VILNIUS 2012

26th of April, 2012

Experiment 2

Tasks

$Country

Space Exploration

General instructions

Wear the supplied plastic coat and protective goggles at all times in the laboratory.

Eating and drinking is prohibited in the laboratory.

It is highly advisable to wear disposable gloves and protective eyewear when handling chemicals.

All paper used, including rough work paper, must be handed in at the end of the experiment.

All results must be entered into your Answer Book.

Your graphs must be handed in along with the Answer Book.

Only the final Answer Book, and the attached graphs, will be marked.

The experiment consists of 4 Tasks and can be completed either individually or as a team.

Task 1: 24 credit points

Task 2: 24 credit points

Task 3: 24 credit points

Task 4: 8 credit points

Introduction:

Ever since the first Moon landing in 1969 many kids from all over Europe have wanted to participate in space exploration.

Every space mission requires huge amounts of teamwork and cooperation. Now Europe has its own Space Agency and is involved in research in this field. Concerted efforts of biologists, chemists, physicists and collaboration with other specialists from different countries contribute to the success of space exploration. In the year 2010, Lithuania signed a Cooperation Agreement with the European Space Agency. Bearing this in mind, today's experiment was designed to show some perspective areas of research in this field.

A modern spacecraft is a very complex system; it needs thousands of components to take off, land safely, collect data, perform experiments, and most importantly, sustain astronauts' life. In addition, the weight of the spacecraft has to be optimized so that it is not too heavy. Otherwise, the spacecraft will not overcome gravity and fail to launch.

Today you will try to improve the essential component of each space mission – the system for regenerating oxygen. Firstly, one person from your team will analyze the current system (a chemical air filter, containing peroxide salts). Meanwhile, your teammates will investigate a new, living air supply (algae). As you know, algae produce oxygen through photosynthesis. You will need to measure the rate of this process, its light requirements, and the amount of algae needed to supply the whole crew with air. Finally, you will compare the two systems and decide which is the more suitable for the expedition.

TASK 1: Light illumination characteristics

During photosynthesis oxygen is produced. This process, however, is affected by a number of factors. One is illuminance (also known as illumination), which describes the total luminous flux incident on a surface, per unit area. In SI derived units these are measured in lux (lx).

In this task you will evaluate the light illuminance irradiating the biological system at different distances between the light source and the object. In addition, you will evaluate the incident light illuminance dependence on the incident angle.

Equipment and material:

- 2 x light source (halogen bulb, 20 W)
- 2 x Connecting wires
- 1 x Photo resistor with holder
- 1 x Multimeter
- 1 x Ruler
- 2 x cardboard boxes: the bigger (longer) box is for shared use with biologists; the smaller box is for angle dependence measurements
- 1 x Protractor

Task 1.1. Investigation of illuminance dependence on distance

Set up the experiment as shown in Fig. 1. Connect the wires to the multimeter. Use the bigger (longer) box.

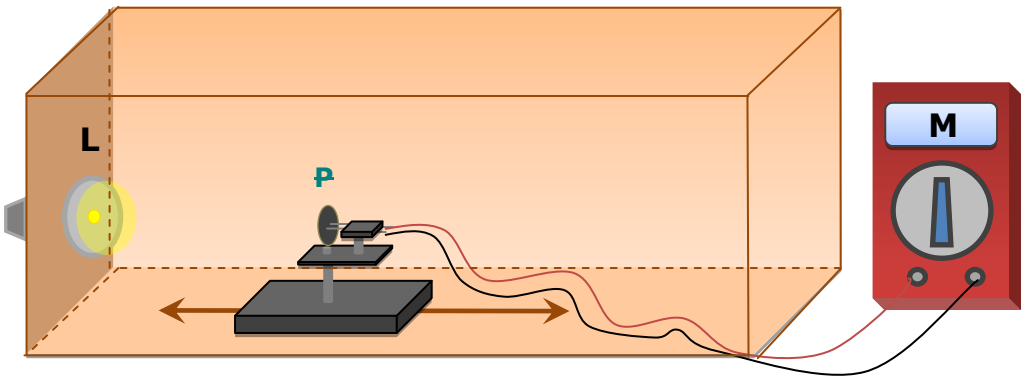


Figure. 1. Experimental set-up system. L - Light source, Ph – Photo resistor with holder, M – multimeter.

Before starting measurements, check that the halogen lamp is plugged into the power socket. Once connected, place the photo resistor at a distance of 5 cm from the face of the lamp. Measure the photo resistor resistance using the multimeter. Follow the instructions below:

Instructions:

1. Connect the red test lead to "V Ω mA" jack and black test lead to the "COM" jack. Ensure that the hold button on the multimeter is not pressed in and the display does not show an "H" symbol. If the "H" symbol is displayed push the hold button. ***Warning! Do not touch the halogen lamp during the experiment, it could be hot.***

2. Set the rotary switch to the desired "Ω" range position and read the LCD display.

Move the photo resistor with the holder from the light source and read the display. NOTE: You will need to collect enough data to draw a valid graph.

Fill in the table in the Answer Sheet (Task 1.1) with the distances and resistance. Do not forget to include the units of measurement.

Draw a graph showing the dependence between resistance and the varying distances as in Fig. 2 (a). Graph paper can be found in your envelope. Label your graph clearly.

Use the calibrating graph to determine the corresponding values of light illumination(refer to Appendix 1 at the end of this document) and fill in the corresponding column (Task 1.1).

Draw the graphical dependence of illuminance on the distance in the same diagram as shown in Figure 2 (b). Label your graph clearly.

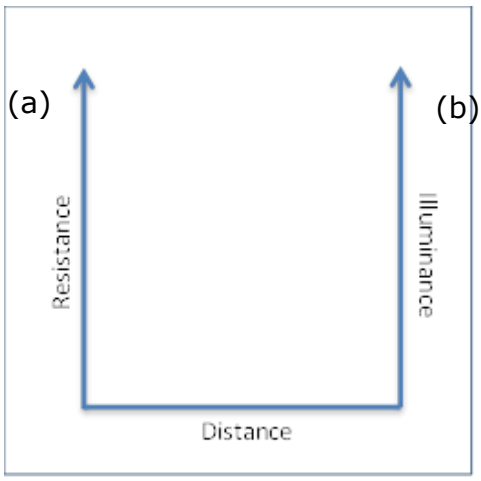


Figure 2. Resistance of the photo resistor (a) and light illuminance (b) as a function of the distance.

Task 1.2. Investigation of light illuminance dependence on angle

Evaluate the incident light illuminance dependence on the incident angle. Use the smaller sized box. Throughout **Task 1.2,** ensure that the photo resistor with holder and the light source are fixed at the same distance. **Please write in the <u>Answer Sheet</u> the distance from the light source that you used.** The illuminance can be measured as a function of the incident light angle (the angle between the light propagation direction and the perpendicular to the photo resistor plane) rotating the photo resistor holder (H) as shown in **Fig. 3**.

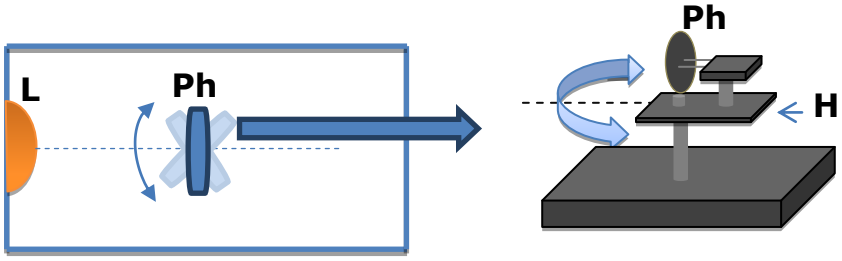


Figure 3. Experimental set-up for the light intensity measurement as a function of incident angle. L - Light source, Ph – Photo resistor with holder, H – holder place which should be used for rotation.

Use the protractor to measure the angle.

Fill in the table on the <u>Answer Sheet</u> (Task 1.2.) with the angle, resistance and illuminance values. Do not forget to include units of measurement.

Draw a graph showing the dependence of illuminance on the incident angle on the <u>graph paper found in your envelope.</u> Label your graph clearly.

Task 1.3.1. Theoretically determine which function correctly describes the illuminance dependence on the incident angle and distance? *E* denotes illuminance I is a constant, *r* is the distance between the light source and the device, and α is the incident angle. Assume that the light is from the point source. **Circle the correct answer on the Answer Sheet**.

a) $E = I \cdot r \cdot \cos\alpha$

b) $E = \frac{I}{r^2}\cos\alpha$

c) $E = \frac{I}{r}\sin\alpha$

d) $E = I \cdot r \cdot \sin\alpha$

e) $E = \frac{I}{r}\cos\alpha$

Task 1.3.2.1 Are the values of illuminance significantly different when the box is closed or open? **Circle the correct answer** on the Answer Sheet.

Task 1.3.2. Circle the answer on the Answer Sheet that best explains the above phenomenon;

a) extra light is penetrating from the environment and is rather intense
b) extra light penetrating from the environment is rather weak
c) the photo resistor is directed to the halogen bulb light
d) the photo resistor collects just the halogen bulb light

Task 1.3.3 Why is the climate different at various Earth latitudes? **Circle the correct answer on the Answer Sheet**.

a) The radiation energy per unit area coming from the Sun is different due to the change of incident angle at various latitudes
b) Different points of the Earth are located at different distances from the Sun
c) The climate is different due to different types of energy reaching the surface of the Earth from its depth
d) The climate is different due to various air and water streams

End of **TASK 1**.

TASK 2: Estimation of photosynthesis rate using the immobilised algae

Algae are plant-like microorganisms, which are able to turn sunlight into chemical energy. Despite the fact that algae are small, large quantities together can produce three quarters of all the oxygen in our atmosphere. With this in mind, this task will investigate whether or not algae could be an efficient oxygen supplier for a spacecraft.

Equipment and material:

- *Chlorella sp.* culture (labelled "Algae")
- Sodium alginate solution (labelled "NaALG")
- 100 mL 0.15 M calcium chloride solution
- 100 mL 1 mM sodium hydrogen carbonate solution
- 5 mL 0.5 M EDTA solution in a 15 mL plastic tube
- 100 mL beaker for calcium chloride solution
- 10 mL pipette for algae
- 1 pipette filling bulb to be shared with chemistry teammates
- Syringe (needleless, 10 mL volume) for alginate and mixture
- Stirring rod

- 50 mL beaker for mixing algae and alginate
- Tea strainer
- Petri dish for algae capsule storing
- Waste container, shared between your teammates
- 5x Glass bottles with stoppers (for photosynthesis reactions)
- Aluminum foil
- Cytometer and cover slips
- Tweezers
- Microscope
- pH meter
- 2xPlastic Pasteur pipettes
- Cardboard box (bigger in size) to share with physicists
- Tube rack
- Timing device

Preparation of immobilised algae

In order to estimate the rate of photosynthesis it is necessary to control the number of cells in the experiment by immobilising unicellular organisms. Immobilisation is easy to perform using sodium salt of alginic acid, which is a polysaccharide extracted from brown seaweed. Calcium ions non-covalently bind to adjacent alginate chains and form a semi-solid gel. Cells or large molecules become trapped in the gel, whereas small molecules can easily diffuse.

2.0 Prepare the capsules of immobilised *Chlorella* sp.(algae):

1. Take the 100mL beaker and pour 50 mL of 0.15M calcium chloride solution into it.
2. Invert the tube with the algae several times to re-suspend the cells completely.
3. In a 50 mL beaker prepare at least 6 mL of mixture containing <u>equal volumes</u> of algae and sodium alginate solution. Use a syringe for alginate and a 10 mL pipette for the algae.
4. Using a stirring rod, mix thoroughly for even distribution of the cells in the solution.
5. Use the syringe to draw in the mixture into a 10 mL syringe (refer to **Fig. 4a and Fig. 4b**).

Follow the instructions below very carefully: <u>if you fail during this step, you may ask for</u>

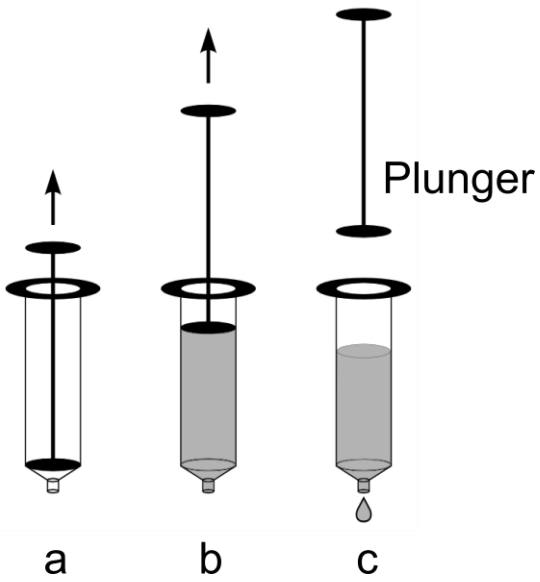


Figure 4: Schematic diagram of a syringe

additional algae or alginate, but you will receive a penalty of 5 points!

6. Hold the syringe approximately 10 cm above the beaker with calcium chloride solution. **Take the plunger out of the syringe** (see **Fig.4c**). You will observe the mixture of sodium alginate drip slowly into the $CaCl_2$ solution. You will then observe the formation of small green capsules that will float in the solution. Leave the capsules in the calcium chloride solution for an additional 10 minutes.

7. Collect the capsules using the tea strainer and wash them with distilled water (perform both actions over the shared waste container, as shown in **Fig. 5**). Place the capsules into a Petri dish and cover with distilled water.

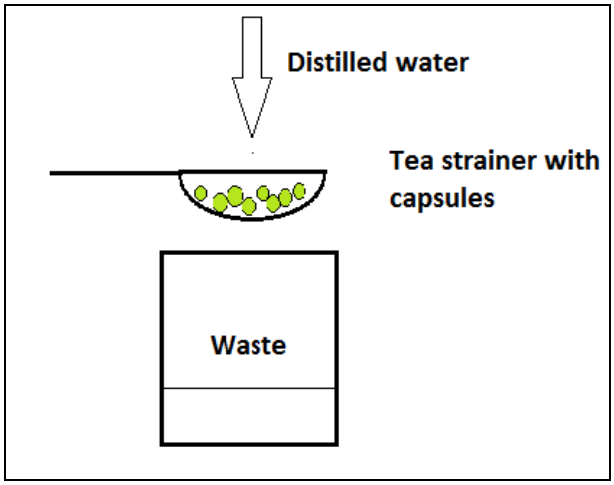


Figure 5. Scheme depicting capsule washing over the waste container.

8. Out of the large number of capsules you have obtained, take at least 65 equal-sized capsules for the following experiments. To get accurate results, use only spherical, equally sized capsules without air bubbles. Keep them in water until you are prepared for **Task 2.1.**

The light source

To avoid the sunlight interfering with your results, you are going to perform the experiment in a big cardboard box. Make sure you plan the experiment with your physics colleagues because they will also need to use the same box for their experiment. ***Throughout the experiments, the box must remain on the table!***

The light source has already been set up for you.

	***CAUTION*** ***Risk of burns and electric shock. DO NOT touch the bulb, as it becomes hot during use. DO NOT touch any wires or sources of electricity. Take extreme care handling reagents and solutions near sources of electricity, wires and the bulb. In case of an emergency, call a lab assistant immediately!***

Task 2.1. Estimating the rate of photosynthesis

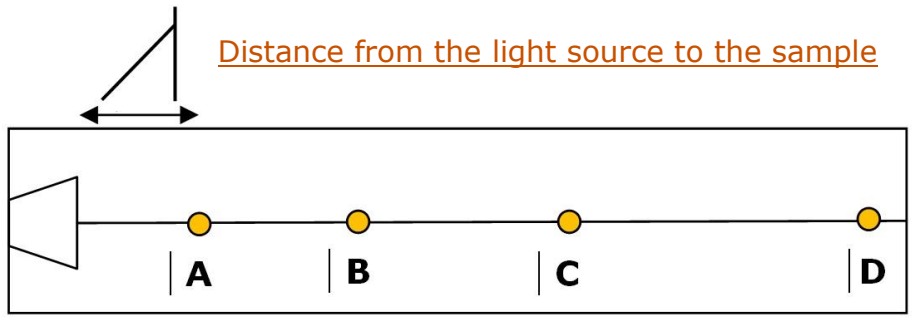
Algal cells exposed to light will perform photosynthesis, because *Chlorella* sp. cells have chlorophyll containing chloroplasts. You will need to measure the pH change of the bicarbonate solution to estimate the rate of oxygen regeneration. Assume that the only sources of inorganic carbon for the cells are the bicarbonate ions in the solution. Follow the instructions below:

1. Select 50 capsules from your petri dish that are equal in size and evenly distribute them into 5 glass bottles (10 capsules into each bottle).
2. Label the bottles A, B, C, D and 0.
3. Fill each bottle with 4 mL of bicarbonate solution using a Pasteur pipette. Make sure that there are no air bubbles in the capsules at the bottom of the bottle. **Stopper each bottle very gently – thin glass walls are prone to breaking!**

Tick (√) the box(es) on the Answer Sheet that would indicate the appropriate placement for the control tube. (Task 2.1.1.).

4. Use bottle "0" as the control; apply the adequate conditions you determined in **Task 2.1.1.**
5. Put the bottles A-D in the box. Use the distances (measured from the light source, as shown) and placement scheme provided in **Fig. 6**.

   NB: the light bulb emits a narrow beam of light, so the bottles must be placed in a straight line directly in front of the source! Absorption and diffraction will not have a significant influence on the results.



Position	A	B	C	D
Distance, m	0.05	0.20	0.40	0.90

Fig. 6. Correct placement of the bottles in the box. Distances to the light source (measured from the light source) shown below.

6. Switch the light source on and leave your samples for 30 minutes. However, when 15 minutes has elapsed, you will need to invert each tube once to mix the solution inside. Use the timing device as a normal clock - do not push any of the buttons on the device.

NB! We strongly recommend proceeding to Task 2.2 while you are waiting.

7. After 30 minutes measure the pH of each of the solutions A-D and 0 using the pH meter. Measure the pH of the initial bicarbonate solution in order to estimate the pH change in the tubes. ***Please refer to Appendix 2 "Operating the pH meter".***

Fill in the table on the Answer Sheet (Task 2.1.2.) with the measured pH values.

Write chemical equations for this experiment (Task 2.1.3.) on the Answer sheet.

Calculate the change in $H_3O^+_{(aq)}$ concentration (Task 2.1.4.) and calculate the maximum possible yield of oxygen per tube (Task 2.1.5.) on the Answer Sheet.

Task 2.2. Calculating the algal cells in the capsules

Like most cells, the majority of unicellular algae are too small to be seen with the naked eye. In order to estimate the number of such organisms, special cell counting chambers (cytometers) will be used. These counting cells are simple devices that resemble a microscopy slide. There are two identical 0.1 mm depth wells with special ruling in between that can be seen under the microscope (see **Fig. 7**).

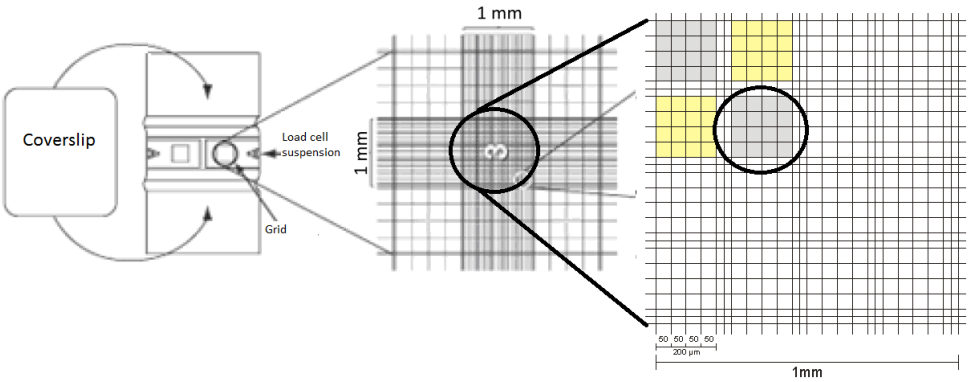


Figure. 7. Cytometer lines. Rulings cover 9 square millimeters. Boundary lines of the ruling are the centre lines of the groups of three. The central square millimeter is ruled into 16 groups of 16 small squares, each group separated by triple lines, the middle one of which is the boundary. The ruled surface is 0.10mm below the cover slip.

Procedure*:*

1. Add 10 capsules (prepared in **Task 2.0**) into the plastic 15 mL tube containing 5 mL EDTA.

2. Estimate the final volume and calculate the average volume of a capsule (**Write your answer on the Answer Sheet Task 2.2.1**).

3. Stopper the tube. Shake the tube until all the capsules are dissolved. This will take a while.

4. Breathe on the surface of the cytometer and place the cover slip on the edge of the cytometer as shown in Fig. 8 below. With your two thumbs firmly, but carefully, push down on the cover slip and slide it forward so that it is now placed in the centre of the cytometer. Once the cover slip is in position you should be able to see diffraction rings. If these are not present try again. Use a pipette to put a drop of your sample in the groove as shown in the picture.

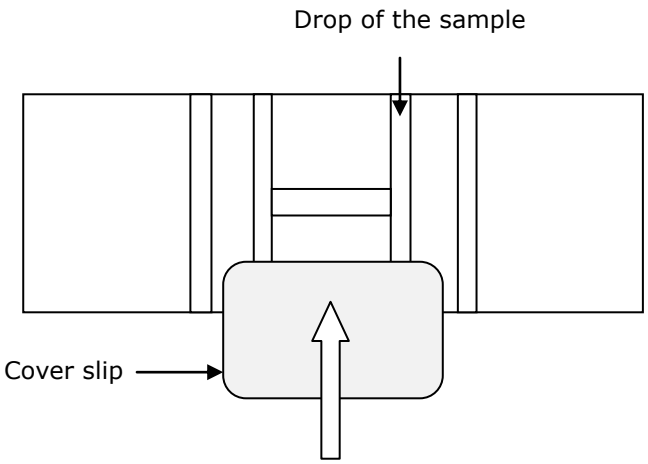


Figure 8: Preparation of the cytometer

5. Load both sides of the cytometer with the cell suspension using a Pasteur pipette, covering both counting grids. Observe under a microscope.

6. Locate the central square. Count the number of cells in one group of 16 small squares. Cells that lie on the triple boundary line should be excluded from the count.

7. Repeat Step 6 four more times, that is, count the number of cells in 4 more groups. To get accurate results, you should choose 5 groups from various places on the cytometer, not 5 groups next to each other.

8. Divide the total number of cells counted by 5, to get the average number of cells per group **(Task 2.2.3).**

Calculate the number of cells per 1 mL of the suspension (Task 2.2.2.) and average number of cells per capsule (2.2.3.) on the Answer Sheet.

Assuming that one *Chlorella* cell has a mass of 1.25 ng on average, calculate the mass of algal cells in 10algae capsules (Task 2.2.4.) and write your answer on the Answer Sheet. Use the data about the number of cells in the experiment obtained from Task 2.2.3.

End of **TASK 2**.

TASK 3: Chemical air filter capacity

In order to supply astronauts with fresh and clean air during space missions, engineers have had to install huge oxygen tanks and carbon dioxide filters in the spacecraft. However, there is a problem: both oxygen tanks and CO_2 filters take up a lot of valuable space and are really heavy. Therefore, scientists have come up with a solution: they have developed an air filter which can clean the air from CO_2 and supply astronauts with oxygen. The active component of these filters consists of a mixture of sodium peroxide Na_2O_2 and activated charcoal. Sodium peroxide reacts with CO_2 to yield Na_2CO_3 and O_2, as you can see from the reaction equation below:

$$2Na_2O_2 + 2CO_2 \rightarrow 2Na_2CO_3 + O_2$$

When sodium peroxide is completely depleted, sodium carbonate reacts with water vapor and carbon dioxide, without the production of oxygen:

$$Na_2CO_3 + CO_2 + H_2O \rightarrow 2\ NaHCO_3$$

Chemical filters are blocks of capsules containing active components - sodium peroxide mixed with charcoal. You have been given the contents of one of these capsules. Your sample is from a used space station air filter, so it contains sodium carbonate, sodium hydrogen carbonate and charcoal.

Your task is to determine the amount of carbon dioxide that was absorbed by your active component sample and calculate the amount of oxygen that was produced by your sample.

Atomic masses for your calculations:

$A_r(H)=1.0$; $A_r(C)=12.0$; $A_r(O)=16.0$; $A_r(Na)=23.0$; $A_r(Cl)=35.5$;

Task 3.1 Standartization of hydrochloric acid

Equipment and material:

- Bottle with $HCl_{(aq)}$ of unknown concentration
- Burette
- Stand with clamps
- 2 different size funnels
- 100 ml volumetric flask
- 10 ml volumetric pipette
- 4 × Pasteur pipette
- 2 × 200 ml Erlenmeyer flask
- 100 ml Erlenmeyer flask
- 3 × small plastic tubes with Na_2CO_3 (mass is shown on label)
- Glass rod
- Dropper with phenolphthalein indicator
- Dropper with methyl orange indicator
- Bottle with distilled water
- Waste container labeled "Waste"
- Filter paper in zip bag
- Pipette filling bulb
- 100 ml beaker
- 50mL measuring cylinder
- Small piece of white paper
- Plastic container labeled "Air filter sample"

Experiment

In order to work with your air filter active component sample, you must first determine the concentration of the HCl solution that has been given to you. In order to do this you will need to follow these instructions:

1. You have received 3 small plastic tubes each with slightly different amount of Na_2CO_3. First you need to pour the Na_2CO_3 from one of the plastic test tubes into an Erlenmeyer's flask. Be sure to transfer all the Na_2CO_3 from the tube to the flask.
2. Add about 30 ml of distilled water, stir the flask in hand in order to dissolve the carbonate.
3. When carbonate dissolves completely, add 2-3 drops of methyl orange.
4. Fill your burette with HCl solution of an unknown concentration.
5. Before you start the titration, prepare a colour standard for methyl orange. This colour standard will help you qualitatively indicate the endpoint of your titration. To do this, take a 100 ml Erlenmeyer flask, add 30 ml of water, 2-3 drops of methyl orange and 1 drop of HCl solution using a Pasteur pipette. Now you can see the colour of the solution, which has been over-titrated by one drop of HCl.
6. Titrate Na_2CO_3 solution until the solution changes colour from yellow to orange. Always place a piece of white paper under the flask to be titrated. This will help you see the colour change at the endpoint more clearly.
7. Repeat titration as many times as necessary. Ask for additional samples if required.

Write down your titration results on the <u>Answer Sheet</u> Task 3.1.1.

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Task 3.1.2. Calculate the concentration of the HCl solution (mol/L).

Task 3.2. Determining the amount of Na_2CO_3 and $NaHCO_3$ in the sample

Carbonate ions react with hydrogen ions in two steps. This can be clearly seen in the so-called titration curve (**Fig. 9**), which shows how the pH of a carbonate solution changes over the course of adding a solution of hydrochloric acid. In **Fig. 9**, zones of gradual and rapid decrease of pH can be seen over the course of the titration. In the beginning, a carbonate ion combines with a hydrogen ion (**1**):

$$H^+ + CO_3^{2-} \rightarrow HCO_3^- \qquad (\mathbf{1})$$

During this reaction, pH will slowly decrease until the endpoint of this reaction is approached. As you get closer to the endpoint the pH will change rapidly. The first zone of rapid pH decrease shows that carbonate ions are depleted and reaction **1** is finished. After that reaction **2** starts:

$$HCO_3^- + H^+ \rightarrow H_2CO_3 \qquad (\mathbf{2})$$

The end of reaction **2** coincides with the second zone of rapid decrease of pH. So the two zones of fast decrease of pH show the corresponding endpoints of reactions **1** and **2**.

Indicators used for titrimetric analysis change their colour within a certain pH range. For our experiment phenolphthalein and methyl orange indicators were chosen, respectively. The phenolphthalein indicator changes colour from pink to colourless at a pH range from 10 to 8. This indicates the endpoint of reaction **1**. The methyl orange indicator changes colour, from yellow to orange, at a pH range from 5 to 3 indicating the endpoint of reaction **2**.

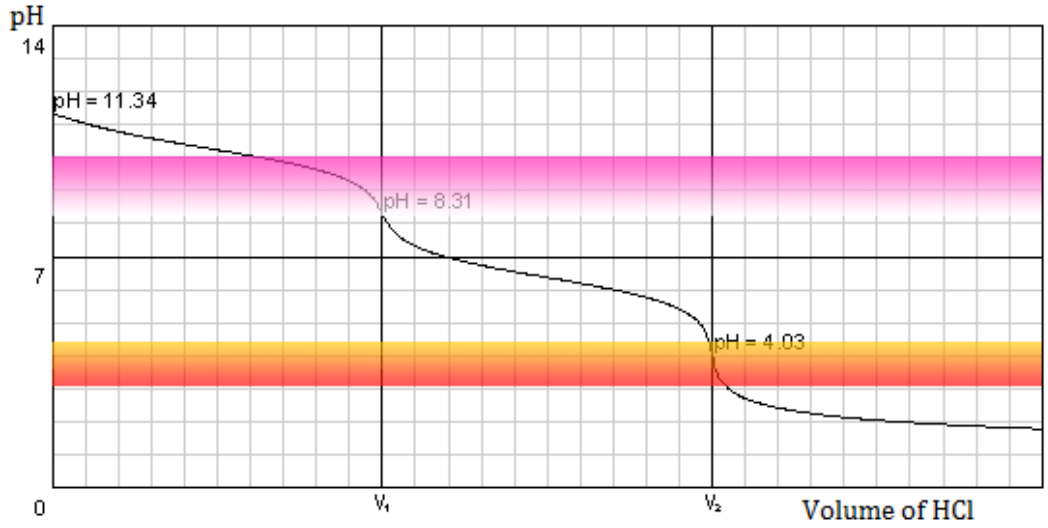

Figure 9. Carbonate ion titration curve showing the pH range at which the two indicators will change colour.

Experiment

Now that you have determined the concentration of your HCl solution you can begin the investigation of the air filter sample. In order to do so you need to follow these instructions:

1. First you need to extract soluble sodium carbonate and sodium hydrogen carbonate from the air filter sample. Put your sample into the beaker and add approximately 30 mL of distilled water. Stir your mixture with a glass rod for approximately 15-20 minutes until all of the soluble compounds are dissolved.
2. Prepare the funnel and filter paper for filtration. Pour your mixture into the funnel using the glass rod and collect the filtrate in an Erlenmeyer flask. In order to extract all soluble carbonates, wash the insoluble residue in your filter by pouring additional portions of distilled water. Before adding a new portion of water, wait until the liquid stops dripping from the funnel.
3. Transfer your filtrate from the Erlenmeyer flask into a 100 mL volumetric flask. After that, carefully add the necessary amount of distilled water to fill the volumetric flask to the 100.0 mL calibration mark. Be careful: add the last portion of water **drop by drop**.

4. By using a volumetric pipette, (shown in **Fig. 10**) transfer 10.00 mL of your solution from the volumetric flask into a clean Erlenmeyer flask. Add about 25 mL of distilled water and 2-3 drops of phenolphthalein indicator.

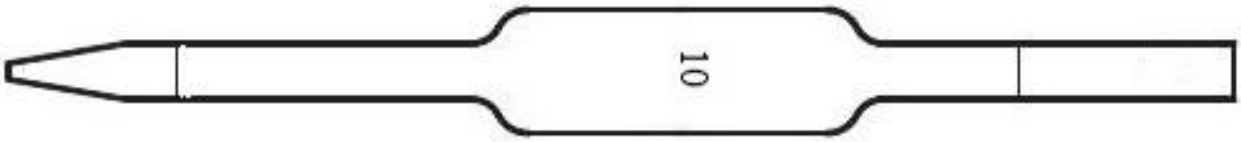

Figure 10: Volumetric Pipette.

*Note: Your volumetric pipette has **two** calibration marks. Stop delivering solution at the second mark to measure out exact volumes. Do not let run out all the solution.*

5. Fill up your burette with HCl solution and titrate your diluted sample solution until the pink colour disappears. This is your first endpoint of the titration.

Write down this titration result on the Answer Sheet (Task 3.2.1).

6. Now add 2-3 drops of methyl orange indicator to the same solution in your Erlenmeyer flask and continue titrating until the yellow colour changes to orange. This is the second endpoint of your titration.
7. Repeat titrations as many times as you feel necessary.

Write down these titration results on the Answer Sheet (Task 3.2.1).

Using data from your titrations complete the following tasks and write your answers on the Answer Sheets:

Task 3.2.1 Calculate the average volume used for the first and second endpoints.

Task 3.2.2 Calculate the amount of moles of Na_2CO_3 and the amount of moles of $NaHCO_3$ that were in your air filter sample.

Task 3.2.3 Calculate the mass of CO_2 which your sample has absorbed.

Task 3.2.4 Calculate the mass of O_2 which your sample has produced.

Task 3.2.5 Calculate the original mass of the active component (80% sodium peroxide and 20% charcoal by mass) of the air filter before its use.

Task 3.2.6 Calculate the mass of O_2 that can be produced by 1.0 kg of active component that consists of 80% sodium peroxide and 20% charcoal by mass.

Task 3.2.7 Which one of these compounds can also be used as an oxygen regenerator? **Circle the correct answer on Answer Sheet.**

a) Na_2O b) NaO_2 c) $Na_2C_2O_4$ d)NaH

Task 3.2.8. The air on Earth contains differing amounts of various noble gases. Which of the following noble gases is the most abundant in the air? **Circle the correct answer on the Answer Sheet.**

a) He b) Ne c) Ar d) Kr e) Xe f) Rn

Task 3.2.9 Which one of the following statements is **not** true? **Circle the correct answer on the Answer Sheet.**

a) Oxygen exists in the Earth's atmosphere as a mixture of allotropes.

b) Oxygen chemically combines with almost all elements.

c) Oxygen is the most abundant element in the Earth's crust.

d) Oxygen is the most abundant element in the Earth's atmosphere.

Task 3.2.10. Which of the following is not a common use of carbon dioxide? **Circle the correct answer on the Answer Sheet.**

a) a fire extinguisher.

b) a beverage ingredient.

c) a refrigerant.

d) an ingredient of toothpaste.

End of **TASK 3**.

Task 4: Oxygen supply sources for the Space Mission

A research expedition to the International Space Station (ISS) is being planned. The ISS volume is 855 m^3. The crew will consist of 5 members and they will work for 1 year.

There are two available systems that can be used for oxygen regeneration; chemical and biological. As previously mentioned in the introduction mass becomes the crucial factor in determining which system is more optimal. Hence, the module that weighs less will be chosen.

The chemical filter is produced in blocks. Each block contains 1000 capsules and a metal compartment.. Each capsule contains a certain mass of active component (sodium peroxide and charcoal) and passive components (capsule walls).

Write your answers to the following questions on the Answer Sheet:

Task 4.1. According to NASA, one person consumes 0.84 kg of oxygen per 24 hours. Calculate the total mass of oxygen that will be consumed during this expedition.

Task 4.1.1 Calculate the mass of active chemical filter component required for the expedition.

Task 4.1.2 Calculate the number of capsules required for the expedition.

Task 4.1.3 Calculate the number of blocks required for the expedition.**Task 4.1.4** Calculate the final mass of a chemical oxygen regeneration system required for an expedition if the mass of one block were 3 kg.

Task 4.2 Even though you have measured both oxygen production and illuminance, real spaceship conditions cannot be simulated. Therefore, a hypothetical scenario will be used to determine the optimal oxygen source for our space mission.

Task 4.2.1 Draw a linear graph (on a piece of graph paper provided in your envelope) of the mass of oxygen produced vs. illuminance. Use the values from tasks **Task 2.1.5** and **Task 1.1**.

Task 4.2.2 Estimate the mass of oxygen produced, if the illuminance equals 50 000 lx. **Mark** this point **on the graph**.

Task 4.2.3 Calculate the mass of algae required for the team to survive, using your data from tasks **Task 2.2.4** and **Task 4.1 and Task 4.2.2**.

Task 4.2.4 The mass of algae makes up only 5% of the biological oxygen regeneration system. The remaining mass comes from various support systems. What is the total mass of such biological oxygen regeneration system?

Task 4.3. In the table on the **Answer Sheet** decide which of the components are required for each oxygen regeneration system. Mark with a "C" for the inclusion of the component in the chemistry oxygen regeneration system, "B" for the inclusion of the component in the biology oxygen regeneration system, and "N" if not required in either system.

Task 4.3.1 Discuss the results with your teammates and decide which of the two systems is more suitable for the expedition. **Circle the correct Answer on the Answer Sheet.**

a) Chemical b) Biological.

End of **Task 4.**