

Final Examination1993 Dec. 17

- Three hours, closed book.
- Attempt all questions.
- Hand calculators are to be used for computation - NOT for storage of information pertinent to this course and examination.
- CLEAR diagrams must be used as required for illustration.

Data

Gas constant, $R = 1.987 \text{ cal/mol} \cdot ^\circ\text{K}$

Faraday, $F = 96,500 \text{ coulomb/equiv.}$

$4.18 \text{ Joule} = 1 \text{ calorie}$

$E^\circ_{\text{Co}/\text{Co}^{2+}} = -0.277\text{V}$

Equilibrium constant, K , for Co^{2+} . CoO conversion = $2.51 \times 10^{-13} \text{ mol/L}$.

Atomic wt. $\text{Fe} = 55.9$, $\text{O} = 16.0$, $\text{C} = 12.0$.

Density $\text{Fe} = 7.85 \text{ g/cm}^3$, $\text{Fe}_3\text{O}_4 = 5.20 \text{ g/cm}^3$, $\text{C} = 2.1 \text{ g/cm}^3$.

1. A chemical process stream that incorporates a carbon steel component generates \$262,300 revenue every year. General operating and maintenance costs amount to \$3,200 p.a., while carbon steel corrosion dictates component replacement every three years at a cost of \$27,600.

Using a net present value calculation, you are to decide if it is worth changing the component to stainless steel, which lasts five years but costs \$41,200. The operating and maintenance costs of the changed process are \$2,800 p.a., but reduced heat transfer of the stainless steel means that revenues will be cut to \$246,800 p.a.

Assume a total lifetime of the process of 14 years, with a constant rate of inflation of 4.5% p.a. over that period.

(14 marks)

- (2) On Figure 1, label the regions of the diagram that are important for understanding the corrosion of iron in aqueous solutions. Indicate on a separate sheet how the lines on the diagram are obtained (the final computations are not required - just the methodologies).

(10 marks)

- (3) Figure 2 is a partial Pourbaix diagram for cobalt at 25°C. Assuming a concentration of Co^{2+} of 10^{-6} g-ion/L, compute:

- (a) the potential (relative to SHE) below which cobalt metal is immune to corrosion;
- (b) the pH above which CoO precipitates as the stable phase.

(11 marks)

- (4) The Butler-Volmer Equation for an electrochemical reaction is written as:

$$i = i_0 \{ \exp(\alpha \eta) - \exp(-[1 - \alpha] \eta) \}$$

Explain the symbols in the equation, and with the aid of a sketch describe the significance of the exponential terms within { }.

By showing schematically with a sketch how the Butler-Volmer Equation can be made into an Evans Diagram, describe the typical kinetic behaviour of a metal corroding in acid solution.

(12 marks)

- (5) What is concentration polarization?

With the aid of an Evans Diagram, explain how a passivating metal immersed in a flowing corrosive solution under mass transfer control can undergo a steady increase in corrosion rate followed by a sudden drop to negligible levels as flow rate is increased.

What conditions must be met before the metal can passivate?

(10 marks)

- (6) Compare and contrast the characteristics and mechanisms of pitting corrosion with those of crevice corrosion.

(10 marks)

- (7) A corrosion coupon is made of a disc of 1.6 mm-thick carbon steel sheet; it is 2.54 cm in diameter, has a central mounting hole 3.5 mm in diameter, and weighs 6.2410 g. The coupon is exposed for 200 days in a test rig containing organic-contaminated water at 320°C, after which it weighs 6.2404 g. The surface is covered with a black deposit, which is determined by analysis of other coupons to be a mixture of 87% Fe₃O₄ (by weight) and 13% C.

The coupon is immersed in a descaling solution for 2.5 h, after which it is found to be completely free from deposit and to weigh 6.2217 g. An identical "blank" coupon immersed in the descaling solution at the same time loses 0.0011 g.

Calculate the average corrosion rate, in mdd, of carbon steel in the hot water, and comment on the amount of scale produced (assuming its porosity is 10%).

(14 marks)

- (8) Assume that the precise kinetic function describing the carbon steel corrosion in Question (7) is cubic, viz....

$$W^3 = Kt$$

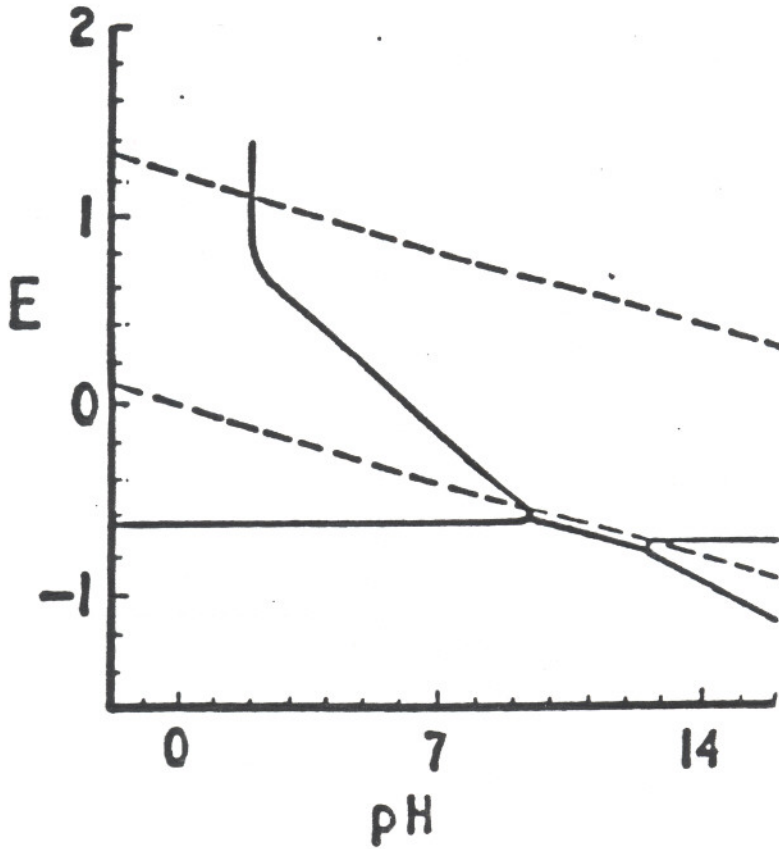
where W = total corrosion
 t = time
 k = constant

What is the instantaneous corrosion rate in mdd at 200 days, and what will it be after 10 years?

(9 marks)

- (9) What usually causes IGA of austenitic stainless steels? How can IGA be avoided in manufactured components?

(10 marks)



A simplified form of the Pourbaix Diagram for Iron.

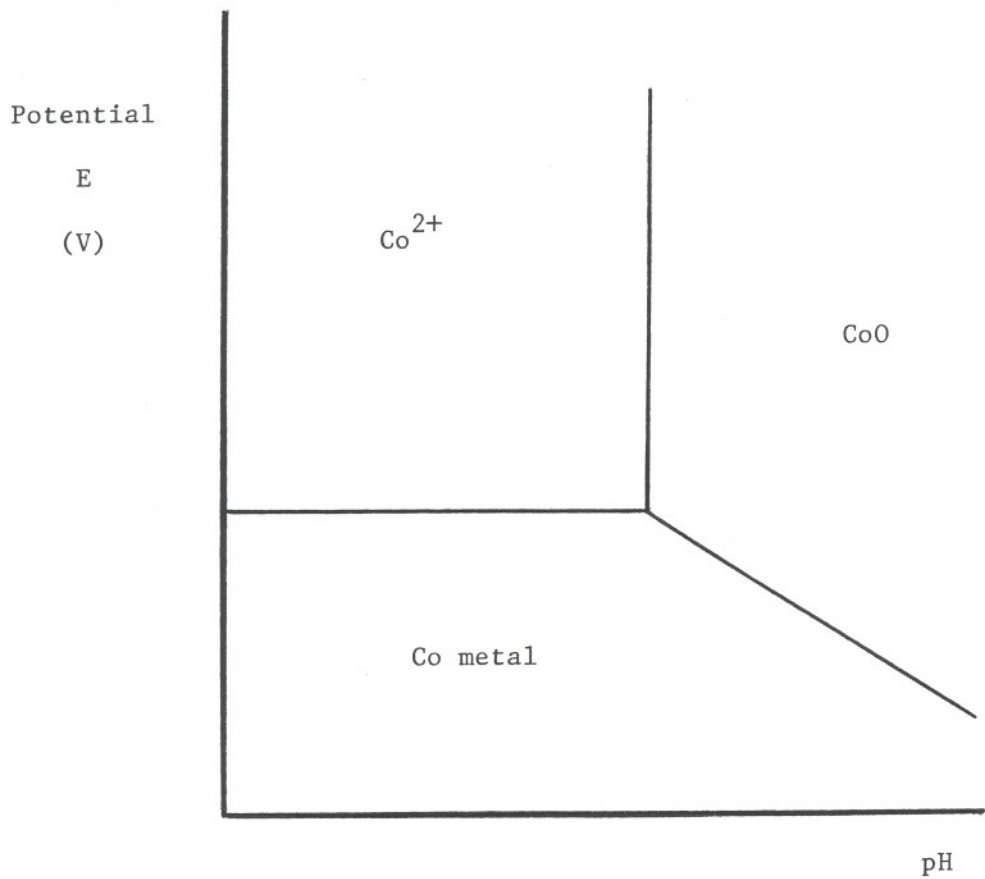


Figure 2. Partial Pourbaix Diagram for cobalt.