DEPARTMENT OF CHEMISTRY

UNIVERSITY OF SWAZILAND

C204 **INTRODUCTION TO ANALYTICAL CHEMISTRY**

MAY 2012 **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 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 sheet.**
2. **Graph paper.**

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Question 1 [25]

a. (i) Write down the equation that describes the Gaussian curve in chemometrics, and explain all terms appearing in it. (3)

(ii) A new gravimetric method is developed for Iron (III), in which the iron is precipitated in crystalline form with an organoboron cage compound. The accuracy of the method is checked by analysing the iron in an ore sample and comparing the results obtained using standard precipitation with ammonia and weighing of Fe_2O_3. The results, reported as % Fe for each analysis, were as follows;

Test Method (%)	Reference Method (%)
20.10	18.89
20.50	19.20
18.65	19.00
19.25	19.70
19.40	19.40
19.99	

Is there a significant difference between the two methods at the 95% confidence interval? (5)

(iii) In the gravimetric and reference methods of question (v) above, comment on the precisions at the 95% confidence level. (4)

b. The following data was obtained from an analysis.

124 125 126 128 147

Should the value "147" be considered as part of the data at the 90% confidence interval? (3)

c. (i) A 0.1000M solution of NaOH is used to titrate 10.00ml of 0.100M CH_3COOH. Calculate the pH at the following volumes of NaOH added during that titration (6)

1.00ml, at equivalence point, at 3ml past equivalence point

(ii) Plot the titration curve. (2)
(iii) Sketch the plot expected if a diprotic weak acid (e.g., oxalic acid) replaced CH_3COOH in the titration in (i) above. (2)

Question 2 [25]

a. (i) Use an example to describe the mechanism of adsorption in gravimetric analysis. How can adsorption be minimized? (3)
(ii) Using Ba^{2+} as an example, describe what is meant by "occlusion" in gravimetry. How can occlusion be minimized? (3)
(iii) What is meant by " Ostwald Ripening" in gravimetric analysis, and how is it accomplished? (3)

b. Consider the titration of 25mL of 0.100M KCl with 0.050M $AgNO_3$ using the Mohr method, given the following: K_{sp} = AgI: 8.3×10^{-17}, AgBr: 5.0×10^{-13}, AgCl: 1.8×10^{-10}

(i) Name the indicator used for the Mohr method. (1)
(ii) Use equations to explain how the end point is detected using this indicator. (3)

(iii)Calculate the pAg at the following stages of titration: (6)

5mL added, at equivalence point, 5mL past equivalence point

(iv) Plot the titration curve. (2)

c. (i) Explain how pH affects the Mohr titration, and state how such effects are avoided. (2)
   (ii) Explain how the indicator concentration affects the Mohr titration, and state how such effects are avoided. (2)

Question 3 [25]

a. For CH_3NH_2, as a non-aqueous solvent, write down the:
   (i) Autoprotolysis equation. (1)
   (ii) Expression for the equilibrium constant for autoprotolysis. (2)
   (iii) Calculate the pH of a "neutral" solution, given that the autoprotolysis constant is $3x10^{-20}$. (3)

b. (i) Calculate the pH of a 400-mL buffer solution containing 0.200M NH_3 and 0.300M NH_4Cl. (4)
   (ii) Calculate the weight of NH_4Cl required to make this buffer. (3)
   (iii) Commercial ammonia solution is 70% NH_3 vol/vol, and density 0.85g/mL. What volume of commercial NH_3 in mL, is required to make this buffer? (4)
   (iv) Calculate the change in pH of the buffer system in 4(i) above upon addition of 10mL of 0.05M HCl. (2)
   (v) Calculate the change in pH of the buffer system in 4(i) above upon addition of 10mL of 0.05M $Ba(OH)_2$ (2)

c. (i) Give two (2) reasons why solvent extraction is carried out in analytical chemistry. (2)
   (ii)State the "Distribution Law" of solvent extraction, and express it mathematically. (2)

Question 4 [25]

a. (i) Use an example to describe the "chelate effect". (2)
   (ii) State two (2) elements that are best extracted into ether after forming metal-chloro complexes. (2)
   (iii) Name and draw the chemical structure of a commonly used chelation agent for Al^{3+}. (1)
   (iv) Name and draw the chemical structure of a commonly used chelation agent for Ni^{2+}. (1)

b. (i) Draw the chemical structure of EDTA, and write down the expression relating the fraction dissociated to the formation constant and pH. (4)
   (ii) What is meant by conditional formation constant in EDTA titrations? (2)

c. Consider the titration of 50mL 0.05M Mg^{2+} in a pH = 10.00 buffer with 0.05M EDTA as titrant. Calculate the pMg at the following volumes of EDTA added: (8)

0mL 5mL 50mL 51mL

d. (i) Draw the chemical structure of the indicator Eriochrome Black T. (2)
   (ii) Use equations to explain how the indicator Eriochrome Black T works in EDTA titrations. (3)

Question 5 [25]

a. (i) What is the difference between "Galvanic" and "non-Galvanic" electrochemical cells? (2)

   (ii) Consider the cell reaction $Cu(s) + PbF_2(s) \Longleftrightarrow Cu^{2+} + 2F^- + Pb(s)$ and indicate whether it would be Galvanic as written. (4)

b. (i) Draw and label the silver-silver chloride reference electrode. (4)

   (ii) Write down the half cell reaction taking place inside the electrode in b(i) above, and state its potential. (2)

c. A titration is carried out in a cell, whereby the potential vs SCE (0.241V) is measured for a 25ml solution of 0.020M Cr^{2+} ($E^0 = -0.41V$) titrated with 0.010M Fe^{3+} ($E^0 = 0.770V$).

   (i) Calculate the potential (vs SCE) after addition of the following volumes during the titration: (6)

   5.00ml 50.00ml 100ml

   (ii) Sketch the titration curve. (2)

   (iii) Use chemical equations to explain how redox indicators are chosen in electrochemical titrations. (3)

d. Use chemical equations to explain the technique of iodimetry in redox chemistry. (2)

Question 6 [25]

a. (i) Describe the principle of "indirect titration" in analytical chemistry. (3)

   (ii) Suppose an unknown is Cl^- ion in 25mL of a water sample, and that 30mL of 0.01M $AgNO_3$ was added to it, and that a titration of the resulting solution with 0.01M HCl took 5mL, calculate the concentration of Cl^- in the sample. (5)

   (iv) In the Volhard method of indirect titration, explain how the indicator works. (3)

   (v) What is the main disadvantage of the Volhard method, and describe the two ways on which this can be overcome. (3)

b. Use chemical equations to explain how the Karl Fischer Method for the determination of water works. (4)

c. (i) Explain why I_2 is an excellent primary standard, but still needs standardization. Name the commonly used reagent for this purpose. (3)

   (ii) $Na_2S_2O_3$ is widely used as a titrant for the iodimetric determination of Cu. Use equations to describe how $Na_2S_2O_3$ is standardized in these titrations. (4)

SOME STANDARD AND FORMAL ELECTRODE POTENTIALS

Half-reaction*	E°, V	Formal potential, V
$Ag^+ + e \rightleftharpoons Ag(s)$	+0.799	0.228, 1 *M* HCl; 0.792, 1 *M* $HClO_4$; 0.77, 1 *M* H_2SO_4
$AgBr(s) + e \rightleftharpoons Ag(s) + Br^-$	+0.073	
$AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-$	+0.222	0.228, 1 *M* KCl
$Ag(CN)_2^- + e \rightleftharpoons Ag(s) + 2CN^-$	−0.31	
$Ag_2CrO_4(s) + 2e \rightleftharpoons 2Ag(s) + CrO_4^{2-}$	+0.446	
$AgI(s) + e \rightleftharpoons Ag(s) + I^-$	−0.151	
$Ag(S_2O_3)_2^{3-} + e \rightleftharpoons Ag(s) + 2S_2O_3^{2-}$	+0.017	
$Al^{3+} + 3e \rightleftharpoons Al(s)$	−1.662	
$H_3AsO_4 + 2H^+ + 2e \rightleftharpoons H_3AsO_3 + H_2O$	+0.559	0.577, 1 *M* HCl, $HClO_4$
$Ba^{2+} + 2e \rightleftharpoons Ba(s)$	−2.906	
$BiO^+ + 2H^+ + 3e \rightleftharpoons Bi(s) + H_2O$	+0.320	
$BiCl_4^- + 3e \rightleftharpoons Bi(s) + 4Cl$	+0.16	
$Br_2(l) + 2e \rightleftharpoons 2Br^-$	+1.065	1.05, 4 *M* HCl
$Br_2(aq) + 2e \rightleftharpoons 2Br^-$	+1.087†	
$BrO_3^- + 6H^+ + 5e \rightleftharpoons \frac{1}{2}Br_2(l) + 3H_2O$	+1.52	
$BrO_3^- + 6H^+ + 6e \rightleftharpoons Br^- + 3H_2O$	+1.44	
$Ca^{2+} + 2e \rightleftharpoons Ca(s)$	−2.866	
$C_6H_4O_2$ (quinone) $+ 2H^+ + 2e \rightleftharpoons C_6H_4(OH)_2$	+0.699	0.696, 1 *M* HCl, $HClO_4$, H_2SO_4
$2CO_2(g) + 2H^+ + 2e \rightleftharpoons H_2C_2O_4$	−0.49	
$Cd^{2+} + 2e \rightleftharpoons Cd(s)$	−0.403	
$Ce^{4+} + e \rightleftharpoons Ce^{3+}$		1.70, 1 *M* $HClO_4$; 1.61, 1 *M* HNO_3; 1.44, 1 *M* H_2SO_4; 1.28, 1 *M* HCl
$Cl_2(g) + 2e \rightleftharpoons 2Cl^-$	+1.359	
$HClO + H^+ + e \rightleftharpoons \frac{1}{2}Cl_2(g) + H_2O$	+1.63	
$ClO_3^- + 6H^+ + 5e \rightleftharpoons \frac{1}{2}Cl_2(g) + 3H_2O$	+1.47	
$Co^{2+} + 2e \rightleftharpoons Co(s)$	−0.277	
$Co^{3+} + e \rightleftharpoons Co^{2+}$	+1.808	
$Cr^{3+} + e \rightleftharpoons Cr^{2+}$	−0.408	
$Cr^{3+} + 3e \rightleftharpoons Cr(s)$	−0.744	
$Cr_2O_7^{2-} + 14H^+ + 6e \rightleftharpoons 2Cr^{3+} + 7H_2O$	+1.33	
$Cu^{2+} + 2e \rightleftharpoons Cu(s)$	+0.337	
$Cu^{2+} + e \rightleftharpoons Cu^+$	+0.153	
$Cu^+ + e \rightleftharpoons Cu(s)$	+0.521	
$Cu^{2+} + I^- + e \rightleftharpoons CuI(s)$	+0.86	
$CuI(s) + e \rightleftharpoons Cu(s) + I^-$	−0.185	
$F_2(g) + 2H^+ + 2e \rightleftharpoons 2HF(aq)$	+3.06	
$Fe^{2+} + 2e \rightleftharpoons Fe(s)$	−0.440	
$Fe^{3+} + e \rightleftharpoons Fe^{2+}$	+0.771	0.700, 1 *M* HCl; 0.732, 1 *M* $HClO_4$; 0.68, 1 *M* H_2SO_4
$Fe(CN)_6^{3-} + e \rightleftharpoons Fe(CN)_6^{4-}$	+0.36	0.71, 1 *M* HCl; 0.72, 1 *M* $HClO_4$, H_2SO_4
$2H^+ + 2e \rightleftharpoons H_2(g)$	0.000	−0.005, 1 *M* HCl, $HClO_4$
$Hg_2^{2+} + 2e \rightleftharpoons 2Hg(l)$	+0.788	0.274, 1 *M* HCl; 0.776, 1 *M* $HClO_4$; 0.674, 1 *M* H_2SO_4
$2Hg^{2+} + 2e \rightleftharpoons Hg_2^{2+}$	+0.920	0.907, 1 *M* $HClO_4$
$Hg^{2+} + 2e \rightleftharpoons Hg(l)$	+0.854	
$Hg_2Cl_2(s) + 2e \rightleftharpoons 2Hg(l) + 2Cl$	+0.268	0.242, sat'd KCl; 0.282, 1 *M* KCl; 0.334, 0.1 *M* KCl
$Hg_2SO_4(s) + 2e \rightleftharpoons 2Hg(l) + SO_4^{2-}$	+0.615	
$HO_2^- + H_2O + 2e \rightleftharpoons 3OH^-$	+0.88	

(CONTINUED)
SOME STANDARD AND FORMAL ELECTRODE POTENTIALS

Half-reaction[*]	E^0, V	Formal potential, V
$I_2(s) + 2e \rightleftharpoons 2I^-$	+0.5355	
$I_2(aq) + 2e \rightleftharpoons 2I^-$	+0.615[†]	
$I_3^- + 2e \rightleftharpoons 3I^-$	+0.536	
$ICl_2^- + e \rightleftharpoons \frac{1}{2}I_2(s) + 2Cl^-$	+1.056	
$IO_3^- + 6H^+ + 5e \rightleftharpoons \frac{1}{2}I_2(s) + 3H_2O$	+1.196	
$IO_3^- + 6H^+ + 5e \rightleftharpoons \frac{1}{2}I_2(aq) + 3H_2O$	+1.178[†]	
$IO_3^- + 2Cl^- + 6H^+ + 4e \rightleftharpoons ICl_2^- + 3H_2O$	+1.24	
$H_5IO_6 + H^+ + 2e \rightleftharpoons IO_3^- + 3H_2O$	+1.601	
$K^+ + e \rightleftharpoons K(s)$	−2.925	
$Li^+ + e \rightleftharpoons Li(s)$	−3.045	
$Mg^{2+} + 2e \rightleftharpoons Mg(s)$	−2.363	
$Mn^{2+} + 2e \rightleftharpoons Mn(s)$	−1.180	
$Mn^{3+} + e \rightleftharpoons Mn^{2+}$		1.51, 7.5 *M* H_2SO_4
$MnO_2(s) + 4H^+ + 2e \rightleftharpoons Mn^{2+} + 2H_2O$	+1.23	1.24, 1 *M* $HClO_4$
$MnO_4^- + 8H^+ + 5e \rightleftharpoons Mn^{2+} + 4H_2O$	+1.51	
$MnO_4^- + 4H^+ + 3e \rightleftharpoons MnO_2(s) + 2H_2O$	+1.695	
$MnO_4^- + e \rightleftharpoons MnO_4^{2-}$	+0.564	
$N_2(g) + 5H^+ + 4e \rightleftharpoons N_2H_5^+$	−0.23	
$HNO_2 + H^+ + e \rightleftharpoons NO(g) + H_2O$	+1.00	
$NO_3^- + 3H^+ + 2e \rightleftharpoons HNO_2 + H_2O$	+0.94	0.92, 1 *M* HNO_3
$Na^+ + e \rightleftharpoons Na(s)$	−2.714	
$Ni^{2+} + 2e \rightleftharpoons Ni(s)$	−0.250	
$H_2O_2 + 2H^+ + 2e \rightleftharpoons 2H_2O$	+1.776	
$O_2(g) + 4H^+ + 4e \rightleftharpoons 2H_2O$	+1.229	
$O_2(g) + 2H^+ + 2e \rightleftharpoons H_2O_2$	+0.682	
$O_3(g) + 2H^+ + 2e \rightleftharpoons O_2(g) + H_2O$	+2.07	
$Pb^{2+} + 2e \rightleftharpoons Pb(s)$	−0.126	−0.14, 1 *M* $HClO_4$; −0.29, 1 *M* H_2SO_4
$PbO_2(s) + 4H^+ + 2e \rightleftharpoons Pb^{2+} + 2H_2O$	+1.455	
$PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}$	−0.350	
$PtCl_4^{2-} + 2e \rightleftharpoons Pt(s) + 4Cl^-$	+0.73	
$PtCl_6^{2-} + 2e \rightleftharpoons PtCl_4^{2-} + 2Cl^-$	+0.68	
$Pd^{2+} + 2e \rightleftharpoons Pd(s)$	+0.987	
$S(s) + 2H^+ + 2e \rightleftharpoons H_2S(g)$	+0.141	
$H_2SO_3 + 4H^+ + 4e \rightleftharpoons S(s) + 3H_2O$	+0.450	
$S_4O_6^{2-} + 2e \rightleftharpoons 2S_2O_3^{2-}$	+0.08	
$SO_4^{2-} + 4H^+ + 2e \rightleftharpoons H_2SO_3 + H_2O$	+0.172	
$S_2O_8^{2-} + 2e \rightleftharpoons 2SO_4^{2-}$	+2.01	
$Sb_2O_5(s) + 6H^+ + 4e \rightleftharpoons 2SbO^+ + 3H_2O$	+0.581	
$H_2SeO_3 + 4H^+ + 4e \rightleftharpoons Se(s) + 3H_2O$	+0.740	
$SeO_4^{2-} + 4H^+ + 2e \rightleftharpoons H_2SeO_3 + H_2O$	+1.15	
$Sn^{2+} + 2e \rightleftharpoons Sn(s)$	−0.136	−0.16, 1 *M* $HClO_4$
$Sn^{4+} + 2e \rightleftharpoons Sn^{2+}$	+0.154	0.14, 1 *M* HCl
$Ti^{3+} + e \rightleftharpoons Ti^{2+}$	−0.369	
$TiO^{2+} + 2H^+ + e \rightleftharpoons Ti^{3+} + H_2O$	+0.099	0.04, 1 *M* H_2SO_4
$Tl^+ + e \rightleftharpoons Tl(s)$	−0.336	−0.551, 1 *M* HCl; −0.33, 1 *M* $HClO_4$, H_2SO_4
$Tl^{3+} + 2e \rightleftharpoons Tl^+$	+1.25	0.77, 1 *M* HCl
$UO_2^{2+} + 4H^+ + 2e \rightleftharpoons U^{4+} + 2H_2O$	+0.334	
$V^{3+} + e \rightleftharpoons V^{2+}$	−0.256	−0.21, 1 *M* $HClO_4$
$VO^{2+} + 2H^+ + e \rightleftharpoons V^{3+} + H_2O$	+0.359	
$V(OH)_4^+ + 2H^+ + e \rightleftharpoons VO^{2+} + 3H_2O$	+1.00	1.02, 1 *M* HCl, $HClO_4$
$Zn^{2+} + 2e \rightleftharpoons Zn(s)$	−0.763	

[*] Sources for E^0 values: A. J. deBethune and N. A. S. Loud, *Standard Aqueous Electrode Potentials and Temperature Coefficients at 25°C*. Skokie, Ill.: Clifford A. Hampel, 1964, and G. Milazzo, S. Caroli, and V. K. Sharma, *Tables of Standard Electrode Potentials*. New York: Wiley, 1978. Source of formal potentials: E. H. Swift and E. A. Butler, *Quantitative Measurements and Chemical Equilibria*. San Francisco: W. H. Freeman and Company. Copyright © 1972.

[†] These potentials are hypothetical because they correspond to solutions that are 1.00 *M* in Br_2 or I_2. The solubilities of these two compounds at 25°C are 0.18 *M* and 0.0020 *M*, respectively. In saturated solutions containing an excess of $Br_2(l)$ or $I_2(s)$, the standard potentials for the half-reactions $Br_2(l) + 2e \rightleftharpoons 2Br^-$ or $I_2(s) + 2e \rightleftharpoons 2I^-$ should be used. On the other hand, at Br_2 and I_2 concentrations less than saturation, these hypothetical electrode potentials should be employed.

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		

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

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

12. ELECTRODE POTENTIALS, ℰ°

$Na^{+} + e \rightleftarrows Na$ SCA	– 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

16. HEATS OF FORMATION

ΔH° 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	$P_{4\,wh}$	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

	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⁻³)

Water at		Air (70 cm)	0.
0_s°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_g°	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 = $\bar{X} \pm ts/\sqrt{n}$

$E = E^\circ - (0.0592/n)\log([Red]/[Ox])$

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

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

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

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

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

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

Vacc

Table 26-5 VALUES OF F AT THE 95% CONFIDENCE LEVEL

ν_2	ν_1					
	2	3	4	5	6	∞
2	19.00	19.16	19.25	19.30	19.33	19.50
3	9.55	9.28	9.12	9.01	8.94	8.53
4	6.94	6.59	6.39	6.26	6.16	5.63
5	5.79	5.41	5.19	5.05	4.95	4.36
6	5.14	4.76	4.53	4.39	4.28	3.67
∞	3.00	2.60	2.37	2.21	2.10	1.00

Table 4-2
Values of Student's t

	Confidence level (%)				
Degrees of freedom	50	80	90	95	99
1	1.000	3.078	6.314	12.706	63.657
2	0.816	1.886	2.920	4.303	9.925
3	0.765	1.638	2.353	3.182	5.841
4	0.741	1.533	2.132	2.776	4.604
5	0.727	1.476	2.015	2.571	4.032
6	0.718	1.440	1.943	2.447	3.707
7	0.711	1.415	1.895	2.365	3.500
8	0.706	1.397	1.860	2.306	3.355
9	0.703	1.383	1.833	2.262	3.250
10	0.700	1.372	1.812	2.228	3.169
15	0.691	1.341	1.753	2.131	2.947
20	0.687	1.325	1.725	2.086	2.845
∞	0.674	1.282	1.645	1.960	2.576

Table 4-4
Values of Q for rejection of data

Q (90% confidence)	0.94	0.76	0.64	0.56	0.51	0.47	0.44	0.41
Number of observations	3	4	5	6	7	8	9	10

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 10.81	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.998403	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 [illegible]	106 Unh [illegible]	107 Uns [illegible]	108 Uno [illegible]	109 Une [illegible]									

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 [illegible]	95 Am [illegible]	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md [illegible]	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}
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.

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1A	2A	3B	4B	5B	6B	7B	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	5.6 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

2.1

1A	2A	3B	4B	5B	6B	7B	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	1.6	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

37

1A	2A	3B	4B	5B	6B	7B	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
Na^+	95
K^+	133
Rb^+	148
Be^{+2}	31
Mg^{+2}	65
Ca^{+2}	99
Sr^{+2}	113
Ba^{+2}	135
B^{+3}	20
Al^{+3}	50
N^{+3}	171
P^{+3}	212
O^{-2}	140
S^{-2}	184
Se^{-2}	198
Te^{-2}	221
F^-	136
Cl^-	181
Br^-	195
I^-	216

9. LATTICE ENERGIE

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

10. HALF LIVES

H^3	12.3 years
F^{20}	11.4 secs
C^{14}	5730 years
Na^{24}	15.0 hours
P^{32}	14.3 days
S^{35}	88 days
Cl^{36}	3.1×10^5y
K^{40}	1.28×10^9y
Ca^{45}	165 days
Fe^{59}	45 days
Co^{60}	5.26 y
Br^{82}	35.5 hours
Sr^{90}	28 years
I^{129}	1.7×10^7y
I^{131}	8.1 da
Cs^{137}	30 yea
Au^{198}	2.69 da
Ra^{226}	1620 y
U^{235}	7.1×10
U^{238}	4.51×10
Pu^{230}	24,400

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Electrode Potentials, $E^\ominus$

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

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

$Cu^{2+} + 2e^- \rightleftharpoons Cu(s) \quad E^\ominus = +0.$

Values of $\alpha_{Y^{4-}}$ for EDTA at 20 C and $\mu = 0.10$ M

pH	$\alpha_{Y^{4-}}$
0	1.3×10^{-23}
1	1.9×10^{-18}
2	3.3×10^{-14}
3	2.6×10^{-11}
4	3.8×10^{-9}
5	3.7×10^{-7}
6	2.3×10^{-5}
7	5.0×10^{-4}
8	5.6×10^{-3}
9	5.4×10^{-2}
10	0.36
11	0.85
12	0.98
13	1.00
14	1.00

Table 14-2
Formation constants for metal–EDTA complexes

Ion	log K_f	Ion	log K_f	Ion	log K_f
Li^{+}	2.79	Mn^{3+}	25.3 (25 C)	Ce^{3+}	15.98
Na^{+}	1.66	Fe^{3+}	25.1	Pr^{3+}	16.40
K^{+}	0.8	Co^{3+}	41.4 (25 C)	Nd^{3+}	16.61
Be^{2+}	9.2	Zr^{4+}	29.5	Pm^{3+}	17.0
Mg^{2+}	8.79	Hf^{4+}	29.5 ($\mu = 0.2$)	Sm^{3+}	17.14
Ca^{2+}	10.69	VO^{2+}	18.8	Eu^{3+}	17.35
Sr^{2+}	8.73	VO_2^{+}	15.55	Gd^{3+}	17.37
Ba^{2+}	7.86	Ag^{+}	7.32	Tb^{3+}	17.93
Ra^{2+}	7.1	Tl	6.54	Dy^{3+}	18.30
Sc^{3+}	23.1	Pd^{2+}	18.5 (25 C, $\mu = 0.2$)	Ho^{3+}	18.62
Y^{3+}	18.09			Er^{3+}	18.85
La^{3+}	15.50			Tm^{3+}	19.32
V^{2+}	12.7	Zn^{2+}	16.50	Yb^{3+}	19.51
Cr^{2+}	13.6	Cd^{2+}	16.46	Lu^{3+}	19.83
Mn^{2+}	13.87	Hg^{2+}	21.7	Am^{3+}	17.8 (25 C)
Fe^{2+}	14.32	Sn^{2+}	18.3 ($\mu = 0$)	Cm^{3+}	18.1 (25 C)
Co^{2+}	16.31	Pb^{2+}	18.04	Bk^{3+}	18.5 (25 C)
Ni^{2+}	18.62	Al^{3+}	16.3	Cf^{3+}	18.7 (25 C)
Cu^{2+}	18.80	Ga^{3+}	20.3	Th^{4+}	23.2
Ti^{3+}	21.3 (25 C)	In^{3+}	25.0	U^{4+}	25.8
V^{3+}	26.0	Tl^{3+}	37.8 ($\mu = 1.0$)	Np^{4+}	24.6 (25 C, $\mu = 1.0$)
Cr^{3+}	23.4	Bi^{3+}	27.8		

Note: The stability constant is the equilibrium constant for the reaction $M^{n+} + Y^{4-} \rightleftharpoons MY^{n-4}$. Values in table apply at 20 C and ionic strength 0.1 M, unless otherwise noted.

SOURCE: Data from A. E. Martell and R. M. Smith, *Critical Stability Constants*, Vol. 1 (New York: Plenum Press, 1974), pp. 204–211.