Lesson plan Synthetic Biology & Chemistry

AN INTRODUCTION FOR CHILDREN AGED 10-12

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CONTENT

INTRODUCTION

This year, team iGEM Aachen and team iGEM TU Eindhoven combined their knowledge to develop this lesson plan. The goal of this plan is to introduce children to basic concepts within the field of chemistry and synthetic biology. This is done by letting them explore chemical phenomena in an interactive and fun way by conducting five small experiments. In general, these experiments can be conducted in under 2 hours, either individually, or in small groups. Additional slides are available that include visuals of the steps that need to be taken for each experiment, as well as extra background information. In this lesson plan, we briefly go through what the learning objective is for each experiment, what the necessary materials are, how the experiment is performed, and the explanation of the underlying concept.

1 – THE FELT-TIP PEN EXPERIMENT (CHROMATOGRAPHY)

Learning Objective

The felt-tip pen experiment is used to teach the children about the different colours that a felt-tip pen is made up of, and how you can separate substances from each other based on their substance properties. With this experiment, they can see for themselves which colours are in the black marker. The colours are separated from each other by a difference in adsorption (how strongly the colour adheres to the paper), and solubility in water.

Equipment And Execution

You will need (per experiment)

- *White coffee filters*
- *Glass rod (can also be a pen)*
- *Drinking glass*
- *Water*
- *Water-soluble felt tip pens (brown and black work best)*
- *Pencil*
- *Ruler*

For each experiment, an oblong strip is cut out of the filter paper that fits into the glass. Then, using a pencil and a ruler, the children will draw a straight line at the bottom of the paper, about 1 cm above the edge. Now the children can mark the line with felt-tip pens; the dots must be at least 1 cm apart. Let the children fold the filter paper so that they can hang it over the rod. The rod can now be placed on the glass so that the paper falls into the glass. Fill the glass with water until it just touches the bottom of the paper. Now wait a few minutes and let the children observe how the dots differentiate into different colours. The colours depend on the brand of the marker.

Explanation

Black is not one of the basic colours of colour mixing, so the black colour in felt-tip pens is obtained by mixing different colours. The colours shown on the filter paper are the colours from which the black was mixed for the felt tip pen.

The colours are separated because the individual colour components dissolve in the water and react with the filter paper to varying degrees. The water "creeps" onto the filter paper and takes the colour pigments with it.

In the laboratory this method is also used, here it is called chromatography. This method is used in the lab to separate products from undesirable by-products.

2 - LAVALAMP

Learning Objective

The aim is to teach the children about the density of materials. In this case, the density of vinegar is greater than that of oil, so the vinegar will sink to the bottom. In addition, the effect of bicarbonate of soda, which will create gas bubbles in the vinegar. We know that gas will rise, so it will take some of the coloured vinegar up with it. In this way, we can give knowledge about density and gases in a 'spectacular' experiment.

Equipment And Execution

You will need (per experiment):

- *Drinking glass*
- *Teaspoon*
- *50 mL vinegar*
- *10 drops of food colouring*
- *150 mL oil*
- *1 tsp baking soda*
- *Optional: Mobile phone with flashlight*

Give the children a transparent glass. Have them put 50 mL of vinegar into the glass and then add about 10 drops of colouring. With a teaspoon, they can then stir well so that the dye is dissolved in the vinegar. Then, about 150 mL of oil will be added to the mixture. Next, the children can add a teaspoon of baking soda, which will cause gas bubbles to form in the vinegar, which will then rise and take coloured vinegar along with them. Baking soda can be added several times, each time creating the same effect. Optionally, a mobile with a flashlight function can be used to light up the glass from below, this way the lava lamp looks even more impressive!

Explanation

When the oil is added to the vinegar, two layers are formed in the liquid; the oil floats on the vinegar. This is due to the difference in density of oil and vinegar. Density indicates how close the particles of a specific substance are to each other. The density of vinegar is higher than the density of oil, so the particles are closer together. Because of this, the oil cannot pass through the vinegar, so it stays on top of the vinegar.

When the baking soda is added, coloured bubbles appear in the mixture. This is due to a chemical reaction between the baking soda and the vinegar, resulting in the formation of gas bubbles. These bubbles are very light and therefore rise up to the top of the mixture. But as soon as the gas in these bubbles reaches the surface, it will escape, causing the bubble to burst and the colour to sink back down.

The nice thing about this experiment is that it can be done more than once. If you add a scoop of bicarbonate of soda a second time, new bubbles will form. In this way, we can make the lava lamp several times

3 - FIZZY DRINK

Learning Objective

The aim of this experiment is to introduce the children to simple chemical reactions. When citric acid and baking soda are added together, this leads to a reaction in which carbon dioxide is produced. You can perceive this as small bubbles in your drink and feel it as a slight stinging feeling on your tongue.

Equipment And Execution

You will need (per experiment):

- *Drinking glass*
- *Spoon*
- *1 tsp sugar*
- *1 tsp citric acid*
- *1 tsp baking soda*
- *Water*

Hand out empty glasses to the children and have the children mix about a teaspoon of sugar, baking soda and citric acid in this glass. Let the children pour about half a glass of water over this mixture, and the fizzy drink is ready! With these ingredients, the drink only tastes of lemon and sugar, but you can experiment with different flavourings and colourings. This way you get coloured lemonade that tastes different.

Explanation

Commercial fizzy drinks contain sugar, baking soda (sodium bicarbonate) and tartaric acid. They also contain flavourings, colourings, and sweeteners. In this experiment, we use citric acid instead of tartaric acid, because you cannot buy tartaric acid in every shop. Citric acid has the same effect as tartaric acid but should not be ingested in large quantities because it can cause nausea. However, a teaspoon per glass is perfectly safe.

Why the drink fizzes is because of the chemical reaction of the acid with the sodium bicarbonate, which produces carbon acid. This bubbles in the glass, and tingles on the tongue. The same effect can be observed with carbonated water.

4 - PEPPER AND SOAP EXPERIMENT

Learning Objective

Through this experiment, children learn what happens when you wash your hands, and why using soap is so important. The pepper on the water surface represents the dirt on our hands. If you put your finger in the bowl without soap, nothing will happen, but if you put a bit of soap on your finger, the pepper moves to the edge of the bowl; the dirt comes off your hands.

Equipment And Execution

You will need:

- *Bowl or container with water*
- *Pepper*
- *Soap*

The children receive a bowl with water in which they can sprinkle their pepper. There is a soap pump and an extra bowl of water for each group of four. Firstly, the children put their finger in the extra bowl of water and then in the bowl of water with pepper. They can see that nothing will happen to the pepper. Next, everyone can put a little soap on their finger, and put their finger in the bowl with pepper. The pepper will now move to the edge of the bowl.

Explanation

How is it possible that the pepper suddenly moves on its own? This is because water consists of small particles (molecules), which all attract each other like magnets. At the top of the water, this creates a strong layer that lies over the water like a net. This net is called the surface tension. The surface tension ensures that the peppercorns can remain on the surface. As soon as we put soap on the surface, the soap particles place themselves between the water particles. This breaks the "net" and the peppercorns can no longer float, so they move quickly to the edge of the bowl where the net is still intact. Eventually, the surface tension is broken everywhere and the pepper stops moving.

This experiment illustrated the importance of washing your hands with soap, because without soap, the dirt particles just stay in place.

5 – CORNSTARCH EXPERIMENT

Learning Objective

The children learn that all kinds of substances have different properties. One of these properties is viscosity. Not all liquids are equally fluid. You can see this, for example, when you put water or syrup on a spoon. Water has a low viscosity and syrup has a high viscosity. Chemists often use this when they make materials.

Equipment And Execution

You will need (per experiment):

- *Bowl or container*
- *Spoon*
- *Paper towels*
- *60 mL water*
- *75 gram cornstarch*

The children are given a container with 60 mL of water and a bag containing 75 grams of cornstarch (weighed out beforehand). They also get a spoon and some pieces of kitchen paper to clean up the mess and dry their hands. The cornstarch is mixed with water and stirred with a spoon. When the mixture is ready, the pupils can investigate on their own. What happens if you move through the mixture quickly with your hands, and what happens if you move through it slowly? Below are some examples of tasks the children can carry out to investigate the properties of the mixture:

- Have the children dip their finger in slowly and pull it out quickly
- Have the children dip their finger in quickly and slowly
- Have the children stir the mixture quickly and slowly
- Have the children make a ball out of the mixture (note: this does make a mess!)

Explanation

This mixture of cornstarch and water is a so-called colloid. If you move your hands through the mixture quickly, the mixture acts like a solid, but if you move slowly, it acts like a liquid. When you mix cornstarch and water, the cornstarch particles do not dissolve in the water. The solid cornstarch particles and the liquid water are mixed. Such a mixture is called a suspension.

The strange thing about this mixture is that it acts like a solid when you move your finger quickly, but it acts like a liquid when you move your finger slowly. When pressure is applied to the mixture, the cornstarch particles are pressed together and the water cannot flow through them properly. The cornstarch particles then look like a solid. If you do not apply force to the mixture, the water can move between the cornstarch particles. The mixture then looks like a liquid.

During this experiment, you may notice that the viscosity of water is much lower than the viscosity of cornstarch with water. Scientists often use this when they make materials. For example, paint should stick to the wall and not drip off, as water would.

6 – DETERMINATION OF BLOOD GROUP

IGEM UNIZAR

Caution! This experiment should only be done with approval of parents.

Learning Objective

This experiment shows the importance of blood group classification and how it is determined. Blood groups are very important when we talk about blood transfusions and pregnancy. Because if we get the wrong group our body can generate antibodies against strange blood antigens and that can cause severe disease.

Equipment and Execution

You will need:

- *Anti-A, Anti-B, Anti-D antibodies*
- *Microscope slides*
- *Blood*

Execution:

1. Collect blood on 3 places of the microscope slides. Note: blood can be easily obtained by finger puncture.

2. On separate places, drop a drop of Anti-A, Anti-B, and Anti-D liquids and mix them with different sticks.

3. Observe and note which place(s) shows agglutination.

The following table helps with the interpretation of the results. Note: "+" means agglutination is shown and "-" means no agglutination.

<table>
<tr><th>Anti-A Agglutination</th><th>Anti-B Agglutination</th><th>Interpretation Group</th><th>Anti-D Agglutination</th><th>Interpretation Rh</th></tr>
<tr><td>+</td><td>-</td><td>A</td><td rowspan="2">+</td><td rowspan="2">+</td></tr>
<tr><td>-</td><td>+</td><td>B</td></tr>
<tr><td>+</td><td>+</td><td>AB</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>-</td><td>-</td><td>O</td></tr>
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Explanation

Blood groups are based on the presence (or not) of antigens on the surface of red blood cells. Antibodies attach their specific antigen (A, B, or Rh) and create a net, which is shown as agglutination in this experiment.

During the experiment is important to be careful with antibodies because if you mix different antibodies in the same place, it can cause false results.

7.1 – DNA EXTRACTION FROM FRUIT

IGEM UNIZAR

Learning Objective

This experiment allows students to see DNA contained in plant cells. This is important because they might know that cells have DNA, but they haven't seen it.

Equipment And Execution

You will need:

- *100mL distilled water.*
- *10mL dish soap.*
- *1/2 spoon salt.*
- *Fruit (if you can't use fruit, you can use juice). The results will be better if mango, kiwi or strawberry is used.*
- *Blender.*
- *Coffee filter.*
- *100-150mL ice-cold alcohol ethanol (or isopropanol).*
- *Beaker.*
- *Funnel.*
- *Test tubes/ Eppendorf.*
- *Sticks.*

Execution:

1. Mix 100mL distilled water with 10mL dish soap and 1/2 spoon salt in a beaker. (10% detergent solution).

2. Cut fruit into small pieces, peel and take out large seeds. Place fruit in a blender and crush it until the fruit is completely mashed.

3. Add soap/salt solution in a blender and mix it for 30 seconds.

4. Filter the liquid through a coffee filter and collect the solution in a test tube. You can use a funnel to do this step.

5. Wait until about 50mL are filtrated. If filtrate lasts more than 5 minutes, add tap water over the coffee filter.

6. Pour between 100-150 mL of ice-cold alcohol into the test tube.

7. DNA will look like white strings or mucus.

Explanation

We cut and puree the fruit to break cell walls, we create a 10% detergent solution to break plasma and nuclear membranes, and we add salt to make DNA stable. Finally, we add ethanol to precipitate the DNA and observe white strings or mucus.

With this procedure, we have released DNA but also other molecules such as proteins. Some proteins can damage the DNA of the solution and that's why sometimes we add different enzymes to the solution.

7.2 – ISOLATE YOUR OWN DNA

TEAM WAGENINGEN_UR

Learning Objective

Every cell in your body contains DNA, a very long string of "letters" that describe all the functions the cell can perform. Every person has their own unique DNA code. The DNA string inside the cell is very small and cannot be seen with the naked eye, but a lot of DNA together from several cells can be made visible. In this practical, you will follow a protocol to do this and have a look at your own DNA!

Equipment And Execution

You will need (per experiment):

- *1 test tubes*
- *Test tube rack*
- *Paper cups*
- *200 ml beaker glass*
- *Teaspoon*
- *1 plastic Pasteur pipette*
- *Salt (few grams)*
- *Liquid dish soap (few drops)*
- *Cup of water*
- *Cold ethanol*

Execution of the experiment:

1. Fill the beaker glass with 100 mL water.
2. Put half a teaspoon of salt in the water and stir until it is completely dissolved.
3. Add 3 drops of liquid dish soap using the plastic pipette and stir. Keep the solution.
4. Take a sip of new water in your mouth and wash your mouth for 1 minute (don't swallow!).
5. Spit out the water in the paper cup.
6. Transfer a bit of the water from your mouth into a test tube until a height of about 3 fingers.
7. Add 2 ml of the salt-soap solution to the test tube.
8. Gently shake the test tube.
9. Carefully add 4 mL of the cold ethanol to the tube. Don't shake!
10. Let the solution rest for a bit and look carefully at what you see.

If successful, you will see a small white 'lump' of precipitate in the liquid. This is your DNA!

Explanation

By washing your mouth with water, some of your cells that are present in your mouth (for instance in your spit) will be dissolved. When you add these cells to the salt-soap solution, the soap will break down the outside of the cells releasing the DNA into the solution. To see the DNA, it needs to clump together to form a large precipitate. This is what the salt does. The individual DNA strands would normally be dissolved (so evenly distributed) in the water, but the addition of the salt cancels this out, and favors the clumping together of the DNA in the solution. If all the DNA of the multiple cells from your mouth water clumps together, it is enough to form a small white sticky mass of DNA, that you can see with the naked eye.

When you shake the solution, the salt effect will be undone, so be careful!

8 – CATCH YOUR OWN MICROORGANISMS

TEAM WAGENINGEN_UR

Learning Objective

Although we normally cannot see microorganisms, they are everywhere! This experiment helps to visualize the diverse world of microorganisms by challenging kids to "catch" microorganisms in and around their houses with agar plates. Different types of agar plates are provided to the kids, and they will open them at the location of their choice. Different agar plates and locations will result in seeing different types of microorganisms. This way all kids will "catch" their own unique microorganisms!

Equipment And Execution

You will need (per experiment per kid):

- *2 agar plates with tween-80*
- *1 agar plate with casein,*
- *1 agar plate with starch*
- *1 agar plate with malt*
- *Iodine solution*
- *1 plastic Pasteur pipette*

What you need to prepare:

1. Sent the kids agar plates at least a week before the kids come together for the experiment
2. Instruct the kids to wipe their fingers on the tween-80 plates before and after washing their hands, or to press small objects in and around the house in them (e.g., keys, coins, earrings)
3. Instruct the kids to leave the casein, starch, or malt plates without a lid for 1 hour inside or 15 minutes outside the house
4. All plates should be kept closed for a week at room temperature before the kids take the plates with them

Execution of the experiment:

5. Let the kids examine their dirty plates. They should describe what they see: shape, color, amount, etc.
6. For the tween-80 plates, the kids should compare the finger swipes and objects to determine what is dirtier
7. Drop some iodine solution onto the starch plates
8. Let the kids examine the changes in the plates: differences in colors for the casein and starch plates, and fungal growth on malt plates.

Explanation

The agar plates provided to the kids are perfect for growing "wild" microorganisms. The different locations, but most importantly, the different nutrients will result in different microorganisms and things to see. The tween-80 plates will show fewer microorganisms for the finger-wipe after washing your hands, as your hands will become "cleaner" (you will remove bacteria from them). For the casein plates, some patches will lose their original white color when the microorganisms on them can degrade the casein (this is visible as a halo around the colonies). The remaining starch in the starch plate will become dark once iodine is added, as iodine binds to the starch. This way it can be determined that the starch is consumed around the colonies on the plate (as those parts of the plate stay light). The tween-80, casein, and starch plates will contain mostly bacteria. In contrast, the malt plate will most likely grow fungi or yeast (while the other plates will contain many bacterial colonies).

9 - THE BIOLOGICAL PUMP

BOKU-VIENNA

Learning Objective

The aim of this experiment is to show the kids what happens during fermentation that microorganisms can use sugar to produce gas. This can be used as an example of the ability of microorganisms to use food that we eat or nutrients that we excrete for their own metabolism. Here it can be hinted that this microorganismal ability could be taken advantage of to produce food and other useful things. Examples of bread, yogurt, or vinegar can be given for processes where microorganisms are commonly used.

Equipment And Execution

You will need (per experiment):

- ¼ cube of yeast
- 3 tablespoons of sugar
- 1 plastic bottle (300-500ml)
- 1 balloon
- 1 jar
- small candle

1. Pour enough lukewarm water into the bottle to fill it about halfway.
2. Add the sugar and yeast to the water, stir well and pour the mixture into the bottle.
3. Blow the balloon a few times to help it expand. Put the mouthpiece over the bottle opening. The balloon must hold firmly on the bottle.
4. Place the bottle in a warm place. Now you just need a little patience. After 15 minutes you will see how the balloon starts to rise. After a few hours, the balloon should be "blown up".
5. Light the small candle and place it in the jam jar, where it will continue to burn cheerfully. Take the filled balloon from the bottle, close the balloon with your fingers, and open it over the jam jar. Let the gas flow from the inside of the balloon into the jar with the burning candle. Observe the flame.
6. Try a new filling of the balloon the same way as before.
7. Smell the contents of the bottle carefully.
8. Dispose of the contents of the bottle via the local sewage system.

Explanation

Fermentation is a process in which an organism converts a carbohydrate, such as starch or sugar, into an alcohol or an acid. This process can be seen as part of the yeast's metabolism during which it also produces gas (CO2). After letting the yeast work for a few minutes, the yeast has broken up enough sugar molecules and therefore has produced enough gas to fill and lift the balloon. If the balloon is then opened over the jar with the small candle, the flame will vanish since it needs oxygen to burn and the CO2 in the balloon will reduce the oxygen and therefore suffocate the flame.

10 – ELEPHANT TOOTHPASTE

iGEM KU Leuven - Belgium

Learning Objective

This experiment aims to show kids the complementarity between biology and chemistry. Most children have a faint idea of these two science fields, but they often think of them as separate tracks. Therefore, using yeast as a biological resource, elephant toothpaste is created from the catalase-mediated decomposition of hydrogen peroxide. This introduces kids to the concept of enzymes and chemical reactions as a link between biology and chemistry.

Equipment And Execution

- Aluminum container (or any other large container)

- 100 ml cylinder
- Beaker
- Spoon
- Yeast powder
- Warm water
- 45 ml hydrogen peroxide (8%)
- Food colouring
- 20 ml liquid soap
- Safety goggles

1. Put the safety goggles on. Place the cylinder in the container so that the foam can be trapped in the container.
2. Add around 45 ml hydrogen peroxide to the cylinder, add around 20 ml of liquid soap, and add several drops of food colouring that will give colour to the foam later.
3. Add around 1 spoon of yeast powder in the beaker, add 3 spoons of warm water to the yeast, and stir.
4. Pour the yeast solution in the cylinder. Coloured foam should develop.

Explanation

The result of the experiment is the creation of coloured foam. This is created from a fast chemical reaction that took place in the cylinder. The added yeast contains within their cells a substance called 'catalase'. This is an enzyme that facilitates a specific chemical reaction that is the fundament for foam development. This enzyme transforms hydrogen peroxide (the liquid in the cylinder) into water and oxygen gas [$2H_2O_2 \dashrightarrow 2H_2O + O_2\uparrow$]. The enzyme works very quickly, making this a very fast reaction. Consequently, oxygen bubbles are rapidly produced in the liquid in the cylinder, which in the presence of the soap are trapped into soap bubbles. Because of the rapid reaction speed and the narrow cylinder, the soap is produced very quickly and is pushed outside the cylinder. The food colouring only ensures the colour of the foam. This experiment easily shows the connection between biology and chemistry: in cells (and our body in general), various fast chemical reactions are performed to sustain life, which are facilitated by special enzymes.

11-RED CABBAGE AS PH INDICATOR

BIELEFELD-CEBITEC

Learning Objective

The children should learn that different liquids are acidic or basic to different degrees. With the help of red cabbage water as a pH indicator, they can see what pH their tested liquids have. Thus, they can learn that acids and bases can be classified by seeing different color changes depending on what testing substances they use.

Equipment And Execution

You will need (per experiment):

- *Test tubes & test tube stand or other small glass containers*
- *Red cabbage*

- *Cutting board & knife*
- *Water boiler*
- *Bottle*
- *Pipettes*
- *Safety goggles*
- *Test substances, e.g.*
    - *Lemons, vinegar, soapy water, sparkling water, dest. water, or anything else you want to test*

Take a raw red cabbage and cut some of it into small pieces. Use a water boiler or a pot to make the water boil. Then put the red cabbage in hot water and boil it until the water takes on a reddish-purple color. Let the liquid cool down. Until the experiment begins, you can store it in a bottle, for example. The reddish-purple water can now be used to test the acidity of various other liquids such as soapy water, vinegar, sparkling water, or distilled water. You can of course test all liquids of your choice! To test, pour some of your red cabbage solution into test tubes or other small glasses. Then drip a few drops of your test liquid (for example vinegar) into it. Observe how the color of the red cabbage water changes! In the case of vinegar, the liquid will turn red, which means that vinegar is acidic!

Explanation

The color change is caused by a pigment in red cabbage called anthocyanin. This dye changes color depending on the acidity. Accordingly, you can use it as a pH indicator. Thus, the pH is a measure that tells you how acidic your solution is. The smaller the number of the pH, the more acidic the solution is. Water (H_2O) has a pH of 7 and is therefore neutral. A pH of 1, on the other hand, is therefore very acidic. In the red cabbage experiment, the color of the sample changes according to the following pattern: red: pH 2 (very acidic), purple: pH 4, blue-violet: pH 6, blue: pH 7 (neutral), blue-green: pH 10, greenish-yellow: pH 12 (very basic).