STUDIES ON THE CORROSION OF ALUMINIUM AND ITS ALLOYS IN ACID SOLUTIONS : EFFECT OF TEMPERATURE

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ABSTRACT

The corrosion of aluminium and its alloys in hydrochloric acid solutions was studied in the temperature range 32-50° C. Energy of activation and temperature coefficient were calculated. The results obtained favour the activation controlled mechanism for the dissolution of aluminium and its alloys in this medium.

INTRODUCTION

The corrosion of 92 per cent aluminium alloy[1], pure aluminium 99.5 per cent[2], 98.8 per cent aluminium[3], aircraft aluminium-copper[4] and aluminium-zinc[5] alloys in hydrochloric acid solutions has been investigated in detail in this laboratory. This paper covers the effect of temperature on the corrosion of these alloys.

EXPERIMENTAL

The aluminium sheets (S.W.G. 22) had the following compositions: (A1-I)—SIB HH aluminium 99.5 (min.), copper 0.05 (max.), iron 0.4 (max.), manganese 0.05 (max.), and silicon 0.3 (max.) per cent; (A1-II)—aluminium 98.8, iron 0.62, silicon 0.13, copper 0.1 per cent, and balance trace elements including manganese; (A1-III)—DTD.687A(WP)—zinc 4.5-6.5, chromium 0.5 (max.), copper 1.5 (max.), iron 0.5 (max.), manganese 0.3-1.0, magnesium 2.0-3.5, silicon 0.5 (max.), titanium 0.3 (max.) per cent, and rest aluminium. The metal coupon was punched in one piece with a steel die. It was of a circular design to minimise the edge effects, diameter 2 cm. with a handle 3 cm. long and 0.3 cm. wide, the total weight being 750-900 mg, and apparent surface area 6.3 cm^2. The corrosion rates, expressed as mg dm^{-2} hr^{-1}, were determined under the following conditions: (a) concentration of hydrochloric acid 0.75, 1.0, 1.25, 1.5 and 2.0 N; (b) temperature 32-50° C $\pm$0.1° C; and (c) immersion period 1 and 2 hours. At the end of the immersion period the geometrical shape of the coupon remained unaltered. The corrosion rates were reproducible to $\pm$ 5 per cent. The experimental details have been described in previous papers.

SUMMARY OF RESULTS AND DISCUSSION

Effect of temperature on corrosion rate is one of the important factors which determines the mechanism of dissolution of metals. Table 1 shows the effect of temperature on the corrosion rate of various aluminium alloys. The corrosion rate is increased with increase in acid concentration as well as increase in temperature. The plots of log. corrosion rate against the reciprocal of temperature give straight lines, whose slopes are used to calculate the energy of activation of the rate controlling process from the Arrhenius equation. The values obtained are 23,800; 23,800; and 40,800 calories per mole respectively for A1-I, A1-II, and A1-III in 1N hydrochloric acid. Earlier work done in this laboratory gave values of the order of 13,200 and 9,150 calories per mole, respectively for 92 per cent aluminium alloy and A1-I in sodium hydroxide[6]. Streicher[7] has reported a value of 13,700 calories per mole in this medium. Sekerka[8] has obtained values between 1,400 and 10,200 calories per mole for aluminium in the acid concentration range 0.05-1. ON, and pointed out that at lower concentration up to 0.1N the dissolution rate is dependent on the rate of diffusion of hydrogen ion towards the metal surface, whereas above 0.5N the rate of discharge of the hydrogen ion is the determining factor.

TABLE 1: *Effect of Temperature on Corrosion Rate*

Acid Conc., N	*Corrosion rate mg dm^{-2} hr^{-1}, for temp., K*									
	305	307	308	309	311	313	315	316	319	323
A1-I:										
1.0	143	—	162	—	—	265	—	420	666	1,438
1.25	295	—	440	—	—	1,150	—	1,582	2,095	3,240
1.5	475	—	1,375	—	—	2,080	—	3,360	4,310	5,250
2.0	2,225	3,985	—	4,585	5,100	5,580	—	—	—	—
A1-II:										
0.75	79	—	95	—	119	159	254	—	435	760
1.0	238	—	262	—	397	—	620	—	945	1,240
1.25	318	—	380	—	588	762	1,000	—	1,525	2,000
A1-III:										
1.0	1,050	—	1,205	—	2,915	3,300	5,800	—	—	—

Khitrov and coworkers[9, 10] found that for aluminium in hydrochloric acid the plot of log. corrosion rate against the reciprocal of temperature was linear up to 40° C; beyond that the dissolution process was diffusion controlled and the temperature coefficient was as low as 1.31. Akulov and Khimchenko[11] have studied the effect of temperature on steel in 5 per cent hydrochloric acid, and found the temperature coefficient of the reaction in the range 1.6-3.7, and the corresponding energy of activation between 30,900 and 32,900 calories per mole. Gardner[12] has stated that if the temperature coefficient for a ten-degree change is 1.2-1.5 the process is diffusion controlled, and if it is 1.8-4.1 the process is activation controlled. The values of the temperature coefficient calculated from the present data are 2.94, 2.61, and 5.30 respectively, for A1-I, A1-II and A1-III. Streicher[7] has stated that the dissolution rate approximately doubles with an increase of 10°C and that this is generally considered to be true for homogeneous chemical reactions. Bryan[13] has also observed that the corrosion rate of aluminium in citric acid solutions under static conditions is approximatley doubled per 10°C rise in temperature; agitation had little effect.

From the values of the energy of activation and temperature coefficient of the reaction, it appears that the corrosion process for different aluminium compositions during the present work is controlled by activation. This checks well with the value of 0.12 for the slope of the Tafel plot during cathode polarization[2,8].

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REFERENCES

1. J. Sundararajan, J. Sci. and Ind. Research, **20D,** 137 (1961).
2. T. L. Rama Char and K. G. Sheth, "Second International Congress on Metallic Corrosion, New York, 1963"; proceedings under publication.
3. K. G. Sheth and T. L. Rama Char, Australasian Corrosion Engineering, **6**, No. 7, 23 (1962).
4. K. G. Sheth and T. L. Rama Char, Werkstoffe U. Korrosion, **14,** 465 (1963).
5. K. G. Sheth and T. L. Rama Char, Corrosion, **18,** 218t (1962).
6. T. L. Rama Char and J. Sundararajan. "First International Congress on Metallic Corrosion, London, 1961"; Butterworths, London, 129 (1962).
7. M. A. Streicher, Trans. Electrochem. Soc., **93,** 285 (1948).
8. I. Sekerka, Werkstoffe U. Korrosion, **10,** 383 (1959).
9. V. A. Khitrov and V. I. Shatalova, Zhur. Prikl. Khim., **34,** 1163 (1961).
10. V. A. Khitrov, I. S. Smol'yaniov, V. I. Shatalova, and Yu. I. Sadovskaya, Russian J. Phys. Chem., **36,** No. 5, 556 (1962).
11. N. S. Akulov and N. V. Khimchenko, Materialy v Khim. Mashinostroenii, **14,** 117 (1953).
12. G. S. Gardner, Corrosion, **16,** 312t (1960).
13. J. M. Bryan, J. Sci. Food Agri., **1,** No. 3, 84 (1950).