LU 8.10. Shades from shapes

Overview

In this unit, we will study the movement of particles occurring across the surfaces of differently shaped objects. We will make different shapes using coloured wheat flour and immerse them into water. We will then see how the colour of the water changes. This shows diffusion of particles from solid surface into water. Also, we will see the opposite case where – it is an acid diffusing into a block of solid gelatin with phenolphthalein indicator and decolourising it.

Minimum time required: Two hours or three sessions of 40 mins each.

Type of Learning Unit: Laboratory and classroom

Unit-specific objectives

- To understand the concept of diffusion
- To understand the influence of surface area on the rate of diffusion across surfaces
- To relate the importance of surface area in various biological structures in the context of diffusion

Links to curriculum

NCERT Class 7 Science Textbook: Chapter 2, Nutrition in Animals
NCERT Class 7 Science Textbook: Chapter 11, Transportation in Animal and Plants

Introduction

Diffusion is a process of movement of particles from regions of higher concentration to regions of lower concentration. When an air freshener is sprayed in one part of the room, the fragrance spreads to other parts of the room. This is diffusion of fragrant particles in the air in the room. Similarly, when we put a drop of coloured ink into a beaker of water, we see the ink diffusing into the water in the beaker. Diffusion is a physical process. It is a passive movement of particles across a medium such as water, air, and so on. In task 1, students start with a generic example of diffusion in a liquid.

Several factors such as temperature or viscosity (in case of fluids) of the medium, affect the rate of diffusion. Whenever diffusion occurs across a membrane, as it happens in biological processes at the cellular level, surface area plays a very important role in the process.

In tasks 2 and 3, students will see how surface area affects the rate of diffusion. Then in task 4, teachers can discuss the importance of surface areas with examples that students may list down in the student sheets, or various other examples such as gills of fish, and villi in intestines.

Materials

Task 1: Beaker, water, ink, dropper.

Task 2: Wheat flour, tap water, food colour powder (green or red) – available with grocer, a bowl (for making the dough), 10 glass beakers (about 250 mL capacity- one for each shape, to submerge shapes in water and for collecting the coloured water for comparison), 5 tea cups.

Task 3: Gelatin powder without any added colour (any branded gelatin powder available with grocer), tap water or any potable water, phenolphthalein solution (1%), plastic cups (as moulds of

CC-BY-SA 4.0 license, HBCSE. May, 2022.

different shapes—chocolate or cookie moulds can be used), glass beaker 100 mL capacity, a shallow wide container or bowl, measuring cylinder (100 mL capacity), heater or stove, dilute base: NaOH 0.1 N or soap solution (10 drops of any liquid soap in 100 mL of water), dilute acid: HCl solution (0.1 N) or bathroom cleaner acid (diluted 10 times with water) or lemon juice (juice from two medium sized lemons in a glass of water), butter paper/transparent plastic sheet.

Task 1: Movements of particles in liquids

Take a beaker filled with water. Add a few drops of ink to it.

Q1. What happens to the ink drop?

____

____

Q2. What colour change do you see?

____

____

Q3. Why doesn’t the drop of ink stay as a drop?

____

____

Q4. Can you think of at least three similar examples from your daily life, where you see such phenomenon? Try to think of such phenomena in air or gases as well.

> 1. Perfume spray in air.
> 2. Spreading of flower fragrance.
> 3. Smell of insect repellent spreading in the room.

Q5. Imagine what will happen to a drop of thick sugar syrup in water?

____

____

When you add a drop of ink to a beaker full of water, the ink diffuses in the water, eventually spreading evenly in the beaker. This phenomenon of mixing of fluids (liquids/gases, as in examples above) happens on its own, even without anyone stirring or mixing the fluids. This phenomena, though widely observed, was very difficult for scientists to explain. A clear explanation could only come after it was recognised that matter must be consisting of very small particles (later called atoms and molecules) and these particles must be in constant motion.

The small particles in fluids cannot be seen by our eyes. These particles can move in any direction. When there is a movement of large number of particles, from one region where they are more to another region where they are less, it is known as diffusion.

Q6. Based on above discussion, tick the appropriate option:

Diffusion of a substance happens from a region of

a) low concentration to a region of high concentration
b) high concentration to a region of low concentration

CC-BY-SA 4.0 license, HBCSE. May, 2022.

Task 2: Effect of surface area on diffusion

Procedure

> This task can be done in groups of 3-4 students. For about 4-5 groups, the teacher can arrange for 0.5 kg flour. To this, 10-15 g of dark food colour must be added. Otherwise, the colour of the resultant solution remains faint and students may not be able to differentiate between the shades of different solutions. Also dark colours, such as red and green food colours available in the market, will work better than lighter colours.

i. In a bowl, add a tea-cup full of wheat flour.
ii. Add food colour (use adequate to get very dark colour) to the bowl and mix it well with the dry flour. Keep some coloured flour aside.
iii. Add water to the remaining flour in small quantities. Mix the flour and water well after each addition of water.
iv. Continue kneading the wheat flour till it becomes a nice smooth dough with uniform colour. The dough should be slightly soft, not hard.
v. In case you add extra water and the dough gets sticky, add more remaining coloured flour till it gets the firm and smooth consistency.
vi. Divide the dough into four equal parts, making small balls (spheres) of approximately 4 g each. The exact mass of the balls is not important but all the balls should be same in size and mass. You may use a rough balance or a small bowl/cup/medicine bottle cap to compare size/mass of the balls (for more accuracy).
vii. Using different moulds or by hands, mould each ball of dough into different shapes: a cylinder, a flat round disc, a sphere, a cone and a brick or a cube.

> Alternatives that can be suggested by the teacher:
>
> An additional way to help students compare the variation in surface area is to let one group choose one shape such as cone. Then using the same amount of dough let them make cones of different dimensions, for example, by simultaneously increasing the height and decreasing the base diameter. Similarly, another group can make cylinders of different dimensions. The data of different groups should be compared together in the end. It may not work so well with spherical shape as calculating surface area of its variants, i.e., ellipsoids, would be difficult for the students.

viii. Measure the dimensions for each shape, such as the diameter and height of the cylinder; diameter for the sphere; slant height and diameter for the cone; height, length, and breadth for the brick etc., and record in your worksheet in table 1.
ix. For each shape, take separate containers and add 150 mL of water to each. Label the beakers with names of the respective shapes.
x. Gently place the shape in the respective container without spilling any water.

> For some shapes, contact of dough surface with base of the beaker prevents diffusion from that surface, thereby reducing the effective surface area contributing to diffusion. This problem can be dealt with in two ways: i) by keeping shapes in such orientation that that their flat surfaces do not lie on the beaker bottom, or ii) by putting a thin wire loop or some grains at the bottom below the flat surface so that there is gap between the bottom surface of dough shape and the base of the beaker.

CC-BY-SA 4.0 license, HBCSE. May, 2022.

xi. The shape should be completely immersed in water. Add more water to each beaker if any of the shapes is not submerged. All the containers should have equal quantity of water.

xii. Keep the containers undisturbed for about 30 minutes. Use this time to calculate the approximate surface area of each shape. You may use the expression for surface area given at the end of this unit.

Table 1

Sr. No.	Dough shape	Dimensions of the shape (diameter, height, length, breadth etc.)	Surface area
1.			
2.			
3.			
4.			

NOTE: One way to obtain the radius of a sphere is by wrapping a thread around it to find the circumference and use the circumference to calculate the radius.

> If the different shapes of dough are kept in solutions for a long time, with the systems attaining equilibrium, all solutions may acquire the same colour shade. Therefore, the shapes should not be kept in the water for longer than 30 minutes.

- After 30 minutes, gently decant the water into a separate glass beaker or carefully remove the dough from the beaker.
- Arrange all the beakers side-by-side, starting with the darkest colour to the lightest.
- Place next to these another beaker with plain water, and record this as zero ('0').
- Record your observations in table 2. Indicate the intensity of colour of the solution in each beaker as "very light, light, dark, or very dark".

Table 2

Sr. No.	Dough shape	Colour score of the solution (very light, light, dark, very dark)
1.		
2.		
3.		
4.		

Observations of the activity performed

- The shape that gave maximum colour to the solution is: ______________________________
- The shape that gave minimum colour to the solution is: ______________________________

Q1. Arrange the dough shapes on the basis of the colour score:

_______________ < _______________ < _______________ < _______________.

Q2. Arrange the dough shapes on the basis of their surface areas:

_______________ < _______________ < _______________ < _______________.

Q3. Is there any relation between the surface area and the rate of diffusion? Explain.

Q4. Why did we initially make balls of approximately equal weight?

Q5. Why should all containers have equal amount of water? What will happen if the volume of water across the beakers is unequal?

Q6. Why should the shapes be completely submerged in water?

Q7. Why does the colour intensity of water change with different shapes?

> After the students have finished writing their answers, the teacher may conduct a whole class discussion. For this, she may have to draw a table of groups and trends (see Q1) and note results of different groups. It is important to note the differences, if any, among the students' results and discuss what may have happened. If a group has not added enough colour, the difference in the colour of the water might not be perceptible. All the groups are working with their own sense of approximation while making shapes. However, make sure that each of the shapes made within a group are of the same mass.

Task 3: Observing the diffusion in gelatin box

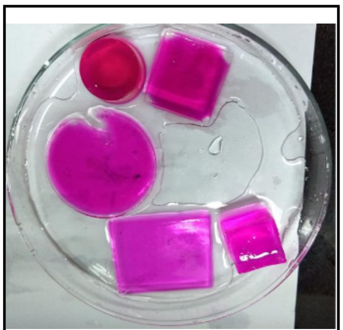


Figure 1

Figure 2

i. Take 100 mL water in a beaker, and heat till it boils.
ii. Add 5-6 g of gelatin powder. Stir to mix well.
iii. Continue heating the solution till the gelatin is completely dissolved.
iv. Stop the heating and let the solution cool down for 5-6-minutes.
v. Add 3-4 drops of phenolphthalein.
vi. Add 1 mL of NaOH or soap solution.
vii. Mix well to get a dark pink colour.
viii. Use a measuring cylinder to pour 10 mL of this coloured gelatin solution in each mould.
ix. One can also make one's own moulds by using household items, such as an empty match box for getting a cuboidal-shaped gel.
x. The amount of gelatin solution poured can be more or less,

CC-BY-SA 4.0 license, HBCSE. May, 2022.

depending on the size of the moulds available. But pour same quantity of solution across all the moulds, i.e., one can put 15 mL of liquid gelatin in each mould instead of 10 mL.

xi. Allow the gelatin to set for 30 min. You may keep it in the refrigerator to speed up the setting (see figure 2).

xii. Carefully take out the shapes from moulds, and put them on a butter paper/ a clean plastic sheet (see figure 3).

xiii. Measure the dimensions of the shapes prepared, and record them in table 3.

xiv. Take a shallow but wide container or a glass bowl. Pour sufficient quantity of a dilute acid solution so that the hardened gelatin shapes can completely submerge.

xv. Gently place all the gelatin shapes into the dilute acid solution. Try to put all shapes in the solution at the same time instead of putting them one-by-one.

xvi. Note the time when the shapes were placed in the acid solution.

xvii. Observe the coloured gelatin shapes and the time taken for every shape to become colourless. Record your observations in table 4 (see figure 4)

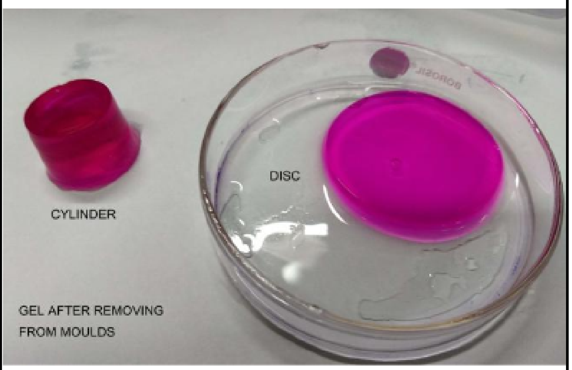


Figure 3

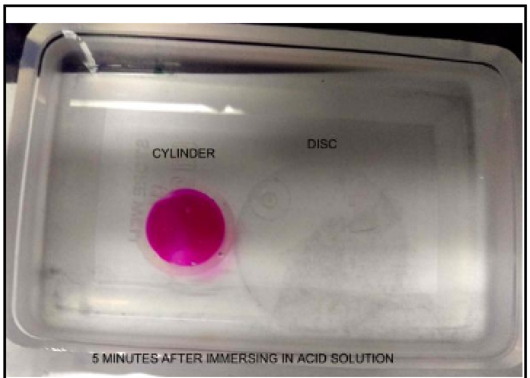


Figure 4

Table 1.3

Sr. No.	Gelatin shape	Dimensions of shapes (diameter, height, length, breadth etc.)	Surface area
1.			
2.			
3.			
4.			

Table 1.4

Sr. No.	Gelatin shape	Time when the shape was placed in acid solution (min: sec)	Time when the shape became colourless (min: sec)	Time taken to become colourless (sec)
1.				
2.				
3.				
4.				

CC-BY-SA 4.0 license, HBCSE. May, 2022.

Observations of activity performed

- The shape that took the maximum time to become colourless is: ________________________
- The shape that took the minimum time to become colourless is: _________________________

Q1. Why was NaOH added to the gelatin solution along with phenolphthalein?

____

____

Q2. Why did all the shapes turn colourless after immersing them in the acid solution?

____

____

Q3. Why did the different shapes take different time to become colourless?

____

____

Q4. What is the role of gelatin in this experiment?

____

____

Q5. What would happen if phenolphthalein was added to the solution in the bowl and not to the gelatin?

____

____

Q6. What will happen if we put these discoloured shapes in a strong basic solution?

____

____

Q7. Can you suggest other easily available dyes/pH indicators instead of the one used in this activity? What changes do you expect when you use those indicators?

____

____

> As after previous task, the teacher may conduct a whole class discussion.
> In comparison with previous case, following questions may come up:

> (i) Why is there a sharp boundary between coloured and discoloured gelatin, whereas in case of dough in water such boundary was not observed between coloured and colourless water regions?
> This can be attributed to slower rate of diffusion within solid and across solid-liquid interface as compared to diffusion in liquid. Thus, in case of coloured doughs, as colour slowly diffuses out of solid, it spreads faster within the liquid. Hence such (faint) boundary zones can be observed in liquid during the initial phase (few minutes) only. With slower diffusion in case of gelatin blocks, the sharp boundary between coloured and colourless zones is visible for longer time.

(ii) As in previous case, does phenolphthalein not diffuse out in the solution?
We cannot negate the possibility. Most likely, phenolphthalein may also be coming out in the solution, but due to acidic nature of the solution it is not showing up any colour. One can check presence of phenolpthalein in solution by taking out the solution and adding base to it till it become alkaline and check if pink colouration develops.
(iii) It might be worth pointing that discolouration of gelatin block is due to diffusion of acid and its simultaneous reactions with base (neutralizing it) and with phenolphthalein (making it colourless). Thus, in comparison to task 2, the phenomena observed in task 3 also involves chemical reactions in addition to diffusion.

Task 4: Diffusion in living beings

Have you ever wondered how nutrients from our food enter the bloodstream? The process is similar to what you observed in the above activities. However, in humans and other living beings, diffusion occurs across membranes. A membrane is a material that acts as a barrier or divider between two regions. A permeable membrane allows most substances to pass across it. On the other hand, a semi-permeable membrane allows only certain substances to cross the membrane, but not others. Most biological membranes such as cell membranes are selectively permeable.

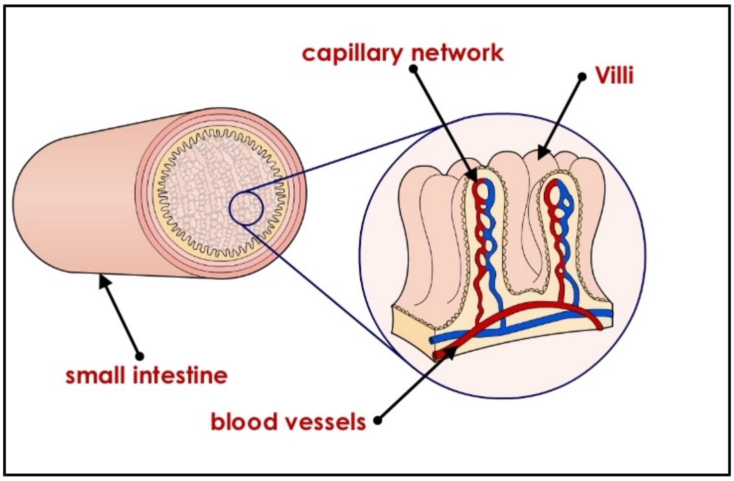


Figure 5: *Small intestine showing villi with capillary networks*

Q.8. Can you think of more examples, of organs in the body, or in nature, where larger surface area affects diffusion? Here is one example:

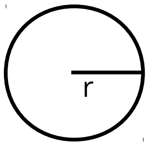
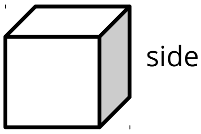
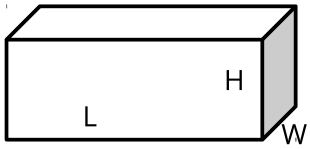
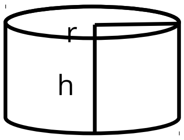
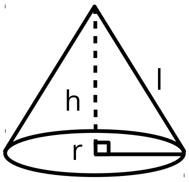
a) Diffusion of oxygen from lungs into red blood cells.

Other examples:
b) Transport of water from soil to plants through root hairs.
c) Flat and thin leaves of plants: Greater area available for CO_2 diffusion.

Expressions for surface area

Sr. No.	Shape	Shape diagram	Expression for surface area

CC-BY-SA 4.0 license, HBCSE. May, 2022.

1	Sphere		$4\pi r^2$
2	Cube		$6 \times side^2$
3	Brick (Cuboid)		2LW + 2HW + 2LH
4	Cylinder and flat disc		$2\pi r(r + h)$
5	Cone		$\pi r(r + \sqrt{h^2 + r^2})$ (students can use the Pythagoras theorem to calculate the height of the cone)

Extended activities

When a biological cell such as an amoeba or a paramecium swims in water, the contents of the cell do not diffuse in the water. Why is this? This is because of the presence of the cell membrane. The following activity can be performed to visualise how cell membrane forms a barrier to prevent diffusion of cytoplasmic contents.

Prepare two identical coloured shapes from the wheat flour. Coat one of the shapes with Vaseline.

Place both the shapes in beakers with water as before. Note the colour of water for each shape as before. Is any difference observed in the two beakers? If yes, how can one explain it?

References and suggested readings

- Diffusion https://www.biology-online.org/dictionary/Diffusion
- Diffusion BBC GCSE Bitesize http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/cells/cells3.shtml
- Marek, E. A., Cowan, C. C.; and Cavallo, Ann M. L. (1994). Students' misconceptions about diffusion: How can they be eliminated? *The American Biology Teacher, Volume 56,* No. 2 , pp. 74-77.

Figure/Image Source: Figure 5 - meyersnet.info/wp-content/uploads/villi-in-small-intestine-biological-examples-of-diffusion.jpg

Credits

Main Authors: Rekha Vartak, Anupama Ronad, Vikrant Ghanekar, Sasikumar Menon, Adarsh Shetty

Contributing Author: Rohini Karandikar

Reviewers: Gouri Krishna Rajesh, Maithreyi Narsimha

Editors: Beena Choksi, Geetanjali Date, Ankush Gupta, Reema Mani, K. Subramaniam

Creative Commons Licence: CC BY-SA 4.0 International, HBCSE