56
$I_2 + 2e \rightleftarrows 2I^-$	0.621
$2HgCl_2 + 2e \rightleftarrows Hg_2Cl_2 + 2Cl^-$	0.63
$O_2 + 2H^+ + 2e \rightleftarrows H_2O_2$	0.69
Quinone + $2H^+ + 2e \rightleftarrows$ Hydroquinone	0.70
$Fe^{+++} + e \rightleftarrows Fe^{++}$	0.771
$Hg_2^{++} + 2e \rightleftarrows 2Hg$	0.792
$Ag^+ + e \rightleftarrows Ag$	0.799
$Hg^{++} + 2e \rightleftarrows Hg$	0.851
$2Hg^{++} + 2e \rightleftarrows Hg_2^{++}$	0.907
$NO_3^- + 3H^+ + 2e \rightleftarrows HNO_2 + H_2O$	0.94
$HNO_2 + H^+ + e \rightleftarrows NO + H_2O$	0.98
$VO_2^+ + 2H^+ + e \rightleftarrows VO^{++} + H_2O$	0.999
$Br_2 + 2e \rightleftarrows 2Br^-$	1.08
$2IO_3^- + 12H^+ + 10e \rightleftarrows 6H_2O + I_2$	1.19
$O_2 + 4H^+ + 4e \rightleftarrows 2H_2O$	1.229
$MnO_2 + 4H^+ + 2e \rightleftarrows Mn^{++} + 2H_2O$	1.23
$Cr_2O_7^= + 14H^+ + 6e \rightleftarrows 7H_2O + 2Cr^{+++}$	1.33
$Cl_2 + 2e \rightleftarrows 2Cl^-$	1.358
$2BrO_3^- + 12H^+ + 10e \rightleftarrows 6H_2O + Br_2$	1.50
$MnO_4^- + 8H^+ + 5e \rightleftarrows 4H_2O + Mn^{++}$	1.51
$Ce^{+4} + e \rightleftarrows Ce^{+3}$	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
1.0	0.606	0.20	0.045

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_3Cl_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
NH_4Cl_s	—203			$(CH_3)_2O_g$	—113

20. CONC. ACIDS AND BASES

	M.W.	Density	Wt. %	Molarity
Acetic	60.05	1.05	99.5	17.4
H_2SO_4	98.07	1.83	94	17.6
HF	20.01	1.14	45	25.7
HCl	36.46	1.19	38	12.4
HBr	80.91	1.52	48	9.0
HNO_3	63.01	1.41	69	15.4
$HClO_4$	100.46	1.67	70	11.6
H_3PO_4	98.00	1.69	85	14.7
NaOH	40.00	1.53	50	19.1
NH_3	17.03	0.90	28	14.8

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

Water at			
0$_s$°C	0.9168	Air (70 cm)	0.0011
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$_g$°	0.0006	Mercury	13.6
		Platinum	21.4

22. MOBILITIES (m^{2}V^{-1}s^{-1} × 10^9)

Li^+	39	H_3O^+	350	$\frac{1}{2}Ba^{++}$	64
Na^+	50	NH_4^+	73	$\frac{1}{3}La^{+3}$	70
K^+	74	Ag^+	62	$\frac{1}{2}SO_4^=$	80
Cl^-	76	OH^-	198	$\frac{1}{3}PO_4^{-3}$	80
Br^-	78	I^-	77	NO_3^-	71

23. WATER V.P. (torr)

0°C	4.6	25°	23.8
15°	12.8	30°	31.8
20°	17.5	50°	92.5

24. MISCELLANEOUS

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

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

$E = E° - (0.0592/n)\log([Red]/[Ox])$

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

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

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

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

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

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

O °C = 273.15 K

1 eV = 1.602×10^{-19} J

1 cal = 4.1840 J

760 torr = 101.3 kPa