Corrosion Study of Iron and Copper Metals and Brass Alloy in Different Medium

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Abstract: The corrosion of iron, copper and brass alloy has been investigated in different medium *i.e.* HNO₃, H₃PO₄, H₂SO₄, HCl, CH₃COOH. The study reveals that corrosion rate increases in the order iron > copper > brass and for the medium the corrosion follows the order HNO₃ > H₃PO₄ > H₂SO₄ > HCl > CH₃COOH. The rate of corrosion increases with increasing concentration of acid and with increase in time.

Keywords: Metal, Alloy Strips, Corrosion, Weight loss

Introduction

Corrosion¹⁻³ is defined as the destruction or deterioration of material because of reaction with its environment. Some insist there the definition should be restricted to metals but often the corrosion engineers must consider both metals and non-metals. Ceramics, rubber and other non-metallic materials, deterioration of paints and rubber by sunlight or chemicals, fluxing or lining of steel making furnace and attack of solid metal by another molten metal (Liquid metal Corrosion) are all considered to be corrosion. Corrosion can be fast or slow.

Corrosion of metal can be considered as extractive metallurgy. Rusting is a term reserved for steel and iron corrosion, although many other metals form their oxides when corrosion occurs. Practically all environments are corrosive to some degree. Air, moisture, fresh distilled, salt and mine waters, rural or urban and industrial atmosphere, steam and other gases such as NH₃, Cl₂, H₂S, SO₂, fuel gases, inorganic acids, organic acids, solvents, petroleum oils cause corrosion environment. Inorganic materials are more corrosive than the organics. High temperature and pressure involve more severe corrosion conditions. Anodizing of aluminum is another beneficial corrosion process used to obtain better and uniform appearance in addition to a protective corrosion product on the surface.

Experimental

Acids like HCl, H₂SO₄, H₃PO₄, HNO₃ and CH₃COOH of different concentrations *viz* 0.1 N, 0.5 N, 1 N, 4 N, were prepared from commercially available (A.R) grades and were

standardized. Similarly bases like NaOH, KOH and NH_4OH have been used in different concentrations⁴⁻⁶. Organic acids like benzoic acid and salicylic acid which are sparingly soluble in water their saturated solutions were used for corrosion studies. Small rectangular size metal-alloy plates of the size 8 x 6 x 0.3 cm were used and were dipped in the different solutions for different timings viz 1 to 5 h. The weight loss in different solutions and the emf was measured for each metal by using the respective metal strips as an electrode and calomel electrode as the reference electrode. From the weight loss and the emf observed, a correlative study of the corrosion rate has been done. The summary of the results are given in Table 1 -14.

Table 1. Comparative corrosion study of metals and alloys in different medium in terms of weight loss (mg) parameter

S. No.	Medium	Weight loss in, mg		
		Fe	Cu	Brass
1	4 N HCl	180	12	07
2	4 N H_2SO_4	550	37	33
3	4 N HNO_3	3422	7536	2974
4	4 N H_3PO_4	824	54	51
5	CH_3COOH	52	08	13
6	NaOH	18	21	12
7	KOH	24	32	19
8	NH_4OH	30	19	09
9	Aniline	10	05	10
10	Sea water	142	04	17
11	Water	20	18	16
12	NaCl	12	16.6	9.5
13	KCl	22	25	12
14	CHCl_3	26	39	32
15	$\text{K}_2\text{Cr}_2\text{O}_7$	09	22	13

Table 2. Comparative corrosion study of metals and Alloy in different medium in terms of emf (mV)

S.No	Medium	EMF in mV		
		Fe	Cu	Brass
1	4 N HCl	370	351	376
2	4 N H_2SO_4	437	52	102
3	4N HNO_3	488	46	356
4	4N H_3PO_4	492	85	72
5	4N CH_3COOH	500	100	132
6	4N NaOH	788	580	585
7	4N KOH	712	623	632
8	4N NH_4OH	373	533	556
9	Aniline	526	358	43
10	Sea water	599	245	261
11	Water	315	39	39
12	NaCl	649	340	370
13	KCl	624	325	303
14	CHCl_3	518	173	129
15	$\text{K}_2\text{Cr}_2\text{O}_7$	537	103	185

Corrosion rate expression⁷⁻⁹

The expression mile per year has been used as the most desirable way of expressing corrosion rate. The expression is readily calculated from the weight loss of the metal specimen during the corrosion test by the formula given below:

$$\text{mpy} = \frac{534W}{DAT}$$

Where, W =Weight loss in mg, D = Density of the Specimen (g/cm³), A = Area of Specimen (sq. inch), T = Exposure time, (hours). In the present study, the corrosion rate is correlated to the weight loss in mg.

Results and Discussion

Corrosion of iron¹⁰⁻¹² in the form of small plate has been studied in different medium by weight loss method. Five different concentrations *viz* 0.1 N, 0.5 N, 1 N, 4 N, were used for different timings *viz* 1-5 h. From the study the following conclusions have been arrived.

- The rate of corrosion increases with increasing the concentration of the acid.
- The rate of corrosion increases with increase in time.

The order of corrosion activity on the acids was $\text{HNO}_3 > \text{H}_3\text{PO}_4 > \text{H}_2\text{SO}_4 > \text{HCl} > \text{CH}_3\text{COOH} > \text{oxalic acid} > \text{benzoic acid} > \text{succinic acid} > \text{salicylic acid} > \text{KOH} > \text{NaOH}$.

Corrosion rate on iron metal was found almost similar to acetic acid, succinic acid and salicylic acid and more at higher concentrations for oxalic and benzoic acids and it has been found to be comparatively less for bases NaOH, and KOH. The potential (emf) studies have also been carried out in the respective solutions on iron metal as electrode and calomel electrode as the reference electrode. For inorganic acids which show more corrosion, the emf was found to be less, and for bases, the emf was found to be more. The potential studies on Fe shows the following order bases > neutral > organic acids > inorganic acids. This is related to the electrochemical behavior of metals under different concentrations. Similar weight loss and potential studies have also been carried out for Cu and brass alloy. The order of reactivity has been found to be Fe > Cu > brass. Since brass is an alloy of Cu and Zn the coupling effect of metals do not occur and hence the corrosion rate is found to be less. This is in relation to the observed literature¹³⁻¹⁵. Solid solution alloys are usually more corrosion resistant than alloys with two or more phases.

Table 3. Weight loss of Fe in HNO_3

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N HNO_3	0.01	0.022	0.034	0.048	0.054
0.5 N HNO_3	0.11	0.246	0.427	0.512	0.556
1 N HNO_3	9.257	11.538	13.62	18.722	21.88
4 N HNO_3	12.113	15.246	19.15	22.52	34.22

Table 4. Weight loss of Fe in H_3PO_4

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N H_3PO_4	0.028	0.039	0.042	0.059	0.078
0.5 N H_3PO_4	0.063	0.236	0.273	0.349	0.435
1 N H_3PO_4	0.085	0.325	0.438	0.664	0.775
4 N H_3PO_4	0.125	0.439	0.562	0.688	0.824

Table 5. Weight loss of Fe in NaOH

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N NaOH	0.001	0.002	0.002	0.003	0.005
0.5 N NaOH	0.002	0.002	0.003	0.004	0.007
1 N NaOH	0.001	0.003	0.004	0.006	0.008
4 N NaOH	0.003	0.006	0.01	0.012	0.018

Table 6. Weight loss of Fe in KOH

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N KOH	0.001	0.002	0.003	0.004	0.005
0.5 N KOH	0.002	0.004	0.006	0.008	0.008
1 N KOH	0.0025	0.006	0.008	0.012	0.016
4 N KOH	0.005	0.012	0.018	0.02	0.024

Table 7. Weight loss of Cu in HNO₃

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N HNO ₃	0.003	0.004	0.005	0.006	0.007
0.5 N HNO ₃	0.002	0.003	0.007	0.013	0.017
1 N HNO ₃	0.001	0.002	0.003	0.004	0.007
4 N HNO ₃	1.21	2.283	4.276	5.086	7.536

Table 8. Weight loss of Cu in H₃PO₄

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N H ₃ PO ₄	0.001	0.004	0.005	0.007	0.009
0.5 N H ₃ PO ₄	0.004	0.006	0.009	0.012	0.015
1 N H ₃ PO ₄	0.007	0.009	0.013	0.018	0.022
4 N H ₃ PO ₄	0.013	0.024	0.03	0.045	0.054

Table 9. Weight loss of Cu in NaOH

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N NaOH	0.003	0.004	0.006	0.008	0.01
0.5 N NaOH	0.002	0.003	0.006	0.01	0.012
1 N NaOH	0.001	0.002	0.003	0.004	0.005
4 N NaOH	0.003	0.011	0.014	0.014	0.021

Table10. Weight loss of Cu in KOH

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N KOH	0.001	0.002	0.004	0.006	0.009
0.5 N KOH	0.002	0.004	0.009	0.011	0.013
1 N KOH	0.004	0.016	0.011	0.013	0.017
4 N KOH	0.0075	0.012	0.019	0.026	0.032

Table 11. Weight loss of Brass in HNO₃

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N HNO ₃	0.002	0.003	0.004	0.005	0.006
0.5 N HNO ₃	0.001	0.003	0.006	0.009	0.013
1 N HNO ₃	0.001	0.004	0.006	0.018	0.019
4 N HNO ₃	1.619	1.063	1.634	2.246	2.974

Table 12. Weight loss of Brass in H₃PO₄

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N phosphoric acid	0.005	0.009	0.012	0.018	0.026
0.5 N phosphoric acid	0.008	0.013	0.017	0.026	0.036
1 N phosphoric acid	0.011	0.016	0.022	0.034	0.042
4 N phosphoric acid	0.017	0.029	0.038	0.046	

Table 13. Weight loss of Brass in NaOH

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N NaOH	0.006	0.007	0.009	0.096	0.104
0.5 N NaOH	0.011	0.01	0.09	0.007	0.006
1 N NaOH	0.017	0.005	0.003	0.002	0.001
4 N NaOH	0.003	0.007	0.009	0.0109	0.012

Table 14. Weight loss of brass in KOH

Weight loss at	1 h	2 h	3 h	4 h	5 h
0.1 N KOH	0.001	0.002	0.003	0.005	0.007
0.5 N KOH	0.002	0.004	0.007	0.012	0.015
1 N KOH	0.001	0.003	0.005	0.008	0.013
4 N KOH	0.004	0.007	0.01	0.015	0.019

Conclusion

The corrosion study results that are found out on Fe, Cu and Brass under different media suggest that metals are highly corroded in acids, as compared to bases and neutral solutions. The rate of corrosion increases with time as well as with concentrations.

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