Study on Metal Leaf Boundary Shape

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Abstract

Metal leaves are metal products which are deposited due to the difference in ionization tendency. We defined the space between two metal leaf boundaries as a circle and expressed it as an equation.

I. Purpose

1. Background

Metal leaves are a kind of metal trees which was taught to us in a chemistry class during a high school. We briefly explain the process of the creation of metal trees.

First, you put metal A in an aqueous solution containing the metal B ion. Then, simple metal A in the solution deposit on the surface of the metal B dendritically by redox reaction. Metal leaves are what make metal ion deposits in a petri dish. (Figure.1)

Previous research has shown the following: metal trees with the same kind of metal at their core form boundaries on a straight line without colliding with each other.(Figure.2) In the present study, we studied what the boundary between different kinds of metal leaves was. We paid attention to two points: (a) Which metal leaves have a faster growth rate and size. (b)What shape does the boundary between the two metal leaves form.

(Figure.1)

(Figure.2)

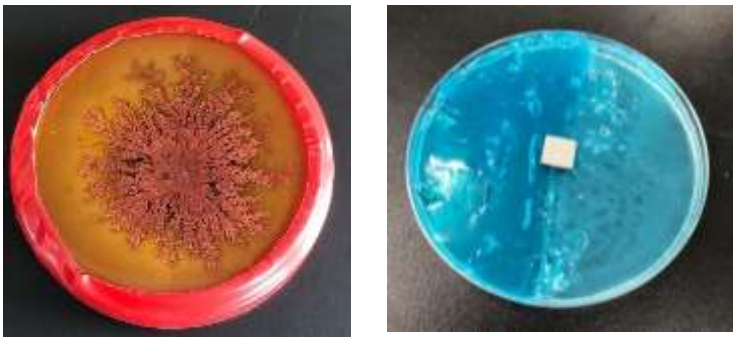
2. Previous Research

Previous research hypothesized the following:

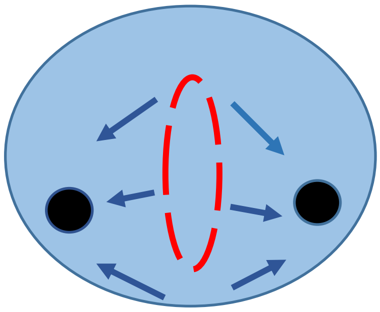
Why is there a space between the two metal leaves? It is not clear, so we made two hypotheses about this. (Figure.3)

1. Metal leaves growth rate will be reduced near the boundary due to the ion concentration being reduced or the gradient effect.
2. Metal emits electrons when it is oxidized. As a result of their repulsion, space is created between the metal leaves.

We made an experimental device and tested. : 1: (a picture divided into two layers) Left one is 0.89mol/L and right one is 0.46mol/L. We observed the change for two weeks.



(Figure.3)



(Figure.4)

[Results]
(Figure.5)
There was no particular difference in the growth distance of the metal leaves due to the difference in molar concentration.　The distance of leaf growth does not change.

[Consideration]
This experiment was conducted only at two concentrations.　For example, leaves cannot grow where the density is almost zero because of a localized gradient. So, assuming that the metal leaves interfere with each other, this experiment is not enough. Therefore, we are currently working on additional experiments.

3.　Our Hypothesis

About Point. (a)

"Which metal leaf deposited from each metal piece grows larger?"
For this question, we expected that of the two metal leaves, one deposited from the piece of metal having higher Ionization tendency would grow larger.　This is because metal with higher ionization tendency is supposed to bring oxidation-reduction reaction with copper ion in the solution faster than the other, then the copper deposits in the form of simple substance around the pieces.

II. Methods

We used a beaker, a graduated cylinder, petri dishes, a tripod, a wire gauze, a gas burner, a glass rod and a piece of vinyl tape.

[Reagents]
We used water, copper sulfate (II) pentahydrate, agar, glycerin, sodium acetate, hydrochloric acid, single metal pieces (such as iron, zinc, aluminum and tin).

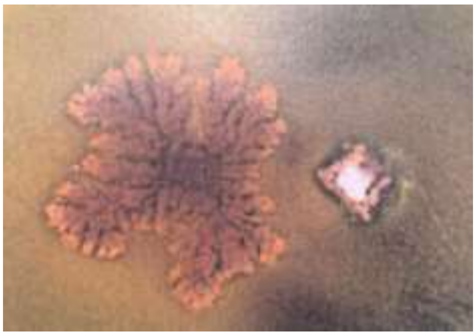
1. **Procedures**

A. You cut the single piece of metal into about 1mm square.

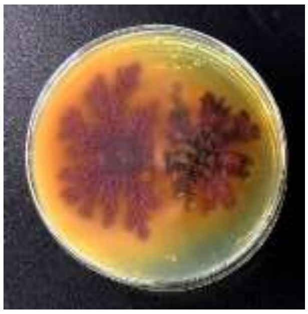
B. You make a buffer solution (fixed to pH 5.0) by mixing 15mL of hydrochloric acid(1.0mol/L), 50mL of acetic acid(1.0mol/L) and 185 mL of water
C. You put the buffer solution into the beaker and heat it with a gas burner.
D. You turn off the burner when it boils, and add 71.4mL of glycerin and 2.86g of agar.
E. You mix them until the temperature drops to 50°C, and add 35.7g of copper sulfate (II) pentahydrate, and stir well.
F. You add it up to 5 mm thick to the dish. 7. You place two pieces of metal in a combination once the solution has solidified. Also, seal the petri dish with vinyl tape.

(1) Set the Petri dishes on a printer and use graph paper.
Enlarge and print the leaf on the paper.

Examination and Result
In order to inspect the hypothesis, we conducted following two examination.



(Figure.6　Zinc and Iron)



(Figure.7　Iron and Aluminum)

Both cases showed that the metal leaf deposited from the piece of metal having smaller ionization tendency grew larger than the other contrary to our hypothesis.

Consideration
For the reason why the metal leaves grew the same rate regardless of their ionization.　It is estimated that metal leaves grow in accordance with the metal piece’s properties.
As regards Iron, in the picture 5, brown color can be observed around the metal leaf, which indicates that Fe^{3+} appears there.　Fe^{3+} promotes as a catalyst the reaction “$Fe \rightarrow Fe^{3+} + 3e^-$”.
In another case, Aluminum makes film over itself which prevents the oxidation reaction and slows the reactiveness and the leaf grows smaller.
Namely, our hypothesis focused on only one aspect of ionization, but actually the nature of metals also effects the growth rate and size of metal leaves.

About Point (b)
What kind of shape is the boundary line formed by the interference of two metal leaves?

Result

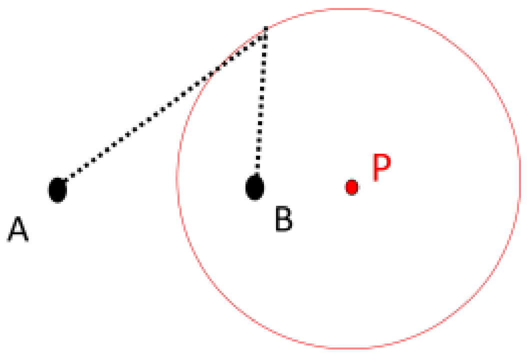
In order to check the hypothesis, we observed the metal leaves again.
We verified that circular shape was formed in 22 out of 31 cases.

Consideration

In the above experiment why was a circular boundary line observed? Here we introduced the idea of Apollonius Circle.

First, we assumed that the growth rate of the metal leaves that grows from each piece of metal was constant. (this assumption remains controversial. However, we proceeded under this assumption)
At this time, we applied the following mathematical properties.

There is a fixed distance ratio from two different points A and B.
The locus of the point P forms a circle and it is called Apollonius Circle. The principle is shown in the figure bellow. (Figure.8)



(Figure.8)

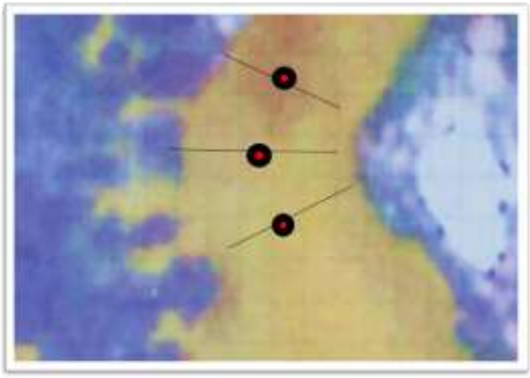
Then how can we use the principal to explain the interference between metal leaves? First let a be the growth rate of metal leaves from metal A,
B from metal B (a and b is constant).
At this time when a certain time has passed both metal leaves intersect at a certain point P (actually they form a boundary line not intersect),
AP:BP=at:bt=a:b(=constant)
That is to say at any point P the ratio of the distance from A and B is constant. In other words, it can be applied to the above*, and we have derived the hypothesis that the part formed by the Internet of metal leaves is part of a circle.

Based on the above hypothesis the following operations were performed in the collected date.

(2) Definition of boundary line

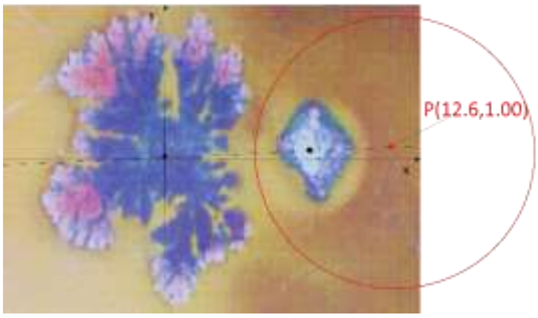
The boundary is defined as the middle point of the line that connect two metal leaves with the shortest distance.

The curve that connect the boundary point was regarded as the outline of boundary shape in this research. (Figure.9)



(Figure.9)

(3) Considering the curve obtained in (2) as a circle, and set the radius and draw. (Figure.10)



(Figure.10)

The following problems are involved in the operation of this drawing.

•we aren’t sure how logical our definition of boundary is.

•It is difficult to accurately measure the growth rate of each metal leaf. Thus, the ratio of growth rate between two metal leaves is unknown.

Ⅲ. Conclusion

We researched the relationship between two growing metal leaves. We succeeded in defining the boundary line of them and expressing it in the equation of a circle. What is notable and valuable in our research is that we found mathematical factors in chemical experiences. Actually we have not come up with a real contribution of our research to the society. However, we believe that this research, focusing on actual phenomena of ionization tendency, will be applied in some technology. Finally our research will help science progress.

IV. Acknowledgments

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V. References

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VI. Key words

Metal leaf
Boundary
Apollonius circle