Shades from Shapes

Overview

In this unit, we will study the movement of particles occurring across the surfaces of objects made up of different shapes. Here, we will make different shapes using coloured wheat flour and immerse it into water. We will then see how the shape changes colour of the water. This shows diffusion of particles from solid surface into water. Also for opposite where a solution diffuses inside a solid block, you will see how an acid diffuses inside a solid block of gelatin which has phenolphthalein indicator and decolourises it.

Minimum Time Required: 2 hours or 4 sessions of 40 mins

Type of Learning Unit: Science laboratory and classroom.

Learning Objectives

Students will learn -

1. The concept of diffusion.
2. The influence of surface area on the rate of diffusion.
3. Relating 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 species in the air in the room. Similarly, as we put a drop of coloured ink into a beaker of water, we see the ink diffusing to the entire water in the beaker. Diffusion is a physical process. It is a passive movement of particles across a medium such as water, air etc.

Several factors such as temperature, viscosity of the medium affect the rate of diffusion. Whenever diffusion is occurring across any membrane as it happens in biological processes at cellular level, surface area plays a very important role in the process.

Since diffusion occurs through surfaces in several situations in biological processes, greater the surface area of membranes faster is the rate of exchange. Teachers can discuss importance of surface areas with examples that students may list down in the student sheets or various other examples such as gills of fish, villi in intestines, etc. We will see how surface area affects the rate of diffusion in the following activities.

Materials Required

Task 1: Beaker, water, ink, etc.

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 etc.

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 different shapes- chocolate or cookie moulds can be used), glass beaker 100

mL capacity, 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) etc.

Task 1: Movement of particles

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

Q 1. What happens to the ink drop?

_____

_____

Q 2. What colour change do you see?

_____

_____

Q 3. Why doesn't the drop of ink stay as a drop?

_____

_____

Can you think of at least 3 more such examples from your daily life, where this phenomenon is seen? Try to think of gaseous medium as well ?

1. Teabag in hot water 2. Perfume smell diffuses in air. 3. Sugar crystals in tea

Q 5. Imagine, what will happen with a drop of thick sugar syrup in water?

_____

_____

This phenomenon is known as Diffusion. When you add a drop of ink in a beaker full of water, the particles of ink diffuse into the water eventually spreading evenly in the beaker.

Q 6. So, diffusion happens from a region of (tick the appropriate)

a) low amount to high amount

b) high amount to low amount

Task 2

Procedure

i. Take one tea cup full of wheat flour in a bowl.
ii. Add the 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 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 and not hard.
v. In case you add extra water and the dough gets sticky, add more remaining coloured flour to it till it gets the correct consistency.
vi. Divide the dough into 4 equal parts of small balls (spheres of about approximately 4 grams each). The exact weight of the ball is not important but all the balls should be of same mass. You may use a rough balance or a small bowl/cup/medicine bottle cap 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.
viii. Measure the dimensions for each shape like diameter and height of the cylinder; diameter for the sphere; slant height, diameter for cone; height, length, breadth for the brick etc. of shapes prepared and record in your worksheet in Table 1.1.

ix. For each shape take separate containers and add 150 mL of water to each. Label the beakers with the respective shapes.
x. Gently place the shape in the respective container without spilling any water.
xi. The shape should be completely immersed in water. Add more water to each beaker if any of the shape 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 1.1

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

(NOTE: To calculate the diameter of sphere, insert a broom stick through the diameter of a sphere- mark the ends and calculate the length. Do all measurements before putting these shapes in water)

- After 30 minutes, gently decant the water into a separate glass beaker or remove the dough carefully from the beaker.
- Arrange all beakers side by side starting with the darkest colour to the lightest.
- Place a beaker with plain water and record this as zero ’0’.
- Record your observations in table 1.2. Indicate the intensity of colour of the solution in each beaker with the words “very light, light, dark or very dark”.

Table 1.2

Sr. No.	Dough shape used	Colour score of solution
1.		
2.		
3.		
4.		

Observations of activity performed

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

Q 1.Arrange the various dough shapes on the basis of colour score:

_____ < _____ < _____ < _____.

Q 2. Is there any relation between surface area and rate of diffusion? Explain.

_____

_____

Q 3. Why did we initially make balls of equal weight?

_____

Q 4. Why should all containers have equal amount of water? What will happen if the volumes of water are unequal?

_____

_____

Q.5. Why should the shapes be completely submerged in water?

_____

_____

Q.6. Why does the colour intensity of water change with different shapes?

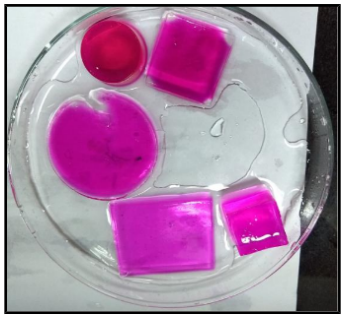
_____

_____

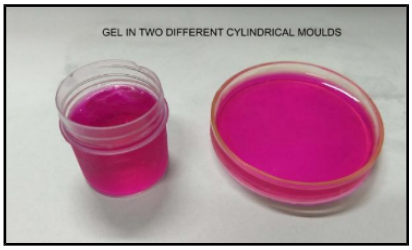
Task 3

Procedure

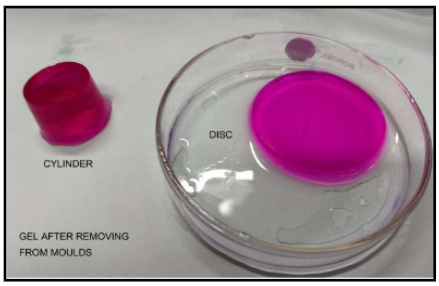
1. Take 100 mL of water in a beaker and heat till it boils.
2. Add 5 - 6 grams of gelatin powder. Stir to mix well.
3. Continue heating the solution till the gelatin is completely dissolved.
4. Stop the heating and let the solution cool down for 2 - 3 minutes.
5. Add 3 - 4 drops of phenolphthalein.
6. Add 1 mL of NaOH or Soap solution.
7. Mix well to get dark pink colour.
8. Use measuring cylinder to pour 10 mL of this coloured gelatin solution in each mould.
9. One can also make one's own moulds by using household items. E.g. empty match box for getting rectangular shaped gel.



10. The amount of gelatin poured can be increased or decreased as per sizes of moulds available but in every mould pour same quantity of solution. i.e. one can put 15 mL of liquid gelatin in each mould instead of 10 mL.
11. Allow the gelatin to set for 30 min. (you may keep it in a refrigerator to speed up the setting).



12. Take out the shapes carefully from moulds and put them on butter paper / clean plastic sheet.



13. Measure and record the dimensions of shapes prepared, in Table 1.3.
14. Take a shallow but wide container or a glass bowl. Pour sufficient quantity of dilute acid solution so that the hardened gelatin shapes can completely submerge.
15. Gently place all gelatin shapes into the dilute acid solution. Try to put all shapes at same time in solution instead of putting one by one.
16. Note the time when the shapes were placed in the acid solution.
17. Observe the coloured gelatin shapes and record the time taken for every shape to become colourless in given table. Record your observations in Table 1.4.

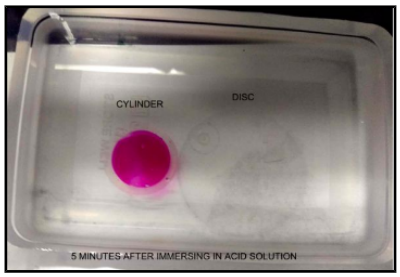


Table 1.3

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 for becoming colourless (sec)
1.				
2.				
3.				
4.				

Observations of activity performed

- The shape that took maximum time for becoming colourless is: _____
- The shape that took minimum time for becoming colourless is: _____

Q 1. Why was NaOH added to the gelatin solution along with phenolphthalein?

_____

_____

Q 2. Why did all shapes turn colourless after immersing in acid solution?

_____

_____

Q 3. Why did the different shapes take different time to become colourless?

_____

_____

Q 4. What is the role of gelatin in this experiment?

_____

_____

Q 5. What would happen if phenolphthalein was added to the solution in the bowl and not in the Gelatin?

_____

_____

Q 6. What will happen if we put these colourless shapes in strong basic solution?

_____

_____

_____

Q 7. Can you suggest different easily available dyes/ pH indicators instead of the ones used in this activity?

_____

_____

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 membrane are selectively permeable.

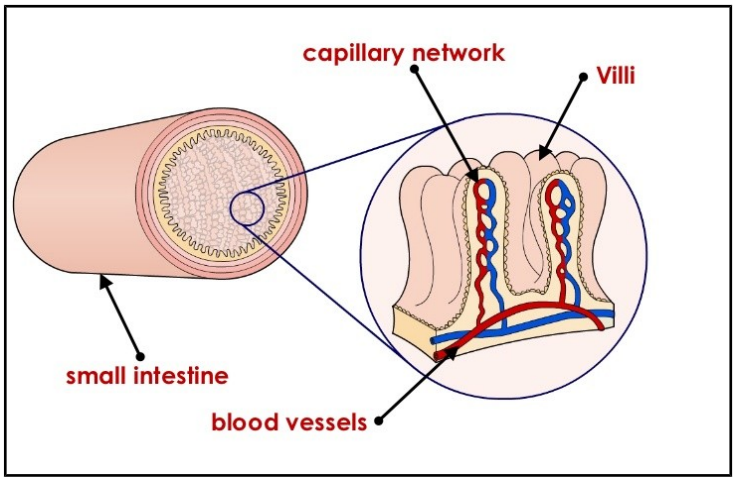
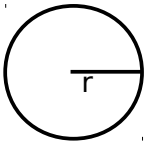
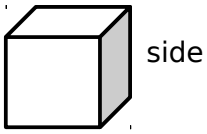
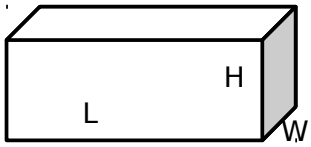
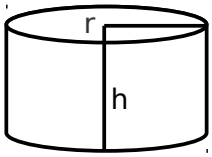
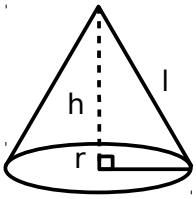


Figure 1: Small intestine showing villi with capillary networks
Source: http://meyersnet.info/wp-content/uploads/villi-in-small-intestine-biological-examples-of-diffusion.jpg

Q.8. Where else, in the body, or even in nature, does maximizing surface area affect diffusion? One example is given:

1. Diffusion of oxygen from lungs into red blood cells.
2. Transport of water from soil to plants through root hairs.
3. Photosynthesis in plants – CO_2 diffuses in through the stomata of leaves.

Expression for Surface Area

Sr. No.	Shape		Expression for surface area
1	Sphere		$4\pi r^2$
2	Cube		6 x $side^2$
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 amoeba, paramecium swims in water, the contents of the cell do not diffuse in the water. Why does this happen? This is because of the presence of cell membrane. The following activity can be performed to visualize how cell membrane forms a barrier to prevent diffusion of cytoplasmic contents.

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

Place both in troughs with water as before. Note the colour of water for each shape as before. Compare. If you noticed a difference, can it be explained?

References and Suggested Readings

1. Diffusion https://www.biology-online.org/dictionary/Diffusion
2. Diffusion BBC GCSE Bitesize http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/cells/cells3.shtml
3. Edmund A. Marek, Connie Cruse Cowan and Ann M. L. Cavallo (1994) **Students' Misconceptions about Diffusion: How Can They Be Eliminated?** The American Biology Teacher, Vol. 56, No. 2 (Feb., 1994), pp. 74-77