Chemistry
the next generation
part of Chemistry for our future

11
ACTIVITY

Year 9 chemistry day

Chemistry of very large molecules

14 age group

4¾ HRS

60 STUDENTS

10 STUDENTS PER GROUP

7 SUPERVISORS

£2050

background

This event involves the students making fridge magnets from milk, identifying polymers by density and making bouncing custard. The final session also deals with new SMART materials since these have recently been added to some GCSE specifications.

pre-planning required

weeks before

- Plan with schools how many students are coming to the session.
- Book rooms, refreshments, staff, inform technicians and ensure chemicals and sufficient safety glasses/lab coats are in stock.

days before

Train demonstrators to do the practical and the associated safety aspects, and highlight questions likely to be asked by students. Ask technicians to prepare kits of apparatus and chemicals.

general equipment

- IR spectrometer

Suggested timings for the day

10.00	Introduction and welcome lecture
10.30	Plastic milk practical session
11.30	Unknown polymers practical session
12.15	Lunch break
13.00	Introduction to afternoon session lecture
13.30	Bouncing custard practical session
14.00	Polymers and smart materials lecture
14.45	Finish

NOTE

Different manufactures use different plastics, check carefully prior to event. PVC and PET can both sink in solution six. These can be identified by IR using the ATR or by preparing thin film.

materials required

Plastic milk

- 150 cm^3 hot milk
- 12 cm^3 vinegar
- 250 cm^3 beaker
- 400 cm^3 beaker
- measuring cylinder
- square piece of cloth eg sheeting
- rubber band
- stirring rod
- paper towels
- small magnet

Bouncing custard

- 15 cm^3 4% polyvinylalcohol (PVA) solution
- measuring cylinder
- solid borax (sodium tetraborate $Na_2B_4O_7.10H_20$)
- 4% borax solution in water
- custard powder or cornflour
- test tube and rack
- 100 cm^3 beaker
- glass stirring rod
- spatula

SAFETY

A risk assessment must be done for this activity.

continued from previous page

SAFETY

Lab coat or apron and safety glasses to be worn in the laboratory. Students to avoid skin contact with chemicals, if contact occurs, wash off immediately with plenty of water. Students should report any spillages and breakages to a demonstrator immediately.

materials required

Identifying unknown polymers

- blister pack
- document folder
- fruit punnet
- milk bottle
- plastic bag
- yoghurt pot
- solutions of known density as per table

Answers to student questions

Plastic milk

1. The milk curdles, separating into solid and liquid.
2. The curds become well separated.
3. The curds settle to the bottom of the beaker.
4. The rest of the milk, ie sugars, water along with the excess vinegar.
5. Creamy-coloured and crumbly, especially before dried.
6. In excess acid (vinegar) uncharged COOH groups are formed on the casein. As these are not as polar as the COO^- groups they are formed from, they do not dissolve as well in the polar solvent water. The protonated casein therefore precipitates from solution.
7. The action of the bacteria makes the milk acidic (like addition of vinegar). This makes the casein precipitate out of the milk and so the 'curds' used in cheese-making can be separated easily.

Identity of plastics and sample results

Solution density/g cm-3	1 0.79	2 0.91	3 0.94	4 1.00	5 1.15	6 1.38	Identity of the plastic
Blister pack	✘	✘	✘	✘	✘	✘	PVC 1.20 – 1.55
Documents folder	✘	✔	✔	✔	✔	✔	PP 0.89 – 0.91
Fruit punnet	✘	✘	✘	✘	✘	✘	PET 1.38 – 1.40
Milk bottle	✘	✘	✘	✔	✔	✔	Hdpe 0.94 – 0.96
Plastic bag	✘	✘	✔	✔	✔	✔	Ldpe 0.91 – 0.93
Yoghurt pot	✘	✘	✘	✘	✔	✔	PS 1.04 – 1.11

Solution	Density/g cm^{-3}	Composition
1	0.79	Ethanol
2	0.91	596 cm^3 ethanol made up to one dm^3 with deionised water
3	0.94	448 cm^3 ethanol made up to one dm^3 with deionised water
4	1.00	Deionised water
5	1.15	184 g K_2CO_3 made up to one dm^3 with deionised water
6	1.38	513 g K_2CO_3 made up to one dm^3 with deionised water

NOTE

Different manufactures use different plastics, check carefully prior to event. PVC and PET can both sink in solution six. These can be identified by IR using the ATR or by preparing thin film.

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aim

In this experiment, you will be isolating the protein found in milk. This protein is called **casein**. In fact, casein is not a single protein but a group of proteins found in milk that are also used to make cheese. Casein is also used to make plastic buttons, when mixed with other ingredients.

history

- The ancient Egyptians used casein as a fixative for the paints used in wall paintings.
- In the 18th century casein glue was developed: it is particularly good for wood.
- The first use of casein as a plastic was patented in 1899 by a German chemist called Adolf Spitteler.
- Casein plastic has been used in making buttons, knitting needles, fountain pens and electrical plugs but nowadays it is mainly used just for buttons.

The experiment

1. Take the 250 cm^3 beaker and ask the demonstrator to measure out 150 cm^3 of hot milk into this.
2. Measure out 15 cm^3 of vinegar using the measuring cylinder provided.
3. Pour the vinegar into the beaker containing the hot milk.

Q1. What do you observe at this stage?

4. Immediately start stirring the milk/vinegar mixture, using a stirring rod.

Q2. What happens as you stir?

5. Continue stirring for 2-3 mins, or until there appear to be no further changes.

Q3. What happens to the mixture when you stop stirring?

6. Take the 400 cm^3 beaker.
7. Place the piece of cloth over the beaker, and secure in place with the rubber band. Do not stretch the cloth too tight – try and make sure that there is a dip as you are going to collect the casein here.
8. Strain the mixture from the other beaker through the cloth.
9. Squeeze as much liquid as you can from the mixture. You may need to remove the rubber band and then twist the cloth above the mixture, allowing the liquid to fall into the beaker.

Q4. The solid you have made is casein or milk protein. What do you think may be present in the liquid?

10. Place the solid on a paper towel and pat dry to remove as much of the remaining liquid as possible.

Q5. What is the appearance of the solid that you have formed?

11. The solid, casein, is an important ingredient in some plastics. Now that you have a sample of homemade plastic, you can use it to make a fridge magnet. Embed a small powerful magnet (from your demonstrator) into the plastic. Your fridge magnet will be dried in an oven, ready for you to take away at the end of the day.

SAFETY

You will need to wear disposable gloves.

Background chemistry

Casein is a protein that contains a number of $–COO^-$ groups. These carry a negative charge and are therefore highly polar. This means that they are attracted to water molecules that are also polar. Vinegar is a dilute solution of ethanoic acid (sometimes called acetic acid), and is a source of H^+. When vinegar is added to casein, the $–COO^-$ groups are protonated to give $–COOH$ groups which are uncharged.

NOTE

Read through all the following instructions carefully before starting the experiment.

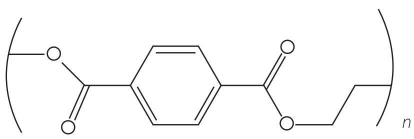
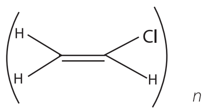
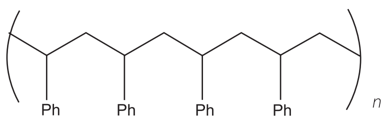
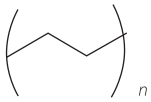
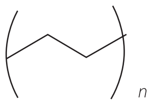
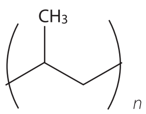
Q6. A common observation in chemistry is that 'like dissolves like', and 'like is attracted to like'. Considering this, can you come up with an explanation for the formation of casein in this experiment?

Q7. In cheese-making, cultured bacteria added to the milk react with the milk sugars to lower the pH to about 4.0. What effect would this have on the milk, and how would this help the cheesemaking process?

Identifying unknown polymers

aim

Almost five million tonnes of plastics are used each year in the UK, of which over a third is used in packaging. If these plastics are to be re-cycled there must be a straightforward method of identifying them. In this experiment you will use density and infrared spectroscopy to identify unknown samples of packaging materials.

Name	Abbreviation	Chemical structure	Density (g cm^{-3})
Polyethylene terephthalate	PET		1.38 – 1.40
Polyvinyl chloride (polychloroethene)	PVC		1.20 – 1.55
Polystyrene (polyphenylethene)	PS		1.04 – 1.11
High density polyethylene (poly(ethene))	HDPE		0.94 – 0.96
Low density polyethylene (poly(ethene))	LDPE		0.91 – 0.93
Polypropylene (polypropene)	PP		0.89 – 0.91

- At present about 7% of household waste consists of plastics and only about 7% of this is recycled.
- For each tonne of polyethylene recycled, about 1.8 tonnes of oil is saved.
- Recycled PVC can be used for sewer pipes and window frames, polyethylene can be used for bin liners and carrier bags, and PET from bottles can be used to make fleeces.
- Most plastics for recycling are currently sorted by hand but automated methods employing flotation or IR absorption are being developed.

NOTE

Next time you use something made from plastic, look for the recycling code, which appears as a number inside a triangle:

Recycling code	Plastic
1	PET
2	HDPE
3	PVC
4	LDPE
5	PP
6	PS

Density measurement

The experiment

All of the different types of plastic have different densities, as listed in the table. One simple method of identifying the materials is to measure their densities.

1. You are supplied with a set of six liquids, each with a different, **accurately known** density. A sample of plastic will float on top of a liquid of higher density and sink in a liquid of lower density.

2. Test all of the plastics in all of the liquids to determine the density of the plastic, and then its identity from the table provided.

Solution density/g cm-3	1 0.79	2 0.91	3 0.94	4 1.00	5 1.15	6 1.38	Identity of the plastic
Blister pack							
Documents folder							
Fruit punnet							
Milk bottle							
Plastic bag							
Yoghurt pot							

Infrared spectroscopy

You may have seen infrared (IR) spectroscopy used in forensic science on TV series such as CSI. This is a very sensitive technique which can be used to identify very small samples of a material.

Infrared spectroscopy depends on the fact that all of the bonds in any molecule are constantly bending and stretching and they absorb IR radiation to do this.

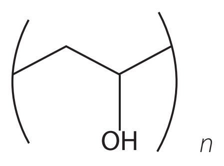
The frequency of radiation which is absorbed depends on the types of bond present in the molecule.

You will be given the opportunity to see an IR spectrum being run or be able to run an IR spectrum yourself.

Bouncing custard

Background chemistry

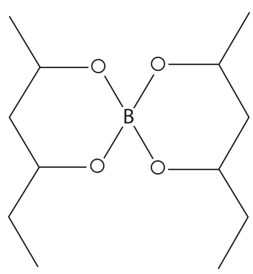
Polyvinylalcohol, usually abbreviated as PVA, has the structure shown below.



This material can be dissolved in water and in this experiment you will be using a viscous (or 'thick') 4% solution of PVA.

The purpose of this experiment is to investigate the effect of cross-linking PVA using sodium tetraborate $Na_2B_4O_7$. When sodium tetraborate is dissolved in water, borate ions $B(OH)_4^-$ are formed. These can interact with the OH groups on PVA chains, forming cross-links between the PVA chains. The O atoms of the OH groups carry a partial negative charge and the H atoms carry a partial positive charge, ie they are polar.

Opposite charges attract each other so there is attraction between the O atoms of $B(OH)_4^-$ and the H atoms of PVA, and between the H atoms of $B(OH)_4^-$ and the O atoms of PVA.



Adapted from an activity presented by Dr Julia Dickinson, Manchester Metropolitan University

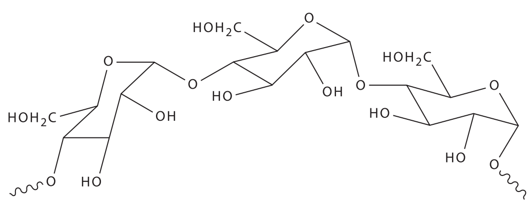
The experiment

1. Pour 15 cm^3 of PVA solution into the beaker.
2. Add two spatulas of custard powder or cornflour and one spatula of dry borax.
3. Add 0.5 cm^3 of the borax solution and stir vigorously. Keep stirring until the mixture is smooth.
4. Remove the mixture from the beaker, shape it into a ball and work it between your hands for about two mins. You should feel the ball gradually becoming more elastic.
5. Test the ball to see how well it bounces.

Troubleshooting

- If the ball is brittle, you have used too much borax.
- If the ball is too soft and not elastic, you have not used enough borax.
- The custard balls will dry out and lose their bounce unless you keep them in a plastic bag.

The borax acts as a cross-linking agent and binds the two polymer chains together as shown in the diagram. The custard powder contains mostly starch which is a polymer made from glucose. A single starch molecule can be made up of over 1000 glucose molecules. Part of a starch molecule is shown in the diagram below:



Investigations

(compare results with other people in your group)

1. **How bouncy is your custard?**
   Roll your bouncing custard into a ball and drop it from a height of 30 cm. How high does it bounce?
2. **How long does it keep its shape?**
   Make a fingerprint on the surface and see how long it stays. Use a glass stirring rod to make a dent in the surface of your custard and see how long it stays.
3. **Things to think about**
   - What is the proportion of water in your bouncing custard?
   - What might happen if you use too much borax?
   - Is your custard a solid or a liquid?