April 26th 2012

Experiment 2

Marking

Space Exploration

Task 1.

Task 1.1 (5.5 credit point)

1. Performed 5 – 10 measurements 1pt., less 0.5 pt.
2. Choose the correct distances (similar, proportional) 1 pt., otherwise 0.5 pt
3. The correct measurement mode of multimeter 1 pt. otherwise 0.5 pt.
4. Correctly set the value of the calibration graph 1 pt.
5. Choose the correct units of measurement 1.5 pt., 0.5 point for every correct.

Graph 1 (5 credit point)

1. The correct size (3/4 of page) **0.5 pt.**
2. Choose the correct scale **0.5 pt**.
3. Correctly drawn line (between points) **1 pt.**
4. Correctly plotted the second curve **1 pt.**
5. For the different curves use different symbols **1 pt.,** otherwise **0.5 pt**
6. Units on the axis **1** pt, 0.5 point for every correct

Task 1.2 (6.5 credit point)

1. Measurement range -90 -- 0 -- +90deg. **2 pt.,** -45 -- 0 -- +45deg. 1 pt., less 0.5 pt.
2. Performed 15-25 measurements **1 pt.,** less 0.5 pt.
3. Correct measurement (angles) **0.5 pt**.
4. The correct measurement mode of multimeter **0.5 pt**.
5. Correctly set the value of the calibration graph **1 pt.**
6. Choose the correct units of measurement **1.5 pt**., 0.5 point for every correct.

Graph 2 (3 credit point)

1. The correct size (3/4 of page) **0.5 pt.**
2. Choose the correct scale **0.5 pt**.
3. Correctly drawn line (between points) **1 pt.**
4. Units on the axis 1 pt, 0.5 point for every correct

Task 1.3.1 Which function describes the illuminance dependence on the incident angle? (1pt)

a) $E = \frac{I}{R}\cos\alpha$

b) $E = I \cdot R \cdot \cos\alpha$

c) $E = \frac{I}{R^2}\cos\alpha$

d) $E = \frac{I}{R}\sin\alpha$

e) $E = I \cdot R \cdot \sin\alpha$

where *E* denotes illuminance, *I* is the light intensity, *R* is the distance between light source and device, and *α* is the incident angle.

Task 1.3.2.1 Are the values of illuminance significantly different when the box is closed or open? **Circle the correct answer:** (0.5 pt)

YES	NO

Task 1.3.2.2

Circle the answer that best explains the above phenomenon; (0.5 pt)

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? (1pt)

a) The radiation energy 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

Task 2.1.1. Tick (√) the box(es) that would indicate the appropriate placement for the control bottle to provide valid results.

[ ] exposed to daylight
[ ] exposed to light as the tube nearest to the light source in the box
[√] bottle wrapped with aluminium foil
[ ] bottle kept without stopper

(1 point; 0 points if more than one answer is marked)

Task 2.1.2. Fill in the table with the measured pH values.

Tube label	A	B	C	D	0	Initial pH
Distance (m)	0.05	0.20	0.40	0.90	-	-
pH	8.2±0.3	7.9±0.2	7.6±0.1	7.5±0.1	7.3±0.2	7.2±0.1

(10 points: measurements from A to D x 1 point, 1 point for measurement of pH value of the control tube, 1 point for measurement of initial pH; if the values of the measurements decrease from A to D, 1 point for each (A>B>C≥D))

Task 2.1.3. Write balanced chemical equations for:

A. the process where glucose is formed from inorganic substances and light $6CO_2 + 6H_2O \xrightarrow{light} C_6H_{12}O_6 + 6O_2$
B. the process that was responsible for pH change in bicarbonate solutions A-D $HCO_3^- \rightarrow CO_2 + OH^-$ (sum of proceses)

(2 points: 1 point for each process, 0.5 points if equation „A“ lacks light)

Task 2.1.4. Calculate the concentrations of H^+(aq.) ions and the change in the amount of hydronium ions during the 30 minutes of exposure to the light (provide calculations in the box below the table):

Tube label	A	B	C	D
Initial $c(H_3O^+)$ (t=0)				
final $c(H_3O^+)$ (t=30)				
Δ $c(H_3O^+)$				
Δ $n(H_3O^+)$				

Calculations:

$$pH = -\log[H^+],\ initial[H^+] = 10^{-7.4} = 3.98 \cdot 10^{-8}\, mol \cdot L^{-1},\ final[H^+] = 10^{-x}\, mol \cdot L^{-1}$$

$$\Delta c(H^+) = final[H^+] - initial[H^+]$$

$$n = c \cdot V,$$

$$V = \text{volume of bicarbonate solution added to a bottle},\ \Delta n(H^+) = n(H^+ final) - n(H^+ initial)$$

(3 points; 0.2 for initial H^+ conc., 4 x 0.2 for final H^+ conc., 4 x 0.25 for Δ $c(H^+)$, 4 x 0.25 for Δ $n(H^+)$: if n=cV was used, but wrong answer 4 x 0.125; if the units are wrong 4 x 0.2)

Task 2.1.5. Assuming that all the change in pH was caused only by photosynthesis, calculate the maximum possible yield of oxygen per tube:

Tube label	A	B	C	D
n (oxygen) in mol	$n(H_3O^+)$ Answer 2.1.4	$n(H_3O^+)$ Answer 2.1.4	$n(H_3O^+)$ Answer 2.1.4	$n(H_3O^+)$ Answer 2.1.4
m (oxygen) in mg	n x M x 1000	n x M x 1000	n x M x 1000	n x M x 1000

(2 points; 0.25 for each calculation)

Task 2.2.1. Estimate the average volume (in µL) of one capsule. Show your calculations:

$$V(initial) = 5mL, V(after addition of capsules) = X\,mL, \Delta V = (X-5)\,mL$$
$$Capsule\,volume(\mu L) = \frac{\Delta V}{number\ of\ capsules}$$

(1 point for correct answer; 0.5 pts, if ΔV/(no. f capsules) is used)

Task 2.2.2. Calculate the number of *Chlorella* cells in 1 mL of suspension assuming that the volume of one 16-square group is 0.004 mm^3. Show your calculations:

Cell no. on cytometer = 30± 10

$$\text{Cell no. in 1 mL suspension} = \text{Cell no. on cytometer} \cdot \frac{1mL}{V(cytometer)}$$

(2 points; 1 point for correct cell count, 1 point for correct final answer, 0.5 points if wrong units were used)

Task 2.2.3. Calculate the average number of cells per capsule. Show your calculations:

$$\text{No. of cells per capsule} = \text{Answer2.2.2} \cdot \text{Answer2.2.1}$$

(1 point)

Task 2.2.4. Assuming that one *Chlorella* cell weighs 1.25 ng on average, calculate the mass (in g) of algal cells in each tube (10 capsules). Use the data about the number of cells in the experiment obtained from **Task 2.2.3**. Show your calculations:

Calculations:

$$Mass\ of\ cells\ in\ each\ tube = Answer(2.2.3.) \cdot 1.25\,\text{ng} \cdot no.\ of\ capsules\ per\ tube$$

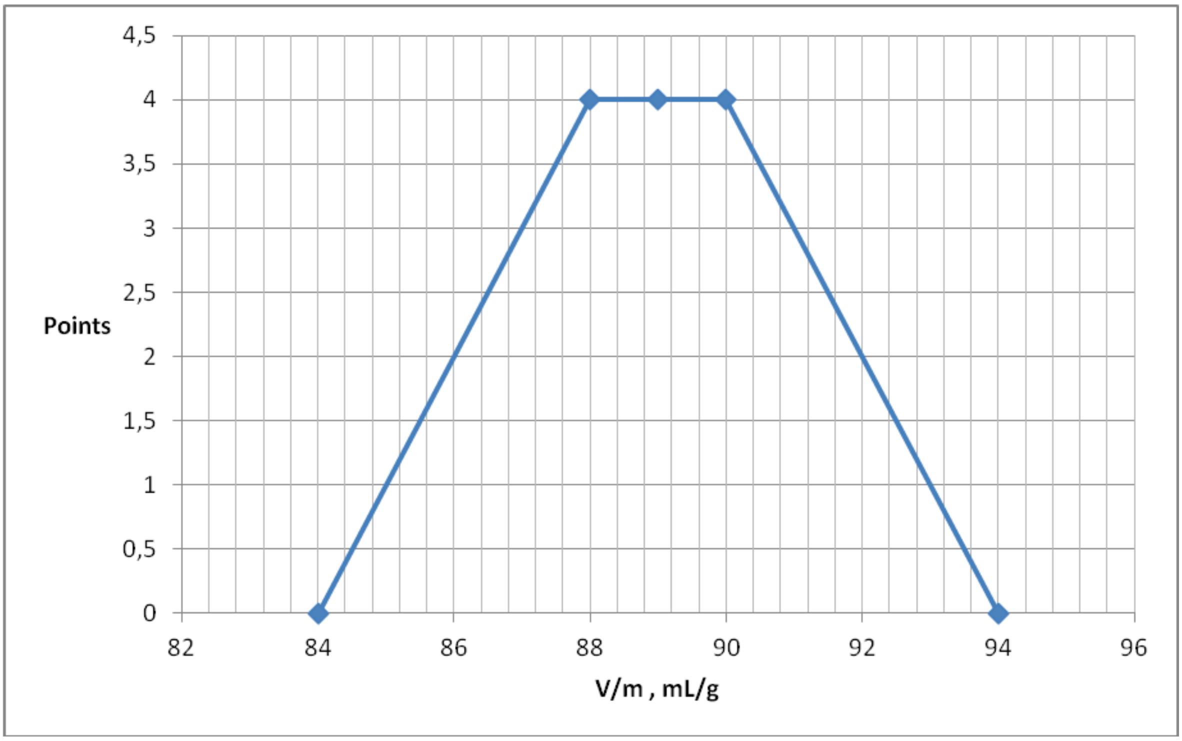
(2 points; 1 point for correct unit conversion, 1 point for correct answer)

End of **TASK 2.**

TASK 3: Chemical air filter capacity

Task 3.1.1. Write your titration results.(4 points)

Titration number	Mass of Na_2CO_3, g	Volume of HCl, ml
1.		
2.		
3.		



Graph 1. Points distribution for the HCl solution standartization results.

Because samples of sodium carbonate differ in mass, V to m ratio will be calculated from students results. Only the bes result will be evaluated.

Task 3.1.2. Calculate concentration of HCl.(1 point)

Calculations:

$m(Na2CO3) = 0.150\ g$

$V(HCl) = 13.3\ mL = 0{,}0133\ L$

$Na_2CO_3 + 2HCl \rightarrow NaCl + H_2O + CO_2$

$n(Na_2CO_3) = \frac{m}{M} = \frac{0.150\ g}{106\ g/mol} = 1.415 \times 10^{-3}\ mol$ (0.5 point)

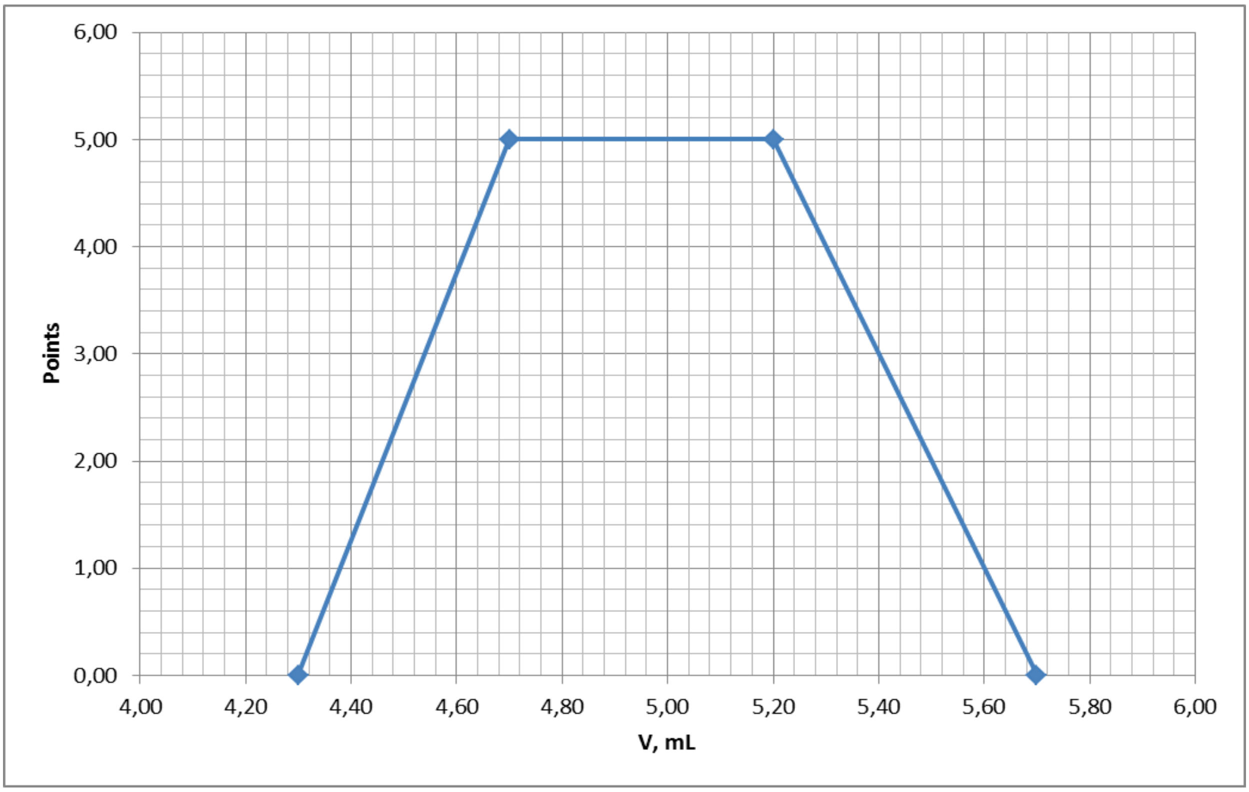
$n(HCl) = 2 \times n(Na2CO3) = 2 * 1.415 \times 10^{-3}\ mol = 2.83 \times 10^{-3} mol$

$c(HCl) = \frac{n}{V} = \frac{2.83 \times 10^{-3}\ mol}{0{,}0133\ L} = 0{,}213\ mol/L$ (0.5 point)

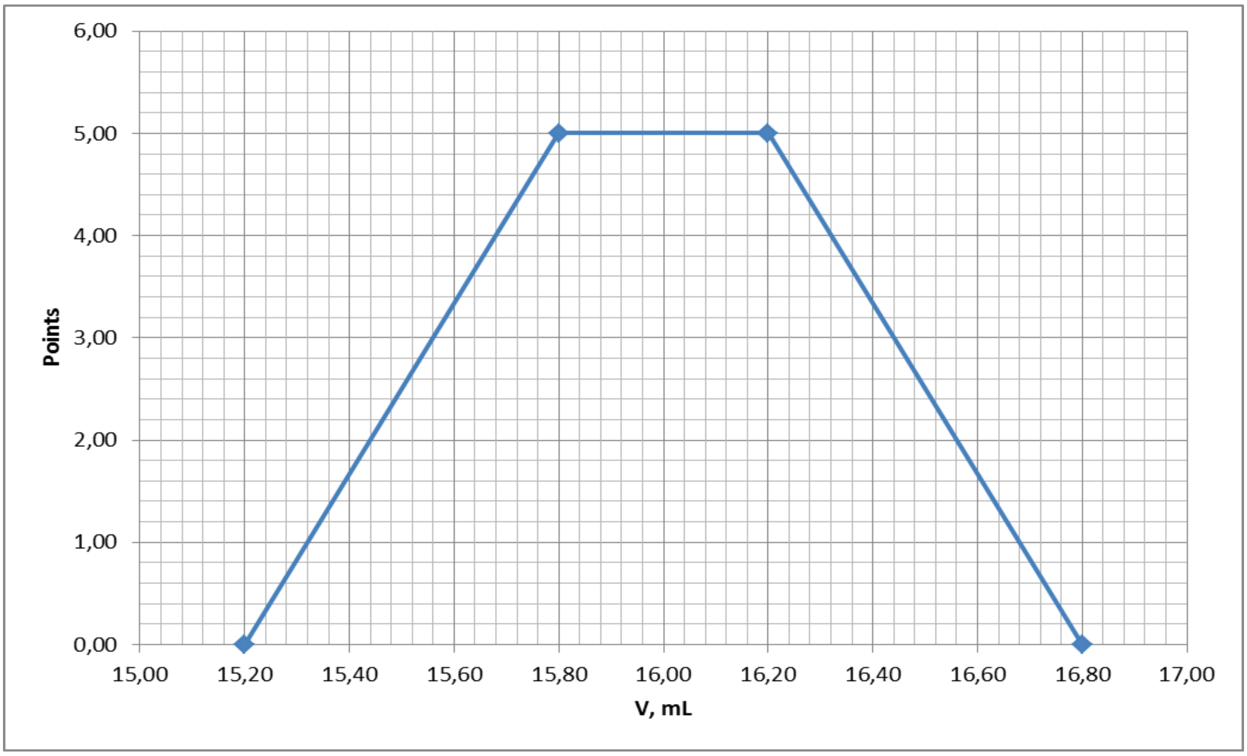
c(HCl)=0.213 mol/L

Task 3.2.1 Write your titration results. (10 points)

Titration number	V_1(first endpoint according to phenolphthalein), mL	V_2(second endpoint according to methyl orange), mL
1.		
2.		
3.		
Average volume that will be used in calculations	4.70 mL	16.00 mL



Graph 2. Points distribution for the first endpoint determination(graph were shifted by 0.1 ml to the right.).



Graph 3. Points distribution for the second point determination.

Task 3.2.2. Calculate the amount of moles of Na_2CO_3 and the amount of moles of $NaHCO_3$ in your sample. (2 points)

Calculations:

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

$HCO_3^- + H^+ \rightarrow H_2CO_3 \ (2)$

From (1):
$n(CO_3^{2-}) = c(HCl) * V_1 = 0.0047\ L * 0.213\ \frac{mol}{l} = 0.001\ mol$

(0.5 point)

From(2):
$n(HCO_3^-) = c(HCl) * V_2 - 2 * n(CO_3^{2-}) = 0.016\ L * 0.213\ \frac{mol}{L} - 2 * 0.001\ mol = 0.0014\ mol$

(1 point)

$0.001\ \text{moles}\ CO_3^{2-}\ \text{in}\ 10\ mL$

$0.0014\ \text{moles}\ HCO_3^-\ \text{in}\ 10\ mL$

$X\ \text{moles}\ CO_3^{2-}\ \text{in}\ 100ml$ $\qquad$ $Y\ \text{moles}\ HCO_3^-\ \text{in}\ 100\ mL$

$X = 0.01\ mol$ $\qquad$ $Y = 0.014\ mols$

$n(CO_3^{2-}) = n(Na_2CO_3) = 0.01\ mol$

$n(HCO_3^-) = n(NaHCO_3) = 0.014\ mol$

(0.5 point)

$n(Na_2CO_3)$=0.01 mol $\qquad$ $n(NaHCO_3)$=0.014 mol

Task 3.2.3 Calculate the weight of CO_2 which your sample has absorbed. (1.5 points)

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

Moles of CO_2 absorbed by Na_2O_2:
$n(CO_2) = n(Na_2CO_3) = 0.01\ mol$

(0.5 points)

$2Na_2O_2 + 4CO_2 + 2H_2O$->$4NaHCO_3\ O_2$
Moles of CO_2 absorbed by $NaHCO_3$:
$n(CO_2)$=$n(NaHCO_3)$=0.014 mol (0.5 points)
Total moles of CO_2 absorbed by filter:
$n(CO_2)$=0.01+0.014=0.024 mol
Total mass of CO_2 absorbed:
$m(CO_2)$=n*M=1.056 g
$m(CO_2)$= 1.056 g (0.5 points)

Task 3.2.4 Calculate the weight of O_2 which your sample has produced. (1 point)

Calculations:

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

$n(O_2) = 0.5 * n(Na_2CO_3) = 0.005$ mol

$2Na_2O_2 + 4CO_2 + 2H_2O \rightarrow 4NaHCO_3 + O_2$

$n(O_2)=0.25*n(NaHCO_3)=0.0035$ mol (0.5 point)

$m(O_2)=n*M=(0.005+0.0035)*32=0.272$ g (0.5 point)

$m(O_2)= 0.272$ g

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. (1.5 point)

Calculations:

$$n_1(Na_2O_2) = n(Na_2CO_3) = 0.010 mol$$

$$n_2(Na_2O_2) = \frac{1}{2} n(NaHCO_3) = 0.007 mol$$ (0.5 points)

$$m(Na_2O_2) = (0.010 + 0.007) mol \times 78 \frac{g}{mol} = 1.326 \approx 1.3 g$$ (0.5 points)

$$m(sample) = \frac{1.326 g}{0.80} = 1.6575 \approx 1.7 g$$

(0.5 points)

m(sample)=1.7 g

Task 3.2.6 Calculate how much O_2 1kg of active filter component can produce.(1 point)

Calculations:

$n(Na_2O_2) = 10.26$ mol

$n(O_2) = 0.5 * n(Na_2O_2) = 5.13$ mol (0.5 points)

$m(O_2) = n * M = 32 \frac{g}{mol} * 5.13 \text{ mol} = 164.2$ g (0.5 points)

m(O_2 produced by 1kg of active component)=164.2 g

Task 3.2.7 Which one of these compounds can also be used as oxygen regenerator? **Circle the correct answer:** (0,5 points)

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

Task 3.2.8. The air on Earth contains some amounts of various noble gases. Which of the noble gases are the most abundant in the air? **Circle the correct answer:** (0,5 points)

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:** (0,5 points)

a) Oxygen exists on Earth 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 common use of carbon dioxide? **Circle the correct answer:** (0,5 points)

a) As a fire extinguisher.

b) As a beverage ingredient.

c) As a refrigerant.

d) As an ingredient of toothpaste.

End of **Task 3.**

Task 4: Oxygen supply sources for the Space Mission

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.

Calculations:

$m(O_2)$= 0.84kg/day×365days×5=1,533 kg

(0.5 points)

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

Calculations:

m(active filter component required for expedition)=$m(O_2)$/ m(O_2 produced by 1kg of active component) = 1,533kg/0.164kg=9348 kg

(0.5 points)

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

Calculations:

N(capsules)= m(active filter component required for expedition)/m(active filter component in one capsule)=9,348 kg/0.00166kg=5,631,325

(0.5 points)

Task 4.1.3 Calculate the number of blocks required for the expedition.

Calculations:

N(blocks)=N(capsules)/N(capsules in one block)= 5,631,325/1,000=5,631 blocks

(0.5 points)

Task 4.1.4 Calculate the final mass of chemical oxygen regeneration system required for the expedition if the mass of one block is 3 kg.

Calculations:

m(chemical oxygen regenaration system)=N(blocks)×m(one block)=5,631×3 kg=16,893 kg

(0.5 points)

(Task 4.2.1, a graph on separate sheet – 1.0 points)

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

$m(O_2)$= (by extrapolation from the graph)

(0.5 points)

Task 4.2.3 Calculate the mass (in kg) of algae required for the team to survive, using your data from **Task 4.2.2.** and **Task 4.1.**

Calculations:

$m(O_2$ by 1 kg of algae) = $m(O_2$ by 10 capsules)/(mass of cells in 10 capsules in g)*1000

(0.5 points)

m(algae) = $m(O_2)/m(O_2$ by 1 kg of algae)

(0.5 points)

(any other solution leading to a correct answer is also worth a total of 1 points)

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?

Calculations:

m(system) = m(algae)*100%/5%

(0.5 points)

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 f the component in the biology oxygen regeneration system, and "N" if not required in either system. (2.25pts)

Component description	Answer Field
Moisture absorbing material	C
System for periodic waste removal	B
Constant glucose supply	N
Non-water based fire extinguisher	C
Liquid nitrogen cooling system	N
Nitrogen fertilizer	B
Non-rechargeable batteries	N
Green light bulbs	N
Protection from cosmic rays	B

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:**

a) Chemical b) Biological.

(Compares answers from Tasks 4.2.4 and 4.1.4, circles the lighter system)

(0.25 points)

End of **Task 4.**