DEPARTMENT OF CHEMISTRY
UNIVERSITY OF SWAZILAND

C304   **INSTRUMENTAL ANALYSIS**

MAY 2006 FINAL EXAMINATION

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

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Instructions:

1. This examination has six (6) questions and one data sheet. The total number of pages is five (5) includir this page.

2. Answer any four (4) questions fully; diagrams should be clear, large and properly labeled. Marks will l 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 GIVE BY THE CHIEF INVIGILATOR.

QUESTION 1 [25]

a) Spectroscopy is an analytical technique based on the interaction between "emr" and atoms/molecules.

    i) What does the acronym "emr" stand for? [1]

    ii) Draw and label the different components of an emr wave. [2]

b) i) Describe the two main practical emr sources in IR. [2]

    ii) Use the chromate/dichromate equilibrium system to illustrate what is known in spectroscopic terms as "hypsochromic shift". [2]

c) Use diagrams to explain what a "double beam" instrument is in IR, and explain its role in this technique [3]

d) The "monochromator" in a spectrometer is a critical component.

    i) What role does a "monochromator " play in a spectrometer? [1]

    ii) State Snell's Law of refraction, and use it to explain how a prism acts as a monochromator. [3]

    iii) Write down the Bragg equation for diffraction, and explain how a grating acts as a monochromator.[3]

e) In spectroscopy, several types of detectors are used.

    i) Draw and label a vacuum phototube and explain how it works. [4]

    ii) Draw and label a photovoltaic cell and explain how it works. [4]

QUESTION 2 [25]

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

    i) Convert this wave number 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 appears 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 c 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 detector 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 3 [25]

(a) Atomic Absorption Spectroscopy (AAS) is one of the most versatile analytical techniques available.

   i)   Draw a cross section of an air-acetylene flame and label the main regions that make up the flame. [2]

   ii) What chemical processes occur in each region of the flame? [3]

   iii) Indicate the region where atomization efficiency is at the maximum. [1]

(b) One of the problems associated with AA analysis of several elements is the susceptibility to interferences. Not forgetting to quote specific examples in each of the cases below,

   i)   Describe ionization interference, and explain how it is eliminated in AA. [2]

   ii) Describe chemical interference, and explain how it is eliminated in AA. [2]

   iii) Describe "matrix effects" and outline one procedure used to combat these effects in AA.[2]

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

   i) What is the major structural difference between flame AA and graphite furnace AA? Use diagrams support your answer. [3]

   ii) Outline three (3) advantages of graphite furnace AA over flame AA. [3]

b) Perhaps the most sensitive technique in analytical atomic spectrometry in the 1990's is the ICP.

   i)   What does the acronym "ICP" stand for? [1]

   ii) In ICP-OES, solutions are normally introduced by the "Venturi Effect". Describe this effect. [3]

   iii) Optics in an ICP are mounted in a "Rowland Circle". Draw this optical arrangement, and show how enhances the multielement capability of ICP. [3]

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:
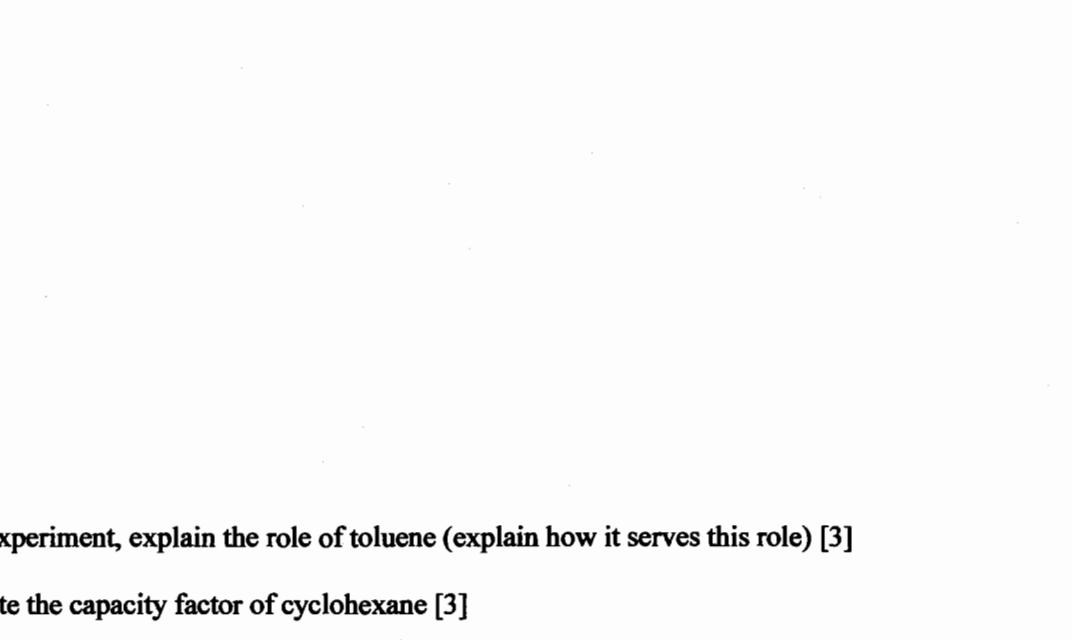
    i) In the experiment, explain the role of toluene (explain how it serves this role) [3]

    ii) Calculate the capacity factor of cyclohexane [3]

    iii) Are the cyclohexane and benzene peaks properly resolved? Why or why not? [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 10m, calculate HETP in mm. [3]

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 Gas Chromatography (GC). [2]

c) Sketch the Van Deempter plot for GC, and indicate the region where mobile phase velocity is optimum for analysis. [3]

d) i) What is meant by Eddy Diffusion in GC? [2]

    ii) State the HETP equation for Eddy Diffusion in a packed bed [2]

e) i) What is meant by Longitudinal Diffusion in GC? [2]

    ii) State the HETP equation for Longitudinal Diffusion in a packed bed [2]

f) i) What is meant by resistance to mass transfer in the mobile phase in GC? [3]

    iii) State the HETP equation for resistance to mass transfer in the mobile phase in GC. [3]

    iv) State the HETP equation for resistance to mass transfer in stationery phase in GC. [3]

QUESTION 6

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

b) Sketch the Van Deempter plot for liquid Chromatography (LC) and explain how it is different from that of GC [3]

c) Use equations to describe the process of "silanization" in LC. [3]

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) With the aid of a diagram, explain how a thermal conductivity detector works. [3]

    ii) With the aid of a diagram, explain how a flame ionization detector works. [3]

    iii) With the aid of a diagram, explain how an electron capture detector works. [3]

ACID-BASE INDICATORS

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

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

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

Reaction		$\mathcal{E}°$
$Na^+ + e \rightleftarrows Na$		−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
$H_3AsO_4 + 2H^+ + 2e \rightleftharpoons H_3AsO_3 + H_2O$		0.56
$I_2 + 2e \rightleftharpoons 2I^-$		0.621
$2HgCl_2 + 2e \rightleftharpoons Hg_2Cl_2 + 2Cl^-$		0.63
$O_2 + 2H^+ + 2e \rightleftharpoons H_2O_2$		0.69
Quinone $+ 2H^+ + 2e \rightleftharpoons$ Hydroquinone		0.70
$Fe^{+++} + e \rightleftharpoons Fe^{++}$		0.771
$Hg_2^{++} + 2e \rightleftharpoons 2Hg$		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	Na₂SO₄	ZnSO₄
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
Δ H° in kJ mol⁻¹ at 25°C
All ions in H₂O 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	HCl_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 B...

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

21. DENSITIES (g cm...)

Water at		Air (70 cm)
0.°C	0.9168	Glass
10°	0.9997	Na_2CO_3
20°	0.9982	NaCl
22°	0.9978	$BaSO_4$
24°	0.9973	AgCl
26°	0.9968	Aluminum
28°	0.9963	Iron
30°	0.9956	Brass
90°	0.9653	Mercury
100.°	0.0006	Platinum

22. MOBILITIES (m²V⁻¹s⁻¹...)

Li^+	39	H_3O	350	½Ba	
Na^+	50	NH_4^+	73	½La	
K^+	74	Ag^+	62	½SO	
Cl^-	76	OH^-	198	½PO	
Br	78	I^-	77	NO	

23. WATER V.P. (torr)

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

24. MISCELLANEOUS

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

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

$E = E° - (0.0592/n)\log([Red]/[Ox\dots$

$\log I_0/I_t = abc = A = \log 1/T$

$\log N_t = \log N_u - 0.301T/T_{\frac{1}{2}}$

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

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

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

$h = 6.626 \times 10^{-34}$ 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 $= 1.661 \times 10^{-27}$ kg

$R = 1.987$ cals mol⁻¹ K⁻¹

$= 0.08206$ litre atm mol⁻¹ K...

$= 8.314$ J mol⁻¹ K⁻¹

$= 8.314$ kPa dm³ mol⁻¹ K⁻¹

0 °C $= 273.15$ K

1 eV $= 1.602 \times 10^{-19}$ J

1 cal $= 4.1840$ J

I. PERIODIC CHART OF THE ELEMENTS

1 1A	2 2A												13 3A	14 4A	15 5A	16 6A	17 7A	18 2 He 4.00260
							1 H 1.00794											
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	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 ─8B─	10	11 1B	12 2B		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

$Ag(CN)_2^-$	$5 \times$
$Ag(NH_3)_2^+$	$1.6 \times$
$Ag(S_2O_3)_2^{-3}$	$4.7 \times$
$Al(OH)_4^-$	$1.0 \times$
$Ca(EDTA)=$	$1.0 \times$
$Cd(CN)_4=$	$8.3 \times$
$Cd(NH_3)_4^+$	$5.5 \times$
$Co(NH_3)_6^{+3}$	$2 \times$
$Cr(OH)_4^-$	$4 \times$
$Cu(CN)_4^{-3}$	$1 \times$
$Cu(NH_3)_4^{++}$	$1.2 \times$
$Fe(CN)_6^{-3}$	$4.0 \times$
$Fe(CN)_6^{-4}$	$2.5 \times$
$Fe(SCN)^{++}$	$1.0 \times$
$HgCl_4=$	$1.3 \times$
$Hg(CN)_4=$	$8.3 \times$
$Hg(SCN)_4=$	$5.0 \times$
$HgI_4=$	$6.3 \times$
$Mg(EDTA)=$	$1.3 \times$
$Ni(NH_3)_4^{++}$	$4.7 \times$
$Pb(OH)_3^-$	$7.9 \times$
$Zn(CN)_4=$	$4.2 \times$
$Zn(NH_3)_4^+$	$7.8 \times$
$Zn(OH)_4=$	$6.3 \times$

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}
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^{-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}
Trimethyl-ammonium Ion		1.6×10^{-10}
Uric		1.3×10^{-4}
Water, K_w, 24°C		1.0×10^{-14}

5. FIRST IONIZATION ENERGIES, e.v.

1A	2A											3A	4A	5A	6A
							14								
5.4	9.3											8.3	11	15	14
5.1	7.6	3B 4B 5B 6B 7B ─8B─ 1B 2B										6.0	8.1	11	10
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
4.2	5.7	6.5	7.0	6.8	7.2			7.5	7.7	8.3	7.6	9.0	5.8	7.3	8.6
3.9	5.2	5.0/6.9	5.5	6	8.0	7.9	8.7	9.2	9.0	8.2	10	4.1	7.4	8	

6. ELECTRONEGATIVITIES, Pauling

1A	2A											3A	4A	5A	6A
							2.1								
1.0	1.5											2.0	2.5	3.0	3.5
0.9	1.2	3B 4B 5B 6B 7B ─8B─ 1B 2B										1.5	1.8	2.1	2.5
0.8	1.0	1.3	1.5	1.6	1.6	1.5	1.8	1.8	1.8	1.9	1.6	1.7	1.8	1.9	2.1
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
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

7. ATOMIC RADII picometers

1A	2A											3A	4A	5A	6A	7A
							37									
155	112											98	91	92	73	71
190	160	3B 4B 5B 6B 7B ─8B─ 1B 2B										143	132	128	127	88
235	197	162	147	134	130	135	126	125	124	128	138	141	137	139	140	114
248	215	178	160	146	139	135	134	134	137	144	154	166	162	159	160	133
267	222	187	167	149	141	137	135	136	139	146	157	171	175	170	176	

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/		
	F	Cl	Br
Li	1030	840	781
Na	914	770	728
K	812	701	671
Rb	780	682	654
Cs	744	630	613

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^{-6}
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}

10. HALF LIVES

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

Electrode Potentials, $E^\ominus$

$H^+ + e^- \rightleftharpoons \frac{1}{2} H_2 \quad E^\ominus = 0.000 V$

$Ca^{2+} + 2e \rightleftharpoons Ca(s) \quad E^\ominus = -0.246 V$

$\rightleftharpoons Ac(s) + Cl^- \quad E^\ominus = -0.023 V$

$Cu^{2+} + 2e^- \rightleftharpoons Cu(s) \quad E^\ominus = +$