UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2007/2008

April 2008

EBB 316/3 - Corrosions & Degradation
[Kakisan & Degradasi]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains TWELVE printed pages and THREE pages APPENDIX before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA BELAS muka surat beserta TIGA muka surat LAMPIRAN yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper contains SEVEN questions. THREE questions in PART A, TWO questions in PART B and TWO questions in PART C.
[Kertas soalan ini mengandungi TUJUH soalan. TIGA soalan di BAHAGIAN A, DUA soalan di BAHAGIAN B dan DUA soalan di BAHAGIAN C.]

Instructions: Answer **FIVE** questions : **TWO** from PART A, **ONE** from PART B, **ONE** from PART C and **ONE** question from any sections. If a candidate answers more than five questions only the first five questions in the answer sheet will be graded.
[Arahan: *Jawab* ***LIMA*** *soalan :* ***DUA*** *dari BAHAGIAN A,* ***SATU*** *dari BAHAGIAN B,* ***SATU*** *dari BAHAGIAN C dan* ***SATU*** *dari mana-mana bahagian. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]*

Answer to any question must start on a new page.
[Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru.]

You may answer a question either in Bahasa Malaysia or in English.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

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PART A

BAHAGIAN A

1. The Pourbaix diagram for iron-water system at 25°C is given in Appendix 1.

Gambarajah Pourbaix untuk sistem besi-air pada 25°C diberikan dalam Lampiran 1.

(a) Label all the domains of immunity, corrosion and passivity.

Labelkan kesemua kawasan kemanglian, kakisan dan kepasifan.

(20 marks/*markah*)

(b) Explain why the Pourbaix diagram has limitation in the prediction of corrosion of metal.

Terangkan mengapa Gambarajah Pourbaix mempunyai had di dalam meramalkan kakisan sesuatu logam.

(30 marks/*markah*)

(c) The reaction that separates the domains of Fe^{2+} and Fe_2O_3 is given as $Fe_2O_3 + 6H^+ + 2e = 2Fe^{2+} + 3H_2O$. Derive the relationship E-pH the equation that represent the equilibrium between Fe_2O_3 and Fe^{2+}. The given E^o value is +0.728V (SHE).

Tindakbalas yang mengasingkan kawasan-kawasan Fe^{2+} dan Fe_2O_3 diberikan oleh persamaan $Fe_2O_3 + 6H^+ + 2e = 2Fe^{2+} + 3H_2O$. Terbitkan suatu perhubungan E-pH bagi persamaan yang mewakili keseimbangan di antara Fe_2O_3 dan Fe^{2+}. Nilai E^o yang diberikan ialah +0.728V (SHE).

(50 marks/*markah*)

2. Table 1 gives representative results from measurements of overpotential, η, versus current density, i, for the evolution of hydrogen on platinum is 0.1M HCl at 25°C.

Jadual 1 memberikan keputusan yang mewakili pengukuran keupayaan lampau, melawan ketumpatan arus, i, untuk pembebasan hidrogen di atas platinum dalam 0.1M HCl pada 25°C.

Table 1 : η vs i for H_2 evolution on Pt in 0.1M HCl at 25°C

Jadual 1 : η mlwn i untuk pembebasan H_2 di atas Pt dalam 0.1M HCl pada 25°C

η, (v)	-0.01	-0.02	-0.06	-0.11	-0.16	-0.21	-0.26	-0.31
i, A cm^{-2}	5.0×10^{-4}	1.0×10^{-3}	3.5×10^{-3}	1.0×10^{-2}	3.0×10^{-2}	9.0×10^{-2}	2.5×10^{-1}	6.0×10^{-1}

The results is plotted as given in Figure 1.

Keputusan diplot seperti diberikan dalam Rajah 1.

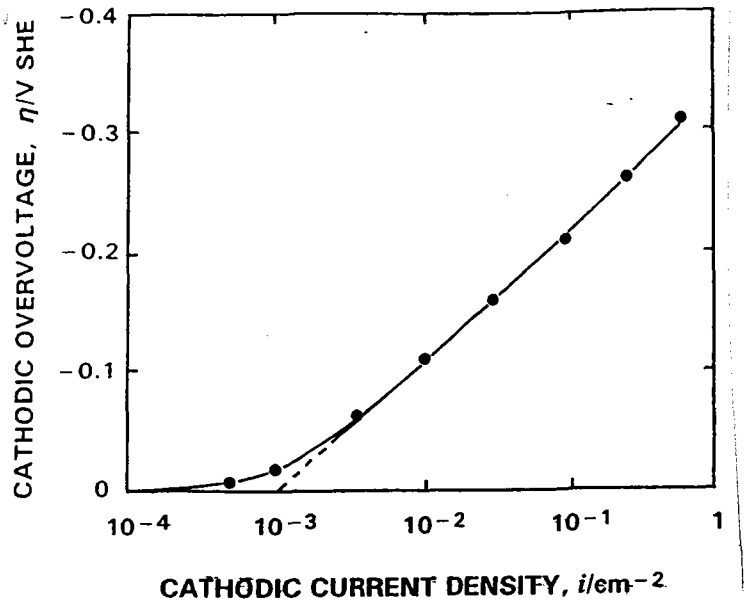

Figure 1 : Plot of η vs i for H_2 evolution on Pt in 0.1M HCl at 25°C

Rajah 1 : Plot η mlwn i untuk pembebasan H_2 di atas Pt dalam 0.1M HCl pada 25°C

(a) Determine the exchange current density, i_o.

Dapatkan nilai ketumpatan arus pertukaran, i_o.

(20 marks/*markah*)

(b) Derive the Tafel equation from the plot.

Terbitkan persamaan Tafel dari plot.

(50 marks/*markah*)

(c) From the Tafel slope, determine the symmetry factor, α.

Daripada kecerunan Tafel, dapatkan faktor simetri, α.

(30 marks/*markah*)

3. [a] A zinc electrode is immersed in a solution of $ZnSO_4$ at 25°C. The electrode shows a potential of -0.804V (SHE). What is the concentration of the solution? Given

$E^o_{Zn/Zn^{2+}}$ = 0.763V

R = 8.314 J mol^{-1}

F = 96490 coulombs mol^{-1}

Suatu elektrod zink direndam dalam larutan $ZnSO_4$ pada 25°C. Elektrod menunjukkan keupayaan -0.804V (SHE). Apakah kepekatan larutan tersebut? Diberikan

$E^o_{Zn/Zn^{2+}} = 0.763V$

$R = 8.314\ J\ mol^{-1}$

$F = 96490\ coulombs\ mol^{-1}$

(40 marks/*markah*)

[b] A cylindrical steel tank is coated with a thick layer of zinc on the inside wall. The tank is 60 cm in diameter, 80 cm high, and filled to the 60 cm level with aerated water. If the corrosion current is 6.2×10^{-5} A/cm^2, how much zinc in grams per minute is being corroded? Given the atomic mass of Zn is 65.37g.

Suatu tangki keluli berbentuk silinder disalut dengan lapisan zink tebal di bahagian dalam. Tangki mempunyai ukuran diameter 60 cm, tinggi 80 cm dan diisi ke takat 60 cm dengan air berudara. Jika arus kakisan adalah 6.2×10^{-5} *A/cm*^{2}*, berapa banyak zink dalam gram per minit telah terkakis. Diberikan jisim atom zink ialah 65.37g.*

(40 marks/*markah*)

[c] In metals, which region is more chemically reactive (anodic), the grain matrix or the grain-boundary regions? Why?

Di dalam logam, kawasan manakah yang lebih reaktif secara kimia (anod), kawasan butir matriks atau kawasan sempadan-butir? Mengapa?

(20 marks/*markah*)

PART B

BAHAGIAN B

4. [a] What is double layer in electrochemistry?

Apakah yang dimaksudkan "dua lapisan" dalam elektrokimia?

(10 marks/*markah*)

[b] Figure 2 shows the impedance spectrum of coated mild steel by paint when exposed to corrosive environment for one day. Calculate the double layer capacitance (C_{dl}) for this system.

Rajah 2 menunjukan spektrum impedan bagi keluli lembut yang disalut cat apabila didedahkan kepada persikitaran berkarat selama satu hari. Kirakan kapasitan dua lapisan (C_{dl}) bagi sistem ini.

(20 marks/*markah*)

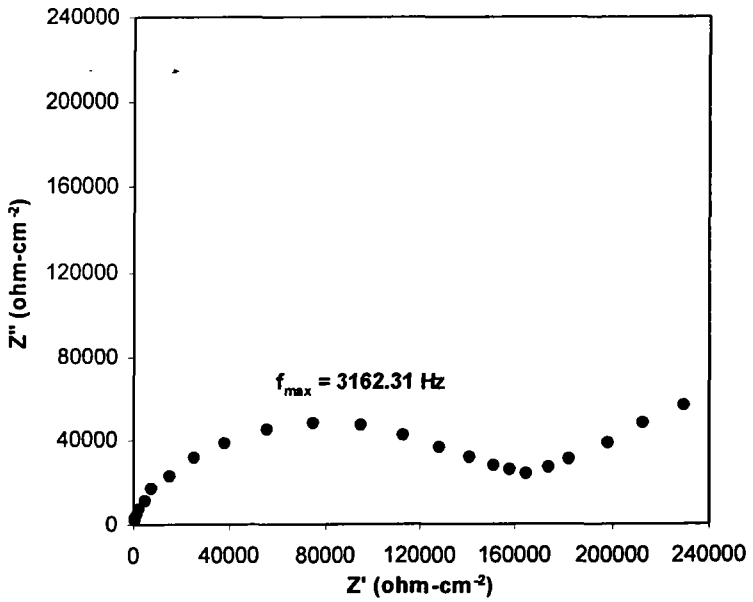

Figure 2

Rajah 2

[c] What is meant by dezincification?

Apakah makna penyahzinkan?

(10 marks/*markah*)

[d] Between zinc and copper which one will always leached in seawater? Why?

Di antara zink dan kuprum yang mana akan selalu kuras ke dalam air laut? Kenapa?

(10 marks/*markah*)

[e] What are two types of dezincification are commonly observed?

Apakah dua jenis penyahzinkan yang selalu diperhatikan?

(20 marks/*markah*)

[f] Explain the mechanism of dezincification in brass.

Terangkan mekanisma penyahzinkan dalam loyang.

(30 marks/*markah*)

5. [a] A sheet of galvanised steel 2.4 m x 1.2 m is uniformly coated on both sides with 2 kg of zinc to protect it from corrosion. When the sheet was exposed to neutral aerated moist conditions a corrosion current density of 1.28×10^{-3} amps/m^2 was measured. Calculate the useful life of the sheet.

Satu kepingan besi 2.4 m x 1.2 m dicatkan secara seragam pada kedua-dua belah bahagian dengan 2 kg zink untuk perlindungan dari pengkaratan. Apabila kepingan ini didedahkan kepada keadaan kelembapan berudara nultral dengan nilai ketumpatan arus pengkaratan 1.28×10^{-3} *amps/*m^2*. Kirakan hayat pengunaan kepingan tersebut.*

(20 marks/*markah*)

[b] With a neat diagram, describe the basic equipment necessary to carry out a laboratory investigation for immersion test (potential versus time).

Lukiskan dan terangkan peralatan asas yang anda perlukan untuk menjalankan ujian perendaman (keupayaan lawan masa) di dalam makmal.

(20 marks/*markah*)

[c] Figure 3 shows the open-circuit potentials of the coated steel in 3% NaCl. Sample i was coated by polymer A only, sample ii was coated by polymer B only and sample iii was coated by polymer A first then coated by Polymer B. Based on this result, explains the corrosion activities for:

Rajah 3 menunjukan keupayaan litar terbuka bagi kepingan besi tercat dalam 3% NaCl. Sampel i dicat dengan polimer A sahaja, sampel ii dicat dengan polimer B sahaja dan sampel iii dicat dengan polimer A dahulu, kemudian dicat sekali lagi dengan polimer B. Berdasarkan keputusan ini, terangkan aktiviti pengkaratan untuk:

(i) Sample i
Sampel i

(20 marks/*markah*)

(ii) Sample ii
Sampel ii

(20 marks/*markah*)

(iii) Sample iii
Sampel iii

(20 marks/*markah*)

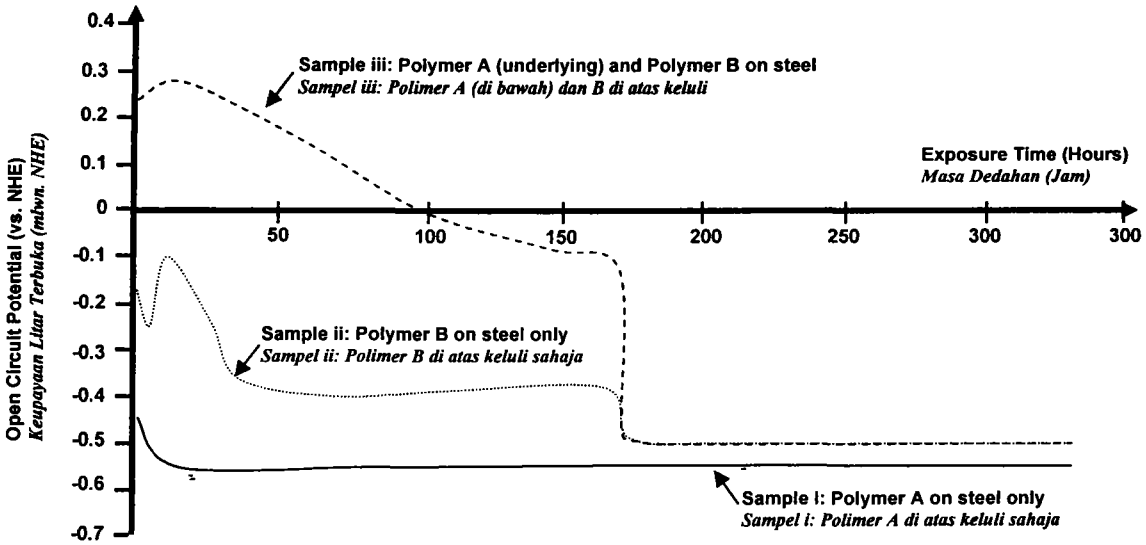

Figure 3

Rajah 3

PART C

BAHAGIAN C

6. [a] Explain the two cathodic protection systems for corrosion prevention. Identify similarities and differences between the two methods, and describe their respective applications.

Terangkan mengenai dua sistem perlindungan katodik untuk menghalang kakisan. Kenalpasti persamaan dan perbezaan di antara kedua-dua kaedah, dan jelaskan penggunaan setiap satunya.

(50 marks/*markah*)

[b] The interior of a tank is to be protected from corrosion. The tank contains 5000 barrels of salt water. The following data is provided:

(1) water level = 7 m

(2) height of tank = 9 m

(3) diameter of tank = 12 m

(4) water level is maintained at 7 m

(5) current density = 0.6 mA/cm^2

(6) resistivity of water = 10 ohm-cm

(7) length of 2 AWG wire = 40 m

(8) resistance = 4.1×10^{-4} ohms/cm

From the above data, calculate the following:

(i) current requirement

(ii) number of anodes required - anode used is 8 cm × 152 cm graphite anode and anode current density is 0.3 A/cm^2

(iii) anode to electrolyte resistance

(iv) resistance of lead wire 40 m long

(v) resistance of anode

Bahagian dalam sebuah tangki perlu dilindungi dari kakisan. Tangki tersebut mengandungi 5000 tong air garam. Data berikut diberikan:

(1) paras air = 7 m

(2) tinggi tangki = 9 m

(3) diameter tangki = 12 m

(4) paras air ditetapkan pada 7 m

(5) ketumpatan arus = 0.6 mA/cm^2

(6) rintangan air = 10 ohm-cm

(7) panjang 2 AWG wayar = 40 m

(8) rintangan = 4.1 x 10^{-4} ohms/cm

Dari data di atas, kirakan yang berikut:

(i) arus yang diperlukan

(ii) bilangan anod yang diperlukan – anod yang digunakan grafit anod 8 cm x 152 cm dan ketumpatan arus anod adalah 0.3 A/cm^2

(iii) rintangan anod ke elektrolit

(iv) rintangan wayar plumbum panjang 40 m

(v) rintangan anod

(50 marks/*markah*)

7. [a] With appropriate examples, explain the importance of design and selection of materials to prevent corrosion.

Dengan contoh-contoh sesuai, bincangkan kepentingan rekabentuk dan pemilihan bahan bagi menghalang kakisan.

(40 marks/*markah*)

[b] Explain the use of inhibitors to prevent corrosion. Classify them and describe their characteristics and application.

Terangkan mengenai penggunaan perencat untuk menghalang kakisan. Klasifikasikan mereka dan jelaskan ciri-ciri dan aplikasinya.

(40 marks/*markah*)

[c] Stainless steels are often thought by many as being highly corrosion-resistant materials, but there are applications where they are less resistant than ordinary steel. Explain briefly why do stainless steels have good corrosion resistance in some environments but less so in certain other environments.

Keluli tahan karat sering difikirkan oleh ramai sebagai bahan yang tinggi ketahanan kakisan, tetapi terdapat aplikasi di mana mereka kurang tahan berbanding keluli biasa. Terangkan dengan ringkas mengapa keluli tahan karat mempunyai ketahanan kakisan yang baik dalam sesetengah persekitaran tetapi kurang tahan dalam sesetengah persekitaran lain.

(20 marks/*markah*)

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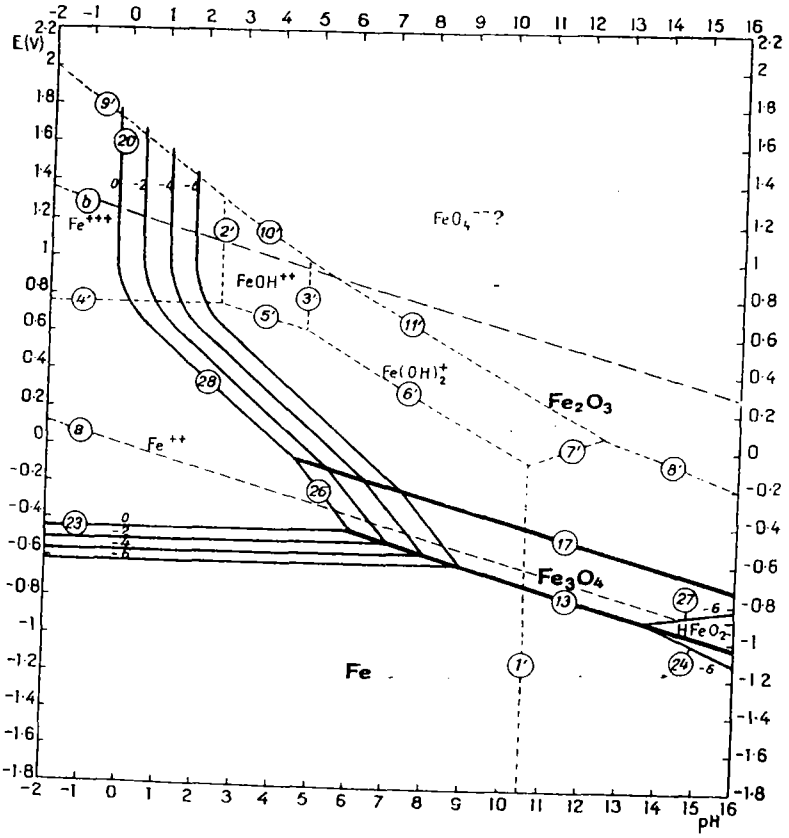
APPENDIX 1

LAMPIRAN 1



The Pourbaix diagram for iron[47].

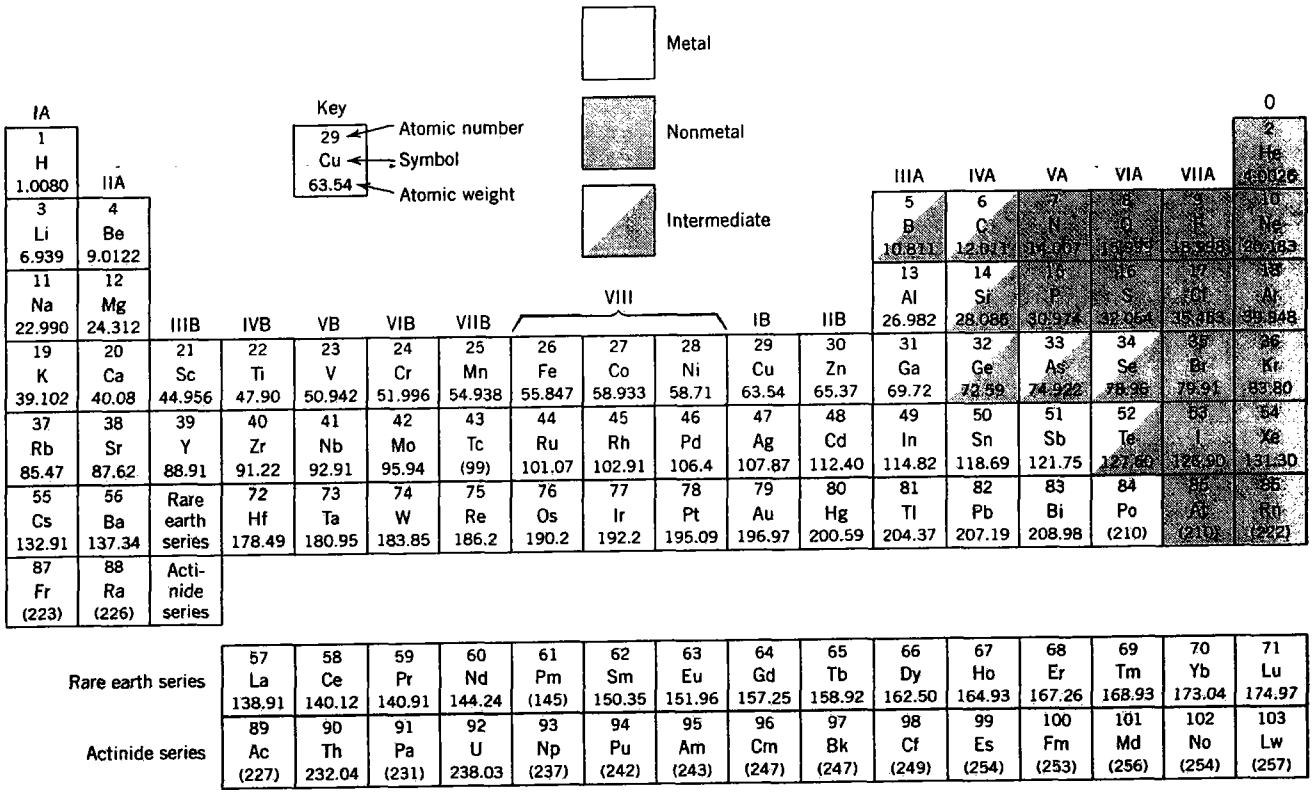
APPENDIX 2

LAMPIRAN 2

Constant Value

Avogadro's constant (N_A)	6.02×10^{23} mol^{-1}
Boltzmann constant (k)	1.38×10^{-23} JK^{-1} 8.62×10^{-5} eV/atom-K
Coulomb constant (k)	9.0×10^{9}N.m^2/C^2
Electron charge (e)	1.60×10^{-19}C
Electron Mass (m_e)	9.11×10^{-31} kg
Faraday's constant	96500 C/mole (i.e. amp.sec/mole)
Gas constant (R)	8.3I JK^{-1}mol^{-1}
Gravity (g)	9.81ms^{-2}
Permeability of a vacuum (μ_0)	$4\pi \times 10^{-7}$ ms^{-1}
Permittivity of a vacuum (ε_0)	8.85 x 10-12 Fm-I
Planck constant (h)	6.63×10^{-34} Js
Velocity of light in a vacuum (c)	3.00×10^{8} ms^{-1}

Periodic Table



APPENDIX 3

LAMPIRAN 3

The Electrochemical Series

Element/Other	Reaction			Electrode Potential (V) (assumptions)
Gold	$Au^{+} + e^{-}$	=	Au	1.692
Gold	$Au^{3+} + 3\ e^{-}$	=	Au	1.498
Chlorine	$Cl_2(g) + 2\ e^{-}$	=	$2\ Cl^{-}$	1.35827
Oxygen, Hydrogen (acid)	$O_2 + 4\ H^{+} + 4\ e^{-}$	=	$2\ H_2O$	1.229
Platinum	$Pt^{2+} + 2\ e^{-}$	=	Pt	1.18
Palladium	$Pd^{2+} + 2\ e^{-}$	=	Pd	0.951
Silver	$Ag^{+} + e^{-}$	=	Ag	0.7996
Oxygen, Hydrogen (acid)	$O_2 + 2\ H^{+} + 2\ e^{-}$	=	H_2O_2	0.695
Copper	$Cu^{+} + e^{-}$	=	Cu	0.521
Oxygen, Water	$O_2 + 2\ H_2O + 4\ e^{-}$	=	$4\ OH$	0.401
Copper	$Cu^{2+} + 2\ e^{-}$	=	Cu	0.3419
Hydrogen (acid)	$2\ H^{+} = 2\ e^{-}$	=	H_2	0
Iron	$Fe^{3+} = 3\ e^{-}$	=	Fe	-0.037
Lead	$Pb^{2+} + 2\ e^{-}$	=	Pb	-0.1262
Tin	$Sn^{2+} + 2\ e^{-}$	=	Sn	-0.1375
Oxygen, Water	$O_2 + 2\ H_2O + 2\ e^{-}$	=	$H_2O_2 + 2\ OH^{-}$	-0.146
Nickel	$Ni^{2+} + 2\ e^{-}$	=	Ni	-0.257
Cobalt	$Co^{2+} + 2\ e^{-}$	=	Co	-0.28
Cadmium	$Cd^{2+} + 2\ e^{-}$	=	Cd	-0.403
Iron	$Fe^{2+} + 2\ e^{-}$	=	Fe	-0.447
Chromium	$Cr^{3+} + 3\ e^{-}$	=	Cr	-0.744
Zinc	$Zn^{2+} + 2\ e^{-}$	=	Zn	-0.7618
Water	$2\ H_2O + 2\ e^{-}$	=	$H_2 + 2\ OH^{-}$	-0.8277
Chromium	$Cr^{2+} + 2\ e^{-}$	=	Cr	-0.913
Manganese	$Mn^{2+} + 2\ e^{-}$	=	Mn	-1.185
Titanium	$Ti^{3+} + 3\ e^{-}$	=	Ti	-1.37
Titanium	$Ti^{2+} + 2\ e^{-}$	=	Ti	-1.63
Aluminum	$Al^{3+} + 3\ e^{-}$	=	Al	-1.662
Magnesium	$Mg^{2+} + 2\ e^{-}$	=	Mg	-2.372
Magnesium	$Mg^{+} + e^{-}$	=	Mg	-2.7
Sodium	$Na^{+} + e^{-}$	=	Na	-2.71
Calcium	$Ca^{2+} + 2\ e^{-}$	=	Ca	-2.868
Potassium	$K^{+} + e^{-}$	=	K	-2.931
Lithium	$Li^{3+} + e^{-}$	=	Li	-3.0401
Calcium	$Ca^{+} + e^{-}$	=	Ca	-3.8