Theme 1: Is Matter Around us Pure?

Prior Knowledge

It is recommended that you revise the following topics before you start working on these questions.

- Pure & impure substances - mixture separation techniques, boiling point, density, centrifuge
- Types of mixtures - solutions, colloids, heterogeneous & homogeneous solutions, solubility

Pure and impure substances

Think of any five substances that are important to you. Do you know what they are made up of? It is highly probable that they are made up of more than one substance because that is true for a majority of substances, which make up the objects we come across in our life. Be it soil, wood, plastic, air or water, all are made up of more than one substance. During the COVID19 pandemic, oxygen became a very important substance. Note that in daily life we do not inhale oxygen alone. We inhale air, which has nitrogen, carbon dioxide, argon and many other gases, along with oxygen, but our body requires pure oxygen to conduct respiration. It is the extraordinary machine in our body called the lungs, which does the job of filtering the oxygen from the air and placing it in our blood. The way our lungs separate out pure oxygen from air, we need to separate out the pure substances out of the mixture (also known as impure substances) which contains that substance. There are various techniques to separate the ingredients of a mixture. Let us look at some of these techniques.

Case Study A - Mixture separation

I. Handpicking & Sedimentation

Each mixture separation technique depends on the difference in at least one property of the ingredients. For instance, if you have to separate red and yellow balls from a mixture, you may handpick the red balls (or yellow balls) and place them in another container. In this simple looking technique you are using the difference in this property - colour - of the balls.

Handpicking is the separation method in which components of a mixture can be separated by just picking them out by hand. Handpicking uses the difference in physical appearance of the components of a mixture to separate them.

Fig. 1.1, Handpicking coffee beans separated using colour of the beans; Image by Quadell via Wikimedia Commons

Sedimentation uses gravity to settle heavier particles present in a liquid mixture by leaving it undisturbed. Sedimentation utilises the difference in the densities of the components of the mixture. A common example observed in daily life is the tea leaves that settle down in a cup of tea.

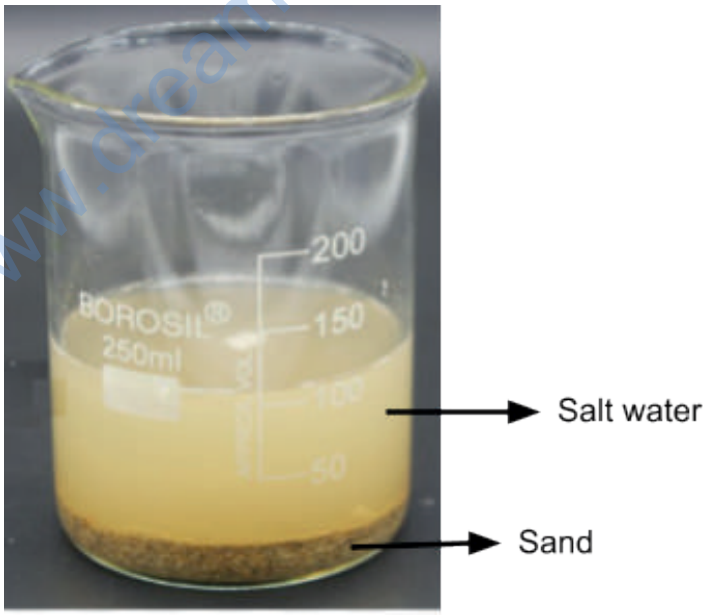


Fig. 1.2, Sedimentation of saltwater and sand

Similarly, we have other properties which are different, which different techniques make use of, like the difference in the density, solubility, boiling point, melting point, size of the particles of the substance, etc.

Question 1

Given below are two mixture separation techniques. Identify the difference in the properties of the ingredients of the mixture which each technique makes use of. Write your answer in the space provided below each question and picture.

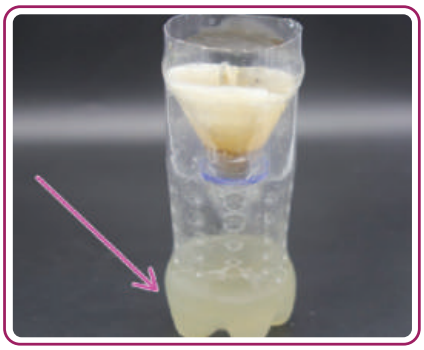


Fig. 1.3, Filtration through a filter paper placed inside a funnel made by cutting a waste plastic bottle

i. Filtration is a process used to separate particles, using a filter medium that allows some components of the mixture to pass through the pores of the medium but not all.

Answer

ii. Distillation is the process by which a liquid is heated to create vapours. These vapours are passed through a medium with low temperature to condense them back into a liquid.

Fig. 1.4, Test tube containing mixture of water and acetone is heated by placing it in hot water; vaporised acetone is passed through the straws and condensed back into the plastic container.

Answer

II. Curcumin Extraction

Curcumin is present in the roots of a turmeric plant but is present in very small quantities (3% to 5%). One of the extraction processes used to extract pure curcumin from turmeric is explained below:

1. **Stage 1**: Turmeric root is cleaned, dried and powdered.
2. **Stage 2**: Turmeric powder is dissolved in alcohol. The reason for this is that curcumin dissolves well in alcohol and poorly in water. This mixture is then filtered.
3. **Stage 3**: Mixture is washed using other liquids, which dissolve other ingredients of turmeric but not curcumin.
4. **Stage 4**: The mixture of this newly added liquid and alcohol is placed in a separating funnel. Note that the two liquids are not miscible. When left undisturbed for some time, the denser liquid settles at the bottom of the funnel from where it can be taken out.
5. **Stage 5**: Alcohol solution is separated out and alcohol is distilled out from this solution. We are left with pure curcumin in solid form.

Question 2

i. What is the main ingredient separated out from turmeric in Stage 1? Write your answer in the space given below.

Answer

ii. Name one main property of the liquid which can be used in Stage 3.

Answer

iii. If the melting point of curcumin is 183 ^{0}C, what can you say about the boiling point of the alcohol used in this process?

a. < 183 ^{0}C	b. > 183 ^{0}C
c. = 183 ^{0}C	d. None of these

Answer

III. Temperature at Boiling Point

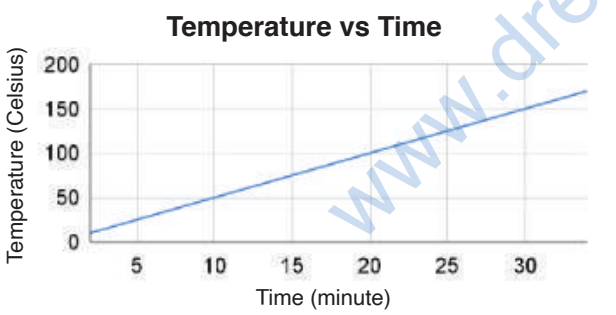
When a liquid is heated, its particles gain energy and the liquid's temperature increases. We often talk about this quantity called temperature to talk about the degree of heat that an object/substance carries. The average energy of all the particles of the object/substance is another way to define the temperature of that substance. When the temperature of the liquid reaches its boiling point, its particles start escaping. As we add more heat, more particles take this heat and run away. This way, the particles which escape (vaporise) take away all the additional heat, thereby keeping the temperature constant until all the liquid gets converted to vapour.

If you have a mixture of two liquids with different boiling points and one starts heating the mixture, the temperature increases till it reaches the temperature at which one of them starts boiling. The temperature remains at this value until all of this liquid vaporises. If we continue to redirect the vapours to another chamber where it gets condensed, then we would have separated the two liquids.

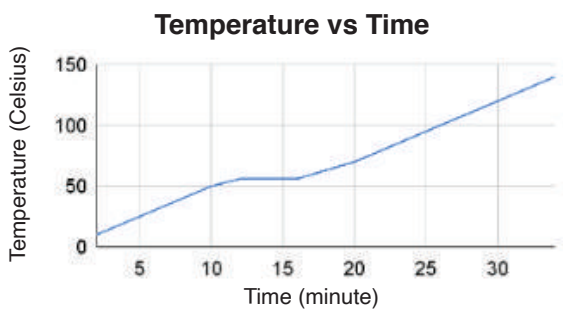
Question 3

A mixture of acetone and water is heated to distil and extract pure forms of both liquids. The boiling point of acetone is 56°C and that of water is 100°C. Which of the following graphs correctly represents the change in temperature with respect to time?

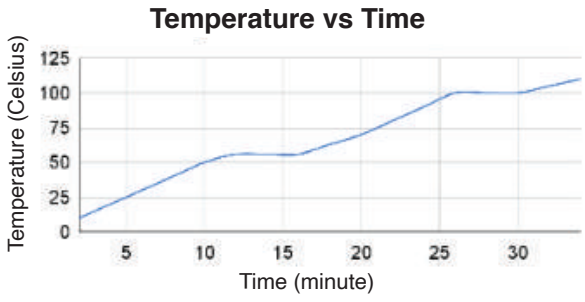
A



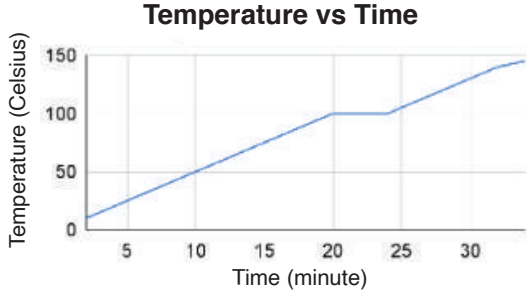
B



C



D



Answer

IV. Fractional Distillation

The technique described in the previous section is called simple distillation and is used to separate mixtures made of liquids with considerable difference in boiling points. On the other hand, we use fractional distillation for mixtures containing chemicals with boiling points close to each other. One of the popular examples of fractional distillation is the separation of crude oil into ingredients like asphalt, diesel, kerosene, petrol, paraffin wax, LPG, etc. Each of these ingredients have their own unique use. Imagine using crude oil for cooking, in vehicles and candles!

The hot crude oil is put in a stack of connected chambers. The temperature of the chambers continues to reduce as you go upwards. The hot vapours rise up. As the vapours enter a chamber that has a temperature below their boiling point, they condense and can be taken out from the outlet of that chamber. The vapours having a boiling point below the temperature in that chamber continue to be in vapour form and rise up to the next chamber.

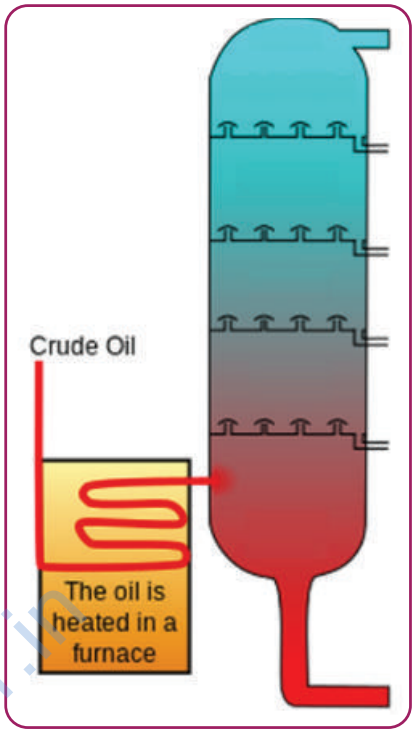


Fig. 1.5, A diagrammatic representation of fractional distillation of crude oil in an oil refinery;Image by Balajijagadeesh via Wikimedia Commons

Question 4

The boiling points of petrol, diesel, paraffin wax and kerosene are given in Table 1.1. Arrange these products from top to bottom in terms of the position of the chambers from which they get collected.

Petrol	Diesel	Paraffin wax	Kerosene
150 ^{0}C	300 ^{0}C	400 ^{0}C	200 ^{0}C

Table 1.1, Boiling points of some products of fractional distillation of crude oil

Topmost chamber ↓	.....
	.....
	.....
Bottom-most chamber	.....

Question 5

i. An attempt is made to conduct fractional distillation of a mixture of three liquids, which have boiling points of 56 ^{0}C, 78 ^{0}C and 100 ^{0}C. The mixture is heated in a flask, called the distilling flask, and through a condenser pipe, passed to another container, called the receiving flask, where the distilled liquid gets condensed. Cold water is circulated on the walls of the condenser pipe. A thermometer is attached on top of the distilling flask. What should be done when the thermometer shows the temperature increase from 56 ^{0}C to 57 ^{0}C?

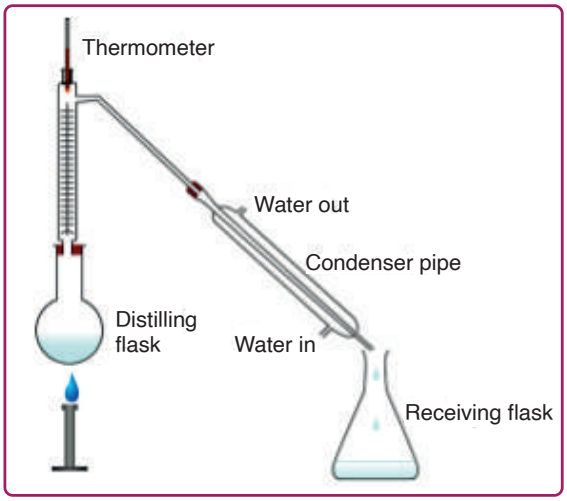


Fig. 1.6, Fractional distillation apparatus; Image by William Crochot via Wikimedia Commons

a. Water circulated around the condenser pipe should be made cooler
b. Receiving flask should be replaced
c. Nothing
d. Distilling flask should be replaced

Answer

i. Justify your answer in part (i).

Answer

V. Solubility and Filtration

In a simple experiment, small quantities of different samples from daily life were mixed with 100 ml of water, one at a time. The mixture was stirred and observations taken on whether the solute was visible after stirring or not. Note that the dissolved substance is called the solute and that in which it is dissolved is called the solvent.

Later, this mixture was made to pass through a filter paper. Observations were taken on whether the solute was visible in the filtrate after filtration or not. Note that the part of the mixture which passes through the filter is called the filtrate and that which is left over on the filter paper is called the residue. The solubility of the solute in water can be inferred based on these observations. The observations of the experiment have been recorded in Table 1.2.

Solute	Visible after stirring	Visible after filtration in the filtrate
Salt	No	No
Cumin (jeera)	Yes	No
Milk	Yes	Yes
Dettol (Antiseptic)	Yes	Yes
Cooking oil	Yes	Yes
Lemon juice	No	No
Mustard seeds	Yes	No

Table 1.2, Observations showing solubility of different substances in water

Question 6

Draw inferences from observation results tabulated in Table 1.2 and answer the following questions.

i. Name two solutes from Table 1.2, which can be inferred to be soluble in water.

Answer

ii. Name two solutes, which can be inferred to be not soluble in water.

Answer

iii. Name one solute that is not soluble in water and can be separated using filtration.

Answer

iv. Name one solute that is not soluble in water but cannot be separated using filtration.

Answer

Case Study B - Homogeneous and Heterogeneous Mixtures

There are two types of mixtures: Homogeneous mixtures and Heterogeneous mixtures. The composition of a homogeneous mixture is the same throughout the mixture whereas it varies in a heterogeneous mixture. When one substance gets dissolved in another, we get a homogeneous mixture. If the solute of a mixture can be separated through filtration we can conclude it is a heterogeneous mixture.

The observations of the experiment conducted in the previous section - mix with 100 ml water and filter - for two solutes named X and Y is shown in Table 1.3.

Solute	Visible after stirring	Visible after filtration in the filtrate
X	Yes	No
Y	No	No

Table 1.3, Observations showing solubility of two unknown solutes, in water

Question 7

Two samples were collected from each of these two mixtures: (X + water) and (Y + water). One was collected from top of the container and one from the bottom. Using the results of the experiment with solubility and filtration shown in Table 1.3, answer the following questions.

i. Will the concentration of the two samples from Mixture X be the same or different? Support your answer with an appropriate justification.

Answer

ii. Will the concentration of the two samples from Mixture Y be the same or different? Support your answer with an appropriate justification.

Answer

Case Study C - Colloids

The main reason we cannot separate the solute and solvent of a homogeneous mixture using filtration, is that the particles of the solute here are very small. They pass through the holes of a filter. On the other hand, the particles of a heterogeneous mixture are bigger and, depending on the size, may be separated by filtering or even by leaving undisturbed to allow the particles to settle (sediment) at the bottom. However, there are some heterogeneous mixtures, like milk, blood, smoke, etc., where the size of the particles is neither too big to filter/sediment nor too small to dissolve fully. These are called colloids.

Centrifuge

One of the ways to separate the ingredients of a colloid is to place the mixture in a container and rotate it at a very high speed. When milk goes through this process, the fat gets separated. This process is called centrifugation and the instrument used is called a centrifuge. A centrifuge throws denser particles of the mixture further away (more than the lighter particles) from the centre of the circle around which it rotates. This leads to the separation.

Inspired by the design of Prof Manu Prakash (Stanford University), here is a simple way to make your own centrifuge using cardboard, a shirt button, cotton thread and small vials to hold the colloid.

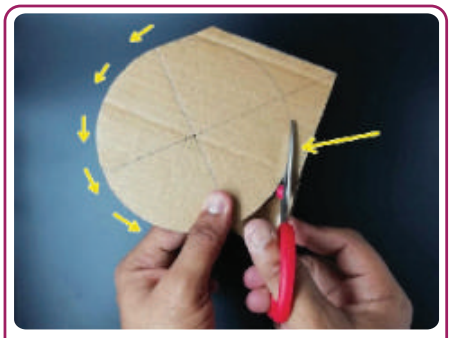


Fig. 1.7, Cut out a circle from cardboard

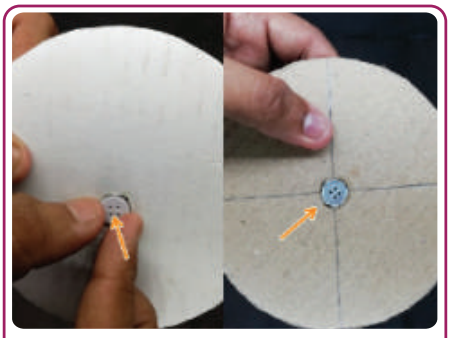


Fig. 1.8, Make a hole at the centre of the circle and glue a shirt button in this hole.

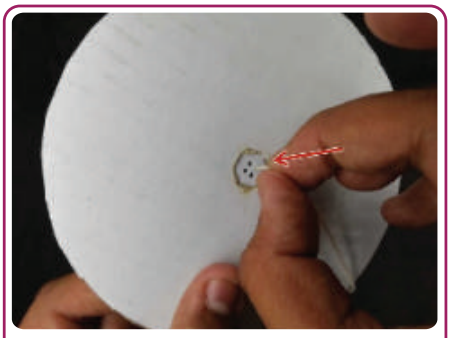


Fig. 1.9, Insert one end of a thread through one of the button holes

Fig. 1.10, Take the thread out on the other side and insert it into the opposite hole

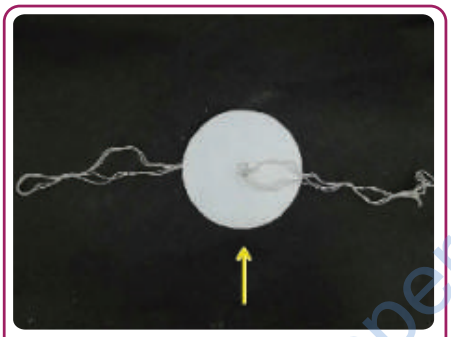


Fig. 1.11, Tie the two ends of the thread and the paper centrifuge is ready.

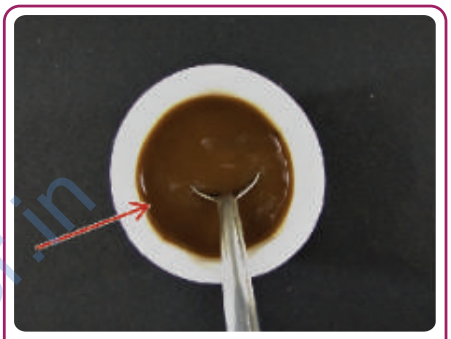


Fig. 1.12, Add fine soil into a small cup of water and stir it well

Fig. 1.13, Add the soil mixture in a small vial

Fig. 1.14, Make sure to fill the vial fully before closing it

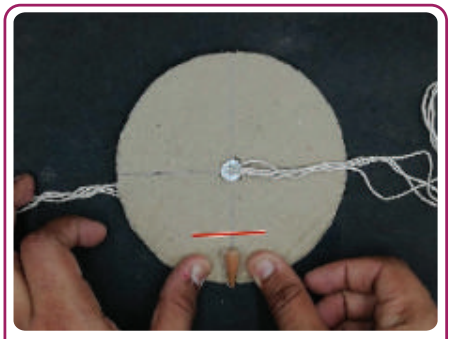


Fig. 1.15, Tape the vial with the sample on one end of the cardboard cutout

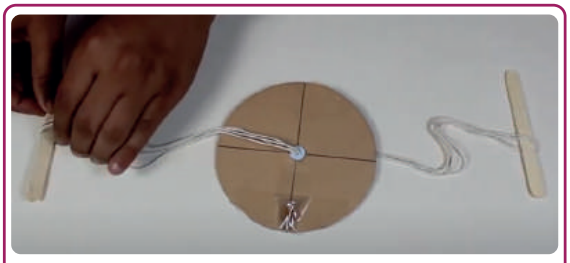


Fig. 1.16, Use two ice cream sticks or your fingers to hold the thread loops at either end.

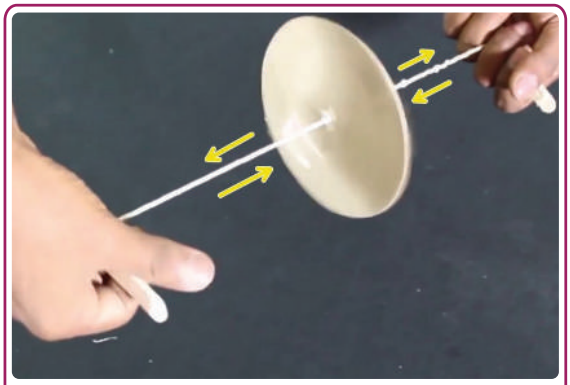


Fig. 1.17, Wind the threads, rewind back by pulling them from the twosides and rotate the centrifuge at high speed

Question 8

You may have noticed that the water in a pond/lake is sometimes brown in colour, especially after rain. This is because of the fine mud particles, which are denser than water but small enough to not sediment easily. A sample of such water was collected in the vials shown in Fig 1.13 and 1.14. These vials have a conical shape with one end wider than the other. If it is fixed on the centrifuge with the wider end pointing towards the centre of the centrifuge, which of the following pictures represents the state of the vial after the mixture gets separated?

A.

Vial with solid at the tip

B.

No solid formation observed

C.

Picture of vial with solid at the wider end (the lid)

a. Option A	b. Option B	Answer
c. Option C	d. This type of mixture can't be separated	

Case Study D - Oil Spills

Humans have been extracting crude oil from offshore oil rigs for decades. These are highly profitable for companies, but can have catastrophic environmental impacts; oil spills being one of the major threats. While stringent prevention methods are employed to minimise their occurrence, rigging companies have to also ensure that there are adequate clean-up methods in place in case there is a spill. One of the simplest methods is called *In Situ Burning*, where the spilled oil is ignited. Note that there are different types of oils which pollute the environment of the ocean. The ease with which the oil can be burnt would depend on the type of oil.

Question 9

If the oil spilled in a certain part of the ocean is burnt successfully, what does it tell you about the solubility and density of that oil?

a. Soluble in water; less dense than water
b. Soluble in water; more dense than water
c. Insoluble in water; less dense than water
d. Insoluble in water; more dense than water

Answer

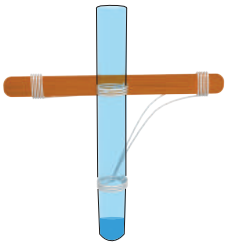
Question 10

Which of the following parameters should be observed to study the side effects of in situ burning on the environment? Tick all which you think are relevant.

a. Time required to burn the oil
b. Residue in water after burning
c. Chemical composition of marine organisms before and after burning
d. Thickness of layer of oil before burning

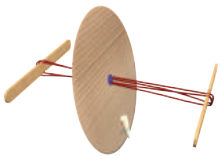
Answer

Exploration Pathway



Explore
Physical Change

Physical change relates to change in the shape, size, appearance or state, of a substance with its chemical composition remaining the same. Physical changes are used to separate mixtures into their component compounds, but cannot usually be used to separate compounds into chemical elements or simpler compounds. In this TACtivity, we explore reversible physical changes in Copper Sulphate and other chemicals.



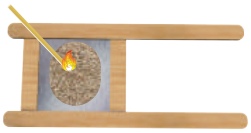
DIY Centrifuge

A centrifuge is a device that uses rapidly spinning containers to separate substances based on their density. The apparent centrifugal force pushes the denser materials to the extreme ends of the container while the less dense materials remain nearer the centre.

In this remarkable creation of Prof. Manu Prakash from Stanford University, we make a "centrifuge", using just cardboard, cotton thread, vials and a button. With one's own hands, one can wind the thread and spin the cardboard at about 3000-4000 rpm, and easily separate certain colloidal mixtures, such as muddy water and even blood!

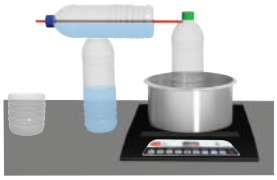
Matter - Solubility

Different solvents have varying solubilities for different solutes. Here, we test the solubility of common salt in water at varying temperatures and the impact of stirring.



Sublimation, Filtration and Evaporation

There are various methods to separate a mixture of solids. This TACtivity explores the common methods of separation - sublimation, sedimentation, decantation, filtration and evaporation.



DIY Distillation

Distillation is the process of separating the components or substances from a liquid mixture by using selective boiling and condensation. In this TACtivity, we create our own distillation setup with plastic bottles and a straw to extract propanol mixed with water.

Mixture - Types

There are two main categories of mixtures: homogeneous mixtures and heterogeneous mixtures. In a homogeneous mixture, all the substances are evenly distributed throughout the mixture (saltwater, air, blood). In a heterogeneous mixture, the substances are not evenly distributed (chocolate chip cookies, pizza, rocks). We explore a few interesting properties of these two types of mixtures in this TACtivity.