



GENERAL CHEMISTRY II

Important Tables, Constants, Formulas

Abstract

Note: You are expected to gain familiarity with the use of the tables, constants and formulas presented in this document for problem solving.

You are expected to choose the relevant constants and formulas needed. In most cases, the problem itself will not state which constant or formula to use. It is your job to choose the proper constants and formulas from this document.

You will be provided with a new table for your exams.

Note: No other resources are allowed in exams.

Do not mark the exam copy!

Relative Strengths of common acids/conjugate bases in water

<i>Acid Name</i>	<i>Acid</i>	<i>Conjugate Base</i>
Hydroiodic	HI	I ⁻
Hydrobromic	HBr	Br ⁻
Perchloric	HClO ₄	ClO ₄ ⁻
Hydrochloric	HCl	Cl ⁻
Sulfuric	H ₂ SO ₄	HSO ₄ ⁻
Nitric	HNO ₃	NO ₃ ⁻
Hydronium	H ₃ O ⁺	H ₂ O (<i>l</i>)
Oxalic	H ₂ C ₂ O ₄	HC ₂ O ₄ ⁻
Sulfurous	H ₂ SO ₃ *	HSO ₃ ⁻
Hydrogen Sulfate	HSO ₄ ⁻	SO ₄ ²⁻
Phosphoric	H ₃ PO ₄	H ₂ PO ₄ ⁻
Nitrous	HNO ₂	NO ₂ ⁻
Hydrofluoric	HF	F ⁻
Formic (methanoic)	HCHO ₂	CHO ₂ ⁻
Lactic	HC ₃ H ₅ O ₃	C ₃ H ₅ O ₃ ⁻
Hydrogen Oxalate	HC ₂ O ₄ ⁻	C ₂ O ₄ ²⁻
Acetic (ethanoic)	HC ₂ H ₃ O ₂	C ₂ H ₃ O ₂ ⁻
Carbonic	H ₂ CO ₃ *	HCO ₃ ⁻
Hydrosulfuric	H ₂ S	HS ⁻
Hydrogen sulfite	HSO ₃ ⁻	SO ₃ ²⁻
Dihydrogen phosphate	H ₂ PO ₄ ⁻	HPO ₄ ²⁻
Hypochlorous	HOCl	OCl ⁻
Hydrocyanic	HCN	CN ⁻
Ammonium	NH ₄ ⁺	NH ₃
Hydrocyanic	HCN	CN ⁻
Hydrogen carbonate	HCO ₃ ⁻	CO ₃ ²⁻
Hydrogen phosphate	HPO ₄ ²⁻	PO ₄ ³⁻
Hydrogen sulfide	HS ⁻	S ²⁻
Water	H ₂ O (<i>l</i>)	OH ⁻
Hydroxide	OH ⁻	O ²⁻
Ammonia	NH ₃	NH ₂ ⁻

These bases do not react with water!

Most common strong base in water

↑ Increasing Acid Strength

↓ Increasing Base Strength

* These unstable acids once formed, decompose in water to their stable products.

1. Acid Dissociation Constants (K_a) of Selected Acids in water at 25 °C.

Acid	Formula	K_{a1}	K_{a2}	K_{a3}	Ref.
Acetic acid	CH ₃ COOH	1.75E-05			1
Arsenic acid	H ₃ AsO ₄	5.8E-03	1.1E-07	3.2E-12	1
Arsenous acid	H ₃ AsO ₃	5.1E-10			1
Boric acid	H ₃ BO ₃	5.81E-10			1
Carbonic acid	H ₂ CO ₃ as [CO ₂ (aq) + H ₂ O]	4.45E-07	4.69E-11		1
Chlorous acid	HOClO	1.1E-02			3
Chloric acid	HOClO ₂	1E+01			3
Chloroacetic acid	ClCH ₂ COOH	1.36E-03			1
Chromic acid	H ₂ CrO ₄	3.55	1.0E-02		1
Citric acid	HOOC(OH)C(CH ₂ COOH) ₂	7.45E-04	1.73E-05	4.02E-07	1
Formic acid	HCOOH	1.80E-04			1
Hydrazoic acid	HN ₃	2.20E-05			1
Hydrobromic acid	HBr	1.0E+08			2
Hydrochloric acid	HCl	1.0E+06			2
Hydrocyanic acid	HCN	6.3E-10			2
Hydrofluoric acid	HF	6.8E-04			1
Hydrosulfuric acid	H ₂ S	9.6E-08	1.3E-14		1
Hydroiodic acid	HI	1.0E+09			2
Hydroxylamine acid	NH ₂ OH	1.1E-06			2
Hypochlorous acid	HOCl	2.90E-08			2
Hypobromous acid	HOBr	2.2E-09			2
Hypoiodous acid	HOI	2.3E-11			2
Iodic acid	HOIO ₂	1.70E-01			1
Lactic acid	CH ₃ CHOHCOOH	1.38E-04			1
Maleic acid	<i>cis</i> -HOOCCH:CHCOOH	1.3E-02	5.9E-07		1
Malic acid	HOOCCHOHCH ₂ COOH	3.48E-04	8.00E-06		1
Malonic acid	HOOCCH ₂ COOH	1.42E-03	2.01E-06		1
Mandelic acid	C ₆ H ₅ CHOHCOOH	4.0E-04			1
Nitric acid	HNO ₃	high (below 2 M), 18 (2-14 M)			1
Nitrous acid	HNO ₂	7.1E-04			1
Oxalic acid	HOCCOOH	5.60E-02	5.42E-05		1
Perchloric acid	HOClO ₃	very high			1
Permanganic acid	HMnO ₄	1.8E+02			1
Peroxyacetic acid	CH ₃ CO ₃ H	6E-09			4
Phosphoric acid	H ₃ PO ₄	6.90E-03	6.21E-08	4.73E-13	2
Phosphorous acid	H ₃ PO ₃	6.3E-02	2.00E-07	1E-14	2
Propanoic acid	CH ₃ CH ₂ COOH	1.34E-05			1
Salicylic acid	C ₆ H ₄ (OH)COOH	1.06E-03			1
Sulfamic acid	H ₂ NSO ₃ H	1.03E-01			1
Succinic acid	HOOCCH ₂ CH ₂ COOH	6.21E-05	2.31E-06		1
Sulfuric acid	H ₂ SO ₄	2E+06	1.02E-02		1
Sulfurous acid	H ₂ SO ₃	1.23E-02	6.6E-08		1
Thiocyanic acid	HSCN	0.13			1
Thiosulfuric acid	H ₂ S ₂ O ₃	0.3	2.50E-02		1
Trichloroacetic acid	Cl ₃ CCOOH	3			1
Water	H₂O	1.0E-14			2

Gen
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Tables
Constants
&
Formulas

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resources
are allowed
during
exams!

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2. Acid Dissociation Constants (K_a) of Selected Hydrated Metal Ions in Water at 25 °C.

Cation	Formula	K_{a1}	pK_{a1}		Ref.
Al ³⁺	Al(H ₂ O) ₆ ³⁺	1.10E-05	4.96		2
Be ²⁺	Be(H ₂ O) ₆ ²⁺	3.2E-07	6.5		2
Co ²⁺	Co(H ₂ O) ₆ ²⁺	1.41E-10	9.85		2
Cr ³⁺	Cr(H ₂ O) ₆ ³⁺	2.19E-04	3.66		2
Cu ²⁺	Cu(H ₂ O) ₆ ²⁺	1E-08	8		2
Fe ²⁺	Fe(H ₂ O) ₆ ²⁺	1.8E-07	6.74		2
Fe ³⁺	Fe(H ₂ O) ₆ ³⁺	3.5E-03	2.46		2
Ni ²⁺	Ni(H ₂ O) ₆ ²⁺	1.4E-10	9.86		2
In ³⁺	In(H ₂ O) ₆ ³⁺	4E-05	4.4		2
Pb ²⁺	Pb(H ₂ O) ₆ ²⁺	1.2E-08	7.93		2
Sn ²⁺	Sn(H ₂ O) ₆ ²⁺	2E-02	1.7		2
Ti ³⁺	Ti(H ₂ O) ₆ ³⁺	5.1E-02	1.29		2
Zn ²⁺	Zn(H ₂ O) ₆ ²⁺	1.1E-09	8.96		2

3. Base Dissociation Constants (K_b) of selected compounds in water at 25 °C.

Base	Formula	K_{b1}	pK_{b1}	pK_{b2}	Ref.
Ammonia	NH ₃	1.76E-05	4.754		2
Aniline	C ₆ H ₅ NH ₂	2.3E-05	4.63		3
Codeine	C ₁₈ H ₂₁ NO ₃	1.6E-06	5.79		3
Diethylamine	(C ₂ H ₅) ₂ NH	1.0E-03	2.98		3
Dimethylamine	(CH ₃) ₂ NH	5.45E-04	3.264		3
Ethylamine	C ₂ H ₅ NH ₂	6.46E-04	3.19		3
Ethylenediamine	H ₂ NCH ₂ CH ₂ NH ₂	5.2E-04	3.285	6.433	3
Hydrazine	H ₂ NNH ₂	1.7E-06	5.77		3
Hydroxylamine	HONH ₂	9.5E-09	8.02		2
Methylamine	CH ₃ NH ₂	4.6E-04	3.340		3
Morphine	C ₁₇ H ₁₉ NO ₃	1.6E-06	5.79		3
Nicotine	C ₁₀ H ₁₄ N ₂	1.0E-06	5.98	3.12	3
Piperidine	C ₅ H ₁₀ NH	1.34E-03	2.874		3
Propylamine	C ₃ H ₇ NH ₂	5.14E-04	3.289		3
Pyridine	C ₅ H ₅ N	1.8E-09	8.75		3
Strychnine	C ₂₁ H ₂₂ N ₂ O ₂	1.8E-06	5.74		3
Triethylamine	(C ₂ H ₅) ₃ N	1.0E-03	2.99		3
Trimethylamine	(CH ₃) ₃ N	6.5E-05	4.19		3

Note: The exponential notation E is 10^x; for example, 1.0E-3 means 1.0 x 10⁻³.

Ref. 1: Analytical Chemistry, An Introduction 7th Edition: Appendix 2, p. A-3

Ref. 2: Dissociation constants of inorganic acids and bases, D.D. Perrin, Butterworths, London, 1965

Ref. 3: CRC handbook of Chemistry and Physics, 60th ed. 1980.

Ref 4: Wikipedia

4. Solubility Product Constants for Selected Compounds at 25 °C

No.	Compound	Formula	K _{sp}	No.	Compound	Formula	K _{sp}
1	Aluminum hydroxide	Al(OH) ₃	1.3×10 ⁻³³	53	Lead(II) iodide	PbI ₂	7.1×10 ⁻⁹
2	Aluminum phosphate	AlPO ₄	6.3×10 ⁻¹⁹	54	Lead(II) sulfate	PbSO ₄	1.6×10 ⁻⁸
3	Barium carbonate	BaCO ₃	5.1×10 ⁻⁹	55	Lead(II) sulfide*	PbS *	3×10 ⁻²⁸
4	Barium chromate	BaCrO ₄	1.2×10 ⁻¹⁰	56	Lithium carbonate	Li ₂ CO ₃	2.5×10 ⁻²
5	Barium fluoride	BaF ₂	1.0×10 ⁻⁶	57	Lithium fluoride	LiF	3.8×10 ⁻³
6	Barium hydroxide	Ba(OH) ₂	5×10 ⁻³	58	Lithium phosphate	Li ₃ PO ₄	3.2×10 ⁻⁹
7	Barium sulfate	BaSO ₄	1.1×10 ⁻¹⁰	59	Magnesium ammonium phosphate	MgNH ₄ PO ₄	2.5×10 ⁻¹³
8	Barium sulfite	BaSO ₃	8×10 ⁻⁷	60	Magnesium arsenate	Mg ₃ (AsO ₄) ₂	2×10 ⁻²⁰
9	Barium thiosulfate	BaS ₂ O ₃	1.6×10 ⁻⁶	61	Magnesium carbonate	MgCO ₃	3.5×10 ⁻⁸
10	Cadmium carbonate	CdCO ₃	5.2×10 ⁻¹²	62	Magnesium fluoride	MgF ₂	3.7×10 ⁻⁸
11	Cadmium hydroxide	Cd(OH) ₂	2.5×10 ⁻¹⁴	63	Magnesium hydroxide	Mg(OH) ₂	1.8×10 ⁻¹¹
12	Cadmium oxalate	CdC ₂ O ₄	1.5×10 ⁻⁸	64	Magnesium oxalate	MgC ₂ O ₄	8.5×10 ⁻⁵
13	Cadmium sulfide*	CdS *	8×10 ⁻²⁸	65	Magnesium phosphate	Mg ₃ (PO ₄) ₂	1×10 ⁻²⁵
14	Calcium carbonate	CaCO ₃	2.8×10 ⁻⁹	66	Manganese(II) carbonate	MnCO ₃	1.8×10 ⁻¹¹
15	Calcium chromate	CaCrO ₄	7.1×10 ⁻⁴	67	Manganese(II) hydroxide	Mn(OH) ₂	1.9×10 ⁻¹³
16	Calcium fluoride	CaF ₂	5.3×10 ⁻⁹	68	Manganese(II) sulfide*	MnS *	3×10 ⁻¹⁴
17	Calcium hydrogen phosphate	CaHPO ₄	1×10 ⁻⁷	69	Mercury(I) bromide	Hg ₂ Br ₂	5.6×10 ⁻²³
18	Calcium hydroxide	Ca(OH) ₂	5.5×10 ⁻⁶	70	Mercury(I) chloride	Hg ₂ Cl ₂	1.3×10 ⁻¹⁸
19	Calcium oxalate	CaC ₂ O ₄	2.7×10 ⁻⁹	71	Mercury(I) iodide	Hg ₂ I ₂	4.5×10 ⁻²⁹
20	Calcium phosphate	Ca ₃ (PO ₄) ₂	2.0×10 ⁻²⁹	72	Mercury(II) sulfide*	HgS *	2×10 ⁻⁵³
21	Calcium sulfate	CaSO ₄	9.1×10 ⁻⁶	73	Nickel(II) carbonate	NiCO ₃	6.6×10 ⁻⁹
22	Calcium sulfite	CaSO ₃	6.8×10 ⁻⁸	74	Nickel(II) hydroxide	Ni(OH) ₂	2.0×10 ⁻¹⁵
23	Chromium(II) hydroxide	Cr(OH) ₂	2×10 ⁻¹⁶	75	Nickel(II) sulfide*	NiS *	3×10 ⁻¹⁹
24	Chromium(III) hydroxide	Cr(OH) ₃	6.3×10 ⁻³¹	76	Scandium fluoride	ScF ₃	4.2×10 ⁻¹⁸
25	Cobalt(II) carbonate	CoCO ₃	1.4×10 ⁻¹³	77	Scandium hydroxide	Sc(OH) ₃	8.0×10 ⁻³¹
26	Cobalt(II) hydroxide	Co(OH) ₂	1.6×10 ⁻¹⁵	78	Silver acetate	AgC ₂ H ₃ O ₂	2.0×10 ⁻³
27	Cobalt(III) hydroxide	Co(OH) ₃	1.6×10 ⁻⁴⁴	79	Silver arsenate	Ag ₃ AsO ₄	1.0×10 ⁻²²
28	Cobalt(II) sulfide*	CoS *	4×10 ⁻²¹	80	Silver azide	AgN ₃	2.8×10 ⁻⁹
29	Copper(I) chloride	CuCl	1.2×10 ⁻⁶	81	Silver bromide	AgBr	5.0×10 ⁻¹³
30	Copper(I) cyanide	CuCN	3.2×10 ⁻²⁰	82	Silver chloride	AgCl	1.8×10 ⁻¹⁰
31	Copper(I) iodide	CuI	1.1×10 ⁻¹²	83	Silver chromate	Ag ₂ CrO ₄	1.1×10 ⁻¹²
32	Copper(II) arsenate	Cu ₃ (AsO ₄) ₂	7.6×10 ⁻³⁶	84	Silver cyanide	AgCN	1.2×10 ⁻¹⁶
33	Copper(II) carbonate	CuCO ₃	1.4×10 ⁻¹⁰	85	Silver iodate	AgIO ₃	3.0×10 ⁻⁸
34	Copper(II) chromate	CuCrO ₄	3.6×10 ⁻⁶	86	Silver iodide	AgI	8.5×10 ⁻¹⁷
35	Copper(II) ferrocyanide	Cu[Fe(CN) ₆]	1.3×10 ⁻¹⁶	87	Silver nitrite	AgNO ₂	6.0×10 ⁻⁴
36	Copper(II) hydroxide	Cu(OH) ₂	2.2×10 ⁻²⁰	88	Silver sulfate	Ag ₂ SO ₄	1.4×10 ⁻⁵
37	Copper(II) sulfide*	CuS *	6×10 ⁻³⁷	89	Silver sulfide*	Ag ₂ S *	6×10 ⁻⁵¹
38	Iron(II) carbonate	FeCO ₃	3.2×10 ⁻¹¹	90	Silver sulfite	Ag ₂ SO ₃	1.5×10 ⁻¹⁴
39	Iron(II) hydroxide	Fe(OH) ₂	8.0×10 ⁻¹⁶	91	Silver thiocyanate	AgSCN	1.0×10 ⁻¹²
40	Iron(II) sulfide*	FeS *	6×10 ⁻¹⁹	92	Strontium carbonate	SrCO ₃	1.1×10 ⁻¹⁰
41	Iron(III) arsenate	FeAsO ₄	5.7×10 ⁻²¹	93	Strontium chromate	SrCrO ₄	2.2×10 ⁻⁵
42	Iron(III) ferrocyanide	Fe ₄ [Fe(CN) ₆] ₃	3.3×10 ⁻⁴¹	94	Strontium fluoride	SrF ₂	2.5×10 ⁻⁹
43	Iron(III) hydroxide	Fe(OH) ₃	4×10 ⁻³⁸	95	Strontium sulfate	SrSO ₄	3.2×10 ⁻⁷
44	Iron(III) phosphate	FePO ₄	1.3×10 ⁻²²	96	Thallium(I) bromide	TlBr	3.4×10 ⁻⁶
45	Lead(II) arsenate	Pb ₃ (AsO ₄) ₂	4×10 ⁻³⁶	97	Thallium(I) chloride	TlCl	1.7×10 ⁻⁴
46	Lead(II) azide	Pb(N ₃) ₂	2.5×10 ⁻⁹	98	Thallium (I) iodide	TlI	6.5×10 ⁻⁸
47	Lead(II) bromide	PbBr ₂	4.0×10 ⁻⁵	99	Thallium(III) hydroxide	Tl(OH) ₃	6.3×10 ⁻⁴⁶
48	Lead(II) carbonate	PbCO ₃	7.4×10 ⁻¹⁴	100	Tin(II) hydroxide	Sn(OH) ₂	1.4×10 ⁻²⁸
49	Lead(II) chloride	PbCl ₂	1.6×10 ⁻⁵	101	Zinc carbonate	ZnCO ₃	1.4×10 ⁻¹¹
50	Lead(II) chromate	PbCrO ₄	2.8×10 ⁻¹³	102	Zinc hydroxide	Zn(OH) ₂	1.2×10 ⁻¹⁷
51	Lead(II) fluoride	PbF ₂	2.7×10 ⁻⁸	103	Zinc oxalate	ZnC ₂ O ₄	2.7×10 ⁻⁸
52	Lead(II) hydroxide	Pb(OH) ₂	1.2×10 ⁻¹⁵	104	Zinc phosphate	Zn ₃ (PO ₄) ₂	9.0×10 ⁻³³



5. Complex Ion formation Constants for Selected Compounds at 25 °C

No.	Formula	K _f
1	[Ag(CN) ₂] ⁻	5.6×10 ¹⁸
2	[Ag(EDTA)] ³⁻	2.1×10 ⁷
3	[Ag(en) ₂] ⁺	5.0×10 ⁷
4	[Ag(NH ₃) ⁺	1.6×10 ³
5	[Ag(NH ₃) ₂] ⁺	1.6×10 ⁷
6	[Ag(S ₂ O ₃) ₂] ³⁻	1.7×10 ¹³
7	[Ag(SCN) ₄] ³⁻	1.2×10 ¹⁰
8	[AgCl ₂] ⁻	2×10 ⁵
9	[Al(EDTA)] ⁻	1.3×10 ¹⁶
10	[Al(OH) ₄] ⁻	1.1×10 ³³
11	[Al(ox) ₃] ³⁻	2×10 ¹⁶
12	[AlF ₄] ⁻	2.0×10 ⁸
13	[AlF ₆] ³⁻	2.5×10 ⁴
14	[Au(CN) ₂] ⁻	2×10 ³⁸
15	[AuCl ₄] ⁻	2×10 ²¹
16	[BeF ₄] ²⁻	1.3×10 ¹³
17	[Cd(CN) ₄] ²⁻	6.0×10 ¹⁸
18	[Cd(en) ₃] ²⁺	1.2×10 ¹²
19	[Cd(NH ₃) ₄] ²⁺	1.3×10 ⁷
20	[Co(EDTA)] ⁻	1×10 ³⁶
21	[Co(EDTA)] ²⁻	2.0×10 ¹⁶
22	[Co(en) ₃] ²⁺	8.7×10 ¹³
23	[Co(en) ₃] ³⁺	4.9×10 ⁴⁸
24	[Co(NH ₃) ₆] ²⁺	1.3×10 ⁵
25	[Co(NH ₃) ₆] ³⁺	4.5×10 ³³
26	[Co(ox) ₃] ³⁻	1×10 ²⁰
27	[Co(ox) ₃] ⁴⁻	5×10 ⁹
28	[Co(SCN) ₄] ²⁻	1.0×10 ³
29	[Cr(EDTA)] ⁻	1×10 ²³
30	[Cr(OH) ₄] ⁻	8×10 ⁻²⁹
31	[Cu(CN) ₂] ⁻	1.0×10 ¹⁶
32	[Cu(CN) ₄] ²⁻	1×10 ²⁵
33	[Cu(EDTA)] ²⁻	5×10 ¹⁸
34	[Cu(en) ₂] ²⁺	1×10 ²⁰

No.	Formula	K _f
35	[Cu(NH ₃) ₂] ⁺	6.3×10 ¹⁰
36	[Cu(NH ₃) ₄] ²⁺	1.1×10 ¹³
37	[Cu(OH) ₄] ²⁻	1.3×10 ¹⁶
38	[Cu(ox) ₂] ²⁻	3×10 ⁸
39	[CuCl ₃] ²⁻	5×10 ⁵
40	[CuCl ₄] ²⁻	4×10 ⁵
41	[Fe(CN) ₆] ³⁻	1×10 ⁴²
42	[Fe(CN) ₆] ⁴⁻	1×10 ³⁷
43	[Fe(EDTA)] ⁻	1.7×10 ²⁴
44	[Fe(EDTA)] ²⁻	2.1×10 ¹⁴
45	[Fe(en) ₃] ²⁺	5.0×10 ⁹
46	[Fe(ox) ₃] ³⁻	2×10 ²⁰
47	[Fe(ox) ₃] ⁴⁻	1.7×10 ⁵
48	[Fe(SCN)] ²⁺	8.9×10 ²
49	[Hg(CN) ₄] ²⁻	3×10 ⁴¹
50	[Hg(EDTA)] ²⁻	6.3×10 ²¹
51	[Hg(en) ₂] ²⁺	2×10 ²³
52	[Hg(ox) ₂] ²⁻	9.5×10 ⁶
53	[HgCl ₄] ²⁻	1.2×10 ¹⁵
54	[HgI ₄] ²⁻	6.8×10 ²⁹
55	[Ni(CN) ₄] ²⁻	2×10 ³¹
56	[Ni(EDTA)] ²⁻	3.6×10 ¹⁸
57	[Ni(en) ₃] ²⁺	2.1×10 ¹⁸
58	[Ni(NH ₃) ₆] ²⁺	5.5×10 ⁸
59	[Ni(ox) ₃] ⁴⁻	3×10 ⁸
60	[Pb(EDTA)] ²⁻	2×10 ¹⁸
61	[Pb(OH) ₃] ⁻	3.8×10 ¹⁴
62	[Pb(ox) ₂] ²⁻	3.5×10 ⁶
63	[Pb(S ₂ O ₃) ₃] ⁴⁻	2.2×10 ⁶
64	[PbCl ₃] ⁻	2.4×10 ¹
65	[PbI ₄] ²⁻	3.0×10 ⁴
66	[Pt(NH ₃) ₆] ²⁺	2×10 ³⁵
67	[PtCl ₄] ²⁻	1×10 ¹⁶
68	[Sn(OH) ₃] ⁻	3×10 ²⁵

No.	Formula	K _f
69	[Zn(CN) ₄] ²⁻	1×10 ¹⁸
70	[Zn(EDTA)] ²⁻	3×10 ¹⁶
71	[Zn(en) ₃] ²⁺	1.3×10 ¹⁴
72	[Zn(NH ₃) ₄] ²⁺	4.1×10 ⁸
73	[Zn(OH) ₄] ²⁻	4.6×10 ¹⁷
74	[Zn(ox) ₃] ⁴⁻	1.4×10 ⁸
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THERMODYNAMIC QUANTITIES FOR SELECTED SUBSTANCES AT 298.15 K (25 °C)

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)	Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)
Aluminum				C ₂ H ₂ (g)	226.77	209.2	200.8
Al(s)	0	0	28.32	C ₂ H ₄ (g)	52.30	68.11	219.4
AlCl ₃ (s)	-705.6	-630.0	109.3	C ₂ H ₆ (g)	-84.68	-32.89	229.5
Al ₂ O ₃ (s)	-1669.8	-1576.5	51.00	C ₃ H ₈ (g)	-103.85	-23.47	269.9
Barium				C ₄ H ₁₀ (g)	-124.73	-15.71	310.0
Ba(s)	0	0	63.2	C ₄ H ₁₀ (l)	-147.6	-15.0	231.0
BaCO ₃ (s)	-1216.3	-1137.6	112.1	C ₆ H ₆ (g)	82.9	129.7	269.2
BaO(s)	-553.5	-525.1	70.42	C ₆ H ₆ (l)	49.0	124.5	172.8
Beryllium				CH ₃ OH(g)	-201.2	-161.9	237.6
Be(s)	0	0	9.44	CH ₃ OH(l)	-238.6	-166.23	126.8
BeO(s)	-608.4	-579.1	13.77	C ₂ H ₅ OH(g)	-235.1	-168.5	282.7
Be(OH) ₂ (s)	-905.8	-817.9	50.21	C ₂ H ₅ OH(l)	-277.7	-174.76	160.7
Bromine				C ₆ H ₁₂ O ₆ (s)	-1273.02	-910.4	212.1
Br(g)	111.8	82.38	174.9	CO(g)	-110.5	-137.2	197.9
Br ⁻ (aq)	-120.9	-102.8	80.71	CO ₂ (g)	-393.5	-394.4	213.6
Br ₂ (g)	30.71	3.14	245.3	CH ₃ COOH(l)	-487.0	-392.4	159.8
Br ₂ (l)	0	0	152.3	Cesium			
HBr(g)	-36.23	-53.22	198.49	Cs(g)	76.50	49.53	175.6
Calcium				Cs(l)	2.09	0.03	92.07
Ca(g)	179.3	145.5	154.8	Cs(s)	0	0	85.15
Ca(s)	0	0	41.4	CsCl(s)	-442.8	-414.4	101.2
CaCO ₃ (s, calcite)	-1207.1	-1128.76	92.88	Chlorine			
CaCl ₂ (s)	-795.8	-748.1	104.6	Cl(g)	121.7	105.7	165.2
CaF ₂ (s)	-1219.6	-1167.3	68.87	Cl ⁻ (aq)	-167.2	-131.2	56.5
CaO(s)	-635.5	-604.17	39.75	Cl ₂ (g)	0	0	222.96
Ca(OH) ₂ (s)	-986.2	-898.5	83.4	HCl(aq)	-167.2	-131.2	56.5
CaSO ₄ (s)	-1434.0	-1321.8	106.7	HCl(g)	-92.30	-95.27	186.69
Carbon				Chromium			
C(g)	718.4	672.9	158.0	Cr(g)	397.5	352.6	174.2
C(s, diamond)	1.88	2.84	2.43	Cr(s)	0	0	23.6
C(s, graphite)	0	0	5.69	Cr ₂ O ₃ (s)	-1139.7	-1058.1	81.2
CCl ₄ (g)	-106.7	-64.0	309.4	Cobalt			
CCl ₄ (l)	-139.3	-68.6	214.4	Co(g)	439	393	179
CF ₄ (g)	-679.9	-635.1	262.3	Co(s)	0	0	28.4
CH ₄ (g)	-74.8	-50.8	186.3				

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)	Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)
Copper				$\text{Li}^+(aq)$	-278.5	-273.4	12.2
Cu(g)	338.4	298.6	166.3	$\text{Li}^+(g)$	685.7	648.5	133.0
Cu(s)	0	0	33.30	$\text{LiCl}(s)$	-408.3	-384.0	59.30
$\text{CuCl}_2(s)$	-205.9	-161.7	108.1	Magnesium			
$\text{CuO}(s)$	-156.1	-128.3	42.59	$\text{Mg}(g)$	147.1	112.5	148.6
$\text{Cu}_2\text{O}(s)$	-170.7	-147.9	92.36	$\text{Mg}(s)$	0	0	32.51
Fluorine				$\text{MgCl}_2(s)$	-641.6	-592.1	89.6
$\text{F}(g)$	80.0	61.9	158.7	$\text{MgO}(s)$	-601.8	-569.6	26.8
$\text{F}^-(aq)$	-332.6	-278.8	-13.8	$\text{Mg}(\text{OH})_2(s)$	-924.7	-833.7	63.24
$\text{F}_2(g)$	0	0	202.7	Manganese			
$\text{HF}(g)$	-268.61	-270.70	173.51	$\text{Mn}(g)$	280.7	238.5	173.6
Hydrogen				$\text{Mn}(s)$	0	0	32.0
$\text{H}(g)$	217.94	203.26	114.60	$\text{MnO}(s)$	-385.2	-362.9	59.7
$\text{H}^+(aq)$	0	0	0	$\text{MnO}_2(s)$	-519.6	-464.8	53.14
$\text{H}^+(g)$	1536.2	1517.0	108.9	$\text{MnO}_4^-(aq)$	-541.4	-447.2	191.2
$\text{H}_2(g)$	0	0	130.58	Mercury			
Iodine				$\text{Hg}(g)$	60.83	31.76	174.89
$\text{I}(g)$	106.60	70.16	180.66	$\text{Hg}(l)$	0	0	77.40
$\text{I}^-(g)$	-55.19	-51.57	111.3	$\text{HgCl}_2(s)$	-230.1	-184.0	144.5
$\text{I}_2(g)$	62.25	19.37	260.57	$\text{Hg}_2\text{Cl}_2(s)$	-264.9	-210.5	192.5
$\text{I}_2(s)$	0	0	116.73	Nickel			
$\text{HI}(g)$	25.94	1.30	206.3	$\text{Ni}(g)$	429.7	384.5	182.1
Iron				$\text{Ni}(s)$	0	0	29.9
$\text{Fe}(g)$	415.5	369.8	180.5	$\text{NiCl}_2(s)$	-305.3	-259.0	97.65
$\text{Fe}(s)$	0	0	27.15	$\text{NiO}(s)$	-239.7	-211.7	37.99
$\text{Fe}^{2+}(aq)$	-87.86	-84.93	113.4	Nitrogen			
$\text{Fe}^{3+}(aq)$	-47.69	-10.54	293.3	$\text{N}(g)$	472.7	455.5	153.3
$\text{FeCl}_2(s)$	-341.8	-302.3	117.9	$\text{N}_2(g)$	0	0	191.50
$\text{FeCl}_3(s)$	-400	-334	142.3	$\text{NH}_3(aq)$	-80.29	-26.50	111.3
$\text{FeO}(s)$	-271.9	-255.2	60.75	$\text{NH}_3(g)$	-46.19	-16.66	192.5
$\text{Fe}_2\text{O}_3(s)$	-822.16	-740.98	89.96	$\text{NH}_4^+(aq)$	-132.5	-79.31	113.4
$\text{Fe}_3\text{O}_4(s)$	-1117.1	-1014.2	146.4	$\text{N}_2\text{H}_4(g)$	95.40	159.4	238.5
$\text{FeS}_2(s)$	-171.5	-160.1	52.92	$\text{NH}_4\text{CN}(s)$	0.4	—	—
Lead				$\text{NH}_4\text{Cl}(s)$	-314.4	-203.0	94.6
$\text{Pb}(s)$	0	0	68.85	$\text{NH}_4\text{NO}_3(s)$	-365.6	-184.0	151
$\text{PbBr}_2(s)$	-277.4	-260.7	161	$\text{NO}(g)$	90.37	86.71	210.62
$\text{PbCO}_3(s)$	-699.1	-625.5	131.0	$\text{NO}_2(g)$	33.84	51.84	240.45
$\text{Pb}(\text{NO}_3)_2(aq)$	-421.3	-246.9	303.3	$\text{N}_2\text{O}(g)$	81.6	103.59	220.0
$\text{Pb}(\text{NO}_3)_2(s)$	-451.9	—	—	$\text{N}_2\text{O}_4(g)$	9.66	98.28	304.3
$\text{PbO}(s)$	-217.3	-187.9	68.70	$\text{NOCl}(g)$	52.6	66.3	264
Lithium				$\text{HNO}_3(aq)$	-206.6	-110.5	146
$\text{Li}(g)$	159.3	126.6	138.8	$\text{HNO}_3(g)$	-134.3	-73.94	266.4
$\text{Li}(s)$	0	0	29.09				

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)	Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)
Oxygen				Scandium			
O(g)	247.5	230.1	161.0	Sc(g)	377.8	336.1	174.7
O ₂ (g)	0	0	205.0	Sc(s)	0	0	34.6
O ₃ (g)	142.3	163.4	237.6	Selenium			
OH ⁻ (aq)	-230.0	-157.3	-10.7	H ₂ Se(g)	29.7	15.9	219.0
H ₂ O(g)	-241.82	-228.57	188.83	Silicon			
H ₂ O(l)	-285.83	-237.13	69.91	Si(g)	368.2	323.9	167.8
H ₂ O ₂ (g)	-136.10	-105.48	232.9	Si(s)	0	0	18.7
H ₂ O ₂ (l)	-187.8	-120.4	109.6	SiC(s)	-73.22	-70.85	16.61
Phosphorus				SiCl ₄ (l)	-640.1	-572.8	239.3
P(g)	316.4	280.0	163.2	SiO ₂ (s, quartz)	-910.9	-856.5	41.84
P ₂ (g)	144.3	103.7	218.1	Silver			
P ₄ (g)	58.9	24.4	280	Ag(s)	0	0	42.55
P ₄ (s, red)	-17.46	-12.03	22.85	Ag ⁺ (aq)	105.90	77.11	73.93
P ₄ (s, white)	0	0	41.08	AgCl(s)	-127.0	-109.70	96.11
PCl ₃ (g)	-288.07	-269.6	311.7	Ag ₂ O(s)	-31.05	-11.20	121.3
PCl ₃ (l)	-319.6	-272.4	217	AgNO ₃ (s)	-124.4	-33.41	140.9
PF ₃ (g)	-1594.4	-1520.7	300.8	Sodium			
PH ₃ (g)	5.4	13.4	210.2	Na(g)	107.7	77.3	153.7
P ₄ O ₆ (s)	-1640.1	—	—	Na(s)	0	0	51.45
P ₄ O ₁₀ (s)	-2940.1	-2675.2	228.9	Na ⁺ (aq)	-240.1	-261.9	59.0
POCl ₃ (g)	-542.2	-502.5	325	Na ⁺ (g)	609.3	574.3	148.0
POCl ₃ (l)	-597.0	-520.9	222	NaBr(aq)	-360.6	-364.7	141.00
H ₃ PO ₄ (aq)	-1288.3	-1142.6	158.2	NaBr(s)	-361.4	-349.3	86.82
Potassium				Na ₂ CO ₃ (s)	-1130.9	-1047.7	136.0
K(g)	89.99	61.17	160.2	NaCl(aq)	-407.1	-393.0	115.5
K(s)	0	0	64.67	NaCl(g)	-181.4	-201.3	229.8
K ⁺ (aq)	-252.4	-283.3	102.5	NaCl(s)	-410.9	-384.0	72.33
K ⁺ (g)	514.2	481.2	154.5	NaHCO ₃ (s)	-947.7	-851.8	102.1
KCl(s)	-435.9	-408.3	82.7	NaNO ₃ (aq)	-446.2	-372.4	207
KClO ₃ (s)	-391.2	-289.9	143.0	NaNO ₃ (s)	-467.9	-367.0	116.5
KClO ₃ (aq)	-349.5	-284.9	265.7	NaOH(aq)	-469.6	-419.2	49.8
K ₂ CO ₃ (s)	-1150.18	-1064.58	155.44	NaOH(s)	-425.6	-379.5	64.46
KNO ₃ (s)	-492.70	-393.13	132.9	Na ₂ SO ₄ (s)	-1387.1	-1270.2	149.6
K ₂ O(s)	-363.2	-322.1	94.14	Strontium			
KO ₂ (s)	-284.5	-240.6	122.5	SrO(s)	-592.0	-561.9	54.9
K ₂ O ₂ (s)	-495.8	-429.8	113.0	Sr(g)	164.4	110.0	164.6
KOH(s)	-424.7	-378.9	78.91	Sulfur			
KOH(aq)	-482.4	-440.5	91.6	S(s, rhombic)	0	0	31.88
Rubidium				S ₈ (g)	102.3	49.7	430.9
Rb(g)	85.8	55.8	170.0	SO ₂ (g)	-296.9	-300.4	248.5
Rb(s)	0	0	76.78	SO ₃ (g)	-395.2	-370.4	256.2
RbCl(s)	-430.5	-412.0	92	SO ₄ ²⁻ (aq)	-909.3	-744.5	20.1
RbClO ₃ (s)	-392.4	-292.0	152				

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)	Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)
SOCl ₂ (l)	-245.6	—	—	Vanadium			
H ₂ S(g)	-20.17	-33.01	205.6	V(g)	514.2	453.1	182.2
H ₂ SO ₄ (aq)	-909.3	-744.5	20.1	V(s)	0	0	28.9
H ₂ SO ₄ (l)	-814.0	-689.9	156.1	Zinc			
Titanium				Zn(g)	130.7	95.2	160.9
Ti(g)	468	422	180.3	Zn(s)	0	0	41.63
Ti(s)	0	0	30.76	ZnCl ₂ (s)	-415.1	-369.4	111.5
TiCl ₄ (g)	-763.2	-726.8	354.9	ZnO(s)	-348.0	-318.2	43.9
TiCl ₄ (l)	-804.2	-728.1	221.9				
TiO ₂ (s)	-944.7	-889.4	50.29				

6. Standard Reduction Half-Cell Potentials at 25 °C.

ALPHABETICAL (Note: All species are in their "aq" state except otherwise noted.) Revision 11/17

No.	Reduction Half-Cell	E° , V	No.	Reduction Half-Cell	E° , V		
1	$\text{Ag}(\text{CN})_2^- + e^-$	$\rightleftharpoons \text{Ag}(\text{s}) + 2\text{CN}^-$	-0.31	63	$\text{Hg}_2^{2+} + 2e^-$	$\rightleftharpoons 2\text{Hg}(\text{l})$	0.776
2	$\text{Ag}^+ + e^-$	$\rightleftharpoons \text{Ag}(\text{s})$	0.792	64	$\text{HO}_2^- + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons 3\text{OH}^-$	0.88
3	$\text{Ag}_2\text{O}(\text{s}) + 2\text{H}^+ + 2e^-$	$\rightleftharpoons 2\text{Ag}(\text{s}) + \text{H}_2\text{O}$	1.173	65	$\text{I}_2(\text{s}) + 2e^-$	$\rightleftharpoons 2\text{I}^-$	0.535
4	$\text{Ag}_2\text{O}(\text{s}) + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons 2\text{Ag}(\text{s}) + 2\text{OH}^-$	0.342	66	$\text{K}^+ + e^-$	$\rightleftharpoons \text{K}(\text{s})$	-2.925
5	$\text{Ag}_2\text{S}(\text{s}) + 2\text{H}^+ + 2e^-$	$\rightleftharpoons 2\text{Ag}(\text{s}) + \text{H}_2\text{S}(\text{g})$	-0.036	67	$\text{Li}^+ + e^-$	$\rightleftharpoons \text{Li}(\text{s})$	-3.045
6	$\text{Ag}_2\text{S}(\text{s}) + 2e^-$	$\rightleftharpoons 2\text{Ag}(\text{s}) + \text{S}^{2-}$	-0.712	68	$\text{Mg}(\text{OH})_2(\text{s}) + 2e^-$	$\rightleftharpoons \text{Mg}(\text{s}) + 2\text{OH}^-$	-2.69
7	$\text{AgCl}(\text{s}) + e^-$	$\rightleftharpoons \text{Ag}(\text{s}) + \text{Cl}^-$	0.228	69	$\text{Mg}^{2+} + 2e^-$	$\rightleftharpoons \text{Mg}(\text{s})$	-2.363
8	$\text{Al}(\text{OH})_3(\text{s}) + 3e^-$	$\rightleftharpoons \text{Al}(\text{s}) + 3\text{OH}^-$	-2.31	70	$\text{Mn}(\text{OH})_2(\text{s}) + 2e^-$	$\rightleftharpoons \text{Mn}(\text{s}) + 2\text{OH}^-$	-1.55
9	$\text{Al}^{3+} + 3e^-$	$\rightleftharpoons \text{Al}(\text{s})$	-1.662	71	$\text{Mn}^{2+} + 2e^-$	$\rightleftharpoons \text{Mn}(\text{s})$	-1.18
10	$2\text{AsO}_4^{3-} + 10\text{H}^+ + 4e^-$	$\rightleftharpoons \text{As}_2\text{O}_3(\text{s}) + 5\text{H}_2\text{O}$	1.27	72	$\text{MnO}_2(\text{s}) + 4\text{H}^+ + 2e^-$	$\rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$	1.23
11	$\text{Au}^+ + e^-$	$\rightleftharpoons \text{Au}$	1.69	73	$\text{MnO}_4^- + 4\text{H}^+ + 3e^-$	$\rightleftharpoons \text{MnO}_2(\text{s}) + 2\text{H}_2\text{O}$	1.695
12	$\text{Au}^{3+} + 3e^-$	$\rightleftharpoons \text{Au}(\text{s})$	1.5	74	$\text{MnO}_4^- + 2\text{H}_2\text{O} + 3e^-$	$\rightleftharpoons \text{MnO}_2(\text{s}) + 4\text{OH}^-$	0.588
13	$\text{AuCl}_2^- + e^-$	$\rightleftharpoons \text{Au}(\text{s}) + 2\text{Cl}^-$	1.154	75	$\text{MnO}_4^- + 8\text{H}^+ + 5e^-$	$\rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	1.51
14	$\text{AuCl}_4^- + 3e^-$	$\rightleftharpoons \text{Au}(\text{s}) + 4\text{Cl}^-$	1.002	76	$\text{N}_2(\text{g}) + 8\text{H}^+ + 6e^-$	$\rightleftharpoons 2\text{NH}_4^+$	0.275
15	$\text{Br}_2(\text{l}) + 2e^-$	$\rightleftharpoons 2\text{Br}^-$	1.065	77	$\text{N}_2(\text{g}) + 6\text{H}^+ + 6e^-$	$\rightleftharpoons 2\text{NH}_3(\text{g})$	0.057
16	$2\text{BrO}^- + 4\text{H}^+ + 2e^-$	$\rightleftharpoons \text{Br}_2(\text{l}) + 2\text{H}_2\text{O}$	2.09	78	$\text{N}_2(\text{g}) + 4\text{H}_2\text{O} + 4e^-$	$\rightleftharpoons \text{N}_2\text{O}_4 + 4\text{OH}^-$	-1.16
17	$\text{BrO}^- + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{Br}^- + 2\text{OH}^-$	0.76	79	$\text{Na}^+ + e^-$	$\rightleftharpoons \text{Na}(\text{s})$	-2.714
18	$2\text{BrO}^- + 2\text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{Br}_2(\text{l}) + 4\text{OH}^-$	0.45	80	$\text{Ni}^{2+} + 2e^-$	$\rightleftharpoons \text{Ni}(\text{s})$	-0.25
19	$\text{Ca}(\text{OH})_2(\text{s}) + 2e^-$	$\rightleftharpoons \text{Ca}(\text{s}) + 2\text{OH}^-$	-3.03	81	$\text{NiOOH} + \text{H}_2\text{O} + e^-$	$\rightleftharpoons \text{Ni}(\text{OH})_2 + \text{OH}^-$	0.49
20	$\text{Ca}^{2+} + 2e^-$	$\rightleftharpoons \text{Ca}(\text{s})$	-2.866	82	$2\text{NO}(\text{g}) + 4\text{H}^+ + 4e^-$	$\rightleftharpoons \text{N}_2(\text{g}) + 2\text{H}_2\text{O}$	1.678
21	$\text{Cd}^{2+} + 2e^-$	$\rightleftharpoons \text{Cd}(\text{s})$	-0.403	83	$2\text{NO}_2^- + 8\text{H}^+ + 6e^-$	$\rightleftharpoons \text{N}_2(\text{g}) + 4\text{H}_2\text{O}$	1.52
22	$\text{Cl}_2(\text{aq}) + 2e^-$	$\rightleftharpoons 2\text{Cl}^-$	1.39	84	$\text{NO}_2^- + 7\text{H}^+ + 6e^-$	$\rightleftharpoons \text{NH}_3(\text{g}) + 2\text{H}_2\text{O}$	0.789
23	$\text{ClO}^- + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{Cl}^- + 2\text{OH}^-$	0.89	85	$\text{NO}_2(\text{g}) + \text{H}^+ + e^-$	$\rightleftharpoons \text{HNO}_2$	1.093
24	$2\text{ClO}^- + 2\text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{Cl}_2(\text{g}) + 4\text{OH}^-$	0.4	86	$\text{NO}_2(\text{g}) + e^-$	$\rightleftharpoons \text{NO}_2^-$	0.893
25	$\text{ClO}_2^- + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{ClO}^- + 2\text{OH}^-$	0.66	87	$\text{NO}_3^- + 4\text{H}^+ + 3e^-$	$\rightleftharpoons \text{NO}(\text{g}) + 2\text{H}_2\text{O}$	0.96
26	$2\text{ClO}_3^- + 12\text{H}^+ + 10e^-$	$\rightleftharpoons \text{Cl}_2(\text{g}) + 3\text{H}_2\text{O}$	1.47	88	$\text{NO}_3^- + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{NO}_2^- + 2\text{OH}^-$	0.1
27	$\text{ClO}_3^- + 3\text{H}^+ + 2e^-$	$\rightleftharpoons \text{HClO}_2 + \text{H}_2\text{O}$	1.21	89	$\text{O}_2(\text{g}) + 4\text{H}^+ + 4e^-$	$\rightleftharpoons 2\text{H}_2\text{O}$	1.23
28	$2\text{ClO}_4^- + 16\text{H}^+ + 14e^-$	$\rightleftharpoons \text{Cl}_2(\text{g}) + 8\text{H}_2\text{O}$	1.39	90	$\text{O}_2(\text{g}) + 2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{H}_2\text{O}_2$	0.682
29	$\text{ClO}_4^- + 2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{ClO}_3^- + \text{H}_2\text{O}$	1.19	91	$\text{O}_2(\text{g}) + 2\text{H}_2\text{O} + 4e^-$	$\rightleftharpoons 4\text{OH}^-$	0.401
30	$\text{CO}_2(\text{g}) + 2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{CO}(\text{g}) + \text{H}_2\text{O}$	-0.12	92	$\text{O}_2(\text{g}) + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{HO}_2^- + \text{OH}^-$	0.076
31	$\text{CO}_2(\text{g}) + 2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{HCOOH}$	-0.2	93	$\text{O}_2(\text{g}) + 2\text{H}_2\text{O} + 4e^-$	$\rightleftharpoons \text{H}_2\text{O}_2 + \text{OH}^-$	-0.146
32	$2\text{CO}_2(\text{g}) + 2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{H}_2\text{C}_2\text{O}_4$	-0.49	94	$\text{O}_2(\text{g}) + e^-$	$\rightleftharpoons \text{O}_2^-$	-0.56
33	$\text{Co}^{2+} + 2e^-$	$\rightleftharpoons \text{Co}(\text{s})$	-0.277	95	$\text{O}_3(\text{g}) + 2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{O}_2(\text{g}) + \text{H}_2\text{O}$	2.07
34	$\text{Cr}^{2+} + 2e^-$	$\rightleftharpoons \text{Cr}(\text{s})$	-0.91	96	$\text{O}_3(\text{g}) + 6\text{H}^+ + 6e^-$	$\rightleftharpoons 3\text{H}_2\text{O}$	1.501
35	$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6e^-$	$\rightleftharpoons 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	1.33	97	$\text{O}_3(\text{g}) + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{O}_2(\text{g}) + 2\text{OH}^-$	1.24
36	$\text{Cr}_2\text{O}_7^{2-} + 10\text{H}^+ + 6e^-$	$\rightleftharpoons 2\text{Cr}(\text{OH})_2^+ + 3\text{H}_2\text{O}$	1.14	98	$\text{OH} + e^-$	$\rightleftharpoons \text{OH}^-$	1.4
37	$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 12e^-$	$\rightleftharpoons 2\text{Cr}(\text{s}) + 7\text{H}_2\text{O}$	0.29	99	$\text{Pb}^{2+} + 2e^-$	$\rightleftharpoons \text{Pb}(\text{s})$	-0.126
38	$\text{Cr}^{3+} + 3e^-$	$\rightleftharpoons \text{Cr}(\text{s})$	-0.744	100	$\text{Pb}_3\text{O}_4(\text{s}) + 8\text{H}^+ + 2e^-$	$\rightleftharpoons 3\text{Pb}^{2+} + 3\text{H}_2\text{O}$	2.094
39	$\text{Cr}^{3+} + e^-$	$\rightleftharpoons \text{Cr}^{2+}$	-0.408	101	$\text{Pb}_3\text{O}_4(\text{s}) + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons 3\text{PbO}(\text{s}) + 2\text{OH}^-$	0.249
40	$\text{CrO}_4^{2-} + 2\text{H}^+ + 3e^-$	$\rightleftharpoons \text{CrO}_3^{3-} + \text{H}_2\text{O}$	0.36	102	$\text{PbO}(\text{s}) + 2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{Pb}(\text{s}) + \text{H}_2\text{O}$	0.249
41	$\text{CrO}_4^{2-} + 4\text{H}^+ + 3e^-$	$\rightleftharpoons \text{CrO}_2^- + 2\text{H}_2\text{O}$	0.95	103	$\text{PbO}(\text{s}) + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{Pb}(\text{s}) + 2\text{OH}^-$	-0.58
42	$\text{CrO}_4^{2-} + 4\text{H}_2\text{O} + 3e^-$	$\rightleftharpoons \text{Cr}(\text{OH})_3(\text{s}) + 5\text{OH}^-$	-0.13	104	$\text{PbO}_2(\text{s}) + 4\text{H}^+ + \text{SO}_4^{2-} + 2e^-$	$\rightleftharpoons \text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O}$	1.685
43	$\text{Cu}(\text{NH}_3)_4^{2+} + 2e^-$	$\rightleftharpoons \text{Cu}(\text{s}) + 4\text{NH}_3$	-0.07	105	$\text{PbSO}_4 + 2e^-$	$\rightleftharpoons \text{Pb}(\text{s}) + \text{SO}_4^{2-}$	-0.35
44	$\text{Cu}(\text{NH}_3)_2^+ + e^-$	$\rightleftharpoons \text{Cu}(\text{s}) + 2\text{NH}_3$	-0.12	106	$\text{Pd}^{2+} + 2e^-$	$\rightleftharpoons \text{Pd}(\text{s})$	0.987
45	$\text{Cu}(\text{NH}_3)_4^{2+} + e^-$	$\rightleftharpoons \text{Cu}(\text{NH}_3)_2^+ + 2\text{NH}_3$	-0.01	107	$\text{Pt}^{2+} + 2e^-$	$\rightleftharpoons \text{Pt}(\text{s})$	1.2
46	$\text{Cu}^+ + e^-$	$\rightleftharpoons \text{Cu}(\text{s})$	0.521	108	$\text{S}(\text{s}) + \text{H}^+ + 2e^-$	$\rightleftharpoons \text{HS}^-$	-0.065
47	$\text{Cu}^{2+} + 2e^-$	$\rightleftharpoons \text{Cu}(\text{s})$	0.34	109	$\text{S}(\text{s}) + 2e^-$	$\rightleftharpoons \text{S}^{2-}$	-0.476
48	$2\text{Cu}^{2+} + \text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{Cu}_2\text{O}(\text{s}) + 2\text{H}^+$	0.2	110	$\text{S}_2\text{O}_8^{2-} + 2e^-$	$\rightleftharpoons 2\text{SO}_4^{2-}$	2.05
49	$\text{F}_2(\text{g}) + 2\text{H}^+ + 2e^-$	$\rightleftharpoons 2\text{HF}(\text{aq})$	3.06	111	$\text{Sn}^{2+} + 2e^-$	$\rightleftharpoons \text{Sn}(\text{s})$	-0.136
50	$\text{F}_2(\text{g}) + 2e^-$	$\rightleftharpoons 2\text{F}^-$	2.87	112	$\text{SO}_2(\text{g}) + 4\text{H}^+ + 4e^-$	$\rightleftharpoons \text{S}(\text{s}) + 2\text{H}_2\text{O}$	0.451
51	$\text{Fe}(\text{OH})_2(\text{s}) + 2e^-$	$\rightleftharpoons \text{Fe}(\text{s}) + 2\text{OH}^-$	-0.88	113	$\text{SO}_3^{2-} + 6\text{H}^+ + 6e^-$	$\rightleftharpoons \text{S}^{2-} + 3\text{H}_2\text{O}$	0.231
52	$\text{Fe}^{2+} + 2e^-$	$\rightleftharpoons \text{Fe}(\text{s})$	-0.44	114	$2\text{SO}_3^{2-} + 6\text{H}^+ + 4e^-$	$\rightleftharpoons \text{S}_2\text{O}_3^{2-} + 3\text{H}_2\text{O}$	0.705
53	$\text{Fe}^{3+} + e^-$	$\rightleftharpoons \text{Fe}^{2+}$	0.771	115	$\text{SO}_4^{2-} + 10\text{H}^+ + 8e^-$	$\rightleftharpoons \text{H}_2\text{S}(\text{g}) + 4\text{H}_2\text{O}$	0.303
54	$\text{Fe}^{3+} + 3e^-$	$\rightleftharpoons \text{Fe}(\text{s})$	-0.04	116	$\text{SO}_4^{2-} + 4\text{H}^+ + 2e^-$	$\rightleftharpoons \text{H}_2\text{SO}_3 + \text{H}_2\text{O}$	0.172
55	$2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{H}_2$	0.000	117	$\text{Ti}^{2+} + 2e^-$	$\rightleftharpoons \text{Ti}(\text{s})$	-1.63
56	$\text{H}_2(\text{g}) + 2e^-$	$\rightleftharpoons 2\text{H}^-$	-2.25	118	$\text{TiO}_2(\text{s}) + 4\text{H}^+ + 2e^-$	$\rightleftharpoons \text{Ti}^{2+} + \text{H}_2\text{O}$	-0.502
57	$2\text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-$	-0.83	119	$\text{Zn}(\text{NH}_3)_4^{2+} + 2e^-$	$\rightleftharpoons \text{Zn}(\text{s}) + 4\text{NH}_3$	-1.04
58	$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2e^-$	$\rightleftharpoons 2\text{H}_2\text{O}$	1.776	120	$\text{Zn}(\text{OH})_2(\text{s}) + 2e^-$	$\rightleftharpoons \text{Zn}(\text{s}) + 2\text{OH}^-$	-1.245
59	$2\text{HBrO} + 2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{Br}_2(\text{l}) + 2\text{H}_2\text{O}$	1.59	121	$\text{Zn}^{2+} + 2e^-$	$\rightleftharpoons \text{Zn}(\text{s})$	-0.763
60	$2\text{HClO} + 2\text{H}^+ + 2e^-$	$\rightleftharpoons \text{Cl}_2(\text{g}) + \text{H}_2\text{O}$	1.63	122	$\text{ZnO}_2^{2-} + 4\text{H}^+ + 2e^-$	$\rightleftharpoons \text{Zn}(\text{s}) + 2\text{H}_2\text{O}$	0.441
61	$2\text{Hg}^{2+} + 2e^-$	$\rightleftharpoons \text{Hg}_2^{2+}$	0.907	123	$\text{ZnO}_2^{2-} + 2\text{H}_2\text{O} + 2e^-$	$\rightleftharpoons \text{Zn}(\text{s}) + 4\text{OH}^-$	-1.216
62	$\text{Hg}^{2+} + 2e^-$	$\rightleftharpoons \text{Hg}(\text{l})$	0.854	124	$\text{ZnS}(\text{s}) + 2e^-$	$\rightleftharpoons \text{Zn}(\text{s}) + \text{S}^{2-}$	-1.4

7. Standard Reduction Half-Cell Potentials at 25 °C.

Voltage Sorted (Note: All species are in their "aq" state except otherwise noted.) Revision 11/17

No.	Reduction Half-Cell	E° , V	No.	Reduction Half-Cell	E° , V
1	$F_2(g) + 2H^+ + 2e^- \rightleftharpoons 2HF(aq)$	3.06	63	$Cu^{2+} + 2e^- \rightleftharpoons Cu(s)$	0.34
2	$F_2(g) + 2e^- \rightleftharpoons 2F^-$	2.87	64	$SO_4^{2-} + 10H^+ + 8e^- \rightleftharpoons H_2S(g) + 4H_2O$	0.303
3	$Pb_3O_4(s) + 8H^+ + 2e^- \rightleftharpoons 3Pb^{2+} + 3H_2O$	2.094	65	$Cr_2O_7^{2-} + 14H^+ + 12e^- \rightleftharpoons 2Cr(s) + 7H_2O$	0.29
4	$2BrO^- + 4H^+ + 2e^- \rightleftharpoons Br_2(l) + 2H_2O$	2.09	66	$N_2(g) + 8H^+ + 6e^- \rightleftharpoons 2NH_4^+$	0.275
5	$O_3(g) + 2H^+ + 2e^- \rightleftharpoons O_2(g) + H_2O$	2.07	67	$Pb_3O_4(s) + H_2O + 2e^- \rightleftharpoons 3PbO(s) + 2OH^-$	0.249
6	$S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-}$	2.05	68	$PbO(s) + 2H^+ + 2e^- \rightleftharpoons Pb(s) + H_2O$	0.249
7	$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	1.776	69	$SO_3^{2-} + 6H^+ + 6e^- \rightleftharpoons S^{2-} + 3H_2O$	0.231
8	$MnO_4^- + 4H^+ + 3e^- \rightleftharpoons MnO_2(s) + 2H_2O$	1.695	70	$AgCl(s) + e^- \rightleftharpoons Ag(s) + Cl^-$	0.228
9	$Au^+ + e^- \rightleftharpoons Au$	1.69	71	$2Cu^{2+} + H_2O + 2e^- \rightleftharpoons Cu_2O(s) + 2H^+$	0.2
10	$PbO_2(s) + 4H^+ + SO_4^{2-} + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O$	1.685	72	$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons H_2SO_3 + H_2O$	0.172
11	$2NO(g) + 4H^+ + 4e^- \rightleftharpoons N_2(g) + 2H_2O$	1.678	73	$NO_3^- + H_2O + 2e^- \rightleftharpoons NO_2^- + 2OH^-$	0.1
12	$2HClO + 2H^+ + 2e^- \rightleftharpoons Cl_2(g) + H_2O$	1.63	74	$O_2(g) + H_2O + 2e^- \rightleftharpoons HO_2^- + OH^-$	0.076
13	$2HBrO + 2H^+ + 2e^- \rightleftharpoons Br_2(l) + 2H_2O$	1.59	75	$N_2(g) + 6H^+ + 6e^- \rightleftharpoons 2NH_3(g)$	0.057
14	$2NO_2^- + 8H^+ + 6e^- \rightleftharpoons N_2(g) + 4H_2O$	1.52	76	$2H^+ + 2e^- \rightleftharpoons H_2$	0.000
15	$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	1.51	77	$Cu(NH_3)_4^{2+} + e^- \rightleftharpoons Cu(NH_3)_2^+ + 2NH_3$	-0.01
16	$O_3(g) + 6H^+ + 6e^- \rightleftharpoons 3H_2O$	1.501	78	$Ag_2S(s) + 2H^+ + 2e^- \rightleftharpoons 2Ag(s) + H_2S(g)$	-0.036
17	$Au^{3+} + 3e^- \rightleftharpoons Au(s)$	1.5	79	$Fe^{3+} + 3e^- \rightleftharpoons Fe(s)$	-0.04
18	$2ClO_3^- + 12H^+ + 10e^- \rightleftharpoons Cl_2(g) + 3H_2O$	1.47	80	$S(s) + H^+ + 2e^- \rightleftharpoons HS^-$	-0.065
19	$OH^- + e^- \rightleftharpoons OH^-$	1.4	81	$Cu(NH_3)_4^{2+} + 2e^- \rightleftharpoons Cu(s) + 4NH_3$	-0.07
20	$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-$	1.39	82	$CO_2(g) + 2H^+ + 2e^- \rightleftharpoons CO(g) + H_2O$	-0.12
21	$2ClO_4^- + 16H^+ + 14e^- \rightleftharpoons Cl_2(g) + 8H_2O$	1.39	83	$Cu(NH_3)_2^+ + e^- \rightleftharpoons Cu(s) + 2NH_3$	-0.12
22	$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$	1.33	84	$Pb^{2+} + 2e^- \rightleftharpoons Pb(s)$	-0.126
23	$2AsO_4^{3-} + 10H^+ + 4e^- \rightleftharpoons As_2O_3(s) + 5H_2O$	1.27	85	$CrO_4^{2-} + 4H_2O + 3e^- \rightleftharpoons Cr(OH)_3(s) + 5OH^-$	-0.13
24	$O_3(g) + H_2O + 2e^- \rightleftharpoons O_2(g) + 2OH^-$	1.24	86	$Sn^{2+} + 2e^- \rightleftharpoons Sn(s)$	-0.136
25	$MnO_2(s) + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O$	1.23	87	$O_2(g) + 2H_2O + 4e^- \rightleftharpoons H_2O_2 + OH^-$	-0.146
26	$O_2(g) + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	1.23	88	$CO_2(g) + 2H^+ + 2e^- \rightleftharpoons HCOOH$	-0.2
27	$ClO_3^- + 3H^+ + 2e^- \rightleftharpoons HClO_2 + H_2O$	1.21	89	$Ni^{2+} + 2e^- \rightleftharpoons Ni(s)$	-0.25
28	$Pt^{2+} + 2e^- \rightleftharpoons Pt(s)$	1.2	90	$Co^{2+} + 2e^- \rightleftharpoons Co(s)$	-0.277
29	$ClO_4^- + 2H^+ + 2e^- \rightleftharpoons ClO_3^- + H_2O$	1.19	91	$Ag(CN)_2^- + e^- \rightleftharpoons Ag(s) + 2CN^-$	-0.31
30	$Ag_2O(s) + 2H^+ + 2e^- \rightleftharpoons 2Ag(s) + H_2O$	1.173	92	$PbSO_4 + 2e^- \rightleftharpoons Pb(s) + SO_4^{2-}$	-0.35
31	$AuCl_2^- + e^- \rightleftharpoons Au(s) + 2Cl^-$	1.154	93	$Cd^{2+} + 2e^- \rightleftharpoons Cd(s)$	-0.403
32	$Cr_2O_7^{2-} + 10H^+ + 6e^- \rightleftharpoons 2Cr(OH)_2^+ + 3H_2O$	1.14	94	$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	-0.408
33	$NO_2(g) + H^+ + e^- \rightleftharpoons HNO_2$	1.093	95	$Fe^{2+} + 2e^- \rightleftharpoons Fe(s)$	-0.44
34	$Br_2(l) + 2e^- \rightleftharpoons 2Br^-$	1.065	96	$S(s) + 2e^- \rightleftharpoons S^{2-}$	-0.476
35	$AuCl_4^- + 3e^- \rightleftharpoons Au(s) + 4Cl^-$	1.002	97	$2CO_2(g) + 2H^+ + 2e^- \rightleftharpoons H_2C_2O_4$	-0.49
36	$Pd^{2+} + 2e^- \rightleftharpoons Pd(s)$	0.987	98	$TiO_2(s) + 4H^+ + 2e^- \rightleftharpoons Ti^{2+} + H_2O$	-0.502
37	$NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO(g) + 2H_2O$	0.96	99	$O_2(g) + e^- \rightleftharpoons O_2^-$	-0.56
38	$CrO_4^{2-} + 4H^+ + 3e^- \rightleftharpoons CrO_2 + 2H_2O$	0.95	100	$PbO(s) + H_2O + 2e^- \rightleftharpoons Pb(s) + 2OH^-$	-0.58
39	$2Hg^{2+} + 2e^- \rightleftharpoons Hg_2^{2+}$	0.907	101	$Ag_2S(s) + 2e^- \rightleftharpoons 2Ag(s) + S^{2-}$	-0.712
40	$NO_2(g) + e^- \rightleftharpoons NO_2^-$	0.893	102	$Cr^{3+} + 3e^- \rightleftharpoons Cr(s)$	-0.744
41	$ClO^- + H_2O + 2e^- \rightleftharpoons Cl^- + 2OH^-$	0.89	103	$Zn^{2+} + 2e^- \rightleftharpoons Zn(s)$	-0.763
42	$HO_2^- + H_2O + 2e^- \rightleftharpoons 3OH^-$	0.88	104	$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$	-0.83
43	$Hg^{2+} + 2e^- \rightleftharpoons Hg(l)$	0.854	105	$Fe(OH)_2(s) + 2e^- \rightleftharpoons Fe(s) + 2OH^-$	-0.88
44	$Ag^+ + e^- \rightleftharpoons Ag(s)$	0.792	106	$Cr^{2+} + 2e^- \rightleftharpoons Cr(s)$	-0.91
45	$NO_2^- + 7H^+ + 6e^- \rightleftharpoons NH_3(g) + 2H_2O$	0.789	107	$Zn(NH_3)_4^{2+} + 2e^- \rightleftharpoons Zn(s) + 4NH_3$	-1.04
46	$Hg_2^{2+} + 2e^- \rightleftharpoons 2Hg(l)$	0.776	108	$N_2(g) + 4H_2O + 4e^- \rightleftharpoons N_2O_4 + 4OH^-$	-1.16
47	$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	0.771	109	$Mn^{2+} + 2e^- \rightleftharpoons Mn(s)$	-1.18
48	$BrO^- + H_2O + 2e^- \rightleftharpoons Br^- + 2OH^-$	0.76	110	$ZnO_2^{2-} + 2H_2O + 2e^- \rightleftharpoons Zn(s) + 4OH^-$	-1.216
49	$2SO_3^{2-} + 6H^+ + 4e^- \rightleftharpoons S_2O_3^{2-} + 3H_2O$	0.705	111	$Zn(OH)_2(s) + 2e^- \rightleftharpoons Zn(s) + 2OH^-$	-1.245
50	$O_2(g) + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	0.682	112	$ZnS(s) + 2e^- \rightleftharpoons Zn(s) + S^{2-}$	-1.4
51	$ClO_2^- + H_2O + 2e^- \rightleftharpoons ClO^- + 2OH^-$	0.66	113	$Mn(OH)_2(s) + 2e^- \rightleftharpoons Mn(s) + 2OH^-$	-1.55
52	$I_2(s) + 2e^- \rightleftharpoons 2I^-$	0.535	114	$Ti^{2+} + 2e^- \rightleftharpoons Ti(s)$	-1.63
53	$MnO_4^- + 2H_2O + 3e^- \rightleftharpoons MnO_2(s) + 4OH^-$	0.588	115	$Al^{3+} + 3e^- \rightleftharpoons Al(s)$	-1.662
54	$Cu^+ + e^- \rightleftharpoons Cu(s)$	0.521	116	$H_2(g) + 2e^- \rightleftharpoons 2H^-$	-2.25
55	$NiOOH + H_2O + e^- \rightleftharpoons Ni(OH)_2 + OH^-$	0.49	117	$Al(OH)_3(s) + 3e^- \rightleftharpoons Al(s) + 3OH^-$	-2.31
56	$SO_2(g) + 4H^+ + 4e^- \rightleftharpoons S(s) + 2H_2O$	0.451	118	$Mg^{2+} + 2e^- \rightleftharpoons Mg(s)$	-2.363
57	$2BrO^- + 2H_2O + 2e^- \rightleftharpoons Br_2(l) + 4OH^-$	0.45	119	$Mg(OH)_2(s) + 2e^- \rightleftharpoons Mg(s) + 2OH^-$	-2.69
58	$ZnO_2^{2-} + 4H^+ + 2e^- \rightleftharpoons Zn(s) + 2H_2O$	0.441	120	$Na^+ + e^- \rightleftharpoons Na(s)$	-2.714
59	$O_2(g) + 2H_2O + 4e^- \rightleftharpoons 4OH^-$	0.401	121	$Ca^{2+} + 2e^- \rightleftharpoons Ca(s)$	-2.866
60	$2ClO^- + 2H_2O + 2e^- \rightleftharpoons Cl_2(g) + 4OH^-$	0.4	122	$K^+ + e^- \rightleftharpoons K(s)$	-2.925
61	$CrO_4^{2-} + 2H^+ + 3e^- \rightleftharpoons CrO_3^{3-} + H_2O$	0.36	123	$Ca(OH)_2(s) + 2e^- \rightleftharpoons Ca(s) + 2OH^-$	-3.03
62	$Ag_2O(s) + H_2O + 2e^- \rightleftharpoons 2Ag(s) + 2OH^-$	0.342	124	$Li^+ + e^- \rightleftharpoons Li(s)$	-3.045

Some general chemistry constants and equations, you may need:

$$P.V=n.R.T \text{ (ideal gas law)}$$

$$K = ^\circ\text{C} + 273.15$$

$$F = (1.8)(^\circ\text{C}) + 32$$

$$\text{Faraday's constant: } 96485 \text{ C/mol e}^-$$

$$K_w = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

$$E = h.c/\lambda \text{ and } E=h.v$$

$$\text{Quadratic equation: } ax^2 + bx + c = 0$$

$$\text{Quadratic Roots: } x = [-b \pm (b^2-4ac)^{1/2}]/(2a)$$

$$\text{Avogadro's no: } 6.022 \times 10^{23} \text{ count.mol}^{-1}$$

$$R=0.082057 \text{ L.atm.mol}^{-1}.K^{-1}$$

$$R = 8.3144 \text{ J.mol}^{-1}.K^{-1}$$

$$c: \text{ speed of light} = 2.998 \times 10^8 \text{ m/s}$$

$$h: \text{ Planck's constant} = 6.626 \times 10^{-34} \text{ J.s/photon}$$

$$1 \text{ amu} = 1.66054 \times 10^{-27} \text{ kg}$$

$$1 \text{ e}^- \text{ charge} = 1.60218 \times 10^{-19} \text{ C}$$

$$1 \text{ amu} = 931.5 \text{ MeV}$$

$$1 \text{ eV} = 1.60217 \times 10^{-19} \text{ J}$$

$$1 \text{ neutron mass} = 1.67493 \times 10^{-27} \text{ kg}$$

$$1 \text{ proton mass} = 1.67262 \times 10^{-27} \text{ kg}$$

$$g = 9.807 \text{ m/s}^2 \text{ (acceleration due to gravity)}$$

Solutions

Note: You should know concentration unit definitions: m, M, %(vol), %(mass), ppm, ppb, ppt

Gas solubility in water (Henry's Law): $C_A=K_H.P_A$

Colligative properties (i = van't Hoff factor for an ionic solute!)

$$\text{Boiling/freezing: } \Delta T_b = K_b.m.i \quad \Delta T_f = K_f.m.i$$

$$\text{Osmotic pressure: } \pi.V = i.n.R.T \quad \Delta V_p = i.X_{\text{solute}}.P_{\text{H}_2\text{O}} \text{ (non-volatile solute)}$$

$$\text{Two volatile liquids: } P_A=X_A.P_A^0 \quad P_B=X_B.P_B^0 \quad P_A+P_B=P_{\text{tot}} \text{ (P}^0\text{: Pure liquid vapor pressure)}$$

$$X_A+X_B=1 \text{ (liquid)} \quad Y_A+Y_B=1 \text{ (gas)}$$

Ligand Spectrochemical series

(Strong-field) $\text{CN}^- > \text{NO}_2^- > \text{en} > \text{NH}_3 > \dots \text{H}_2\text{O} > \text{OH}^- > \text{F}^- > \text{Cl}^- > \text{Br}^- > \text{I}^-$ (weak-field)

Kinetics

Order	Integrated form	Half-Life
0	$[A]_t = -k.t + [A]_0$	$t_{1/2} = [A]_0 / (2k)$
1	$\ln[A]_t = -k.t + \ln[A]_0$ or $\ln [A]_t/[A]_0 = -kt$	$t_{1/2} = 0.693/k$
2	$1/[A]_t = k.t + 1/[A]_0$	$t_{1/2} = 1/(k[A]_0)$

$$k = Ae^{-E_a/RT} \text{ or } \ln k = -E_a/(R.T) + \ln A$$

$$\ln (k_2/k_1) = (-E_a/R)(1/T_2 - 1/T_1) \text{ (note: lower case "k" is used for rate constant)}$$

Equilibrium

$$K_p = K_c.(RT)^{\Delta n_g} \quad R = 0.08206 \text{ L.atm.mol}^{-1}.K^{-1}$$

Acid-Base

$$K_a \cdot K_b = K_w$$

$$\text{pH} = \text{p}K_a + \log [\text{base}]/[\text{acid}]$$

$$\text{p}K = -\log K$$

Thermodynamics

$$\Delta S = q_{\text{rev}}/T$$

$$\Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{sur}}$$

$$\Delta G^\circ = \Delta H^\circ - T.\Delta S^\circ$$

$$\Delta G = \Delta G^\circ + R.T.\ln Q \quad R = 8.3144 \text{ J.mol}^{-1}.K^{-1}$$

$$\Delta G^\circ = -R.T.\ln K_{\text{eq}}$$

$$\ln K_{\text{eq}} = -\Delta H^\circ/(RT) + \Delta S^\circ/R$$

$$\ln(K_2/K_1) = -\Delta H^\circ/R(1/T_2 - 1/T_1)$$

Electrochemistry

$$\Delta G = -n.F.E$$

$$\Delta G^\circ = -n.F.E^\circ$$

$$E^\circ = R.T/(n.F) \ln K_{\text{eq}} \text{ or}$$

$$\text{At } 25^\circ\text{C: } E^\circ = (0.02569 \text{ V} / n) \cdot \ln K_{\text{eq}}$$

$$\text{or } E^\circ = (0.05916 \text{ V} / n) \cdot \log K_{\text{eq}}$$

(V is the volts unit)

(ln = 2.3026 log)

$$E = E^\circ - R.T/(n.F) \ln Q \text{ or}$$

$$\text{At } 25^\circ\text{C: } E = E^\circ - (0.05916 \text{ V} / n) \cdot \log Q$$

Faraday's constant: 96485 C/mol e⁻

Thermodynamic Quantities for Selected Substances

Periodic Table of the Elements

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
 IA IIA IIIA IVA VA VIA VIIA VIIIA

1 H 1.008																	2 He 4.003
3 Li 6.939	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.91	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (99)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.90	56 Ba 137.34	57 La* 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac** (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (269)	110 Uun (269)	111 Uuu (272)	112 Uub (277)	113	114 Uuq (289)	115	116 Uuh (289)	117	118 Uuo (293)

*	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (147)	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
**	90 Th 232.04	91 Pa (231)	92 U 238.03	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (248)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (255)	103 Lr (257)