NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

DEPARTMENT OF CIVIL, MINING AND PROCESS ENGINEERING

QUALIFICATION: BACHELOR OF ENGINEERING IN METALLURGY	
QUALIFICATION CODE: 08BMET	LEVEL: 8
COURSE CODE: CEN810S	COURSE NAME: Corrosion Engineering 414
SESSION: June 2023	PAPER: 1
DURATION: 2 HOURS	MARKS: 70

FIRST OPPORTUNITY PAPER	
EXAMINER(S)	Prof D Groot
MODERATOR:	Prof J van der Merwe, University of the Witwatersrand

INSTRUCTIONS

1. Answer all questions.
2. Read all the questions carefully before answering.
3. Marks for each questions are indicated at the end of each question.
4. Please ensure that your writing is legible, neat and presentable.

PERMISSIBLE MATERIALS

1. Examination paper.
2. Scientific calculator, non-programmable

THIS PAPER CONSISTS OF 5 PAGES (Including this front page)

Question 1

Consider the situation where you are part of a design team, and you are responsible for corrosion issues. The team is designing a chemical plant, and you are tasked to consider the following. A waste process solution (temperature about 30 degrees) containing about 3% sodium chloride and saturated in gypsum (calcium sulfate) has to be pumped from a reactor. Due to cost sensitivity, the team is suggesting hot dip galvanised mild steel pipes and a centrifugal pump that has a ductile cast iron casing and impeller.

(a) What do you think are the important advantages (excluding cost) and disadvantages of these material choices for the pipes and pump? Motivate your choices. [3]

(b) Based on the supplied information, what would you consider as suitable metal choices for the pipes and pump? Motivate your choices. [3]

NOTE: See ALL given information attached to this paper.

Question 2

Calculate the concentration of Zn^{+2} ions required to stop the zinc corroding when immersed in a solution containing 0.1 mol/l $FeCl_2$. State the assumptions you made. [5]

Question 3

Consider the corrosion of Fe in a hydrogen-saturated solution of HCl at an activity of 0.10 mol/l. The activity of Fe^{+2} is 10^{-6} mol/l. The exchange current density for Fe/Fe^{+2} is $2x10^{-10}$ A/cm^2 with a Tafel slope of 30 mV/dec.

(a) Calculate the exchange equilibrium potentials of the hydrogen and iron redox reactions. [1]

(b) Calculate the corrosion potential and current. [5]

Question 4

Microbiologically induced corrosion, MIC, is one of several forms of corrosion.

(a) Describe in detail what is meant by MIC, and how it may be positively identified. [3]

(b) Give an example of where MIC might occur. [1]

(c) Discuss how MIC may be controlled. [2]

Question 5

Corrosion may be controlled by suitable coats or coating systems. Describe the major types of coatings and coating systems, and briefly discuss how they control corrosion. [8]

Question 6

Sometimes corrosion occurs at elevated temperatures, where no moisture is directly involved. Briefly discuss the differences between dry corrosion at elevated temperatures, and hot corrosion, and the results of these, giving suitable examples of each. [7]

Question 7

Pitting corrosion is often considered to be identical to that of crevice corrosion because the natures of the corrosion processes that occur are almost identical. Discuss how these two types of corrosion are different. [6]

Question 8

The steel of a ship's hull is normally protected against corrosion by a combination of paint and sacrificial anodes.

(a) Explain, in terms of the basic aqueous corrosion cell, how the corrosion of unprotected areas can occur. State the electrochemical reactions that are expected. [7]

(b) Draw a suitable schematic Evans diagram for the hull corrosion system. [4]

(c) Is it feasible from a corrosion point of view to make the ship's hull of stainless steel, unpainted, but with sacrificial anodes made of zinc? Explain your point of view. [4]

Question 9

It is known that that the presence of stress promotes corrosion.

(a) Briefly discuss the two main types of corrosion promoted by stress. Describe each type, and indicate what factors affect the time before failure occurs. [9]

(b) Assume a component that failed by one of these mechanisms was given to you. If you looked at the failure site on the component, how could you see which of the mechanisms caused the failure? [2]

Given information

$i = i_0 [\exp(\alpha\eta zF/RT) - \exp((1-\alpha)\eta zF/RT)$ $E = E^0 - (0.059/n) \log([\text{product}] / [\text{reagent}])$

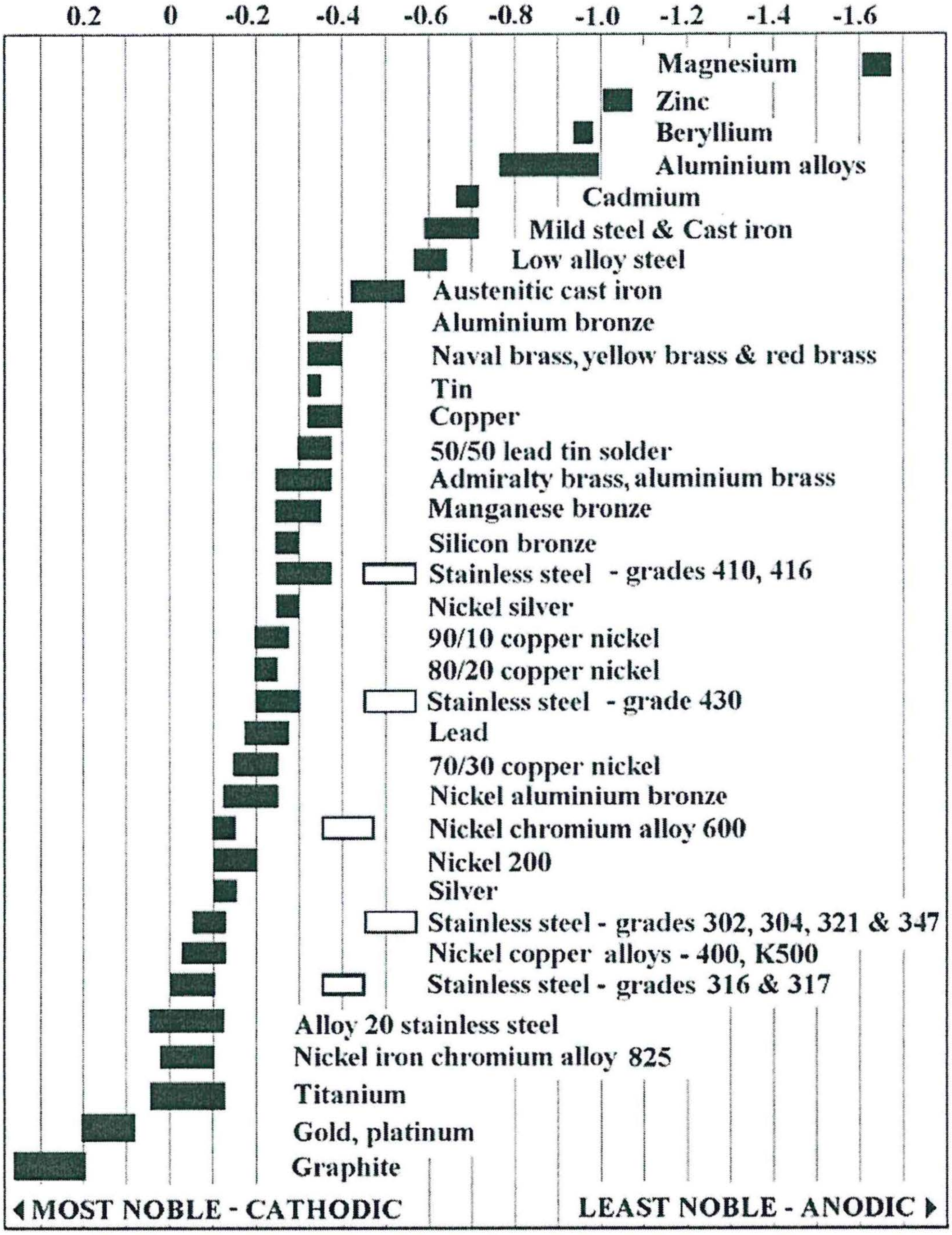
$\eta = b \log(i/i_0)$ $\eta = a_a + b_a \log I$ $F = 96\,485$ Coulomb/mol $\Delta G = -nFE$

$a_a = -2.303 (RT/(\alpha nF)) \log i_0$ $b_a = 2.303 (RT/(\alpha nF))$

E^0 for Cu^{+2}/Cu = 0.337 V; H^+/H_2 = 0.000 V; Fe^{+2}/Fe = -0.440 V; Zn^{+2}/Zn = -0.763 V; Ag^+/Ag = 0.799 V

Electrode	Solution	j_0 (A/cm^2)	b_c (mV/dec)	b_a (mV/dec)
For reaction	$2H^+ + 2e \rightarrow H_2$			
Pt	1 M HCl	10^{-2}	30	
	0.1 M NaOH	0.7×10^{-3}	110	
Au	1 M HCl	10^{-5}	50	
Ag	0.1 M HCl	0.15	100	100
Fe	0.26 M H_2SO_4	2×10^{-5}	110	
Cu	0.1 M HCl	2×10^{-6}	120	
Zn	0.5 M H_2SO_4	2×10^{-10}	120	
Pb	1 M HCl	2×10^{-12}	120	
For reaction	$Cl_2 + 2e \rightarrow 2Cl^-$			
Pt	1 M HCl	5×10^{-3}	110	130

Galvanic series in seawater



http://www.ssina.com/images/corrosion/galvanic-series.gif

Table 17.3 Corrosion-resistance ranking of materials in common environments

Environment			Aqueous environments				Acids and alkalis							Fuels, oils and solvents								Alcohols and aldehydes			
Material			Water (fresh)	Water (salt)	Soils, acidic (peat)	Soils, alkaline (clay)	Acetic acid (10%)	Hydrochloric acid (10%)	Hydrofluoric acid (40%)	Nitric acid (10%)	Sulfuric acid (10%)	Sodium hydroxide (10%)	Sodium hydroxide (60%)	Benzene	Carbon tetrachloride	Diesel oil	Lubricating oil	Paraffin oil (kerosene)	Petroleum (gasoline)	Silicone fluids	Vegetable oils	Acetone	Ethyl alcohol (ethanol)	Formaldehyde (40%)	Methyl alcohol (methanol)
Metals	Ferrous	Cast iron	B	C	B	B	C	D	D	D	B	A	B	A	A	A	A	A	A	A	A	A	B	A	B
		High carbon steel	B	C	B	B	C	D	D	D	D	B	B	A	A	A	A	A	A	A	A	A	B	A	B
		Medium carbon steel	B	C	B	B	C	D	D	D	D	B	B	A	A	A	A	A	A	A	A	A	B	A	B
		Low carbon steel	B	C	B	B	C	D	D	D	D	B	B	A	A	A	A	A	A	A	A	A	B	A	B
		Low alloy steel	B	C	B	B	C	D	D	D	D	B	B	A	A	A	A	A	A	A	A	A	B	A	B
		Stainless steel	A	A	A	A	A	A	C	A	B	A	A	B	A	A	A	A	A	B	A	A	A	A	A
	Non-ferrous	Aluminum alloys	A	B	D	A	C	C	D	C	D	D	D	A	A	A	A	A	A	A	A	A	A	A	C
		Copper alloys	A	A	A	A	C	C	D	B	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Lead alloys	A	A	A	A	B	C	D	B	B	B	D	A	A	A	A	A	A	A	A	A	A	A	A
		Magnesium alloys	A	C	C	C	C	D	D	D	D	B	B	A	A	A	A	A	A	A	A	A	A	A	A
		Nickel alloys	A	A	A	A	A	B	D	B	B	B	B	A	A	A	A	A	A	A	A	A	A	A	A
		Titanium alloys	A	A	A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Zinc alloys	A	B	B	A	C	D	D	D	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A
Ceramics and glasses	Glasses	Borosilicate glass	A	A	A	A	A	A	D	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A
		Glass ceramic	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Silica glass	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Soda-lime glass	A	A	A	A	A	A	D	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A
	Porous	Brick	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Concrete	A	A	A	A	B	B	D	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Stone	A	A	A	A	C	C	D	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	Technical	Alumina	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Aluminum nitride	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Boron carbide	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Silicon	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Silicon carbide	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Silicon nitride	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Tungsten carbides	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
		Zirconia	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

A: excellent; B: acceptable; C: limited use; D: unacceptable

M Ashby, H Shercliff and D Cebon. Materials. Engineering, Science, Processing and Design. 3rd Edition (2014). Elsevier Butterworth-Heinemann.