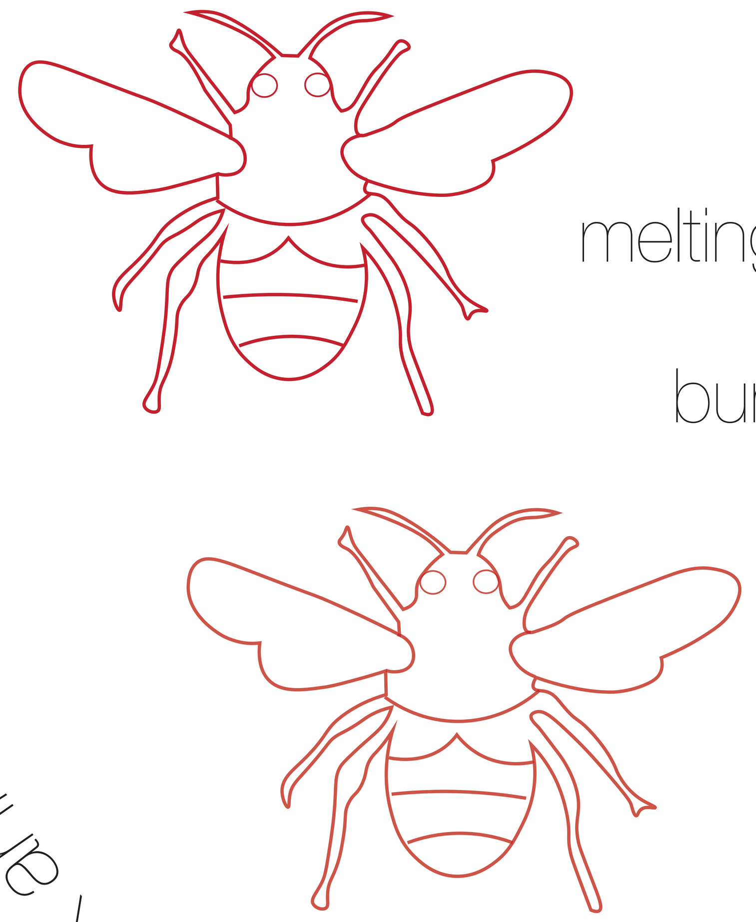
ADAPTIVE TECHTONICS AND MATERIAL INTELLIGENCE

STUDYING AND ANALYSING THE TRANSFORMATIVE MATERIAL NATURE OF PARAFFIN WAX AND NITINOL

ASSESSING DIFFERENT TYPES OF WAX TO STUDY

animal wax animal wax animal wax animal wax animal wax animal wax animal wax animal wax animal wax animal wax animal wax

$C_{15}H_{31}COOC_{30}H_{61}$



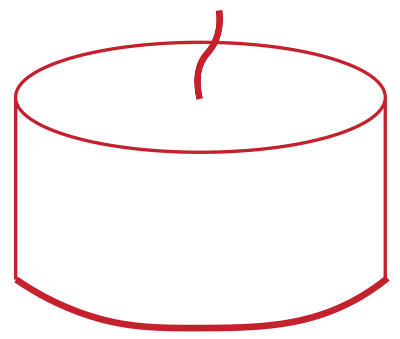
melting point : 62-65¡C

burns over 200¡C

Natural Scent

paraffin wax paraffin wax paraffin wax paraffin wax paraffin wax paraffin wax paraffin wax paraffin wax paraffin wax

CnH2n+2

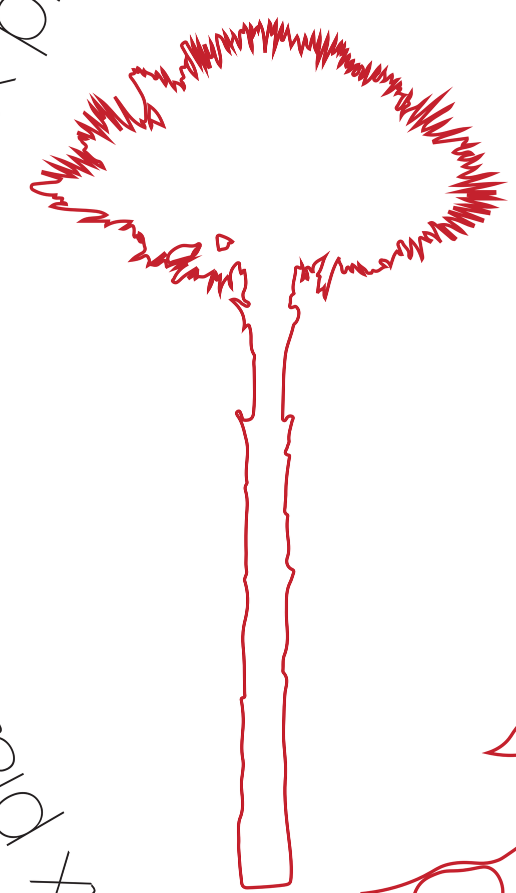


melting point : 46-68¡C

boiling point : 370¡C

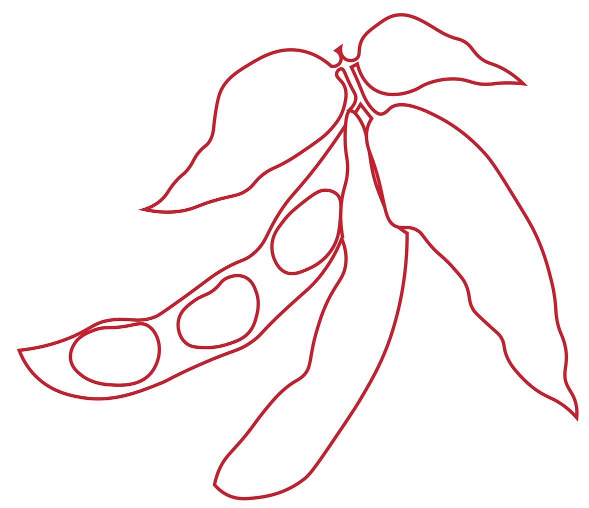
plant wax plant wax plant wax plant wax plant wax plant wax plant wax plant wax plant wax plant wax

Carnauba tree, soy



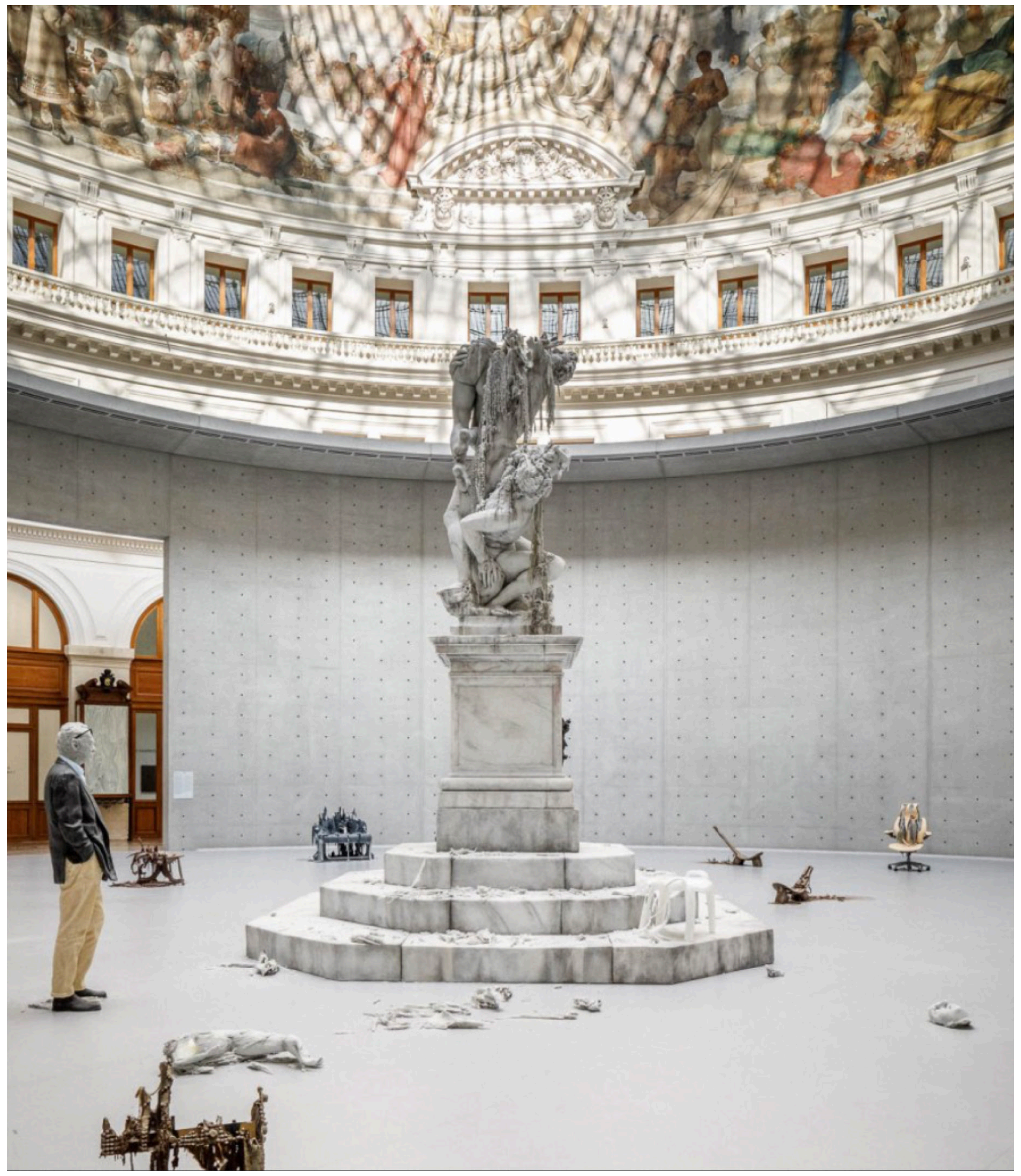
melting point : 75-85¡C

boiling point : 370¡C

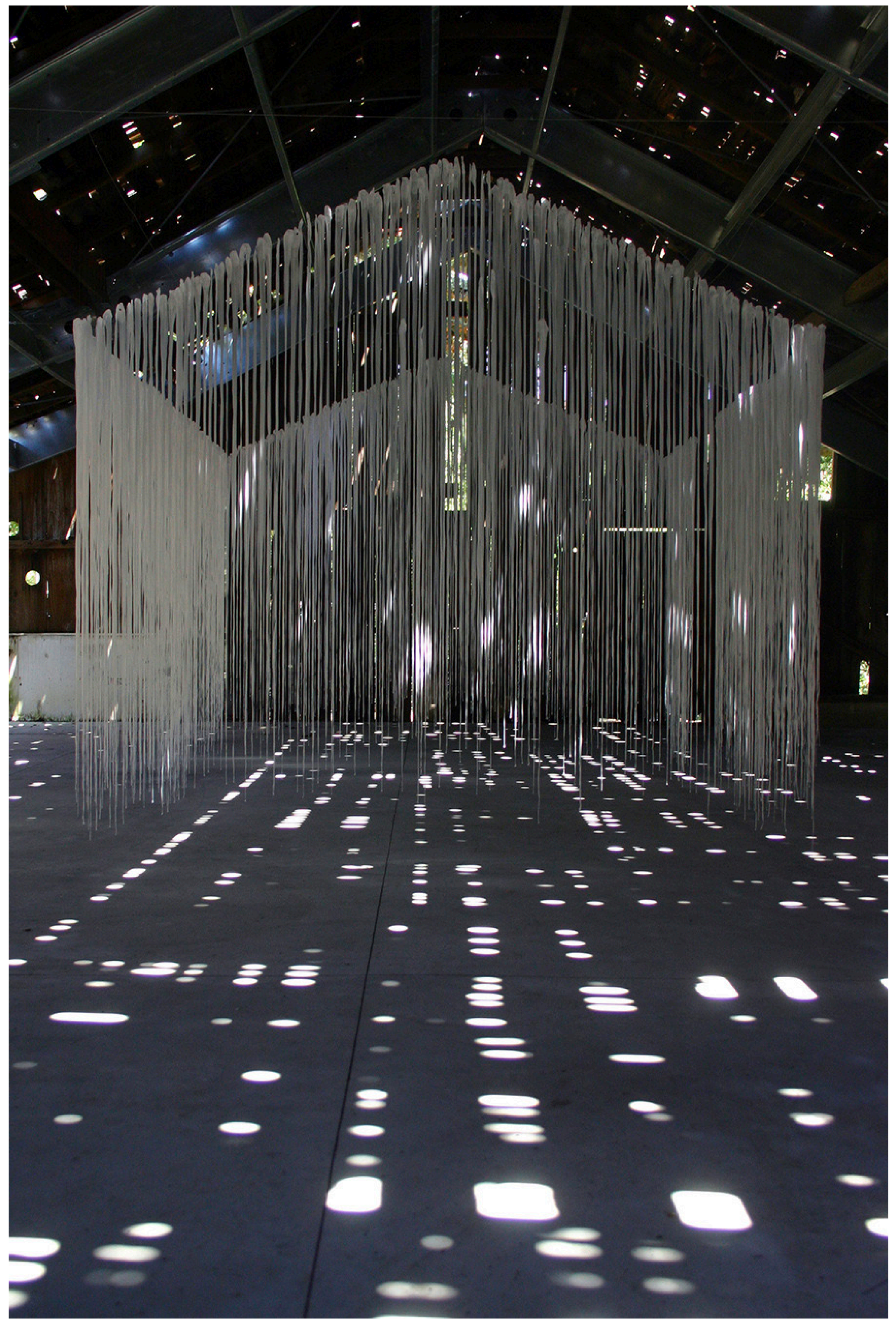


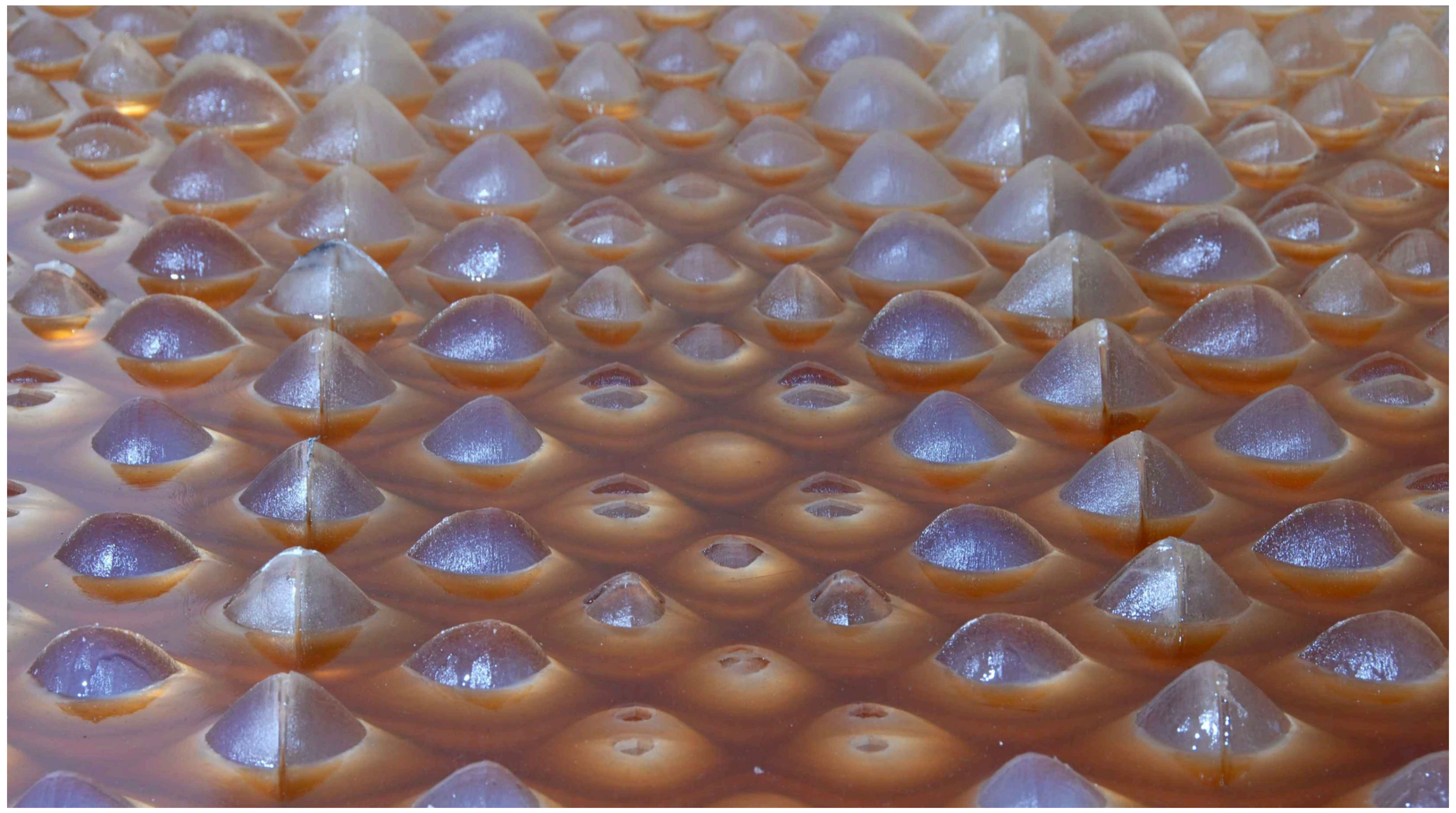
No Scent

INITIAL INSPIRATIONS FOR WAX AND EXPLORING IT'S MATERIALITY



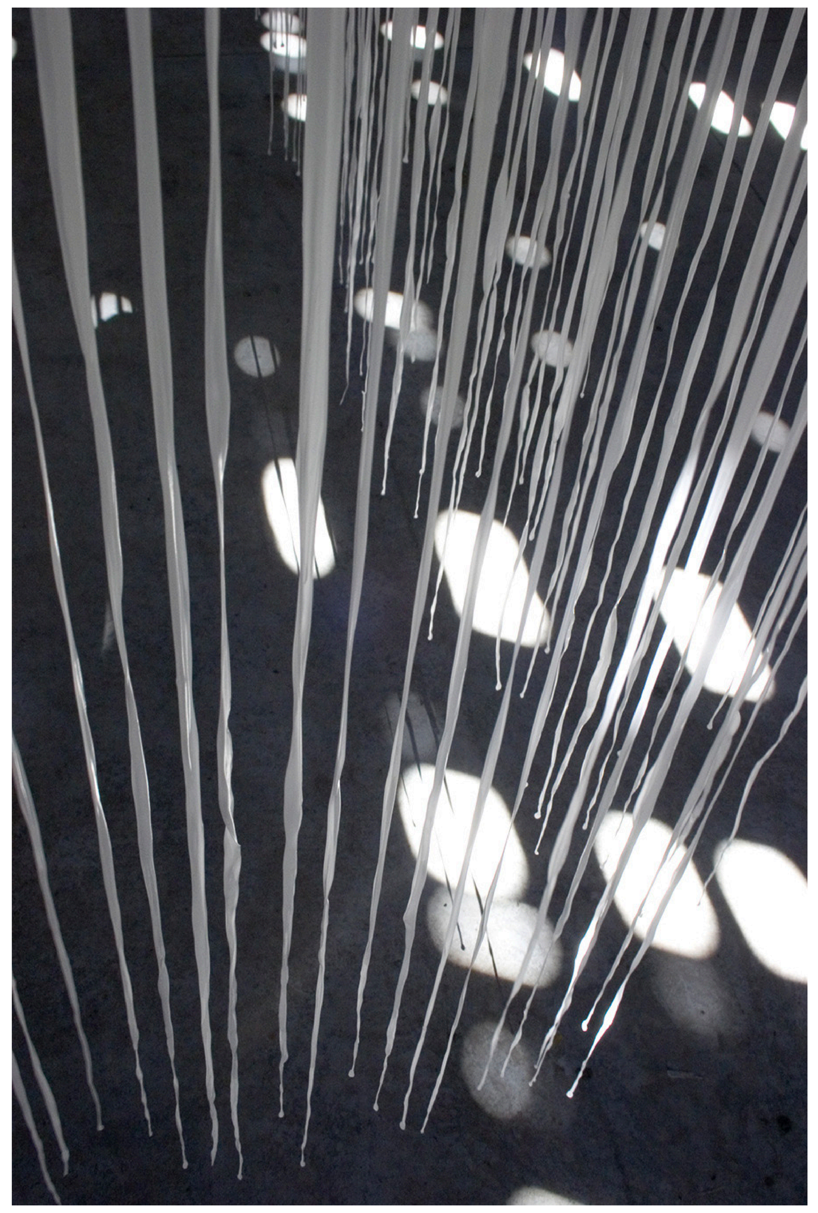
URS FISCHER' S SCULPTURE





CARTESIAN WAX

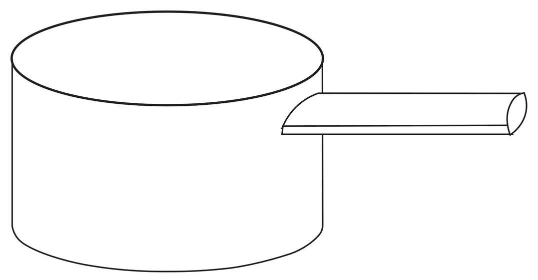
LAVA LAMP



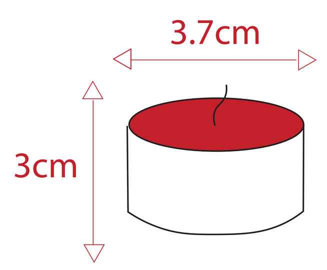
BEILI LIU'S "THE HOUSE PHASE
INSTALLATION SERIES

EXPERIMENT 1: TO ANALYSE THE RELATIONSHIP OF WAX IN WATER.

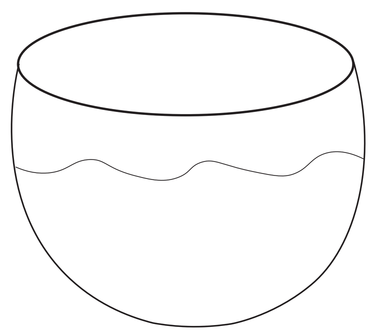
APPARATUS



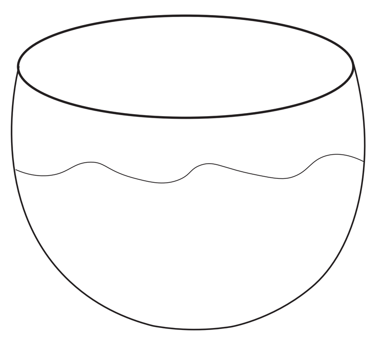
Water Bath



Candle



Vessel with Temperate Water

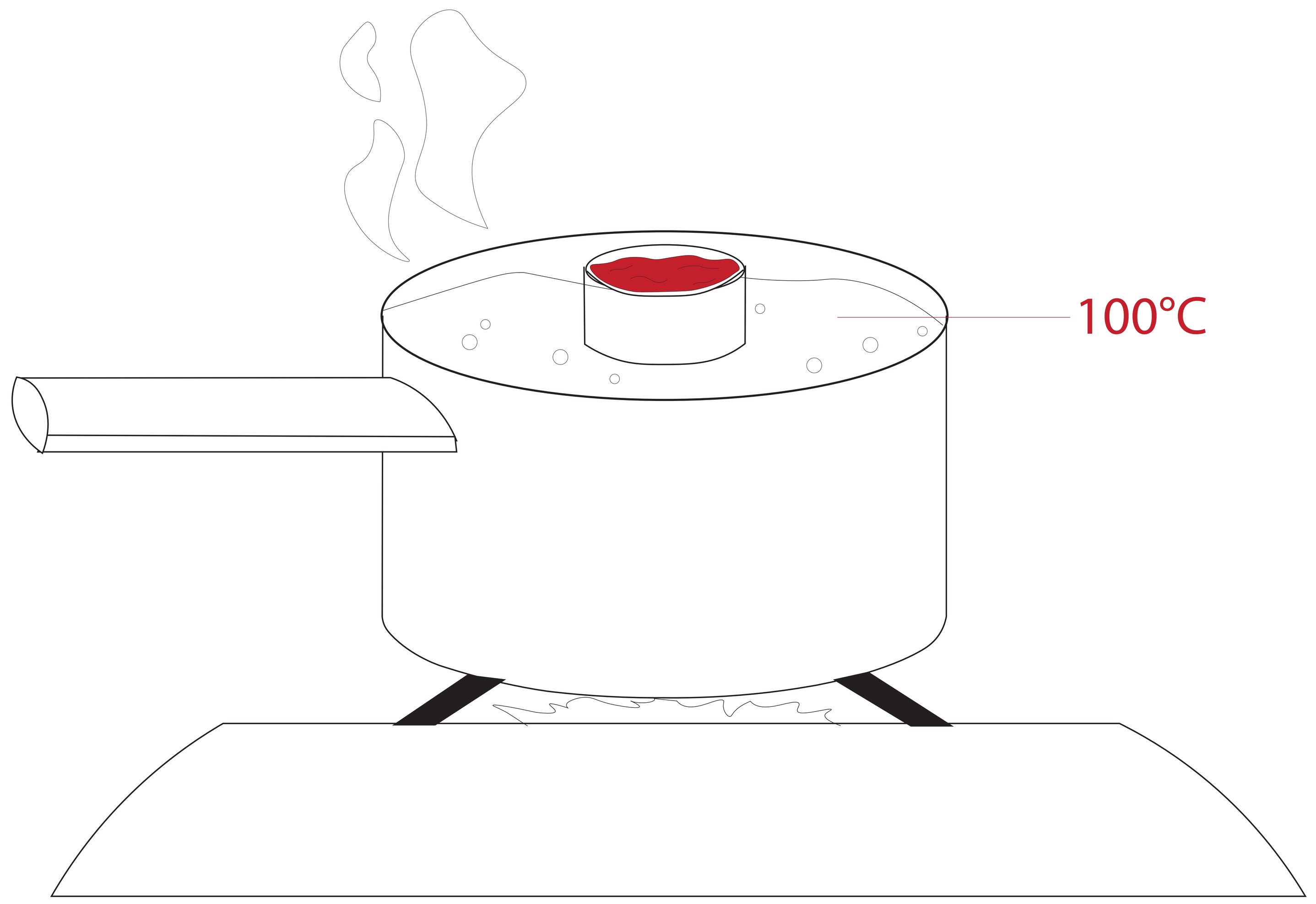


Vessel with Cold Water

CONSIDERATIONS

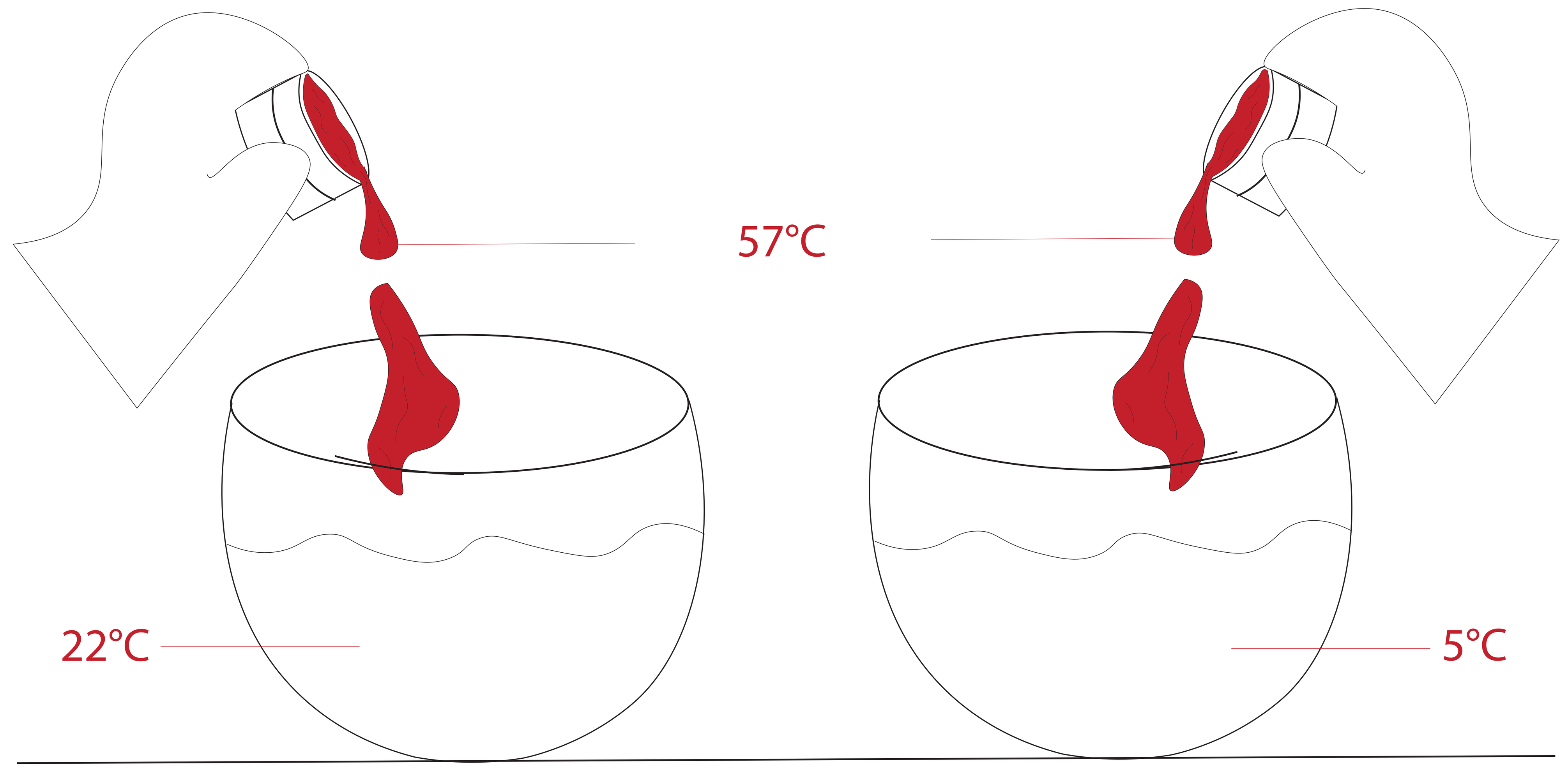
The Wax Specimen studied in the experiment was Paraffin Wax obtained from a scented candle. However, for the facilitation of the experiment we disregard the presence of artificial fragrance and colouring in the speciment.

EXPERIMENTAL PROCEDURE



STEP 1 : The wax is melted by heating the candle in a hot water bath.

STEP 2 : Once the wax melts completely, it is removed from the hot water bath carefully.



STEP 3 : The molten wax is then poured into two vessels, one containing temperate water and the other containing cold water.

STEP 4 : The resultant form of wax is then carefully removed from both the vessels.

STEP 5 : The results of the experiment are observed and documented.

OBSERVATIONS

Temperature of Water in Water Bath = above 100 °C

Total Volume of Wax Specimen = 129 cm^3

Time Taken to Melt Wax = 5 min 21 sec

Temperature of Temperate Water = 22 °C

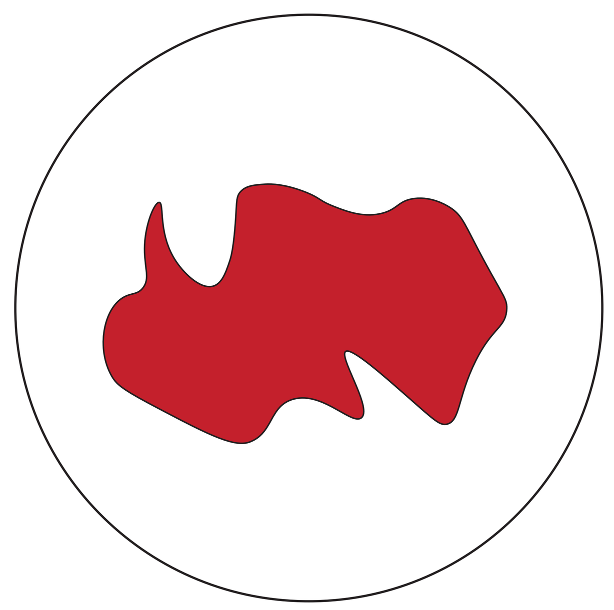
Temperature of Cold Water = 5 °C

Wax in Temperate Water :
-Initial poured wax solidifies under the surface of the water and subsequently the wax spreads over the surface and solidifies.
-The wax floats in water.
-When removed from water, the wax is still soft (like clay).
-When the wax specimen is cut, bubbles can be seen formed by water trapped inside.

Wax in Cold Water :
-The wax solidifies instantly under water.
-The wax floats in water.
-When removed from water, the wax is hard.
-When the wax specimen is cut, no bubbles can be seen and a clean cut can be seen.

CONCLUSIONS AND EXPLANATIONS

-Wax does not dissolved in water.
This is due to the hydrophobic nature of wax. Wax is one of the most hydrophobic substance and repel water.
-Wax floats on water.
Wax is a buoyant material, which means that it normally floats, rather than sinks, in water. This is because it is less dense than the water.
-The wax solidifies in water.
Wax is a solid at room temperature. When immersed in water, it does now dissolve due to it's hydrophobic nature. Instead it stays suspended. Simultaneosly the lowered temperature of the water cools the melted wax back to room temperature and hence returning to its solid state.
-The wax in temperate water is softer compared to cold water.
Since the cold water has a lowered temperature than temperate water, it takes longer for the hot liquid wax to cool down and return to the solid state in temperate water. This is why, when both specimen are removed from water the temperate specimen is softer as it hasn't completely solidified.
-The wax in temperate water has bubbles trapped within.
Since the wax takes longer to cool down, water bubbles make their way between the molten wax before it solidifies. However, since the solidification is comparatively instantaneous in cold water, there are no bubbles within.



top view

EXPERIMENT 1: TO ANALYSE THE RELATIONSHIP OF WAX IN WATER.

HEATING WAX IN A HOT WATER BATH

TEMPERATE WATER

COLD WATER

TEMPERATE WATER

COLD WATER

TEMPERATE WATER

COLD WATER

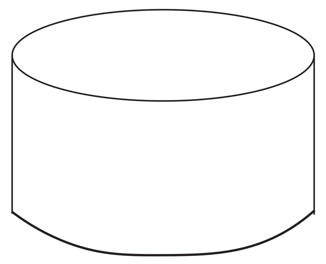
FINAL RESULT SPECIMENS FROM EXPERIMENT 1

WAX SPECIMEN FROM TEMPERATE WATER

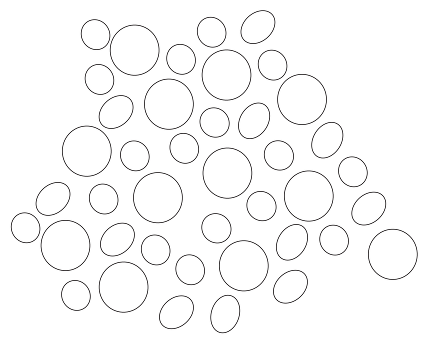
WAX SPECIMEN FROM COLD WATER

EXPERIMENT 2: TO ANALYSE THE RELATIONSHIP OF WATER IN WAX.

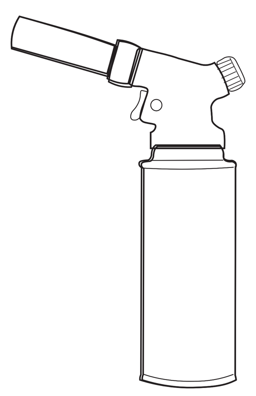
APPARATUS



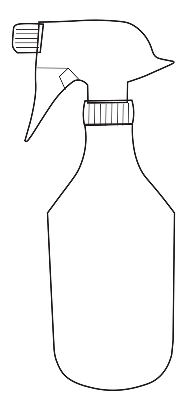
Thermoresistant Container



Paraffin Wax Pellets

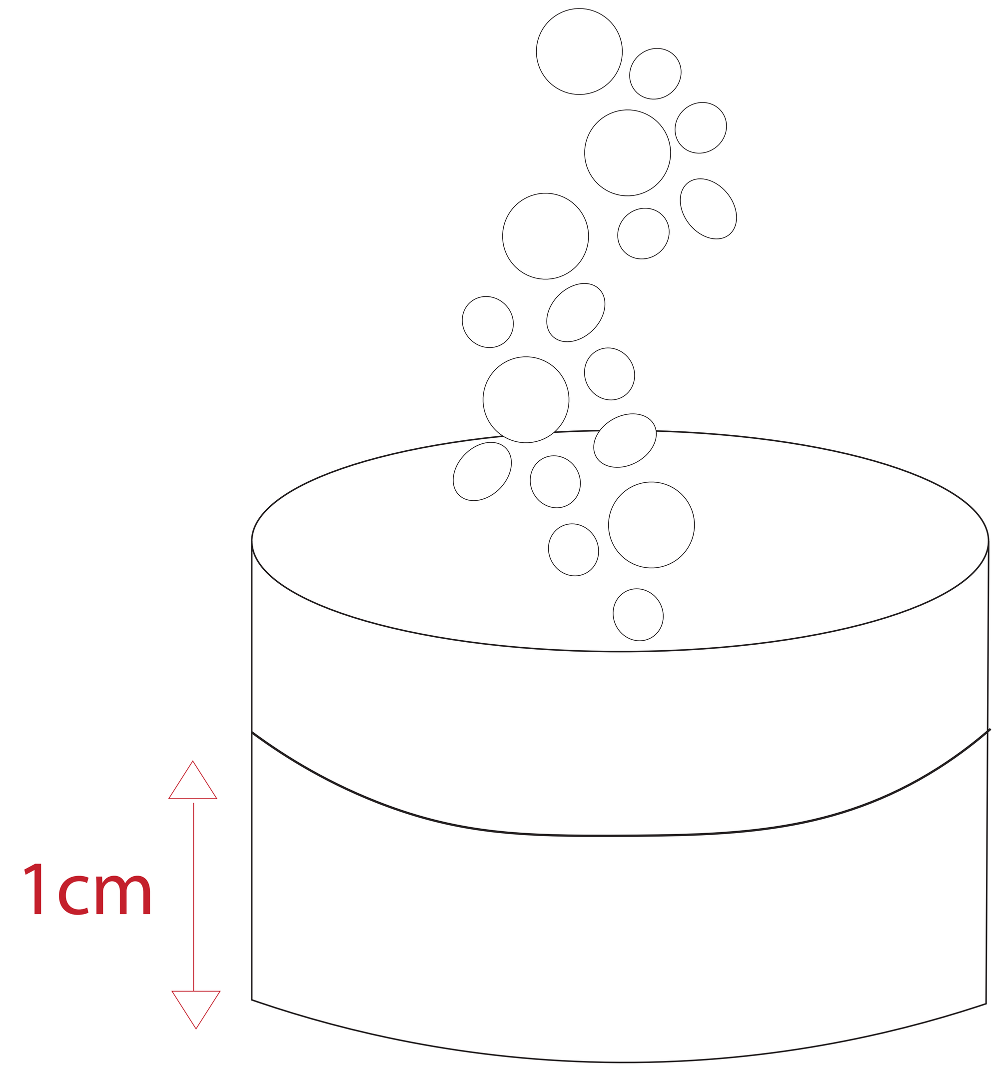


Blow Torch

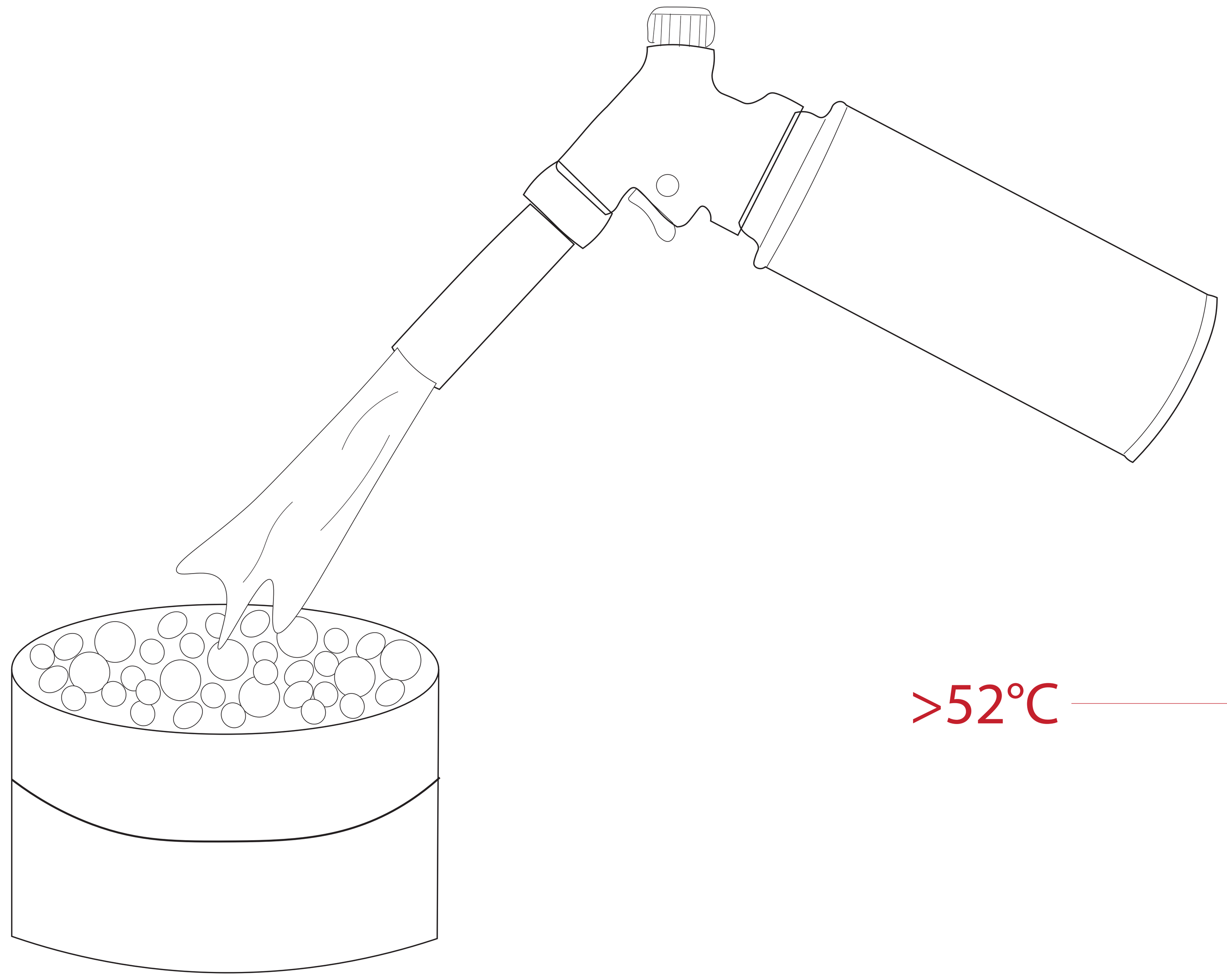


Spray Bottle with Water

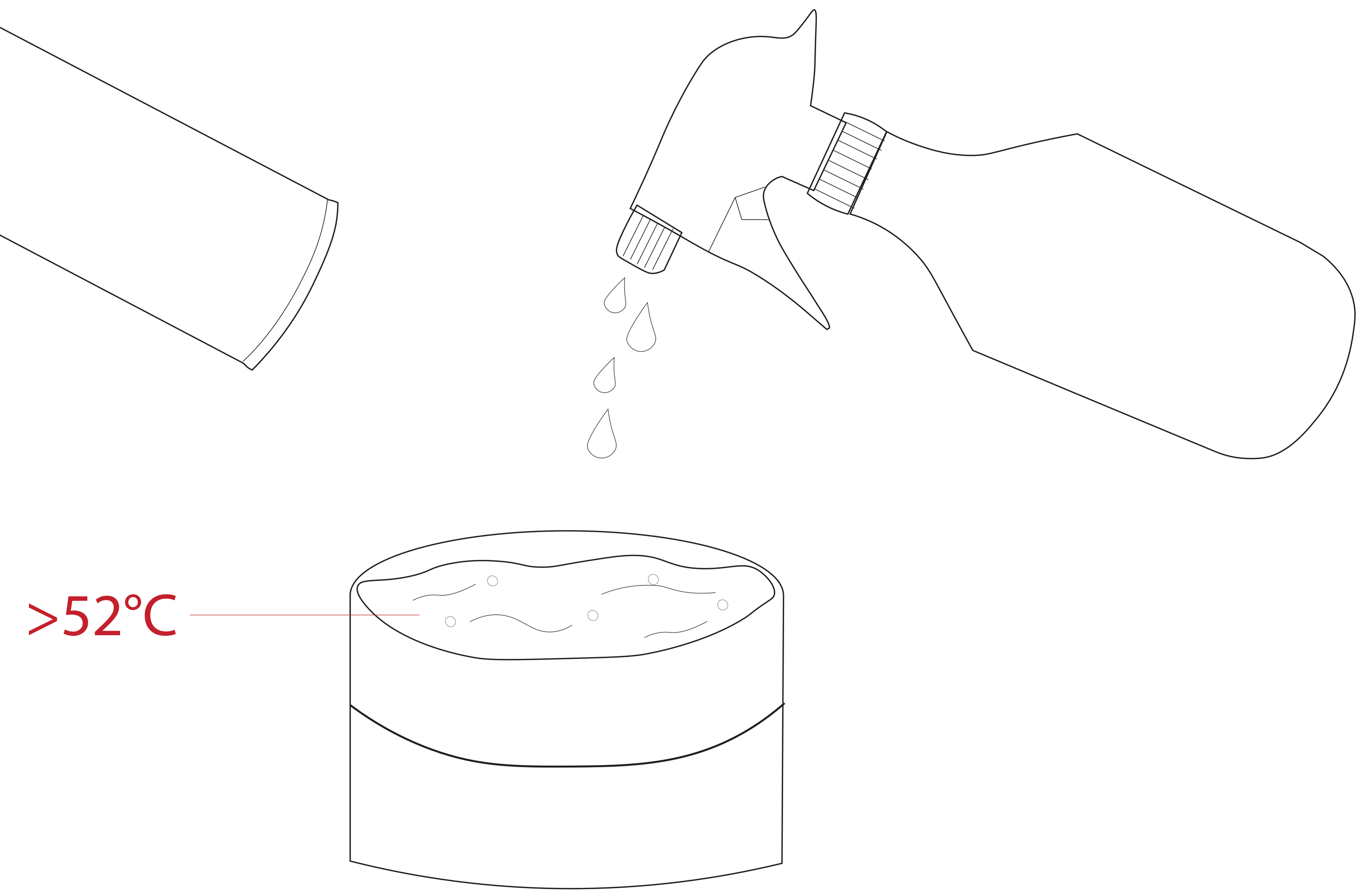
EXPERIMENTAL PROCEDURE



STEP 1 : The Thermoresistant container is filled up with paraffin wax pellets for upto 1 cm



STEP 2 : The was is melted using a blow torch until the wax develops a flame



STEP 3 : Cautiously spray water using a spray bottle onto the melted wax

STEP 4 : Observe and Document the results

CONCLUSIONS AND EXPLANATIONS

When water is sprayed onto the wax, it causes a sizzling sound and a very large flame.
The flamed up wax indicates that the wax has reached a high temperature and is undergoing combustion. Following the basic rules of the fire triangle, for a reaction to take place three ingredients are required: oxygen, fuel, and heat. In the case of wax melted down, only the top surface has access to oxygen, so the fire progresses slowly. When water is added to the wax, two things happen. Firstly, the water — being denser than wax — sinks to the bottom of the container. Secondly, as burning wax quickly reaches a temperature of well over 200 degrees C, the water instantly vapourises. When water changes from a liquid to a gas, there is more than a thousand-fold increase in volume. The water expands violently, and throws the hot wax layer above it into the air as small droplets. The wax now has a much bigger surface area exposed to oxygen so combustion takes place very quickly.

PRECAUTIONARY MEASURES

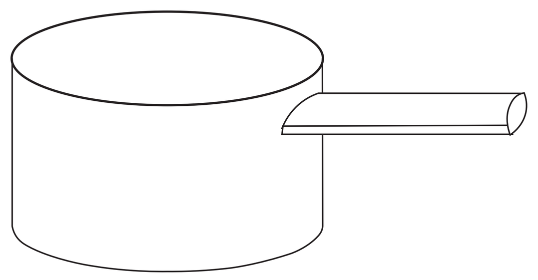
The Wax Specimen studied in the experiment was Paraffin Wax obtained from a scented candle. However, for the facilitation of the experiment we disregard the presence of artificial fragrance and colouring in the speciment.

OBSERVATIONS

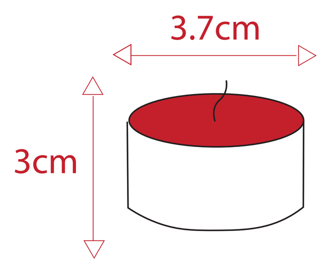
The experiment was not conducted due to the inavailability of a blow torch. It was attempted with a flame but the desired result was not garnered so the experiment and the properties that were initially required to explore from it were abandoned for the simple reason that it was not feasible and we lost interest in these properties.

EXPERIMENT 3: TO STUDY THE SOLIDIFICATION OF WAX IN DISTINCTLY SHAPED CONTAINERS

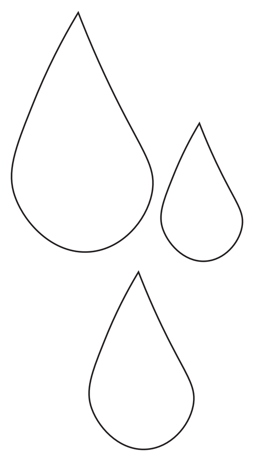
APPARATUS



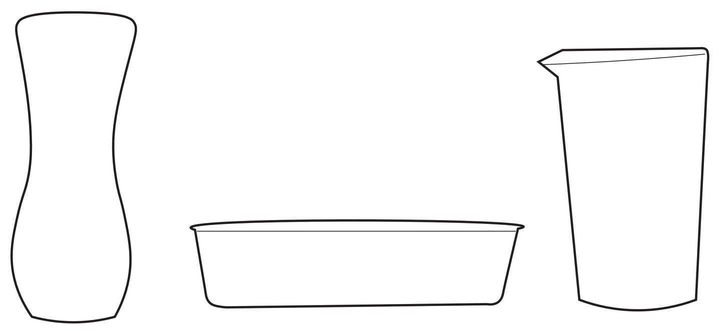
Water Bath



Candle



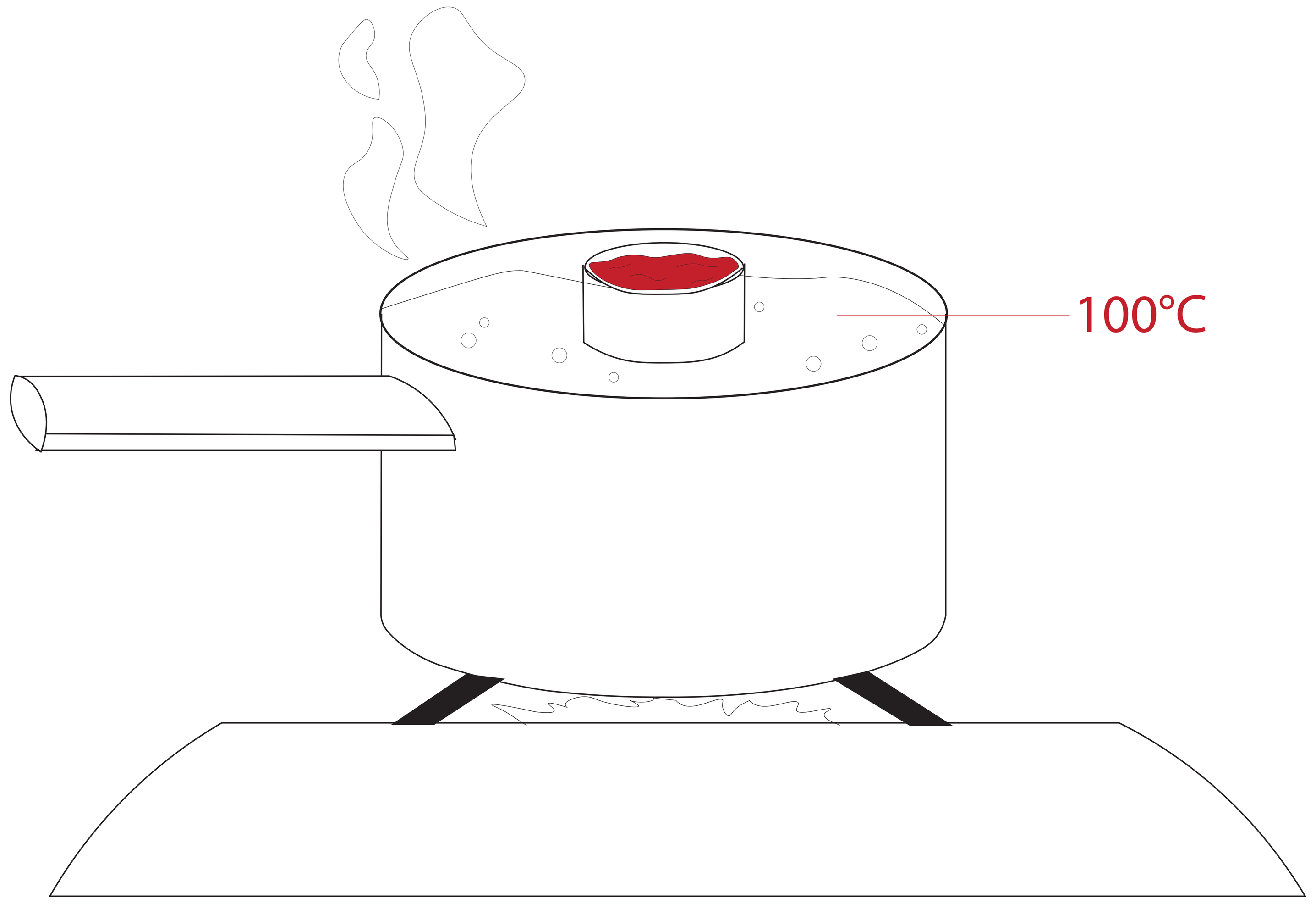
500 mL of Water



Distinctly Shaped Containers

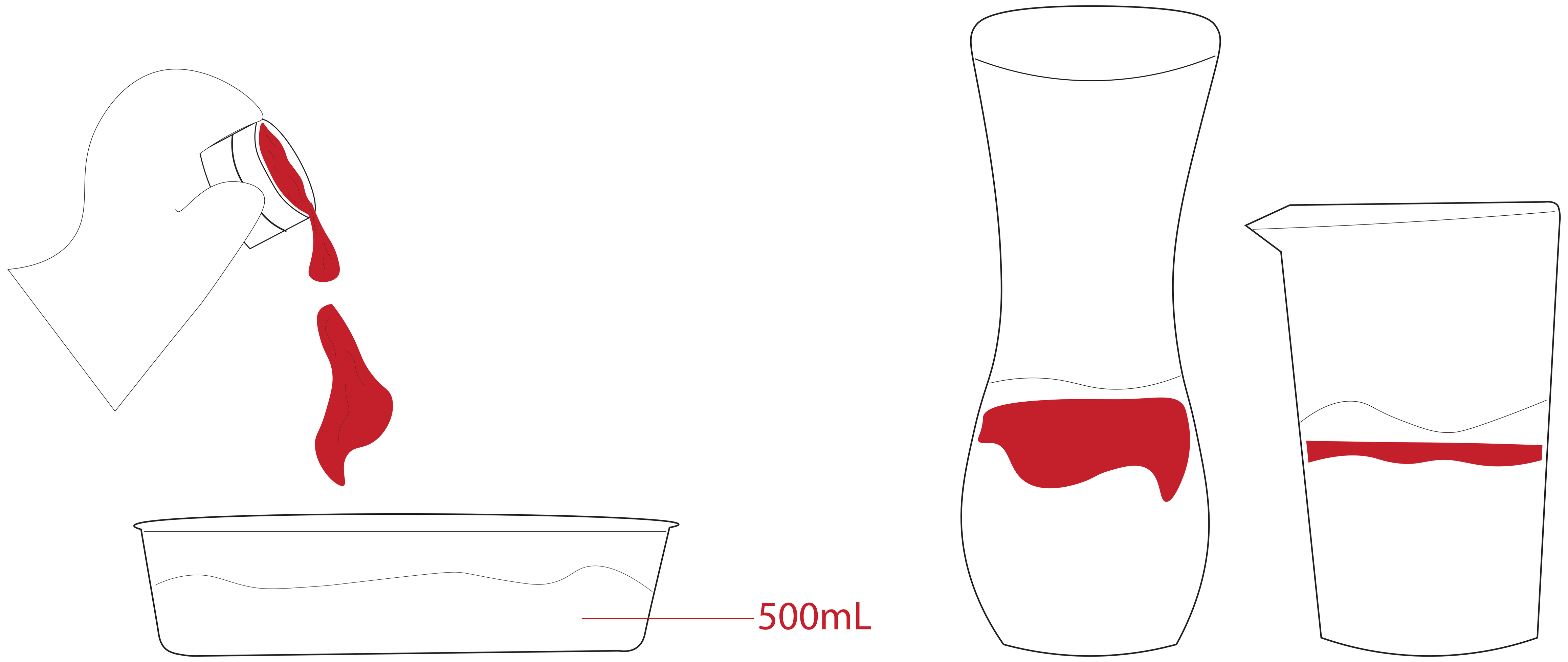
CONSIDERATIONS

EXPERIMENTAL PROCEDURE



STEP 1 : The wax is melted by heating the candle in a hot water bath.

STEP 2 : Once the wax melts completely, it is removed from the hot water bath carefully.



STEP 3 : The molten wax is then poured into three vessels, all having a distinct shape, depth and surface area.

STEP 4 : The resultant form of wax is then carefully removed from the vessels.

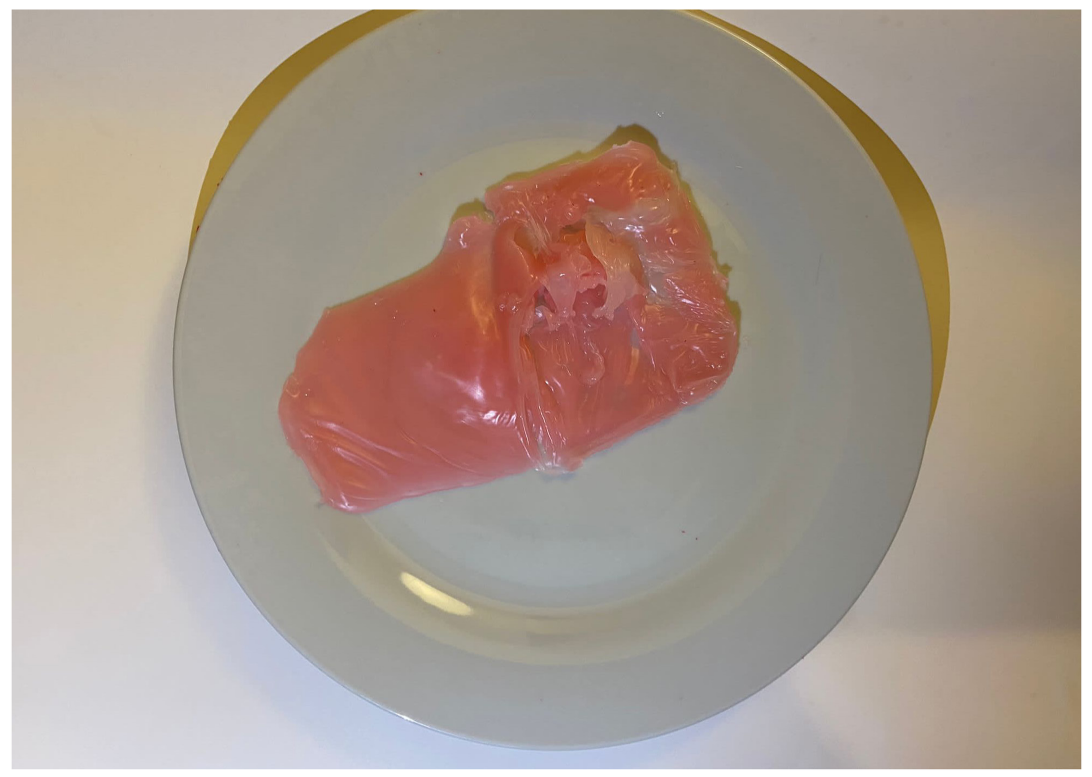
STEP 5 : The results of the experiment are observed and documented.

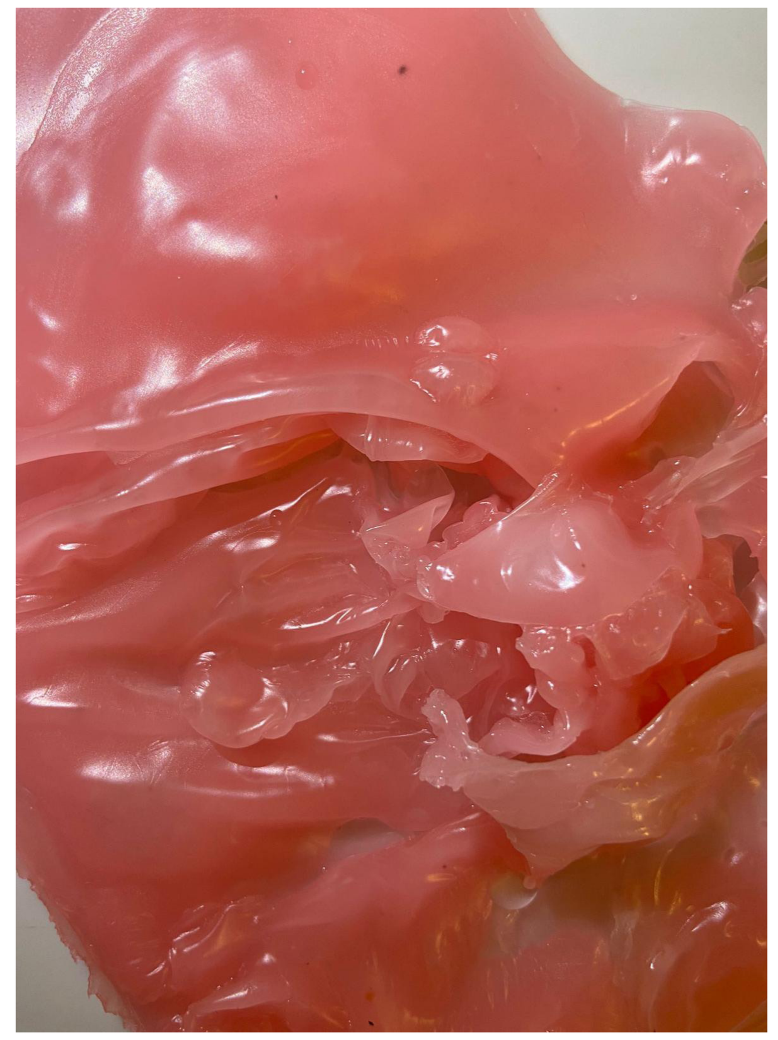
CONCLUSIONS

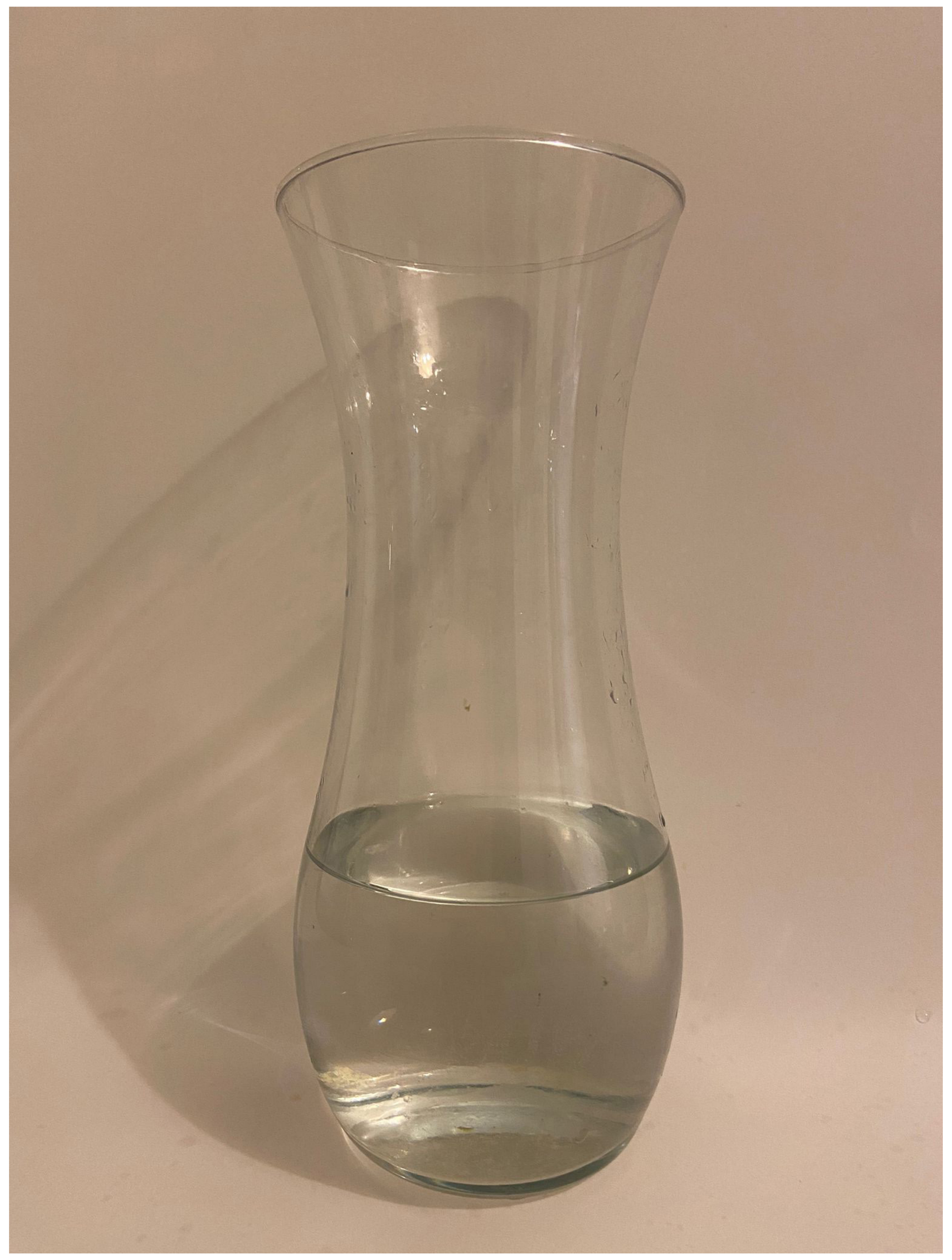
The surface area of the water determines the shape of the wax solid.
-When there is a larger surface area, the wax tends to spread over the surface. If the surface area is smaller, the wax either goes deeper into the container, or forms a solid barrier causing a quantity of the liquid wax to float above the surface.
The depth affects the solid formation.
-In a deeper container the wax tends to solidify more in the vertical direction.

OBSERVATIONS

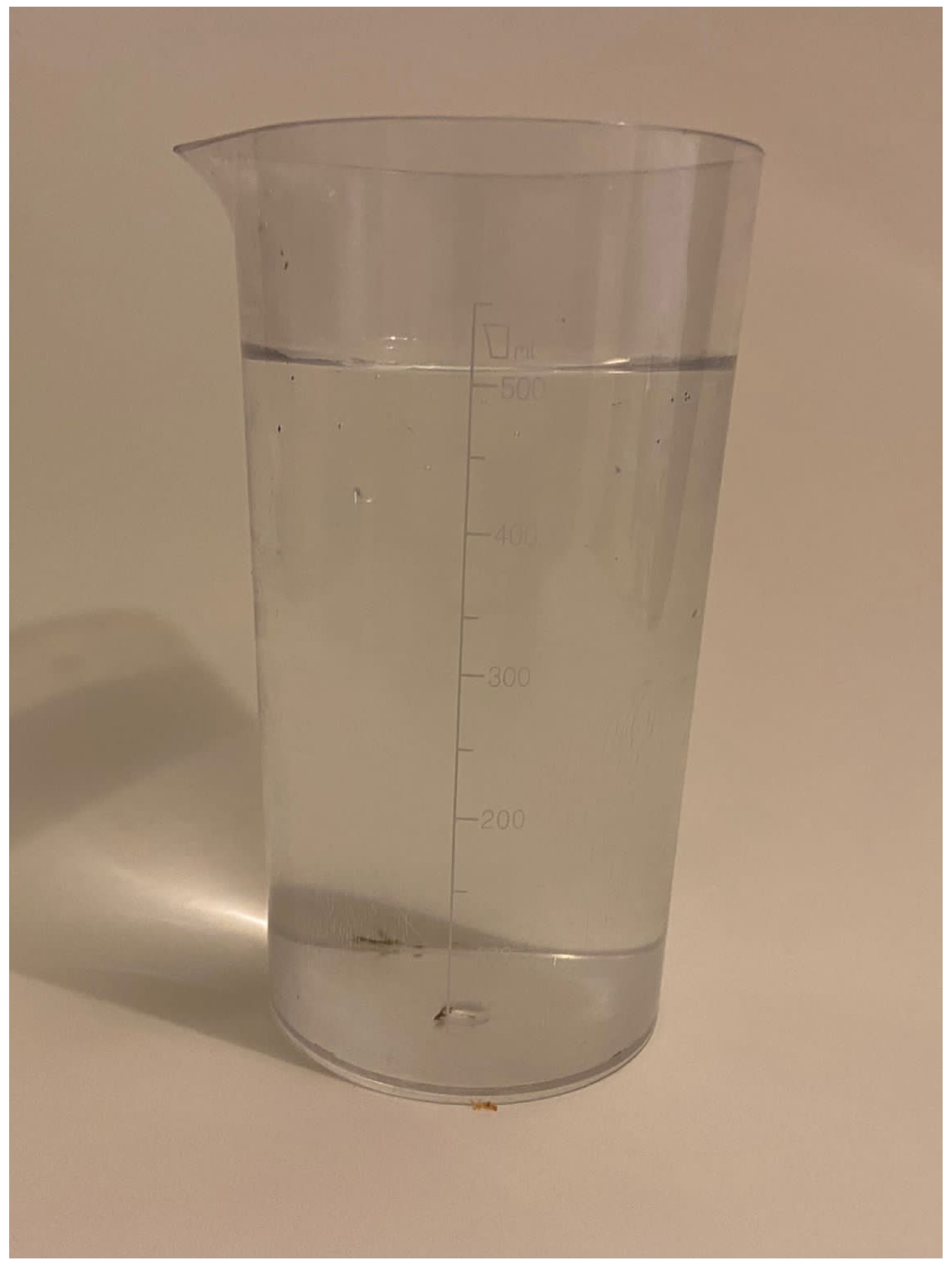
Container A

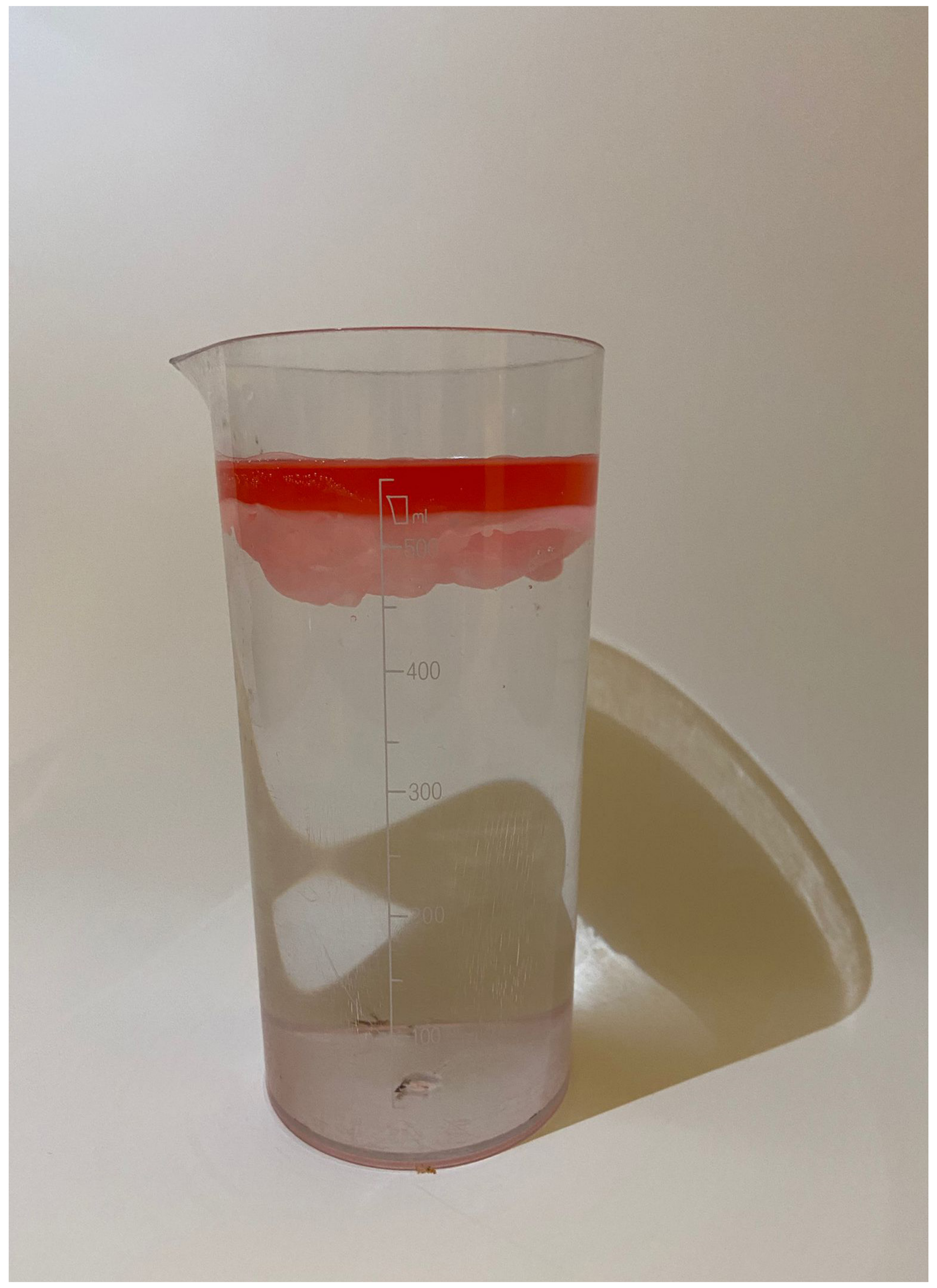






Container B

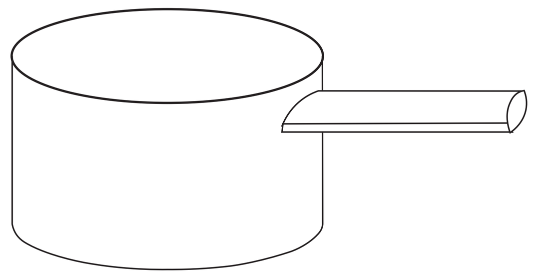




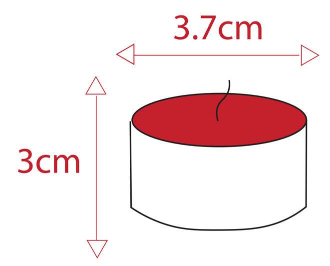
Container C

EXPERIMENT 4 : TO ESTIMATE THE ENERGY REQUIRED TO SOLIDIFY WAX

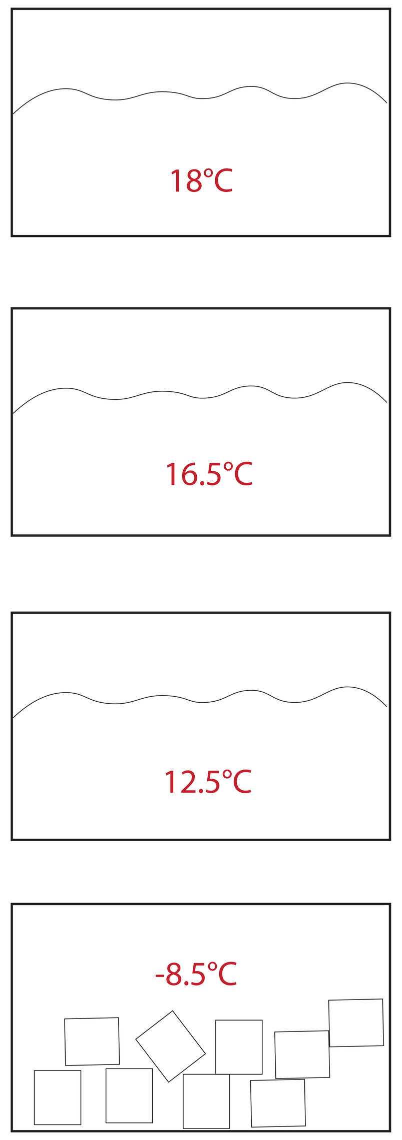
APPARATUS



Water Bath



Candle



Water at Different Temperatures

CONSIDERATIONS

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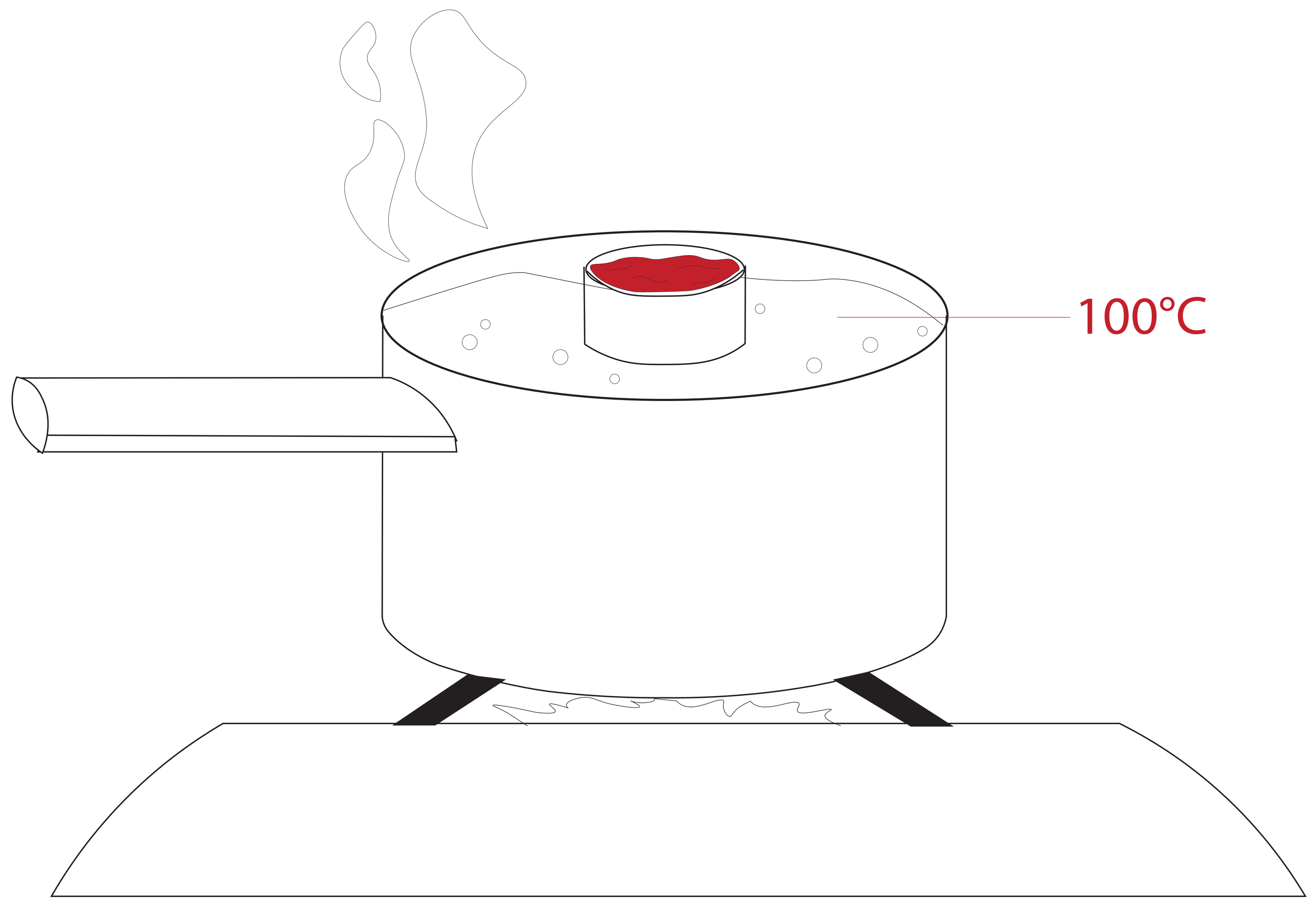
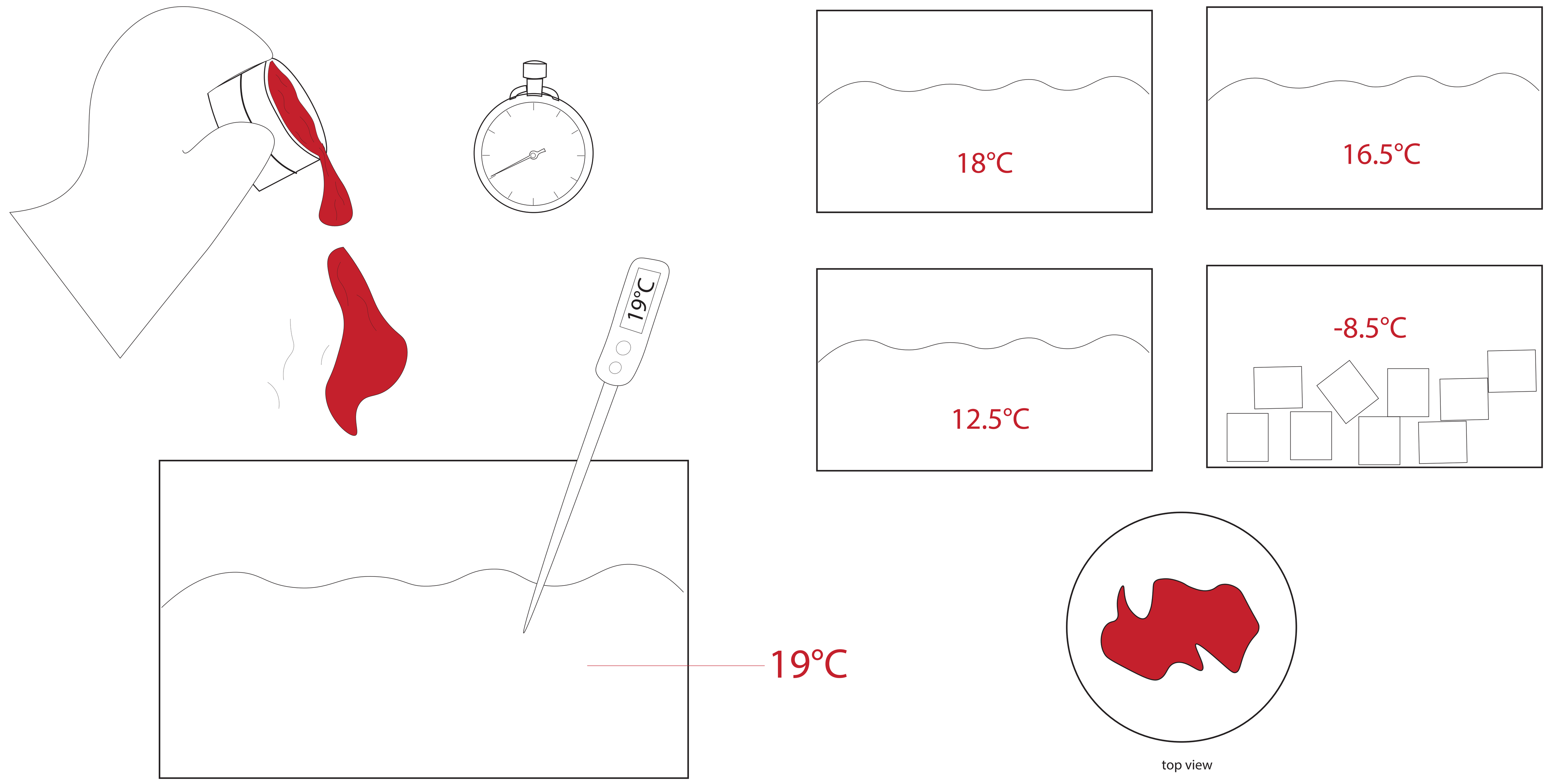
EXPERIMENTAL PROCEDURE





STEP 1 : The wax is melted by heating the candle in a hot water bath.

STEP 2 : Once the wax melts completely, it is removed from the hot water bath carefully.

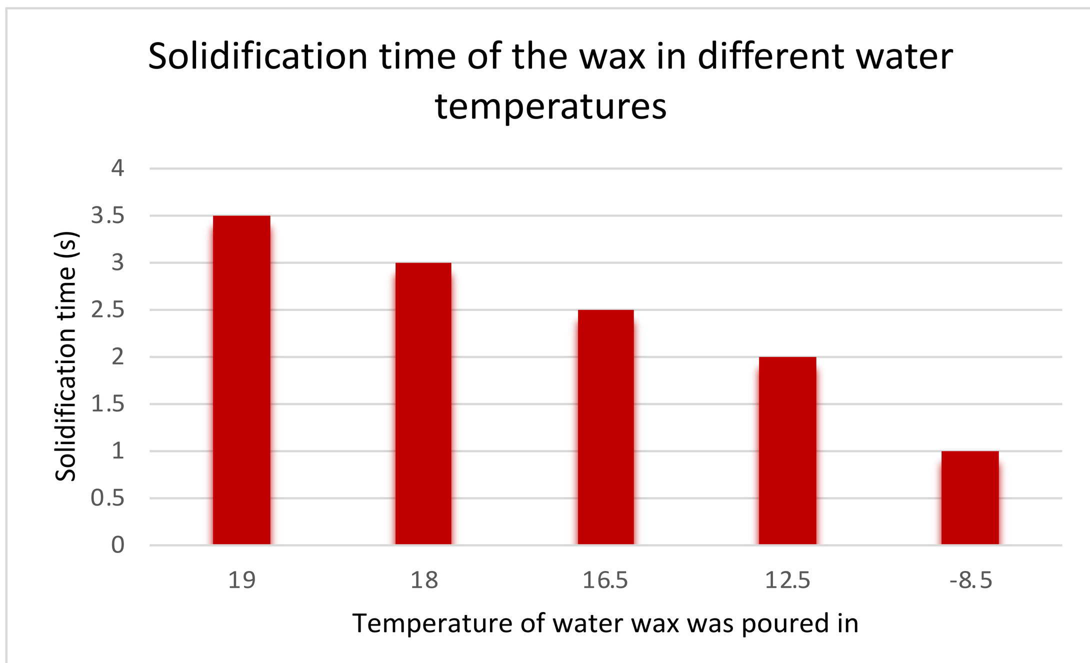
STEP 3 : The molten wax is then poured into a vessel containing temperate water.

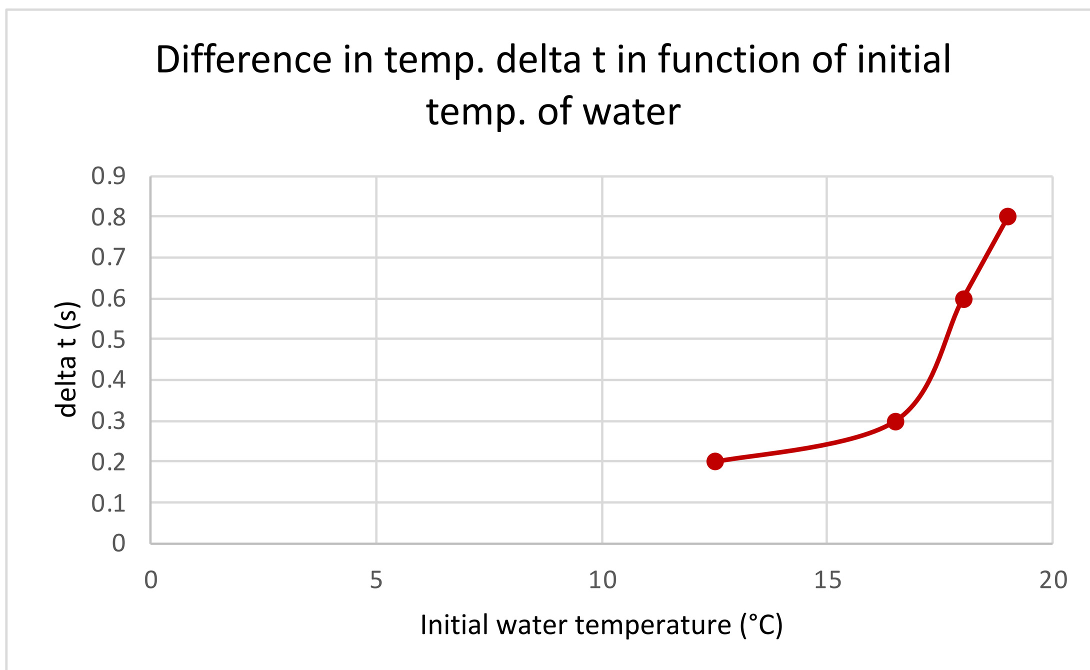
STEP 4 : The temperatures of the water before and 1 minute after the wax was poured are recorded.

STEP 5 : The process is repeated with different temperatures of water.

STEP 6 : The results are observed and analysed.

OBSERVATIONS





CONCLUSIONS

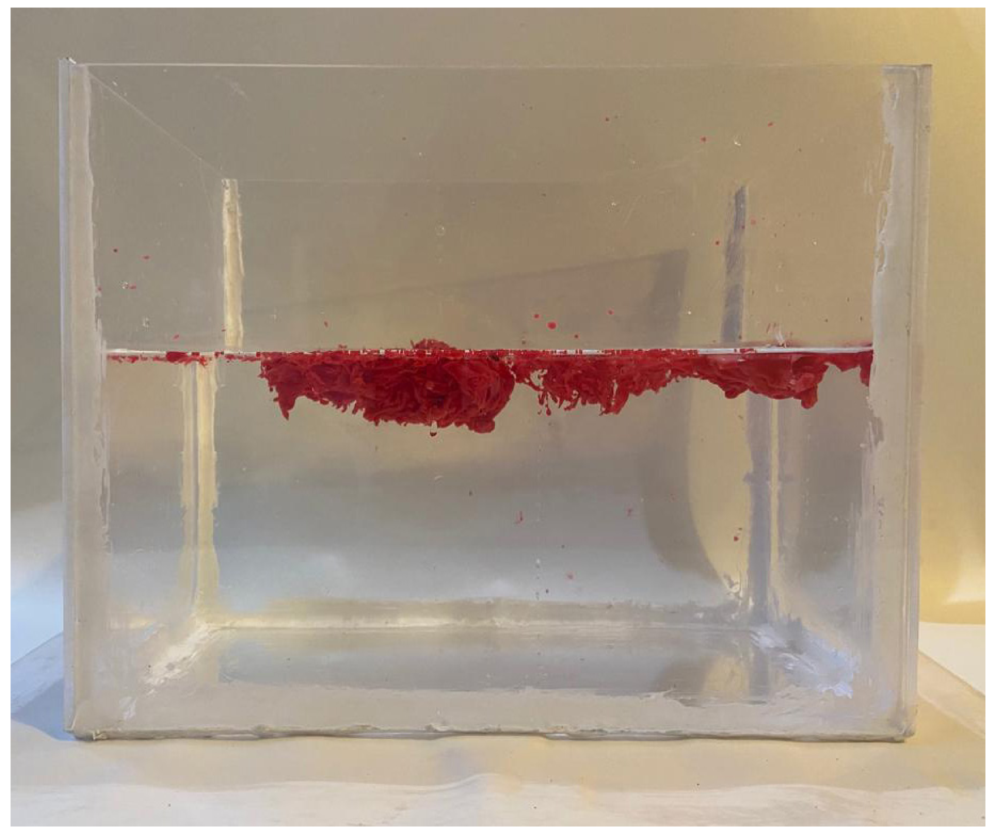
-The wax solidifies in water.
Wax is a solid at room temperature. When immersed in water, it does now dissolve due to it's hydrophobic nature. Instead it stays suspended. Simultaneosly the lowered temperature of the water cools the melted wax back to room temperature and hence returning to its solid state.
The wax solidifies more instantly as the temperature of water is reduced
-When the water is colder, the wax is able to release its heat much faster and solidify to return to its original state.
The initial temperature of water affects the temperature differential.
-For lower temperatures of water, the change in temperature is much lower in comparison to higher temperatures of water.
The wax tends to get more disintegrated when heated and solidified over multiple cycles.
-Multiple cycles of heating and solidifying causes the bonds between the wax particles to loosen. This leads to the disintegration of the wax particles.

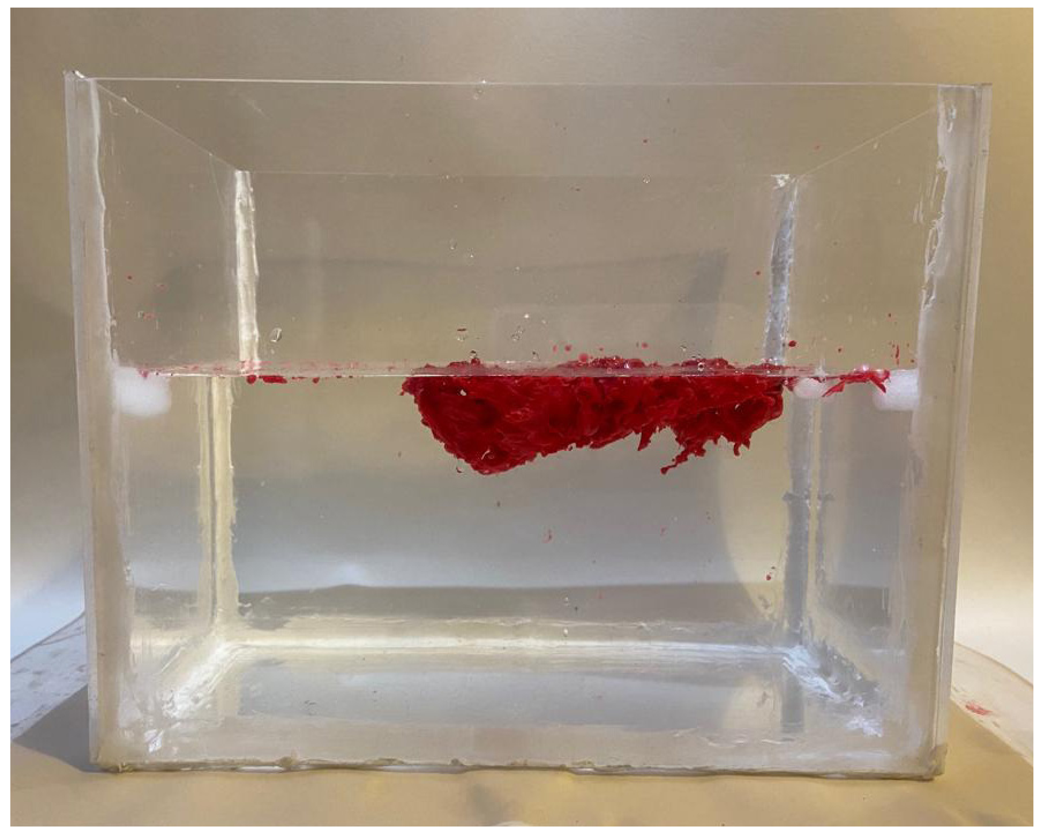
18 °C

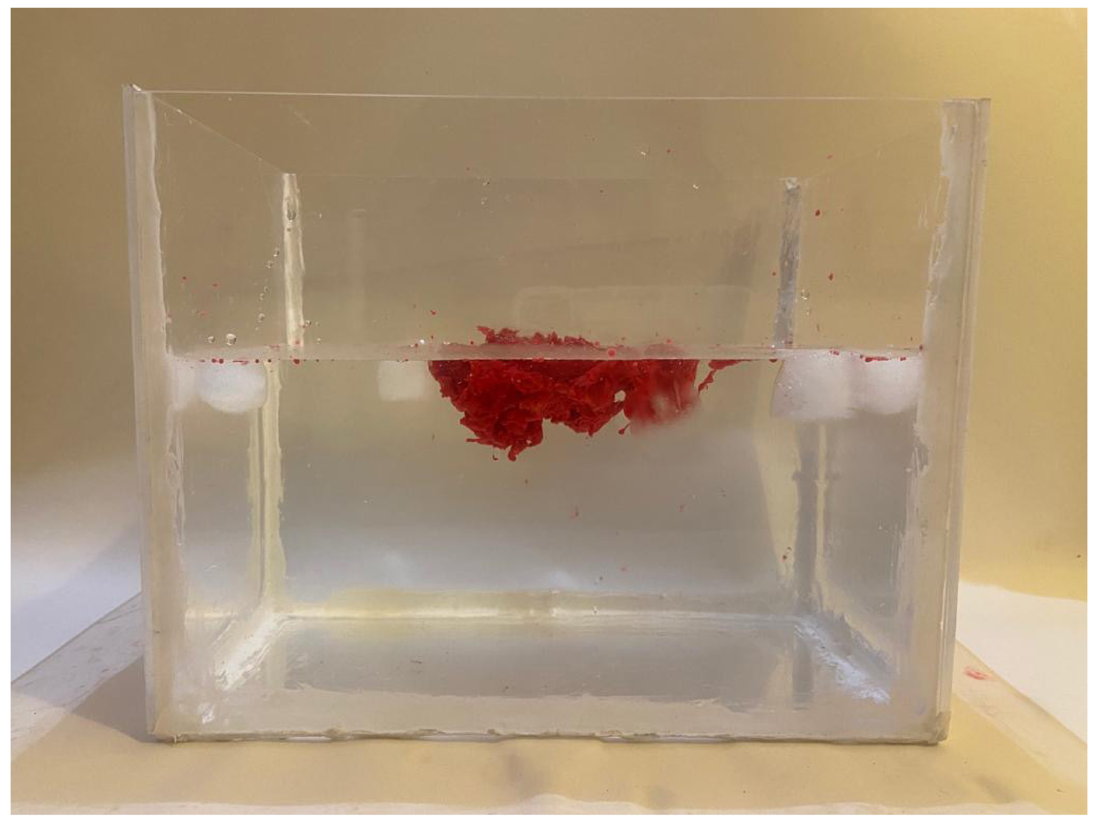
16.5 °C

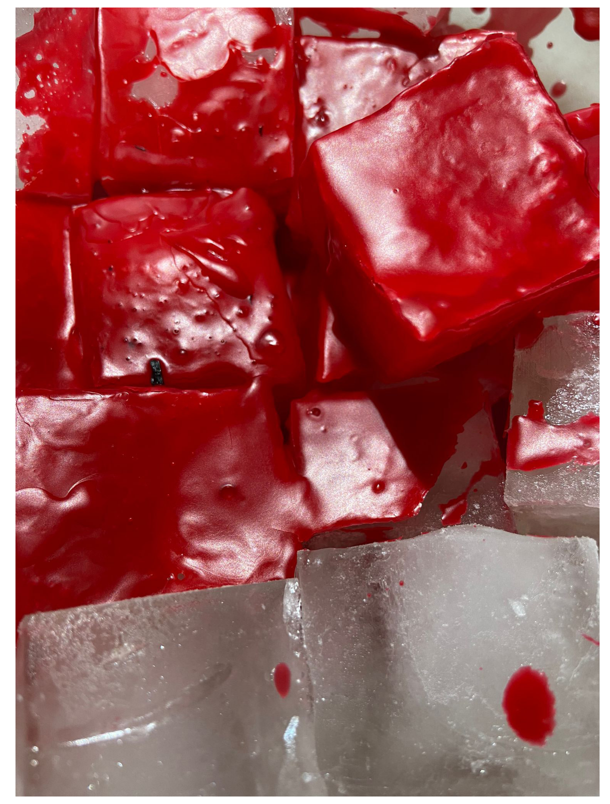
12.5 °C

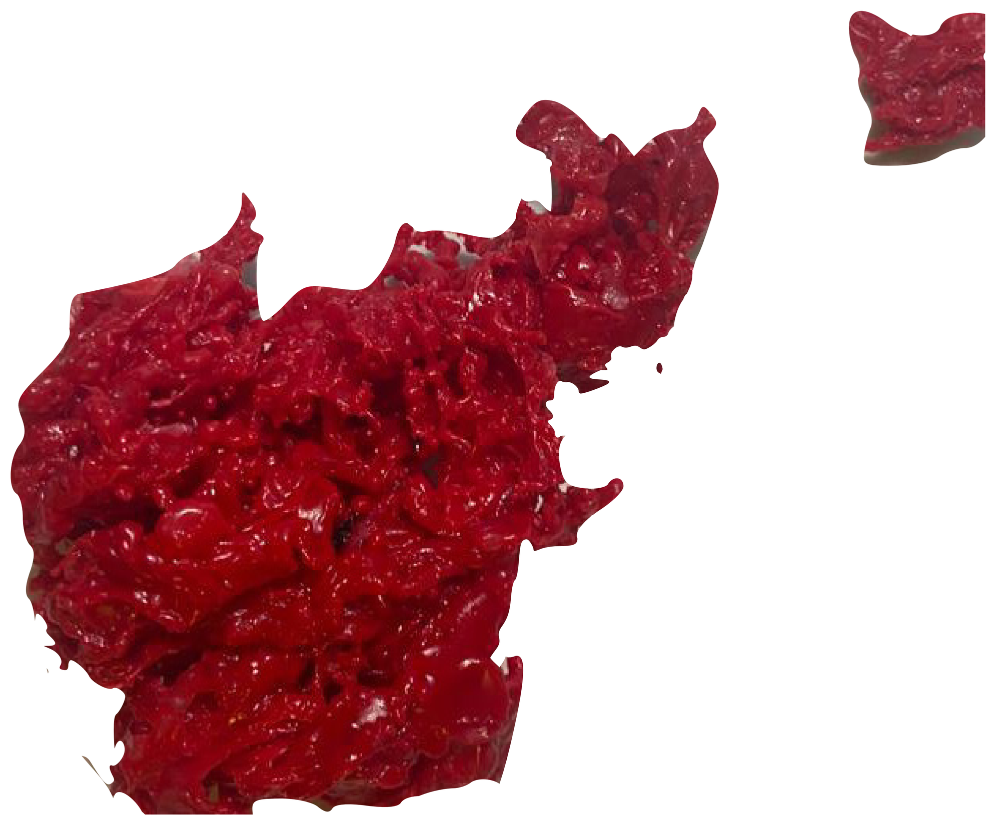
-8.5 °C

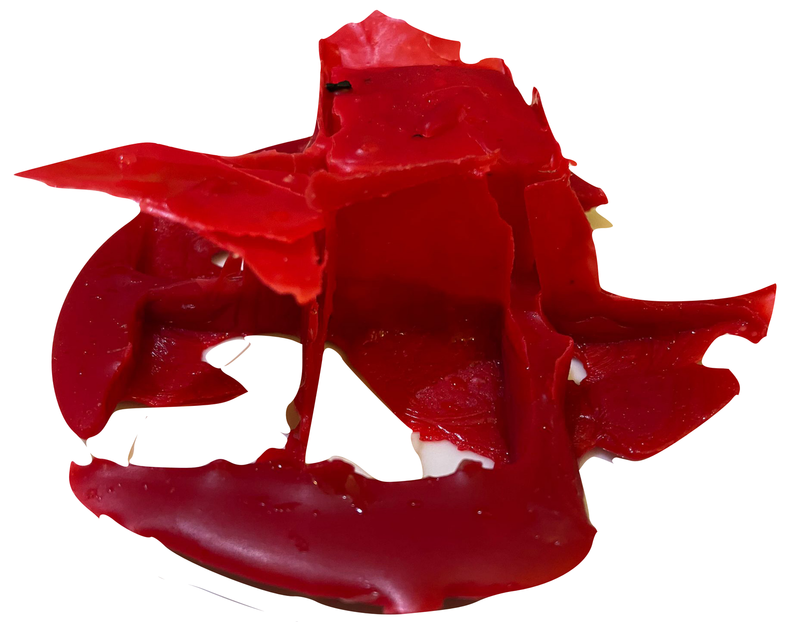






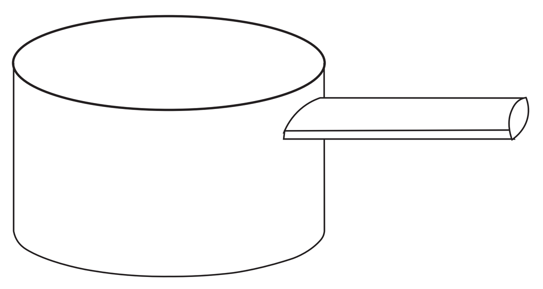




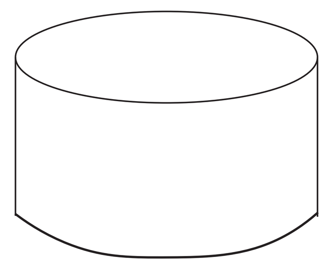


EXPERIMENT 5: ASSESSING THE CHANGE IN WATER TEMPERATURE WHEN DIFFERENT QUANTITIES OF WAX ARE ADDEDTO IT

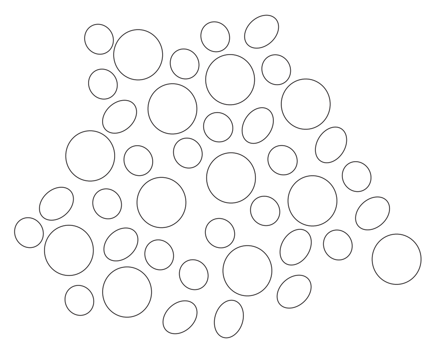
APPARATUS



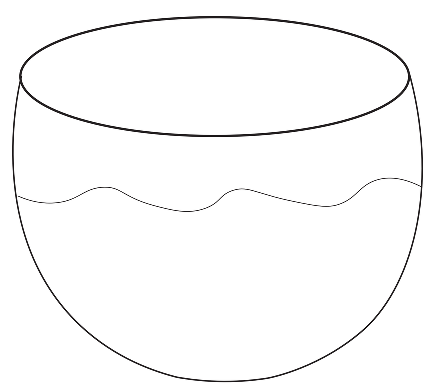
Water Bath



Thermoresistant Container

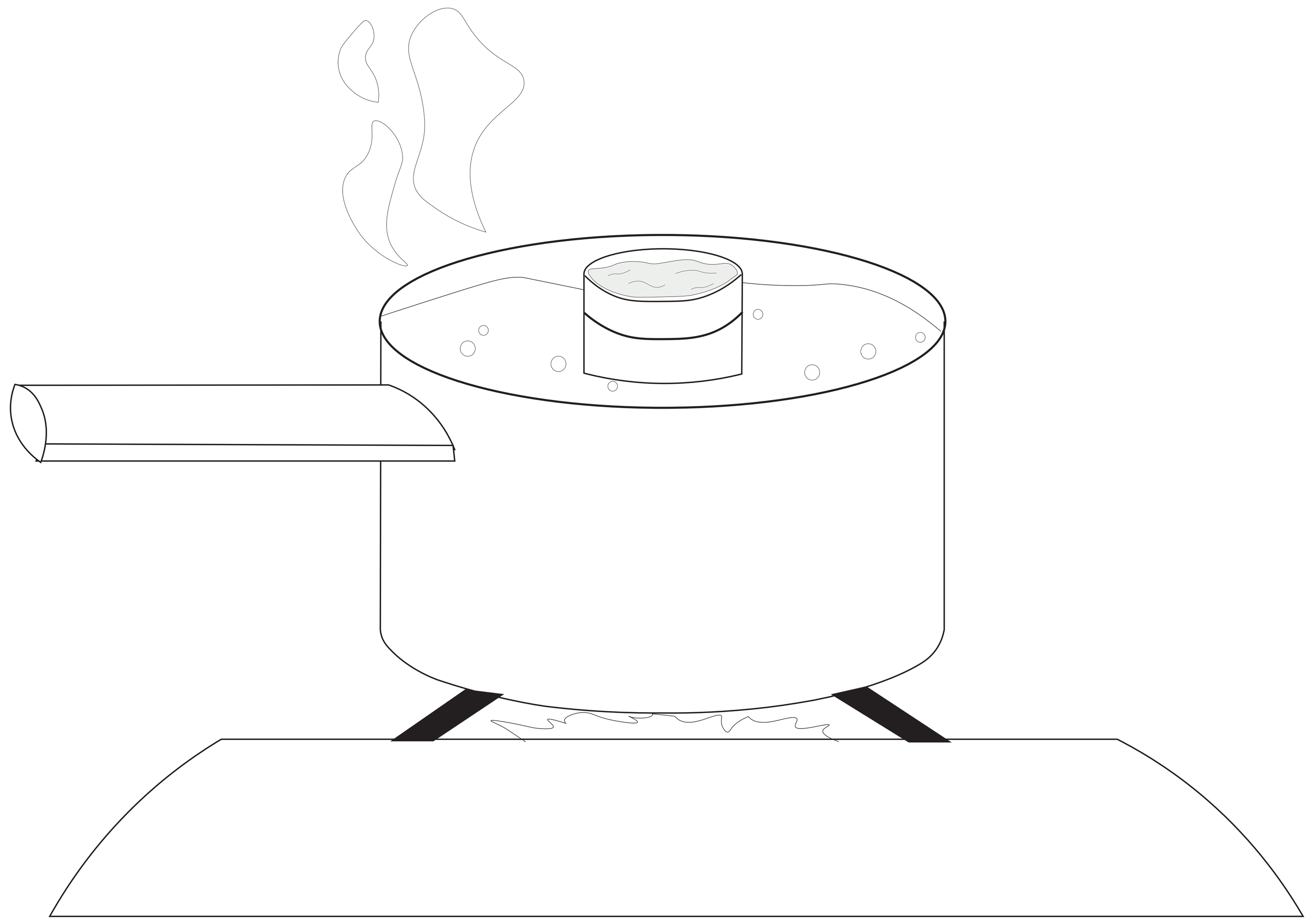


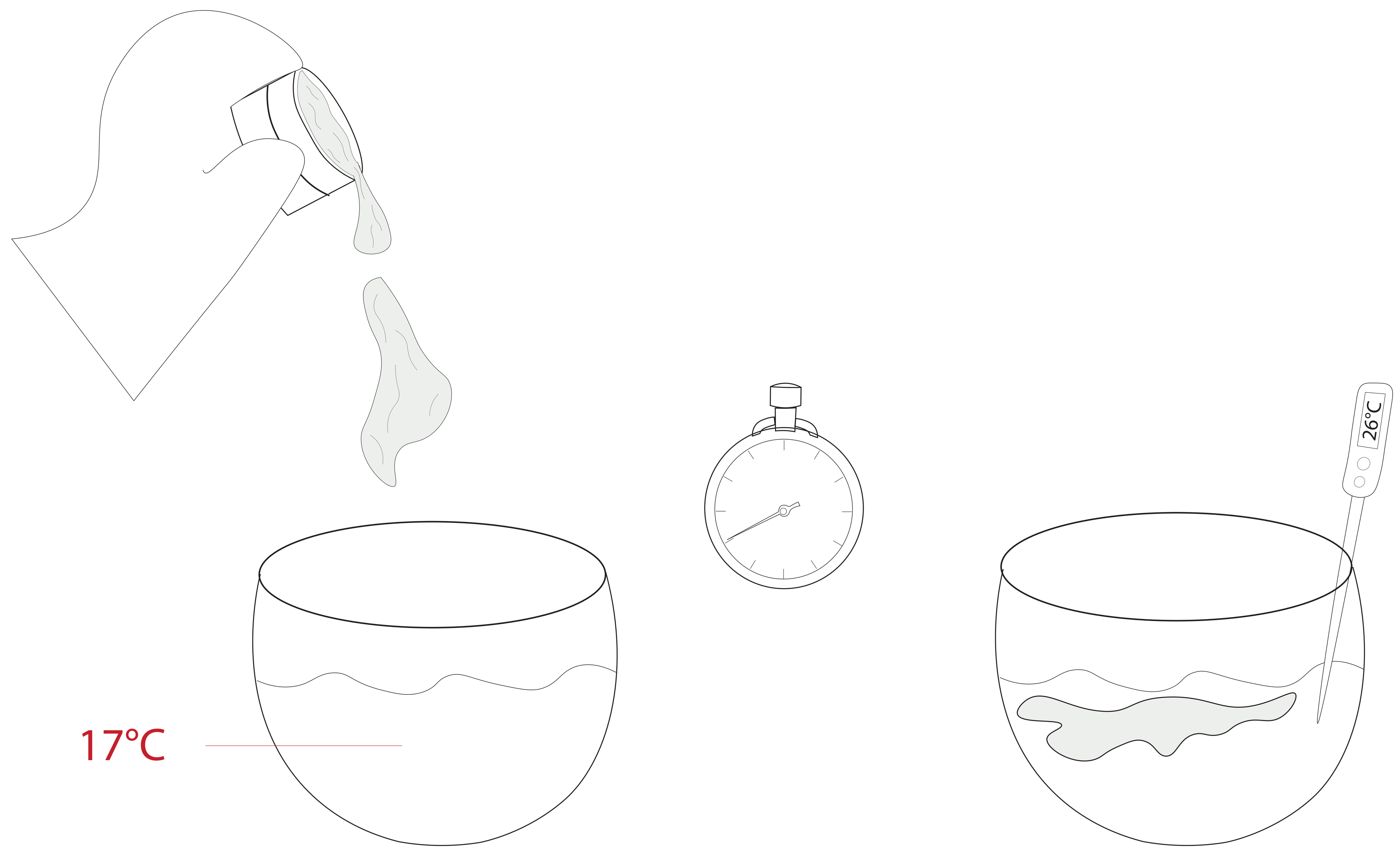
Paraffin Wax Pellets



Vessel Containing Temperate Water

EXPERIMENTAL PROCEDURE





STEP 1 : The wax is melted by heating the candle in a hot water bath.

STEP 2 : Once the wax melts completely, it is removed from the hot water bath carefully.

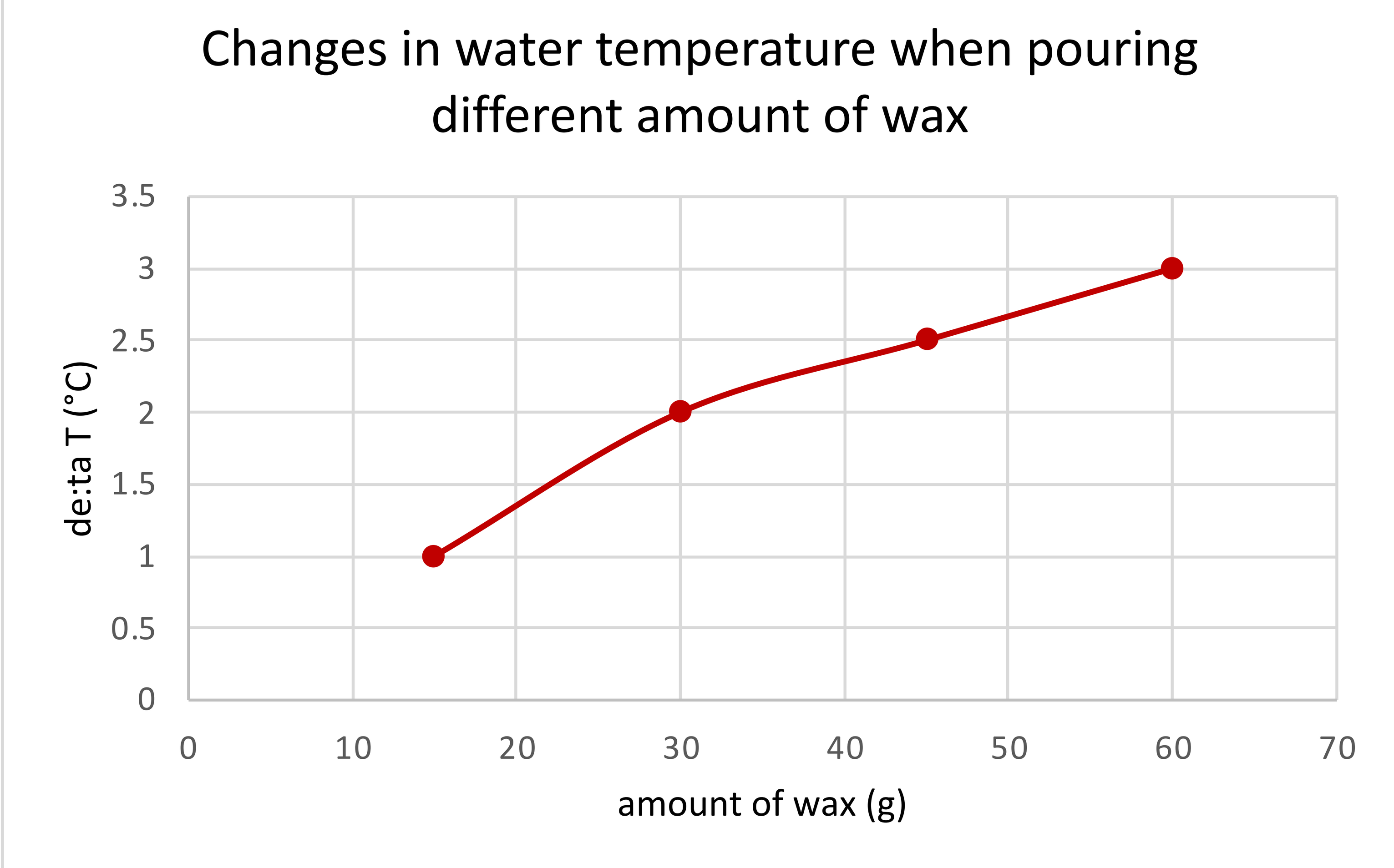
STEP 3 : The molten wax is then poured into a vessel containing temperate water.

STEP 4 : The temperatures of the water before and 1 minute after the wax was poured are recorded.

STEP 5 : The process is repeated with different temperatures of water.

STEP 6 : The results are observed and analysed.

OBSERVATIONS

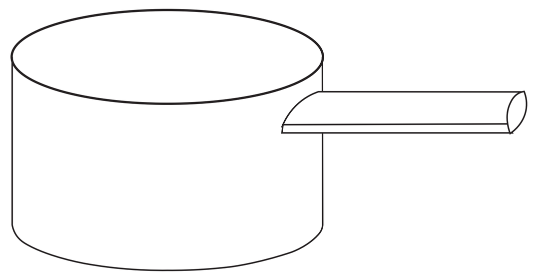


CONCLUSIONS AND EXPLANATIONS

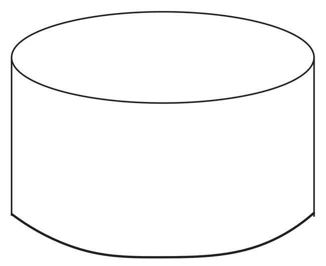
-The wax causes a change in temperature of water.
This indicated that the wax uses energy from the water in order to change from a liquid to a solid state.
-As the amount of was increases, the temperature of the water also increases
This is due the fact that larger quantites of wax require a larger amount of energy to solidify causing a larger change in temperature of the water

EXPERIMENT 6: ASSESSING THE CHANGE

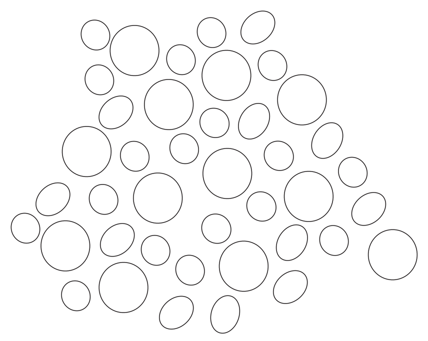
APPARATUS



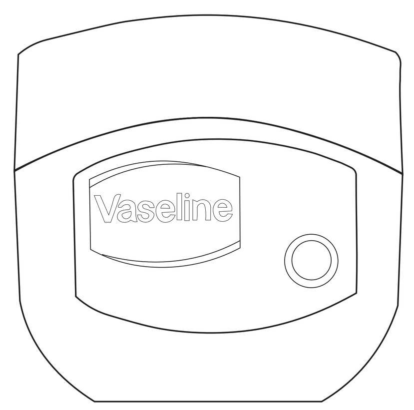
Water Bath



Thermoresistant Container



Paraffin Wax Pellets



Petroleum Jelly

CONSIDERATIONS

The petroleum jelly used is vaseline so its properties might differ from that of pure petroleum jelly.

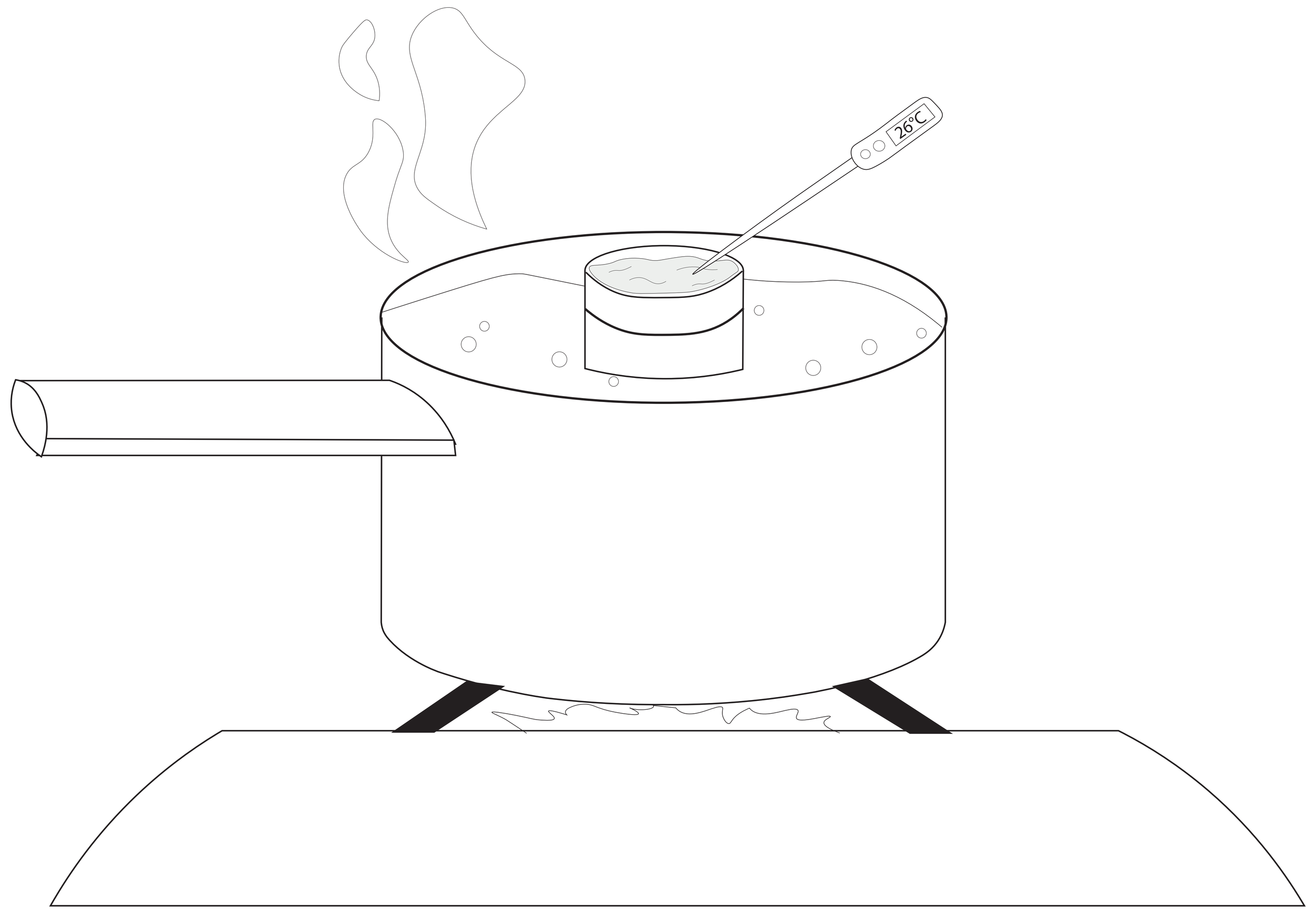
EXPERIMENTAL PROCEDURE

STEP 1 : 30 g wax is heated in a water bath and its temperature is recorded every 30 seonds till the temperature becomes constant, i.e., the melting point is reched.

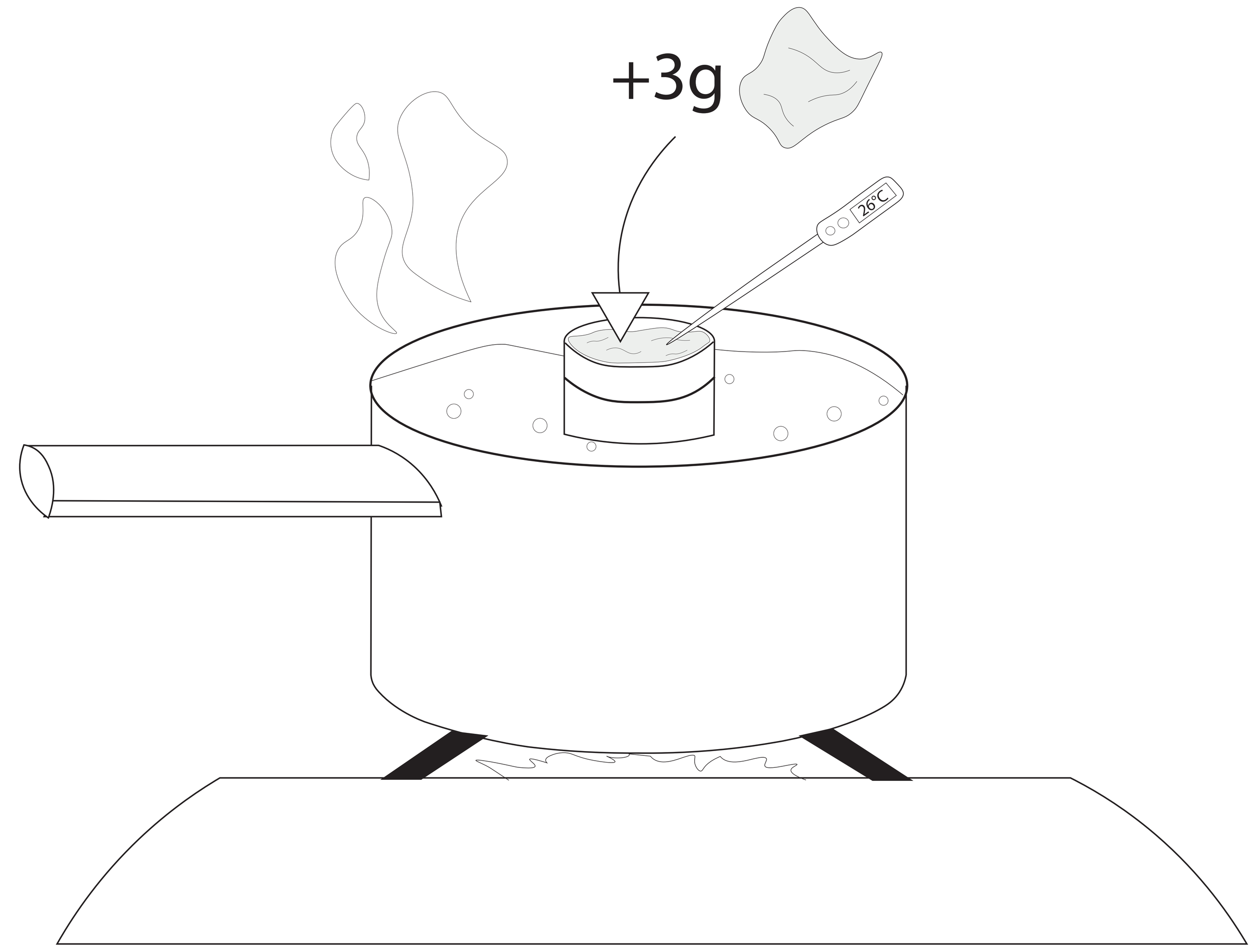
STEP 2 : The process is repeated with added petroleum jelly in increments of 3 g to the wax.

STEP 3 : The results are observed and recorded.

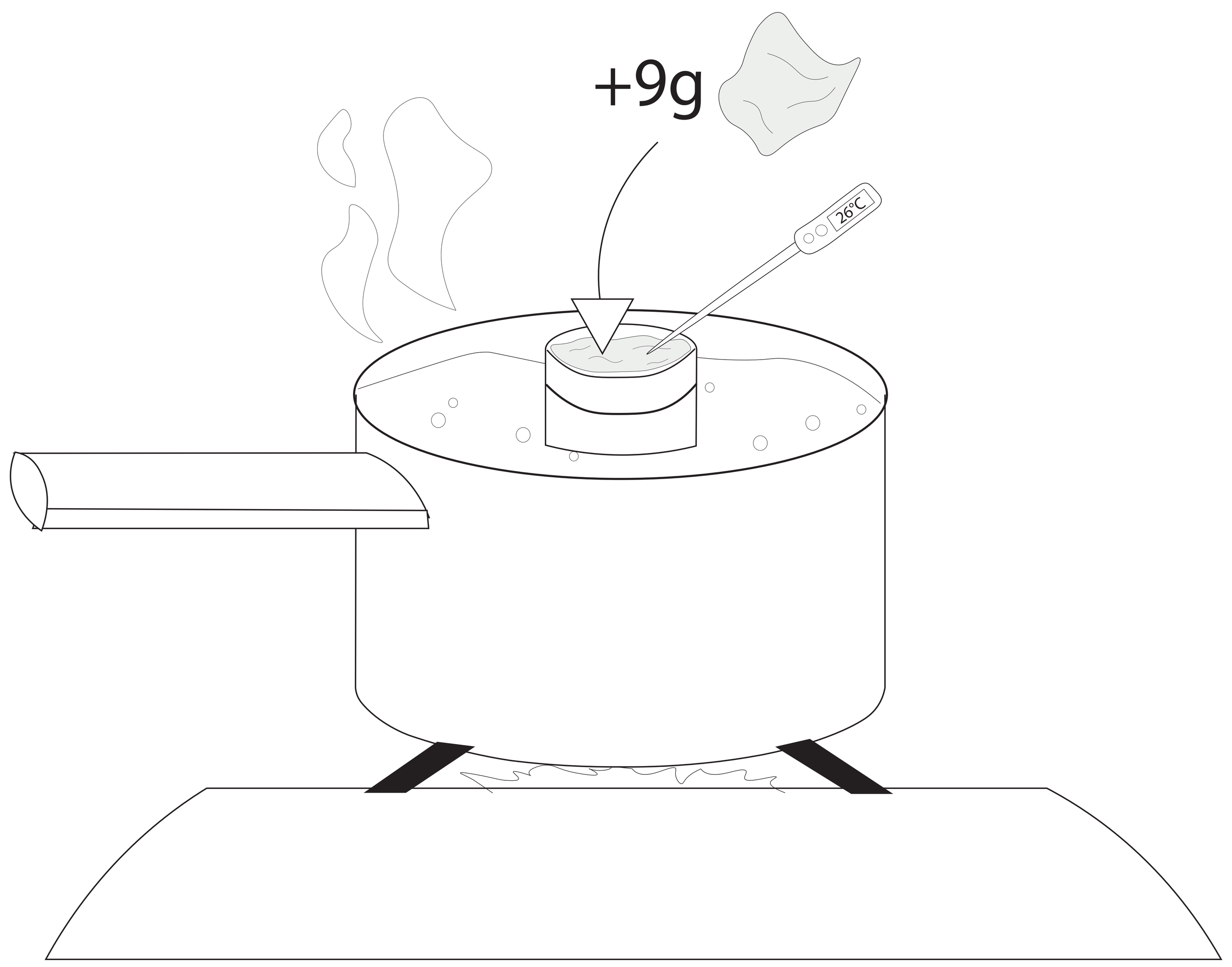
OBSERVATIONS



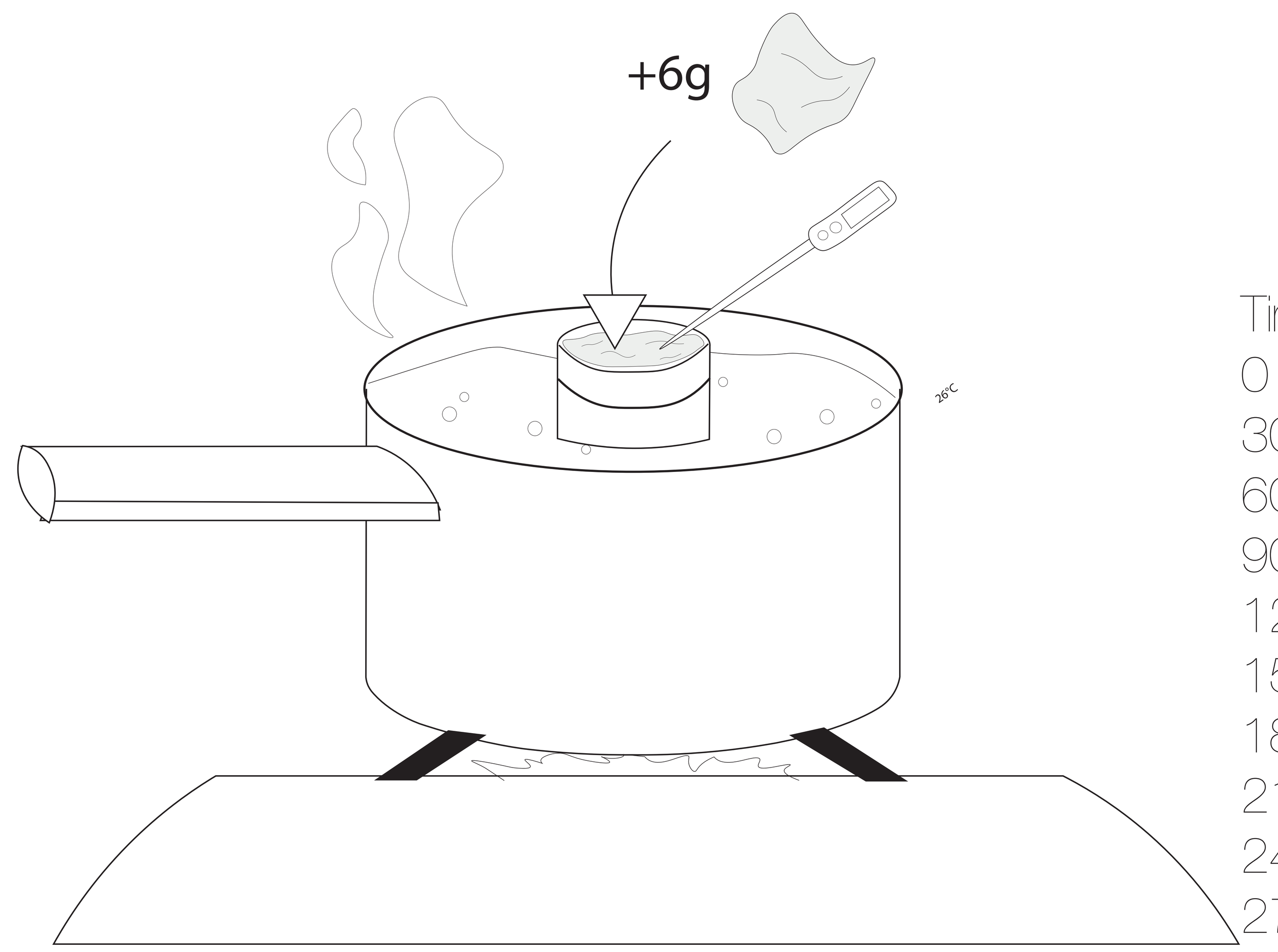
Time (s)	Temperature (¡C)
0	26
30	34
60	56
90	63
120	74
150	78
180	81
210	83
240	83
270	83



Time (s)	T (¡C)
0	26
30	32
60	54
90	78
120	79
150	80
180	80
210	80
240	80
270	80



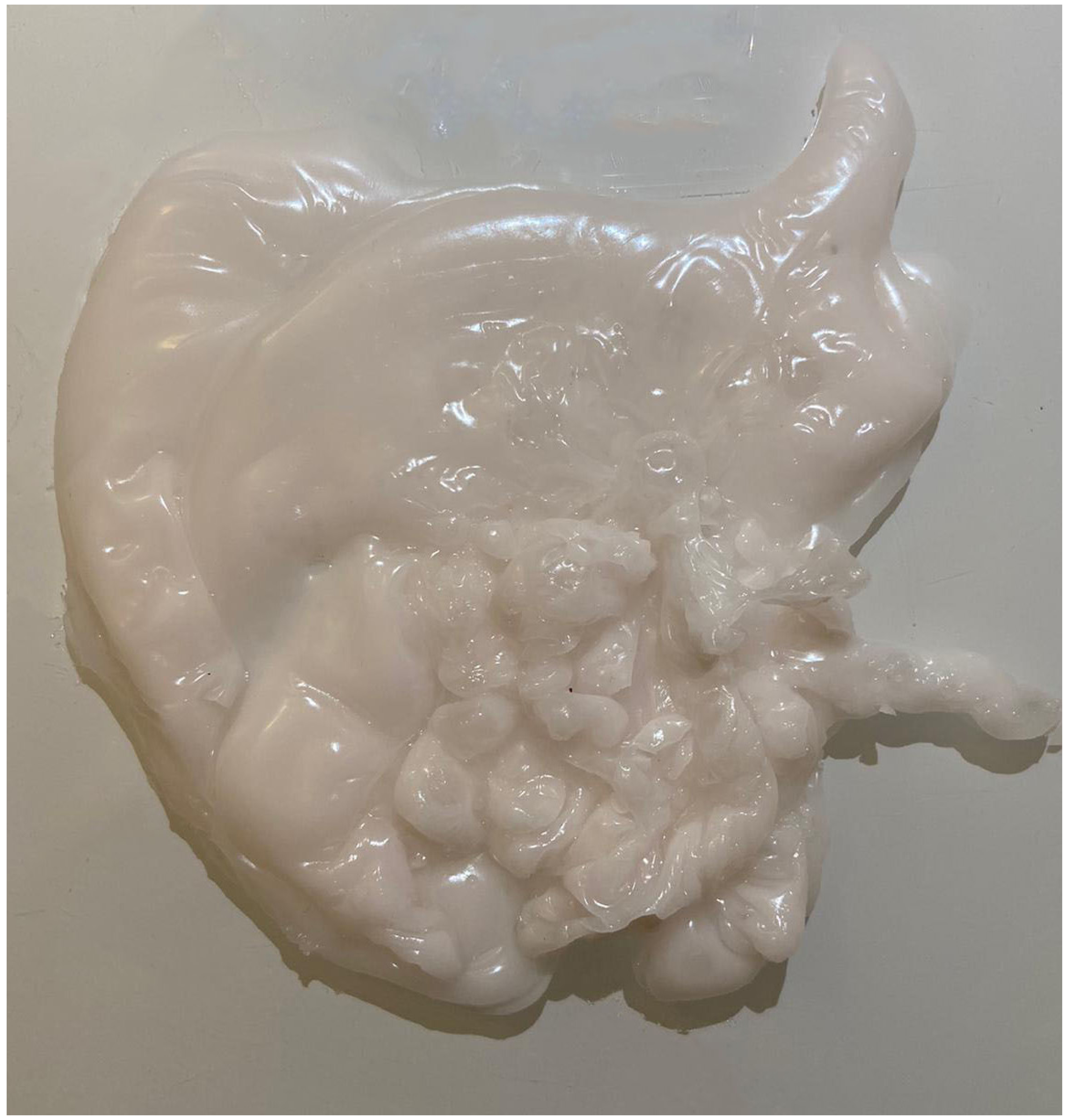
Time (s)	T (¡C)
0	26
30	32
60	45
90	67
120	71
150	72
180	78
210	78
240	78
270	78



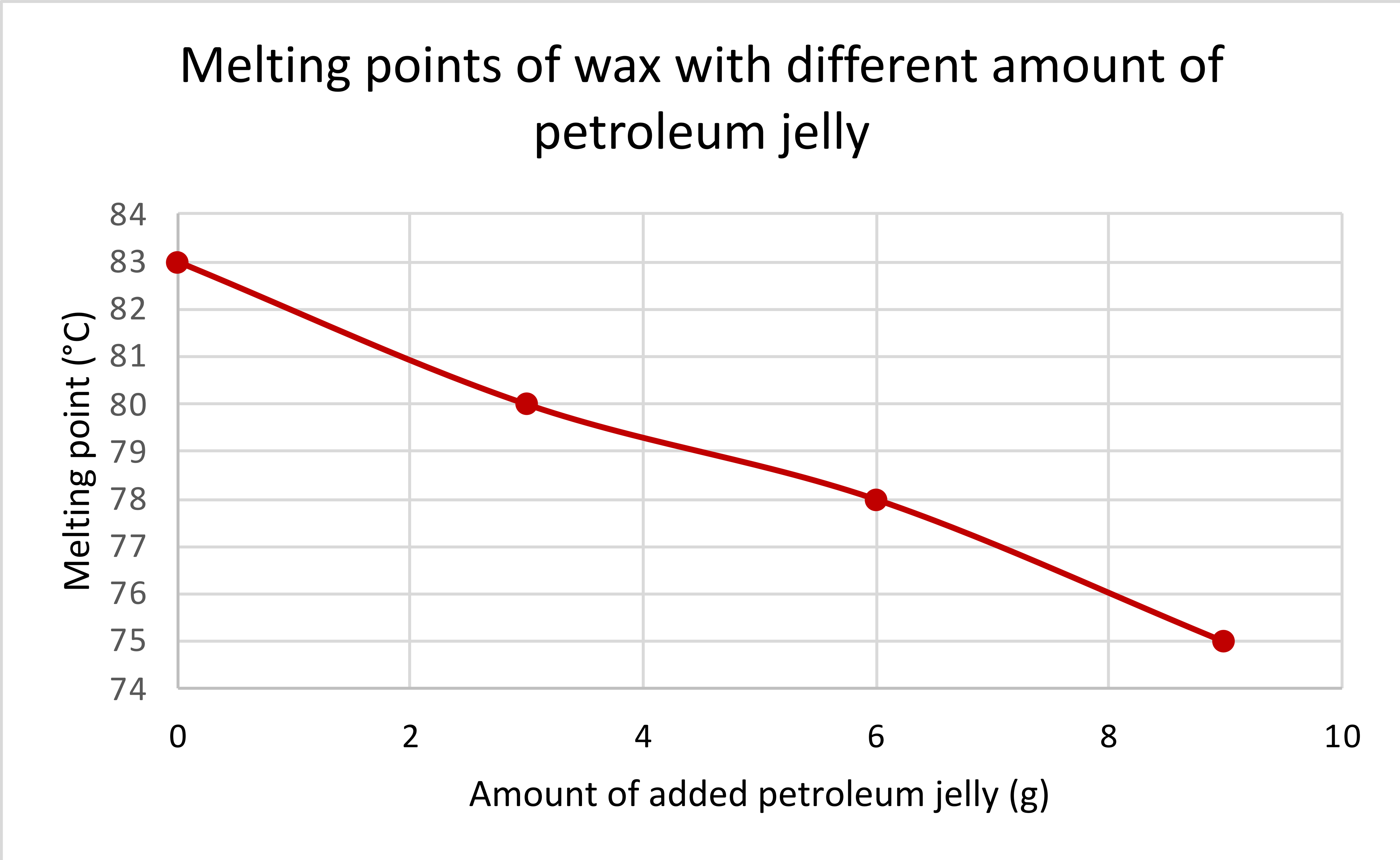
Time (s)	T (¡C)
0	26
30	27
60	53
90	70
120	75
150	75
180	75
210	75
240	75
270	75

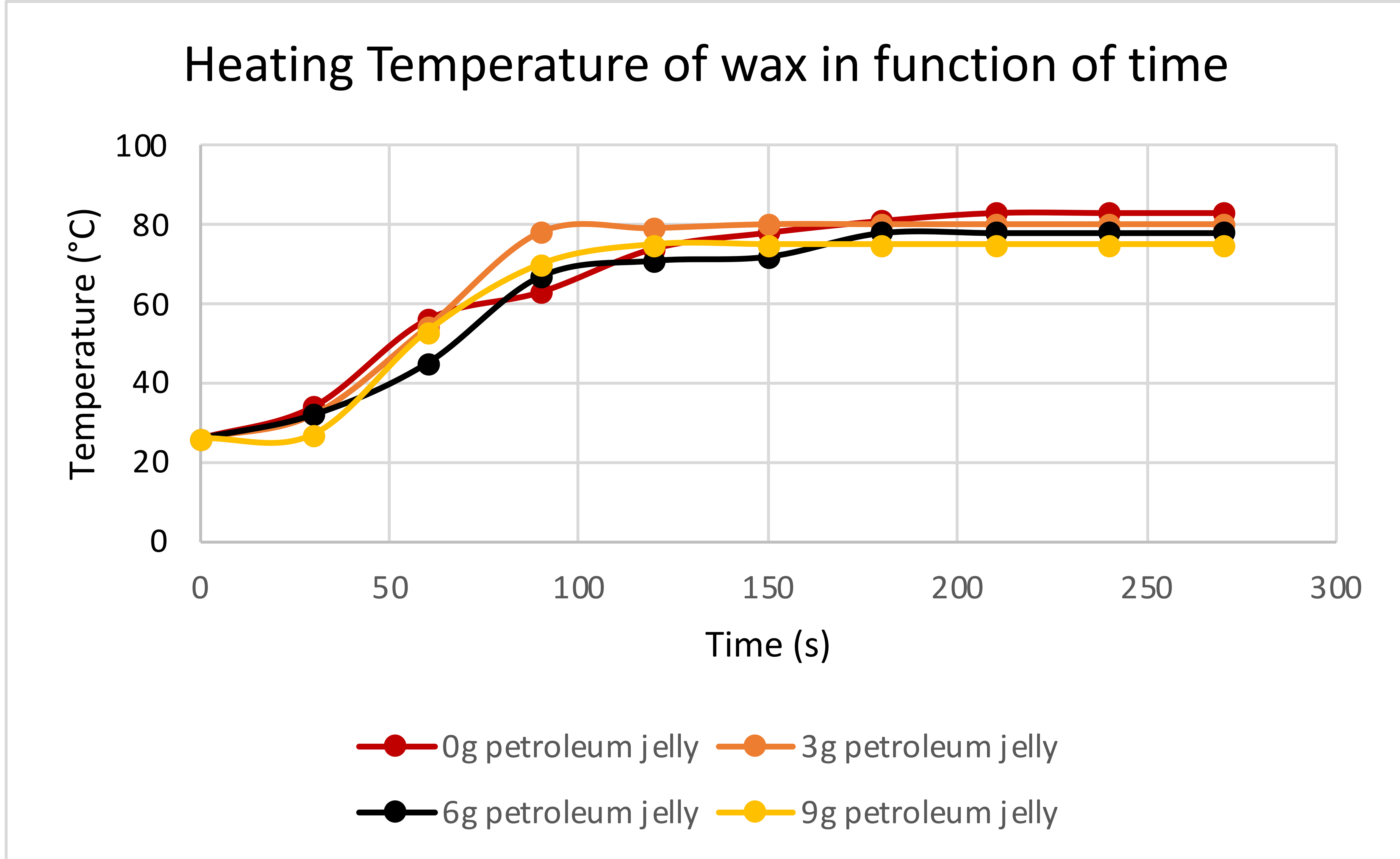
Mixing petroleum jelly in molten wax

Solidified Jelly and Wax mixture: bubbly exterior

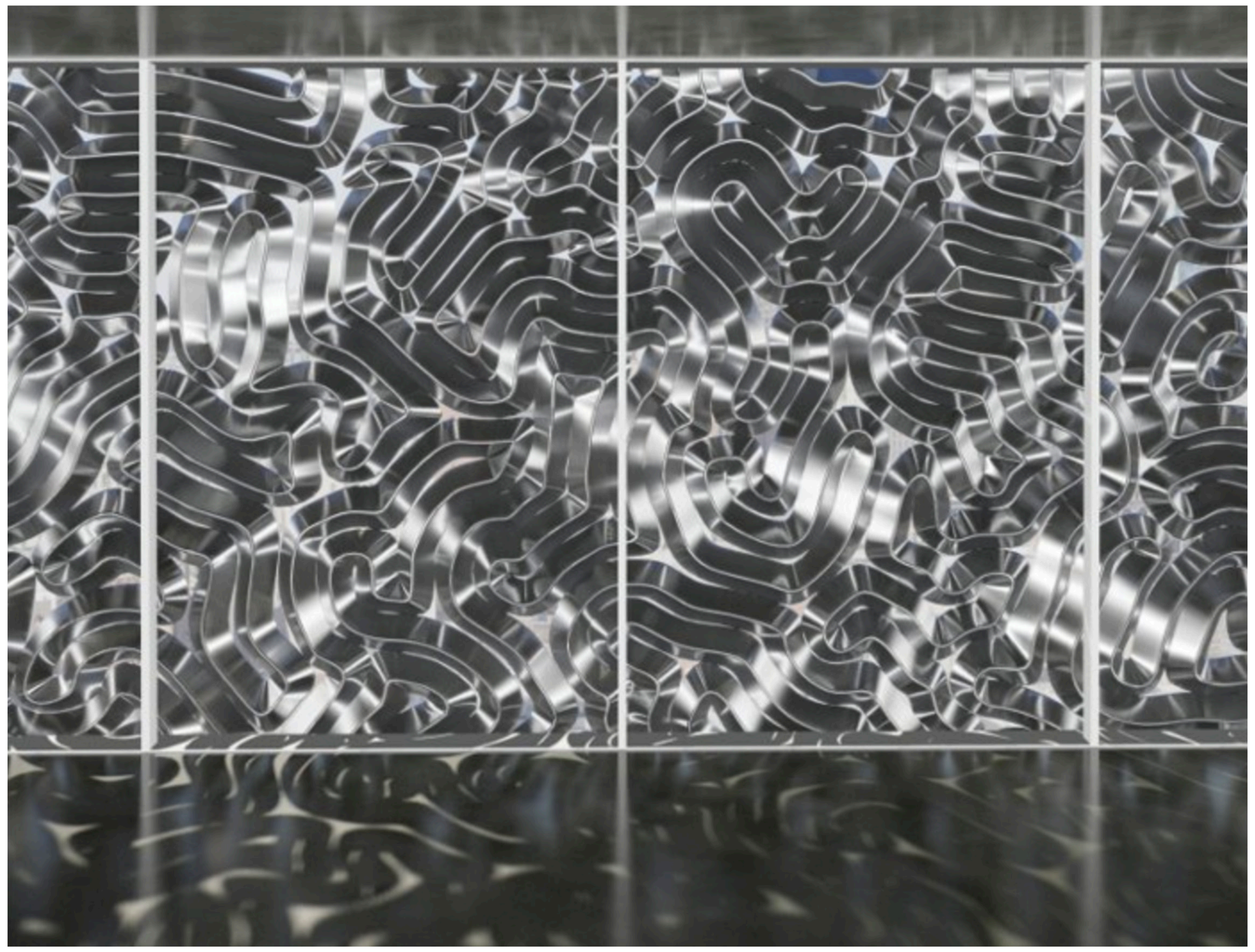


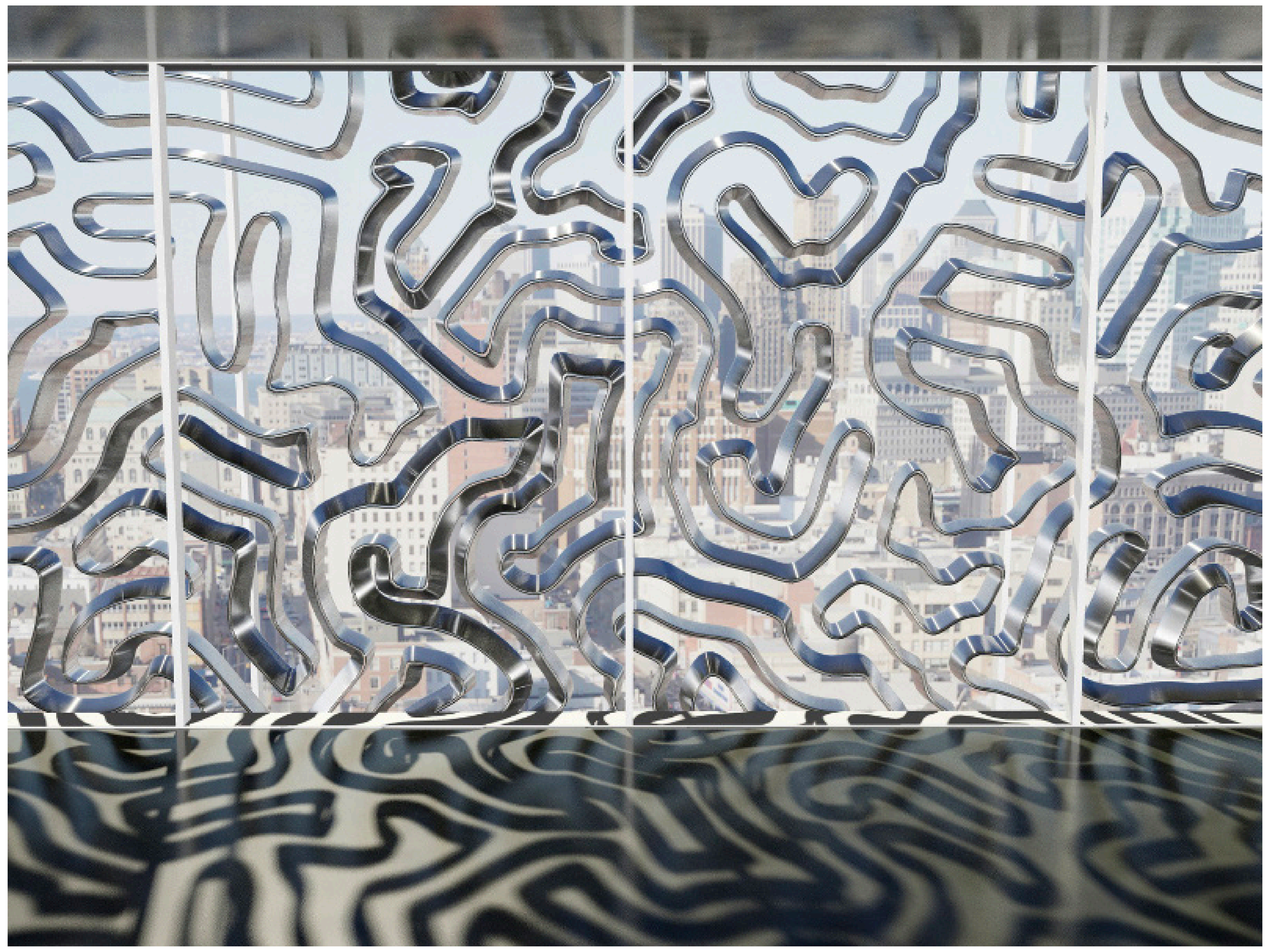
The mixture exhibits similar properties when it solidifies in water

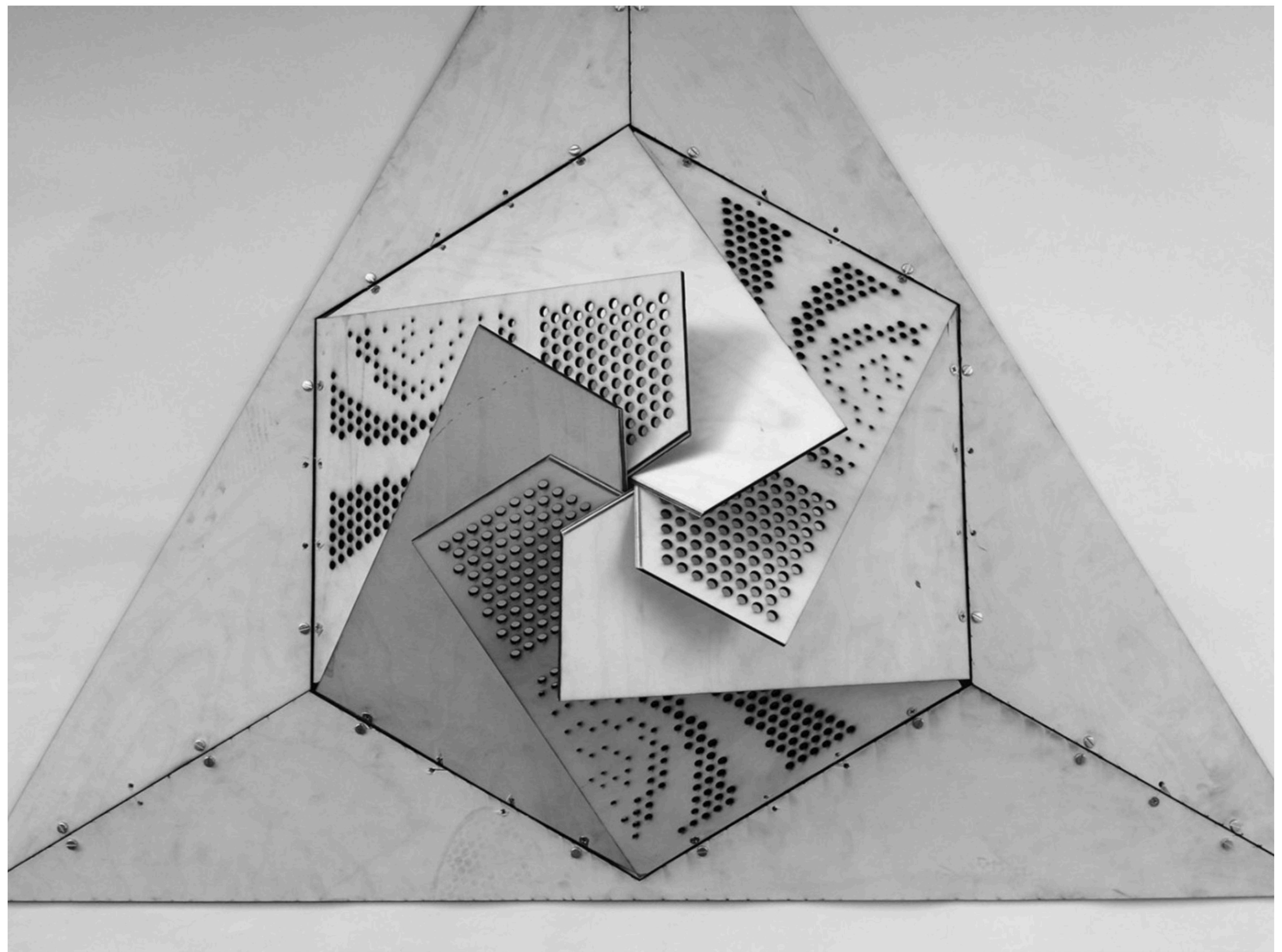

Melting points of wax with different amount of petroleum jelly
Melting point (°C)
84
83
82
81
80
79
78
77
76
75
74
0
2
4
6
8
10
Amount of added petroleum jelly (g)

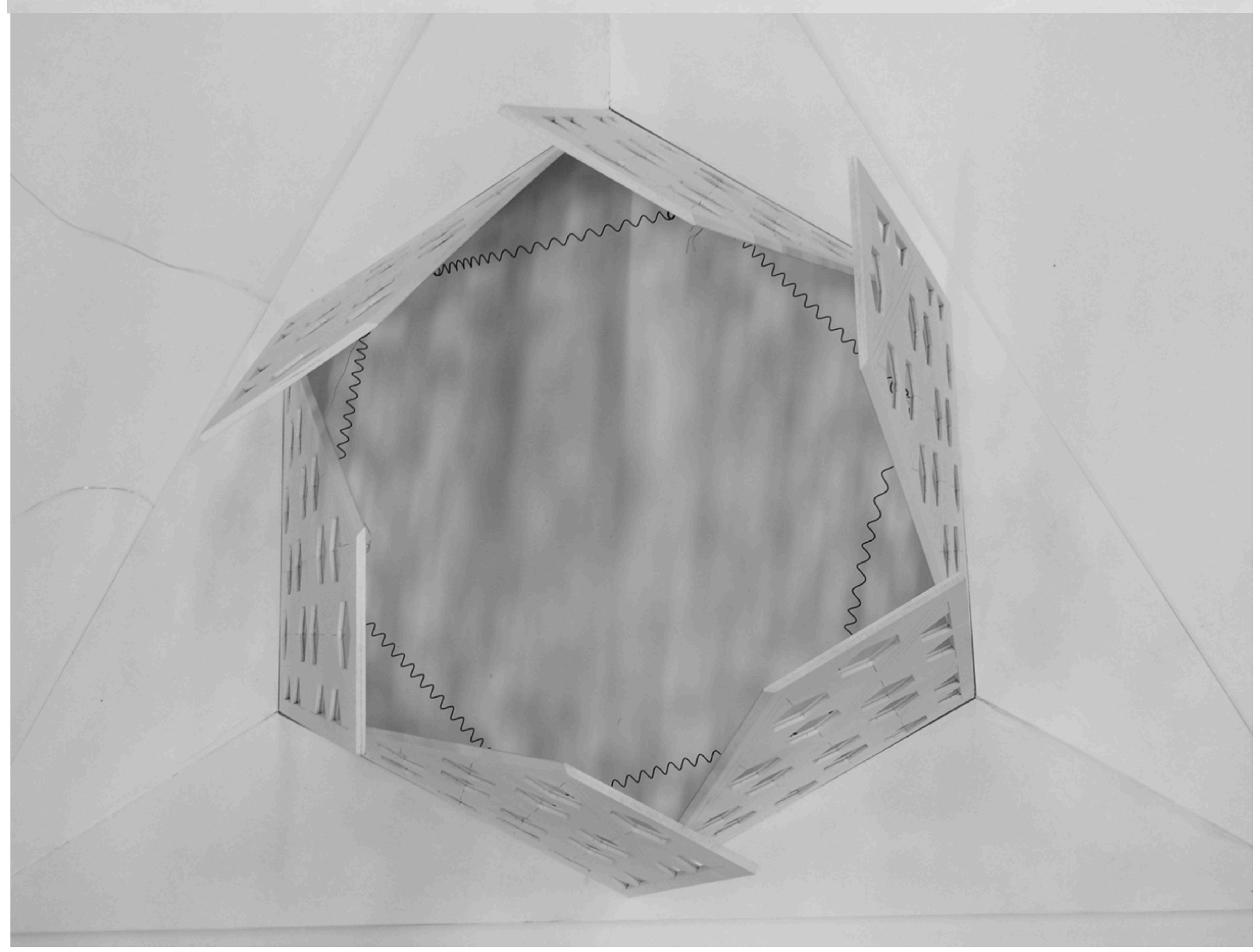

Heating Temperature of wax in function of time
Temperature (°C)
100
80
60
40
20
0
0
50
100
150
200
250
300
Time (s)
0g petroleum jelly
3g petroleum jelly
6g petroleum jelly
9g petroleum jelly

INITIAL INSPIRATIONS FOR NITINOL AND EXPLORING IT'S MATERIALITY



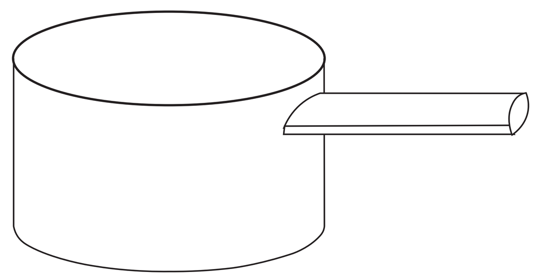




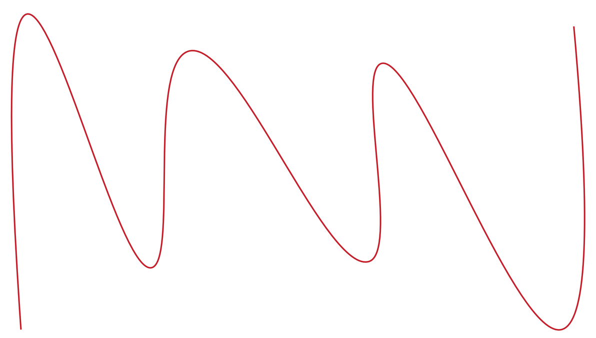


EXPERIMENT 7: TESTING THE METAL MEMORY OF NITINOL AND REPORTING MINIMUM HEAT REQUIRED TO RETAIN SHAPE

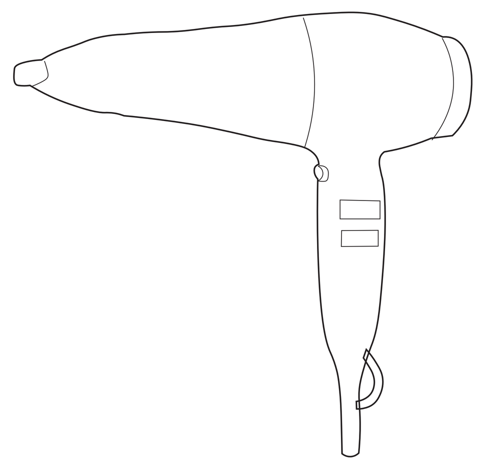
APPARATUS



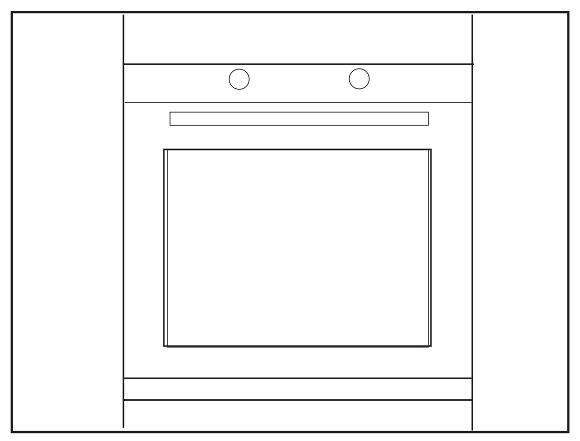
Water Bath



Nitinol Wire



Blow Drier



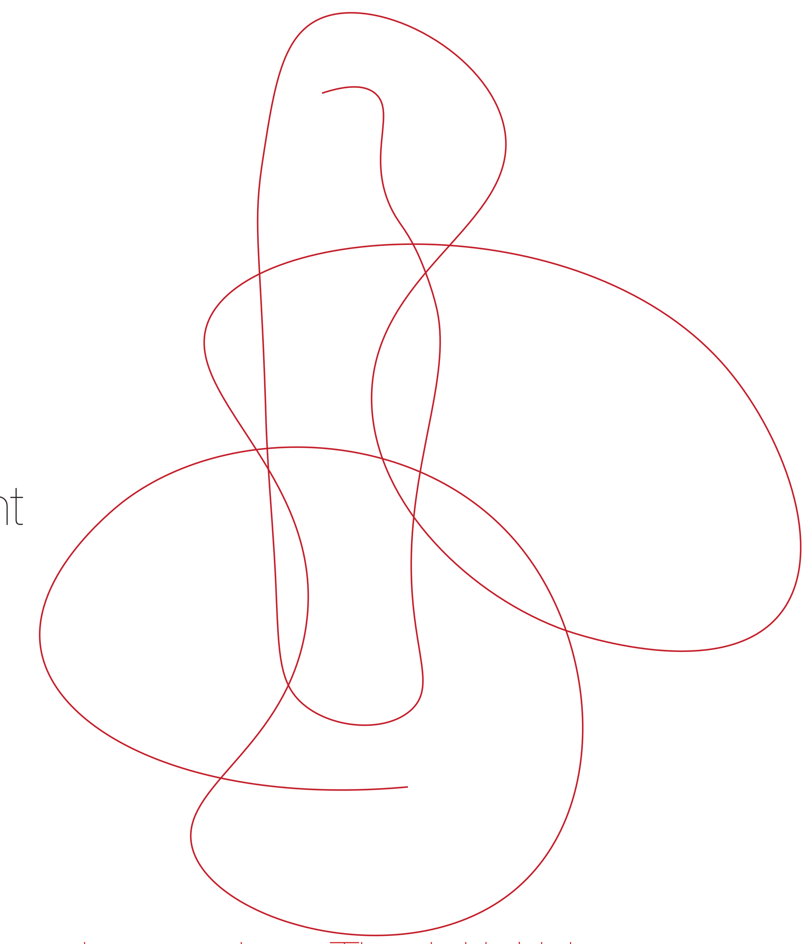
Oven

EXPERIMENTAL PROCEDURE

STEP 1 : 3 strips of Nitinol wire of equal length are taken for study.

STEP 2 : The Nitinol pieces are each tangled to the same extent quantitatively.

STEP 3 : One strip is placed in boiling water, one is placed in the oven and the last is placed infront of a turned on blow dryer.



OBSERVATIONS

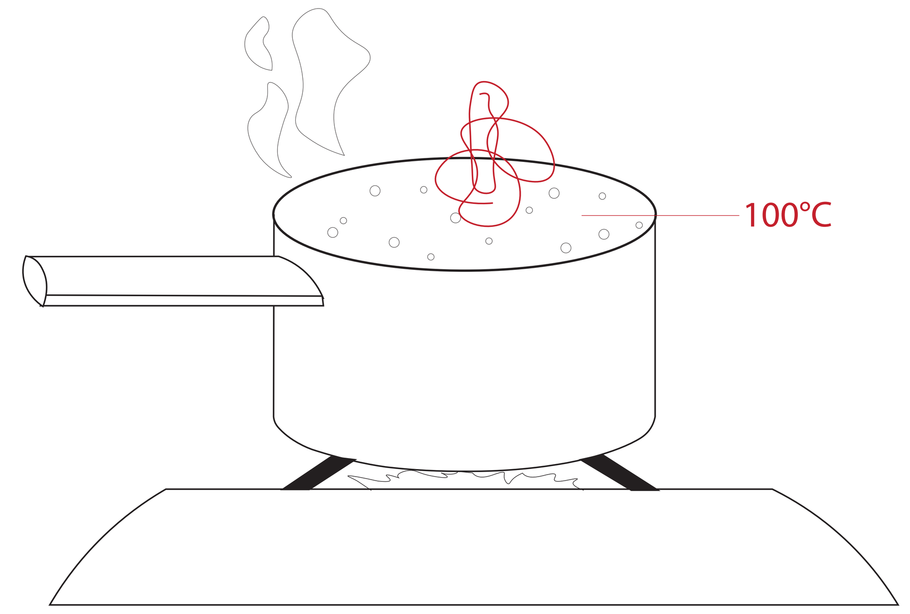
The scope of the Nitinol Wire.
-The Nitinol wire arrived was extremely thin and malleable. It did not have much scope for further experimentation. The initial idea was to use it as a binder but the extremely small cross-section and fragile nature of the wire presented as a failure in itself
The quanlitive nature of the experiment
-Prior to formalising the experimental recordings, the wire was tangled and placed on a flame and it returned to its initial stage in just a few seconds. This made us conclude that quantifying the heat required for the shape change to occur was not extremely high and since the change happened quick it would be hard to measure. Hence we decided to do a more qualitative experiment.
The basic observation that was made in the experiment was that the higher the temperature the wire was exposed to the faster the shape-change occured.
-It was also observed that in the case of the boiling water and the oven, the wire completely returned to the initial shape within a few seconds. However, in the case of the hair dryer, it was observed that the shape retention was localised to the point of application of heat indicating the the heat conduction of the wire. This suggested that the wire was not a strong heat conductor.

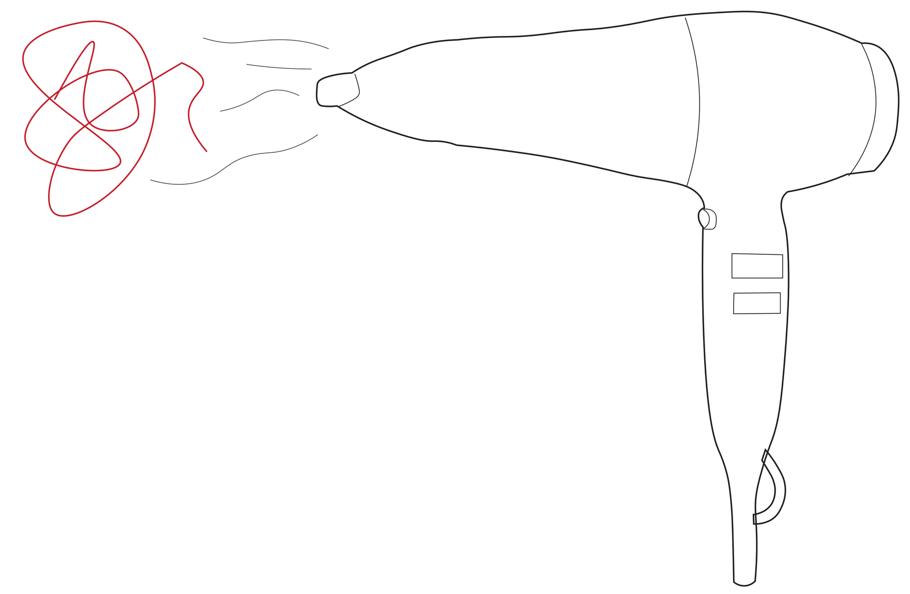
CONCLUSIONS AND EXPLANATIONS

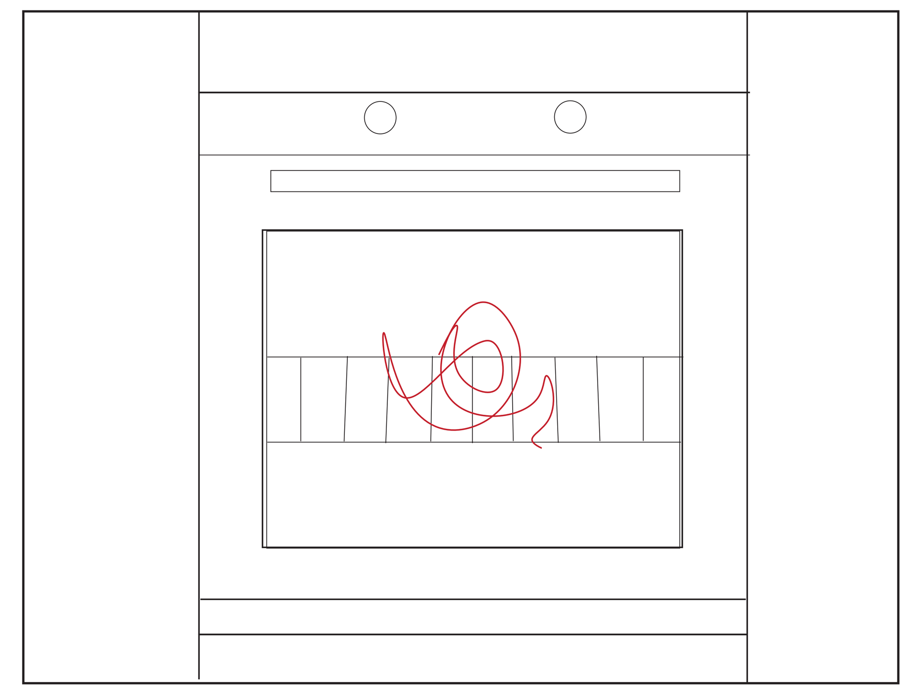
Nitinol is a shape memory alloy that retains its initial shape from a dismorphed state when exposed to heat
-From a simple but scientific standpoint, the shape memory effect exhibited by Nitinol is a result of its unique crystalline structure and phase transformations. Nitinol is a shape memory alloy composed primarily of nickel and titanium.

At low temperatures, Nitinol exists in a crystal structure known as martensite, which is relatively soft and easily deformable. In this phase, the Nitinol wire can be bent, coiled, or otherwise shaped without much resistance. This is the "temporary" shape that can be imparted to the wire. When Nitinol is heated above a critical temperature called the austenite finish temperature, a reversible phase transformation occurs, and the alloy transitions into its austenite phase. The austenite phase has a different crystal structure compared to martensite and possesses a higher stiffness and shape memory properties. The key characteristic of the shape memory effect lies in the fact that Nitinol "remembers" its original shape, which is the austenite phase, even after being deformed in its martensitic phase. When the deformed Nitinol is heated above the austenite finish temperature, the material reverts back to its original shape, recovering the shape it had prior to deformation. This is known as the shape recovery process.

The shape recovery is attributed to a reversible phase transformation that occurs during heating, causing the atoms to rearrange and the crystal lattice structure to change from martensite back to austenite. This phase transformation is facilitated by the diffusion of atoms within the material. As the atoms rearrange themselves, the internal stress that was initially present due to the deformation is released, allowing the Nitinol wire to return to its original shape. It's important to note that the shape memory effect is repeatable and can be induced multiple times by cycling the Nitinol wire between the martensitic and austenitic phases through heating and cooling.



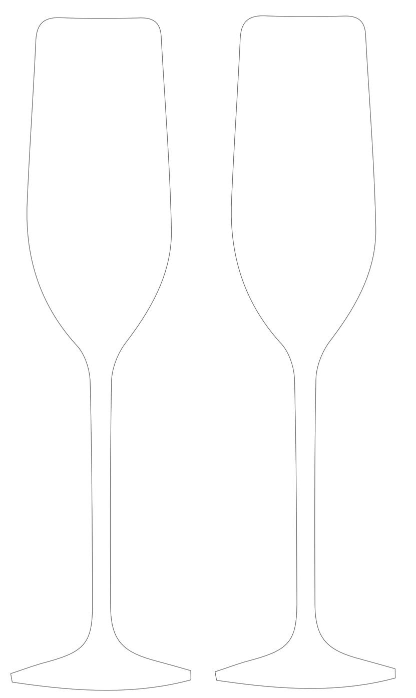




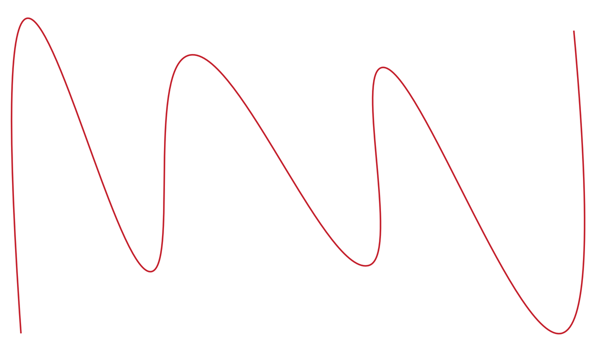
The shape memory effect of nitinol wire is dependent on the heat source. When subjected to boiling water, the wire exhibited complete and uniform shape recovery. In contrast, exposure to a hair dryer resulted in localized shape memory effect limited to the point of heat application.
-Boiling water provides a consistent and homogeneous distribution of heat, allowing for a uniform phase transformation and shape recovery throughout the nitinol wire.
On the other hand, the hair dryer emits a localized stream of hot air, leading to uneven heating along the wire's length.

EXPERIMENT 8: TESTING THE SEE-SAW EFFECT OF A CANDLE SUSPENDED CENTRALLY

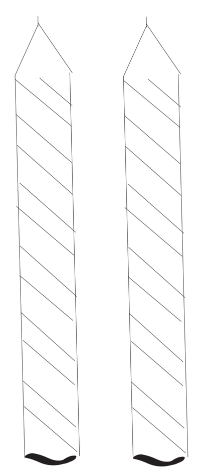
APPARATUS



Two Long Glasses

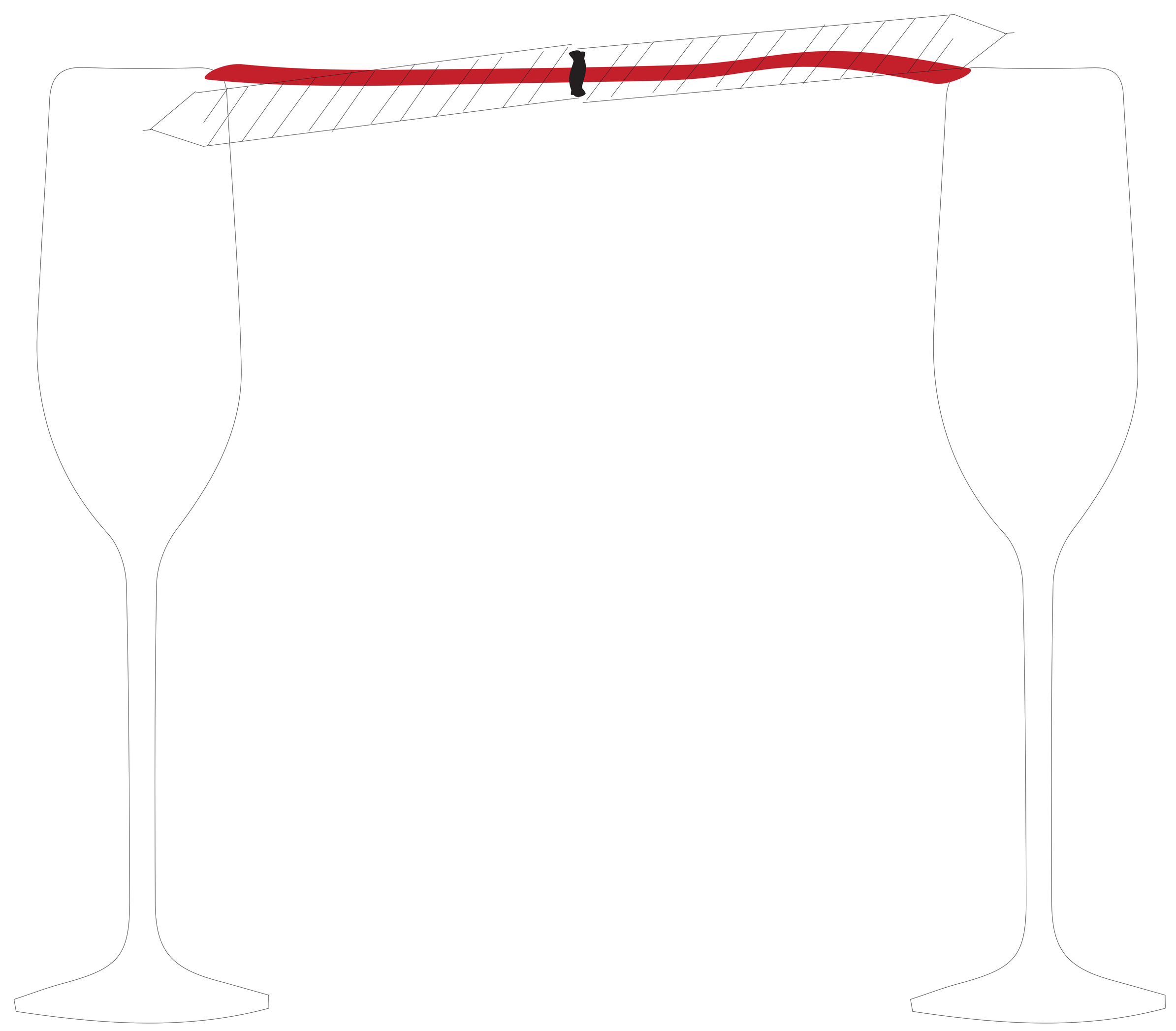


Nitinol Wire

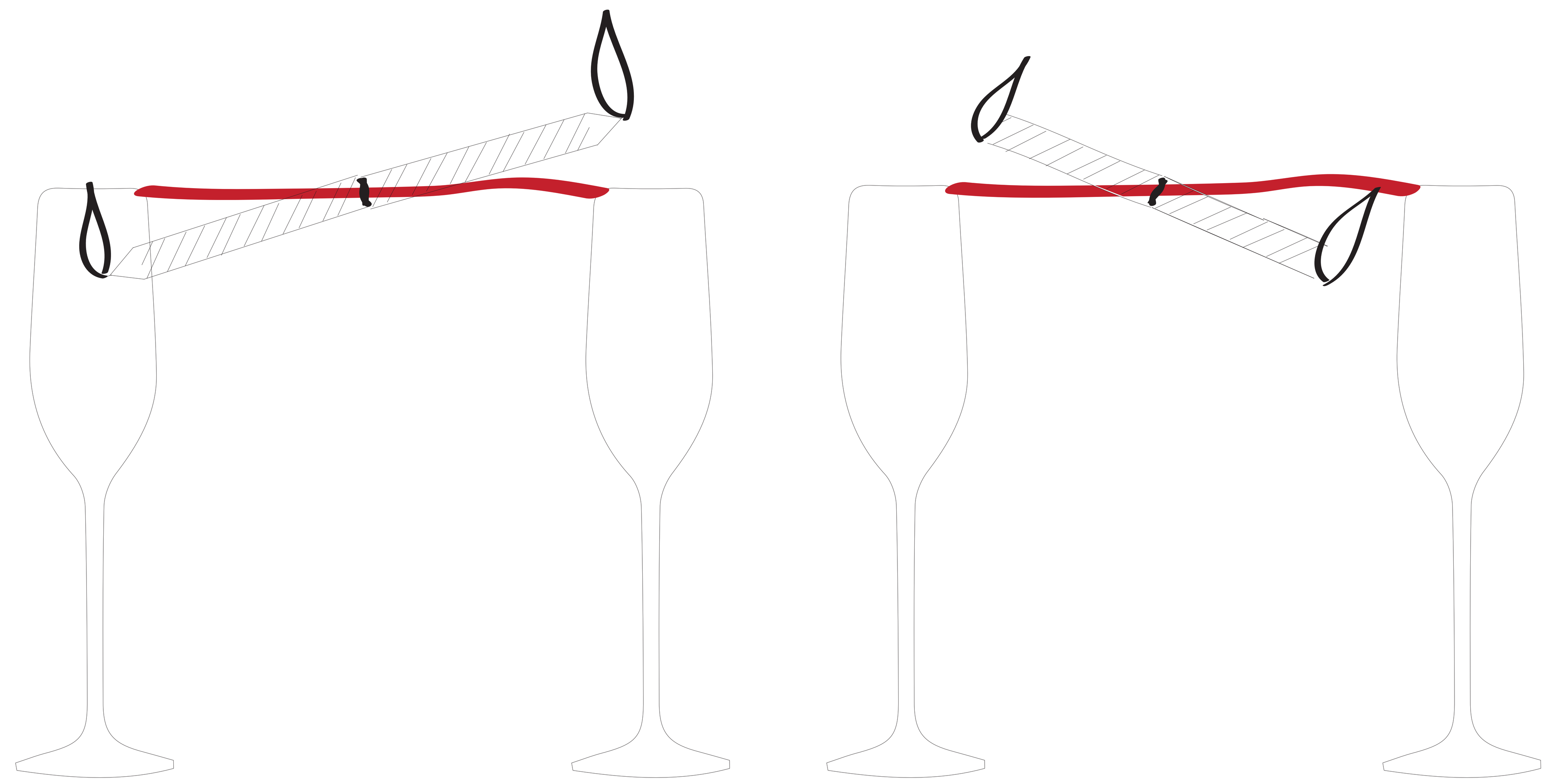


Two Candles

EXPERIMENTAL PROCEDURE



OBSERVATIONS



Scan for Experiment Video

STEP 1 : Attach two identical candles together at their bases using a small amount of melted wax and ensure that they are securely connected.

STEP 2 : Take the nitinol wire and thread it through the center of the connected candles, creating a suspension system. Make sure the wire is tightly secured to prevent the candles from slipping or falling. Suspend the wire from a the two long glasses, ensuring that the candles hang freely and are not in contact with any other objects.

STEP 3 : Light both candles simultaneously using a lighter or a matchstick and observe the results.

The experiment demonstrated that when two candles are attached at the base and suspended from a wire through their center, they exhibit a see-saw behavior as they burn. This behavior continues until the candles burn out completely.

CONCLUSIONS AND EXPLANATIONS

The experiment demonstrated that when two small birthday candles are attached at the base and suspended from a wire through their center, they exhibit a see-saw behavior as they burn. This behavior continues until the candles burn out completely.
-The see-saw behavior observed during the burning of the candles can be explained by the principle of conservation of angular momentum. Angular momentum is a property associated with rotating objects and depends on their mass distribution and rotational speed.
Initially, when both candles are lit, they start to burn and gradually consume the wax. As the wax melts, the mass distribution of the candles changes, affecting the rotational speed and thus the angular momentum. The candle that burns faster and loses more mass experiences a decrease in its moment of inertia, resulting in an increase in its rotational speed.
As a consequence, the candle with the higher rotational speed produces a greater centrifugal force, causing the system to tilt towards that side. This tilting motion resembles a see-saw effect, with the higher candle side becoming lower due to the increased rotational speed.
The see-saw behavior continues as the candles burn and the mass distribution further changes. The side with the burning candle now has less mass, which leads to a higher rotational speed and a stronger tilting effect. This cyclic process of tilting back and forth continues until the wax of both candles is completely consumed.
The heat from the flames did revert some of the nitinol from the coiled to a straight shape, this resulted in a slight change in the pattern of the dripping wax, however this did not have scope for further exploation since the nitinol wire was extremely thin to take the weight of the candles and was only possible for a short length of wire and the set-up was extremely flimsy due to the fragile nature of the Nitinol.

RESULTS OF EXPERIMENTATION AND TRANSITION TO CREATING FINAL APPARTUS

Pouring liquid wax in water

-The results obtained from observing the solidification of liquid wax in water was a factor that interested me the most and was something I wanted to explore more through the apparatus. The unpredictibilty of different specimens of wax in different temperetures of water as well as in different temperatures was intriguiging and I aimed to produce some sort of a logic and pattern from this process through the apparatus.

Interesting shapes of solidifying wax

-The experiments yeilded extremely interesting abstract shapes that wax took and these shapes changed depending on how the wax was poured into the water and the conditions under which it hardened. I aim to create an apparatus to control these conditions in order to create interesting shapes and typologies of wax by controlling the conditions under which the wax is poured into water.

Rejection of Nitinol

-Nitinol, as the secondary material, was rejected for two reasons. Firstly the material did not perform to expectations due to the extremely thin cross-section of the wire specimen that was available. Secondly, thicker cross-sections of Nitinol were not easily available or feasible options in terms on procurement and so while Nitinol was an extremely fascinating material with interesting properties it would not be used in the project beyond a basic experimentation stage.

Experimenting changing depth while pouring liquid wax in water

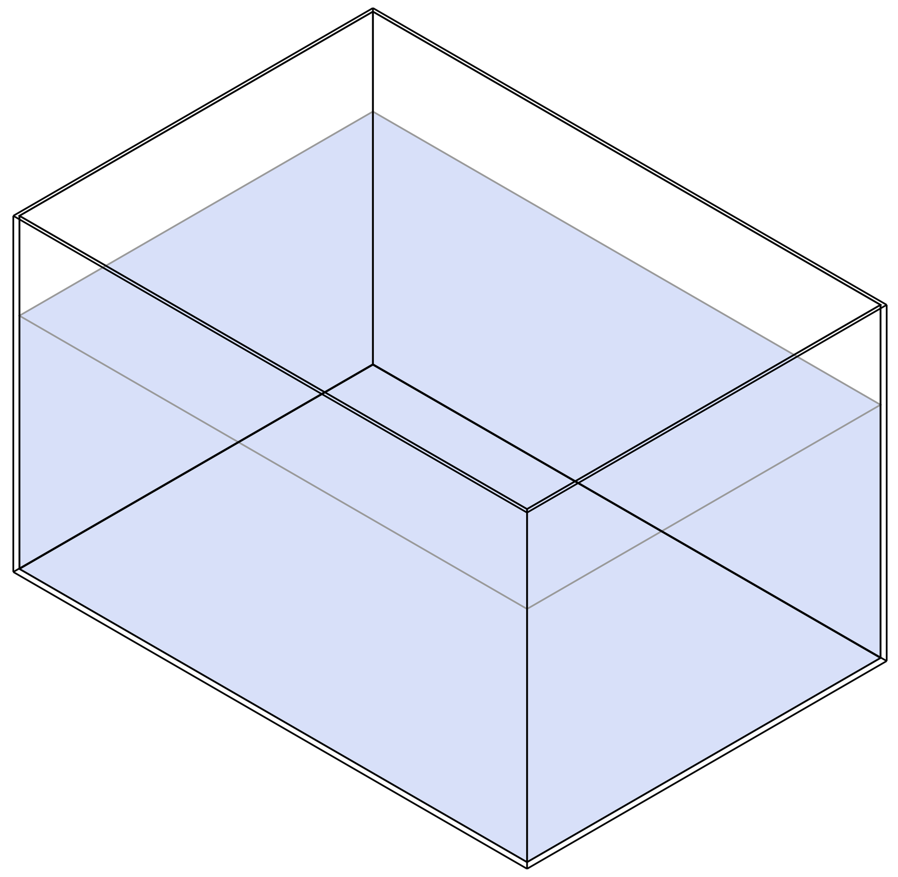
-Through the experiments conducted, it was observed that wax solidified differently when poured into containers of varying depths. I want to create and apparatus wherein the depth of the container changes as the wax is being poured to see what kind of shapes would be created.

Experimenting wax formations in containers of different cross-sections

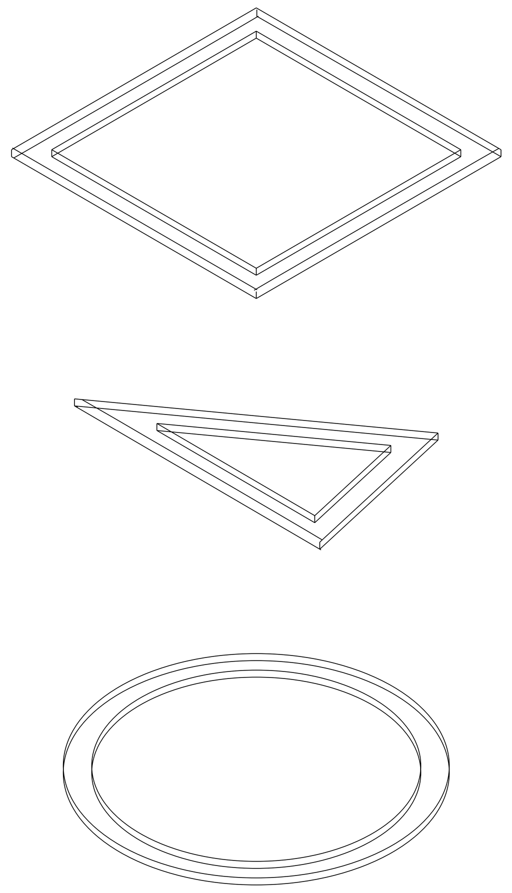
-Through the experiments conducted, it was observed that wax solidified differently when poured into containers of varying shapes. I aim to control the shape of the resulting solid wax outcome by manipulating the shape of the container into which the wax is poured.

EXPERIMENT FINALIS: CREATING THE FINAL APPARATUS

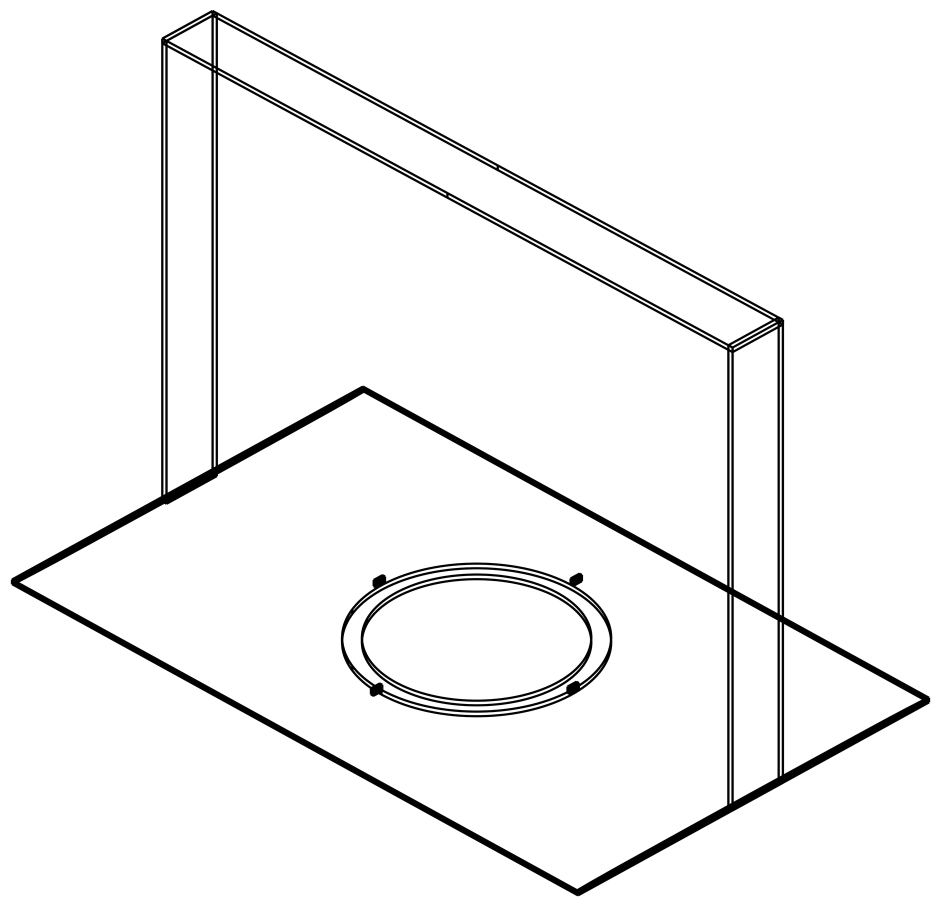
APPARATUS



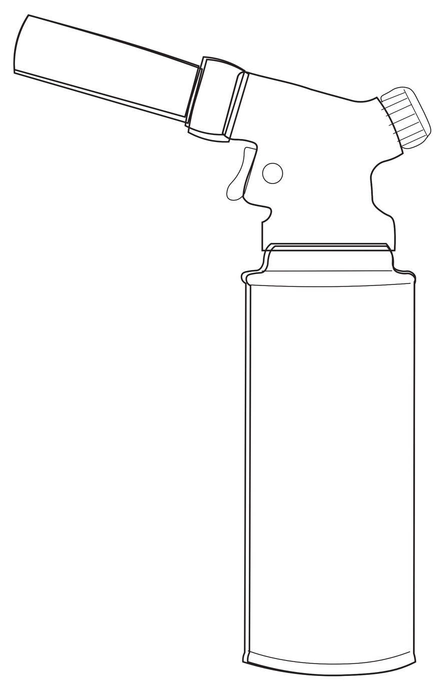
A Reasonably Large Container Filled with Water



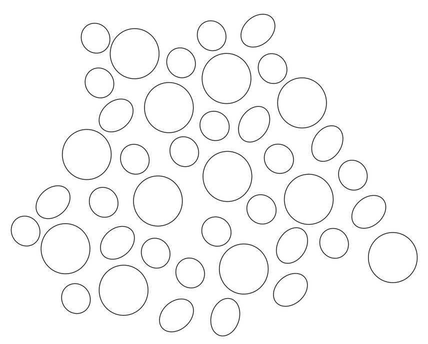
Frames with different shapes



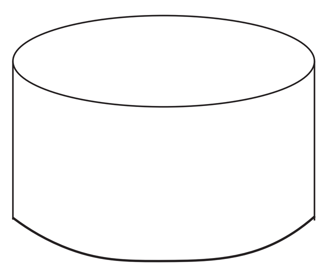
A platform to be suspended into the water container with groovers to fit different shaped frames



Heat Gun



Paraffin Wax Pellets



Thermoresistant Container

EXPERIMENTAL PROCEDURE

STEP 1 : Set up a work area with a water container, a platform, frames with different shapes (such as a circular, square, and triangular frame), and liquid wax.

STEP 2 : Fill the water container with an adequate amount of water, ensuring that the water level is sufficient to immerse the frames.

STEP 3 : Place the platform on top of the water container, ensuring it is stable and properly aligned and attach the desired frame, such as the circular frame, securely onto the platform.

STEP 4 : Start pouring the liquid wax into the center of the circular frame on the platform. Take care to pour the wax slowly and evenly, allowing it to spread across the frame's surface.

STEP 5 : Observe the behavior of the wax as it comes into contact with the water. Notice the shape it takes and any patterns or abstract forms that emerge due to the viscosity of the water.

STEP 6 : Allow the wax to solidify completely in the water and carefully remove the frame and the solidified wax from the water container

STEP 7 : Repeat this procedure with the square and triangular frames, obtaining different wax forms for each shape.

STEP 8 : Record these observations and note any distinct shapes or patterns obtained for each frame shape.

OBSERVATIONS

During the experiment, the following observations can be made:
-As the liquid wax is poured into the frames, it spreads out and takes the shape of the frame due to surface tension and gravity.
-When the wax comes into contact with the water, the viscosity of the water causes the wax to solidify in a distorted or abstract shape.
-Different frame shapes, such as circular, square, and triangular, yield distinct wax forms when solidified in the water.

CONCLUSIONS AND EXPLANATIONS

The experiment demonstrates that when liquid wax is poured onto a platform fitted with frames of different shapes and submerged in water, the viscosity of the water causes the wax to solidify into abstract shapes. The resulting wax forms vary depending on the shape of the frame used.
The viscosity of the water plays a crucial role in shaping the solidified wax. As the liquid wax is poured onto the platform, it spreads across the frame's surface due to surface tension and gravity. When the wax reaches the water, the higher viscosity of the water compared to the liquid wax causes it to solidify more slowly.

As the wax solidifies in the water, the water's viscosity hinders the smooth flow and settling of the wax molecules. This leads to the formation of irregularities, distortions, and abstract shapes in the solidified wax. The shape and pattern of the wax are influenced by the interaction between the wax's viscosity, the water's viscosity, and the shape of the frame used.

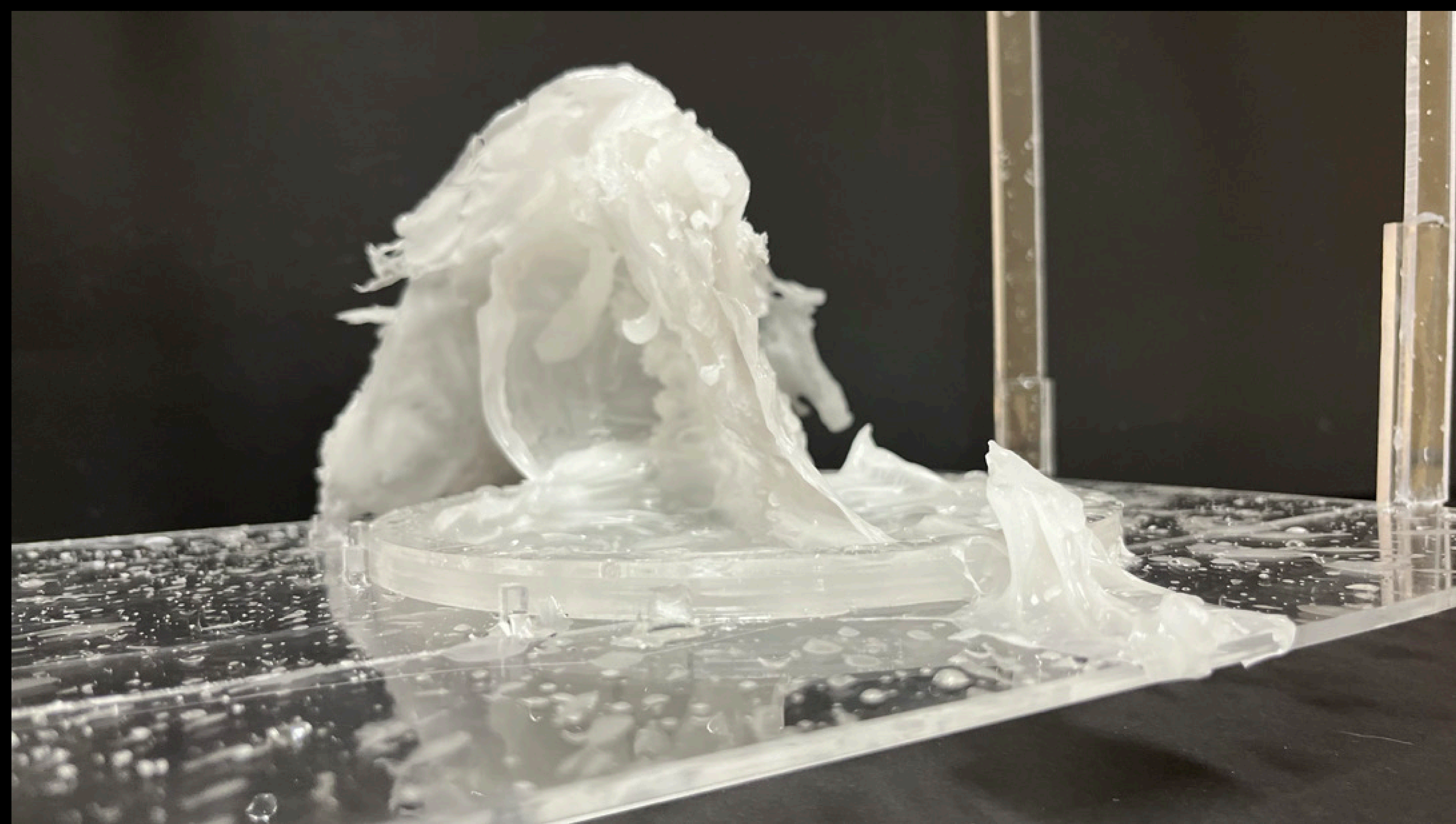
The different shapes of the frames, such as circular, square, and triangular, provide varying boundaries and constraints for the spreading wax. These boundaries influence the overall shape and pattern of the solidified wax, resulting in distinct and unique forms for each frame shape.

EXPERIMENT FINALIS: CREATING THE FINAL APPARATUS

Scan to watch the video of the final experiment

RESULTS FROM THE CIRCULAR-SHAPED FRAME DURING THE EXPERIMENT

Result from Apparatus



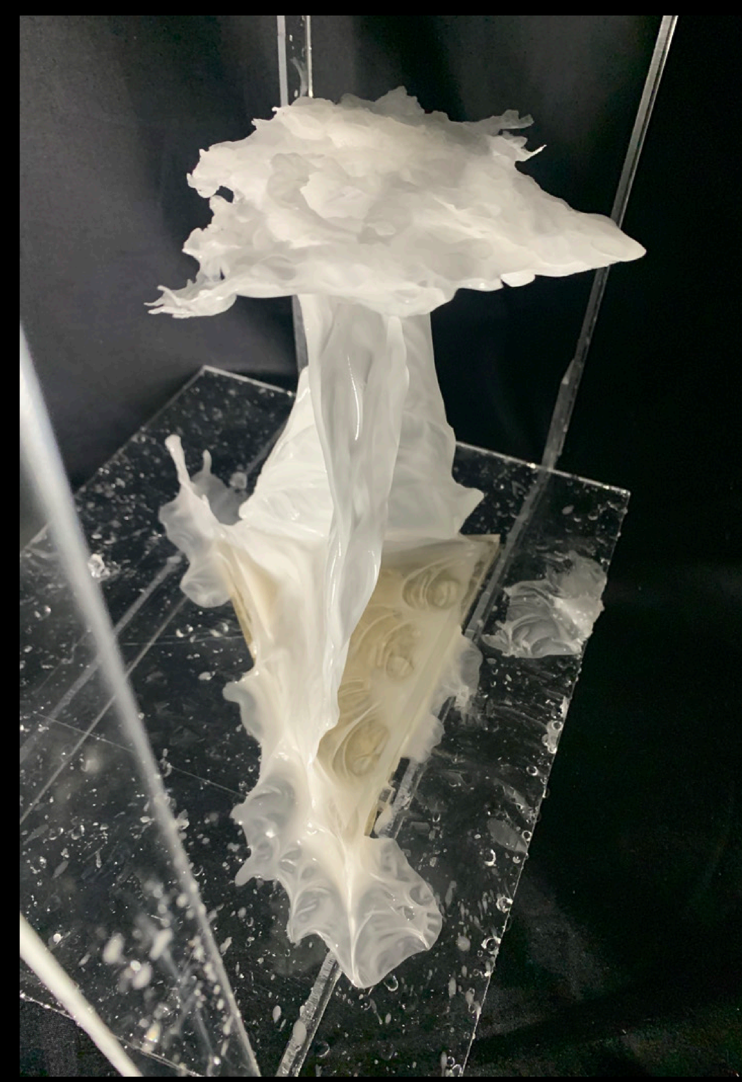
ITERATIVE RESULTS FROM THE CIRCULAR-SHAPED FRAME DURING THE EXPERIMENT

RESULTS FROM THE SQUARE-SHAPED FRAME DURING THE EXPERIMENT

Result from Apparatus

RESULTS FROM THE TRIANGULAR-SHAPED FRAME DURING THE EXPERIMENT

Result from Apparatus



FINAL WAX MODELS PRODUCED FROM THE FINAL APPARATUS