Work Package 3
UNIT EXPLORING HOLES
Teacher Information

Lead partner for Unit: Dublin City University (DCU)

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**DISSEMINATION LEVEL**

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**Document History**

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Mareike Wilms, Martin Fach, Jens Friedrich Dr., Marco Oetken Prof. Dr, Molekulares Sieben: Mit Einmachfolie ins Diskontinuum, Chemkon, Volume 11, Issue 3, pages 127-130, July 2004

James Chapman, Laura Barron and Susan Ryan, Dublin City University.


A. Teacher Information

I. Unit description

In this unit, the links between chemical structure, properties and use/application will be made. It can also be used to address the representation of materials at macro, sub-micro and symbolic levels.

The unit is built around the theme of ‘holes’ and that not all holes are visible to the naked eye. Various materials will be tested to determine if they can be effectively used as filters (therefore have holes) and also if different filters have different sized holes. Polymer films are interesting materials here as their structure can be altered by the addition of plastisisers and therefore the size, shape and extent of the holes can be varied. In addition, polymers can be synthesised as required. This can develop for applications such as dialysis, separations, osmosis etc. Also, the use of polymers films with controllable holes in particularly useful applications such as in drug release (as in hydrogels) and in environmental protection (as antimicrobial coatings).

The unit is divided into 3 subunits which can be used independently at different levels. Each subunit can take different directions and emphasis depending on the curriculum and particular learning aims of the teacher. The subunits can also be used in a spiral type curriculum with subunit 1 focussed at an introductory chemistry level, subunit 2 at intermediate level and subunit 3 at the higher stages of second-level school. The activities are designed in such a way that they could be used in different areas of chemistry and biology – e.g. in dialysis or food contamination.

Throughout the unit, the emphasis should be on developing understanding of molecular size and shape and particularly on linking molecular properties to structure to macro properties.

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<td>Upper second level (15-17)</td>
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Involved disciplines:
Chemistry

Estimated duration:
Each subunit is flexible as they are designed to fit into a topic already taught through the curriculum. A time estimate has been given for each of the activities within the subunits.

II. IBSE character
This unit can be used to develop the students’ ability to plan investigations, develop hypothesis, distinguish alternatives, searching for information, constructing models and
debating with peers. As each teacher will implement the unit in different manners, the emphasis can be placed on different sections and hence different elements of inquiry.

Each of the subunits can be used for each aspect of inquiry. In each subunit, the teacher may start with either a series of questions or with an interactive demonstration e.g. in subunit 2, the initial demonstration may be of iodine passing through cling film which then leads to questions for further investigations such as to the reproducibility, does this always happen, does this effect depend on the film used, does this effect depend on the particular molecules used, and determination of the film characteristics. These activities may be guided, bounded or lead into open inquiry activities.

Alternatively, the sub unit could be introduced by discussing examples of polymers we use every day, such as cling film, and addressing common misconceptions about its properties in keeping elements of the environment from spoiling food. Another application is in raincoats where the layer is impervious to water in one direction but permeable to water vapour in the other direction.

The focus of this unit is to provide ideas and activities that can be implemented in an inquiry based series of lessons. The initial activities given in this unit will form the background for further more open inquiry activities by the students.

The activities given are not developed to be performed in a linear order. Particular activities can be selected for use in various types of inquiry. The series of activities should be aligned to students’ ideas and questions so that creativity, imagination and flexibility are always an integral part of the inquiry based teaching and learning.

**III. Science Content Knowledge**

For subunits 1 and 2 the required science knowledge is a basic understanding of the particulate nature of matter and particle movement based on diffusion and osmosis.

Subunit 3 applies more specific knowledge on different polymers such as superabsorbers, cyclodextrines or PVC.

**Polymers belong** to the group of macromolecular substances. They are compounds with the number of atoms bound by covalent bonds in a macromolecule reaching hundreds to millions. Polymers are divided into natural and synthetic. Synthetic polymers can be prepared by a set of chemical reactions of the type of polycondensation, polyaddition or polymerization. Special **superabsorbing polymers (SAP) – so-called superabsorbents** can be included in the group of special polymers.

**What is a superabsorbing polymer**

Polymer that is able under a load to absorb liquid of at least 10 g relating to every 1 g of the dry polymer. It swells in water solutions and gel is produced.

**Superabsorbents** are polymers with a significant ability to absorb liquids which is manifested by increasing their volume, so-called swelling. They absorb aquatic liquid solutions and make granular gels of permanent consistency with them. The amount of absorbed liquid is significantly dependent on the content of ions and pH of the given absorbed solution.
Some superabsorbents are able to absorb as much as 2000 multiple of their weight. When using 0,9 % solution of table salt 50 multiple of its own weight is absorbed by the polymer – it is similar in the absorption of human urine into nappies.

Superabsorbent polymers have become an integral part of hygiene products (for example in nappies, ladies hygiene, hygiene goods for incontinent patients) in the last decade. They are also used as a protection of undersea cables from moisture, textile mats under frozen food, for preserving moisture in the soil, etc.

Using polymers based on SAP, however, brings along certain problems. First of all, they are for single use. Thus they are not environmentally friendly as they are not biogradable and are difficult to recycle. Development of a new generation of superabsorbent is therefore based on renewable material (polysaccharides – pectins, starch, cellulose), which are biogradable.

Scheme of the superabsorbent structure before and after water absorption
Chemical structure of superabsorbent - networked sodium salt of polyacrylic acid before and after water absorption


**Hydrogels** have many important applications. For example in tissue engineering (hydrogels can contain human cells for repairing tissues), in administration of medicines, in biosensors (gels reacting with specific molecules, such as glucose or antigens), contact lenses (silicone hydrogels, poly acrylamides) and healing gels.

**Cyclodextrines are polycarbohydrates**

α-Cyclodextrin (αCyD), which is a cyclic oligosaccharide of six α(1→4) linked α-D-glucopyranoside units, can be topologically represented as toroids (figure below). α-D-glucopyranoside units in αCyD are usually in the most stable chair conformation.

*Image taken from the IChO, Japan 2009*

Membrane films have different polymeric composition – comparison between cellulose, parafilm, Teflon, clingfilm (polyvinylchloride), polypropylene, dialysis membranes. Need to be careful here in translation that particular household films may have local / brand names that may not be recognisable in other countries. Composition of some of the common polymers are given below.
Polyvinyl Chloride (PVC)
PVC is a flexible plastic consisting of long chains. Each chain consists of repeating units where every second carbon atom has a chlorine atom attached.

The polymerisation of vinyl chloride produces mainly atactic polymer molecules. This means that Cl are orientated randomly along the chain.

![Atactic PVC - the Cl atoms have random orientations along the chain.](image)

Because of the way the chlorine atoms stick out from the chain at random, and because of their large size, it is difficult for the chains to lie close together. Therefore, atactic PVC is mainly amorphous with only small areas of crystallinity.

However PVC polymer chains can also be isotactic, with Cl atoms in the same orientation along the chain. (Syndiotactic is where the Cl atoms are in opposite orientation)

![Isotactic, Syndiotactic, Atactic](image)

When PVC plastic is bent it becomes opaque where the bend occurs. This is due to the chlorine groups being forced into the same orientation along the chain (isotactic). The polymer chains can then move closer together and become more crystalline.

Properties and uses
You normally expect amorphous polymers to be more flexible than crystalline ones because the forces of attraction between the chains tend to be weaker. However, pure PVC tends to be rather hard and rigid.

This is because of the presence of additional dipole-dipole interactions due to the polarity of the carbon-chlorine bonds. Chlorine is more electronegative than carbon, and so attracts the electrons in the bond towards itself. That makes the chlorine atoms slightly negative and the carbons slightly positive. These permanent dipoles add to the attractions due to the temporary dipoles and hence hold the chains closer together.

Plasticisers
Plasticisers are added to polymers to make the material softer, flexible and therefore more workable. PVC is the most widely plasticised polymer due to its excellent plasticiser compatibility characteristics. Molecules which contain both polar and non-polar groups act as good plasticizers, as the polar group helps retain the molecule within the polymer chains and the non-polar part separates the chains, hence increasing flexibility.

Dibutyl sebacate is a commonly used plasticiser in polymers used in food packaging and in the pharmaceutical industry in polymer coatings for tablets and granules.
The dibutyl sebacate molecule works by bonding to the polymer chain through the oxygen atom on the plasticiser. The bulky plasticiser wedges itself between the polymer chains and pushes them further apart from each other. This causes the plastic to become more flexible.

![Dibutyl Sebacate](image)

Another compound used as plasticizer is sodium lauryl sulphate.

**Resources:**
- Polymer Website; (Macrogalleria – teaching materials); [http://pslc.ws/mactest/maindir.htm](http://pslc.ws/mactest/maindir.htm) - accessed 17 DEC 2010
- Overview of Silver nanoparticles (project report - N344); Aalborg university, Faculty of Physics and Nanotechnology, [http://repetit.dk/files/projects/p3.pdf](http://repetit.dk/files/projects/p3.pdf) - accessed 17 DEC 2010
IV. Pedagogical Content Knowledge

Students can find the particulate state of matter difficult to conceptualise and model. Later on, they have to draw conclusions from structure-properties to microscopic properties, which they also find difficult.

It is well known from the literature that many students expect air or water to be between particles rather than nothing between particles. So the perspective on holes in this unit particularly highlights the emptiness in between matter and confronts them with the “horror vacui”. It is also well documented that students transfer microscopic properties onto particles. When a coloured solution is seen – what is causing the colour? Linking colour to the molecule can therefore be difficult for students.

Possible arguments to explain observations will be based on ‘colour’, imperfections in the membrane, density, mass of particles. Discussion (and further experiments) will counter these arguments.
Linking molecular structure to macro properties can be difficult for students. Subunit 2 and 3 can therefore be helpful as properties of polymer films are changed, e.g. to be dependent on the amount of plasticizers added or the pH of a solution added to a superabsorber. Hence, the structure of the polymer must be different.

By analyzing structure-property-relations, students also have to combine experimental observations with model-based explanations. The role of models as essential addition to experiments could be highlighted to form a better understanding of the nature of science and inquiry-based approaches.

V. Industrial Content Knowledge

By pointing out the use of the same polymers in completely different contexts, the interaction between research, societal developments and industry becomes more obvious to the students.

The use of polymers in medical applications is extensive. Dialysis machines use a semi-permeable tubing in the treatment of toxic waste material thus alleviating the problems associated with kidney failure. Gas permeable contact lenses allow more oxygen to reach the cornea thus preventing swelling of the eye. Polymeric membranes incorporated with silver nanoparticles can be used in the treatment of wounds and infections. Hydrogels which in the process of swelling in water have the ability to release compounds from their matrix can act as efficient drug delivery systems. Sensor research uses semi-permeable polymer membranes in monitoring air quality and detection of certain gases like carbon monoxide. Both impermeable and semi-permeable polymeric membranes are also used in the food industry e.g. in food packaging, meat packaging (e.g. Western Plastics in Ireland [www.westernplastics.ie]). Many clothes are based on polymers, and those which are most relevant to this unit include waterproof breathable jackets that display resistance to rain passing through the membrane but allow water vapour to be transported outwards using solid state diffusion e.g. Gore-Tex ([http://www.gore-tex.com/remote/Satellite/home](http://www.gore-tex.com/remote/Satellite/home)).

- [www.packagingtoday.com](http://www.packagingtoday.com) (manufacturers)

VI. Learning path

Sub Unit 1: Visible Holes

This subunit introduces the idea of “holes” in materials which we can see and use on a daily basis. These holes are used in sieves, as a means of separation e.g. large stones from sand, coffee filters, muslin in cheese production etc. The idea that there is a lack of holes in some materials should also be discussed as well as their uses.

The learning outcome of this sub unit is that students recognise that holes exist in many materials, and can be used to separate substances. However, the separation depends on both the size of the holes and the sizes of the substances to be separated.

This subunit can also be used to introduce the concept of osmosis and diffusion.
Sub Unit 2: Invisible Holes
This sub unit develops on what the student has learned from Visible Holes and focuses on Invisible Holes. To understand the existence of invisible holes and processes of substances being able to pass these holes, students have to enter the world of particles. To introduce them to this “new world”, surprising and fascinating phenomena are used, such as the “sieving of different dyes”. Following this, the students are invited to develop a series of experiments to investigate properties of sieves, particles and diffusion processes.

This can be followed by questions whether all membranes (plastics) are the same (Activity 2.1). Different polymer films can be investigated and polymer films can be made with different levels of plasticizer and retested (Activity 2.5). Do they all have the same structure? Additionally, different compounds can be used on the same films to determine the pore size (Activity 2.2).

As an application, the leaching of plasticisers from packaging will be explored and can link to food packaging and possible hazards (Activity 2.5). Leading questions throughout the unit allow the students to progress from activity to activity as well as develop activities of their own.

Students can examine the uses of holes in dialysis membranes, in polymers used for absorbance, and in other polymer packaging materials.

Sub Unit 3: Interesting Holes
This unit deals with the idea of Interesting Holes which can be used in many medical and environmental technologies. Students can investigate different functional polymers such as superabsorbers and cyclodextrines to find out and explain why these polymers absorb solutions, such as water, or smells. The properties of hydrogels, as drug delivery systems, are investigated.

Nanotechnology can be applied to both medicine and environmental science using silver nanoparticles as an example. These can be incorporated into polymeric membranes which can then be used to treat wounds, burns and infections as the silver ions migrate from the membrane and attack any bacterial or fungal cells. They can also be used to coat different materials to enhance sterility.
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**VII. Assessment**

Assessment can take several different forms depending on the age level of the students. The focus can be on prediction and associated reasoning e.g. questions predicting properties of ‘fictional’ polymers with various plasticizers. Generation of concept maps to link main ideas may also be useful.

Specific activities have been suggested that can be used for assessment (Activity 1.5 and 2.3)
SUB UNIT 1. VISIBLE HOLES

Activity 1.1 Making sieves

Learning aims:

This sub-unit will illustrate how different materials can be used as sieves. Separation depends on the hole size in the ‘sieve’ as well as the particle size of the compounds/materials to be separated. Hence this subunit focuses on the microscopic properties and structures.

- to recognize the need for holes to separate materials
- to recognize the need for particular size of holes matching the size of the materials to be separated
- to construct a model and debate with peers

Materials:

- Mixture of different sized seeds (or the like), filter paper, scissors, containers, “distractors”, such as magnet, glue...

Suggestions for use:

Present students with the challenge to separate the seeds without touching the seeds using some of the materials provided. We expect at least some students to come up with the idea of sieves. Of course they can also discuss other methods of separation. If the idea of preparing a sieve from the paper does not arise, discussion can be directed towards the use of sieves in everyday applications.

Possible Questions:

- Why did you create your technique as you did?
- What are the advantages and disadvantages of your technique compared to others?
- What do you already know about separation procedures in every-day life?
Activity 1.2 Observation and explanation of filters

Learning aims:

- to observe carefully and describe observations
- to use models
- to distinguish alternative (models)

Materials:

- coffee filter, empty tea bags as filters, different mixture such as tea, coffee, orange juice, mud in water…
- pictures of particle models of different sizes

Suggestions for use:

Start by showing the class the coffee filter paper and asking them what they think it is or what it can do. Ask the students why they think the coffee granules do not pass through the filter paper but the water can? Why has the water in the cup now turned brown? Ask the students to discuss whether the sieve from the previous activity could be used to make coffee.

Students carry out tests on the mixtures provided and work out which can be separated by filtration and which can’t and why.

Possible questions:

Why do mud, coffee granules, … do not pass through the filter paper but the water can? How could you use the models in the picture to explain your observation? What is the difference between tea and mud in water?
Activity 1.3 Use of filters in industry

Learning aims:
- to recognize the importance of filters for industry and society

Materials:
- sour milk, gauze or muslin

Suggestions for use:

Pupils should work out that the mixture that is produced this way can be separated by pouring it through gauze, thus separating curd from whey.

Sieves can have important uses within the food industry. Muslin is used in cheese making to separate the liquid whey from the solid curd. It is also used in wine making to remove sediments.

Possible questions:

Why are sieves used in food industry?
What are important sieves to consider when choosing sieves for the food industry?

Activity 1.4 Separation challenge

Learning aims:
- to differentiate between solutions and mixtures
- to recognize the importance of different solubilities
- to identify possibilities of recovering salts from solutions

Materials:
- salt, water, dirt, beaker

Suggestions for use:

Tell the students that you have spilled your salt on the floor where it has mixed with small dirt particles and other impurities on the floor. Ask the students to come up with an experiment using the idea of sieves to obtain a pure sample of salt from the mixture. Advise students to think about the previous activities when devising their experiment. Students should use the idea from the coffee filter that if the salt is dissolved in the water it can fit through the filter paper and the water can then be evaporated off.

Possible questions:

- Why can you not separate salt from dirt using a sieve (without water)?
- Why can you not separate salt from water using a filter paper?
- What other techniques could you use to regain the salt from the water
Activity 1.5: Assessment: Crime story

Learning aims:
- Students have to use separation techniques they have learned to solve the murder mystery.

Materials:
See Worksheet

Suggestions for use:
See Worksheet

Possible questions:
See Worksheet

Activity 1.6: Transfer: Air filters in car engines

Learning aims:
- to transfer the knowledge developed from solids and liquids to gases

Materials:
- salt, water, dirt, beaker

Suggestions for use:
Students read stimulus material about car engine air filters and answer questions about how it works, what happens if it is not there and why racing cars have only a thin filter.

Possible questions:
See Worksheet
SUB UNIT 2. INVISIBLE HOLES

Overall learning aims: In this subunit the students will transfer their macroscopic knowledge onto the invisible level of atoms and molecules. They will develop a better understanding of the particulate nature of matter. The activities can be used to show the existence of molecules and that they have different sizes. Students can investigate different pore sizes within plastics/polymers.

Underlying experiment: Invisible sieves

The sequence of activities is based on one central experiment which is described in the following paragraphs.

Chemicals:
- Red food dye solution
- Iodine-Starch Solution
- Potassium Permanganate Solution
- Iodine-Dextrin solution
- Iodine Solution (Just for Part 2)

Apparatus:
4 Rubber bands, 5x50ml beakers, 4 lengths of visking tubing, 5 sheets of cling film, 10ml plastic dropper.

Procedure (Part 1):
- Prepare a 1% starch solution with water at 70°C
- Add iodine and leave iodine and starch solution to one side (Turns blue)
- Add 0.5g of dextrin to 100ml of water and then add a few drops of iodine (Turns red)
- Open the visking tubing lengths by holding it under running water for a few minutes. Tie one end with an elastic band tightly. Ensure the elastic band is stretched very tightly so that no liquid leaks out.
- Add a different solution (from list of chemicals above) into each of the four lengths carefully using a dropper. Stick the dropper to the bottom of the visking tubing and release the solution. Make sure none of the solutions touch the outside membrane. Tie off the other end of the visking tubing firmly with an elastic band.
- Submerge each tube into different beakers of water.
- Record what is observed over 10 minutes.
- Wash all glassware and dispose of visking tubing.

Procedure (Part 2):
- Repeat this experiment using cling film instead of visking tubing as follows:
- Fill 5 beakers with water and loosely place strips of cling film over the top allowing the cling film to touch the water. Try not to stretch the cling film. Secure the edges of the cling film around the side of the beaker.
- Add a different solution onto each of the five cling film strips resting on the beakers. Make sure the solutions do not overflow the sides of the beakers.
- Leave overnight and record your observations the following day.
- Compare and contrast the results from part one and two and suggest reasons for your findings.
### Activity 2.1. Membranes with invisible holes

**Learning aims:**
- to draw conclusions from observations
- to explain the phenomenon through the existence of invisible holes and the movement of particles
- to distinguish alternative explanations and debate with peers

**Materials:**
- worksheet 2.1 or underlying experiment

**Suggestions for use:**

The teacher could either demonstrate the phenomenon as shown in the underlying experiment and let the students develop questions or start with a context of wrapping food. Worksheet 2.1 offers a possibility to investigate different plastic wrappings. Examples of investigations could be:

1. **Iodine diffusing into a soluble starch solution**
   - (i) No membrane
   - (ii) Jam pot cover
   - (iii) Plastic bag/cling film
   - (iv) Latex glove

2. **Vinegar diffusing into water with Universal indicator**
   - (i) No membrane
   - (ii) Jam pot cover
   - (iii) Cling film/roasting bag
   - (iv) Latex glove/plastic bag
   - (v)

Students match results to models of particles. Teacher should encourage a discussion of possible reasons and let the students deal with and encourage the development of the idea of particles of different sizes or membranes with holes of different sizes as one explanation.

**Possible questions:**
See worksheet
Activity 2.2. Set of activities on diffusion, particles, and holes

Learning aims:

- to develop the concepts of particles moving, of particles in solution moving
- to introduce diffusion and osmosis
- to develop and apply mental models
- to control variables
- to be able to predict, observe and explain processes

Materials:
- see worksheets 2.2a-2.2e

Suggestions for use:

The activities can be carried out in a learning cycles in small groups. The teacher can decide whether there should be a particular sequence to the activities or a free combination. Station 1 focuses on diffusion which can be explained by the Brownian motion. Station 2 focuses on the permeability of polymer membranes. Stations 3 and 4 extend the concept of particles and holes to different sizes of particles and explain it through molecular models. Station 5 develops visual models for the invisible structures and processes.

Possible questions:
See worksheets

Activity 2.3 Transfer and extension: Dialysis

Learning aims:

- to apply knowledge to an important/medical process
- to assess the capability to transfer understanding to an authentic context

Materials:
- worksheet 2.3

Suggestions for use:

This activity can be used either as a kind of transfer or as an assessment.

Possible questions:
See worksheet
Activity 2.4. What is the best wrapping material?

Learning aims:

- to develop criteria for wrapping material
- to develop mental models

Materials:

- none

Suggestions for use:

This activity is a thinking exercise that leads to the aspect of producing polymer films. The starting question could be: When preparing a sandwich, what's the best material to use to wrap it? What criteria would you apply? Below are possible factors that pupils might suggest: availability, cost, environmental impact (biodegradable, combustible, ...), insoluble in water, impermeable to fat and water, non-reactive (e.g. with acids in various foods), odorless and tasteless, keeps odours in (or out), ..., breathable or not?

The students should then rank the criteria they have named in order of importance and find out if there were materials that have the properties of higher ranked criteria. This ranking and questioning will lead to the suggestion of a plastic (cling film). Analyse what properties plastics have from the list of criteria. *Water will not pass through it; therefore it is impermeable, maybe inferring that there are 'no holes'.*

To get students to start thinking at a deeper level get them to draw what a sheet of cling film looks like.

![Drawing of cling film](image)

Ask them about the size and the number of atoms.

Invite the students to imagine to shrink themselves down to the size of an atom and ask them what the plastic will look like.

Experimentally - show briefly that cling film will hold water. Show Cling Film as an example of a polymer, made up of monomer units, each monomer is long chain. The students could be invited to think again about the size of the chains, the polymers, the atoms, etc.

A following question could be on the making of films and if it was possible to make films without holes (see extra activities 2.5). The following questions could then lead to further investigations:

- Will anything else pass through holes e.g. oxygen?
- Can we make films with different sized holes?
- When a sandwich is wrapped, lots of other compounds present – e.g. fat, oil, ketchup etc. What are these compounds?
- If you are wrapping a hot dog, then temperature is important. So how does temperature affect the film?
- Can bacteria pass through?
Extra Activity 2.5 Syntheses and testing of products

Making polymer films often involves hazardous chemicals. It depends on the facilities and regulations whether these experiments can be carried out.

Making Polyvinyl Chloride film
Polyvinyl chloride (PVC) is a cheap and durable plastic that is often used in pipes, signs and clothing. Plasticisers are often added to PVC to make it more flexible and easier to manipulate. This activity details how to make a film of PVC from powder PVC with and without a plasticiser. Students can then compare both the physical and chemical properties of each sample.

Chemicals:
Tetrahydrofuran (THF) or Toluene (solvent), Polyvinyl chloride powder, di-butyl sebacate or other plasticizer

Apparatus:
Hotplate, magnetic stirrer, beaker, glass substrate (e.g. beaker, clockglass, glass slide)
- All steps in this procedure are to be completed under the fume hood

Making PVC (without a plasticiser):
- Using a hotplate and a magnetic stirrer, heat 20mLs of the solvent.
- Weigh out 1.5g of the polyvinyl chloride powder and add it slowly to the heated solvent.
- After 10 minutes the solution will become more viscous, at which point the beaker should be removed from the heat.
- Remove the magnetic stirrer and spread the PVC as thinly and as evenly as possible over a glass slide/clockglass/inside or outside a beaker. It is important here to spread the polymer thinly by moving the glass substrate while the solution is still hot.
- Leave the PVC in the fume hood to allow the THF to evaporate off (takes about 15 mins). The PVC film can then be removed easily from the glass substrate.

Making PVC (With a plasticiser):
- A number of samples of PVC can be made by repeating the steps above, each time adding different volumes of the plasticiser, di-butyl sebacate to the heated solvent.
- Follow the remaining steps as above and pour the solution onto the glass substrate trying to get as good a spread as possible.

<table>
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<tr>
<th>Sample No.</th>
<th>PVC (g)</th>
<th>Toluene(mL)</th>
<th>Di-butyl sebacate (mL)</th>
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<tr>
<td>4</td>
<td>1.5</td>
<td>20</td>
<td>3</td>
</tr>
</tbody>
</table>
The PVC samples prepared can then be used in Activity 3.

Discussion:

- What affect did the plasticiser have on the plastic?
- What do you think happens to the plastic when more plasticiser is added?

The following are SEM images of PVC films prepared as above with different quantities of plasticizer. Holes are clearly visible in sample C.

SEM images of A) un-plasticised PVC, B) PVC with 0.5 mL plasticiser with dimples or rough surface and C) PVC with 2ml plasticiser displaying clear holes.
Testing the Pore Size of Plasticised and Un-Plasticised PVC

The PVC films (with and without plasticizer, i.e. films with different sized holes) can be used to separate different compounds or the compounds can be used to determine the pore size (i.e. larger or smaller than the molecular size).

Materials:
Test tubes, test tube stand, black marker, retort stands, 25 mL beakers, elastic bands, parafilm, plastic Pasteur pipettes, number of readymade PVC samples with varying plasticiser from activity 2.2.

Chemicals:
Water, Iodine Solution, Potassium Permanganate solution

Procedure:
Devised a suitable procedure using material available and previous experiments.

Discussion:
- Rank each PVC film in terms of permeability, starting from non permeable to permeable.
- Differentiate between the structure and size of iodine molecules and potassium permanganate molecules in solution.
- At what point does the plasticiser allow the PVC to become permeable to iodine? Explain what happens on a molecular level.
- Why was parafilm used as well as PVC?
- Give examples of other polymers you think may be permeable / impermeable and construct an experiment to test this.

Removing Plasticiser from PVC Clingfilm

Plasticizers are added to plastics such as PVC to make them more flexible and durable. They are often based on esters of polycarboxylic acids with linear or branched aliphatic alcohols of moderate chain length. Plasticizers embed themselves between the chains of polymers, spacing them apart. For plastics such as PVC, the more plasticiser added the more flexible it will be although its strength and hardness will decrease as a result of it.

In this activity, the plasticizer is removed from the PVC, leaving an inflexible glob of PVC.

Chemicals:
PVC cling film (or PVC with plasticiser produced in activity 2), diethyl ether, hot water.

Apparatus:
250 cm$^3$ conical flask, 250 cm$^3$ beaker(s), graduated cylinder, hot plate, spatula, balance.

Procedure:
- Weigh out approximately 1 g of PVC cling film/plastic
- Measure out 75 cm$^3$ of diethyl ether into a 250 cm$^3$ conical flask.
• Warm up the flask for 5-10 minutes in a water bath at 50°C in a fume cupboard. If a hot plate is not available then an unheated beaker of hot water can be used instead as diethyl ether boils at 35°C.

• Decant the diethyl ether from the conical flask into a 250 cm³ waste beaker. Add fresh ether and repeat the process.

• Remove the cling film/plastic from the beaker using a spatula after it has undergone two runs of diethyl ether and allow it to dry off in a fume cupboard.

• Weigh the cling film/plastic again and note the difference. Calculate the percentage weight loss (which should be over 20%).

• To collect the sample of the plasticiser, distill off the ether in the waste beaker and you will obtain a viscous oil.

Discussion:

• Compare and contrast the appearance and texture of the plastic before and after the experiment.

• On a molecular level, what occurred to the polymer chains on removal of the plasticiser?

• Design an experiment whereby you could test the size of pores in polymers using a plastic containing plasticiser and one without.
**Overall learning aims:**

Subunit 3 specifies the students’ understanding of particles through a systematic look at molecular structures, forces and interactions. As examples, functional polymers such as superabsorbers, cyclodextrines or hydrogels, etc. can be used. The aim of the IBSE investigations is to find out effects of changing conditions on the properties.

### Activity 3.1: Investigating the development of particular polymer products

**Learning aims:**
- to find out about particular products, including the people, who came up with it, the industry and the societal impact
- to use different sources of information systematically
- to make a short presentation

**Materials:**
- access to resources

**Suggestions for use:**
Let the students form groups and provide them with suggestions on products, e.g. contact lenses, nappies and hydrogels for plants.

### Activity 3.2: Investigation of properties and factors affecting SAP function

**Learning aims:**
- to develop experimental series including control of variables
- to explain the absorption of water by using structures and intermolecular forces (“functional holes”)
- to present findings in the forms of texts and graphs

**Materials:**
- Baby nappy or superabsorber bought in the store
- Sodium chloride solution \((c = 0,01 \text{ mol/l}, 0,1 \text{ mol/l}, 1 \text{ mol/l})\)
- Distilled water

**Apparatus:**
- 4 beakers (250 ml), 4 paper tea filter-each with 2 paperclips to close it, crucible tongs, graduated cylinder, weighing scale, plastic bag
Suggestions for use:

To start the investigation, the teacher could demonstrate how much water a small amount of SAP can take up. This could even be done in a fun way by pretending to spill a cup of coffee which does not come out of its cup when turned over...

Referring to upper secondary level students, the investigation of properties and factors affecting them could be developed by the students themselves. In case this is not possible, the following activities can be suggested:

- Examine the layered assembly of a baby nappy and find out which layer contains the superabsorbing polymer.
- Pull apart the fibrous web with the pellets of superabsorber in a plastic bag. Blow into the bag and separate the pellets from the fibrous web by shaking the (closed) bag vigorously.
- Add 200 ml of different concentrations of sodium chloride solution to each of three beakers and add 200 ml of distilled water to a fourth beaker.
- Fill each of the 4 tea filters with 2 g of the superabsorber, close with the paper clips and hang one in each beaker.
- Remove the filter after 45 minutes and allow excess liquid to drip off over the beakers for about 5 minutes (might have to use a funnel).
- Weigh the expanded tea filters and record the volume of the liquid remaining in the beakers.
- Repeat steps 3-6 with the aim to find out how the pH affects the retaining properties.

Possible questions:

How could you explain the absorption of water with a simple model?
How can you explain that the water does not get out again?
How can you explain the influence of pH and concentration of ions on the structure-property relation?
Compare the properties of SAP to other absorbing substances you could find at home.
How could you explain the different properties through the different structures?
Looking at nappies, how do the properties of urine differ from pure water? How could that influence the properties of SAP?
If the facilities and regulations allow for it, the following synthesis could be carried out:

**Chemicals:**
- distilled water
- acrylic acid
- N,N’-methylenebisacrylamid solution (MBA, w= 1%) (Xn)
- Ascorbic acid solution (w= 1.9%)
- H2O2 solution (w=0.6%) (C)
- Sodium hydroxide solution (c=0.5 mol/l) (C)
- Ethanol (T, F+)

**Apparatus:**
Beakers, syringes (1ml, 2ml, 5ml), temperature sensor, spatula, glass stirrers, 2 pointed tweezers, spoon, crystallizing dish, graduated cylinders (50ml, 100ml)

**Safety:**
Wear protective gloves and goggles. Work in the fume hood.

**Procedure:**

a) In a beaker, add the following solutions in the given order (use the syringes for measuring the liquids):

2.7 ml distilled water
2.0 ml acrylic acid
0.2 ml MBA-solution (w=1%)
1.4 ml ascorbic acid solution (w=1.9%)
0.7 ml H2O2 solution (w=0.6%)

Mix the contents of the beaker by gently swirling it. Let the beaker sit at room temperature. Record the temperature change during the reaction. The next part (part b) can follow right after cooling or the following day.

b) Transfer the product obtained to an evaporating dish. Pour 40 ml of sodium hydroxide solution c=0.5 mol/l) over the product.

With the help of the tweezers, separate the polymer into little pieces (be sure to wear protective gloves and goggles). After complete absorption of the liquid by the gel (about 30 minutes), add 100 ml of ethanol (do so in the fume hood). The content of the evaporating dish needs to be swirled around carefully from time to time (do not stir with a utensil because the gel is very sticky).
After about 10 minutes, remove the remaining liquid (make sure to dispose of this as organic solvent) and add 60 ml of ethanol. Repeat the last step twice (after waiting 10 minutes each time). Depending on the consistency of the polymer pieces, they might have to be separated from each other or the container with the help of the tweezers.
After the last removal of the liquid, leave the product sit under the fume hood overnight (or put into the oven for 1 hour at 80°C).
**Activity 3.3. Properties and applications of cyclodextrines**

**Learning aims:**
- to develop experimental series including control of variables
- to explain the absorption of substances
- to identify applications of cyclodextrines

The cyclodextrine needed in the following experiments can either be isolated as described later or be bought.

**3.3a) Removal of Phenolphthalein**

**Chemicals:**
- alkaline Phenolphthalein solution [C] (made from 20 ml distilled water, 3 ml sodium hydroxide solution (5 M) [C] and 4 ml Phenolphthalein solution (0.1%) [F]),
- cyclodextrine

**Materials:**
2 pieces of cloth, pipette, spatula

**Procedure:**
Spread a thin layer of the cyclodextrine onto a piece of cloth. Add a few drops of the alkaline Phenolphthalein solution to both pieces of cloth.

**3.3b) Removal of Maggi ®**

**Chemicals:**
- cyclodextrine
- Maggi ® food seasoning, liquid

**Materials:**
2 pieces of cloth, spatula, piece of white cardboard

**Procedure:**
Spread a thin layer of the cyclodextrines onto a piece of cloth. Add a drop of Maggi ® food seasoning to both pieces of cloth.
3.3c) Removal of cigarette smoke

**Apparatus:**
Gas syringe, Erlenmeyer flask (250 ml) with stopper, short piece of tubing, funnel, evaporating dish, pipette, tweezers, 2 pieces of cloth

**Chemicals:**
- cyclodextrine (product from activity 3.3a)
- cigarette

**Procedure:**
Spread a thin layer of the gel-like precipitate (product from activity 3.3a) onto a piece of cloth. Place both pieces of cloth side by side into the Erlenmeyer flask. Mount a funnel to the gas syringe via the piece of tubing. Fit a cigarette without filter into the funnel. Keep a evaporating dish ready for the cigarette ashes. Collect the cigarette fumes in the gas syringe. Pour the smoke into the Erlenmeyer flask and close the flask tightly right away. After about 1 minute, retrieve the pieces of cloth from the Erlenmeyer flask and dampen them.

**Suggestions for use:**
To start the investigation, the teacher could show an advertisement showing a product that promises to remove smells from fabric. The students need information on the structure of cyclodextrines. The students could make predictions about the forces at play. Before carrying out the investigations, the cyclodextrines could be extracted from Febreze® in the following way:

**Note:**
The reduction of the water takes about 1 hour and that of the alcohol about 15 minutes.

**Chemicals:**
Febreze®, ethanol [F], ice

**Apparatus:**
Magnetic stirrer with stirring bar, beaker (100 ml), graduated cylinder (50 ml), beaker (400 ml) for cooling

**Safety:**
Beware of possible boiling delays.

**Procedure:**
- Pour 40 ml of Febreze® into the small beaker and, while stirring, reduce the liquid almost until dry with the heatable magnetic stirrer.
- After letting the beaker cool, add 20 ml of ethanol and again, reduce the liquid almost until dry.
- Let the beaker cool and put into larger beaker filled with ice water for a few minutes.
- Save the resulting gel-like participate for further investigations.
**Extra activities:**

**Activity a:** Testing sorption properties of hydrogel

**Learning aims:**
Examination of changing physical properties of dried and hydrated hydrogel

**Materials:**
sodium polyacrylate or another hydrogel, distilled water, ceramic evaporator and spoon, beaker (150 cm³)

**Procedure:**
Put one spoon of sodium polyacrylate into the evaporator and then add ca. 100 cm³ of water. Observe any changes.

**Activity b:** Testing volume phase transition in sodium polyacrylate.

**Materials:** obtained in the previous experiment hydrated sodium polyacrylate, phosphorus(V) oxide (P₄O₁₀), a desiccator, Petri dishes, porcelain spoon

**Procedure:**
Pour spoonful of P₄O₁₀ onto Petri dishes and place it in the desiccator or a big jar with a tight cover. Place a few particles of hydrated hydrogel into another Petri dish and put it into the desiccator. Observe the changes.

**Suggested Questions:**
- Does the volume of the used substance change during the experiment?
- What could happen with water used in the experiment?
- How could you explain decreasing the size of hydrated hydrogel particles and the state change of P₄O₁₀?
- Are there other factors which could cause the observed effect?
- Which phenomena are observed in these experiments?
- What are the possible applications of the tested materials?

**Preparation of Ag hydrosol:**

The Ag hydrosol preparation was carried out by a chemical reduction of silver nitrate by sodium citrate. An aliquot of 3.0 or 4.5mL of an aqueous solution of sodium citrate (10 mg/mL) was added drop-wise into 150 mL of a boiling and stirred aqueous solution of silver nitrate of 0.18 mg/mL concentration. After addition, the resulting hydrosol was further boiled for 10–15 min. The hydrosol was stirred for more than 15 min and, after that, diluted with water to get a total volume of 126 mL.
Making Hydrogels using PVA and PAA

Hydrogels have been applied as intelligent carriers in controlled drug-delivery systems. In the dry state, they are usually hard and glossy and can protect the active ingredients from the influence of oxygen, UV light and other possible degradation. Once swollen in water or bodily fluids, they allow the passage of drug molecules out of the body of the hydrogel. The practical use of hydrogels is mainly limited to applications of high water absorption because gels have low mechanical strength. However, hydrogels with high water content, strength and elasticity can be synthesized easily by repeatedly freezing and thawing the hydrogel.

Hydrogels are made of three dimensional semi-crystals held together by hydrogen bonds. The amount of time the gel is frozen does not affect the strength of the gel. However, the slower the frozen gel is allowed to thaw the stronger the hydrogels become (crystallization of the 3-D semi-crystals is promoted by slow thawing).

**Application:** Hydrogels can be used to deliver drugs to the body, in dressings to heal wounds as they create and maintain a moist environment and in sensors due to their flexibility and strength. In this activity, acetylsalicylic acid is held within a hydrogel and then the release of the acetylsalicylic acid can be followed either by titration or by UV.

**Materials:** PVA, PAA, acetyl salicylic acid, deionised water, weigh boat(s), spatula, magnetic stirrer, hot plate and stirrer, fridge.

**Procedure:**
- Heat 40mL of deionised water to 60°C
- Weigh out 1.0g of PVA and slowly add to the hot water over 1 hour. The solution should be constantly stirred by a magnetic stirrer.
- Weigh out 0.2g of PAA and slowly add to the beaker and stir for a further half hour.
- Add 1 g of acetylsalicylic acid to the mixture and allow to mix for 5-10 minutes.
- A thick gel will have formed. Pour the gel into a mould (e.g. an empty weigh boat)
- Freeze the hydrogel for 4 hours at approx -20°C.
- Allow the gel to thaw slowly in a fridge and repeat the freezing and thawing process once more.
- Place the hydrogel in 500mls of water and leave to one side.
- Note any changes in shape to the hydrogel and if the water level has decreased/increased/stayed the same.
- Test the aqueous solution after 1 hour, 2 hours, 5 hours etc. to determine the release of the acetylsalicylic acid from the hydrogel. This can be done either by UV analysis or by titrimetric analysis. The release rate can be determined by plotting the acetylsalicylic acid concentration released versus time.
Antibacterial PVC

Incorporating silver nanoparticles / microparticles into polymers forms antimicrobial films that can be used in many medical technologies. Silver ions are released from elemental silver in the presence of oxygen and water. These silver ions can break down cell walls, inhibit cell reproduction and disturb metabolism within a microbe. This property can be utilised to treat wounds and burns as well as infections like MRSA and E.Coli.

To prepare a PVC film with small silver particles, silver nitrate is added in the preparation of the PVC film. A film with large holes is required so plasticizer must be added. The silver nitrate is then reduced using sodium citrate, leaving dispersed silver particles throughout the film.

Chemicals:
Tetrahydrofuran (THF) or Toluene (solvent), Polyvinyl chloride powder, di-butyl sebacate, silver nitrate, sodium citrate

Apparatus:
Hotplate, magnetic stirrer, 75ml beaker(s), graduated cylinder, Pasteur pipette, spatula.

Procedure:
- Prepare 20ml solution of PVC (see Activity 2.5) with 2.5 mL of the plasticiser di-butyl sebacate.
- While the PVC is still in solution, add 2.5 mL of 10mM silver nitrate (AgNO₃) and stir with the magnetic stirrer for 1-2 minutes.
- Divide the solution over two 75ml beakers. Quickly rotate each beaker so that the whole inside of the beaker is coated with the solution creating a film in the shape of a beaker. Ensure that there are no gaps as the film must be capable of holding water. Allow the solvent to evaporate off and when dry, carefully remove the film from the beaker.
- Make up a 5mM solution of sodium citrate and pour this into the beaker shaped membrane, allowing it to pass through the membrane and react with the silver nitrate to form silver nano/microparticles.
- Note the colour changes to the membrane.
- Allow the film to dry off in a fume hood and analyse it under a SEM to see if any elemental silver has formed.

The SEM images below show the Ag particles dispersed in the PVC membrane.

The antimicrobial properties of this film can be tested by placing a piece on an agar plate and leaving the plate in good conditions for microbial growth. An area of no growth will be observed close to the film.

Potential applications of these films can be discussed in environmental and medical areas.
ESTABLISH SEM image of PVC membrane with silver microparticles and nanoparticles (bright white clusters).

Fig Four different spectra of the PVC membrane from the SEM image (Figure 1) showing elemental silver present in the polymer sample.
Lead partner for Unit: Dublin City University (DCU)

The ESTABLISH project has received funding from the European Community’s Seventh Programme (FP7/2007-2013) under grant agreement no 244749
Start Date: 1st January 2010
Duration: 48 months
The research leading to these results has received funding from the European Community’s Seventh Framework Programme [FP7/2007-2013]

DISSEMINATION LEVEL

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Document History

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This document has been generated following discussions by the Chemistry sub group, namely:

Odilla Finlayson, Ilka Parchmann, Iwona Maciejowska, Hana Čtrnáctová, Paweł Bernard, Paweł Bros, Małgorzata Krzeczkowska, Jack Holbrook
Rory Geoghegan, Wolfgang Graeber, Alison Graham, Stefanie Herzog, Petr Šmejkal, Mária Ganajjvá, Elzbeiet Szostak, Anna Bialas, Loukia Anastasiadou, Michael Nicolaou, Nicos Valanides

Activities have been based on information from:

Mareike Wilms, Martin Fach, Jens Friedrich Dr., Marco Oetken Prof. Dr, Molekulares Sieben: Mit Einmachfolie ins Diskontinuum, Chemkon, Volume 11, Issue 3, pages 127-130, July 2004

James Chapman, Laura Barron and Susan Ryan, Dublin City University.


Exemplary Classroom Materials (Subunit 1)

1.2

What do you think?

From your observations in the activity, suggest which model above describes your separation.
Activity 1.5

Teachers notes

The case of Liam Johnson
Using separating techniques to solve a crime

Equipment required:
Per group: Bunsen burner, gauze, pyrex beaker/evaporating dish
Beaker, stirrer, filter funnel, filter paper
Chromatography paper, beaker, wooden splint to support paper

This activity works well in groups of 3 - each person does one of the tests and they pool their results to come up with the answer

What you need to do in advance:
Photocopy sheets needed
Lung water sample: tap water
Tea sample: some cold tea
Sugar sample: some dark brown sugar with powdered carbon/iron filings added

Expected results:
Lung water sample: heating does not give salt
Tea sample: chromatography does not show visible contamination
Sugar sample: shows another substance when sugar dissolves

Suggested answers to questions:
1. Lung sample is not salt water so Liam was not drowned at sea - but may have drowned in swimming pool. (Discussion point: Negative results can be very important in giving information!)
2. Tea sample shows no contamination (Discussion point: limitations of this method, visible contaminants revealed only - in Forensic labs separation of components of the mixture is followed by chemical detection)
3. Sugar sample does show contamination.
4. It is important that the students realise that there are often several ways to interpret results and it is important that scientists are able to think laterally of possible explanations! The evidence suggests that Liam was poisoned and/or drowned in the pool but then moved to the sea.
5. What is the contamination in the sugar? Who else was in the house at the time? etc etc
6. Student worksheet

The Case of Liam Johnson

The crime
This is a newspaper cutting about the discovery of a body at Howth Head.

**BODY FOUND AT HOWTH HEAD**
The body of Liam Johnson was pulled from the sea yesterday evening at Howth Head. Forensic scientists have placed time of death as sometime between 6 and 9 pm the previous evening. His grieving wife and daughters were too distraught to talk to the press but it is believed that his once booming business was now in some financial difficulties

Irish Independent, May 7th 2009

Although initially it looks like a tragic drowning accident the Gardai are not convinced that all is as it seems.
The Forensic team have collected samples at the post mortem and at the home of Liam Johnson where they found his towel near the pool ......

...and a table with a used tea cup, tea pot and brown sugar.

You are the Forensic Scientist appointed to investigate the samples collected which are
(a) a sample of water from the lungs of Liam Johnson
(b) a sample of tea from the teapot
(c) a sample of sugar from the sugar bowl

What you need to know!

You have learnt a number of separating techniques which will be very useful to you here! You will have to think carefully about which ones you need to use.

- magnetism
- filtration
- distillation
- evaporation
- chromatography
What you need to do to solve the crime!

Decide what tests to carry out on your samples to find out
1. Did Liam Johnson die from drowning in the sea?
2. Is there any evidence that the tea is contaminated with another substance?
3. Is there any evidence that the sugar is contaminated with another substance?

Record your findings carefully on the chart below

<table>
<thead>
<tr>
<th>Sample</th>
<th>Method used</th>
<th>Results</th>
<th>Conclusions</th>
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<tbody>
<tr>
<td>(a) water from the lungs of Liam Johnson</td>
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<tr>
<td>(b) the tea in the teapot</td>
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<td></td>
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<tr>
<td>(c) the sugar in the sugar bowl</td>
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</tbody>
</table>
What have you found out?

1. Did Liam Johnson drown in the sea? Outline the evidence for your answer.

2. Is there any evidence for contamination of the tea by another substance. Outline the evidence for your answer.

3. Is there any evidence that the sugar was contaminated by another substance. Outline the evidence to support your answer.

4. What do you think happened in this case?

5. What further evidence or tests would need to be collected to prove that your ideas are correct?
Activity 1.6. Car Engines Worksheet

Car engines usually have 4 cylinders. Inside the cylinders a petrol air mixture explodes pushing down a piston which pushes the wheels around. The 4 cylinders are coordinated like the pedals on a bike so there is always one pushing down to turn the wheels.

It is important that there is the right mixture of air and petrol to cause the best explosion in the cylinder.

Air is filtered before it enters the engine. If the air filter gets clogged not enough air gets in and the petrol does not burn well. If the air is not filtered dust causes problems in the cylinders.

In racing cars they improve the performance of the engine by using a very thin filter which lets through much more air to mix with the fuel.

1. Why is it necessary to change the air filter on the car after 12,000 miles? ........................................................................................................................................................................................................................................

2. What clogs the air filter?
........................................................................................................................................................................................................................................................................................................................................................................................................................................

3. Why does the engine stop working well if the air is not filtered?
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4. What is the advantage of using a thin filter in a racing car? What is the disadvantage?........
........................................................................................................................................................................................................................................................................................................................................................................................................................................

Activity 2.1 Membranes with invisible holes - worksheet Page 1 of 2

1. Set up the experiment as advised. Put in the labels on each tube.

![Diagram of membranes with invisible holes]

Observations:

<table>
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</thead>
<tbody>
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<td><strong>Colour at start</strong></td>
<td><strong>In small bag</strong></td>
<td><strong>In tube</strong></td>
<td><strong>In small bag</strong></td>
<td><strong>In tube</strong></td>
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<tr>
<td><strong>Colour at end</strong></td>
<td><strong>In small bag</strong></td>
<td><strong>In tube</strong></td>
<td><strong>In small bag</strong></td>
<td><strong>In tube</strong></td>
</tr>
</tbody>
</table>

2. Can you explain what is happening?

........................................................................................................................................................................................................................................
........................................................................................................................................................................................................................................
........................................................................................................................................................................................................................................
........................................................................................................................................................................................................................................
........
3. Can you match each tube of your experiment to one of these diagrams?

4. What would happen in each tube if the solutions were reversed - if the solution of smaller molecules was in the tube and the solution of larger molecules in the membrane at the start?

<table>
<thead>
<tr>
<th>Observations:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Colour at start</strong></td>
<td>In small bag</td>
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<td></td>
<td>In tube</td>
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<td><strong>Colour at end</strong></td>
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<td></td>
<td>In tube</td>
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</table>
Activity 2.2A: Station 1: Colored Chemical Substances in Water

Worksheet 1:

Discuss in your group and then perform the following activities

Experiment 1-Indicative Procedure

1.  i. Pour 120 mL of distilled water into a 150mL beaker. If you placed one drop of red food colouring at the centre of the bottom of the beaker, what changes do you predict will occur; try to briefly explain your predictions.

ii. Pour distilled water into a Petri dish (up to approximately 1 cm height). If you placed a few crystals of potassium permanganate in the centre of the Petri dish, what changes do you predict will occur; try to briefly explain your predictions.

Imagine that you wear magic magnifying glasses, so that you can clearly see the content of the Petri dish, what kind of changes do you expect to observe in the Petri dish; Draw your expectations and observations after 1 min, after two minutes and after 10 minutes, in the following diagrams:

![Diagram showing changes over time]

2. Conduct the following experiments:
   i. Using a plastic dropper, put 3-4 drops of red food colouring in the center of the bottom of a beaker (A) containing 120 mL of distilled water.
   ii. Using a plastic dropper, put 3-4 drops of red food colouring in the center of the surface of a beaker (B) containing 120 mL of distilled water.
   iii. Put 2-3 crystals of Potassium permanganate on the center of a Petri dish using forceps.
3. Make as many careful observations as possible concerning the three experiments and try to record the way the three substances are moving and what changes in color are progressively happening in the three cases. Draw somehow, the movement of Potassium permanganate and the red food coloring substance in each of the three containers, in three different consecutive drawings indicating your observations after 2, 5 and 10 minutes (question 5).

Discuss in your group and carefully record your observations and your interpretations for the following questions: (questions 4, 5, 6, 7, 8, 9, 10)

**Results**

4. Describe your observations for the Petri dish and the other two containers:

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

5. Draw in the following diagrams your observations concerning the movement of Potassium permanganate time period and justify your drawings.

![Diagram](1)

<table>
<thead>
<tr>
<th>After 2 minutes</th>
<th>After 5 minutes</th>
<th>After 10 minutes</th>
</tr>
</thead>
</table>

**Explanations**

6. a) Explain the movement of Potassium permanganate in the Petri dish.

b) Explain the movement of the red food coloring in the beakers A and B.

7. Were your predictions and your drawings the same as your observations and their consequent explanations;
8. Imagine that you wear magic magnifying glasses. In such a case, draw the contents of the beaker before and after pouring the drops of the red food colouring.

![Diagram of two beakers](image)

9. What kind of changes occur in the Petri dish and in the two beakers after adding either potassium permanganate and the red food colouring: How do you justify your answers; 

10. Describe briefly your observations in the beaker where the red food coloring was added. In your description, please use the following terminology: particles, movement, water, distributed, homogeneously, diffusion.

11. At the corner of your classroom, the chemistry teacher put an open small bottle containing pure alcohol, but she did not mention anything to her students. John smelled the alcohol after a minute, but Jack smelled it after several minutes.
EXPLORING HOLES

i. Why do you think the two students smelled the alcohol at different times and why.

ii. What is the relation of the smell of the alcohol with the experiments that you have performed earlier;

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Homework

1. How many particles are included in a tiny crystal of potassium permanganate;
   A. 100 000 000 000 000 000 000 000   B. 1 000
   C. 100 000 000   D. 100 000

2. Describe the phenomenon of diffusion that is presented in the following drawings.
   (White spheres represent particles of water and the other spheres represent particles of potassium permanganate.)

3. Do you expect that the particles of a gas behave the same way as the particles of potassium permanganate and the particles of the red food coloring substance; Justify your answer.

____________________________________________________________________________________

____________________________________________________________________________________

4. Is the following statement true or false; explain why.
   “The same experiment can be performed using cooking salt instead of potassium permanganate. The only difference relates to the fact that we will not be able to observe the movement of the particles, because the cooking salt does not have any color.”

   __________
Activity 2.2B: Station 2: Invisible Holes

Worksheet 2:

The transparent membranes, which appear in the pictures, are used to wrap presents, flowers, sweets and all sorts of foodstuffs (fruit, vegetables, meat, cheese etc) usually in order to preserve them and keep them fresh.

These membranes are made of polymers, such as, polyethene, polypropene, PVC, polycellulose etc.

The factory “PLASTICO” is advertising that the transparent membranes of the series “FoodFilms,” which it produces and sells in the market, are suitable for wrapping foodstuffs, because they are not penetrated by micro-organisms and chemical substances.

Your teacher has provided you with two of these membranes and asks you to investigate whether the company’s advertisement is true.

**Prediction:** Before proceeding to carry out the experiment examine the two membranes and make your own prediction and exchange opinions with the members of your group:

Are the two membranes (or one of the two) permeable to chemical substances or not? On what do you base your hypothesis?

_____________________________________________________

Discuss with your group and carry out experiment 2.

**Experiment 2 - Procedure**

1. To carry out the experiment, you have two transparent membranes (A and B) and an iodine solution available.
2. Place two 150 mL beakers in a row and add 120 mL water into each.
3. In two test tubes (A and B), add the same quantity of iodine solution (to about a 3cm height)
4. With a piece of membrane, which you should previously dampen with water, close the opening of tube A by wrapping it on the tube’s external surface and securing it tightly using a rubber band.
5. After that, secure the tube upside down on a stand with its opening inside the water, as shown in the figure below.
6. In the same way, work with membrane B.

If one of the membranes is permeable to the iodine solution, what observations do you predict in the beaker with the water and why?

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

7. Leave the two solutions to stand for 7-8 minutes attentively observing all the changes in the two beakers.

Discuss with your group and write down the results and the interpretation of the results (questions 9,10,11,12,13,14,15)

Results

8. Write down your observations of the two beakers:
   Beaker A: ________________________________________________________________
   Beaker B: ________________________________________________________________

Interpretation of Results

9. What do you conclude from the above experiment?
   ________________________________________________________________
   ________________________________________________________________

10. Draw your observations of the two membranes in the figures below. Correct the size of the pores in each membrane if needed.
11. Is the prediction you made in question 7 concerning the changes in the beakers with the water right or wrong? If there is a need, amend your explanation accordingly.

________________________________________________________________________

12. Is the advertisement of the “PLASTICO” factory justified? Is the claim of the company that the “FoodFilms” membranes are not permeable true or false?

________________________________________________________________________

________________________________________________________________________

13. Is your prediction concerning the membranes’ permeability correct or not?

________________________________________________________________________

14. The factors (variables), which influence the experiment, are the following: membrane (pores of the membrane), permeability, dissolved substance (size of its particles), liquid in the beaker, quantity of solution in the test tube.

Which of the above variables are:

a. Controlled variables (factors which I keep constant): __________________________

________________________________________________________________________

b. Independent variable (a factor which I can alter): ____________________________

c. Dependent variable (a factor which I can measure/observe): _________________
Answer questions 15 and 16 individually

15. Which one of the membranes would you use to wrap your sandwich? Support your answer.

________________________________________________________________________

________________________________________________________________________

16. If you used salt water instead of iodine solution in the above experiment, what would happen? Explain your answer.

________________________________________________________________________

________________________________________________________________________

Homework

1. Which one of the membranes would you use to wrap flowers? Explain your choice.

________________________________________________________________________

________________________________________________________________________

2. Do you think that the particle (molecule) of iodine is larger than a cell of a microorganism?

Are there particles that are smaller than the particle of iodine? ______________
Are there particles that are larger than the particle of iodine? ____________

3. Search the internet for more information on transparent membranes and mention their different uses. For every example, explain the relationship between the permeability of the membrane and its use.
Activity 2.2C: Station 3: Membranes in Medicine

Work Sheet 3:

Artificial membranes are widely used today in medicine, for example, in artificial kidneys. As it is well-known, the kidneys are a basic organ of the human organism which, among other things, cleans (filters) the blood from toxic substances, which are secreted through urine. In order to deal with renal failure several different methods are used, including haemodialysis or as it is usually called “artificial kidneys.” Through a membrane, the useless (toxic) substances are removed from the blood, while, at the same time, the useful substances are retained.

The pictures below show such artificial membranes, which are used in haemodialysis.

These membranes are made from various plastics and polymers.

Prediction:

Do you think that chemical substances can pass through a transparent membrane?

Before carrying out the experiment, discuss with your group and try to answer the question after handling the membrane which you are going to use.

Discuss in your group and carry out experiment 3.

Experiment 3 – Procedure

1. In order to carry out the experiment, you have a transparent membrane available as well as two solutions:
   i. iodine solution and
   ii. starch coloured with iodine.

2. Place two 150 mL beakers in a row and add 120 mL of water in each.

3. In two test tubes (A and B) add a solution of iodine to the first and a solution of starch to the second (about the same quantity, to a height of 3 cm).

4. With a piece of membrane, which you should firstly dampen with water, close the opening of tube A by wrapping it on the tube’s external surface and securing it tightly using a rubber band.

5. After that, secure the tube upside down on a stand with its opening inside the water as shown in the figure below.

6. In the same way, set up test tube B.
7. In case the two solutions, or one of them, passes through the membrane what changes do you predict you will observe in the beaker with the water and why?

____________________________________________________________________________________
____________________________________________________________________________________

8. Leave the three solutions to stand for 7-8 minutes attentively observing all the changes in both beakers.

Discuss in your group and write down the results and the interpretation of the results (questions 9,10,11,12,13,14,15)

**Results:**

9. Write down your observations of the two beakers:
   Beaker A: ________________________________________________________________________
   Beaker B: ________________________________________________________________________

**Interpretation of Results:**

10. What do you conclude from the results of the two experiments?
    ________________________________________________________________________________
    ________________________________________________________________________________

11. Illustrate your observations of the two solutions in the figures below:
12. **Is the prediction, you made in question 7, right or wrong? If necessary, revise your prediction.**

_________________________________________________________________________________

13. **Which one of the two substances that you used (iodine, starch) has a larger size particle? On what do you base your answer?**

_________________________________________________________________________________

14. **Compare the conclusion you have drawn after completing the experiment with the prediction which you made concerning the initial problem under investigation. Do you need to revise your prediction? Why?**

_________________________________________________________________________________

_________________________________________________________________________________

_________________________________________________________________________________

15. **The factors (variables) which influence this experiment are the following:**

   membrane (pores of the membrane), permeability, dissolved substance (size of its particles), liquid in the beaker, quantity of solution in the test tube.

   Which of the above variables are:

   a. **Controlled variables (factors which I keep constant):** _______________________

      ___________________________________________________________________

   b. **Independent variable (a factor which I can alter):** _______________________

   c. **Dependent variable (a factor which I can measure/observe):** _______________
Answer questions 16 and 17 individually

16. Why do you think the starch solution, which you used, has been previously coloured?
   ____________________________________________________________________________
   ____________________________________________________________________________

17. Do you believe that hydrogen gas can pass through the membrane which you used in the previous experiment? On what do you base your opinion?
   ____________________________________________________________________________
   ____________________________________________________________________________
   ____________________________________________________________________________

Homework

1. Why should the membrane be dampened before being applied to the opening of the test tube?
   ____________________________________________________________________________
   ____________________________________________________________________________

2. It is well known that polymers (starch, cellulose, natural rubber, nylon, etc) comparatively have very large molecules. The image below presents the starch molecule coloured with iodine.

   ![Starch molecule coloured with iodine](image)

   Explain why the polymers have large molecules.
   ____________________________________________________________________________
   ____________________________________________________________________________

3. Could the membrane that you examined be used in haemodialysis? On what do you base your answer?
   ____________________________________________________________________________
   ____________________________________________________________________________

4. Search the internet and collect information concerning renal failure and haemodialysis or “artificial kidneys”.

   ____________________________________________________________________________
   ____________________________________________________________________________
Activity 2.2D: Station 4: Chemical Substances through membranes

Work Sheet 4:

The transparent membranes which appear in the pictures are used to wrap presents, flowers, sweets and all sorts of foodstuffs (fruit, vegetables, meat, cheese etc) usually in order to preserve them and keep them fresh.

In the experiment that you are going to carry out in this station, you will investigate whether different chemical substances such as food colouring substances pass through a transparent membrane.

**Before carrying out the experiment described below, make your own prediction as to whether chemical substances can pass through the transparent membrane which you have. Justify your prediction.**

**Discuss in your group and carry out experiment 4**

**Experiment 4 – Procedure**

1. In order to carry out the experiment you should have a type of transparent membrane as well as the following solutions:
   i. Potassium permanganate
   ii. red food colouring substance
   iii. green food colouring substance

2. Place three 150 mL beakers in a row and add 120 mL of water in each.
3. In three test tubes (A, B and C) add three solutions in the order they are stated in 1. (about the same quantity to a height of 3 cm).
4. With a piece of membrane which you should first dampen with water, close the opening of tube A by wrapping it on the tube’s external surface and securing it tightly using a rubber band.
5. After that secure the tube upside down on a stand with its opening inside the water as shown in the figure below.
6. In the same way, set up test tubes B and C.
7. Leave the three solutions to stand for 7-8 minutes attentively observing all the changes in all three beakers.

Discuss in your group and write down the results and the interpretation of the results (questions 8, 9, 10, 11, 12, 13)

**Results**

8. What common physical property is common to all the solutions that you used?

_____________________________________________________________

9. Write down your observations of the three beakers:
   Beaker A: ___________________________________________________
   Beaker B: ___________________________________________________
   Beaker C: ___________________________________________________

**Interpretation of Results**

10. What can you conclude from the above experiment?

_____________________________________________________________
    ___________________________________________________________

11. Compare your conclusions with the prediction you made of the initial problem under investigation.

_____________________________________________________________
    ___________________________________________________________

12. Which comparative conclusions can be justified based on the results of the previous experiment?

_____________________________________________________________
    ___________________________________________________________

13. The factors (variables) which influence the above mentioned experiment are the following:
membrane (pores of the membrane), permeability, dissolved substance (size of its particles), liquid in the beaker, quantity of solution in the test tube.

Which of the above variables are:

a. Controlled variables (factors which I keep constant): _____________________

b. Independent variable (a factor which I can alter): ________________________

c. Dependent variable (a factor which I can measure/observe): _______________

**Answer question 14 individually**

14. The images below in the circles show the particles (molecules or ions) of three substances which you used in the experiment. Can you match the particles with the three substances?

Using the above information justify the observations which you made about the permeability of the three substances.

**Homework**

1. Do you think that the membranes used to wrap foodstuffs should be permeable to oxygen gas or not? Justify your answer.

2. Why do you think certain factors should be kept constant during the experiment?
Activity 2.2E

Note: These activities should be performed by all groups and should be linked to the previous activities where the groups were rotating from one station to the other. Obviously, teachers should be randomly or otherwise divided into four groups and they should be instructed to perform all the activities concerning the four stations by moving from one station to the other.

A model for the separation of mixtures

Separation of mixtures, using sieves or filters, is frequently applied in all the human activities: at home (kitchen), in the industry, research and medicine. There are plenty of sieves and filters available for different uses. In the Chemistry laboratory, we usually use filter papers for the separation of mixtures which consist of a liquid and un-dissolved solids.

Procedure

Experiment a: Separating of mixtures with sieves – Separation model

At your work place you will find:
   a. Sieve A (with bigger holes)
   b. Sieve B (with smaller holes)

Furthermore you will find:
   i. mixture A (Soya Beans – Tapioca)
   ii. mixture B (Tapioca – Alfalfa Seeds)
   iii. mixture C (Soya Beans – Tapioca - Alfalfa Seeds)

Discuss in your group and plan an appropriate procedure for separating the above mixtures in their components. Purpose of the activity is to compare the visible components of these mixtures with the invisible particles (molecules – ions) of chemical substances in mixtures.

Procedure Plan and carry out the following trials:

(a) Try to separate the three mixtures with sieve A.
(b) Try to separate the three mixtures with sieve B.
(c) Try to separate the three mixtures using both sieves A and B, if you consider this necessary.

Results

1. Carefully record your observations
Interpretation of results

2. Summarising your results, explain which sieve or sieves you used to separate each of the three mixtures?
   - Mixture A: ______________________________________________
   - Mixture B: ______________________________________________
   - Mixture C: ______________________________________________

3. Which factors (variables) affect the trials you carried out?
   __________________________________________________________

4. Which factor did you decide to keep constant (controlled variable)?
   __________________________________________________________

5. Which factor did you decide to change (dependent variable)?
   __________________________________________________________

6. Which factor did you decide to use for recording your observations (independent variable)?
   __________________________________________________________

7. Represent your observations for each one of the above trials using the following symbols:

   Particles for separation:
   ○  ○  ○  
   Soya Beans  Tapioca  Alfalfa Seeds

   Screens: (Use the sheets with the screen models you will find at your working place)

   Screen A
**Experiment b**

You have to investigate whether the samples of the inks you have been given by your teacher permeate transparent membranes.

**Prediction:** Before you proceed to carry out this activity, discuss in your group and make together a prediction regarding the permeability of the two samples through the membranes. Which observation are you going to record in the experiments you plan?

**Procedure**

1. At your work place you will find:
   i. two transparent membranes A and two transparent membranes B
   ii. two samples of ink: black ink and blue ink
   iii. all the necessary instruments and glassware
2. Plan an experiment to investigate the permeability of the inks through the transparent membranes.
   During the planning of the experiment determine the different kind of variables:
   Controlled variables, dependent variable and independent variable.
3. Now:
   3.1 Carry out the experiment, as you have planned it.
   3.2 Record your observations.
   3.3 Discuss in the group your results. Was your initial prediction correct or incorrect? Comment on it.
   3.4 Explain the results, comparing the two kinds of ink with the mixtures used in the experiment a’ and according to the model you have suggested.
      Draw a model, using for the components of ink small cycles of different sizes and for the membranes holes of different spaces.
   3.5 **Suggest a title for the above activity;**

**Home work**

3. Based on the model you developed and after some information you will get from the internet explain how haemodialysis is working.
The human kidney is an amazing organ. It has two essential functions, the excretion of urea, salts and water and the maintenance of water balance in the body. Each day the kidneys filter 180l of fluid out of the blood. Most of the fluid is reabsorbed with all the useful nutrients which the body needs such as glucose and amino acids. About 2l of urine is made and excreted via the bladder. This contains waste products such as urea which is toxic to the body.

1. Why do you think there are not normally plasma proteins in the urine even though they are in solution in the blood plasma?

2. In the case of certain injuries or diseases blood cells appear in the urine. What may have happened to allow this to occur?
If kidneys fail death follows in about 4 days due to build up of urea and lack of control of water balance in the body. This can be prevented by the patient attending hospital 3 times a week for dialysis. Blood travels in a tube from the body and flows into the machine, where it passes next to a filter called the dialysis membrane. A specialized dialysis solution flows on the other side of the membrane. This is designed so that urea passes from the blood through the membrane into the dialysis fluid but glucose and amino acids do not. The blood is then returned to the body.

1. Explain why the red blood cells and plasma proteins are not removed from the blood in dialysis?

2. Urea, glucose and amino acids are similar sized molecules. Explain why urea passes across the dialysis membrane but glucose and amino acids do not.

3. What would happen if water was used as the dialysis fluid?

4. How can dialysis be used to remove excess salts?

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2.http://3.bp.blogspot.com/_7MhVC-  
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