April 3d, 2014 – TASK B

All about Sea Water

- Task sheet -

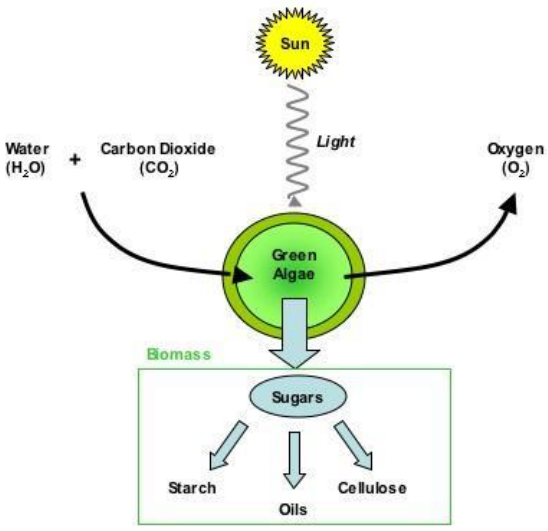
TASK B

Task B1 - Biology

Task B1: Study on the growth of microalga *nannochloropsis sp.* used for biodiesel production

Background information

In order to reduce the **greenhouse gas** (GHG), carbon dioxide (CO_2) emission responsible for global warming, many studies have been focused on biofuels and their potential in substituting fossil fuels. Biodiesel production from microalgae is considered to be a very promising source of energy, mainly because of its reduced competition for land, higher oil yields from microlagae compared to those currently available from agricultural crops and their ability to be cultivated in seawater, brackish water or waste water on non-arable land. Algal biodiesel reduces CO_2 emission up to 78% compared to emissions from petroleum diesel. The production of biofuel from microalgae is dependent on the microalgae biomass production rate and lipid content. Lipid accumulation and biomass production are controlled by several factors, such as nutrient, temperature, CO_2, light, salinity etc.



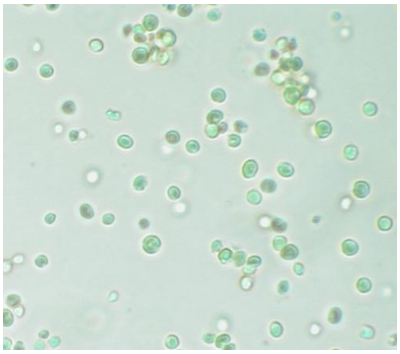
Algae are a very diverse group of aquatic photosynthetic organisms that account for approximately 50% of the photosynthesis that takes place on earth. They are proposed to play a significant role in the global carbon cycle by removing excess CO_2 from the environment. Algae are recognized as a promising biodiesel source due to their efficient absorption and conversion of solar energy to chemical energy. Algal biodiesel is derived from biomass therefore is renewable, biodegradable and quasi-carbon neutral under

sustainable production. Furthermore, algal biodiesel is not toxic and contains reduced levels of particulates CO, soot, hydrocarbons and SO_X.

Most plants, algae and cyanobacteria undergo the process of **photosynthesis** in order to convert light energy normally originating from the sun into chemical energy that can be utilised to fuel several organism's activities. This chemical energy is stored in carbohydrate molecules (such as sugars), which are synthesized from CO_2 and water. Furthermore, oxygen is also released. Algae are highly efficient in their photosynthetic capability when compared to land plants.

Green plants have six, closely related, photosynthetic pigments. *Nannochloropsis sp.* only have chlorophyll a, which is the most common of the six and present in every plant that undergoes photosynthesis. The requirement for more than one pigment eminates from the fact that each pigment absorbs light in varying parts of the electromagnetic spectrum with different efficiencies. For instance, chlorophyll a absorbs most efficiently at a wavelength of about 400-450 nm and at 650-700 nm wavelength; chlorophyll b, however, at 450-500 nm and at 600-650 nm. Moreover, xanthophyll absorbs most efficiently at 400-530 nm and yet, none of the pigments absorbs adequately enough in the green-yellow region, which is responsible for the abundant green colour we see in nature.

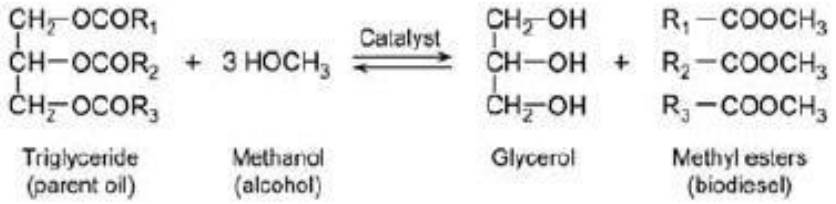
Carbon dioxide dissolves in water to form carbonic acid (H_2CO_3), bicarbonate (HCO_3^-) and carbonate ions (CO_3^{2-}). The amount of CO_2 dissolved in oceanic water is approximately fifty times more than the amount present in the atmosphere. In seawater, more than 90% of the inorganic form of dissolved carbon is in the form of bicarbonate (HCO_3^-) . Many microalgae can actively take up bicarbonate ions (HCO_3^-) from the external environment and transport them across the plasma membrane and into the cytosol, subsequently generating CO_2 via the activity of carbonic anhydrase. Moreover, extracellular carbonic anhydrase can catalyse the inter-conversion of HCO_3^- and CO_2, through the following reaction:



$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

Nannochloropsis sp. is a small, 2-3 μm size eukariotic unicellular marine alga belonging to the order of Eustigmatales. Its ability to accumulate high levels of poly-unsaturated fatty acids has made *Nannochloropsis sp.* a very promising tool in industrial applications.

Nannochloropsis sp., alongside several other microalgae with high lipid content per dry weight of biomass, is able to accumulate 30% to 68% of triglycerides in its dry biomass. Algal oil used in the making of biodiesel consists of triglycerides that react with methanol in a reaction known as transesterification. Transesterification requires 3 moles of alcohol for each mole of triglyceride to produce 1 mole of glycerol and 3 moles of methyl esters. When equilibrium is reached, methyl esters (biodiesel) and glycerol are produced. Glycerol is generated from triglycerides, which are gradually broken down to diglycerides, monoglycerides and finally glycerol.



Biodiesel is one of the most promising sources of renewable energy in this century. Its superiority over petroleum diesel is best described by its lower exhaust emissions and the fact that biodiesel is biodegradable, non-toxic, renewable and free of sulphur compared to petroleum diesel. For all these reasons and the environmentally friendly nature of biodiesel, the use of this form of fuel has denoted a shift towards obtaining more sustainable sources of energy. Biodiesel is produced by a mono-alcoholic transesterification process, in which triglycerides react with a short-chain alcohol (most commonly methanol or ethanol) under the catalysis of alkali, acids, or enzymes. The primary sources for biodiesel production can be divided into four groups: vegetable oils (edible and non-edible), animal fats, used cooking oils and algae. The use of biodiesel is simple, yet effective as it can be mixed with petroleum-based diesel in different

proportions and can be used as fuel, either in pure form or blended with petroleum based diesel fuel. Nowadays, the mixtures of biodiesel and petrodiesel used depend on each country's minimum requirements for blended biodiesel.

Having a longstanding interest in biodiesel production from microalgae, we can study the development of these microorganisms in different environmental conditions (e.g. CO_2 concentration), while the availability of light, nutrients, salinity, temperature and pH remain stable.

The problem:

In this Task you will study the effect of CO_2 on the growth rate of *Nannochloropsis sp.* considering that CO_2 source changes in three different areas where CO_2 emissions vary (low to high).

Your laboratory is asked to determine the region of an unknown sample (that belongs to one of the above areas considering that the sampling lasted for twelve days) and to decide which of the three regions is best for the installation of a microalgae biodiesel production unit.

Equipment and material

- Marker pen, graph paper
- Glass pipettes (2 ml) and plastic Pasteur pipettes
- Plastic tubes (Falcon 15 ml) **containing prepared solutions of microalgae**
- Support for Falcons
- Distilled water
- Solution of unknown concentration labelled "**14**"

On the main bench of the laboratory, you will find:

- Spectrophotometer with the filter position set at 750 nm
- Vortexer
- Spectrophotometer cuvettes **(4/group)**
- **Tissue and distilled water**
- **Sample to 'zero' the spectrophotometer**

Description of the task

In order to determine the microalgal Dry Cell Weight (DCW) per liter (mg L^{-1}), it is initially necessary to measure the absorbance data, which corresponds to concentrations of microalgal cells. After the 3rd, 6th, 9th and 12th day of culture, the microalgal cell solutions will be used for measuring the optical density OD. A UV/Visible spectrophotometer will be used to measure OD at 750 nm. A growth curve of *Nannochloropsis sp.* has to be prepared for each region of different CO_2 concentrations. Region A, with low concentrations of CO_2 is located on an island with low CO_2 levels; Region B with medium concentrations of CO_2, is near a motorway with normal CO_2 levels; finally, Region C with high concentrations of CO_2, exists near an industrial area with high CO_2 levels. The Region of the unknown sample has to be determined from the growth curves. Culture is performed under constant conditions (e.g. light level, temperature, etc.).
Furthermore, it has to be mentioned that sodium bicarbonate was used as the source of bicarbonate in all experiments.

Information about spectrophotometry

Every chemical compound absorbs, transmits, or reflects light (electromagnetic radiation) over a certain range of wavelength. Spectrophotometry is a quantitative measurement of the reflection or transmission properties of a material/compound as a function of wavelength. A spectrophotometer is an instrument that measures the amount of photons (the intensity of light) absorbed after they pass through a sample in solution. With the spectrophotometer, the amount of a known chemical substance (concentration) can be

determined by measuring the intensity of light detected. The Beer-Lambert law describes the relationship between the absorbance and the concentration of a sample, which is applied when there is a linear relationship between the absorbance measured and concentration of a sample.

The Beer-Lambert law equation is:

$$A = \varepsilon l c$$

where *A* is the measure of absorbance (no units), *ε* is the molar extinction coefficient or molar absorptivity (or absorption coefficient), *l* is the path length, and *c* is the concentration. The molar extinction coefficient is given as a constant and varies for each molecule. Since absorption (A), molar extinction coefficient (ε) and path length (l) are known, we can calculate the concentration (c) of the sample.

Experimental procedure

Important Note: There will be a limited number of 3 spectrophotometers / 12 groups, so arrange your time accordingly

a. Each of 13 tubes contains *Nannochloropsis sp.* that was taken from the initial culture solutions and diluted 4 times at different periods (0, 3rd, 6th, 9th and 12th day) from the three different environmental conditions (the three CO_2 concentration).

b. Tube 14 contains the unknown sample taken from the same culture under investigation the 10th day **and diluted 4x**.

c. Tube 0 (blank) only contains seawater enriched with medium nutrients and will serve to adjust the spectrophotometer to zero absorbance.

Sample	Region A	Sample	Region B	Sample	Region C
1	0 day				
2	3rd day	6	3 rd day	10	3rd day
3	6th day	7	6th day	11	6th day
4	9th day	8	9th day	12	9th day
5	12th day	9	12th day	13	12th day
14	Unknown sample				

d. **Raise your hands when ready to obtain access to the spectrophotometer.** Before performing each measurement, thoroughly vortex each tube for 3- 5 seconds **to homogenise the sample**.

e. **Keep in mind that you will only be given 25 minutes in total to use the spectrophotometer.** Transfer solution of tube 0 (blank) and insert the cuvette into the spectrophotometer. It is important to place the cuvette so that the light ray travels through the transparent side.

f. Press the "Zero" button and the apparatus screen will show 0.000 (calibrated).

g. Use a pipette to remove 3 ml of culture from the provided solutions for each day. Transfer it into the cuvette. The upper level of the solution has to be about 1 cm from the top of the cuvette.

Check that the spectrophotometer is working at 750 nm and follow the instructions provided besides each spectrophotometer (the laboratory supervisor will provide help).

The solution of each vial and the residues from washing each cuvette must be poured into the waste container provided, when the experiment has finished.

h. Record the readings of all samples in your Answer Sheet (Table 1).

i. Draw a graph of the growth curve using the graph paper sheet provided; the graph needs

to show the absorbance values for each culture solution against the days of culture. You have to do that three times, once for each environmental condition (A, B, C). Draw your 3 exponential curves on the same graph, by connecting each of the points derived from your values. This is graph 1.

j. From the graph, determine the Region of the unknown sample provided for this exercise and write the answer to the Answer Sheet.

k. The optical density (OD) measurements at 750 nm need to be converted to Dry Cell Weight (DCW) (mg L^{-1}) using a factor that was determined previously (the calibration curve equation appears on the spectrophotometer). You have to record this equation in your answer sheet under Task B.1.4. Calculate DCW for the samples of the region you have determined. Record values in table 2.

l. Using the provided graph paper, draw a graph that represents the dry cell weight DCW of each culture solution against the days of culture. You have to do this for the specific environmental conditions that you determined. **This is graph 2**. Then, determine the **DCW** of the unknown sample.

m. If we assume that the alga *Nannochloropsis sp.* is able to accumulate almost 50% of triglycerides in its dry biomass, calculate the concentration (mg L^{-1}) of triglycerides for the specific environmental condition that you determined and write the values to the Answer Sheet. In order to do this choose the day of maximum DCW.

n. As mentioned before, the transesterification reaction requires 3 moles of alcohol for each mole of triglyceride in order to produce 1 mole of glycerol and 3 moles of methyl esters (biodiesel). Based on the amount of triglycerides you calculated in the previous question (question m), calculate the amount of biodiesel (in milligrams; mg) produced in a litre (L), assuming that the main triglyceride present is palmitic triglyceride and its molecular weight is 807. In addition, the molecular weight of palmitic acid methyl ester (biodiesel) is 270.

Task B2 - Chemistry

Task B3.1 - Purification of NaCl

SAFETY RULES FOR EXPERIMENT "Purification of NaCl"

1. Wear a lab coat and goggles while carrying out experiments and gloves while handling chemicals.

2. Never taste anything. Never directly smell the source of any vapor or gas

3. Many common reagents, for example, alcohols, are highly flammable. **Do not use them anywhere near open flames**.

4. Remove your gloves while you are using the laboratory burner.

5. Never leave burners unattended.

6. If chemicals come into contact with your skin or eyes, flush immediately with copious amounts of water and consult with your instructor.

7. Dispose of chemicals properly. Waste containers will be provided.

8. Be aware with the use of concentrated H_2SO_4!!!! Never pour water into **H_2SO_4**.

Introduction

The use of salt as a food **preservative** has been known since the ancient times. Salt was an integral part of the life of all people as it was often part of their customs, tradition and even religious beliefs. In ancient Rome, salt was so valuable, that it was often used instead of money in peoples' transactions. When one thinks about it, the English word 'salary' comes from the Latin 'salarium' which means payment with salt. According to the Ancient Greeks, salt symbolizes friendship and solidarity. They used it to seal their deals, during sacrifices and as offering to the Gods.

Salt can be distinguished into **rock salt** and **sea salt.**

Rock salt, which covers 70% of international consumption, was formed millions of years ago, when the ocean water evaporated as well as through the geological realignments of the Earth. It contains large amounts of impurities and purification is required for their removal.

Sea salt is comes from sea water and is collected at saltworks. The salt concentration varies from sea to sea. Northern Seas have a lower concentration of salt, about 3%, while the Dead Sea is much higher at 8%. Salt, NaCl, as collected at saltworks, also contains impurities. Some of these, like sand, are easy to remove, while others, such as sulphate salts ($MgSO_4$ or $CaSO_4$), are much more difficult.

The basis for the purification of soluble substances (like salt), is their dissolution in water and recrystallization, either by cooling or by the addition of an appropriate reagent, e.g., HCl. In this way, the pure substance crystallizes while the impurities remain in solution. One of these methods will be used in the following experiment which involves the purification of salt.

Method of Purification

The proposed method of purification involves the following steps:

1. A saturated solution of the rock salt is prepared. The solution should be decanted, if needed, so that any insoluble impurities, eg. sand, are removed.

2. When H_2SO_4 is added a gas is formed which is bubbled through the above solution. This causes an increase in the concentration of chloride ions (Cl^-). This will result in the recrystallization of pure NaCl as the soluble impurities will remain in solution.

3. Pure NaCl can be retrieved through filtration.

4. The above purified material will be dried in a drying oven.

The above procedure can be repeated one or more times if NaCl of high purity is required.

APPARATUS	MATERIALS
▪ 1 spoon ▪ Laboratory Burner (I) ▪ Round bottomed flask (A) ▪ Tube adapter with three joints (B) ▪ Fasteners of various sizes (H) ▪ Nozzle for the connection with the silicon tubing and the tube adapter with 3 joint (C) ▪ Addition funnel (D) ▪ Bubbler (E) ▪ Wash bottle ▪ 2 clear plastic silicon tubes for the experimental set up ▪ 3 beakers (100, 250 and 400 mL (G)) ▪ 2 volumetric cylinders (25 and 100 mL) ▪ 1 small funnel (F) ▪ 1 small plastic funnel ▪ 1 large funnel ▪ 1 piece of filter paper ▪ 4 test tubes ▪ 1 test tube rack ▪ Conical flask (250 mL) for the filtration ▪ 3 retort stands ▪ 3 metal clamps (L) ▪ 3 double bolts (K) ▪ Watch glass ▪ Wooden tweezers ▪ 1 stirring rod ▪ Drying oven ▪ Weighing paper ▪ Electronic balance (accuracy ± 0.1 g) ▪ Vaseline ▪ Pencil ▪ Lighter	▪ Cooking salt (NaCl) ▪ Impure NaCl ▪ Concentrated H_2SO_4 ▪ 1 M $BaCl_2(aq)$ solution ▪ Ethanol (CH_3CH_2OH) ▪ Distilled water

Experimental Procedure

Be aware, if you violate the lab safety instructions given, your supervisor may ask you to leave the lab or penalize your test record.

2.1. Weigh 37 g of impure NaCl and add to the 250 mL beaker which contains 100 mL distilled water (solubility of NaCl is 35,7 g /100 mL H_2O at 20^{o}C). Stir until the NaCl dissolves, forming a saturated solution. If some insoluble residue remains, decant the solution into another beaker of 400 mL volume (**beaker G in Figure 1**).

2.2. Measure 10mL of this solution and add to a test tube **(solution 1). Put it aside until step 2.11.**

2.3. Add 40 g of cooking salt to the round bottom flask **(flask A in Figure 1)** and then place the tube adapter (**B**) on the opening of the round bottom flask using the green colored fastener. **Every time you connect joints, use a small amount of vaseline.** Then assemble the apparatus as shown in **Figure 2**. **This must be done in the fume hood.** Follow the detailed instructions given below.

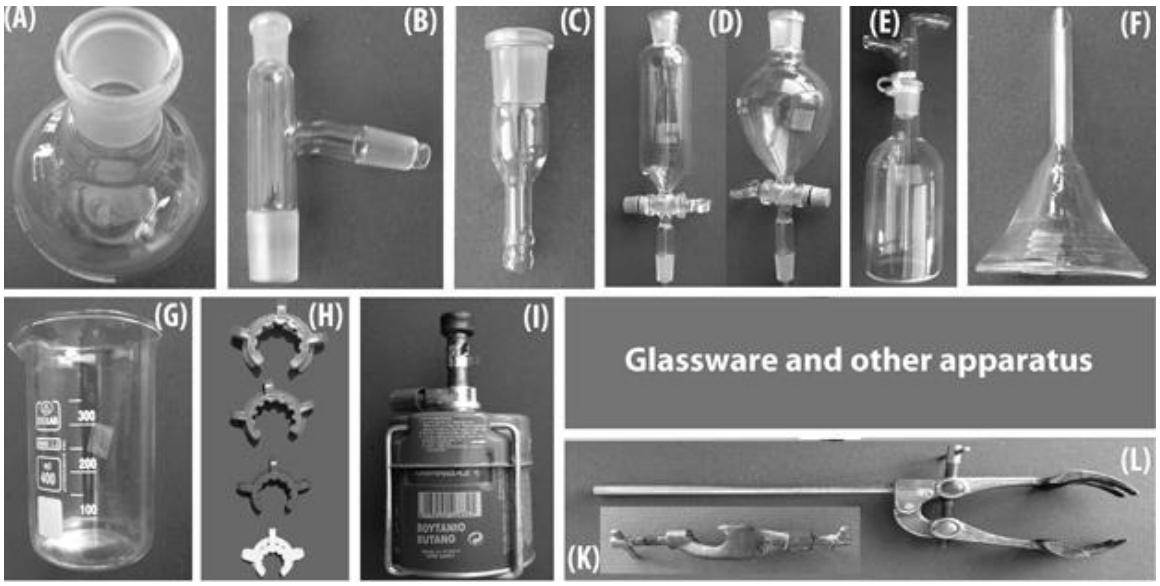


Figure 1: Photos of the glassware and other apparatus that will be used for the experiment. (**A**) Round bottom flask
(**B**) Tube adapter with 3 joints
(**C**) Nozzle for the connection with the silicon tubing and the tube adapter with 3 joints
(**D**) Addition funnel (two different types)
(**E**) Bubbler which acts as a trap
(**F**) Small funnel
(**G**) 400 mL beaker

(**H**) Fasteners of various sizes and colours
(**I**) Laboratory burner
(**K**) Double bolt
(**L**) Metal clamp

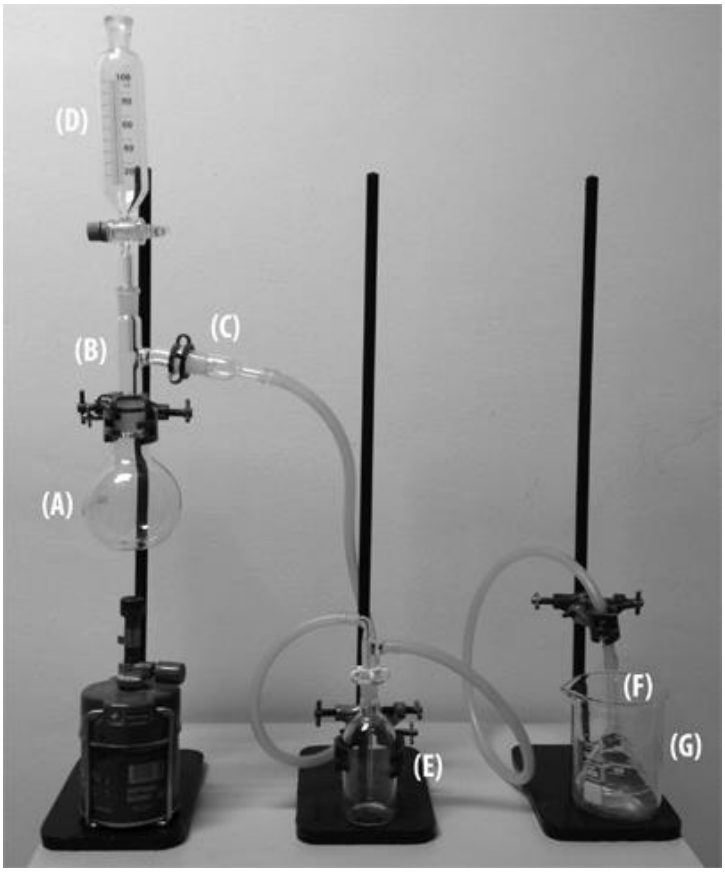


Figure 2: The experimental set up for the purification of NaCl.

With the help of a metal clamp and a double bolt, attach the round bottom flask (**A**) with the tube adapter (B) to the retort stand. Make sure that the level is such that a laboratory burner, which will be needed for heating, fits underneath. Attach the addition funnel (**D**) at the top joint of the tube adapter (**B**) using a yellow plastic fastener. **Make sure the tap of the addition funnel is closed.** Using another metal clamp and double bolt attach the bubbler (**E**) to a second retort stand. The bubbler (**E**) has two silicon tubes connected to it. One end of the tubing is connected to nozzle (**C**). Connect this end to the side arm of the tube adapter (**B**) and secure with a blue plastic fastener. The other silicon tube, connected to the bubbler (**E**), is connected to the small glass funnel (**F**). Finally, suspend the funnel (**F**) upside down in the beaker (**G**) making sure that it is below the level of the

saturated solution but not touching the bottom of the beaker. Support the funnel with another metal clamp and double bolt to a third retort stand.

Ask the supervisor to check your assembly before proceeding.

Che 1. Answer the question in the answer sheet

2.4. Wear your gloves and carefully add the 40 mL of concentrated H_2SO_4 to the addition funnel **(D)**.

ATTENTION: THE TAP OF THE ADDITIONAL FUNNEL MUST BE CLOSED

2.5. Add the concentrated H_2SO_4 **dropwise** to the round bottom flask, heating it **gently periodically**. **Remove your gloves during the heating procedure.** The procedure is completed when all of the concentrated H_2SO_4 is added to the NaCl and no more bubbles are formed in beaker **G** which contains the saturated NaCl solution. Make sure that the tap of the additional funnel is closed after the addition of H_2SO_4.

Che 2 – Che 4. Answer the questions in the answer sheet

2.6. On a piece of filter paper, on the border, write the initials of your country using a pencil. In the fume hood, filter the mixture formed in beaker **G**.

2.7. Wash the precipitate three times using 10 mL of ethanol each time.

2.8. Place the filter paper with the precipitate on a watch glass and spread the solid over the whole surface. Place the watch glass in the drying oven for 40 min at 110^{o}C.

Che 5. Answer the question in the answer sheet

2.9. After the drying process, use wooden tweesers to remove watch glass from drying oven. Weigh **x** g of the purified NaCl (calculations in Che 5) and add it to a 100 mL beaker which contains 15 mL distilled water. Stir the solution until NaCl fully dissolves and a solution of equal concentration to that of the original saturated **solution 1** is formed.

2.10. Place 10 mL of this solution in a test tube **(solution 2)**

2.11. Add 3 drops of $BaCl_2(aq)$ solution to test tubes 1 and 2 and stir with the stirring rod.

Che 6 – Che 12. Answer the questions in the answer sheet

Task B3.1 - Electrolysis of NaCl(*aq*) with graphite electrodes C(*s*)

Introduction

Electrolysis is the sum of the oxidation and reduction reactions which occur when a potential difference is applied across an electrolyte which is either in the molten state or in solution. In both cases, positive and negative ions which are free to move are present. The redox reactions occur due to an electric current going through the electrolyte. As a result, electrical energy is converted to chemical energy. This process occurs in what is called an electrolytic cell, a diagram of which is shown below.

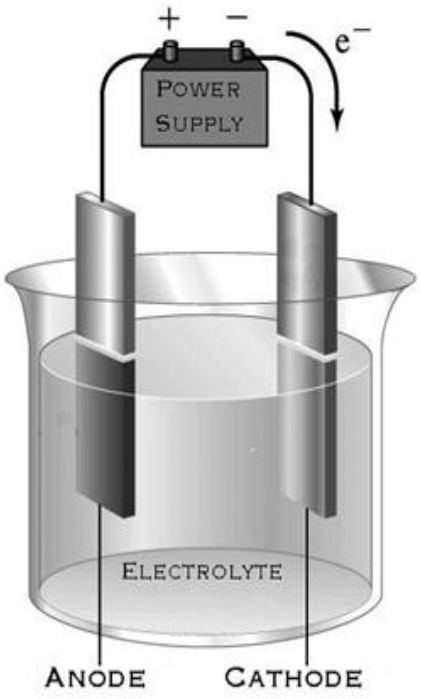
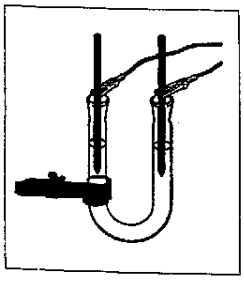


Figure 3: A diagram of an electrolytic cell.

Electrolysis has a number of applications, some examples of which include the industrial production of Na, Al, Cl_2, HCl, NaClO, $NaClO_3$ and NaOH, as well as electroplating, i.e. placing a thin layer of a precious metal (e.g., Ag, Au or Pt) over a "not so precious" one.

Apparatus	Materials
• Power supply (5V) • U shaped glass tube • Retort stand and clamp • 2 dropper pipettes • 2 test tubes • Test tube stand • 2 connecting wires	• 2 graphite electrodes • 2.0 M NaCl(*aq*) • Phenolphthalein • 1.0 M KI(*aq*) • A piece of bread

Experimental Procedure



3.1. Support the U shaped glass tube on the retort stand using the clamp and add 2.0 M NaCl solution to approximately 2 cm below the mouth. Connect the graphite electrodes to the power supply (≈5V) and place them into the solution. Allow electrolysis to continue for about 5 min.

3.2. Remove the electrodes.

3.3. With a dropper pipette, take approximately 2 mL of the solution at the **cathode** and place in a test tube (**solution C**).

3.4. With a dropper pipette, take approximately 2 mL of the solution at the **anode** and place in a test tube (**solution A**).

3.5. To solution A add approximately 10 drops KI(*aq*) .

Che 13 - 18. Answer the questions on the answer sheet.

3.6. To solution C add 2 – 3 drops of phenolphthalein.

Che 19 - 23. Answer the questions on the answer sheet.

Task B3 - Physics

Task B3 - Using an electrolytic device to measure mass concentration of a sodium chloride solution

Summary

Our aims are (a) to **experimentally study the relationship of the electrical conductivity of a dilute sodium chloride solution contained in an electrolytic device to the mass concentration of the solution** and (b) to **calibrate the electrolytic device**.

Mass concentration, ρ_A, of the ingredient A of a solution is defined from the relationship $\rho_A = \frac{m_A}{V}$, where m_A is the mass of the ingredient A of the solution and V is the volume of the solution.

The study is limited to a specific range of the mass concentration values, from $2\ \frac{\text{g}}{100\ \text{mL}}$ to $6\ \frac{\text{g}}{100\ \text{mL}}$. Your results are used for the calibration of the electrolytic device, so that we can experimentally determine the unknown concentration of a salt solution contained in the electrolytic device.

Theoretical framework - Experimental procedure layout

Conductivity of a sodium chloride ionic solution – Ohm's law

It is known that an ionic solution is conducting electric current. Under specific conditions – which hold in the case we are studying – it obeys **Ohm's law**.

We place a sodium chloride solution of mass concentration ρ_A into a container. We submerge two identical metal plates (**electrodes**) into the liquid. We have built an **electrolytic device** (Figure 1).

According to Ohm's law, if there is a potential difference V across the two electrodes,

then there is going to be a current through the solution, which will be directly proportional to the potential difference:

$$I = G \cdot V \quad (1)$$

G is a constant, representing the **electrolytic device conductivity**. Conductivity is the reverse of the device's resistance, $G = 1/R$. It is measured in Ω^{-1} or siemens (S).

To **experimentally determine the device's conductivity**: connect the electrolytic device in series with an 120 Ω resistor to a closed circuit, use a **voltmeter** to measure the potential difference across the device's poles and an **ammeter** to measure the current through it.

The conductivity of an electrolytic device containing an ionic solution depends on the following factors:

1) The size, position, and shape of the device's electrodes.

2) The temperature of the solution.

3) The concentration of the ionic solution.

It follows that, if we are going to experimentally study the conductivity as a function of one of the above factors, we have to control (keep constant) the other two, throughout the experiment. So, to study conductivity as a function of the solution's concentration, we must make sure that the device's electrodes are kept in specific positions and the solution's temperature is constant.

Under the conditions and circumstances that these experiments are carried out, we may assume that there is a linear relationship between the conductivity and the concentration of sodium chloride in the solution. So, if we dissolve cooking salt in tap water and create a solution of concentration ρ_A, then the solution's conductivity as a function of its concentration is given by the relationship:

$$G = \lambda \cdot \rho_A + G_0 \quad (2)$$

where: λ, G_0 are constants that depend on temperature, the type of the solution and the way that the electrolytic device was built.

During the experimental procedure, for different values of the concentration of salt-water solution, we measure the corresponding conductivity value and plot the G as a function of ρ_A graph. We will check if the experimental data agree with relationship (2) and determine the values of constants λ, G_0.

Equipment and materials

1. Generator YB16200. [Adjustments: sinusoidal waveform AC, Frequency 1.5 kHz, Power Out 24 watt]
2. Two multi-meters.
3. 120 Ω - resistor.
4. Electrolytic device: system of two electrodes and a solution in a container.
5. Switch.
6. Cables.
7. One volumetric flask of 100 mL.
8. Stand with six test tubes.
9. Plastic syringe 20 mL.
10. Six plastic vials of 100 mL.
11. Balance 0.1 g.
12. Solid sodium chloride.
13. Plastic spoon.
14. Plastic container.
15. Marker.
16. Graph paper.
17. 2 calculators.
18. Ruler 20 cm - 30 cm.
19. Pencil, 3 pens, eraser.
20. Kitchen paper.

Experimental procedure

Use the correct number of the significant figures in all measurements and calculations

1. Use the volumetric flask, the syringe and the balance to prepare five salt-water solutions, with mass concentrations (use tap water as solvent):

$$2\ \frac{\text{g}}{100\ \text{mL}},\ 3\ \frac{\text{g}}{100\ \text{mL}},\ 4\ \frac{\text{g}}{100\ \text{mL}},\ 5\ \frac{\text{g}}{100\ \text{mL}}\ \text{and}\ 6\ \frac{\text{g}}{100\ \text{mL}},$$

which we place into the plastic vials. We mark each vial with the concentration of the solution it contains.

2. Assign one test-tube to each vial and mark it. Half-fill each test-tube with the solution from the corresponding vial. Note on every test-tube the concentration of the solution it contains.
3. Place the system of the two electrodes into the first test-tube, containing the $2\ \frac{\mathrm{g}}{100\ \mathrm{mL}}$ solution.
4. Draw an appropriate circuit diagram for your measurements on the answer sheet.
5. Adjust the frequency of the generator to 1.5 kHz **and keep it constant throughout the experiment**. Build this circuit.
6. **Do not close the switch, before the circuit is evaluated by the supervisor**. The supervisor will correct the circuit if necessary.

   The switch should be open, at all times that you are not taking measurements.

   Adjust the amplitude of the generator's signal to be maximum. Wait for a little, until the readings of the potential difference across the poles of the electrolytic device and the current through the circuit are stabilized. Record these values in table A and then open the switch.

   Repeat the above procedure for each solution you have prepared. Each time, be sure to wash and dry the device's electrodes. Fill out all the cells of table A.

Data processing and evaluation

[Record all your calculations in the answer sheet]

1. On graph paper, plot the experimental straight line of conductivity (G) vs concentration (ρ_{A}).
2. Determine the values of the constants λ, G_0, used in relationship (2).
3. Ask the lab-assistant to provide you with a vial containing salt-solution of unknown concentration in sodium chloride, ρ_{X}. Experimentally determine the solution's concentration in sodium chloride, using your experimental device and your graph.