PAUL SCHERRER INSTITUT

Elektrochemie – P. Novák WS 2019/2020

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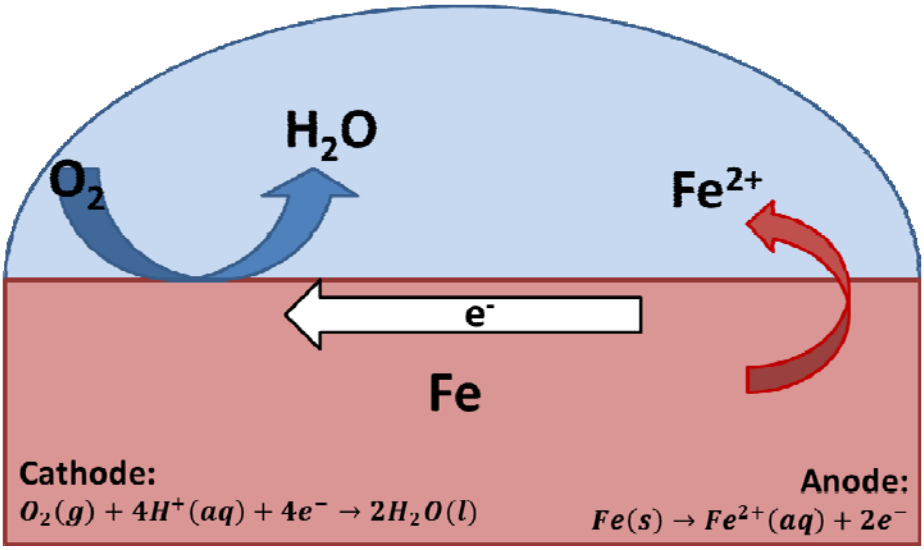
Übung 12: Corrosion marta.mirolo@psi.ch

Please send the solved exercise in **English** by e-mail or by post, to be received before the **15.01.2020**.

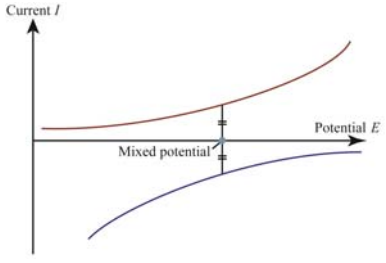
Exercise 1. General questions: (10 points)

a) Explain what is corrosion and what is the difference with erosion. Give an example for both processes.
Corrosion is a process taking place on a metal surface when simultaneous electrochemical processes occur, giving rise to an anodic and a cathodic partial current. Thus, corrosion involves electrochemical processes (e.g., corrosion of an iron pipe in water), while erosion is the removal of material due to physical processes, such as the erosion of a stone in a river.

b) Schematically draw an iron surface in contact with water (pH = 7). Which reactions are occurring on the iron surface? Where are the cathode and the anode?

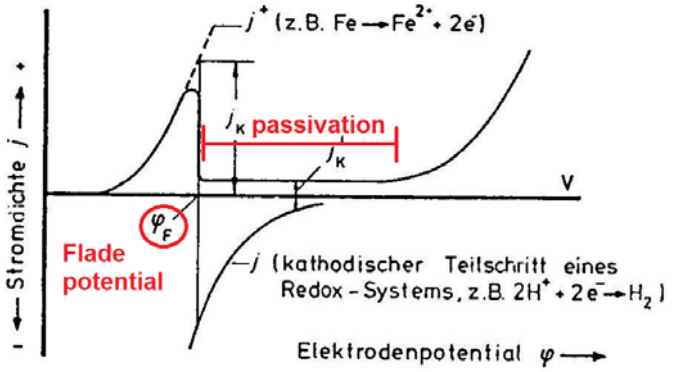


c) What is the mixed potential?
The mixed potential is the potential at which the net current flow is 0, i.e. the anodic and cathodic partial currents are equal and opposite.



d) What is the Flade potential? Draw the current-voltage curve.
The Flade potential is the potential at which the passivation

process starts and it is due to the high concentration of dissolved metal ions near the surface.



e) Briefly explain a method that you can use to protect from corrosion an iron rod in atmosphere.
Examples: painting (will avoid the contact between oxygen and iron) or galvanization (deposition of Zn, which will be corroded before the iron rod).

Exercise 2. Pourbaix diagram: (5 points)

Given the Pourbaix diagram in Figure 1, answer the following questions:

a) Describe what the vertical, horizontal and diagonal lines mean.
Vertical: acid-base reactions which do not depend on the potential
Horizontal: redox reaction which are not pH-dependent
Diagonal: redox reactions in which hydroxide or hydrogen are involved

b) What are the dashed lines? Why are they shown?
The dashed lines enclose the stability window of water. In the Pourbaix diagram of Fe it is clear that Fe-metal is not stable in contact with water, and it will undergo corrosion.

c) Write the equilibria reactions for points A, B and C.
A: $Fe^{2+} + 2\ e^- \rightarrow Fe(s)$
B: $2\ Fe^{2+} + 3\ H_2O \rightarrow Fe_2O_3(s) + 6\ H^+ + 2e^-$
C: $2\ Fe^{3+} + 3\ H_2O \rightarrow Fe_2O_3(s) + 6\ H^+$

d) Given the following parameters, which processes will occur? Write the expected product.
   i. pH = 12, E = -1.2 V : immunity, Fe
   ii. pH = neutral, E = 0.8 V : passivation, Fe_2O_3
   iii. solution of HCl 0.0025 M, E = 0 V : pH = -log(0.0025) = 2.6 → corrosion, Fe^{2+}

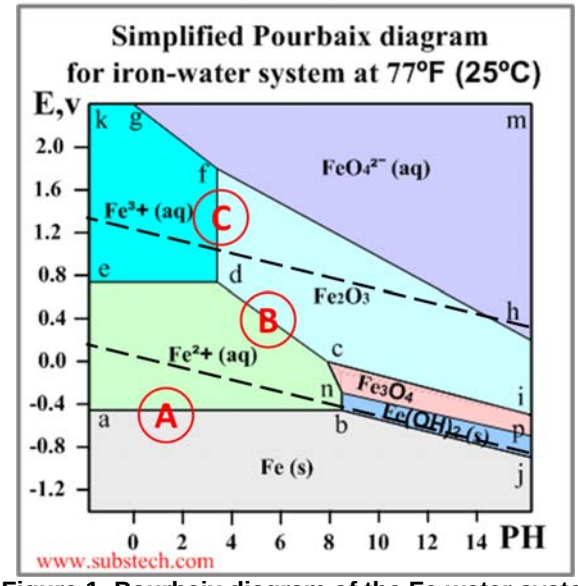


Figure 1: Pourbaix diagram of the Fe-water system.

Exercise 3. (3 points)

An iron piece is connected to a copper one and both parts are immersed in a solution containing both Fe^{2+} and Cu^{2+} ions. Answer the following questions.

a) Which metal corrodes? Give an explanation.
Knowing that E°(Fe) = -0.44 V (vs. SHE) and E°(Cu) = +0.34 V (vs. SHE), Fe will corrode/dissolve.

b) Which one is the cathode? Write the equations occurring at each electrode, assuming each metal has a valence of 2.
Because of the previous consideration:
Anode: $Fe \rightarrow Fe^{2+} + 2e^-$
Cathode: $Cu^{2+} + 2e^- \rightarrow Cu$

c) Calculate the standard reversible potential of the resulting corrosion cell.
E(cell) = E°(cat.) – E°(an.) = (+0.34 V) – (-0.44 V) = + 0.78 V

Exercise 4. (2 points)

After keeping a steel plate for 10 years in seawater, you observe a thickness reduction of 3 mm. Considering that the dissolution reaction is mainly $Fe \rightarrow Fe^{2+}+2e^-$, and that the density and the atomic weight of iron are 7.8 g/cm^3 and 56, respectively, calculate the average corrosion current.

$ds/dt = i_{corr}\ M / z\ F\ \rho$

i_{corr} = 256 µA/cm^2