DEPARTMENT OF CHEMISTRY

UNIVERSITY OF SWAZILAND

C304 INSTRUMENTAL ANALYSIS

JULY 2006 SUPPLEMENTARY EXAMINATION

Time Allowed: Three (3) Hours

Instructions:

1. This examination has six (6) questions and one data sheet. The total number of pages is eight (8) 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.

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

SECTION A SPECTROSCOPY

Answer any two (2) questions from this section

Question 1 [25]

a) For a spectroscopic band occurring at 1685 cm^{-1},

(i) convert to energy in joules [1]
(ii) state in which region of the electromagnetic spectrum the band falls [1]
(iii) state the kind of transition taking place [1]

b) Explain using diagrams, why atomic spectra appear as lines, whereas molecular spectra appear as bands [4]

c) The cheapest (affordable) uv-visible instruments (typically the *Bosch and Laumb Spectronic 20* series) rely on the use of a "Bunsen" arrangement of the optical components.

(i) By means of a diagram, explain what is meant by this arrangement. [3]
(ii) Explain how this arrangement enables light from the source to be split into individual wavelengths. [3]

d) The cheapest (affordable) infrared instruments rely on the use of a "Czerny-Turner" arrangement of the optical components.

(i) By means of a diagram, explain what is meant by this arrangement. [3]
(ii) Explain how this arrangement enables light from the source to be split into individual wavelengths. [3]

e) In the *Jasco* instrument used by researchers at the University of Swaziland for functional group identification of molluscicidal compounds in traditional herbs, a bolometer is used for detection. With the aid of a diagram, explain how this component works. [4]

f) State two (2) reasons why in the *Jasco* instrument the sample is placed before the monochromator, whereas in the *Spectronic 20* instrument the sample is placed after it. [2]

Question 2 [25]

a) Atomic spectroscopy is a powerful tool available to the analyst today.

(i) Two elements, X and Y are to be analyzed by flame AA and emission. The transition for element X is designated $^2S_{1/2} \longrightarrow {}^2P_{3/2}$ and has a wavelength of 852.1 nm. For Y, it is $^1S_0 \longrightarrow {}^1S_1$ at 228 nm. What is the ratio of excited to ground state atoms for each element, if the flame is operated at 2250° C? [5]

(ii) Which of the two elements would be best analyzed by absorption, and why? [2]

b) Atomic spectroscopic techniques have many applications in agriculture, especially in the area of mineral nutrition. Explain, with the aid of suitable diagrams and appropriate equations:

(i) the "Doppler Shift" and its effect on atomic spectra [4]
(ii) why in the determination of Zn and K in soils, emission is favored for K, whereas absorption is favored for Zn [3]

c) Describe the path of a Ca atom (starting as off Ca Cl_2 solution) as soon as it enters the spray chamber in an AA instrument, up until it emits in flame emission spectrometry [6]

d) With respect to Ca, explain chemical interference in flame atomic absorption spectrometry and explain how it is eliminated [5]

Question 3 [25]

a) Analytical chemists agree that the technique of atomic absorption came of age with the invention of the hollow cathode lamp by Sir Walsh in 1955.

(i) Draw and label the hollow cathode lamp [2]
(ii) Explain how the hollow cathode lamp works [2]

b) There are several unique techniques employed by the agronomy laboratory at the Simunye Sugar Estate when using the Varian Spectr-AA-10 spectrophotometer. Explain:

(i) Why in the analysis of Sr, 100 ppm La is added to all solutions [2]
(ii) Why in the analysis of Cu, the instrument is operated under "standard additions" mode [2]

c) A major breakthrough in atomic absorption spectrophotometry since the invention of the hollow cathode lamp is graphite furnace AA.

(i) What is the major structural difference between flame AA and graphite furnace AA? Use diagrams to support your answer [3]
(ii) Identify the physical stages involved in a furnace program and describe the processes that occur during each stage. At what stage is the signal sampled, and why? [5]
(iii) Outline three (3) advantages of graphite furnace AA over flame AA [3]

d) In 2001, the Swaziland Water Services Corporation acquired a new atomic spectrometer called Liberty 110 ICP.

(i) What does ICP stands for? [1]
(ii) With the aid of a diagram briefly describe the ICP torch, how the ICP is initiated, and how it is maintained and stabilized. [3]
(iii) What are the normal operating values of the ICP in terms of:
Power in kW-------------------- Temperature in K----------------------------- [2]

SECTION B Chromatographic Techniques

Answer any two questions from this section.

Question 4 [25]

a) A typical GC instrument has several standard components, each of which is listed below. In each case give a brief description of the component, followed by its function.

(i) Nitrogen Gas Cylinder [2]
(ii) Filter Cartridge [2]
(iii) Soap Bubble Flow Meter [2]
(iv) Syringe [2]
(v) Oven [2]

b) One of the applications of GC is the separation of benzene from its mixture with cyclohexane, followed by quantification of the benzene. A typical output from the instrument is shown below:

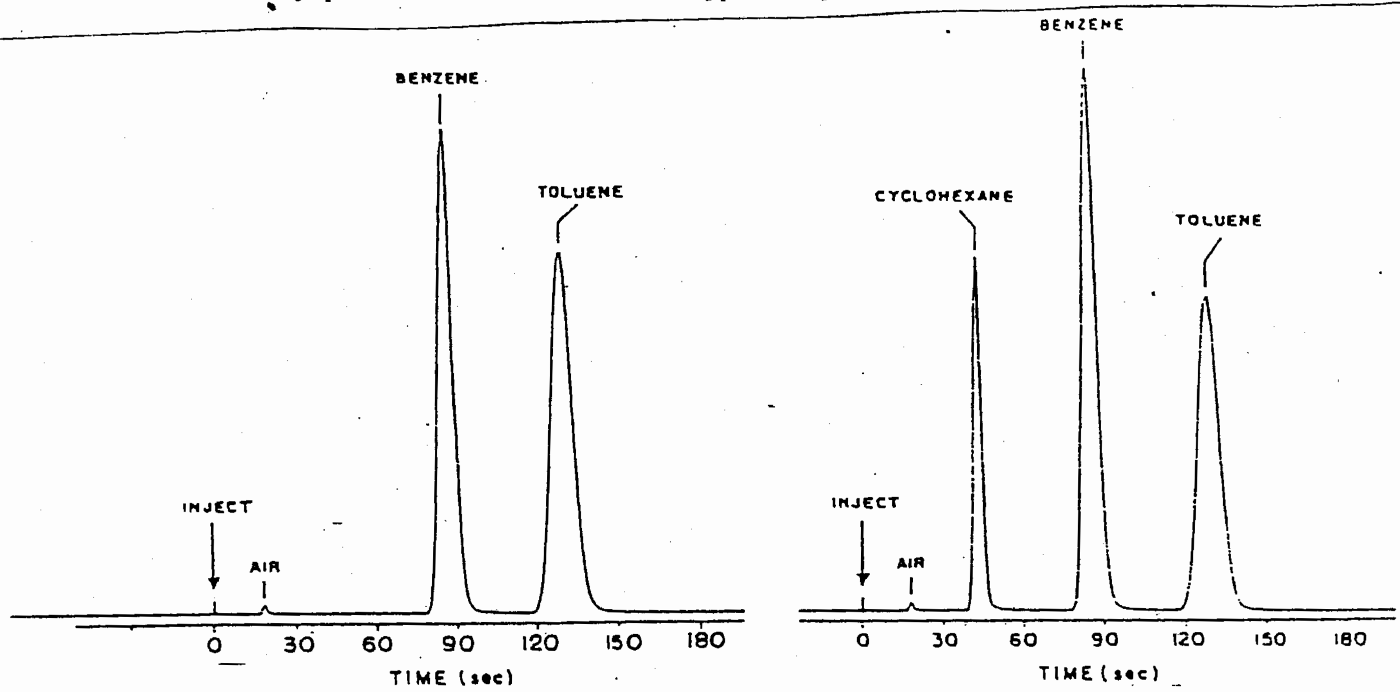

Figure IX-1. Gas chromatograms of injections of a standard mixture of benzene and toluene (left), and a sample containing cyclohexane and benzene with the internal standard toluene added (right).

(i) In the experiment, explain the role of toluene (explain how it serves this role) [3]
(ii) Calculate the capacity factor of cyclohexane [3]
(iii) Are the cyclohexane and benzene peaks properly resolved [3]

(iv) Use the benzene peak in the sample chromatogram to calculate N; show how this value was obtained. [4]

(v) Given that the column used was 10 m, calculate HETP in mm. [2]

Question 5 [25]

a) Use diagrams to describe the process of "elution" in chromatography [3]

b) Describe each of the two ways by which elution is performed in GC [2]

c) Sketch the Van Deempter plot for GC and indicate the region where mobile phase velocity is optimum for analysis [2]

d) (i) What is meant by resistance to mass transfer in the mobile phase in GC? [3]
(ii) State the HETP equation for resistance to mass transfer in the mobile phase in GC [3]
(iii) What is meant by resistance by mass transfer in the stationery phase in GC [3]
(iv) State the HETP equation for resistance to mass transfer in stationery phase in GC [3]

e) The following results were obtained in a GC experiment whereby two standards were prepared by weighing the pure compounds, followed by injection on to the GC. The sample (3.9786 g) was also injected following addition of toluene as indicated in the table. The peak areas were taken directly from the integrator.

	Wt. Of benzene (g)	Wt. Of toluene (g)	Peak area, benzene	Peak area, toluene
STANDARD # 1	0.5361	0.5023	35012	34754
STANDARD # 2	1.0026	0.5001	85600	36251
UNKNOWN # 005	?	0.5015	53620	35621

Draw an appropriate calibration on the graph paper provided, and use it to calculate the % benzene in unknown #005 [6]

Question 6 [25]

a) What is meant by the "race track" effect in chromatography, and how is it eliminated? [2]

b) Sketch the Van Deempter plot for LC and explain how it is different from that of GC. [2]

c) Use equations to describe the process of "silanization" in LC. [2]

d) A typical LC instrument has several standard components, each of which is listed below. In each case give a brief description of the component, followed by its function.

(i) Column [3]

(ii) Sample loop and injector [3]

e) Describe each of the two ways by which elution is performed in LC [2]

f) (i) What is meant by longitudinal diffusion in chromatography? [3]

(ii) State the HETP equation for longitudinal diffusion in open tubes [2]

(iii) What is meant by Eddy Diffusion in chromatography? [3]

(iv) State the HETP equation for Eddy Diffusion in packed tubes [3]

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 .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 .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 .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 .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 2.9055	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^{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

cetic		1.9×10^{-5}
-Amino-pyridinium Ion		2×10^{-7}
mmonium Ion		5.6×10^{-10}
nilinium Ion		2.3×10^{-5}
rsenic	K_1	5.6×10^{-3}
enzoic		6.7×10^{-5}
oric	K_1	5×10^{-10}
arbonic	K_1	4.3×10^{-7}
	K_2	5.6×10^{-11}
hloroacetic		1.5×10^{-3}
hromic	K_2	3.2×10^{-7}
itric	K_1	8.7×10^{-4}
	K_2	1.8×10^{-5}
	K_3	4×10^{-6}
ichloroacetic		5×10^{-2}
DTA	K_1	7×10^{-3}
	K_2	2×10^{-3}
	K_3	7×10^{-7}
	K_4	6×10^{-11}
ormic		2×10^{-4}
-D(+)-Glucose		5.2×10^{-13}
lycinium 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}
Hydroxyl-ammonium 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}
Monoethanol-ammonium Ion		3×10^{-10}
Nicotinium Ion		9.6×10^{-11}
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}
Trimethyl-ammonium Ion		1.6×10^{-10}
Uric		1.3×10^{-4}
Water, K_w, 24°C		1.0×10^{-14}

3. SOLUBILITY PRODUCT CONSTANTS

gBr	4×10^{-13}	BaC_2O_4	2×10^{-8}	$KClO_4$	2×10^{-2}
g_2CO_3	6×10^{-12}	$BaSO_4$	1×10^{-10}	$MgCO_3$	1×10^{-5}
gCl	1×10^{-10}	$CaCO_3$	5×10^{-9}	MgC_2O_4	9×10^{-5}
g_2CrO_4	2×10^{-12}	CaF_2	4×10^{-11}	$MgNH_4PO_4$	2×10^{-13}
$g[Ag(CN)_2]$	4×10^{-12}	CaC_2O_4	2×10^{-9}	$Mg(OH)_2$	1×10^{-11}
gI	1×10^{-16}	CdS	1×10^{-28}	MnS	1×10^{-15}
g_3PO_4	1×10^{-19}	$Cu(OH)_2$	2×10^{-20}	$PbCrO_4$	2×10^{-14}
g_2S	1×10^{-50}	CuS	1×10^{-36}	PbS	1×10^{-28}
gCNS	1×10^{-12}	$Fe(OH)_3$	1×10^{-36}	$PbSO_4$	2×10^{-8}
$l(OH)_3$	2×10^{-32}	Hg_2Br_2	3×10^{-23}	$SrCrO_4$	4×10^{-5}
aCO_3	5×10^{-9}	Hg_2Cl_2	6×10^{-19}	$Zn(OH)_2$	3.6×10^{-10}
$aCrO_4$	1×10^{-10}	HgS	1×10^{-52}	ZnS	1×10^{-24}

5. FIRST IONIZATION ENERGIES, e.v.

H: 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

H: 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

H: 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/mo

	F	Cl	Br	I
Li	1030	840	781	71
Na	914	770	728	68
K	812	701	671	63
Rb	780	682	654	61
Cs	744	630	613	58

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^{239}	24,400 y

11. ACID-BASE INDICATORS AT 25°C

Indicator	pH range	pKin	Acid	Base
hymol blue	1.2 – 2.8	1.6	red	yellow
ethyl yellow	2.9 – 4.0	3.3	red	yellow
ethyl orange	3.1 – 4.4	4.2	red	yellow
romocresol green	3.8 – 5.4	4.7	yellow	blue
ethyl red	4.2 – 6.2	5.0	red	yellow
hlorophenol red	4.8 – 6.4	6.0	yellow	red
romothymol blue	6.0 – 7.6	7.1	yellow	blue
henol red	6.4 – 8.0	7.4	yellow	red
resol purple	7.4 – 9.0	8.3	yellow	purple
hymol blue	8.0 – 9.6	8.9	yellow	blue
henolphthalein	8.0 – 9.8	9.7	colorless	red
hymolphthalein	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
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, $\mathcal{E}°$

$a^+ + e \rightleftarrows Na$	– 2.713
$g^{++} + 2e \rightleftarrows Mg$	– 2.37
$l^{+++} + 3e \rightleftarrows Al$	– 1.66
$n^{++} + 2e \rightleftarrows Zn$	– 0.763
$e^{++} + 2e \rightleftarrows Fe$	– 0.44
$d^{++} + 2e \rightleftarrows Cd$	– 0.403
$r^{+++} + e \rightleftarrows Cr^{++}$	– 0.38
$l^+ + e \rightleftarrows Tl$	– 0.336
$^{+++} + e \rightleftarrows V^{++}$	– 0.255
$n^{++} + 2e \rightleftarrows Sn$	– 0.14
$b^{++} + 2e \rightleftarrows Pb$	– 0.126
$H^+ + 2e \rightleftarrows H_2$	0.000
$_4O_6^{=} + 2e \rightleftarrows 2S_2O_3^{=}$	0.09
$iO^{++} + 2H^+ + e \rightleftarrows Ti^{+++} + H_2O$	0.10
$+ 2H^+ + 2e \rightleftarrows H_2S$	0.14
$n^{+4} + 2e \rightleftarrows Sn^{++}$	0.14
$u^{++} + e \rightleftarrows Cu^+$	0.17
$O_4^{=} + 4H^+ + 2e \rightleftarrows H_2O + H_2SO_3$	0.17
$gCl + e \rightleftarrows Cl^- + Ag$	0.222
aturated calomel	(0.244)
$g_2Cl_2 + 2e \rightleftarrows 2Cl^- + 2Hg$	0.268
$i^{+++} + 3e \rightleftarrows Bi$	0.293
$O_2^{++} + 4H^+ + 2e \rightleftarrows U^{+4} + 2H_2O$	0.33
$O^{++} + 2H^+ + e \rightleftarrows V^{+++} + H_2O$	0.34
$u^{++} + 2e \rightleftarrows Cu$	0.34
$e(CN)_6^{-3} + e \rightleftarrows Fe(CN)_6^{-4}$	0.355
$u^+ + e \rightleftarrows Cu$	0.52
$_3^- + 2e \rightleftarrows 3I^-$	0.545
$_3AsO_4 + 2H^+ + 2e \rightleftarrows H_3AsO_3 + H_2O$	0.56
$_2 + 2e \rightleftarrows 2I^-$	0.621
$HgCl_2 + 2e \rightleftarrows Hg_2Cl_2 + 2Cl^-$	0.63
$_2 + 2H^+ + 2e \rightleftarrows H_2O_2$	0.69
uinone + 2H$^+$ + 2e ⇄ Hydroquinone	0.70
$e^{+++} + e \rightleftarrows Fe^{++}$	0.771
$Ig_2^{++} + 2e \rightleftarrows 2Hg$	0.792
$g^+ + e \rightleftarrows Ag$	0.799
$Ig^{++} + 2e \rightleftarrows Hg$	0.851
$Hg^{++} + 2e \rightleftarrows Hg_2^{++}$	0.907
$IO_3^- + 3H^+ + 2e \rightleftarrows HNO_2 + H_2O$	0.94
$INO_2 + H^+ + e \rightleftarrows NO + H_2O$	0.98
$VO_2^+ + 2H^+ + e \rightleftarrows VO^{++} + H_2O$	0.999
$Br_2 + 2e \rightleftarrows 2Br^-$	1.08
$IO_3^- + 12H^+ + 10e \rightleftarrows 6H_2O + I_2$	1.19
$)_2 + 4H^+ + 4e \rightleftarrows 2H_2O$	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
$BrO_3^- + 12H^+ + 10e \rightleftarrows 6H_2O + Br_2$	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

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

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)	0.00
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} × 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°	2
15°	12.8	30°	3
20°	17.5	50°	9

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 × 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