11th EUROPEAN UNION SCIENCE OLYMPIAD

Test 2

Answer sheet

Luxembourg, March 21th, 2013

Country: Team:

Names and signatures:

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TASK 1: Microbiology of biogas production (20 marks)

1.1 **Gram staining of the samples** (2 marks)

⇨ mark the correct answer with an (X)

Sample (A)

Gram +	
Gram + and Gram -	
Gram -	

Sample (B)

Gram +	
Gram + and Gram -	
Gram -	

1.2 **Quality of the microscopic preparation of sample A** (5 marks)

⇨ call a member of the jury to look at your microscopic slide and to evaluate your preparation.

...... marks

1.3 **Organisms involved or not involved in Methane production in the biogas plant of Alfred Bioman (sample A)** (2 marks)

⇨ Mark with X if the following organisms are involved or not involved in Methane production.

	Involved	Not Involved
Archaebacteria		
Eubacteria		
Protista		
Plantae		
Fungi		
Animalia		

1.4 **Microorganisms present in sample (B):** (1 mark)

Use the corresponding numbers from the identification sheet. [ ]

1.5 **Drawing of the microorganisms in sample (A) (field of view of microscope x 1000) and identification of microorganism(s) present. (5 marks)**

Make a drawing of the microorganisms present in sample (A) and name the specimens using the corresponding number from the identification sheet (Answer 1.5).

1.6 **Concerning the cell wall structure you can say after observation of sample (B) that these microorganisms:** (1 mark)

Have a thick Peptidoglycan cell wall	
Have a thin or no Peptidoglycan cell wall	

1.7 **Gram staining:** (1 mark)

Is suitable to distinguish Archaea from Bacteria	
Is not suitable to distinguish Archaea from Bacteria	

1.8 **Duplication ratio:** (3 marks)

How much time do <u>the most common species</u> of microorganisms, from the mentioned groups, need to duplicate their cells once?

Mark and X in each appropriate time frame :

Duplication time	0.5-1 hour	1-5 hours	1-2 days	10-15 days
Archaea				
Bacteria				
Yeast (Eukaryota, Fungi)				

TASK 2: Identifications of two gases in a biogas mixture (21 marks)

Experimental procedure (1 marks)

2.1 m_1 =

2.2 m_2 =

2.3 m_3 =

2.4 V =

Calculations (15 marks)

2.5. Calculation of m_A

2.6 Calculation of m_B

2.7.1 Calculation of m_X

2.7.2 Calculation of M_x

2.7.3

Calculation of n_X/n_Y

Calculation of M_y

Conclusions

Formula of gas X =

Formula of gas Y =

Additional questions (5 marks)

2A Indicate for each of the following statements if they are true or false

In the Ideal Gas law:	True	False
the volume of the molecules is negligible.		
the gas itself does not exert any pressure.		
the atomic radius is larger than 10 nm.		
there are no intermolecular interactions.		
the gas is not soluble in water.		

2B Indicate for each of the following statements if they are true or false

Methane:	True	False
gives rise to a stronger greenhouse effect than carbon dioxide.		
can combine with water at the bottom of the ocean.		
is very soluble in water.		
forms a cubic molecular structure.		
has a characteristic smell		

TASK 3: Monitoring the biogas production process

3.1.1 What is the average volume of gas produced in the eudiometer after adding the acid? (5 marks)

Assay 1		mL/100 mL digestate
Assay 2		mL/100 mL digestate
Assay 3		mL/100 mL digestate
Average		**mL/100 mL digestate**

3.1.2 What is the best description of the gas(es) produced in the reaction bottle? Select one answer (1 mark)

- Methane (CH_4) and carbon dioxide (CO_2) ☐
- A mixture of 50% CO_2 and 50% CH_4 and traces of H_2S ☐
- Pure carbon dioxide (CO_2) ☐
- A mixture of mainly CO_2 and traces of H_2S ☐
- Pure hydrogen sulphur (H_2S) ☐
- A mixture of mainly CH_4 and traces of Hydrogen (H_2) ☐

3.1.3 What happened to the buffer capacity of the digestate after the reaction in the eudiometer? Select one answer (1 mark)

- The buffer capacity is reinforced by the addition of the diluted strong acid (HCl). ☐
- The buffer capacity of the digestate is completely exhausted by the strong acid. ☐
- The buffer capacity remains identical to that of the original digestate. ☐
- The buffer capacity is slightly decreased by the addition of the diluted strong acid (HCl). ☐
- The buffer capacity is stable under all conditions ☐

3.1.4 What are the weak acids formed or present in water when CO_2 and H_2S are solubilized in the digestate in the absence of oxygen? Select one answer (1 mark)

- Sulfuric acid (H_2SO_4) and Hydrochloric acid (HCl): ☐
- Hydrosulfuric acid (H_2S) and Hydrochloric acid (HCl): ☐
- Carbonic acid (H_2CO_3) and Sulphuric acid (H_2SO_4): ☐
- Hydrosulfuric acid (H_2S) and Carbonic acid (H_2CO_3): ☐
- Carbonic acid (H_2CO_3) and Sulphuric acid (H_2SO_4): ☐
- Carbonic acid (H_2CO_3) and Hydrochloric acid (HCl): ☐

3.1.5 Based on the measurement made with the eudiometer, calculate the buffer capacity (total alkalinity) of the digestate in terms of $CaCO_3$ equivalent? (2 marks)

$CaCO_{3\ eq}$..................mg/100 mL of digestate

3.1.6 What are the approximate volumetric proportions of CH_4 and CO_2 produced by the degradation of sugars and lipids during biomethanation? (2 mark)

Sugars → biogas with: CH_4 (%) =……….. and CO_2 (%) =……......
Lipids → biogas with: CH_4 (%) =……….. and CO_2 (%) =……......

3.1.7 Assuming that the digester was fed exclusively with (A) glucose ($C_6H_{12}O_6$) or exclusively with (B) lipids what would be the equivalent of methane produced that corresponds to the measured volume of gas in the eudiometer? (1 mark)

A) Exclusive substrate = Glucose:…………………………………..........mL equivalent methane
B) Exclusive substrate = Lipid:………………………………..............mL equivalent methane

3.1.8 If Mr Alfred Bioman wanted to know the amount of ammonia (NH_3) in solution in the biogas digestate (solubility in water), what would be the adequate reactant to choose while using the same eudiometer design? (1 mark)

- NaOH mixed with ammonium nitrate (NH_4NO_3) to produce an insoluble gas ☐
- H_2SO_4 mixed with a strong reducing agent to transform NH_3 in an insoluble gas ☐
- NaOH mixed with a strong oxidant agent to transform NH_3 in an insoluble gas ☐
- H_2SO_4 mixed with a strong oxidant agent to transform NH_3 in an insoluble gas ☐
- NaOH mixed with a strong reducing agent to transform NH_3 in an insoluble gas ☐
- Water mixed with a strong oxidant agent to transform NH_3 in an insoluble gas ☐

3.2.1 What are the pH values observed for the two digestates (2 marks)

- pH of the original digestate:………………..
- pH of the digestate after the reaction in the eudiometer:………………

3.2.2 On the basis of the expertise you acquired during Tasks 3.1 and 3.2, what is your diagnosis concerning the status of Alfred Bioman's digester ? (1 mark)

- The digester pH is close to neutrality and the buffer capacity is almost equal to zero
  → the digester is stable ☐
- The digester pH is close to neutrality and the buffer capacity is adequate
  → the digester is stable ☐
- The digester pH is acidic and the buffer capacity is adequate
  → the digester is stable ☐
- The digester pH is acidic and the buffer capacity is almost equal to zero
  → the digester is at risk ☐
- The digester pH is strongly alkaline and the buffer capacity is almost equal to zero
  → the digester is stable ☐
- The digester pH is strongly alkaline and the buffer capacity is high
  → the digester is at risk ☐

TASK 4: Determination of the specific heat capacity of a heat carrier liquid used in a solar collector (31 marks)

Task 4.1: Mass of calorimeter (0.5 mark)

Number of calorimeter	
Mass of the empty calorimeter with lid and stirrer	

Task 4.2: Table (4 marks)

t (min)	θ_{water} (°C) Water	θ_{Tyfo} (°C) Anti-freezer liquid

t (min)	θ_{water} (°C) Water	θ_{Tyfo} (°C) Anti-freezer liquid

Task 4.3: Cooling curves (11 marks)

Task 4.4: Slopes of the cooling curves at 70°C (4 marks)

Slope of the cooling curve of water	
Slope of the cooling curve of Tyfo	

Task 4.5: Specific heat capacity of Tyfo (6 marks)

Formula for the specific heat capacity of Tyfo:

Specific heat capacity of Tyfo (at 70°C)	
Specific heat capacity of Tyfo (at +30°C)	
Specific heat capacity of Tyfo (at −20°C)	

Task 4.6: Concentration of the heat carrier mixture (1 mark)

Tyfo concentration of the heat carrier mixture in a solar collector properly working down to a temperature of −20°C	

Question 4A: Specific heat capacity of a mixture (2 marks)

Specific heat capacity of the heat carrier containing 40% of Tyfocor®L at a temperature of 30°C	

Question 4B: Calorimeter's thermal equilibrium (2.5 marks)

For every item tick the boxes "Yes" or "No".

Items	Yes	No
Choosing a calorimeter of the same material with a different mass		
Changing the contact area between calorimeter and liquid		
Placing the calorimeter in a small plastic box		
Not stirring the liquid		
Increasing the ambient temperature and the temperature of the heated liquid by 5°C (specific heat capacities and heat conductivities of the calorimeter and the liquid remaining invariant)		

Task 5: General questions about Biomethanation (6 marks)

5A Methane synthesis: (1 mark)

Write down the equation of methane production by acetototrophic methane producers using acetic acid (CH_3COOH):

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Write down the equation of methane production by hydrogenotrophic methane producers using hydrogen and carbon dioxyde:

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5B Calculate the total amount of petrol (L) which could be displaced annually by the use of biomethanation for energy production in Luxembourg. (1 mark)

Petrol displaced by biogas:_______________L

5C The government of Luxembourg, in an effort to lower the greenhouse gas emissions and to meet her emissions reduction target as set by the Kyoto Protocol, may propose a levy on the ruminant farmers (flatulence tax: 0.01 € /L of CH_4 and 0.005 €/L of CO_2 emitted annually) because their livestock was the biggest emitters of methane (196470 cows in total). How much money could the government of Luxembourg earn per year (365 days) by raising such a tax? (2 marks)

Annual earning:_____________€

5D Since Mr Alfred Bioman has turned his farm into a biogas unit he makes good use of the digestate as an organic fertilizer. His farm has an arable land area of 100 ha and he uses the equivalent of 170 kg of nitrogen/ha per annum (the digestate on Mr Bioman's farm contains on average 4 kg of nitrogen/m^3). Calculate how many m^3 of natural gas is saved annually thanks to the action of Mr Bioman. (2 marks)

Natural gas saved annually:_________________ m^3