DEPARTMENT OF CHEMISTRY
UNIVERSITY OF SWAZILAND

C404 **ELECTROANALYTICAL CHEMISTRY**

MAY 2006 FINAL EXAMINATION

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

Instructions:

1. **This examination has six (6) questions and one data sheet. The total number of pages is six (6) includi this page.**
2. **Answer any four (4) questions fully; diagrams should be clear, large and properly labeled. Marks will 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 GIVI BY THE CHIEF INVIGILATOR.

QUESTION 1 **[25]**

a) Explain the difference between a "Galvanic" and an "Electrolytic" cell in electroanalytical chemistr [2]

b) Explain the difference between "Potentiometry" and "Voltametry" in electroanalytical chemistry. [2]

c) In a Galvanic cell employing Zn/Zn^{2+} and Cu/Cu^{2+}, explain which is the anode and which is the cathod [2]

d) In electroanalytical chemistry, what do the following acronyms stand for? [3]

i) DME ii) ISE iii) NCE

e) For the $Cr_2 O_7^{2+} / Cr^{3+}$ system in acid,

i) Write down the balanced redox half cell reaction. [1]
ii) Write down the Nernst expression. [2]
iii) Calculate the concentration of $Cr_2 O_7^{2-}$ at pH=3 if the potential measured for a 0.0625M Cr solution is 0.562V. [3]

f) What is the role of a reference electrode in potentiometry? [1]

g) Discuss each of the two (2) main requirements of reference electrodes in potentiometry. [2]

h) i) With the aid of a diagram, explain how an AgCl/Ag electrode is fabricated, and explain the role each component in the electrode. [3]

ii) Write down its half cell reaction and Nernst expression. [1]

iv) State its standard electrode potential and typical input impendance. [1]

v) Under what experimental conditions will this electrode not work? [2]

QUESTION 2 **[25]**

a) i) With the aid of a diagram, use ion exchange theory to explain how a pH glass membrane electro works. [3]

ii) Write the Nernst expression for an ideal pH glass electrode, and show that unit calibrations in t readout are in increments of 59mV. [3]

b) i) With theaid of a diagram, explain how an SCE electrode is fabricated, and explain the role of eacl component in the electrode. [3]

ii) Write down its half cell reaction and Nernst expression. [1]

iii) State the standard electrode potential for the SCE. [1]

iv) Under what conditions will the SCE not work. [1]

c) In the analysis of fluoride ion in tap water using the LaF_3 solid state electrode, TISAB is almost alwa added to both standards and unknown samples.

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

iii) List all the components that make up "TISAB" and explain briefly the role of each. [3]

d) i) Outline the steps involved in calibration of pH glass electrodes. [2]

ii) List two (2) sources of standards used in the calibration of pH glass electrodes. [2]

iii) Scratched membranes make electrodes difficult to calibrate. Explain how scratched membranes a regenerated in potentiometry. [2]

iv) Explain, using diagrams and equations, how the selectivity coefficient and ion exchange principl enable fabrication of a pNa electrode. [3]

QUESTION 3 **[25]**

a) In voltammetry, what do the following acronyms stand for? [3]

i) HMDE ii) NPP iii) RDE

b) Describe the term "overpotential" in relation to the polarography technique, and explain wl overpotential is desirable in this electroanalytical technique. [2]

c) Draw and label the electrode used in classical polarography, explain how it works, and use chemic equations to explain the shape of the polarogram of Pb^{2+}. [4]

d) Voltammetry in the upper right quadrant can be complicated by the presence of dissolved oxygen solution.

i) Use chemical equations to explain the origin of oxygen waves. [3]

ii) How are oxygen waves eliminated in voltammetry? [1]

e) i) Use diagrams to explain the origins of "non-faradaic" current in polaragraphy. [2]

ii) Use a diagram to illustrate the dependence of "non-faradaic" current on time during the lifetime of mercury drop in polaragraphy. [2]

iii) Use a diagram to illustrate the dependence of "faradaic" current on time during the lifetime of mercury drop in polaragraphy. [2]

iv) Use a diagram to illustrate the effect of concentration on "non-faradiac" current during the lifetir of a mercury drop in polarography. [2]

f) Use equations to explain the processes that dictate the useful range of potentials in polarography. [4]

QUESTION 4 **[25]**

a) For each of the following modern variants of the polarographic technique, draw the shape of t voltammogram:

i) Alternating current polarography. [1]
ii) Fast linear sweep polarography. [1]
iii) Cyclic sweep voltammetry. [1]

b) For each of the following techniques, indicate, on a voltage-time plot, when sampling of the signal carried out. Draw the shape of the resultant voltammogram, and indicate the typical resolution (in Vol and detection limit (in mol/L).

i) Tast polarography. [3]
ii) Normal pulse polarography. [3]

c) i) Draw a schematic diagram of the apparatus used in Anodic Stripping Voltametry (ASV). [3]

ii) Assume that ASV is being carried out on an environmental sample containing the toxic eleme cadmium. Use equations to describe the chemical processes taking place at each of the three ste involved in the ASV of the sample. [3].

iii) Explain why ASV is considered superior over most analytical techniques in terms of detection limi [2]

d) Cyclic voltametry is a very useful analytical tool in thermodynamic studies.

i) Write down the Randles-Sevcik equation for reversible and irreversible systems, and explain t difference between the two. [3]

ii) Use diagrams to explain how cyclic voltamograms of reversible systems are different from thc obtained for irreversible systems. [3]

iii) Explain how you would differentiate between reversible and irreversible systems on the basis o the peak current and peak potentials observed in cyclic voltametry? [2]

QUESTION 5 [25]

a) In the coulometric titration of Fe^{3+}, describe the role of Ti^{4+} intermediate added at the beginning of t analysis. [2]

b) i) Use diagrams and equations to describe how an amperometric titration of Pb^{2+} can be carried out wi a one-polarized electrode system using SO_4^{2-} as titrant (Pb^{2+} is electroreducible at potentials mo negative than -1.0V vs SCE). [3]

ii) Plot the titration curve expected for an amperometric titration with one polarized electrode for each the following:

- SO_4^{2-} (non-electroreducible at -1.0V vs SCE) with Pb^{2+} as titrant. [2]
- Pb^{2+} titrated with a ligand that is also electroreducible at -1.0V vs SCE. [2]

c) i) Describe how an amperometric titration of Fe^{2+} with Ce^{4+} can be carried out with two indicat electrodes. [2]

ii) Draw the current-voltage curve for the Fe^{2+} / Ce^{4+} system mentioned in c (i) above at the followi stages of titration. [4]

f = 0; f = 0.5; f = 1.0; f = 1.5

iii) Draw the expected titration curve for the Fe^{2+} / Ce^{4+} system described in c (i) and c (ii) above. [2]

d) Consider the voltametric titration of Tl^+ with electrochemically generated Br_2 according to the reaction

$Tl^+ + Br_2 \Longleftrightarrow Tl^{3+} + 2Br^-$, where

$Tl^{3+} + 2e^- \Longleftrightarrow Tl^+$ $E^0 = -0.78V$ vs SCE

$Br_2 + 2e^- \Longleftrightarrow 2Br^-$ $E^0 = -1.08V$ vs SCE

i) Draw the current-voltage curves of this titration at the following stages of the titration: [4]

f = 0; f = 0.5; f = 1.0; f = 1.5

ii) Plot the titration curve expected for this system using a single indicator electrode. [2]

iii) Plot the titration curve expected for this system using a two-indicator electrode system. [2]

QUESTION 6 [25]

a) i) Use diagrams to describe the Rotating Disk Electrode (RDE). [3]

ii) Use diagrams to describe the hydrodynamic movement of solution in the vicinity of the RDE. [3]

iii) Describe the two mass transfer phenomena occurring in the RDE. [2]

iv) Write down the Levich Equation for the RDE and explain all terms appearing in it. [3]

v) Describe two limitations of the RDE when compared to the dropping mercury electrode. [2]

vi) What is the advantage of adding a "ring" to the RDE to form what is known as a Rotating Ring Di
Electrode (RRDE)? [1]

b) Use equations to explain the role of a depolarizer in electrogravimetry. [2]

c) Use equations to describe the anodic and cathodic reactions taking place during electrodeposition in t
measurement of copper in an unknown solution. [3]

d) A solution of 0.200M Cu^{2+} in 1M H^+, resistance 0.5 Ω, is to be electrodeposited to 99.995% completi
with 1A in an open cell (partial pressure of O_2 in air = 0.2 atm). In the equation $E_{app} = E_{cathode} + IR +$
used to ascertain the potential at which electrodeposition will occur:

i) Calculate $E_{cathode}$. [1]
ii) Calculate E_{anode}. [1]
iii) Calculate the IR drop. [1]

iv) Describe the term ω, and explain its origins in electrogravimetry using suitable equations. [3]

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. BASIC REFERENCE [illegible]

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	6
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, ℰ°

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

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		

20. CONC. ACIDS AND BA[illegible]

	M.W.	Density	Wt. %	M
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⁻³

Water at		Air (70 cm)	0.
0,°C	0.9168	Glass	2
10°	0.9997	Na_2CO_3	2
20°	0.9982	NaCl	2
22°	0.9978	$BaSO_4$	4
24°	0.9973	AgCl	5
26°	0.9968	Aluminum	2
28°	0.9963	Iron	7
30°	0.9956	Brass	8
90°	0.9653	Mercury	13
100,°	0.0006	Platinum	21

22. MOBILITIES ($m^2V^{-1}s^{-1}$ ×

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	$\frac{1}{3}PO_4$	
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 = $\bar{X} \pm ts/\sqrt{n}$

$E = E° - (0.0592/n)\log([Red]/[Ox])$

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

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

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

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

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

$h = 6.626 \times 10^{-34}$ 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 dm³ mol⁻¹ K⁻¹

0 °C = 273.15 K

1 eV = 1.602×10^{-19} J

1 cal = 4.1840 J

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
$Ag(NH_3)_2^+$	1.6×10
$Ag(S_2O_3)_2^{-3}$	4.7×10
$Al(OH)_4^-$	1.0×10
$Ca(EDTA)^=$	1.0×10
$Cd(CN)_4^=$	8.3×10
$Cd(NH_3)_4^{++}$	5.5×10
$Co(NH_3)_6^{+3}$	2×10
$Cr(OH)_4^-$	4×10
$Cu(CN)_4^{-3}$	1×10
$Cu(NH_3)_4^{++}$	1.2×10
$Fe(CN)_6^{-3}$	4.0×10
$Fe(CN)_6^{-4}$	2.5×10
$Fe(SCN)^{++}$	1.0×10
$HgCl_4^=$	1.3×10
$Hg(CN)_4^=$	8.3×10
$Hg(SCN)_4^=$	5.0×10
$HgI_4^=$	6.3×10
$Mg(EDTA)^=$	1.3×10
$Ni(NH_3)_4^{++}$	4.7×10
$Pb(OH)_3^-$	7.9×10
$Zn(CN)_4^=$	4.2×10
$Zn(NH_3)_4^{++}$	7.8×10
$Zn(OH)_4^=$	6.3×10

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

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}
$I(OH)_3$	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^{-16}
$aCrO_4$	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
5.4	9.3											8.3	11	15	14	17
5.1	7.6											6.0	8.1	11	10	13
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
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
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		

6. ELECTRONEGATIVITIES, Pauling

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

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A
155	112											98	91	92	73	71
190	160											143	132	128	127	99
235	197	162	147	134	130	135	126	125	124	128	138	141	137	139	140	114
248	215	178	160	146	139	136	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 ENERGI

(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

10. HALF LIVES

H^3	12.3 years	K^{40}	1.28×10^9y	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 d
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}	7.1×1
S^{35}	88 days	Sr^{90}	28 years	U^{238}	4.51×1
Cl^{36}	3.1×10^5y	I^{129}	1.7×10^7y	Pu^{230}	24,40