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Project

MARANGONI EFFECT IN LIQUID ENVIRONMENTS

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Introduction

What is the Gibbs-Marangoni effect?

What is the Marangoni effect? In simple words it is a flow that is formed in a liquid because of surface tension. As an analogue we can imagine pressure drop in the air, and as a result the wind always blows from the point of high pressure to the point of lower pressure. In the Marangoni effect it is the opposite. The flow is moving from the points of lower pressure of surface tension to the points of higher pressure. The effect was first discovered in 1855 by James Thomson but was called after the Italian scientist Karlo Marangoni.

Here is the mechanism of the effect. It is quite simple. The more surface tension the liquid has, the stronger it is pinched by it. This happens because inside the liquid the particles are gathered to each other evenly. But on the surface they are not even. The particles of the liquid from the inside attract the particles on the top.

Problems of Marangoni effect exploration

The studying of this effect is very difficult, but very important for many different branches of science and technology. It is a bit complicated to study this effect because there is no specific method to study it. The Marangoni effect lies both in chemistry and physics. There are still no methods for describing processes in physical chemistry.

I decided to experiment with the Marangoni effect myself. To be exact the purpose of my experiment is to study the Marangoni effect visually and see what factors change the speed and intensity of of the effect.

Experiment

Purpose

To study and measure the duration of the Marangoni effect by observing it, changing the fat content of milk and identifying factors that affect the duration of the Marangoni effect.

Question

What are the factors that affect the duration of the Marangoni effect?

Materials

- Food colouring
  - ➢ Red
  - ➢ Blue
  - ➢ Green
  - ➢ Yellow
- Milk
  - ➢ 0%
  - ➢ 1%
  - ➢ 2%
  - ➢ 3.25%
  - ➢ 5%
  - ➢ 10%
  - ➢ 18%
  - ➢ 35%
- Detergent “Ultra Sunlight”
- Flat bowl, diameter - 19.5 cm
- Timer

Hypothesis

My hypothesis is that milk with lower fat level (lower viscosity level) has faster and more effective flows of the Marangoni effect than milk with higher fat level.

Variables

Independent variable - Milk fat level

Dependent variable - Time the milk stops moving

Procedure

1. Put the bowl on a flat surface, e.g. table.
2. Use the table below to set up each part of the experiment.

Number of part	Materials used
1	100mL of 0% milk, 0.1mL of detergent
2	100mL of 1% milk, 0.1mL of detergent
3	100mL of 2% milk, 0.1mL of detergent
4	100mL of 3.25% milk, 0.1mL of detergent
5	100mL of 5% milk, 0.1mL of detergent
6	100mL of 10% milk, 0.1mL of detergent
7	100mL of 18% milk, 0.1mL of detergent
8	100mL of 35% milk, 0.1mL of detergent

3. We will observe the factors that affect the time of the Marangoni effect by timing it. We will stop the the timer when we see that all the fluids stopped moving.
4. Calculate each time for how long the milk keeps moving.
5. Repeat the above procedure for every part of the experiment from the table.
6. Record your measurements in the Results table.

Results

Conclusions

My hypothesis was partly correct. As we can see from our Results table, the milk that has the lowest fat level (0%) has the shortest duration of the Marangoni effect (1.44 minutes). As he fat level increases, the flows' speed decreases. When the fat content reaches 5%, the duration of the Marangoni effect reaches its highest point (3.38 minutes). However, the duration starts decreasing until, at the point when milk fat content reaches 35%, the effect becomes impossible.

Discussion

As we increased the fat amount in milk, the surface tension reduced more and more. Starting at 5% milk the Marangoni effect began to decay visually. At 18% the decay got stronger, and at 35% the effect became impossible.

The higher fat-level the milk has, the less surface tension it has. The difference between surface tensions reduces, so the process of milk and detergent becomes the most balanced to the point of 5% milk fat level. Then, the viscosity of milk increases. The milk particles start to surround the detergent particles and the effect decays. The process is absolutely faded at 35% milk fat level. I suppose that if we repeat the experiment vice versa, that is if we add 100mL of detergent and 1 drop of milk, milk will be doing the role of the detergent from the first experiment. Moreover, the higher the fat level of the milk in this experiment is, the more glamorous it looks. I suppose that in this experiment the 35% fat level milk would have the most effective flows of the Marangoni effect, but still not as effective as in my experiment. They'd be very slow because the viscosity of both liquids is very high and their surface tensions are very small.

The effect was studied on the example of detergent and milk reacting to each other. I tried to study the effect with a laundry detergent. The Marangoni effect didn't work. I concluded that Marangoni effect doesn't

work the same in all environments. We need to choose the environments precisely.

The results would be a bit more exact if we repeated them more times. That was one of the possible sources of error.

How could we use the Marangoni effect in real life?

Economic expediency

With the correct choice of mixtures, the Marangoni effect can excellently clean not only the surface of milk, but also of water. Scientists from Princeton University discovered the method of cleaning water with alcohol. This happens because alcohol has less surface tension than water by approximately 3 times, and we can see the Marangoni effect very clearly.The Princeton University's scientists created the visualization model from water and alcohol. I showed you a visualisation of the Marangoni effect with the help of milk and food colouring.

We can make a conclusion that if humans can once systematize all their knowledge, the Marangoni effect can find wide application in the following fields:

1. Cleaning water (lakes, rivers, seas).
   For example, we have a dirty pool that is 25m². It has some dust on the surface. We need to clean it up quickly. We can add 500mL of alcohol and the Marangoni effect will occur. The light dust will spread all over the borders of the pool becoming less scattered. After that we can easily collect the dust with a scoop-net. Its material should let the water go through while collecting all the dust.
2. Medical use (studying bladder, lungs, etc.).

Medical scientists are actively working to create an effective carrier for drugs that will deliver the medicine to the needed organ.

3. Use in space and astronomy (semiconductors in pure environments).
   The Marangoni effect is very important for astronomy. Any liquid in weightless conditions changes its properties. The study of the effect will help create liquids with specified properties for weightless conditions.
4. Use in industry (make oil clean, without dirt and bacteria).
   Oil is a difficult liquid system, made out of mixtures of different fractions. In this mixture, on the border of the fractions, different Marangoni effect flows and thermodynamic effects occur.

Resources

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