

Corrosion Testing of Mild Steels

ENSC1004

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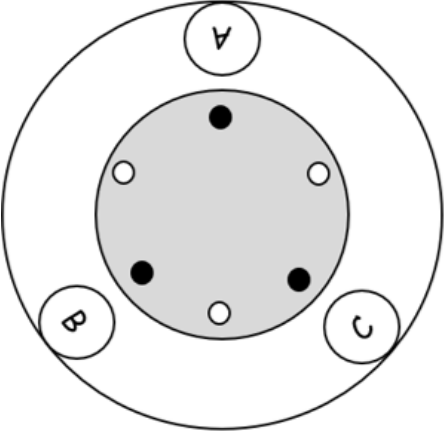
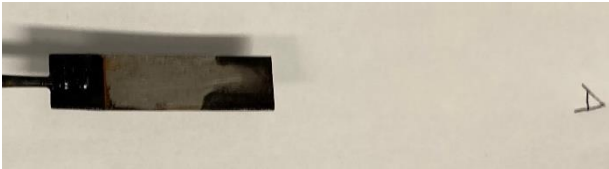



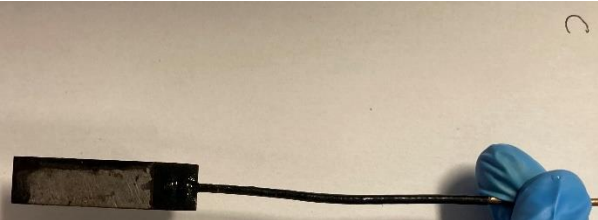

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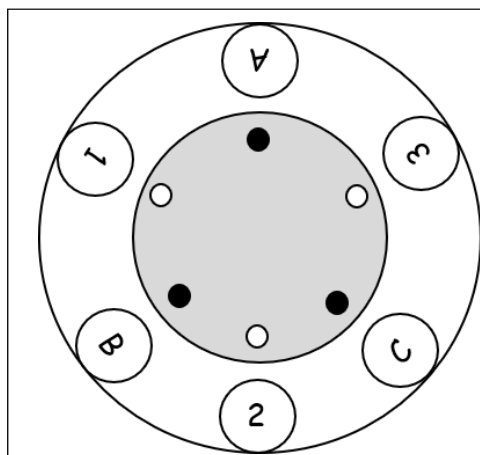
Recording of Experiment 1

Corrosion of mild steel in aqueous solutions

	<p>Date: 7/05/21</p> <p>Time: 11:17AM</p> <p>Corrosion Cell Disassembled:</p> <p>Cell 2- 0.1 M KI aerated solution</p>
<p>Photo of sample A front side</p> 	<p>Photo of sample A reverse side</p> 
<p>Photo of sample B front side</p> 	<p>Photo of sample B reverse side</p> 
<p>Photo of sample C front side</p> 	<p>Photo of sample C reverse side</p> 
<p>Key Observations of the mild steel corrosion behavior and associated reduction reaction(s): Flaky black substance coating the steel. Focused on the end of the coupons that streaked up either side. Substance can be scrubbed off relatively easily with plastic brush.</p> <p>Reduction Reactions:</p> $\text{O}_{2(g)} + 2\text{H}_2\text{O}_{(l)} + 4e^- \rightarrow 4(\text{OH}^-)_{(aq)}$	

Recording of Experiment 2

Galvanic corrosion of mild steel-zinc in 0.1 M KI



Each letter corresponds to a single discrete zinc coupon, while each number corresponds to a single discrete steel coupon.

Measurement Time (min)	Couple A-1	Couple B-2	Couple C-3
	Voltage (mV)	Voltage (mV)	Voltage (mV)
1.00	66.5	56.5	61.4
2.00	65.2	56.0	61.5
3.00	64.5	55.2	60.8
4.00	63.2	55.5	60.0
5.00	52.7	55.8	59.0
6.00	53.7	55.5	58.0

Couple A-B	Couple B-C	Couple C-A
Voltage (mV)	Voltage (mV)	Voltage (mV)
0.35	0.36	0.64

Couple 1-2	Couple 2-3	Couple 3-1
Voltage (mV)	Voltage (mV)	Voltage (mV)
0.67	0.13	0.12

Bridged Couple A-1	
Voltage (mV)	Current (μ A)
0	0

Data Analysis of Experiment 1

Table 1. Average Mass Loss and Corrosion Penetrative Rate of Mild Steel in 0.1M KI Aerated Solution

	Original Mass (Grams)	Final Mass (Grams)	Change in Mass (Grams)	Corrosion Penetrative Rate (CPR) (mmpy)
A	8.812	8.802	0.010	
B	8.853	8.840	0.013	
C	8.340	8.327	0.013	
Average			0.012	0.268

Weight loss into volume loss over 2 days - $\frac{\text{Weight Loss}}{\text{Density}} = \frac{0.012[g]}{7.8[\frac{g}{cm^3}]} = 0.001538 \text{ cm}^3$

Spreading volume loss over plate surface for corrosion

$$\text{depth} - \frac{\text{Volume Loss}}{\text{Surface Area}} = \frac{1.538 \times 10^{-3} [cm^3]}{(2(3.8 \times 1.27 + 1.27 \times 0.08 + 3.8 \times 0.08)) [cm^2]} = 1.4704 \times 10^{-2} \text{ mm}$$

$$\text{Annual corrosion rate (mm depth per year)} - 365 \times \frac{1.4704 \times 10^{-2} [mm]}{2} = 0.268 \text{ mmpy}$$

Data Analysis of Experiment 2

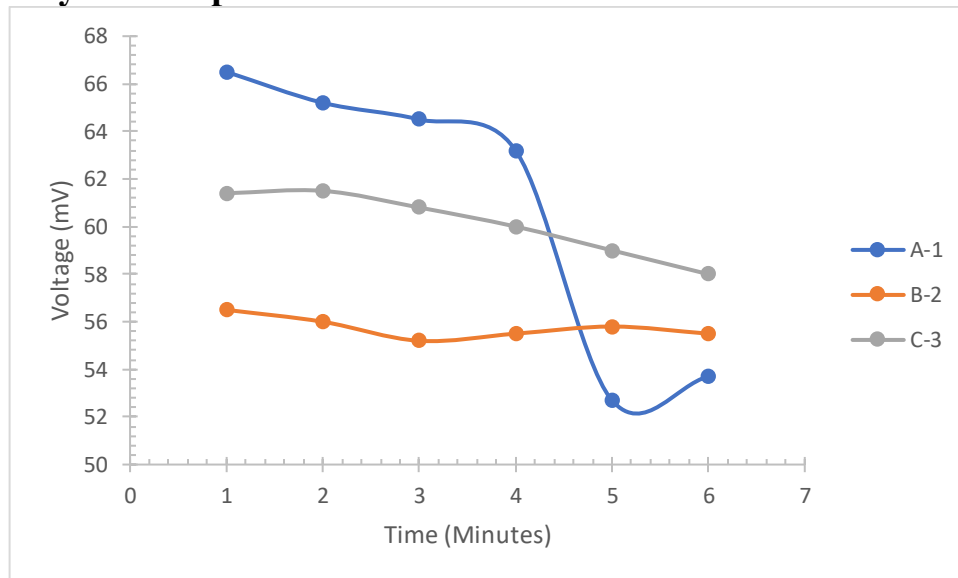


Figure 1. Measured Voltage Against Time

Figure 1. seems to show a general downward trend between voltage and time, with some couples fluctuating radically. A reason for this non-steady measure of voltage is that it takes a long time for the voltage to stabilise as the current is carried in electrolytes by migration of ions. These ions take time to reach a steady concentration around the electrodes.

Table 2. Final Voltage for Each Couple

Couple	Final Voltage (mV)	Cathode	Anode
A-1	53.7	Steel	Zinc
B-2	55.5		
C-3	58		

Oxidation Half-Reaction – $\text{Zn}_{(s)} \rightarrow \text{Zn}^{2+}_{(aq)} + 2e^-$

Reduction Half-Reaction – $2\text{H}^{+}_{(aq)} + 2e^- \rightarrow \text{H}_{2(g)}$
 – $\text{O}_{2(g)} + 2\text{H}_2\text{O}_{(l)} + 4e^- \rightarrow 4(\text{OH}^{-})_{(aq)}$

Discussion of Experiment 1

Expected Ranking of Expected Corrosion Severity

Least Severe

Most Severe

Deionized water no aeration pH 4 buffered solution aerated 35 g/L NaCl solution deoxygenated 35 g/L NaCl solution aerated 0.1 M KI solution aerated

The more possible reduction reactions that exist, the faster the metal would oxidise or corrode. Another reason for faster corrosion is the solution is an electrolyte, which would facilitate the flow of ions. Low pH, an oxygenated solution, and dissolved salts (electrolytes) are all conditions that could lead to more or faster reduction reactions. The deionized water I expect to have the least corrosion as it has none of these factors, then the buffer as it does have oxygen as well as having some free hydrogen ions, then the NaCl deoxygenated solution as it is an electrolyte, then the aerated NaCl solution as it an electrolyte and contains oxygen. Finally, I placed the 0.1 M KI aerated solution as it has a relatively high concentration of ions as well as having oxygen molecules.

Table 3. Observation of Each Coupon and Possible Reduction Equations

Solution	Observations of Coupon	Observation of Solution	Possible Reduction Reactions
Deionized Water	Some small lines of black corrosion outlined by orange	Yellow hue with small amount of brown suspension	$\text{O}_{2(g)} + 2\text{H}_2\text{O}_{(l)} + 4e^- \rightarrow 4(\text{OH}^{-})_{(aq)}$
0.1 M KI Solution Aerated	Very heavy corrosion with half the coupon affected with it	Saturated Orange liquid with heavy amount of brown suspension	$\text{O}_{2(g)} + 2\text{H}_2\text{O}_{(l)} + 4e^- \rightarrow 4(\text{OH}^{-})_{(aq)}$ $2\text{H}^{+}_{(aq)} + 2e^- \rightarrow \text{H}_{2(g)}$
Deoxygenated NaCl	Corrosion climbing up from the bottom to one eighth up the coupon	Light Orange hue with a small amount of brown suspension	$2\text{H}^{+}_{(aq)} + 2e^- \rightarrow \text{H}_{2(g)}$
Aerated NaCl	A quarter of coupon covered in corrosion	Orange hue with brown suspension	$\text{O}_{2(g)} + 2\text{H}_2\text{O}_{(l)} + 4e^- \rightarrow 4(\text{OH}^{-})_{(aq)}$ $2\text{H}^{+}_{(aq)} + 2e^- \rightarrow \text{H}_{2(g)}$
pH 4 Buffer	Tiny black spots with bubbles on them	Very dark orange liquid	$\text{O}_{2(g)} + 2\text{H}_2\text{O}_{(l)} + 4e^- \rightarrow 4(\text{OH}^{-})_{(aq)}$ $2\text{H}^{+}_{(aq)} + 2e^- \rightarrow \text{H}_{2(g)}$

From looking at the pictures, my expected ranking of severity almost lines up, but I placed the deionized water as less severe than the buffer solution. I overestimated the strength of the pH 4 buffered solution as well as underestimated how big a factor having electrolytes is when it comes to corrosion.

Discussion of Experiment 2

With the bridged couple, we measured a voltage and a current of 0. When unbridged we measured 53.7 mV. The reason for this is that brass is a weak conductor, so when the voltage was measure between the brass points, the resistance was too high to measure any value.

If we were to remove the C-3 couple from the cell and use the brass connector on the A-1 couple while leaving the B-2 untouched. After two days, I predict the B-zinc coupon would be very corroded, with the 2-steel coupon having been zinc plated. Similar things would happen to the A-1 couple, but to a much lesser extent. This is because the B-2 couple would have electrons freely flowing from anode to cathode, leading to corrosion. This also happens with the A-1 couple, but have a “resistor” between them, limiting the flow of electrons. This leads to a slower rate of corrosion.