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A DISSOLUTION RATE STUDY
IN HYDROFLUORIC ACID OF TITANIUM
AND THE ALPHA SOLID SOLUTIONS OF OXYGEN IN TITANIUM

BY

JOHN LEIGH RATLIFF

A

THESIS

submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
in partial fulfillment of the work required for the
Degree of
MASTER OF SCIENCE IN METALLURGICAL ENGINEERING

Rolla, Missouri

1960

Approved by

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ABSTRACT

The dissolution mechanism of titanium in hydrofluoric acid was studied by collecting the hydrogen evolved during the dissolution reaction. A concentration range of 0.05 N to 0.50 N and a temperature range of 15°C to 45°C were employed for the determination. Values of the reaction order and energy of activation were determined for both pure titanium and the alpha solid solutions of oxygen in titanium and found to be the same within experimental limits. This indicated that the reaction giving rise to hydrogen evolution on the surfaces of both pure titanium and the TiO_x alloys was the same. The order of the reaction was approximately $(3/4)$ and the activation energy was 6.9 ± 0.7 kcal/mole. These measurements were shown to be indicative of a diffusionally controlled process. The reaction involved the penetration and attack or removal of a sub-oxide layer with subsequent mass transfer of HF_{un} to the surface and direct chemical attack. Difference effect measurements made on some TiO_x alloys indicated that an electrochemical reaction was also occurring on the surface. The large value of the difference effect constant, 9.5, indicated that a secondary process was affecting the surface of the TiO_x alloys so as to render them more than 100% polarizable as predicted by an equation published in previous literature.

The reaction mechanism proposed from this study was the penetration and/or removal of a sub-oxide film on the

surface of the titanium with subsequent direct chemical attack. Diffusionally controlled chemical and electrochemical dissolution processes were thought to be occurring simultaneously on the surface.

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I. INTRODUCTION

Previous investigations⁽¹⁾ concerning the dissolution reaction of titanium in hydrofluoric acid have yielded rather limited information as to the exact nature of the process. With this viewpoint in mind it was decided that the dissolution of titanium in hydrofluoric acid merited further consideration.

Corrosion research, as pointed out by U. R. Evans,⁽²⁾ may be carried out with two objectives in mind. The first of these and perhaps the most fundamental includes studies undertaken to provide better scientific understanding of corrosion mechanisms. The second objective concerns studies carried out to yield information as to what material or protective process might minimize corrosive attack. This thesis is concerned with the first category and is primarily a study of the dissolution reaction mechanism of titanium in hydrofluoric acid.

The reaction mechanism was studied by determining the kinetics of the dissolution process so as to yield quantitative information relating to the order of the reaction and energy of activation.

The problem was extended to cover the kinetics of dissolution of homogeneous solid solutions of oxygen in titanium and the difference effect exhibited by these solid solutions in hydrofluoric acid. Similar quantitative information was derived from the kinetic study of the solid solutions as was obtained from the study of the

pure metal. The difference effect measurements led to further knowledge of the dissolution process and the effect of an internal anodic current on the dissolution rate.

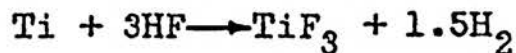
The above studies resulted in a correlation between the reaction order, activation energy, oxygen content of the titanium, and the reaction mechanism.

II. LITERATURE REVIEW

Early investigations concerning the corrosion properties of titanium firmly established the excellent corrosion resistance of the metal. Previous studies with both the impure and pure metal have yielded much information regarding reaction with and resistance to various chemical reagents. This research was concerned with the reaction mechanism of one of these reagents, hydrofluoric acid, and consequently specific literature pertaining to this subject was reviewed.

Investigations in this laboratory^(1,3) were undertaken to determine the reaction mechanism between titanium and hydrofluoric acid. Remington Arms titanium of 97.50 per cent purity and Battelle Memorial Institute titanium of 99.63 per cent purity were used in their studies. They established a dissolution mechanism from measurements of the reaction rate, difference effect, and dissolution potentials and observations of film formation and noble metal salt additions during dissolution experiments. The results of this were as follows:

(1) Reaction rate measurements: Hydrogen volume measurements revealed that titanium dissolves in hydrofluoric acid according to the reaction,



Reaction rate measurements based on the stoichiometry of the above reaction indicated that the

rate is an exponential function of acid concentration below 0.20 N according to

$$R = kC^{2/3}$$

and above 0.20 N the rate may be expressed by a linear function of concentration conforming to

$$R = 473C + 88$$

(2) Difference effect measurements: The presence of the positive difference effect obtained from the study was strong evidence of an electrochemical mechanism. Hydrofluoric acid solutions of 0.10 N, 0.24 N, 0.50 N, 1.00 N, and 2.00 N were employed for the investigation. As a result the difference effect was found to be independent of acid concentration and a linear function of current density up to 35 ma/cm². The relation between the difference effect, Δ , and the current density, I , was expressed as

$$\Delta = 5.70 I$$

(3) Dissolution potential measurements:

Open circuit potential measurements were made in eleven concentrations of hydrofluoric acid ranging from 0.0125 N to 1.00 N. The potential was found to decrease rapidly to more negative or anodic values from 0.0125 N to 0.20 N and then to level off and remain practically constant for the higher concentrations.

Closed circuit potentials in 0.50 N acid gave the anodic polarization curve for titanium. The potential was observed to increase linearly with current density to more positive or cathodic potentials.

(4) Film formation: A visible film was observed to form on the surface of the titanium in acid concentrations below 0.50 N. At the time of these investigations the composition of the film was not known, though it was assumed to be an oxide film which dissolved in concentrations above 0.50 N. More recent examination of the film by X-ray diffraction techniques⁽⁴⁾ revealed it to consist of titanium hydride.

(5) Noble metal salt additions: Noble metal salt additions of Pt, Au, Cu, Ag, and salts of less noble metals Ni, Fe, Mg, and Pb, arranged in the order of increasing hydrogen over-voltage, were added to the hydrofluoric acid solution during dissolution experiments. The first six salt additions produced a stimulating effect on the rate of dissolution. The magnitude of the effect was found to be closely related to the order of increasing hydrogen over-voltage. These observations lent support to an electrochemical mechanism of dissolution from a consideration of the activity of local cathodic areas.

The chemical similarity existing between titanium and zirconium suggests that a review of the literature pertaining to the zirconium-hydrofluoric acid reaction might provide the present research with additional information. Recent studies on zirconium in this laboratory⁽⁵⁾ and by Smith and Hill⁽⁶⁾ have postulated the slow step in the reaction mechanism of zirconium with hydrofluoric acid as diffusion of molecular HF to the surface of the metal and subsequent direct chemical attack by the un-ionized HF.

Smith and Hill studied the rate of reaction between zirconium and hydrofluoric acid by measuring the rate of build up of Zr^{95} in the hydrofluoric acid media. The rate of reaction was found to be first order with respect to un-ionized HF and an activation energy of 3.34 kcal/mole was obtained. In view of this low activation energy and first order reaction conditions diffusion of molecular HF to the surface of the metal was thought to be the slow step.

Similar studies on zirconium were also conducted in this laboratory to inquire more into the reaction mechanism between zirconium and hydrofluoric acid. The reaction rate was determined by measuring the rate of hydrogen evolution. The results of these investigations revealed that the rate was first order with respect to un-ionized HF. An activation energy of 3.80 kcal/mole was obtained. The first order reaction conditions and the

low activation energy seem to indicate that the rate controlling step was a physical process. On the basis of this information a reaction mechanism similar to that of Smith and Hill was proposed as follows:

Even the purest zirconium is covered with a thin tenacious layer of oxide. The surface of the zirconium can only react after this oxide layer has been removed or penetrated by the molecular HF. With the presence of such a film in mind the slow step in the dissolution mechanism was thought to consist of attack and removal of the oxide film and subsequent mass transfer of molecular HF to the surface by diffusion and direct chemical attack.

The present research was conducted to extend the previous work in hopes that a reaction mechanism can be proposed which will substantiate the ideas of transport controlled mechanisms. In view of the chemical similarity existing between titanium and zirconium such a mechanism would be expected. The previous studies concerning titanium all lack a determination of the activation energy for the dissolution process of titanium in hydrofluoric acid, therefore a temperature effect study will be conducted. This, supplemented by investigations concerning the solid solutions of oxygen in titanium should provide new and interesting insight as to the dissolution mechanism of titanium in hydrofluoric acid.

III. THE RATE OF DISSOLUTION OF TITANIUM IN HYDROFLUORIC ACID

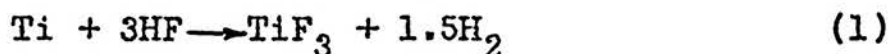
The rate of dissolution investigated in this phase of the research was based on hydrogen volume measurements in acid concentrations up to a maximum of 0.50 N.

1. Materials

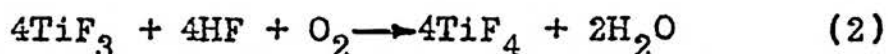
The titanium used in the following work was obtained from the Titanium Metals Corporation of America. It was a commercial grade of titanium, Ti-75A, having a nominal chemical composition of 0.10% Fe, 0.02% N, trace of O, and balance Ti.

2. Reactions involving titanium with hydrofluoric acid

Previous work⁽¹⁾ concerning the dissolution of titanium in hydrofluoric acid revealed the stoichiometry of the process as

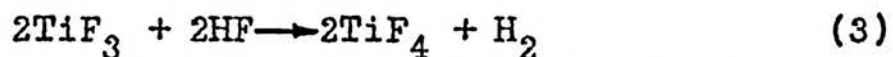


In the presence of oxygen the following reaction was also found to occur simultaneously with the main dissolution reaction between titanium and hydrofluoric acid.



This reaction resulted in a contraction of the volume of gas above the solution, and therefore special precautions were taken to eliminate oxygen from the apparatus. This was done by flashing the system with hydrogen prior to performing the dissolution experiment.

Another reaction involving the trivalent titanium fluoride also occurred.



Previous studies have indicated that this reaction proceeds very slowly and can not be prevented. However, its rate is so slow that it could not possibly influence the dissolution rate of the titanium.

3. Apparatus

The apparatus used for determination of the rate of dissolution of titanium in hydrofluoric acid is shown in Figures 1 and 2. It consisted mainly of a reactor flask to contain the acid solution and the specimen for dissolution, a belt driven stirring mechanism in conjunction with a mercury seal, a gas burette for collection and measurement of the hydrogen evolved during dissolution, and a constant temperature water bath for temperature control.

The capacity of the reactor flask was approximately 500 milliliters. It was lined with a thin coating of bees wax "c" for the purpose of protecting the glass walls of the flask from attack by the acid. The flask was designed so as to possess three openings all of which could be fitted with standard glass taper joints. One of the openings contained a glass fitting equipped with a three way stopcock "j" for the purpose of introducing hydrogen into the system to achieve the desired flushing action. Another of the openings contained the mercury seal "h" through which the stirring mechanism was inserted. The third opening contained a glass fitting which served

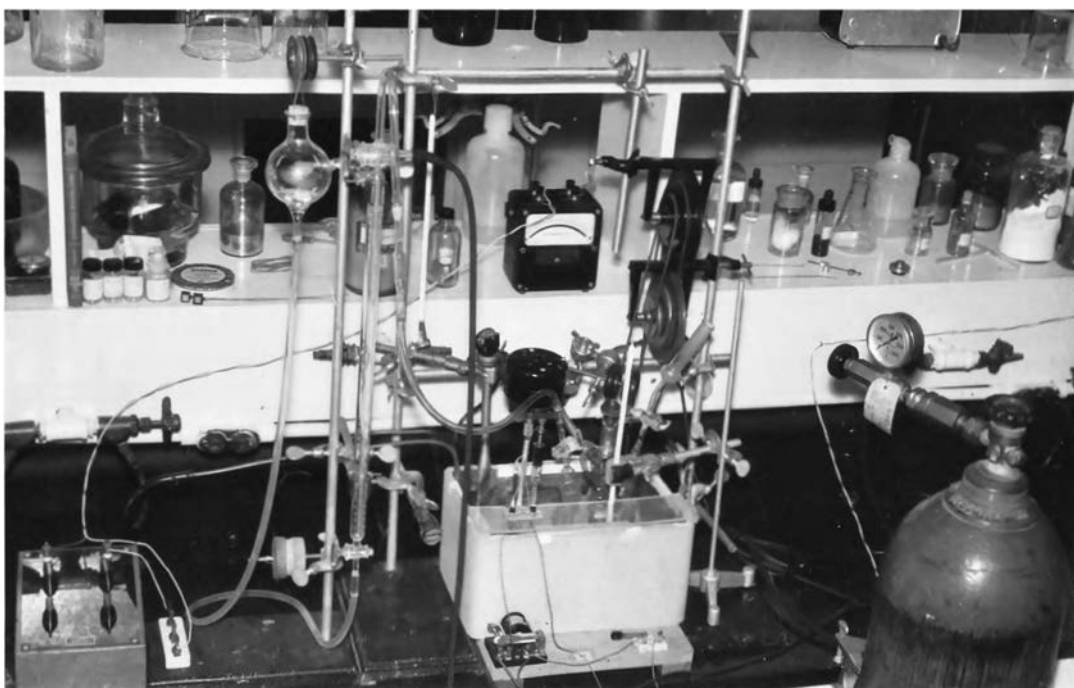
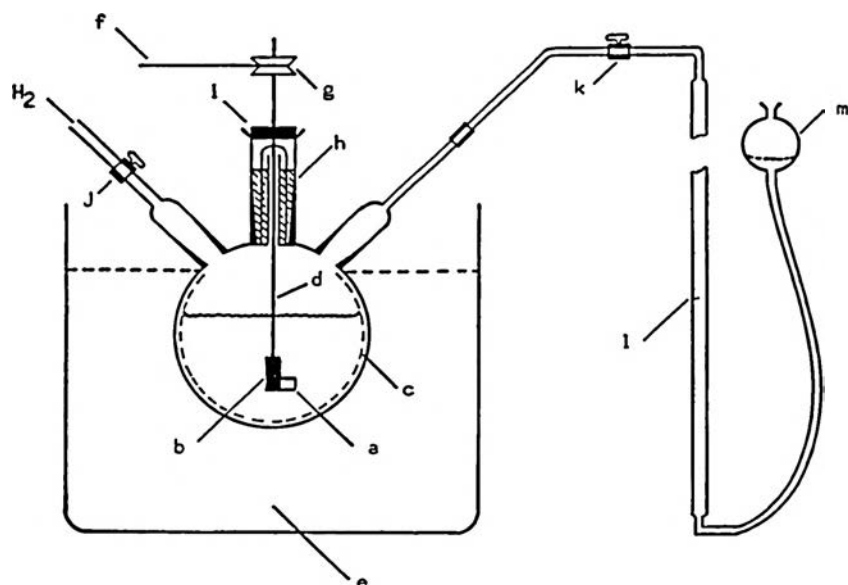
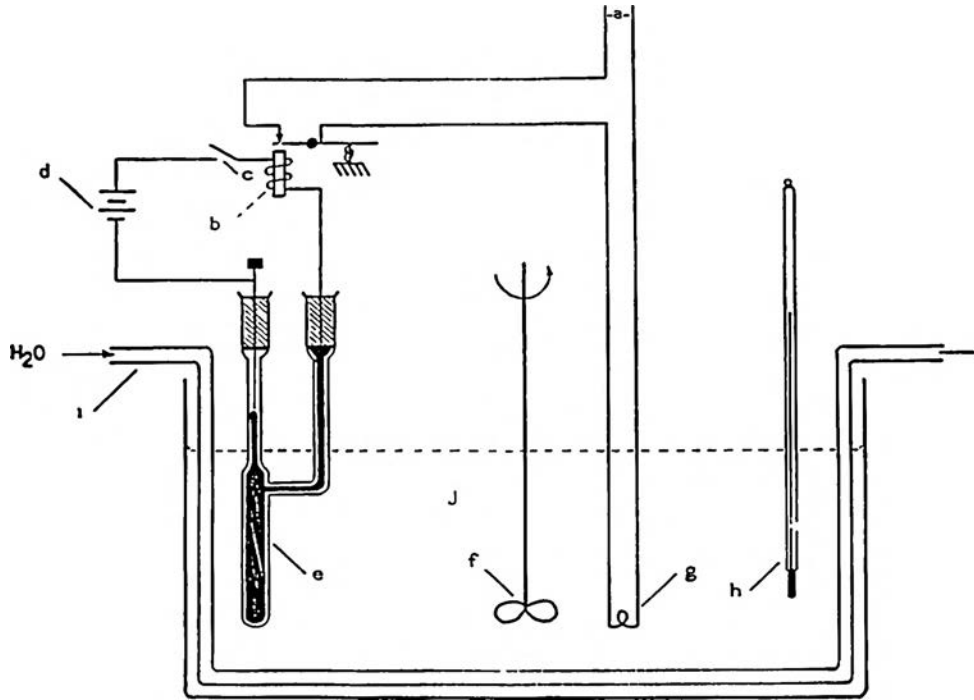


Figure 1
Photograph of apparatus for
dissolution experiments



- | | |
|--|----------------------------|
| a) Ti specimen positioned at 45° on P/C foot | h) mercury seal |
| b) PVC foot | i) ball bearing mount |
| c) beeswax lining | j) valve for inlet of gas |
| d) glass stirring rod | k) valve for outlet of gas |
| e) constant temperature water bath | l) gas burette |
| f) driving belt | m) leveling bulb |
| g) pulley | |

Figure 2
 Apparatus for determining the rate of
 dissolution in hydrofluoric acid of titanium
 and the alpha solid solution of oxygen in titanium



- | | |
|------------------------------|--------------------|
| a) line voltage, 110V | f) stirrer |
| b) relay normally closed | g) heating element |
| c) switch | h) thermometer |
| d) battery, 6V | i) cooling coil |
| e) mercury thermo-controller | j) water bath |

Figure 3

Wiring diagram of the thermoregulator with water bath

as an exit for the hydrogen gas evolved during the dissolution reaction. The reaction flask was positioned in the constant temperature bath "e" to such a depth so as to insure complete submergence of that part of the flask containing the acid.

The stirring mechanism consisted of a vertical glass rod "d". An aluminum driving pulley "g" was connected to the upper end of the rod and a (PVC) foot "b" was attached to the lower end of the rod. The titanium specimen "a" was fastened with bees wax to a flat portion of the plastic foot which was inclined at an angle of 45° with the vertical. The stirring mechanism had a vertical displacement of approximately three centimeters without disrupting the seal caused by the mercury contained in the seal. This displacement allowed for ample clearance of the titanium specimen above the acid solution while the system was being flushed with hydrogen prior to performing each experiment. The stirring mechanism was connected by means of a belt drive "f" to a high speed motor through a reduction pulley. The stirring speed after reduction was fixed at 200 r.p.m. by the particular pulley arrangement chosen.

The gas burette "l" used for collection and measurement of hydrogen was 100 milliliters in capacity. The lower end of the burette was connected by means of "Tygon" tubing to a leveling bulb "m". Proper adjustment of the leveling bulb throughout the course of an experiment

allowed the reaction to proceed at atmospheric pressure. The upper end of the burette contained a three way stopcock "k". When adjusted to one position the stopcock allowed an exit for the hydrogen gas during flushing. When adjusted to another position the stopcock allowed passage of the hydrogen evolved from the reaction into the gas burette to be collected and measured over distilled water contained in the leveling bulb. The gas burette was connected to the exit receptacle of the reaction flask by means of a piece of "Tygon" tubing.

The constant temperature water bath employed for the dissolution study was capable of controlling a set temperature within the limits of $\pm 0.10^{\circ}\text{C}$. The thermostating device relied on the expansion and contraction of mercury in a capillary. The wiring diagram with the water bath and other components is shown schematically in Figure 3.

4. Procedure

A specimen of titanium metal was cut from a sheet of the commercial metal and the edges filed down so that the specimen had a surface area of exactly one centimeter square. The dimensions were checked with the aid of a micrometer.

The specimen was mounted in bakelite so as to protect five of its six surfaces from further exposure. One surface of one centimeter square was left exposed. The mounting procedure followed was that usually employed

for mounting specimens for metallographic observations. Since the die used for the mounting operation was one inch in diameter, the specimen after mounting was surrounded by an excess of bakelite. The excess bakelite was trimmed away to facilitate further handling of the specimen.

Before subjecting the specimen to a dissolution rate investigation it was ground and polished. The polishing operation was followed by etching the specimen in 3 N hydrofluoric acid. This was done to remove the thin layer of distorted metal on the surface of the specimen which was incurred through grinding and polishing.

The reactor flask was filled with 300 milliliters of acid solution. Thirty minutes were allowed for the acid solution to come to thermal equilibrium with the water bath. The specimen of titanium was attached to the PVC foot of the stirring mechanism with bees wax. Before assembling the stirring mechanism into the reactor flask, the glass stirring rod was raised vertically, as already mentioned, and held at that position by a temporary support during the flushing operation which followed.

The air contained in the apparatus was displaced by opening valves "j" and "k" and allowing a steady stream of hydrogen to flow through the system. Valve "j" served as the inlet and valve "k" provided the exit for the gas. The hydrogen was allowed to pass through the apparatus for a minimum of ten minutes. Near the end of the flushing operation the air contained between valve "k" and the

water level in the gas burette "m" was displaced. This was done by first closing valve "k" and allowing hydrogen to displace the water in the burette and then opening valve "k" to allow the gas to escape. This cycle was repeated twice. After the flushing operation was completed the system was allowed to stand idle for five minutes. This provided time for the hydrogen contained within the apparatus to come to thermal equilibrium with its surroundings.

At this point the apparatus was fully prepared for use. The initial burette reading, the room temperature, and the barometric pressure were recorded. The stirring rod with the specimen was lowered into the acid solution, the belt drive was connected to the stirring mechanism, and the stop watch and stirring motor were started.

As soon as hydrogen gas was evolved from the reaction between the metal and acid, it displaced the water column in the burette. In order to equalize the pressure between the inside of the burette and the outside atmosphere the leveling bulb was adjusted continuously to the same water level as indicated by the burette.

The rate of dissolution was followed by recording the reading of the gas burette at regular time intervals. Time intervals of five or ten minutes were chosen depending on the speed of the reaction. The reaction was allowed to proceed until sufficient data had been accumulated to calculate an average maximum rate for the dissolution. The rate was expressed in terms of $\text{mm}^3/\text{cm}^2 \text{ min.}$

When the experiment was completed the stirring mechanism was removed from the reactor flask. The specimen was flushed with distilled water to stop the reaction on the surface of the metal. A siphon was used to remove the acid solution remaining in the flask. The room temperature and barometric pressure were recorded again so that an average of the temperature and pressure might be taken over the duration of the investigation. The recorded volumes were reduced to standard conditions.

5. Results

The dissolution of titanium at four different acid concentrations, 0.05 N, 0.075 N, 0.10 N, and 0.50 N and at four temperatures, 15°, 25°, 35°, and 45°C was investigated. These results are tabulated in Tables I through XVII in the Appendix and summarized in Table A. From the data collected both the order of the reaction and the energy of activation for the reaction were determined.

A. Sample calculation of reaction rate

The following calculation was taken from the data in Table IV Run No. 1 in the Appendix.

Average room temperature = 31.5°C

Average barometric pressure = 738.6 mm Hg

Pressure corrections:

(1) Correction for vapor pressure of water at
31.5°C = 34.7 mm Hg

(2) Temperature correction to brass scale on
barometer = 3.8 mm Hg

Corrected average barometric pressure = 700.1 mm Hg

Table A

Summary of Dissolution of Ti in HF Taken from Tables I through XVII in the Appendix

<u>Temp.</u> <u>(°C)</u>	<u>Conc.</u> <u>(moles/liter)</u>	<u>Rate</u> <u>(mm³/cm² min)</u>	<u>Avg. Rate</u> <u>(mm³/cm² min)</u>
15.0	0.05	41.3	
15.0	0.05	41.3	41.3
15.0	0.075	52.2	
15.0	0.075	48.3	50.3
15.0	0.10	64.5	
15.0	0.10	68.1	66.3
15.0	0.50	235.0	
15.0	0.50	241.0	238.0
25.0	0.05	58.8	
25.0	0.05	60.8	59.8
25.0	0.075	91.7	
25.0	0.075	91.4	91.6
25.0	0.10	121.0	
25.0	0.10	120.0	121.0
25.0	0.50	369.0	
25.0	0.50	366.0	368.0
25.0	1.00	727.0	
25.0	1.00	630.0	679.0
35.0	0.05	93.3	
35.0	0.05	90.9	92.1
35.0	0.075	113.0	
35.0	0.075	108.0	111.0
35.0	0.10	165.0	
35.0	0.10	168.0	167.0
35.0	0.50	582.0	
35.0	0.50	579.0	581.0
45.0	0.05	118.0	
45.0	0.05	116.0	117.0
45.0	0.075	192.0	
45.0	0.075	189.0	191.0
45.0	0.10	239.0	
45.0	0.10	270.0	
45.0	0.10	254.0	254.0
45.0	0.50	870.0	
45.0	0.50	1070.0	970.0

Initial burette reading = 10.40 ml

Correction of initial reading to standard conditions:

$$10.40 \times \frac{273}{304.7} \times \frac{700.1}{760} = 8.60 \text{ ml}$$

This type of calculation was applied to each burette reading as the reaction proceeded.

Values of ΔV were calculated between each burette reading as can be seen from a portion of Table IV.

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.60	0.00
5	10.97	2.31
15	12.65	1.74
25	15.04	2.39✓
35	17.19	2.15✓
45	19.75	2.56✓

An average maximum value of ΔV was calculated over those values which were practically constant during the experiment and found to be 2.35 cm³. The average value of ΔV was converted into rate per unit area by the rate equation

$$R = \frac{1000 \Delta V}{A t} \quad (4)$$

where R is the rate expressed in mm³/cm² min, ΔV is the volume increment of gas collected in cm³, A is the surface area of the specimen in cm², and t is the time interval over which the measurement was taken, expressed in minutes. Application of equation (4) to the example being discussed yields

$$R = \frac{1000 \times 2.35}{1.00 \times 10} = 235 \text{ mm}^3/\text{cm}^2 \text{ min}$$

B. Reaction order

Observations of the reaction rate data with respect to hydrofluoric acid concentration suggested the rate to

be dependent only on the acid concentration. Accordingly the rate was expressed by the exponential rate equation

$$R = kC^n \quad (5)$$

where R is the reaction rate ($\text{mm}^3/\text{cm}^2 \text{ min}$), k is the reaction rate constant ($\text{mm}^3 \text{ liters}/\text{cm}^2 \text{ min mole}$), C is the acid concentration (moles/liter), and n is an exponential term. Plots of $\ln R$ versus $\ln C$ yielded straight lines as shown in Figure 4 with slope, n . The reaction order for the dissolution process was obtained from the average slopes of these plots.

The straight line plots on Figure 4 numbered 1 through 4 represent temperatures of 15°C , 25°C , 35°C , and 45°C respectively. The equations for the straight lines are:

$$Y = 0.78 X + 6.00 \quad (6)$$

$$Y = 0.78 X + 6.51 \quad (7)$$

$$Y = 0.81 X + 5.92 \quad (8)$$

$$Y = 0.89 X + 7.53 \quad (9)$$

The reaction order as determined from the above equations was found to be 0.81, therefore the rate of dissolution is expressed as

$$R = kC^{0.81} \quad (10)$$

C. Activation energy

Values of the reaction rate constant were calculated from equation (10) and summarized in Table B. The energy of activation was determined from an Arrhenius plot of $\ln k$ versus $1/T$ as shown in Figure 5. The slope of the plot is related to the activation energy by

$$\text{Slope} = - \frac{E_a}{R} \quad (11)$$

where E_a is the activation energy in cal/mole, and R is the gas constant expressed in cal/mole deg.

The equation for the straight line shown in Figure 5 is:

$$Y = -3.83 \times 10^3 X + 19.39 \quad (12)$$

where -3.83×10^3 is the slope. Application of equation (11) gives the activation energy.

$$\begin{aligned} -3.83 \times 10^3 &= - \frac{E_a}{1.99} \\ E_a &= 7.60 \text{ kcal/mole} \end{aligned}$$

In all cases the rate of dissolution showed a small induction period with the rate increasing to a maximum, holding constant for a short period of time, and then diminishing slowly. In acid concentrations of 0.50 N and smaller the surface of the titanium was covered with a black film of titanium hydride⁽⁴⁾, the thickness of which seemed to increase at lower acid concentrations.

Table B

Summary of Reaction Rate Constants
of Titanium in HF Solutions

	<u>15°C</u>	<u>25°C</u>	<u>35°C</u>	<u>45°C</u>
$k, \frac{\text{mm}^3 \text{ liters}}{\text{cm}^2 \text{ min equiv}}$	437	714	1026	1575
$k, \frac{\text{mg Ti liters}}{\text{cm}^2 \text{ min equiv}}$	0.623	1.02	1.46	2.24

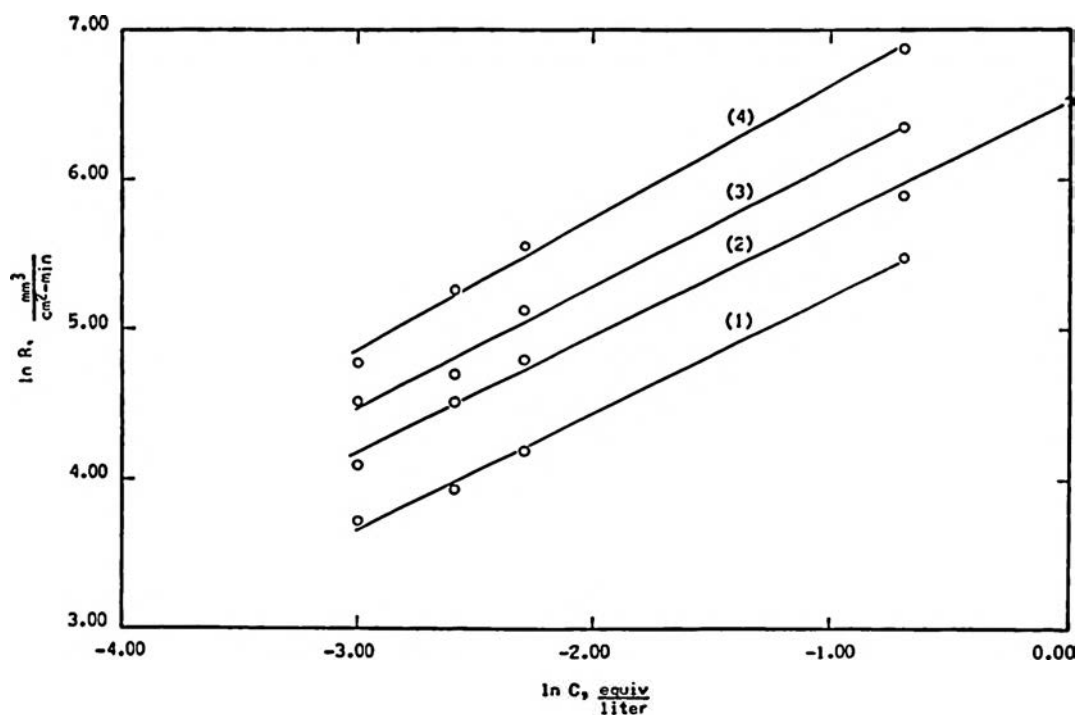


Figure 4

Determination of reaction order over the concentration range 0.05 N HF-0.50 N HF

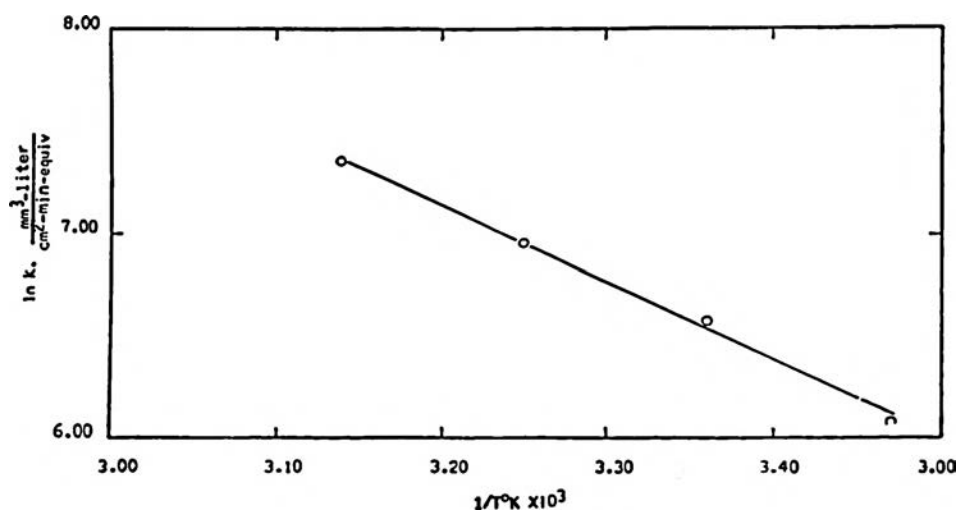
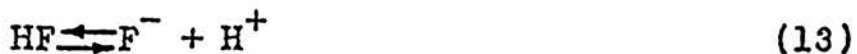


Figure 5

Determination of activation energy over the temperature range 15°C-45°C in (0.05-0.50) N HF

IV. THE RATE OF DISSOLUTION OF TITANIUM IN HYDROFLUORIC ACID · HYDROCHLORIC ACID SOLUTIONS

The rate of dissolution of titanium in HF·HCl solutions was conducted to determine whether the shift of the equilibrium



influenced the rate of reaction, the order of reaction, or the activation energy.

Addition of hydrochloric acid to the hydrofluoric acid solutions greatly increased the hydrogen ion concentration thereby shifting the equilibrium (13) to the left. Hydrochloric acid was chosen as the acid for adjusting the equilibrium because of its large hydrogen ion concentration in solution and its inability to react with titanium⁽³⁾

The composition of the titanium used for these investigations is given in Chapter III.

1. Apparatus and procedure

The apparatus was the same as that used previously for dissolution rate measurements as shown in Figure 2.

The procedure was modified over the description given in Chapter III only in that hydrochloric acid additions were made to all the hydrofluoric acid solutions used in the experiments. Each solution contained a sufficient amount of hydrochloric acid to make it 1.00 N. with respect to hydrochloric acid.

2. Results

The dissolution of titanium was investigated at four different hydrofluoric acid concentrations, 0.05 N,

0.075 N, 0.10 N, and 0.50 N, all of which were 1.00 N with respect to hydrochloric acid and at two temperatures of 25°C and 35°C. Experiments were also conducted at 15°C and 45°C at the single concentration of 0.10 N HF·1.00 N HCl. These results are tabulated in Tables XVIII through XXVII and summarized in Table C. From the data collected both the order of the reaction and the energy of activation for the reaction were determined according to the procedure previously outlined in Chapter III.

A. Reaction order

The reaction order was determined from an average slope of plots of $\ln R$ versus $\ln C$ as shown in Figure 6. The straight line plots on Figure 8 which are numbered 1 and 2 represent temperatures of 25°C and 35°C respectively. The equations for the straight lines are:

$$Y = 0.75 X + 6.70 \quad (14)$$

$$Y = 0.76 X + 7.13 \quad (15)$$

The reaction order as determined from the plots was found to be 0.76, therefore the rate of dissolution is expressed as

$$R = kC^{0.76} \quad (16)$$

B. Activation energy

The energy of activation was determined from the slope of a plot of $\ln k$ versus $1/T$ as shown in Figure 7. Values of the reaction rate constants used in this plot were calculated from equation (16) and summarized in Table D. The equation for the straight line shown in Figure 7 is:

$$Y = -3.50 \times 10^3 X + 18.48 \quad (17)$$

Table C

Summary of Dissolution of Ti in HF·HCl Taken from Tables XVIII through XXVII in the Appendix

<u>Temp.</u> <u>(°C)</u>	<u>Conc.</u> <u>(moles/liter)</u>	<u>Rate</u> <u>(mm³/cm² min)</u>	<u>Avg. Rate</u> <u>(mm³/cm² min)</u>
15.0	0.10	99.8	
15.0	0.10	94.7	97.3
25.0	0.05	80.6	
25.0	0.05	81.0	80.8
25.0	0.075	104.0	
25.0	0.075	115.0	110.0
25.0	0.10	149.0	
25.0	0.10	145.0	147.0
25.0	0.50	467.0	
25.0	0.50	455.0	461.0
35.0	0.05	128.0	
35.0	0.05	134.0	131.0
35.0	0.075	168.0	
35.0	0.075	166.0	167.0
35.0	0.10	193.0	
35.0	0.10	225.0	209.0
35.0	0.50	736.0	
35.0	0.50	750.0	743.0
45.0	0.10	316.0	
45.0	0.10	311.0	314.0

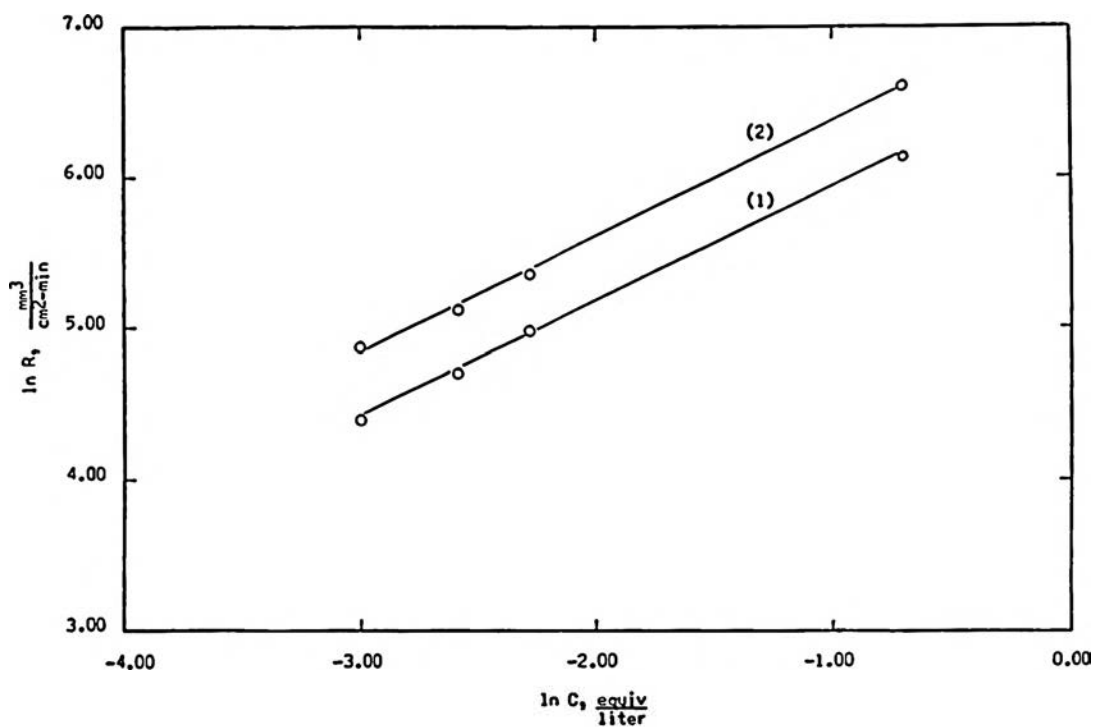


Figure 6

Determination of reaction order over the concentration range (0.05 N HF-0.50 N HF)·1.00 N HCl

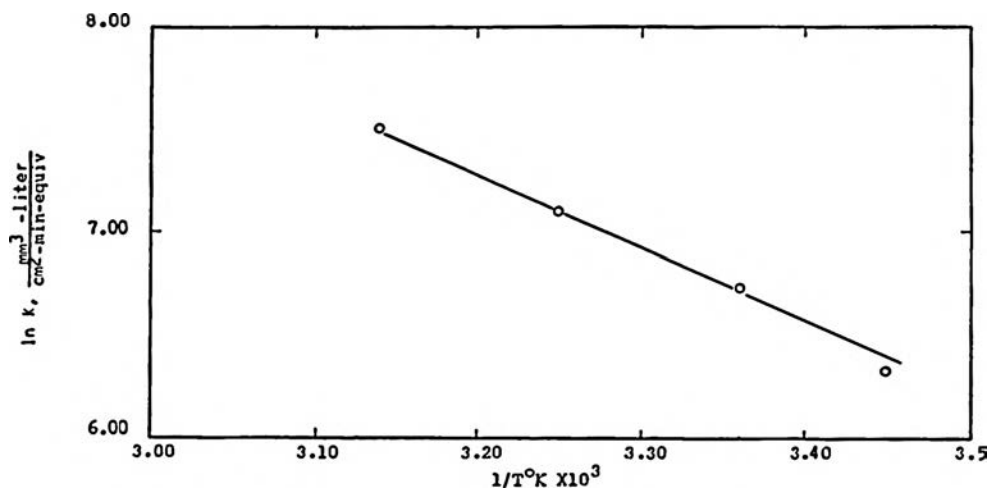


Figure 7

Determination of activation energy over the temperature range 15°C-45°C in 0.10 N HF·1.00 N HCl

therefore
$$-3.50 \times 10^3 = -\frac{E_a}{1.99}$$

$$E_a = 6.93 \text{ kcal/mole}$$

The behavior of the titanium specimens in HF·HCl solutions was similar to that described in Chapter III for titanium in HF solutions.

The reaction rate in each case showed a slight increase over experiments carried out under similar conditions in plain hydrofluoric acid solutions. This seemed to indicate a dependency of the reaction rate on the concentration of un-ionized HF since the HF·HCl solutions contained a larger concentration of molecular HF.

Table D

Summary of Reaction Rate Constants
of Titanium in HF·HCl Solutions

	<u>15°C</u>	<u>25°C</u>	<u>35°C</u>	<u>45°C</u>
k, $\frac{\text{mm}^3 \text{ liters}}{\text{cm}^2 \text{ min equiv}}$	559	845	1201	1805
k, $\frac{\text{mg Ti liters}}{\text{cm}^2 \text{ min equiv}}$	0.796	1.20	1.71	2.57

V. THE RATE OF DISSOLUTION IN HYDROFLUORIC ACID
HYDROCHLORIC ACID SOLUTIONS OF THE ALPHA SOLID SOLUTIONS
OF OXYGEN IN TITANIUM

Four specimens of the alpha solid solution of oxygen in titanium were prepared so that the effect of oxygen on the rate of dissolution might be studied. The oxygen contents of the four specimens were 4.971%, 7.023%, 7.981%, and 10.84% (weight per cent). The alpha solid solution region of the Ti-O phase diagram occupies the compositional range from 0 to 14.4% oxygen at room temperature.

The rate of dissolution of the alpha solid solution was conducted in HF·HCl solutions for reasons previously stated in Chapter IV. The dissolution experiments were performed in the same apparatus and according to the same procedure as described in Chapter III.

1. Preparation of alpha solid solution specimens

The Ti-O alloys were prepared by sintering titanium powder with titanium dioxide. The titanium powder (Belmont Smelting and Refining) was -65 mesh and was 98.27% pure as analyzed in this laboratory; the balance was assumed to be oxygen. The titanium dioxide was reagent grade, 99.9% pure. Precalculated amounts of dry titanium and titanium dioxide were weighed out, thoroughly mixed, and compacted in a punch and die assembly. A pressure of seven tons per square inch was applied to the die. After a powder specimen was compacted it was transferred to an alundum crucible. The alundum crucible containing the specimen was placed in the

reaction tube of a vacuum resistance furnace. The furnace was evacuated down to a pressure of approximately 15 microns. At this point the furnace was heated up to a temperature of 300°C. The temperature was controlled at this level for one hour. This allowed time for further drying and for evolution of any entrapped gases in the system. After the preliminary heating period the furnace was heated to 1400°C and controlled at this temperature for four hours. The final vacuum achieved by the system was of the order of two microns. At the end of the reaction period the reaction tube was sealed off from the surroundings by means of a stopcock and quenched in air. Upon removing the specimen from the reaction tube it appeared to be thoroughly sintered and was covered with a thin golden film. After grinding the layer from the surface, microscopic examination provided evidence that the specimen was homogeneous.

The specimen for dissolution was obtained by trimming the alloy down to a surface area of one centimeter square. The trimmings were ground and saved for analysis. Final sizing of the specimen was done on a belt grinder with the aid of a micrometer to check the dimensions.

Analysis of the Ti-O specimens prepared by the above procedure was performed by the hydrogen evolution method⁽⁷⁾ to obtain the exact composition of the specimens with respect to free titanium and oxygen.

2. Results

The following table gives the analyses and formulae of the four alpha solid solution specimens prepared for the

dissolution experiments.

Table E
Summary of the Alpha Solid Solution Specimens

<u>%O</u>	<u>Formula</u>
4.971	TiO _{0.157}
7.023	TiO _{0.226}
7.981	TiO _{0.260}
10.84	TiO _{0.365}

The dissolution of the four solid solution specimens was conducted at 25.0°C and in four different hydrofluoric acid concentrations of 0.05 N, 0.075 N, 0.10 N, and 0.50 N all of which were 1.00 N with respect to hydrochloric acid concentration. Experiments were also conducted at 15.0°C, 35.0°C, and 45.0°C in the single acid concentration of 0.10 N HF·1.00 N HCl. The results of these investigations are tabulated in Tables XXVIII through XLV in the Appendix and summarized in Table F. From the data collected, the order of the reaction, the energy of activation, and the variation of the dissolution rate with respect to oxygen content was determined.

A. Reaction order

The order of the reaction was obtained by the method previously described in Chapter III. A plot of $\ln R$ versus $\ln C$ was constructed for the determination as shown in Figure 8. The equation for the straight line shown on Figure 8 is:

$$Y = 0.83 X + 0.86 \quad (18)$$

The reaction order as determined from the above equation was 0.83, and the rate of dissolution followed the equation

$$R = kC^{0.83} \quad (19)$$

Table F

Summary of Dissolution of the Alpha Solid Solutions in
HF-HCl Taken from Tables XXVIII through LV in the Appendix

——— $\text{TiO}_{0.157}$ ———

Temp. (°C)	Conc. (moles/liter)	Rate ($\text{mm}^3/\text{cm}^2 \text{ min}$)	Avg. Rate ($\text{mm}^3/\text{cm}^2 \text{ min}$)
15.0	0.10	144.0	
15.0	0.10	132.0	138.0
25.0	0.05	92.6	
25.0	0.05	112.0	102.0
25.0	0.075	154.0	
25.0	0.075	174.0	164.0
25.0	0.10	228.0	
25.0	0.10	268.0	248.0
25.0	0.50	973.0	
25.0	0.50	875.0	924.0
35.0	0.10	283.0	
35.0	0.10	275.0	279.0
45.0	0.10	371.0	
45.0	0.10	360.0	366.0

——— $\text{TiO}_{0.226}$ ———

15.0	0.10	176.0	
15.0	0.10	159.0	168.0
25.0	0.05	88.0	
25.0	0.05	90.0	89.0
25.0	0.075	163.0	
25.0	0.075	151.0	157.0
25.0	0.10	204.0	
25.0	0.10	216.0	210.0
25.0	0.50	708.0	
25.0	0.50	721.0	715.0
35.0	0.10	338.0	
35.0	0.10	342.0	340.0
45.0	0.10	450.0	
45.0	0.10	444.0	447.0

Table F (continued)

Summary of Dissolution of the Alpha Solid Solutions in
HF·HCl Taken from Tables XXVIII through LV in the Appendix

—— $\text{TiO}_{0.260}$ ——

Temp. (°C)	Conc. (moles/liter)	Rate ($\text{mm}^3/\text{cm}^2 \text{ min}$)	Avg. Rate ($\text{mm}^3/\text{cm}^2 \text{ min}$)
15.0	0.10	137.0	
15.0	0.10	123.0	130.0
25.0	0.05	117.0	
25.0	0.05	118.0	118.0
25.0	0.075	186.0	
25.0	0.075	159.0	175.0
25.0	0.10	191.0	
25.0	0.10	194.0	193.0
25.0	0.50	681.0	
25.0	0.50	555.0	618.0
35.0	0.10	288.0	
35.0	0.10	292.0	290.0
45.0	0.10	412.0	
45.0	0.10	354.0	383.0

—— $\text{TiO}_{0.365}$ ——

15.0	0.10	137.0	
15.0	0.10	129.0	133.0
25.0	0.05	93.5	
25.0	0.05	107.0	100.0
25.0	0.075	205.0	
25.0	0.075	202.0	204.0
25.0	0.10	270.0	
25.0	0.10	221.0	246.0
25.0	0.50	770.0	
25.0	0.50	779.0	775.0
35.0	0.10	368.0	
35.0	0.10	349.0	359.0
45.0	0.10	486.0	
45.0	0.10	443.0	465.0

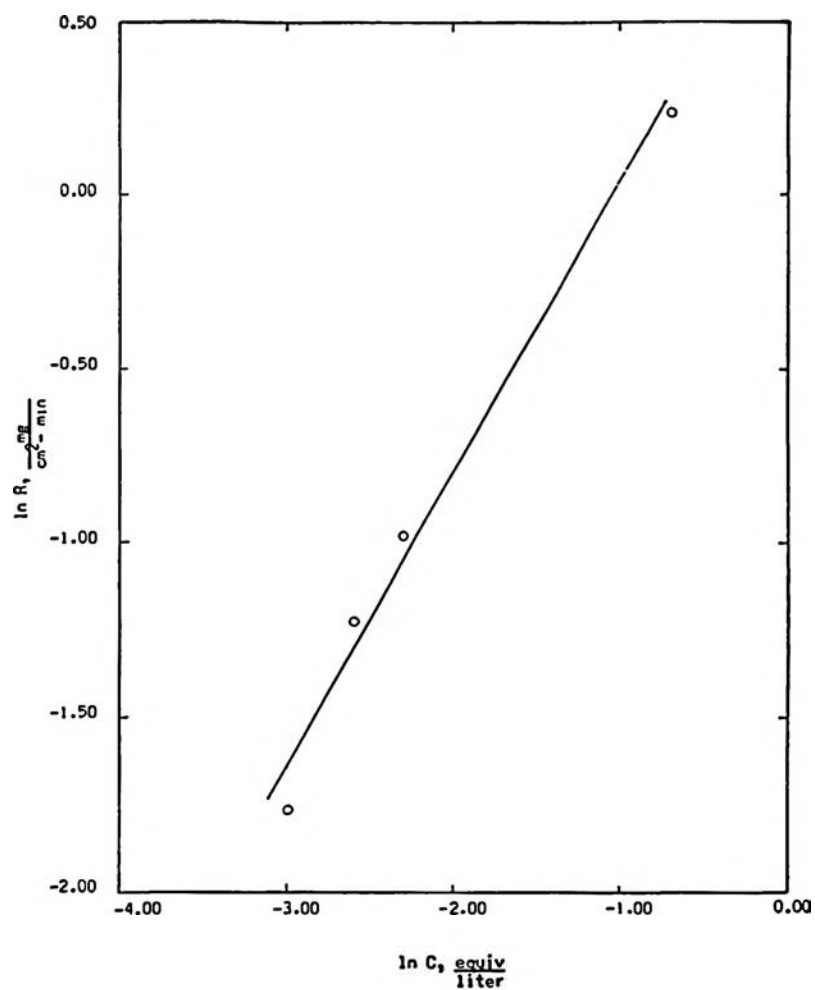


Figure 8

Determination of reaction order for $TiO_{0.157}$ over the concentration range (0.05 N HF-0.50 N HF)·1.00 N HCl at 25°C

where R is the dissolution rate ($\text{mg TiO}_x/\text{cm}^2 \text{ min}$) or ($\text{mm}^3/\text{cm}^2 \text{ min}$), k is the reaction rate constant (mg TiO_x liters/ $\text{cm}^2 \text{ min moles}$) or (mm^3 liters/ $\text{cm}^2 \text{ min moles}$), and C is the concentration of the acid (moles/liter).

B. Variation of the dissolution rate with oxygen content

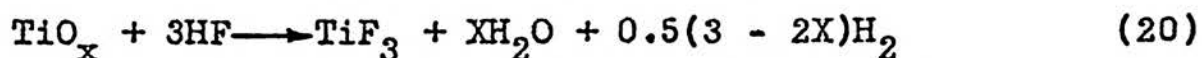
All of the TiO_x alloys were observed to evolve hydrogen at approximately the same rate for a given acid concentration and temperature. On the basis of these observations an average maximum rate of hydrogen evolution was calculated for each concentration and temperature. These values are given in Table G.

Table G

Average Values of the Hydrogen Evolution Rate for the TiO_x Alloys at the Temperatures and Acid Concentrations Investigated

<u>Concentration</u>	<u>($\text{mm}^3/\text{cm}^2 \text{ min}$)</u>			
	<u>15°C</u>	<u>25°C</u>	<u>35°C</u>	<u>45°C</u>
0.05 N HF		102.0		
0.075 N HF		175.0		
0.10 N HF	142.0	224.0	317.0	415.0
0.50 N HF		758.0		

The stoichiometry for the dissolution of TiO_x alloys has been formulated as⁽⁷⁾



On the basis of this reaction and a knowledge of both the TiO_x composition and the rate of hydrogen evolution the actual rate of dissolution for the TiO_x alloys was calculated in terms of $\text{mg TiO}_x/\text{cm}^2 \text{ min}$. See Table H.

Table H
Actual Dissolution Rates of the TiO_x Alloys
at the Temperatures and Acid Concentrations Investigated

<u>Formula</u>	———— (mg TiO _x /cm ² min) ————						
	25°C	25°C	15°C	25°C	35°C	45°C	25°C
	<u>0.05 N HF</u>	<u>0.075 N HF</u>	<u>0.10 N HF</u>	<u>0.10 N HF</u>	<u>0.10 N HF</u>	<u>0.10 N HF</u>	<u>0.50 N HF</u>
TiO _{0.157}	0.171	0.293	0.238	0.375	0.530	0.695	1.27
TiO _{0.226}	0.184	0.316	0.256	0.404	0.571	0.748	1.37
TiO _{0.260}	0.191	0.328	0.266	0.420	0.594	0.778	1.42
TiO _{0.365}	0.216	0.370	0.300	0.474	0.670	0.875	1.60

The variation of the dissolution rate of the alpha solid solution specimens in 0.10 N HF·1.00 N HCl at 25°C with respect to the atomic ratio (O/Ti) is shown in Figure 9. The experimental conditions from which the data for this plot were taken were chosen arbitrarily. The equation for the straight line in Figure 9 is:

$$Y = 0.478 X + 0.296 \quad (21)$$

With reference to the above equation Y is the dissolution rate (mg/cm² min) and X represents the atomic ratio (O/Ti).

C. Activation energy

The activation energy was determined by the method previously described in Chapter III. A plot of ln k versus 1/T was constructed for the determination as shown in Figure 10. The values of the reaction rate constants used for this determination were in terms of the rate of hydrogen evolution (mm³ liters/cm² min moles) instead of (mg liters/cm² min moles). The former system of units was adopted so that the plot as shown in Figure 10 would represent any general TiO_x composition. The values of the reaction rate constants were calculated from equation (19) and summarized in Table I. The equation for the straight line shown in Figure 10 is:

$$Y = -3.33 \times 10^3 X + 18.47 \quad (22)$$

$$-3.33 \times 10^3 = \frac{-E_a}{1.99}$$

therefore

$$E_a = 6.63 \text{ kcal/mole}$$

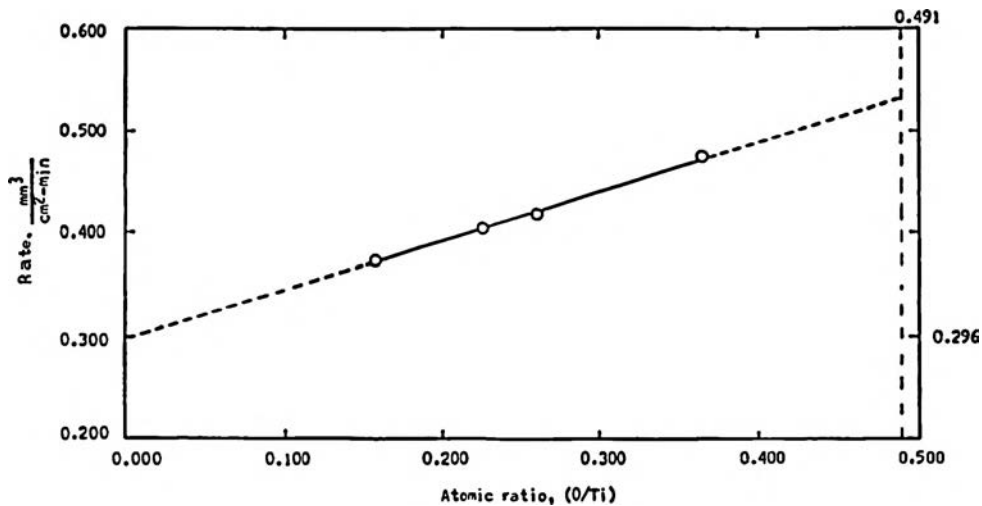


Figure 9

Dissolution rate variation of the alpha solid solutions
with respect to oxygen content in
0.10 N HF·1.00 N HCl at 25°C

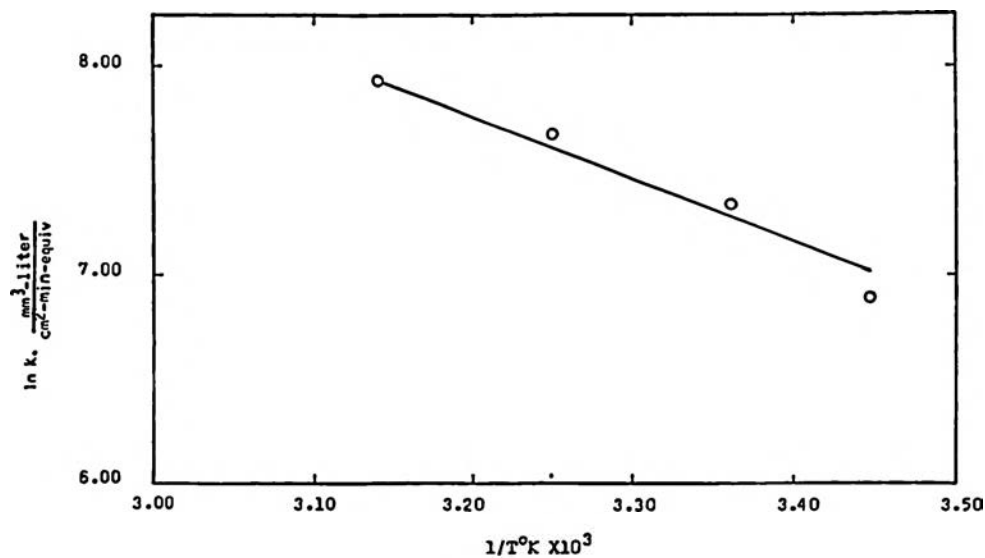


Figure 10

Determination of activation energy for the TiO_x alloys
over the temperature range 15°C-45°C
in 0.10 N HF·1.00 N HCl

Table I

Summary of Reaction Rate Constants for the
Alpha Solid Solutions in HF·HCl

	<u>15°C</u>	<u>25°C</u>	<u>35°C</u>	<u>45°C</u>
k, $\frac{\text{mm}^3 \text{ liters}}{\text{cm}^2 \text{ min equiv}}$	960.0	1513.0	2141.0	2803.0

VI. THE EFFECT OF STIRRING SPEED ON THE DISSOLUTION RATE OF TITANIUM IN HF·HCl SOLUTIONS

The effect of stirring speed on the dissolution rate was investigated so as to provide a reference state for future investigators wishing to reproduce the results of this research.

1. Principles

The rate of dissolution of a metal for a given acid concentration and temperature is mainly dependent on the transport rate of fresh acid to its surface and the rate of removal of reaction products from the interface. Both of these phenomena are influenced by the stirring speed and the geometry of the apparatus. The geometrical influence refers to the shape and construction of the reactor flask and its components (see Figure 2).

The effect of the apparatus construction on the dissolution rate was assumed to be constant for all the dissolution experiments conducted in this research. Therefore, variation of the stirring speed on the rate of dissolution with other conditions such as acid concentration and temperature being constant would establish the characteristics of the apparatus. In the event that future investigators should wish to reproduce the results of this research using a different apparatus design, reference to this work would provide the necessary information for the adjustment of the new apparatus to the conditions of the present research.

2. Results

The investigation of the dissolution rate with the stirring speed was conducted on specimens of the sheet metal and in an acid concentration of 0.10 N-1.00 N HCl at a temperature of 25°C. The results are tabulated in Table LVI in the Appendix and summarized in Table J. Figure 11 shows the variation of reaction rate with stirring speed.

Table J
Summary of the Effect of Stirring Speed
on the Dissolution Rate

<u>Stirring Speed</u> <u>(r.p.m.)</u>	<u>Rate</u> <u>(mm³/cm² min)</u>
45	47.7
90	80.3
160	127.0
200	147.0
250	162.0
310	176.0
400	183.0
460	189.0

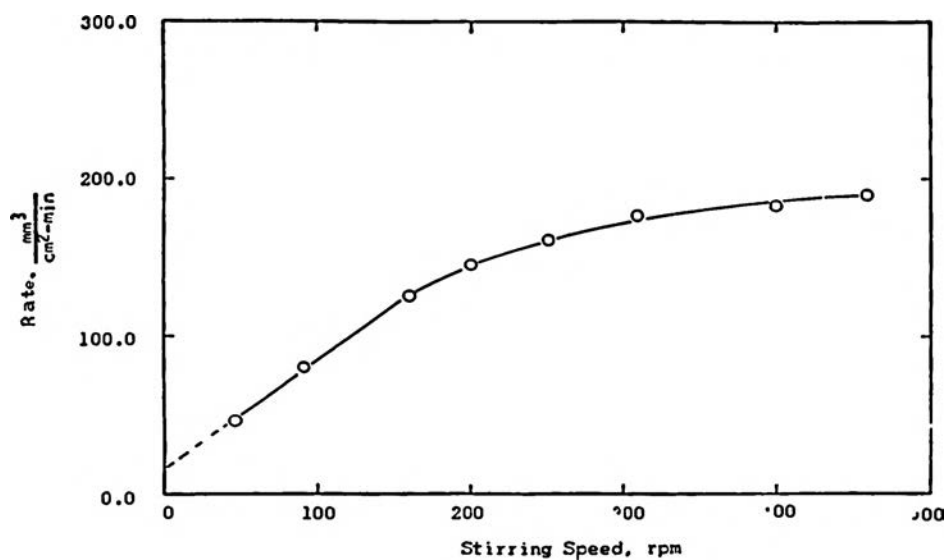


Figure 11

The effect of stirring speed on the dissolution rate of titanium in 0.10 N HF-1.00 N HCl at 25.0°C

VII. THE DIFFERENCE EFFECT IN HYDROFLUORIC ACID·
HYDROCHLORIC ACID SOLUTIONS ON THE ALPHA SOLID SOLUTIONS
OF OXYGEN IN TITANIUM

Difference effect measurements were made with samples of the alpha solid solutions of oxygen in titanium to obtain further information concerning the dissolution processes of both pure titanium and the alpha solid solutions.

1. Principles

When an active metal such as zinc is immersed in a corrosive medium, i.e. HCl, and connected to a more noble metal such as platinum the rate of hydrogen evolution on the less noble metal decreases⁽⁸⁾. This phenomena is known as the positive difference effect.

The difference effect for a given cell arrangement is determined by comparing the rate, V_1 , of hydrogen evolution during self dissolution of the metal in a corrosive medium with the rate, V_2 , observed during current flow in the cell. The flow of current produces a condition of anodic polarization on the less noble metal at the liquid-metal interface. The difference between the two rates, V_1 and V_2 , is the quantity known as the difference effect. For conditions where ($V_1 > V_2$) the difference effect is said to be positive and conversely when ($V_2 > V_1$) the difference effect is negative. The positive and negative difference effects refer to the dissolution rate as effected by an internal or external current flow between the anode and cathode of the cell.

The difference effect may be expressed in terms of volume units of hydrogen evolved using the following equation⁽⁹⁾

$$\Delta = V_1 + 6.97 I - V_t \quad (23)$$

where V_1 is the rate of self dissolution of the anode ($\text{mm}^3/\text{cm}^2 \text{ min}$), V_t is the total rate of hydrogen evolution from the anode and cathode while current, I , is flowing ($\text{mm}^3/\text{cm}^2 \text{ min}$), and Δ is the difference effect ($\text{mm}^3/\text{cm}^2 \text{ min}$). The factor, 6.97, converts the milliamperes passing through the cathode for one minute into mm^3 of hydrogen reduced on the cathode.

It is found experimentally that the positive difference effect can be expressed by the following empirical equation:

$$\Delta = KI \quad (24)$$

The combination of equations (23) and (24) yields an expression for K :

$$K = 6.97 + \frac{(V_1 - V_t)}{I} \quad (25)$$

The constant, K , shows the influence of the internal anodic current on the dissolution rate of the anode per milliampere of current flowing through the cell. In the absence of secondary surface phenomena which might tend to complicate the dissolution process, K should take on limiting values of 0 and 6.97.

The zero value indicates that the current has no effect on the dissolution rate of the anode. No difference effect is exhibited. The rate of hydrogen evolution from the

anode is the same for both the open and closed circuit conditions. This can be seen from the following example:

Assume that the:

Self dissolution rate, $V_1 = 100 \text{ mm}^3/\text{cm}^2 \text{ min}$

Total rate of dissolution with current flow, $V_t = 120 \text{ mm}^3/\text{cm}^2 \text{ min}$

Current density = $2.87 \text{ ma}/\text{cm}^2$

Applying equation (25),

$$K = 6.97 + \frac{(100-120)}{2.87} = 0 \text{ mm}^3/\text{ma min}$$

The maximum value of K, 6.97, indicates that the surface of the metal is polarized to 100 per cent of the attainable value. This condition is achieved only when the total rate of dissolution (anode + cathode) with current flowing is the same as that of the self dissolution (anode). The maximum polarization presents itself when hydrogen evolution on the cathode during current flow is completely annihilated by the difference effect at the anode. This can be seen from the following example:

Assume that the:

Self dissolution rate, $V_1 = 100 \text{ mm}^3/\text{cm}^2 \text{ min}$

Total rate of dissolution with current flow, $V_t = 100 \text{ mm}^3/\text{cm}^2 \text{ min}$

Current density = $5.00 \text{ ma}/\text{cm}^2$

Applying equation (25),

$$K = 6.97 + \frac{(100-100)}{5.00} = 6.97 \text{ mm}^3/\text{ma min}$$

The maximum and minimum values of K provide a convenient means of expressing the per cent polarizability, P, of different metals in terms of the constant, K.

$$\%P = \frac{100K}{6.97} = 14.35K \quad (26)$$

2. Apparatus

The apparatus used for the difference effect measurements was modified only slightly over that used in the dissolution experiments as described in Chapter III. The diagram of the apparatus with the modifications is shown in Figures 12 and 13.

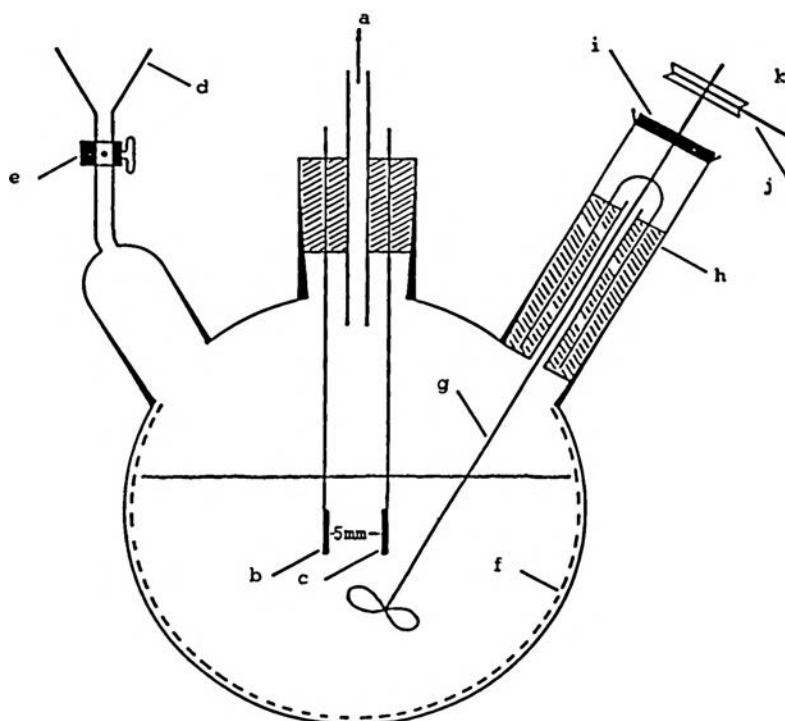
3. Procedure

The procedure was very similar to that used for the dissolution rate measurements as presented in Chapter III.

The same alpha solid solution specimens used in the dissolution experiments were also used for the difference effect measurements with the only exception being the specimen $TiO_{0.260}$. This specimen was badly corroded after the dissolution experiments, therefore it was replaced by a new specimen, $TiO_{0.263}$. Each specimen was modified only in that an electrical connection was made through the back of the bakelite mount and pressed against the unexposed surface of the specimen.

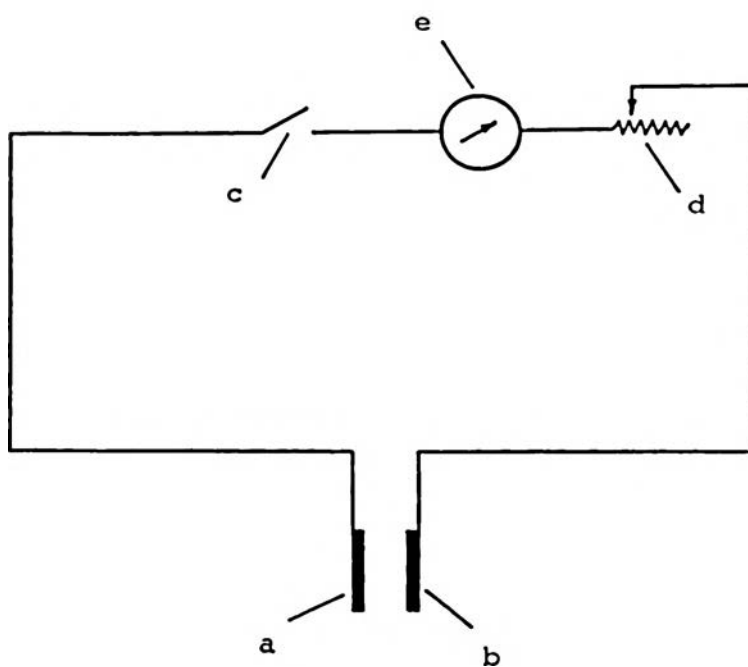
A platinized platinum electrode was also prepared to act as a cathode for the difference effect cell as shown in Figures 12 and 13. The surface area of the platinum electrode was four centimeters square and was mounted at a distance of five millimeters from the exposed surface of the solid solution specimen as shown in Figure 12.

After the apparatus had been assembled as shown in Figure 12, the flask was immersed in the water bath which was



- | | |
|--------------------------------|-----------------------|
| a) outlet to gas burette | f) beeswax lining |
| b) Pt electrode | g) glass stirring rod |
| c) TiO_x electrode | h) mercury seal |
| d) funnel for addition of acid | i) ballbearing mount |
| e) valve for inlet of hydrogen | j) driving belt |
| | k) pulley |

Figure 12
Apparatus for determining the difference effect
on the alpha solid solutions



- | | |
|-----------------------------|------------------------|
| a) TiO_x electrode | d) galvanometer |
| b) Pt electrode | e) variable resistance |
| c) switch | |

Figure 13
Wiring diagram for the difference effect

controlled at 25°C for all of the difference effect measurements.

The apparatus was flushed with hydrogen according to the procedure given in Chapter III. After displacing all the air within the system, a quantity of 300 ml of acid solution was introduced into the reactor flask. This quantity was the same as that previously used in the dissolution experiments and was sufficient to completely immerse the electrodes. The stopcocks were then closed and the dissolution rate observed in the same way as before. The solid solution specimen as assembled into the apparatus was mounted in a stationary position while the hydrofluoric acid solution was agitated with a stirring mechanism at 200 r.p.m.

The experiments were carried out in the following manner: Initially the rate of self dissolution (open circuit) was determined. This was followed by an observation of the dissolution rate and current flow (closed circuit). The first determination under current flow was made at the maximum current density, i.e. no resistance. The dissolution rate at the maximum current density was followed by an open circuit observation of the self dissolution rate. At the end of this interval the current was switched on again and the resistance box adjusted so as to obtain a measurement at a lower current density. This procedure was followed with a regular decrease of the current density after each reading at zero current until a series of six

or eight values of the dissolution rate at various current densities were obtained. Readings at two consecutive regular time intervals of five or ten minutes were taken for each open and closed circuit condition investigated. This usually provided sufficient time to clearly establish the dissolution rate. In a few instances more than two time intervals were employed.

4. Results

A. Sample calculations

According to Faraday's Law, one coulomb or 96500 ampere seconds of current liberate one gram equivalent weight of hydrogen gas. At standard conditions of temperature and pressure 96500 ampere seconds are equivalent to 11207 cm³ of hydrogen. Therefore

$$\frac{11207 \times 60}{96500 \times 1000} = 0.00697 \text{ cm}^3 \text{ of H}_2/\text{ma min}$$

or $1 \text{ ma} = 6.97 \text{ mm}^3 \text{ of H}_2/\text{min}$

On the basis of the above calculation, the rate of hydrogen evolution on the cathode due to a flow of internal current can be expressed as 6.97 I.

A sample calculation of the difference effect will now be shown using the data from Table LIX.

The average rate of self dissolution at the 72nd and 76th minutes (before current flow) is 858.4 mm³/cm² min.

The average rate of self dissolution at the 88th and 92nd minutes (after current flow) is 843.4 mm³/cm² min.

The average rate of self dissolution before and after the current flow is therefore:

$$V_1 = \frac{858.4 + 843.4}{2} = 850.9 \text{ mm}^3/\text{cm}^2 \text{ min}$$

The total rate of hydrogen evolution while current, 41.33 ma/cm², was flowing was an average of the rates obtained at the 80th and 84th minutes:

$$V_t = \frac{743.3 + 773.3}{2} = 758.3 \text{ mm}^3/\text{cm}^2 \text{ min}$$

By knowing the values of V_1 , V_t , and I , the difference effect can be calculated using equation (23):

$$\Delta = 850.9 + 6.97 \times 41.33 - 758.3 = 380.7 \text{ mm}^3/\text{cm}^2 \text{ min}$$

The value of K for this example may be calculated using equation (24):

$$K = \frac{\Delta}{I} = 9.21 \text{ mm}^3/\text{ma min}$$

B. Data

The difference effect measurements were conducted on three specimens of the alpha solid solutions, $\text{TiO}_{0.157}$, $\text{TiO}_{0.263}$, and $\text{TiO}_{0.365}$. The following table lists the acid concentrations investigated with respect to the three specimens.

Table K

The Acid Concentrations Investigated for the TiO_x Alloys

<u>Specimens</u>	<u>HF Concentrations (moles/liter)</u>
$\text{TiO}_{0.157}$	0.10, 0.50, and 0.75
$\text{TiO}_{0.263}$	0.50 and 0.75
$\text{TiO}_{0.365}$	0.20, 0.50, and 0.75

The experimental data obtained are given in Tables LVII through LXIV in the Appendix and summarized in Table L.

Table L

Summary of the Difference Effect on the TiO_x Alloys

Current Density (ma/cm ²)	—— $TiO_{0.157}$ ——		
	—— Δ (mm ³ /cm ² min) ——		
	<u>0.10 N</u>	<u>0.50 N</u>	<u>0.75 N</u>
2.00	19.28		
3.33	38.55		
5.00		51.50	
6.00	37.26		
8.40	67.08		
10.00		135.7	93.00
15.00		188.1	
20.00		200.7	197.7
25.00		247.6	
29.33			311.1
30.00		256.5	
41.33			380.7
44.00		455.4	
50.60			460.3
57.33			527.1
65.00			502.3
77.33			722.6
	—— $TiO_{0.263}$ ——		
2.00		17.20	
5.00		39.10	
10.05		121.5	
17.50			148.5
21.00		212.4	
25.00			263.6
31.50		326.8	
33.00			284.4
40.00		379.5	
44.00			350.5
50.00			467.5
56.00			535.5
65.00			614.3
70.25			717.9

Table L (continued)

Summary of the Difference Effect on the TiO_x Alloys

Current Density (ma/cm^2)	$TiO_{0.365}$		
	Δ (mm^3/cm^2 min)		
	<u>0.20 N</u>	<u>0.50 N</u>	<u>0.75 N</u>
3.00	27.20		
5.00		47.50	
5.83	46.90		
9.42	113.9		
10.00		102.3	
12.56	161.8		
15.00		150.3	110.6
20.00		166.0	
25.00		250.7	211.6
30.00		251.3	203.9
35.00			303.7
37.40		316.2	
40.00			356.5
45.00			416.7
52.31			529.4
62.50			580.0
70.25			650.0

Figures 14, 15, and 16 are plots of the difference effect, Δ , versus the current density, I , for the three solid solutions investigated. The equations for the straight lines as shown on the plots are:

$$\text{Figure 14: } \Delta = 9.7 I \quad (27)$$

$$\text{Figure 15: } \Delta = 9.6 I \quad (28)$$

$$\text{Figure 16: } \Delta = 9.3 I \quad (29)$$

From the above equations it can be seen that the values of K remain practically constant over the solid solution range investigated.

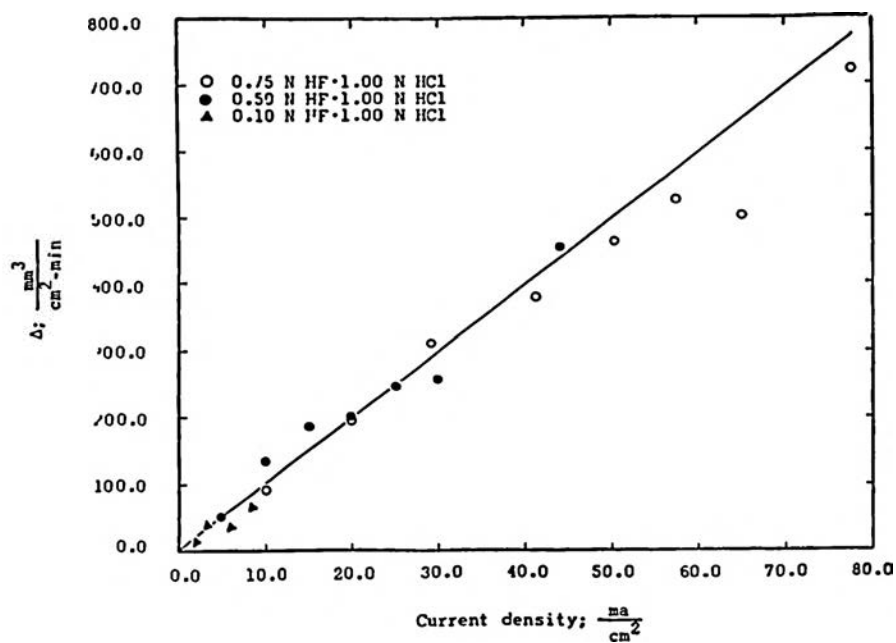


Figure 14

The effect of current density on the difference effect obtained from $\text{TiO}_{0.157}$

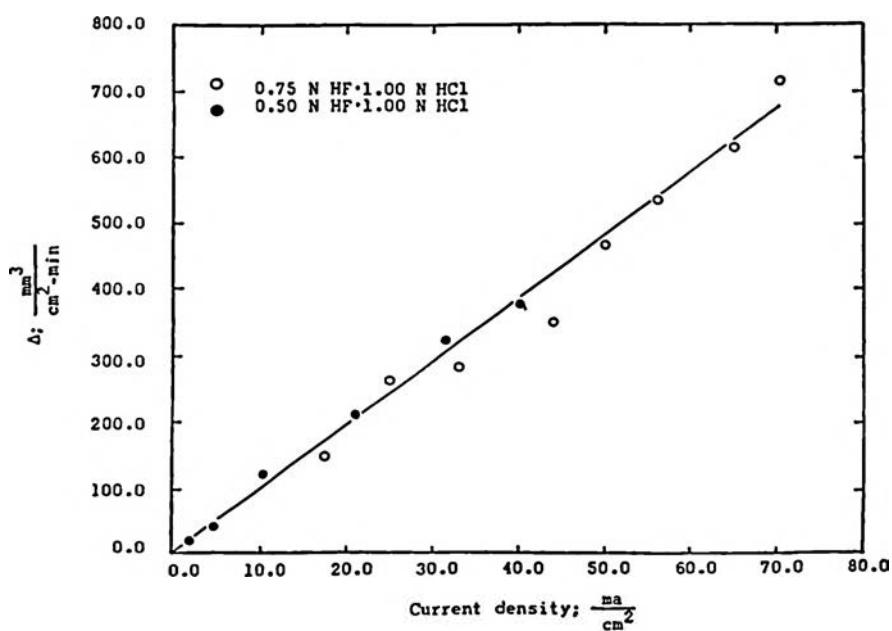


Figure 15

The effect of current density on the difference effect obtained from $\text{TiO}_{0.263}$

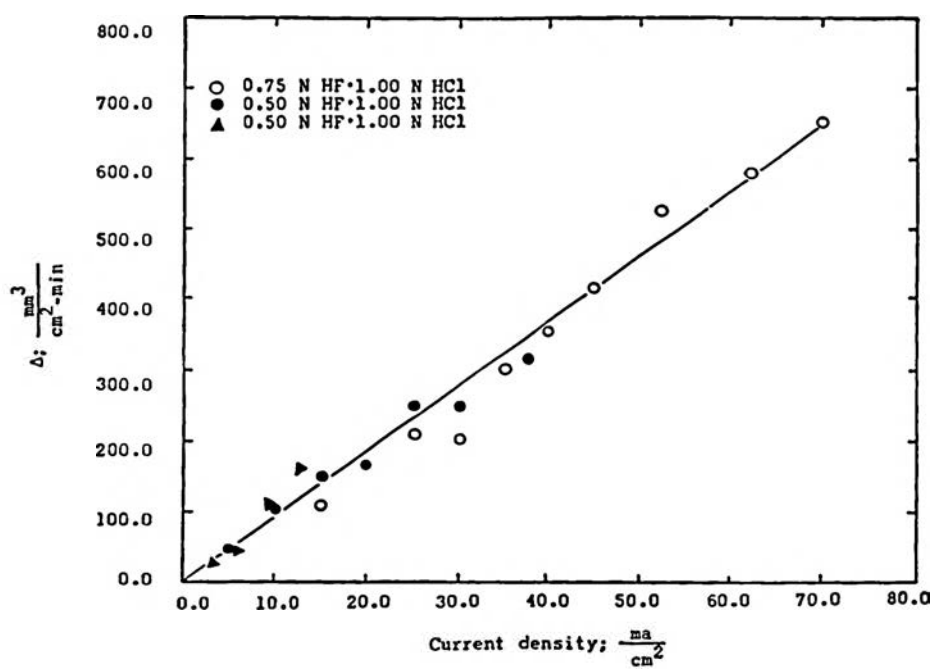


Figure 16
The effect of current density on the
difference effect obtained from $TiO_{0.365}$

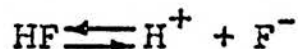
VIII. DISCUSSION

The discussion is presented in three sections:

(1) The reaction of titanium with hydrofluoric acid, (2) The reaction of the alpha solid solutions of oxygen in titanium with hydrofluoric acid, and (3) The difference effect in hydrofluoric acid on some alpha solid solutions of oxygen in titanium.

1. The reaction of titanium with hydrofluoric acid

The kinetic behavior of titanium in HF was determined over the concentration range, 0.05 N to 0.50 N, and temperature range, 15°C to 45°C. Investigations were conducted in both pure HF solutions and HF·HCl solutions. The addition of HCl to the HF solutions shifted the equilibrium



to the left as a result of increasing hydrogen ion concentration. This produced a greater concentration of unionized hydrofluoric acid, HF_{un} . The HCl at the concentration (1.00 N) present in the HF solutions had previously been found to be inert with $\text{Ti}^{(3)}$, but additions of NaF to the HCl solution caused a reaction to occur. The NaF additions apparently provided F^- to the solution, and the following reaction occurred:



Being in the presence of a large hydrogen ion concentration, nearly all of the fluorine ions introduced into the solution were suppressed to HF_{un} . This indicated that the dissolution rate was dependent on the presence of HF_{un} .

The results of the work conducted during this research indicated that the rate at 25°C in pure HF solutions could be expressed

$$R = 714 C^{0.81}$$

where R is the rate ($\text{mm}^3/\text{cm}^2 \text{ min}$) and C is the acid concentration (moles/liter). This revealed the rate to be dependent only on the acid concentration.

The rate expression for the dissolution experiments conducted at 25°C in HF·HCl solutions is:

$$R = 845 C^{0.76}$$

This expression indicates a (3/4) order, and predicts a higher dissolution rate for a given acid concentration than was obtained in the pure HF solutions.

A study of the effect of temperature on the dissolution reaction in 0.10 N HF indicated activation energies of 7.6 ± 0.7 kcal/mole in pure HF solutions and 6.9 ± 0.7 kcal/mole in HF·HCl solutions. Therefore, the increase in the molecular HF concentration as effected by the HCl additions was responsible for the increased rate as the activation energies are the same within the limits of error.

Previous work⁽⁵⁾ concerning the dissolution of zirconium in HF solutions resulted in a first order dependency on the concentration of HF_{un} and an activation energy of 3.8 kcal/mole. On the basis of these observations a reaction mechanism was proposed as the penetration or attack and removal of a thin tenacious oxide film, and the subsequent diffusion of HF_{un} to the metal surface and direct chemical attack.

The first order rate condition was characteristic of a diffusionally controlled process as shown by Fick's Law,

$$-J = D \frac{dC}{dx} \quad (30)$$

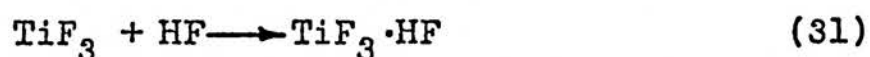
where J is the rate of mass transfer per unit area, D is the diffusion coefficient, and dC/dx represents the concentration gradient. Assuming that the barrier through which diffusion occurs (dx) remains constant for a given set of experimental conditions, then the rate of mass transfer (J) across the concentration gradient would depend only on the concentration of the HF_{un} thus leading to a first order condition.

The low activation energy, 3.80 kcal/mole, was thought to be characteristic of a physical transport process since its order of magnitude was several times too low for a normal chemical reaction. The physical transport process proposed was the diffusion of HF_{un} to the surface of the metal.

On the basis of the chemical similarity existing between zirconium and titanium a similar mechanism is hereby proposed for the reaction between titanium and hydrofluoric acid. A complication in such a proposal is the observation of the near (3/4) reaction order which is not readily explainable in terms of diffusion kinetics. A hypothesis will now be presented to explain the origin of the (3/4) order phenomenon.

As the titanium dissolved in the HF solution, Ti^{+3} ions surrounded by 3F^- were released at the liquid-metal

interface into the concentration gradient across which HF_{un} was diffusing toward the surface. Although the valency of the titanium was only trivalent its coordinating ability was not completely satisfied. Since HF is a polar molecule which exhibits strong hydrogen bonding⁽¹⁰⁾ tendencies, it was theorized that the TiF_3 structure could coordinate an HF_{un} molecule into the configuration through a hydrogen bond according to the following scheme:



The occurrence of such a reaction would consume on the average one out of every four HF_{un} molecules attempting to cross the concentration gradient. This would reduce the order of the dissolution reaction to (1/4) of that originally expected under ideal diffusion conditions thereby giving a (3/4) order. Conductivity measurements are now in progress in this laboratory to confirm the validity of this hypothesis.

The dissolution reaction of zirconium and hafnium⁽¹¹⁾ was not complicated by a fractional order, because both zirconium and hafnium have only one stable valence state, i.e. Zr^{+4} and Hf^{+4} . These ions apparently completely satisfy their coordinating tendencies with F^- as ZrF_4 and HfF_4 and do not interfere with the diffusion of the HF_{un} by reducing the order of the reaction.

2. The reaction of the alpha solid solutions of oxygen in titanium with hydrofluoric acid

Four homogeneous specimens of the alpha solid solutions of oxygen in titanium were prepared. The disso-

lution kinetics were conducted on these specimens in HF-HCl solutions over the concentration range, 0.05 N to 0.50 N, and temperature range, 15°C to 45°C. The same apparatus was used for these experiments as was previously used in the investigation of pure titanium.

The structure of the alpha solid solutions was proposed⁽⁷⁾ as a hexagonal lattice of titanium with interstitial oxygen ions chemically bonded to a limited number of titanium ions. The oxygen ions originate from oxygen atoms which have acquired electrons from the normally metallic bonded titanium atoms. The loss of electrons by the titanium atoms produces titanium ions in the structure of varying valency, Ti^+ , Ti^{+2} , Ti^{+3} . Dissolution experiments revealed that there was a possibility as if on the average $3 O^{-2}$ were associated with $2 Ti^{+3}$. Therefore, it was proposed that the alpha solid solutions were actually solutions of Ti_2O_3 in Ti. During dissolution of these alloys only the free titanium reacts rapidly to liberate hydrogen; the Ti_2O_3 reacts slowly to form water.

The results of this work revealed that the rate of hydrogen evolution per unit area of TiO_x was constant within experimental limits for a given acid concentration and temperature. The rate expression is given as

$$R = 1513 C^{0.83}$$

for the dissolution at 25°C. The order of the reaction, 0.83, is within the experimental error limits of the value, 0.76, obtained for the dissolution of the pure metal. Knowing the rate of hydrogen evolution at a constant

temperature and acid concentration, and the composition of the TiO_x , the actual rate of dissolution ($mg/cm^2 \text{ min}$) i.e. including the dissolution rate of Ti_2O_3 , could be calculated from the reaction:

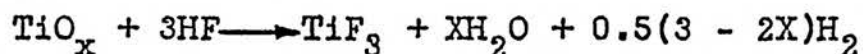


Figure 9 is an illustration of the dissolution rate variation of the TiO_x alloys in 0.10 N acid at $25^\circ C$. This plot was extrapolated in both directions so that further information concerning the variation of dissolution over the entire alpha solid solution range might be obtained. As can be seen from the plot, the extrapolated value of the dissolution rate at zero per cent oxygen is $0.296 (mg/cm^2 \text{ min})$. The actual rate of the cast metal under similar conditions was found to be $0.210 (mg/cm^2 \text{ min})$. The two values of the dissolution rate compare quite well even though one of the values was obtained from a powder metallurgical product and the other from the cast metal. The larger value might be expected from the powder metallurgical specimen since it had a larger surface area due to porosity.

The constant rate of hydrogen evolution from each solid solution specimen also lent support to the previously proposed diffusion mechanism as follows:

The addition of oxygen to titanium up to 10.84% by weight oxygen altered the surface of the alloys so as to provide an increased number of local cathodic areas on the surface. These local cathodic areas consisted of Ti_2O_3 ⁽⁷⁾. If the reaction on the surface was controlled by an electrochemical process the large increase in the cathodic

areas would promote the rate of hydrogen evolution. Since the latter was essentially constant for the various TiO_x alloys, it was concluded that the reaction on the surface was not essentially electrochemically controlled, but was dependent only on the diffusion rate of HF_{un} to the surface. This condition would account for the constant rate of hydrogen evolution observed assuming that the diffusion rate did not change from one solid solution specimen to the next.

A temperature effect study indicated an activation energy of 6.6 kcal/mole. This agreed within the error limits of the value, 6.9 kcal/mole, obtained for the pure metal.

The similarity existing between the reaction order, activation energy, and hydrogen evolution rate for constant conditions suggested that the dissolution process of the TiO_x alloys was generally the same as that previously proposed for pure titanium.

3. The difference effect in hydrofluoric acid on some alpha solid solutions of oxygen in titanium

The difference effect was observed on three solid solution specimens, $TiO_{0.157}$, $TiO_{0.263}$, and $TiO_{0.365}$. The study was carried out in a series of acid concentrations and at various current densities. This yielded information concerning the dissolution of titanium as affected by anodic polarization produced from an internal current flowing between the TiO_x and Pt electrodes.

The very fact that a condition of anodic polarization can be observed during the dissolution process indicated that some electrochemical reaction was occurring on the surface of the TiO_x , i.e. free titanium goes into solution at one place while hydrogen was evolved at another.

The results obtained from this work indicated that the difference effect on the TiO_x alloys was independent of acid concentration and was the same within error limits for a given current density (K was constant). Taking an average of the K constant from equations (27), (28), and (29) yielded an expression for the difference effect on the TiO_x alloys investigated as a function of current density:

$$\Delta = 9.5 I$$

As can be seen from the above equation, the value of K , 9.5, indicated that the TiO_x electrodes were polarizable to greater than 100% of the value given by equation (26). The large anodic polarization phenomenon observed might be explained in the following manner:

Apparently the flow of current through the TiO_x electrode produces a condition of severe anodic polarization, i.e. passivation, due to concentration of Ti_2O_3 on the surface of the electrode as free titanium goes into the solution. This effect is probably accompanied by a secondary process of a dense film formation which slows down the dissolution reaction and renders the TiO_y electrodes more polarizable than the pure metal, i.e. $K = 5.7$.

The absence of a reducing atmosphere over the surface as affected by the diminished hydrogen evolution rate might also enhance the formation of these films.

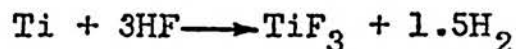
The K value for the difference effect on pure titanium dissolving in hydrofluoric acid is expressed in the equation⁽³⁾:

$$\Delta_{Ti} = 5.7 I$$

This value of K was checked during the course of the investigations on the TiO_x alloys, therefore a transition from K values of 5.7 to 9.5 seems to occur in a region of oxygen content below those investigated during this research. Studies are now in progress to determine the oxygen contents and K values corresponding to the transition region.

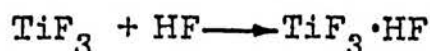
IX. SUMMARY AND CONCLUSIONS

The order of the reaction and the energy of activation for the dissolution reaction



was determined. The order of the reaction was found to be approximately (3/4), and the energy of activation was 6.9 ± 0.7 kcal/mole.

The (3/4) order was thought to originate from the competing reaction:



This reaction coordinated on the average one out of every four HF_{un} diffusing toward the surface of the titanium thus reducing the reaction order to (3/4) of that originally expected for a diffusionally controlled process.

The activation energy, 6.9 kcal/mole was slightly higher than the value obtained for zirconium⁽⁵⁾, but in view of the more complicated diffusion mechanism a larger value might be expected.

The chemical similarity existing between titanium and zirconium, i.e. both belong to Group IV B of the Periodic Table, suggested that the dissolution mechanism of titanium in hydrofluoric acid might be analogous to the previously investigated dissolution mechanism of zirconium in hydrofluoric acid. On this basis the following reaction mechanism was proposed:

Even the purest titanium is covered with a thin layer of a sub-oxide the thickness of which is in Angstrom dimensions. This thin layer protects titanium from corrosion in most instances both because of its adherent non-porous

nature and its regeneration tendency. Hydrofluoric acid is unique in that it is the only acid known to attack these oxide films. Therefore, the dissolution process probably consists of attack and penetration of this film by the HF_{un} with subsequent direct chemical attack on the surface. The oxide film is then replaced partially or completely by a hydride film. The rate of the chemical reaction on the surface is thought to be diffusionally controlled by the transport of HF_{un} through the film to the surface.

Dissolution studies on the alpha solid solutions of oxygen in titanium revealed that the order of reaction, the energy of activation, and the rate of hydrogen evolution from the surface were nearly the same as those obtained from the pure metal under the same experimental conditions. This indicated that the dissolution process was the same in both instances.

The constant rate of hydrogen evolution observed from each TiO_x specimen at a given acid concentration and temperature lent support to the proposal that the dissolution reaction was diffusionally controlled.

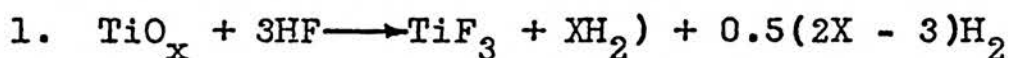
The difference effect measurements in HF on the alpha solid solutions of oxygen in titanium indicated that an electrochemical process was occurring on the surface of the specimen during dissolution. The difference effect was found to be the same at a given current density for the three TiO_x alloys investigated:

$$\Delta = 9.5 I$$

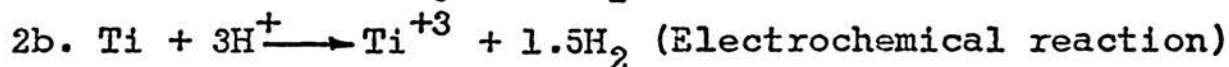
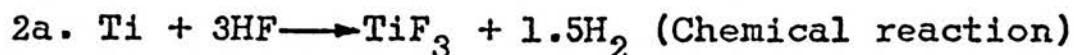
The large value of K, 9.5, indicated that the TiO_x electrode surfaces were polarizable to more than 100% as predicted by equation (26). Apparently the flow of current in the cell altered the surfaces of the electrodes by some secondary process in such a manner as to render them more passive to dissolution.

The following reactions best summarize the dissolution process of titanium in hydrofluoric acid.

Attack and penetration of the sub-oxide film by diffusion:



Chemical attack on the surface of the titanium:



A portion of the atomic hydrogen responsible for hydrogen gas evolution (equations 2a and 2b) reacts with the surface of the titanium to form a dark hydride film, TiH_x . In stronger concentrations of HF, above 0.50 N, these films may partially or completely dissolve.

X. APPENDIX

This appendix includes tables containing all of the data for the dissolution rate and difference effect measurements.

Tables I through XVII give the data for:

The Rate of Dissolution of Titanium in Hydrofluoric Acid

Tables XVIII through XXVII give the data for:

The Rate of Dissolution of Titanium in Hydrofluoric Acid • Hydrochloric Acid Solutions

Tables XXVIII through LV give the data for:

The Rate of Dissolution in Hydrofluoric Acid • Hydrochloric Acid Solutions of the Alpha Solid Solutions of Oxygen in Titanium

Table LVI gives the data for:

The Effect of Stirring Speed on the Dissolution Rate of Titanium in HF•HCl Solutions

Tables LVII through LXIV give the data for:

The Difference Effect in Hydrofluoric Acid • Hydrochloric Acid Solutions on the Alpha Solid Solutions of Oxygen in Titanium

Table I
Dissolution of Ti in 0.05 N HF at 15.0°C

Run No. 1

Average barometric pressure: 741.5 mm Hg

Average room temperature: 28.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.63	0.00
5	11.17	2.54
15	11.17	0.00
25	11.17	0.00
35	11.34	0.17
45	11.67	0.33✓
55	12.10	0.43✓
65	12.52	0.42✓
75	12.90	0.38✓
85	13.37	0.47✓
95	13.87	0.50✓
105	14.30	0.43✓
115	14.72	0.42✓
125	15.06	0.34✓

✓ Average maximum rate for first run: 41.3 mm³/cm² min.

Run No. 2

Average barometric pressure: 741.2 mm Hg

Average room temperature: 28.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.60	0.00
5	10.14	2.54
15	10.14	0.00
25	10.22	0.08
35	10.47	0.25
45	10.81	0.34✓
55	11.19	0.38✓
65	11.61	0.42✓
75	12.04	0.43✓
85	12.50	0.46✓
95	12.92	0.46✓
105	13.47	0.55✓
115	13.77	0.30✓
125	14.15	0.38✓

✓ Average maximum rate for second run: 41.3 mm³/cm² min.

Average maximum rate for both runs: 41.3 mm³/cm² min.

Table II
Dissolution of Ti in 0.075 N HF at 15.0°C

Run No. 1

Average barometric pressure: 738.5 mm Hg

Average room temperature: 30.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.66	0.00
5	10.24	2.58
15	10.24	0.00
25	10.53	0.29
35	10.91	0.38
45	11.32	0.41✓
55	11.90	0.58✓
65	12.32	0.42✓
75	12.90	0.58✓
85	13.40	0.50✓
95	13.78	0.38✓
105	14.19	0.41✓

✓ Average maximum rate for first run: 48.3 mm³/cm² min.

Run No. 2

Average barometric pressure: 739.1 mm Hg

Average room temperature: 30.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	6.91	0.00
5	9.70	2.79
15	9.70	0.00
25	9.83	0.13
35	10.16	0.33
45	10.66	0.50✓
55	11.12	0.46✓
65	11.53	0.41✓
75	12.16	0.63✓
85	12.74	0.58✓
95	13.32	0.58✓
105	13.82	0.50✓

✓ Average maximum rate for second run: 52.2 mm³/cm² min.

Average maximum rate for both runs: 50.3 mm³/cm² min.

Table III
Dissolution of Ti in 0.10 N HF at 15.0°C

Run No. 1

Average barometric pressure: 740.1 mm Hg

Average room temperature: 27.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.73	0.00
5	10.47	2.74
15	10.76	0.29
25	10.97	0.21
35	11.43	0.46✓
45	12.10	0.67✓
55	12.95	0.85✓
65	13.70	0.75✓
75	14.54	0.84✓
85	15.13	0.59✓
95	15.72	0.59✓
105	16.31	0.41✓

✓ Average maximum rate for first run: 64.5 mm³/cm² min.

Run No. 2

Average barometric pressure: 737.9 mm Hg

Average room temperature: 30.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	6.79	0.00
5	9.61	2.82
15	9.86	0.25
25	10.44	0.58✓
35	11.18	0.74✓
45	11.93	0.75✓
55	12.51	0.58✓
65	13.25	0.74✓
75	13.92	0.67✓
85	14.66	0.74✓
95	15.32	0.66✓
105	15.99	0.67✓

✓ Average maximum rate for second run: 68.1 mm³/cm² min.

Average maximum rate for both runs: 66.3 mm³/cm² min.

Table IV
Dissolution of Ti in 0.50 N HF at 15.0°C

Run No. 1

Average barometric pressure: 738.6 mm Hg

Average room temperature: 31.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.60	0.00
5	10.91	2.31
15	12.65	1.74
25	15.04	2.39✓
35	17.19	2.15✓
45	19.75	2.56✓
55	21.90	2.15✓
65	24.46	2.56✓
75	26.78	2.32✓
85	28.76	1.98✓
95	31.24	2.48✓
105	33.47	2.23✓

✓ Average maximum rate for first run: 235.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 738.2 mm Hg

Average room temperature: 31.8°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.09	0.00
5	9.15	2.06
15	11.37	2.22
25	13.76	2.39✓
35	16.32	2.56✓
45	18.62	2.30✓
55	21.09	2.47✓
65	23.48	2.39✓
75	26.04	2.56✓
85	28.35	2.31✓
95	31.15	2.80✓
105	33.45	2.30✓

✓ Average maximum rate for second run: 241.0 mm³/cm² min.

Average maximum rate for both runs: 238.0 mm³/cm² min.

Table V
Dissolution of Ti in 0.05 N HF at 25.0°C

Run No. 1

Average barometric pressure: 732.9 mm Hg

Average room temperature: 30.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.24	0.00
5	11.46	3.22
15	12.16	0.70✓
25	12.53	0.37✓
35	13.11	0.58✓
45	13.69	0.58✓
55	14.18	0.49✓
65	14.84	0.66✓
75	15.54	0.70✓
85	16.16	0.62✓

✓ Average maximum rate for first run: 58.8 mm³/cm² min.

Run No. 2

Average barometric pressure: 735.0 mm Hg

Average room temperature: 28.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.96	0.00
5	10.81	2.85
15	11.23	0.42✓
25	11.73	0.50✓
35	12.36	0.63✓
45	12.99	0.63✓
55	13.66	0.67✓
65	14.41	0.75✓
75	15.08	0.67✓
85	15.67	0.59✓

✓ Average maximum rate for second run: 60.8 mm³/cm² min.

Average maximum rate for both runs: 59.8 mm³/cm² min.

Table VI
Dissolution of Ti in 0.075 N HF at 25.0°C

Run No. 1

Average barometric pressure: 738.1 mm Hg

Average room temperature: 29.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.35	0.00
5	9.86	2.51
15	10.36	0.50
25	11.36	1.00✓
35	12.36	1.00✓
45	13.37	1.01✓
55	14.12	0.75✓
65	15.04	0.92✓
75	15.96	0.92✓
85	16.78	0.82✓

✓ Average maximum rate for first run: 91.7 mm³/cm² min.

Run No. 2

Average barometric pressure: 737.2 mm Hg

Average room temperature: 31.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	6.94	0.00
5	9.42	2.58
15	9.91	0.49
25	10.82	0.91✓
35	11.81	0.99✓
45	12.72	0.91✓
55	13.55	0.83✓
65	14.46	0.91✓
75	15.45	0.99✓
85	16.35	0.90✓
95	17.22	0.87✓

✓ Average maximum rate for second run: 91.4 mm³/cm² min.

Average maximum rate for both runs: 91.6 mm³/cm² min.

Table VII
Dissolution of Ti in 0.10 N HF at 25°C

Run No. 1

Average barometric pressure: 733.2 mm Hg

Average room temperature: 30.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.94	0.00
5	11.73	3.79
15	12.28	0.55
25	13.69	1.41✓
35	14.93	1.24✓
45	16.05	1.12✓
55	17.21	1.16✓
65	18.20	0.99✓
75	19.53	1.33✓
85	20.56	1.03✓
95	21.76	1.20✓

✓ Average maximum rate for first run: 121.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 733.7 mm Hg

Average room temperature: 28.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.18	0.00
5	11.02	2.84
15	11.90	0.88
25	12.73	0.83
35	13.86	1.13✓
45	15.15	1.29✓
55	16.32	1.17✓
65	17.57	1.25✓
75	18.87	1.30✓
85	19.95	1.08✓

✓ Average maximum rate for second run: 120.0 mm³/cm² min.

Average maximum rate for both runs: 121.0 mm³/cm² min.

Table VIII
Dissolution of Ti in 0.50 N HF at 25.0°C

Run No. 1

Average barometric pressure: 733.9 mm Hg

Average room temperature: 28.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	9.18	0.00
5	11.92	2.74
15	15.61	3.69✓
25	19.25	3.64✓
35	22.93	3.68✓
45	26.53	3.60✓
55	30.29	3.76✓
65	33.97	3.68✓
75	37.66	3.69✓
85	41.42	3.76✓

✓ Average maximum rate for first run: 369.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 733.5 mm Hg

Average room temperature: 30.1°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.93	0.00
5	13.19	4.26
15	16.58	3.39
25	20.26	3.68✓
35	23.86	3.60✓
45	27.46	3.60✓
55	31.10	3.64✓
65	34.82	3.72✓
75	38.54	3.72✓
85	42.18	3.64✓

✓ Average maximum rate for second run: 366.0 mm³/cm² min.

Average maximum rate for both runs: 368.0 mm³/cm² min.

Table IX
Dissolution of Ti in 1.00 N HF at 25.0°C

Run No. 1

Average barometric pressure: 733.8 mm Hg

Average room temperature: 28.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	1.50	0.00
5	6.10	4.60
15	12.91	6.81✓
25	19.97	7.06✓
35	27.23	7.26✓
45	34.59	7.36✓
55	41.77	7.18✓
65	49.21	7.44✓
75	56.81	7.60✓
85	64.24	7.43✓

✓ Average maximum rate for first run: 727.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 733.1 mm Hg

Average room temperature: 29.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	1.87	0.00
5	6.55	4.68
15	12.02	5.47
25	18.41	6.39✓
35	24.59	6.18✓
45	30.80	6.21✓
55	37.36	6.56✓
65	43.86	6.50✓
75	50.00	6.14✓
85	56.14	6.14✓

✓ Average maximum rate for second run: 630.0 mm³/cm² min.

Average maximum rate for both runs: 679.9 mm³/cm² min.

Table X
Dissolution of Ti in 0.050 N HF at 35.0°C

Run No. 1

Average barometric pressure: 735.8 mm Hg

Average room temperature: 29.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	11.64	0.00
5	12.47	0.83
15	13.47	1.00✓
25	14.21	0.74✓
35	15.29	1.08✓
45	16.21	0.92✓
55	17.29	1.08✓
65	18.29	1.00✓
75	19.29	1.00✓
85	19.95	0.66✓
95	20.87	0.92✓

✓ Average maximum rate for first run: 93.3 mm³/cm² min.

Run No. 2

Average barometric pressure: 737.3 mm Hg

Average room temperature: 30.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.31	0.00
5	11.63	3.32
15	12.46	0.83✓
25	13.33	0.87✓
35	14.37	1.04✓
45	15.33	0.96✓
55	16.32	0.99✓
65	17.16	0.84✓
75	18.07	0.91✓
85	18.90	0.83✓

✓ Average maximum rate for second run: 90.9 mm³/cm² min.

Average maximum rate for both runs: 92.1 mm³/cm² min.

Table XI
Dissolution of Ti in 0.075 N HF at 35.0°C

Run No. 1

Average barometric pressure: 738.7 mm Hg

Average room temperature: 28.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.07	0.00
5	9.76	2.69
15	10.61	0.85
25	11.66	1.05✓
35	12.79	1.13✓
45	13.89	1.10✓
55	15.07	1.18✓
65	16.20	1.13✓
75	17.34	1.14✓
85	18.52	1.18✓
95	19.61	1.09✓

✓ Average maximum rate for first run: 113.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 737.8 mm Hg

Average room temperature: 28.7°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	4.87	0.00
5	7.43	2.56
15	8.06	0.63
25	8.90	0.84
35	10.11	1.21✓
45	11.12	1.01✓
55	12.25	1.13✓
65	13.26	1.01✓
75	14.27	1.01✓
85	15.36	1.09✓

✓ Average maximum rate for second run: 108.0 mm³/cm² min.

Average maximum rate for both runs: 111.0 mm³/cm² min.

Table XII
Dissolution of Ti in 0.10 N HF at 35°C

Run No. 1

Average barometric pressure: 734.1 mm Hg

Average room temperature: 29.7°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.88	0.00
5	11.29	3.41
15	12.82	1.53✓
25	14.44	1.62✓
35	16.27	1.83✓
45	18.05	1.78✓
55	19.62	1.57✓
65	21.33	1.71✓
75	22.90	1.57✓
85	24.47	1.57✓

✓ Average maximum rate for first run: 165.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 734.0 mm Hg

Average room temperature: 27.7°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.57	0.00
5	11.27	3.70
15	12.95	1.68✓
25	14.47	1.52✓
35	16.23	1.76✓
45	17.85	1.62✓
55	19.68	1.83✓
65	21.44	1.76✓
75	23.04	1.60✓
85	24.72	1.68✓

✓ Average maximum rate for second run: 168.0 mm³/cm² min.

Average maximum rate for both runs: 167.0 mm³/cm² min.

Table XIII
Dissolution of Ti in 0.50 N HF at 35.0°C

Run No. 1

Average barometric pressure: 736.7 mm Hg

Average room temperature: 32.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.97	0.00
5	13.31	5.34
15	19.22	5.91✓
25	25.30	6.08✓
35	31.21	5.91✓
45	36.80	5.59✓
55	42.71	5.91✓
65	48.37	5.66✓
75	54.12	5.75✓
85	59.83	5.71✓

✓ Average maximum rate for first run: 582.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 735.8 mm Hg

Average room temperature: 32.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.77	0.00
5	14.88	7.11
15	21.09	6.21✓
25	26.98	5.89✓
35	32.87	5.89✓
45	38.42	5.55✓
55	43.98	5.56✓
65	49.70	5.72✓
75	55.43	5.73✓
85	61.23	5.80✓

✓ Average maximum rate for second run: 579.0 mm³/cm² min.

Average maximum rate for both runs: 581.0 mm³/cm² min.

Table XIV
Dissolution of Ti in 0.05 N HF at 45.0°C

Run No. 1

Average barometric pressure: 736.2 mm Hg

Average room temperature: 30.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.03	0.00
5	10.59	3.56
15	11.70	1.11✓
25	12.77	1.07✓
35	14.22	1.45✓
45	15.50	1.28✓
55	17.03	1.53✓
65	18.02	0.99✓
75	19.22	1.20✓
85	20.17	0.95✓
95	21.17	1.00✓

✓ Average maximum rate for first run: 118.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 734.5 mm Hg

Average room temperature: 32.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.68	0.00
5	10.95	3.27
15	11.93	0.98✓
25	13.07	1.14✓
35	14.22	1.15✓
45	15.36	1.14✓
55	16.67	1.31✓
65	17.98	1.31✓
75	18.96	0.98✓
85	20.27	1.31✓
95	21.41	1.14✓

✓ Average maximum rate for second run: 116.0 mm³/cm² min.

Average maximum rate for both runs: 117.0 mm³/cm² min.

Table XV
Dissolution of Ti in 0.075 N HF at 45.0°C

Run No. 1

Average barometric pressure: 736.3 mm Hg

Average room temperature: 29.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	4.84	0.00
5	8.02	3.18
15	9.52	1.50✓
25	11.77	2.25✓
35	13.53	1.76✓
45	15.70	2.17✓
55	17.70	2.00✓
65	19.75	2.05✓
75	21.71	1.96✓
85	23.38	1.67✓

✓ Average maximum rate for first run: 192.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 735.6 mm Hg

Average room temperature: 30.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	5.79	0.00
5	8.94	3.15
15	10.59	1.65✓
25	12.58	1.99✓
35	14.62	2.24✓
45	16.72	1.90✓
55	18.37	1.65✓
65	20.36	1.99✓
75	22.18	1.82✓
85	24.09	1.91✓

✓ Average maximum rate for second run: 189.0 mm³/cm² min.

Average maximum rate for both runs: 191.0 mm³/cm² min.

Table XVI
Dissolution of Ti in 0.10 N HF at 45.0°C

Run No. 1

Average barometric pressure: 733.9 mm Hg

Average room temperature: 33.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.80	0.00
5	10.89	3.09
15	13.49	2.60✓
25	16.09	2.60✓
35	18.37	2.28✓
45	20.81	2.44✓
55	23.16	2.35✓
65	25.52	2.36✓
75	27.71	2.19✓
85	29.99	2.28✓
95	32.43	2.44✓

✓ Average maximum rate for first run: 239.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 737.6 mm Hg

Average room temperature: 27.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.46	0.00
5	11.16	2.70
15	13.70	2.54✓
25	16.32	2.62✓
35	19.12	2.80✓
45	21.82	2.70✓
55	24.61	2.79✓
65	27.23	2.62✓
75	30.11	2.88✓
85	32.82	2.71✓
95	35.44	2.62✓

✓ Average maximum rate for second run: 270.0 mm³/cm² min.

Table XVI (continued)
Dissolution of Ti in 0.10 N HF at 45.0°C

Run No. 3

Average barometric pressure: 735.4 mm Hg

Average room temperature: 30.1°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	3.48	0.00
5	7.22	3.74
15	9.62	2.40✓
25	12.11	2.49✓
35	14.93	2.82✓
45	17.71	2.78✓
55	20.32	2.61✓
65	22.56	2.24✓
75	25.05	2.49✓
85	27.54	2.49✓

✓ Average maximum rate for third run: 254.0 mm³/cm² min.

Average maximum rate for three runs: 254.0 mm³/cm² min.

Table XVII
Dissolution of Ti in 0.50 N HF at 45.0°C

Run No. 1

Average barometric pressure: 737.6 mm Hg

Average room temperature: 28.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	6.72	0.00
5	13.62	6.90
10	18.15	4.53✓
15	22.86	4.71✓
20	27.23	4.37✓
25	31.69	4.46✓
30	36.14	4.45✓
35	40.85	4.71✓
40	45.47	4.62✓
45	50.43	4.96✓
50	55.30	4.87✓
55	59.68	4.38✓
60	64.72	5.04✓
65	69.68	4.96✓
70	74.64	4.96✓
75	79.34	4.70✓
80	83.88	4.54✓

✓ Average maximum rate for first run: 870.0 mm³/cm² min.

Table XVII (continued)
Dissolution of Ti in 0.50 N HF at 45.0°C

Run No. 2

Average barometric pressure: 737.2 mm Hg

Average room temperature: 29.2°C

<u>Time</u> <u>(Minutes)</u>	Corr. Volume H ₂ <u>(cm³)</u>	ΔV <u>(cm³)</u>
0	7.19	0.00
5	15.55	8.36
10	20.98	5.4 ^r ✓
15	26.42	5.4 ^r ✓
20	31.68	5.26✓
25	37.12	5.44✓
30	42.47	5.3 ^F ✓
35	45.98	3.51
40	51.83	5.85✓
45	57.68	5.85✓
50	63.20	5.52✓
55	68.59	5.39✓
60	73.57	4.98✓
65	79.92	5.35✓
70	83.60	4.68✓

✓ Average maximum rate for second run: 1070.0 mm³/cm² min.

Average maximum rate for both runs: 970.0 mm³/cm² min.

Table XVIII

Dissolution of Ti in 0.10 N HF · 1.00 N HCl at 15.0°C

Run No. 1

Average barometric pressure: 738.2 mm Hg

Average room temperature: 29.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.35	0.00
5	11.03	2.68
15	11.57	0.54
25	12.53	0.96✓
35	13.70	1.17✓
45	14.53	0.83✓
55	15.54	1.01✓
65	16.71	1.17✓
75	17.83	1.12✓
85	18.67	0.84✓
95	19.55	0.88✓

✓ Average maximum rate for first run: 99.8 mm³/cm² min.

Run No. 2

Average barometric pressure: 737.3 mm Hg

Average room temperature: 31.7°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	9.55	0.00
5	11.36	1.81
15	12.68	1.32✓
25	13.58	0.90✓
35	14.57	0.99✓
45	15.31	0.74✓
55	16.30	0.99✓
65	17.17	0.87✓
75	18.24	1.07✓
85	18.98	0.74✓
95	19.88	0.90✓

✓ Average maximum rate for second run: 94.7 mm³/cm² min.Average maximum rate for both runs: 97.3 mm³/cm² min.

Table XIX
Dissolution of Ti in 0.05 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 740.6 mm Hg

Average room temperature: 29.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	6.88	0.00
5	9.56	2.68
15	10.40	0.84✓
25	11.24	0.84✓
35	11.99	0.75✓
45	12.75	0.76✓
55	13.58	0.83✓
65	14.42	0.84✓
75	15.26	0.84✓
85	16.02	0.76✓
95	16.81	0.79✓

✓ Average maximum rate for first run: 80.6 mm³/cm² min.

Run No. 2

Average barometric pressure: 739.9 mm Hg

Average room temperature: 30.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.97	0.00
5	10.47	2.50
15	11.13	0.66✓
25	11.96	0.83✓
35	12.75	0.79✓
45	13.62	0.87✓
55	14.45	0.83✓
65	15.28	0.83✓
75	16.12	0.84✓
85	16.95	0.83✓
95		

✓ Average maximum rate for second run: 81.0 mm³/cm² min.

Average maximum rate for both runs: 80.8 mm³/cm² min.

Table XX

Dissolution of Ti in 0.075 N HF·1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 736.0 mm Hg

Average room temperature: 30.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	5.46	0.00
5	8.48	3.02
15	9.18	0.70
25	10.05	0.87✓
35	11.12	1.07✓
45	12.24	1.12✓
55	13.32	1.08✓
65	14.31	0.99✓
75	15.38	1.07✓
85	16.46	1.08✓
95	17.53	1.07✓

✓ Average maximum rate for first run: 104.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 739.8 mm Hg

Average room temperature: 28.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.06	0.00
5	10.93	3.87
15	11.60	0.67
25	12.44	0.84✓
35	13.78	1.34✓
45	14.96	1.18✓
55	16.14	1.18✓
65	17.31	1.17✓
75	18.66	1.35✓
85	19.83	1.17✓
95	20.84	1.01✓

✓ Average maximum rate for second run: 115.0 mm³/cm² min.

Average maximum rate for both runs: 110.0 mm³/cm² min.

Table XXI

Dissolution of Ti in 0.10 N HF·1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 739.2 mm Hg

Average room temperature: 29.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.37	0.00
5	10.73	3.36
15	12.11	1.38
25	13.57	1.46✓
35	15.08	1.51✓
45	16.59	1.51✓
55	18.10	1.51✓
65	19.61	1.51✓
75	21.12	1.51✓
85	22.62	1.50✓
95	24.09	1.47✓

✓ Average maximum rate for first run: 149.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 739.0 mm Hg

Average room temperature: 29.8°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	6.67	0.00
5	9.67	3.00
15	11.17	1.50✓
25	12.63	1.46✓
35	13.92	1.29✓
45	15.50	1.58✓
55	16.92	1.42✓
65	18.42	1.50✓
75	19.88	1.46✓
85	21.25	1.37✓
95	22.67	1.42✓

✓ Average maximum rate for second run: 145.0 mm³/cm² min.

Average maximum rate for both runs: 147.0 mm³/cm² min.

Table XXII
Dissolution of Ti in 0.50 N HF·1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 738.7 mm Hg

Average room temperature: 29.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	6.70	0.00
5	11.98	5.28
15	16.59	4.61✓
25	21.11	4.51✓
35	25.64	4.53✓
45	30.33	4.69✓
55	34.85	4.52✓
65	39.38	4.53✓
75	43.86	4.48✓

✓ Average maximum rate for first run: 455.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 739.2 mm Hg

Average room temperature: 29.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	6.04	0.00
5	10.33	4.79
15	15.28	4.45✓
25	20.90	5.62✓
35	24.76	3.86✓
45	29.21	4.45✓
55	33.91	4.70✓
65	38.95	5.04✓
75	43.65	4.70✓
85	48.27	4.62✓
95	52.88	4.61✓

✓ Average maximum rate for second run: 455.0 mm³/cm² min.

Average maximum rate for both runs: 461.0 mm³/cm² min.

Table XXIII
Dissolution of Ti in 0.05 N HF·1.00 N HCl at 35.0°C

Run No. 1

Average barometric pressure: 736.8 mm Hg

Average room temperature: 28.8°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	4.19	0.00
5	7.62	3.43
15	8.71	1.09
25	9.89	1.18✓
35	11.23	1.34✓
45	12.57	1.34✓
55	13.74	1.17✓
65	15.25	1.51✓
75	16.50	1.25✓
85	17.76	1.26✓
95	18.93	1.17✓

✓ Average maximum rate for first run: 128.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 736.7 mm Hg

Average room temperature: 25.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	5.80	0.00
5	8.70	2.90
15	9.89	1.19✓
25	11.13	1.24✓
35	12.71	1.58✓
45	14.16	1.45✓
55	15.52	1.36✓
65	17.14	1.62✓
75	18.25	1.11✓
85	19.45	1.20✓
95	20.73	1.28✓

✓ Average maximum rate for second run: 134.0 mm³/cm² min.

Average maximum rate for both runs: 131.0 mm³/cm² min.

Table XXIV
Dissolution of Ti in 0.075 N HF-1.00 N HCl at 35.0°C

Run No. 1

Average barometric pressure: 735.6 mm Hg

Average room temperature: 26.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	5.08	0.00
5	8.30	3.22
15	9.78	1.48✓
25	11.52	1.74✓
35	13.30	1.78✓
45	15.08	1.78✓
55	16.77	1.69✓
65	18.47	1.70✓
75	20.16	1.69✓
85	21.86	1.70✓
95	23.38	1.52✓

✓ Average maximum rate for first run: 168.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 734.8 mm Hg

Average room temperature: 27.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	7.17	0.00
5	10.62	3.45
15	12.14	1.52✓
25	13.66	1.52✓
35	15.60	1.94✓
45	17.29	1.69✓
55	18.97	1.68✓
65	20.66	1.69✓
75	22.34	1.68✓
85	23.90	1.56✓

✓ Average maximum rate for second run: 166.0 mm³/cm² min.

Average maximum rate for both runs: 167.0 mm³/cm² min.

Table XXV
Dissolution of Ti in 0.10 N HF.1.00 N HCl at 35.0°C

Run No. 1

Average barometric pressure: 734.9 mm Hg

Average room temperature: 27.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	4.88	0.00
5	8.75	3.87
15	10.60	1.85✓
25	12.45	1.85✓
35	14.30	1.85✓
45	16.15	1.85✓
55	18.84	2.69✓
65	20.18	1.34✓
75	22.20	2.02✓
85	24.22	2.02✓

✓ Average maximum rate for first run: 193.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 733.4 mm Hg

Average room temperature: 29.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	3.82	0.00
5	7.30	3.48
15	9.41	2.11✓
25	11.61	2.20✓
35	13.94	2.33✓
45	16.26	2.32✓
55	18.66	2.40✓
65	21.01	2.35✓
75	23.23	2.22✓
85	25.30	2.07✓

✓ Average maximum rate for second run: 225.0 mm³/cm² min.

Average maximum rate for both runs: 209.0 mm³/cm² min.

Table XXVI
Dissolution of Ti in 0.50 N HF·1.00 N HCl at 35.0°C

Run No. 1

Average barometric pressure: 732.6 mm Hg

Average room temperature: 30.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	4.71	0.00
5	9.74	5.03
15	16.92	7.18✓
25	23.94	7.02✓
35	31.70	7.76✓
45	39.05	7.35✓
55	46.56	7.51✓
65	53.91	7.35✓
75	61.25	7.34✓

✓ Average maximum rate for first run: 736.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 732.4 mm Hg

Average room temperature: 30.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	5.12	0.00
5	10.89	5.77
15	18.40	7.51✓
25	26.08	7.68✓
35	33.83	7.75✓
45	41.43	7.60✓
55	48.77	7.34✓
65	55.95	7.18✓
75	63.38	7.43✓

✓ Average maximum rate for second run: 750.0 mm³/cm² min.

Average maximum rate for both runs: 743.0 mm³/cm² min.

Table XXVII
Dissolution of Ti in 0.10 N HF.1.00 N HCl at 45.0°C

Run No. 1

Average barometric pressure: 736.5 mm Hg

Average room temperature: 29.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	5.02	0.00
5	9.20	4.18
15	12.38	3.18✓
25	15.72	3.34✓
35	18.73	3.01✓
45	22.04	3.31✓
55	24.92	2.88✓
65	28.27	3.35✓
75	31.61	3.34✓
85	34.46	2.85✓

✓ Average maximum rate for first run: 316.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 735.9 mm Hg

Average room temperature: 30.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	6.64	0.00
5	10.51	3.87
15	13.46	2.95✓
25	16.70	3.24✓
35	19.93	3.23✓
45	23.09	3.16✓
55	26.41	3.32✓
65	28.82	2.41✓
75	32.14	3.32✓
85	35.38	3.24✓

✓ Average maximum rate for second run: 311.0 mm³/cm² min.

Average maximum rate for both runs: 314.0 mm³/cm² min.

Table XXVIII
Dissolution of $TiO_{0.157}$ in 0.10 N HF · 1.00 N HCl at 15.0°C

Run No. 1

Average barometric pressure: 732.3 mm Hg

Average room temperature: 24.7°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	9.71	0.00
5	12.27	2.56
15	13.12	0.85✓
25	14.31	1.19✓
35	15.67	1.36✓
45	16.52	0.85✓
55	17.46	0.94✓
65	18.48	1.02✓
75	19.85	1.37✓
85	20.95	1.10✓

✓ Average maximum rate for first run: 144.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 730.6 mm Hg

Average room temperature: 25.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	7.26	0.00
5	10.13	2.87
15	10.81	0.68
25	11.82	1.01✓
35	12.83	1.01✓
45	13.68	1.85✓
55	14.69	1.01✓
65	15.70	1.01✓
75	16.72	1.02✓
85	17.73	1.01✓

✓ Average maximum rate for second run: 132.0 mm^3/cm^2 min.Average maximum rate for both runs: 138.0 mm^3/cm^2 min.

Table XXIX

Dissolution of $TiO_{0.226}$ in 0.10 N HF · 1.00 N HCl at 15.0°C

Run No. 1

Average barometric pressure: 733.6 mm Hg

Average room temperature: 24.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	8.91	0.00
5	11.66	2.75
15	12.60	0.94
25	13.76	1.16
35	15.60	1.84✓
45	17.32	1.72✓
55	18.77	1.45✓
65	20.40	1.63✓
75	22.12	1.72✓
85	23.66	1.54✓

✓ Average maximum rate for first run: 176.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 733.6 mm Hg

Average room temperature: 25.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	6.98	0.00
5	9.53	2.55
15	10.38	0.85
25	11.75	1.37✓
35	13.28	1.53✓
45	14.81	1.53✓
55	16.17	1.36✓
65	17.62	1.45✓
75	19.32	1.70✓
85	20.77	1.45✓

✓ Average maximum rate for second run: 159.0 mm^3/cm^2 min.

Average maximum rate for both runs: 168.0 mm^3/cm^2 min.

Table XXX

Dissolution of $TiO_{0.260}$ in 0.10 N HF · 1.00 N HCl at 15.0°C

Run No. 1

Average barometric pressure: 729.7 mm Hg

Average room temperature: 25.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.30	0.00
5	11.01	2.71
15	11.35	0.34
25	12.54	1.19✓
35	13.72	1.18✓
45	14.99	1.27✓
55	16.18	1.19✓
65	17.28	1.10✓
75	18.47	1.19✓
85	19.82	1.35✓

✓ Average maximum rate for first run: 137.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 729.6 mm Hg

Average room temperature: 25.1°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	5.59	0.00
5	8.30	2.71
15	8.88	0.58
25	9.90	1.02✓
35	11.00	1.10✓
45	12.10	1.10✓
55	13.29	1.19✓
65	14.39	1.10✓
75	15.49	1.10✓
85	16.51	1.02✓

✓ Average maximum rate for second run: 123.0 mm³/cm² min.

Average maximum rate for both runs: 130.0 mm³/cm² min.

Table XXXI

Dissolution of $TiO_{0.365}$ in 0.10 N HF · 1.00 N HCl at 15.0°C

Run No. 1

Average barometric pressure: 729.2 mm Hg

Average room temperature: 26.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	6.48	0.00
5	8.84	2.36
15	9.09	0.25
25	9.68	0.59✓
35	10.27	0.59✓
45	11.24	0.97✓
55	12.13	0.89✓
65	13.47	1.34✓
75	14.40	0.93✓
85	15.49	1.09✓

✓ Average maximum rate for first run: 137.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 729.4 mm Hg

Average room temperature: 26.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	4.72	0.00
5	7.59	2.87
15	8.09	0.50
25	8.77	0.68
35	9.57	0.80✓
45	10.42	0.85✓
55	11.26	0.84✓
65	12.15	0.89✓
75	13.03	0.88✓
85	13.92	0.89✓

✓ Average maximum rate for second run: 129.0 mm^3/cm^2 min.

Average maximum rate for both runs: 133.0 mm^3/cm^2 min.

Table XXXII

Dissolution of $TiO_{0.157}$ in 0.05 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 735.2 mm Hg

Average room temperature: 31.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	5.09	0.00
5	7.71	2.62
15	8.04	0.33
25	8.69	0.65✓
35	9.35	0.66✓
45	10.09	0.74✓
55	10.83	0.74✓
65	11.81	0.98✓
75	12.55	0.74✓
85	13.29	0.74✓

✓ Average maximum rate for first run: 92.6 mm³/cm² min.

Run No. 2

Average barometric pressure: 738.3 mm Hg

Average room temperature: 30.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	3.91	0.00
5	6.57	2.66
15	7.11	0.54✓
25	7.82	0.71✓
35	8.82	1.00✓
45	9.56	0.74✓
55	10.65	1.09✓
65	11.64	0.99✓
75	12.64	1.00✓
85	13.47	0.83✓

✓ Average maximum rate for second run: 112.0 mm³/cm² min.

Average maximum rate for both runs: 102.0 mm³/cm² min.

Table XXXIII

Dissolution of $TiO_{0.157}$ in $0.075\ N\ HF \cdot 1.00\ N\ HCl$ at $25.0^{\circ}C$

Run No. 1

Average barometric pressure: 737.7 mm Hg

Average room temperature: $32.4^{\circ}C$

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.69	0.00
5	6.81	3.12
15	7.63	0.82
25	8.78	1.15✓
35	10.00	1.22✓
45	11.24	1.24✓
55	12.63	1.39✓
65	14.03	1.40✓
75	15.26	1.23✓
85	16.40	1.14✓

✓ Average maximum rate for first run: $154.0\ mm^3/cm^2\ min.$

Run No. 2

Average barometric pressure: 737.5 mm Hg

Average room temperature: $33.0^{\circ}C$

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	2.61	0.00
5	5.31	2.70
15	6.21	0.90
25	7.52	1.31✓
35	8.82	1.30✓
45	10.13	1.31✓
55	11.52	1.39✓
65	13.07	1.55✓
75	14.62	1.55✓
85	16.09	1.47✓

✓ Average maximum rate for second run: $174.0\ mm^3/cm^2\ min.$

Average maximum rate for both runs: $164.0\ mm^3/cm^2\ min.$

Table XXXIV

Dissolution of $TiO_{0.157}$ in 0.10 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 738.9 mm Hg

Average room temperature: 31.1°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	2.82	0.00
5	6.05	3.23
15	7.46	1.41
25	9.11	1.65✓
35	11.10	1.99✓
45	12.92	1.82✓
55	14.91	1.99✓
65	16.73	1.82✓
75	18.56	1.83✓
85	20.38	1.82✓

✓ Average maximum rate for first run: 228.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 737.6 mm Hg

Average room temperature: 34.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.73	0.00
5	7.14	3.41
15	8.93	1.79✓
25	11.04	2.11✓
35	13.39	2.35✓
45	15.42	2.03✓
55	17.57	2.15✓
65	19.72	2.15✓
75	22.56	2.84✓
85	24.51	1.95✓

✓ Average maximum rate for second run: 268.0 mm^3/cm^2 min.

Average maximum rate for both runs: 248.0 mm^3/cm^2 min.

Table XXXV

Dissolution of $TiO_{0.157}$ in 0.50 N HF-1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 737.5 mm Hg

Average room temperature: 34.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	2.66	0.00
5	7.58	4.92
15	15.08	7.50✓
25	22.99	7.91✓
35	31.05	8.06✓
45	38.87	7.82✓
55	47.02	8.15✓
65	54.92	7.90✓
75	62.91	7.99✓
85	70.65	7.74✓

✓ Average maximum rate for first run: 973.0 mm³/cm² min.

Run No. 2

Average barometric pressure 738.9 mm Hg

Average room temperature: 31.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	3.65	0.00
5	0.45	5.80
15	16.33	6.88✓
25	23.54	7.21✓
35	30.67	7.13✓
45	37.79	7.12✓
55	44.76	6.97✓
65	52.05	7.29✓
75	59.18	7.13✓
85	66.14	6.96✓

✓ Average maximum rate for second run: 875.0 mm³/cm² min.

Average maximum rate for both runs: 924.0 mm³/cm² min.

Table XXXVI

Dissolution of $TiO_{0.226}$ in 0.05 N HF.1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 735.2 mm Hg

Average room temperature: 29.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	4.66	0.00
5	6.99	2.33
15	7.44	0.45
25	7.98	0.54
35	8.82	0.84✓
45	9.65	0.83✓
55	10.48	0.83✓
65	11.39	0.91✓
75	12.31	0.92✓
85	13.31	1.00✓
95	14.14	0.83✓

✓ Average maximum rate for first run: 88.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 737.8 mm Hg

Average room temperature: 32.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.27	0.00
5	5.80	2.53
15	6.21	0.41
25	6.87	0.66✓
35	7.85	0.98✓
45	8.83	0.98✓
55	9.81	0.98✓
65	10.71	0.90✓
75	11.65	0.94✓
85	12.59	0.94✓
95	13.41	0.82✓

✓ Average maximum rate for second run: 90.0 mm^3/cm^2 min.

Average maximum rate for both runs: 89.0 mm^3/cm^2 min.

Table XXXVII

Dissolution of $TiO_{0.226}$ in 0.075 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 740.7 mm Hg

Average room temperature: 32.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	3.62	0.00
5	6.21	2.59
15	7.24	1.03
25	8.44	1.20
35	10.04	1.60✓
45	11.73	1.69✓
55	13.33	1.60✓
65	15.06	1.73✓
75	16.62	1.56✓
85	18.23	1.61✓

✓ Average maximum rate for first run: 163.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 738.2 mm Hg

Average room temperature: 33.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	1.95	0.00
5	4.89	2.94
15	5.82	0.93
25	7.00	1.18✓
35	8.80	1.80✓
45	10.26	1.46✓
55	11.81	1.55✓
65	13.36	1.55✓
75	14.90	1.54✓
85	16.41	1.51✓

✓ Average maximum rate for second run: 151.0 mm³/cm² min.

Average maximum rate for both runs: 157.0 mm³/cm² min.

Table XXXVIII

Dissolution of $TiO_{0.226}$ in 0.10 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 738.6 mm Hg

Average room temperature: 34.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.73	0.00
5	6.98	3.25
15	8.27	1.29
25	10.06	1.79✓
35	12.05	1.99✓
45	14.11	2.06✓
55	16.31	2.20✓
65	18.50	2.19✓
75	20.48	1.98✓
85	22.55	2.07✓

✓ Average maximum rate for first run: 204.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 739.2 mm Hg

Average room temperature: 32.8°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	2.79	0.00
5	5.57	2.78
15	6.39	0.82
25	8.36	1.97✓
35	10.49	2.13✓
45	11.97	1.48✓
55	14.76	2.79✓
65	17.05	2.29✓
75	19.35	2.30✓
85	21.48	2.13✓

✓ Average maximum rate for second run: 216.0 mm^3/cm^2 min.

Average maximum rate for both runs: 210.0 mm^3/cm^2 min.

Table XXXIX

Dissolution of $TiO_{0.226}$ in 0.50 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 737.7 mm Hg

Average room temperature: 34.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	4.05	0.00
5	8.95	4.90
15	15.07	6.12✓
25	21.55	6.48✓
35	28.43	6.88✓
45	35.48	7.05✓
55	43.26	7.78✓
65	50.71	7.45✓
75	58.73	8.02✓
85	65.62	6.89✓

✓ Average maximum rate for first run: 708.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 735.4 mm Hg

Average room temperature: 30.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	3.31	0.00
5	8.35	5.04
15	14.39	6.04
25	21.09	6.70✓
35	28.37	7.28✓
45	35.64	7.27✓
55	43.09	7.45✓
85	50.61	7.52✓
75	57.81	7.20✓
85	64.84	7.03✓

✓ Average maximum rate for second run: 721.0 mm³/cm² min.

Average maximum rate for both runs: 715.0 mm³/cm² min.

Table XL

Dissolution of $\text{TiO}_{0.260}$ in 0.05 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 733.3 mm Hg

Average room temperature: 33.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.32	0.00
5	5.82	2.50
15	6.31	0.49
25	7.08	0.77
35	7.76	0.68
45	8.73	0.97✓
55	9.95	1.22✓
65	11.16	1.21✓
75	12.37	1.21✓
85	13.59	1.22✓

✓ Average maximum rate for first run: 117.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 732.8 mm Hg

Average room temperature: 34.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	4.58	0.00
5	7.24	2.66
15	8.08	0.84
25	9.17	1.09
35	9.97	0.80✓
45	11.26	1.29✓
55	12.54	1.28✓
65	13.67	1.13✓
75	15.03	1.36✓
85	16.24	1.21✓

✓ Average maximum rate for second run: 118.0 mm^3/cm^2 min.

Average maximum rate for both runs: 118.0 mm^3/cm^2 min.

Table XLI

Dissolution of $TiO_{0.260}$ in 0.075 N HF-1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 733.5 mm Hg

Average room temperature: 33.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	2.76	0.00
5	6.01	3.25
15	6.98	0.97
25	8.45	1.47✓
35	10.11	1.66✓
45	11.86	1.75✓
55	13.81	1.95✓
65	15.92	2.11✓
75	18.07	2.15✓
85	20.31	2.24✓
95	21.85	1.54✓

✓ Average maximum rate for first run: 186.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 735.5 mm Hg

Average room temperature: 31.7°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.94	0.00
5	6.85	2.91
15	7.79	0.94
25	9.06	1.27✓
35	10.70	1.64✓
45	12.30	1.60✓
55	13.94	1.64✓
65	15.75	1.81✓
75	17.39	1.64✓
85	18.95	1.56✓

✓ Average maximum rate for second run: 159.0 mm^3/cm^2 min.

Average maximum rate for both runs: 173.0 mm^3/cm^2 min.

Table XLII

Dissolution of $TiO_{0.260}$ in 0.10 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 734.8 mm Hg

Average room temperature: 32.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	4.09	0.00
5	7.28	3.19
15	8.67	1.39
25	10.31	1.64✓
35	11.94	1.63✓
45	13.91	1.97✓
55	15.87	1.96✓
65	17.83	1.96✓
75	19.84	2.01✓
85	21.76	1.92✓

✓ Average maximum rate for first run: 191.0 mm³/cm² min.

Run No. 2

Average barometric pressure: 734.3 mm Hg

Average room temperature 32.1°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	4.91	0.00
5	8.18	3.27
15	9.81	1.63
25	11.77	1.96✓
35	13.57	1.80✓
45	15.53	1.96✓
55	17.58	2.05✓
65	19.62	2.04✓
75	21.50	1.88✓
85	23.38	1.88✓

✓ Average maximum rate for second run: 194.0 mm³/cm² min.

Average maximum rate for both runs: 193.0 mm³/cm² min.

Table XLIII

Dissolution of TiO_2 in 0.50 N HF. 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 736.7 mm Hg

Average room temperature: 29.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	5.00	0.00
5	6.33	1.33
15	12.83	6.50
25	19.67	6.84
35	26.17	6.50✓
45	33.17	7.00✓
55	40.17	7.00✓
65	47.34	7.17✓
75	54.34	7.00✓
85	60.84	6.50✓

✓ Average maximum rate for first run: 681.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 736.1 mm Hg

Average room temperature: 31.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.13	0.00
5	7.75	4.62
15	12.77	5.02
25	18.30	5.53✓
35	23.73	5.43✓
45	29.34	5.61✓
55	35.19	5.85✓
65	40.55	5.36✓
75	46.23	5.68✓
85	51.59	5.36✓

✓ Average maximum rate for second run: 555.0 mm^3/cm^2 min.

Average maximum rate for both runs: 618.0 mm^3/cm^2 min.

Table XLIV

Dissolution of $TiO_{0.365}$ in 0.05 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 737.9 mm Hg

Average room temperature: 32.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	4.26	0.00
5	7.21	2.95
15	7.71	0.50
25	8.36	0.65✓
35	8.89	0.53✓
45	9.51	0.62✓
55	10.25	0.74✓
65	10.99	0.74✓
75	11.72	0.73✓
85	12.42	0.70✓

✓ Average maximum rate for first run: 93.5 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 737.2 mm Hg

Average room temperature: 33.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.92	0.00
5	6.86	2.94
15	7.35	0.49
25	8.00	0.65✓
35	8.98	0.98✓
45	9.64	0.66✓
55	10.62	0.98✓
65	11.27	0.65✓
75	12.09	0.82✓
85	12.74	0.65✓

✓ Average maximum rate for second run: 107.0 mm^3/cm^2 min.

Average maximum rate for both runs: 100.0 mm^3/cm^2 min.

Table XLV

Dissolution of $TiO_{0.365}$ in 0.075 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 737.6 mm Hg

Average room temperature: 30.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.24	0.00
5	6.15	2.91
15	7.23	1.08✓
25	8.31	1.08✓
35	9.81	1.50✓
45	11.31	1.50✓
55	12.97	1.66✓
65	14.63	1.66✓
75	16.46	1.83✓
85	17.96	1.50✓

✓ Average maximum rate for first run: 205.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 736.7 mm Hg

Average room temperature: 30.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	2.82	0.00
5	5.81	2.99
15	7.14	1.33✓
25	8.14	1.00✓
35	9.55	1.41✓
45	10.96	1.41✓
55	12.79	1.83✓
65	14.36	1.57✓
75	15.94	1.58✓
85	17.43	1.49✓

✓ Average maximum rate for second run: 202.0 mm^3/cm^2 min.

Average maximum rate for both runs: 204.0 mm^3/cm^2 min.

Table XLVI

Dissolution of $TiO_{0.365}$ in 0.10 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 735.8 mm Hg

Average room temperature: 30.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.65	0.00
5	6.97	3.32
15	8.30	1.33
25	9.96	1.66✓
35	11.79	1.83✓
45	13.78	1.99✓
55	15.77	1.99✓
65	17.93	2.16✓
75	20.09	2.16✓
85	21.92	1.83✓

✓ Average maximum rate for first run: 270.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 736.0 mm Hg

Average room temperature: 31.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	4.29	0.00
5	6.36	2.07
15	7.51	1.15
25	9.00	1.49✓
35	10.65	1.65✓
45	12.47	1.82✓
55	13.95	1.48✓
65	15.52	1.57✓
75	17.17	1.65✓
85	18.66	1.49✓

✓ Average maximum rate for second run: 221.0 mm^3/cm^2 min.

Average maximum rate for both runs: 246.0 mm^3/cm^2 min.

Table XLVII

Dissolution of $TiO_{0.365}$ in 0.50 N HF-1.00 N HCl at 25.0°C

Run No. 1

Average barometric pressure: 734.0 mm Hg

Average room temperature: 28.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.68	0.00
5	8.20	4.52
15	13.05	4.85
25	18.57	5.52✓
35	24.34	5.77✓
45	29.61	5.27✓
55	35.29	5.68✓
65	40.98	5.69✓
75	46.50	5.52✓
85	51.85	5.35✓

✓ Average maximum rate for first run: 770.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 734.0 mm Hg

Average room temperature: 28.7°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	4.01	0.00
5	8.35	4.34
15	13.28	4.93
25	18.71	5.43✓
35	24.31	5.60✓
45	29.99	5.68✓
55	35.67	5.68✓
65	41.44	5.77✓
75	47.03	5.59✓
85	52.55	5.52✓

✓ Average maximum rate for second run: 779.0 mm^3/cm^2 min.

Average maximum rate for both runs: 775.0 mm^3/cm^2 min.

Table XLVIII

Dissolution of $TiO_{0.157}$ in 0.10 N HF · 1.00 N HCl at 35.0°C

Run No. 1

Average barometric pressure: 734.8 mm Hg

Average room temperature: 25.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	7.23	0.00
5	11.73	4.50
15	13.90	2.17✓
25	16.24	2.34✓
35	18.20	1.96✓
45	20.49	2.29✓
55	22.62	2.13✓
65	24.66	2.04✓
75	26.70	2.04✓
85	28.74	2.04✓

✓ Average maximum rate for first run: 283.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 734.8 mm Hg

Average room temperature: 25.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	6.99	0.00
5	10.91	3.92
15	13.16	2.25✓
25	15.34	2.18✓
35	17.38	2.04✓
45	19.26	1.88✓
55	21.47	2.21✓
65	23.35	1.88✓
75	25.39	2.04✓
85	27.44	2.05✓

✓ Average maximum rate for second run: 275.0 mm^3/cm^2 min.

Average maximum rate for both runs: 279.0 mm^3/cm^2 min.

Table XLIX

Dissolution of $TiO_{0.226}$ in 0.10 N HF + 1.00 N HCl at 35.0°C

Run No. 1

Average barometric pressure: 736.2 mm Hg

Average room temperature: 24.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	7.17	0.00
5	10.76	3.59
15	13.41	2.65✓
25	16.40	2.99✓
35	19.56	3.16✓
45	22.89	3.33✓
55	25.88	2.99✓
65	29.04	3.16✓
75	32.11	3.07✓
85	35.62	3.51✓

✓ Average maximum rate for first run: 338.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 736.8 mm Hg

Average room temperature: 23.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	8.81	0.00
5	12.79	3.98
15	15.64	2.85✓
25	18.79	3.15✓
35	22.12	3.33✓
45	25.57	3.45✓
55	29.03	3.46✓
65	32.40	3.37✓
75	35.77	3.37✓
85	38.44	2.67✓

✓ Average maximum rate for second run: 342.0 mm^3/cm^2 min.

Average maximum rate for both runs: 340.0 mm^3/cm^2 min.

Table L

Dissolution of $TiO_{0.260}$ in 0.10 N HF · 1.00 N HCl at 35.0°C

Run No. 1

Average barometric pressure: 737.6 mm Hg

Average room temperature: 26.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	7.49	0.00
5	11.75	4.26
15	13.96	2.21
25	16.60	2.64✓
35	18.90	2.30✓
45	21.45	2.55✓
55	24.00	2.55✓
65	26.64	2.64✓
75	29.11	2.47✓
85	31.75	2.69✓

✓ Average maximum rate for first run: 288.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 739.4 mm Hg

Average room temperature: 27.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	11.36	0.00
5	15.09	3.73
15	17.46	2.37
25	20.00	2.54✓
35	22.55	2.55✓
45	25.09	2.54✓
55	27.81	2.72✓
65	30.35	2.54✓
75	32.98	2.63✓
85	35.52	2.54✓

✓ Average maximum rate for second run: 292.0 mm^3/cm^2 min.

Average maximum rate for both runs: 290.0 mm^3/cm^2 min.

Table LI
Dissolution of $TiO_{0.365}$ in 0.10 N HF · 1.00 N HCl at 35.0°C

Run No. 1

Average barometric pressure: 733.5 mm Hg

Average room temperature: 23.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	7.56	0.00
5	11.08	3.52
15	12.54	1.46
25	14.42	1.88
35	16.83	2.41✓
45	19.06	2.23✓
55	21.64	2.58✓
65	24.21	2.57✓
75	26.62	2.41✓
85	29.19	2.57✓

✓ Average maximum rate for first run: 368.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 732.0 mm Hg

Average room temperature: 23.8°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	7.19	0.00
5	10.61	3.42
15	12.75	2.14
25	15.15	2.04✓
35	17.54	2.39✓
45	19.85	2.31✓
55	22.16	2.31✓
65	24.56	2.40✓
75	26.87	2.31✓
85	29.10	2.23✓

✓ Average maximum rate for second run: 349.0 mm^3/cm^2 min.Average maximum rate for both runs: 359.0 mm^3/cm^2 min.

Table LII

Dissolution of $TiO_{0.157}$ in 0.10 N HF · 1.00 N HCl at $45.0^{\circ}C$

Run No. 1

Average barometric pressure: 746.6 mm Hg

Average room temperature: $26.0^{\circ}C$

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	4.66	0.00
5	8.28	3.62
15	11.91	3.63
25	14.67	2.76✓
35	17.60	2.93✓
45	20.45	2.85✓
55	23.34	2.89✓
65	25.88	2.54✓
75	28.64	2.76✓
85	31.41	2.77✓

✓ Average maximum rate for first run: $371.0 \text{ mm}^3/\text{cm}^2 \text{ min.}$

Run No. 2

Average barometric pressure: 747.0 mm Hg

Average room temperature: $26.6^{\circ}C$

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	3.09	0.00
5	6.88	3.79
15	9.47	2.59
25	12.22	2.75✓
35	14.89	2.67✓
45	17.60	2.71✓
55	20.31	2.71✓
65	23.02	2.71✓
75	25.73	2.71✓
85	28.40	2.67✓

✓ Average maximum rate for second run: $360.0 \text{ mm}^3/\text{cm}^2 \text{ min.}$

Average maximum rate for both runs: $366.0 \text{ mm}^3/\text{cm}^2 \text{ min.}$

Table LIII

Dissolution of $TiO_{0.226}$ in 0.10 N HF • 1.00 N HCl at 45.0°C

Run No. 1

Average barometric pressure: 737.0 mm Hg

Average room temperature: 26.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	8.00	0.00
5	12.86	4.86
15	17.11	4.25✓
25	22.14	5.03
35	26.56	4.42✓
45	30.82	4.26✓
55	35.41	4.32✓
65	39.59	4.18✓
75	43.42	3.83✓
85	47.67	4.25✓

✓ Average maximum rate for first run: 450.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 746.0 mm Hg

Average room temperature: 24.8°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	6.77	0.00
5	11.46	4.69
15	14.93	3.47
25	19.10	4.17✓
35	23.61	4.51✓
45	27.77	4.16✓
55	32.11	4.34✓
65	36.28	4.17✓
75	40.27	3.99✓
85	44.09	3.82✓

✓ Average maximum rate for second run: 444.0 mm^3/cm^2 min.

Average maximum rate for both runs: 447.0 mm^3/cm^2 min.

Table LIV

Dissolution of $TiO_{0.260}$ in 0.10 N HF · 1.00 N HCl at 45.0°C

Run No. 1

Average barometric pressure: 746.0 mm Hg

Average room temperature: 26.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	8.29	0.00
5	12.78	4.49
15	16.15	3.37✓
25	19.52	3.37✓
35	23.50	3.98✓
45	26.95	3.45✓
55	30.75	3.80✓
65	34.72	3.97✓
75	38.35	3.63✓
85	41.98	3.63✓

✓ Average maximum rate for first run: 412.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 745.7 mm Hg

Average room temperature: 26.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	5.68	0.00
5	9.64	3.96
15	12.74	3.10✓
25	15.84	3.10✓
35	19.02	3.18✓
45	22.12	3.10✓
55	25.22	3.10✓
65	28.40	3.18✓
75	31.59	3.19✓
85	34.52	2.93✓

✓ Average maximum rate for second run: 354.0 mm^3/cm^2 min.

Average maximum rate for both runs: 383.0 mm^3/cm^2 min.

Table LV

Dissolution of $TiO_{0.365}$ in 0.10 N HF · 1.00 N HCl at 45.0°C

Run No. 1

Average barometric pressure: 738.3 mm Hg

Average room temperature: 26.2°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	6.13	0.00
5	10.05	3.92
15	12.78	2.73
25	15.68	2.90
35	19.08	3.40✓
45	22.41	3.33✓
55	25.65	3.24✓
65	28.71	3.06✓
75	31.95	3.24✓
85	35.18	3.23✓

✓ Average maximum rate for first run: 486.0 mm^3/cm^2 min.

Run No. 2

Average barometric pressure: 738.6 mm Hg

Average room temperature: 26.3°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>
0	5.45	0.00
5	9.03	3.58
15	11.59	2.56
25	14.31	2.72
35	17.21	2.90✓
45	20.19	2.98✓
55	23.17	2.98✓
65	26.24	3.07✓
75	29.31	3.07✓
85	32.29	2.98✓

✓ Average maximum rate for second run: 443.0 mm^3/cm^2 min.

Average maximum rate for both runs: 465.0 mm^3/cm^2 min.

Table LVI
Dissolution of Ti in 0.10 N HF · 1.00 N HCl at 25.0°C

Run No. 1

Stirring speed: 45 r.p.m.

Average barometric pressure: 744.3 mm Hg

Average room temperature: 24.8°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	9.97	0.00
10	10.45	0.48✓
20	10.92	0.47✓
30	11.40	0.48✓
40	11.79	0.39✓
50	12.31	0.52✓
60	12.83	0.52✓

✓ Average maximum rate for first run: 47.7 mm³/cm² min.

Run No. 2

Stirring speed: 90 r.p.m.

Average barometric pressure: 739.0 mm Hg

Average room temperature: 27.9°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	9.71	0.00
10	10.39	0.68✓
20	11.32	0.93✓
30	12.33	1.01✓
40	13.09	0.76✓
50	13.77	0.68✓
60	14.53	0.76✓

✓ Average maximum rate for second run: 80.3 mm³/cm² min.

Table LVI (continued)

Dissolution of Ti in 0.10 N HF · 1.00 N HCl at 25.0°C

Run No. 3

Stirring speed: 160 r.p.m.

Average barometric pressure: 739.0 mm Hg

Average room temperature: 28.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	15.19	0.00
10	16.46	1.27✓
20	17.64	1.18✓
30	18.99	1.35✓
40	20.17	1.18✓
50	21.61	1.44✓
60	22.79	1.18✓

✓ Average maximum rate for third run: 127.0 mm³/cm² min.

Run No. 4

Stirring speed: 200 r.p.m.

See Table XXI

✓ Average maximum rate for fourth run: 147.0 mm³/cm² min.

Table LVI (continued)

Dissolution of Ti in 0.10 N HF·1.00 N HCl at 25.0°C

Run No. 5

Stirring speed: 250 r.p.m.

Average barometric pressure: 737.6 mm Hg

Average room temperature: 25.5°C

<u>Time</u> <u>(Minutes)</u>	Corr. Volume H ₂ <u>(cm³)</u>	ΔV <u>(cm³)</u>
0	8.54	0.00
5	9.31	0.77✓
10	10.17	0.86✓
15	10.94	0.77✓
20	11.79	0.85✓
25	12.56	0.77✓
30	13.41	0.85✓

✓ Average maximum rate for fifth run: 162.0 mm³/cm² min.

Run No. 6

Stirring speed: 310 r.p.m.

Average barometric pressure: 737.6 mm Hg

Average room temperature: 25.5°C

<u>Time</u> <u>(Minutes)</u>	Corr. Volume H ₂ <u>(cm³)</u>	ΔV <u>(cm³)</u>
0	12.82	0.00
5	13.67	0.85✓
10	14.52	0.85✓
15	15.38	0.86✓
20	16.32	0.94✓
25	17.17	0.85✓
30	18.11	0.94✓

✓ Average maximum rate for sixth run: 176.0 mm³/cm² min.

Table LVI (continued)

Dissolution of Ti in 0.10 N HF • 1.00 N HCl at 25.0°C

Run No. 7

Stirring speed: 400 r.p.m.

Average barometric pressure: 732.4 mm Hg

Average room temperature: 25.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	3.90	0.00
5	7.29	3.39
10	8.22	0.93✓
15	9.16	0.94✓
20	10.00	0.84✓
25	10.93	0.93✓
30	11.95	1.02✓
35	12.88	0.93✓
40	13.73	0.85✓
45	14.58	0.85✓

✓ Average maximum rate for seventh run: 183.0 mm³/cm² min.

Run No. 8

Stirring speed: 460 r.p.m.

Average barometric pressure: 737.6 mm Hg

Average room temperature: 25.8°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H₂</u> <u>(cm³)</u>	<u>ΔV</u> <u>(cm³)</u>
0	8.53	0.00
5	9.47	0.94✓
10	10.41	0.94✓
15	11.42	1.02✓
20	12.37	0.94✓
25	13.31	0.94✓
30	14.21	0.90✓

✓ Average maximum rate for eighth run: 189.0 mm³/cm² min.

Table LVII

Difference Effect on $\text{TiO}_{0.157}$ in 0.10 N HF · 1.00 N HCl
at 25.0°C

Run No. 1

Average barometric pressure: 733.6 mm Hg

Average room temperature: 25.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>	<u>Rate</u> <u>($\text{mm}^3/\text{cm}^2 \text{ min}$)</u>	<u>I</u> <u>(ma/cm^2)</u>
0	8.50	0.00	0.00	-
10	9.01	0.51	68.00	-
20	9.60	0.59	78.67	-
30	10.28	0.68	90.67	-
40	10.70	0.42	56.00	8.40
50	11.13	0.43	57.33	8.40
60	11.72	0.59	78.67	8.40
70	12.15	0.43	57.33	-
80	12.66	0.51	68.00	-
90	13.17	0.51	68.00	6.00
100	13.85	0.68	90.67	6.00
110	14.36	0.51	68.00	6.00
120	14.87	0.51	68.00	-
130	15.55	0.68	90.67	-
140	15.97	0.42	56.00	3.33
150	16.48	0.51	68.00	3.33
160	16.99	0.51	68.00	3.33
170	17.59	0.60	80.00	-
180	18.18	0.59	78.67	-
190	18.69	0.51	68.00	2.00
200	19.29	0.60	80.00	2.00

Table LVIII

Difference Effect on $TiO_{0.157}$ in 0.50 N HF·1.00 N HCl
at 25.0°C

Run No. 2

Average barometric pressure: 725.9 mm Hg

Average room temperature: 25.7°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>	<u>Rate</u> <u>(mm^3/cm^2 min)</u>	<u>I</u> <u>(ma/cm^2)</u>
0	6.55	0.00	0.00	-
5	8.23	1.68	448.0	-
10	9.99	1.76	469.3	-
15	11.75	1.76	469.3	-
20	13.10	1.35	360.0	44.00
25	14.27	1.17	312.0	44.00
30	15.49	1.22	325.3	44.00
35	17.30	1.81	482.7	-
40	19.31	2.01	536.0	-
45	21.24	1.93	514.7	30.00
50	23.09	1.85	493.3	30.00
55	25.52	2.43	648.0	-
60	27.54	2.02	538.7	-
65	29.34	1.80	480.0	25.00
70	31.40	2.06	549.3	25.00
75	33.58	2.18	581.3	-
80	35.77	2.19	584.0	-
85	37.61	1.84	490.7	20.00
90	39.55	1.94	517.3	20.00
95	41.64	2.09	557.3	-
100	43.66	2.02	538.7	-
105	45.46	1.80	480.0	15.00
110	47.31	1.85	493.3	15.00
115	49.57	2.26	602.7	-
120	51.76	2.19	584.0	-
125	53.73	1.97	525.3	10.00
130	55.67	1.94	517.3	10.00
135	57.85	2.18	581.3	-
140	60.03	2.18	581.3	-
145	62.21	2.18	581.3	5.00
150	64.31	2.10	560.0	5.00
155	66.50	2.19	584.0	-
160	68.76	2.26	602.7	-

Table LIX

Difference Effect on $TiO_{0.157}$ in $0.75\ N\ HF \cdot 1.00\ N\ HCl$
at $25.0^{\circ}C$

Run No. 3

Average barometric pressure: 732.9 mm Hg

Average room temperature: $23.5^{\circ}C$

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>	<u>Rate</u> <u>($mm^3/cm^2\ min$)</u>	<u>I</u> <u>(ma/cm^2)</u>
0	8.41	0.00	0.00	-
4	10.73	2.32	773.3	-
8	12.87	2.14	713.3	-
12	15.28	2.40	803.3	-
16	16.99	1.71	570.0	77.33
20	18.71	1.72	573.3	77.33
24	20.85	2.14	713.3	-
28	23.17	2.32	773.3	-
32	25.40	2.23	743.3	65.00
36	27.55	2.15	716.7	65.00
40	29.95	2.40	800.0	-
44	32.44	2.49	830.0	-
48	34.50	2.06	686.7	57.33
52	36.65	2.15	716.7	57.33
56	39.13	2.48	826.7	-
60	41.71	2.58	860.0	-
64	43.94	2.23	743.3	50.60
68	46.17	2.23	743.3	50.60
72	48.75	2.58	860.0	-
76	51.32	2.57	856.7	-
80	53.55	2.23	743.3	41.33
84	55.87	2.32	773.3	41.33
88	58.36	2.49	830.0	-
92	60.93	2.57	856.7	-
96	63.08	2.15	716.7	29.33
100	65.31	2.23	743.3	29.33
104	67.88	2.57	856.7	-
108	70.29	2.41	803.3	-
112	72.60	2.31	770.0	20.00
116	74.92	2.32	773.3	20.00
120	77.41	2.49	830.0	-
124	79.90	2.49	830.0	-
128	82.30	2.40	800.0	10.00
132	84.70	2.40	800.0	10.00
136	87.19	2.49	830.0	-
140	89.60	2.41	803.3	-

Table LX

Difference Effect on $TiO_{0.263}$ in 0.50 N HF · 1.00 N HCl
at 25.0°C

Run No. 1

Average barometric pressure: 733.6 mm Hg

Average room temperature: 24.4°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>	<u>Rate</u> <u>(mm^3/cm^2 min)</u>	<u>I</u> <u>(ma/cm^2)</u>
0	5.62	0.00	0.00	-
5	7.83	2.21	578.6	-
10	10.03	2.20	575.6	-
15	11.88	1.85	483.1	40.00
20	13.67	1.79	470.5	40.00
25	15.89	2.22	580.1	-
30	18.09	2.20	575.6	-
35	19.89	1.80	471.2	31.50
40	21.71	1.82	477.4	31.50
45	23.95	2.24	587.6	-
50	26.18	2.23	582.4	-
55	28.15	1.97	514.7	21.00
60	30.15	2.00	523.3	21.00
65	32.38	2.23	582.4	-
70	34.62	2.24	587.6	-
75	36.72	2.10	549.9	10.05
80	38.80	2.08	543.7	10.05
85	41.13	2.33	610.3	-
90	43.47	2.34	612.4	-
95	45.78	2.31	604.2	5.00
100	48.09	2.31	604.2	5.00
105	50.40	2.31	604.2	-
110	52.72	2.32	606.8	-
115	55.02	2.30	603.1	2.00
120	57.31	2.29	600.7	2.00
125	59.61	2.30	603.1	-
130	61.93	2.32	606.8	-

Table LXI

Difference Effect on $TiO_{0.263}$ in 0.75 N HF-1.00 N HCl
at 25.0°C

Run No. 2

Average barometric pressure: 737.7 mm Hg

Average room temperature: 23.0°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>	<u>Rate</u> <u>(mm^3/cm^2 min)</u>	<u>I</u> <u>(ma/cm^2)</u>
0	6.80	0.00	0.00	-
5	9.57	2.77	724.2	-
10	12.33	2.76	722.6	-
15	14.21	1.88	491.6	70.25
20	16.11	1.90	497.6	70.25
25	18.86	2.75	720.6	-
30	21.63	2.77	724.2	-
35	23.77	2.14	559.1	65.00
40	25.94	2.17	567.1	65.00
45	28.71	2.77	724.2	-
50	31.49	2.78	728.2	-
55	33.71	2.22	580.9	56.00
60	35.95	2.24	587.1	56.00
65	38.73	2.78	728.2	-
70	41.54	2.81	736.1	-
75	43.90	2.36	619.0	50.00
80	46.24	2.34	611.8	50.00
85	49.05	2.81	736.1	-
90	51.87	2.82	737.4	-
95	54.32	2.45	641.3	44.00
100	56.81	2.49	651.9	44.00
105	59.67	2.86	749.1	-
110	62.51	2.84	743.2	-
115	65.19	2.68	702.2	33.00
120	67.84	2.65	693.2	33.00
125	70.74	2.90	760.1	-
130	73.63	2.89	755.8	-
135	76.20	2.57	673.8	25.00
140	78.76	2.56	669.2	25.00
145	81.68	2.92	763.6	-
150	84.60	2.92	763.6	-
155	87.39	2.79	730.1	17.50
160	90.20	2.81	736.1	17.50
165	93.09	2.89	755.8	-
170	95.98	2.89	755.8	-

Table LXII

Difference Effect on $TiO_{0.365}$ in 0.20 N HF-1.00 N HCl
at 25.0°C

Run No. 1

Average barometric pressure: 743.4 mm Hg

Average room temperature: 24.6°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>	<u>Rate</u> <u>(mm^3/cm^2 min)</u>	<u>I</u> <u>(ma/cm^2)</u>
0	8.66	0.00	0.00	-
10	10.56	1.90	284.0	-
20	12.38	1.82	272.0	-
30	13.77	1.39	207.8	12.56
40	15.15	1.38	206.3	12.56
50	17.06	1.91	285.5	-
60	18.96	1.90	284.0	-
70	20.35	1.39	207.8	9.42
80	21.82	1.47	219.7	9.42
90	23.46	1.64	245.1	-
100	25.02	1.56	233.2	-
110	26.54	1.52	227.2	5.83
120	28.05	1.51	225.7	5.83
130	29.61	1.56	233.2	-
140	31.08	1.47	219.7	-
150	32.64	1.56	233.2	3.00
160	34.20	1.56	233.2	3.00
170	35.76	1.56	233.2	-
180	37.36	1.60	239.2	-

Table LXIII

Difference Effect on $TiO_{0.365}$ in 0.50 N HF · 1.00 N HCl
at 25.0°C

Run No. 2

Average barometric pressure: 742.8 mm Hg

Average room temperature: 25.8°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>	<u>Rate</u> <u>(mm^3/cm^2 min)</u>	<u>I</u> <u>(ma/cm^2)</u>
0	7.05	0.00	0.00	-
5	8.94	1.89	565.0	-
10	10.66	1.72	514.2	-
15	12.46	1.80	538.1	-
20	13.97	1.51	453.6	37.40
25	15.51	1.54	460.0	37.40
30	17.06	1.55	463.4	-
35	18.69	1.63	487.3	-
40	20.08	1.39	416.0	30.00
45	21.43	1.35	405.4	30.00
50	22.85	1.42	424.5	-
55	24.31	1.46	436.5	-
60	25.58	1.27	379.4	25.00
65	26.87	1.29	385.6	25.00
70	28.50	1.63	487.3	-
75	30.13	1.63	487.3	-
80	31.63	1.50	449.8	20.00
85	33.16	1.53	459.6	20.00
90	34.70	1.54	460.4	-
95	36.34	1.64	490.3	-
100	37.95	1.61	482.1	15.00
105	39.53	1.58	473.5	15.00
110	41.42	1.89	565.0	-
115	43.22	1.80	538.1	-
120	44.81	1.59	474.8	10.00
125	46.44	1.63	487.0	10.00
130	47.99	1.55	463.4	-
135	49.62	1.63	487.3	-
140	51.25	1.63	487.3	5.00
145	52.80	1.55	463.4	5.00
150	54.43	1.63	487.3	-
155	56.15	1.72	514.2	-

Table LXIV

Difference Effect on $\text{TiO}_{0.365}$ in 0.75 N HF·1.00 N HCl
at 25.0°C

Run No. 3

Average barometric pressure: 742.6 mm Hg

Average room temperature: 25.5°C

<u>Time</u> <u>(Minutes)</u>	<u>Corr. Volume H_2</u> <u>(cm^3)</u>	<u>ΔV</u> <u>(cm^3)</u>	<u>Rate</u> <u>($\text{mm}^3/\text{cm}^2 \text{ min}$)</u>	<u>I</u> <u>(ma/cm^2)</u>
0	5.87	0.00	0.00	-
5	7.59	1.72	514.2	-
10	9.49	1.90	568.0	-
15	11.26	1.77	529.1	70.25
20	13.00	1.74	520.9	70.25
25	15.24	2.24	669.7	-
30	17.56	2.32	693.6	-
35	19.10	1.54	458.7	62.50
40	20.69	1.59	475.3	62.50
45	22.97	2.28	681.6	-
50	25.30	2.33	696.6	-
55	27.19	1.89	565.0	52.31
60	28.91	1.72	514.2	52.31
65	37.32	2.41	720.5	-
70	33.73	2.41	720.5	-
75	35.79	2.06	615.8	45.00
80	37.86	2.07	618.8	45.00
85	40.18	2.32	693.6	-
90	42.68	2.50	747.4	-
95	44.83	2.15	642.8	40.00
100	46.98	2.15	642.8	40.00
105	49.39	2.41	720.5	-
110	51.80	2.41	720.5	-
115	54.03	2.23	666.7	35.00
120	56.18	2.15	642.8	35.00
125	58.51	2.33	696.6	-
130	60.92	2.41	720.5	-
135	63.24	2.32	693.6	30.00
140	65.56	2.32	693.6	30.00
145	67.89	2.33	642.8	-
150	70.21	2.32	693.6	-
155	72.45	2.24	669.7	25.00
160	74.60	2.15	642.8	25.00
165	77.00	2.40	717.5	-
170	79.41	2.41	720.5	-
175	81.82	2.41	720.5	15.00
180	84.23	2.41	720.5	15.00
185	86.64	2.41	720.5	-
190	89.14	2.50	747.4	-

BIBLIOGRAPHY

1. Chen, P.C.: A Study of the Dissolution of Titanium in Acids with Emphasis on Hydrofluoric Acid, Unpublished Ph.D. Thesis, Library, University of Missouri School of Mines and Metallurgy, Rolla, Missouri, (1950)
2. Evans, U.R.: Metallic Corrosion, Passivity and Protection, London, Arnold, 747, (1946)
3. Straumanis, M.E. and Chen, P.C.: The Mechanism and Rate of Dissolution of Titanium in Hydrofluoric Acid, J. Electrochem. Soc., 98, 234, (1951)
4. James, W.J. and Straumanis, M.E.: Formation of Hydride Films on Ti, Zr, Hf, Th Dissolving in Hydrofluoric Acid, J. Electrochem. Soc., 106, 631, (1959)
5. James, W.J., Custead, W.G., and Straumanis, M.E.: Chemical Kinetics of the Zirconium Hydrofluoric Acid Reaction, Jour. of Phys. Chem., 64, 286, (1960)
6. Smith, T. and Hill, G.R.: A reaction Rate Study of the Corrosion of Low-Hafnium Zirconium in Aqueous Hydrofluoric Acid Solutions, J. Electrochem. Soc., 105, 117, (1958)
7. Straumanis, M.E., Cheng, C.H., and Schlechten, A.W.: Hydrogen Evolution from Dissolving Titanium-Oxygen Alloys in Hydrofluoric Acid and the Constitution of Ti-O Alloys, J. Electrochem. Soc., 103, 439, (1956)
8. Thiel, A. and Eckell, J.Z.: J. Electrochem. Soc., 33, 370, (1927)
9. Straumanis, M.E. and Wang, Y.N.: The Difference Effect on Aluminum Dissolving in Hydrofluoric and Hydrochloric Acids, J. Electrochem. Soc., 102, 304, (1955)
10. Pauling, Linus: The Nature of the Chemical Bond, p. 284, Cornell University Press, Ithaca, N.Y., 1948. 2ed.
11. James, W.J., Johnson, J.W., and Straumanis, M.E.: Dissolution of Hafnium in Hydrofluoric Acid, Unpublished Progress Report, Corrosion of Nuclear Metals, AEC AT(11-1)-73, Project 5, (1960)

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