8th International Junior Science Olympiad
Durban, South Africa

Practical Examination: Part 1 - Biology

7 December 2011

Duration: 3 hours **Total Marks:** 30

EXAMINATION RULES

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3. Each competitor has to sit at his or her designated desk.

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5. Each competitor has to check the question and answer sheets. Raise your hand, if you find any missing sheets. Start after the bell rings.

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TO DETERMINE THE EFFECT OF CHEMICALS AND TEMPERATURE ON MEMBRANE DESTRUCTION AND PERMEABILITY IN BEETROOT (*Beta vulgaris*)

Introduction

The cell membrane is made up primarily of phospholipids and proteins which contribute to its selectively permeable nature. The function and permeability of the cell membrane depends on its intact structure. When destroyed, the permeability of the cell membrane is disrupted causing cellular contents to leak out. The cell membrane can be destroyed by physical damage, chemicals and high temperature. When cells are cut, the cell membranes are mechanically ruptured. High temperature disrupts the structure of proteins and certain chemicals such as fat solvents dissolve the phospholipids, leading to damage of the membrane and therefore increased permeability.

Beetroot contains a red pigment called betacyanin, which is located in the large central vacuole of the beetroot cells. The vacuole is enclosed by a single membrane called the tonoplast and the whole cell is enclosed by the cell membrane made up of phospholipids and proteins. Betacyanin will remain inside the vacuoles of intact cells. However, if the membranes are damaged, betacyanin will leak out and produce a red/dark pink colour in the surrounding water. Cut cylinders of beetroot are used in this experiment. The beetroot cylinders were repeatedly washed following cutting until not more colour appeared in the wash water.

Materials

1. Washed cylinders of beetroot (1 cm in diameter, 4 cm long) in distilled water
2. 3 x test tubes labelled TT1, TT2 and TT3.
3. 1 x test tube containing distilled water, cyclohexane and a cylinder of beetroot labelled TT4.
4. Test tube rack
5. A bottle containing 8 ml distilled water
6. A bottle containing 8 ml 50% acetone
7. A bottle containing 8 ml 100% acetone
8. 1x sheet graph paper

Experimental procedure

1. Prepare the 3 test tubes as follows (see Table 1):
   Pour the distilled water into TT1.
   Pour the 50% acetone into TT2.
   Pour the 100% acetone into TT3.
2. Place all tubes in the test tube rack.
3. Immediately place a washed cylinder of beetroot in TT1, TT2 and TT3.
4. Shake test tubes 1-4 gently for a few seconds.
5. After 15 minutes observe the colour of the solution in each test tube.

Table 1: Solvents in Test Tubes 1-4

TEST TUBES	**Test tube 1 (TT1)**	**Test tube 2 (TT2)**	**Test tube 3 (TT3)**	**Test tube 4 (TT4)**
SOLVENTS	Distilled water	50% Acetone	100% Acetone	Distilled water + Cyclohexane

QUESTIONS

SECTION 1

a. At the start of the experiment, the distilled water surrounding the washed cylinders of beetroot appeared clear in colour. Why? Choose the correct answer by ticking the appropriate box in the answer sheet.

i. Betacyanin is not soluble in water. ☐

ii. Betacyanin is soluble in organic solvents only. ☐

iii. Damaged cells were empty of betacyanin after repeated washing, and no further cell membrane damage occurred. ☐

iv. All the above. ☐

(0.5 mark)

b. Which test tube represents the control? Choose the correct answer by ticking the appropriate box in the answer sheet.

TT1	TT2	TT3	TT4

(0.5 mark)

c. Based on the colour of the solution in TT2 and TT3, where was betacyanin more soluble? Choose the correct answer by ticking the appropriate box in the answer sheet.

50% acetone	100% acetone

(0.5 mark)

d. In TT4 which layer represents water? Choose the correct answer by ticking the appropriate box in the answer sheet.

Upper ☐

Lower ☐

(0.5 mark)

e. Why was the water coloured in TT4 but NOT in TT1? Choose the correct answer by ticking the appropriate box in the answer sheet.

i. The cell membranes in TT1 were not further disrupted. ☐

ii. Cyclohexane damaged the cell membranes in TT4, causing betacyanin to leak out. ☐

iii. Cyclohexane dissolved the lipids in the cell membranes in TT4, causing betacyanin to leak out, which dissolved in the water only. ☐

iv. All the above statements are correct. ☐

(0.5 mark)

SECTION 2

f. An experiment to determine the effect of temperature on membrane structure and permeability in beetroot was conducted earlier this week. The washed cylinders of beetroot were placed in test tubes containing distilled water and then incubated at 20ºC, 30ºC, 40ºC, 60ºC and 80ºC for 15 minutes. Thereafter the absorbance of the solution in each test tube was recorded at a wavelength of 605 nm. Distilled water was used as the blank. The experiment was repeated three times and the data is shown in Table 2 below. The absorbance is a measure of the amount of light absorbed by the sample. The darker the sample the greater the absorbance.

Based on the information given in this extract (f) and Table 2 below, complete the following tasks in the answer sheet.

i. Complete Table 2 by calculating the mean absorbance at each temperature and record in the column provided.

(0.25 x 4 = 1 mark)

ii. Based on the mean absorbance values, at what temperature did the proteins in the membranes begin to denature? Write your answer in the box below.

(0.5 mark)

iii. Plot a graph on the graph paper provided using the mean absorbance to show the effect of temperature on membrane permeability in beetroot.

(2.5 marks)

Table 2: Effect of temperature on membrane permeability in beetroot

Temperature (ºC)	**Absorbance**			
	Sample A	**Sample B**	**Sample C**	**Mean**

20	0.000	0.000	0.000	
30	0.023	0.013	0.012	
40	0.018	0.025	0.032	
60	0.144	0.176	0.213	
80	0.384	0.474	0.492	

SECTION 3

g. The mean absorbance readings of the solutions in TT2 and TT3 (in the first experiment in SECTION A) were 0.084 and 0.054 respectively. Indicate whether the following statements are true or false. Write T or F in the box provided.

i. Betacyanin requires water for maximum solubility ☐

ii. Betacyanin is more soluble in 100% acetone than in 50% acetone ☐

(0.5 x 2 = 1 mark)

h. From all the information gathered in these experiments on beetroot, in which solvent/s was betacyanin soluble? Choose the correct answer by ticking the appropriate box/es.

Cyclohexane	Water	Hot water

(0.5 mark)

SECTION 4

i. The remaining washed cylinders of beetroot (approximately 50 cylinders) were placed in a glass jar containing 500 ml of 5 M sodium chloride (NaCl). Based on this information, indicate whether the following statements are true (T) or false (F) in the answer sheet.

		TRUE	FALSE
i.	NaCl caused plasmolysis in the beetroot cells.		
ii.	NaCl dissolved the lipids in the cell membranes.		
iii.	The beetroot cells absorbed NaCl and became turgid.		
iv.	The beetroot cells lost betacyanin to the surrounding water.		

(0.5 x 4 = 2 mark)

TOTAL MARK (10)

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Practical Examination: Part 2 - Chemistry

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Read the following instructions carefully:

The three tasks are independent. Students in each team can decide to work cooperatively or separately.

1. The time available is 3 hours.

2. The practical examination paper is in 3 parts. Check that you and each member of your team have a complete set of practical instructions and the corresponding answer sheets. Part 2 of the examination paper consists of 6 pages.

3. Use only the stationery and equipment provided.

4. Write your name, seat number, country and signature on the first page of your answer sheet. You will only need to write your name and seat number on the next pages of your answer sheet. Your team code and student codes must be written on every page of the final answer sheets. Each team member must sign on the front page of the final answer sheets.

5. All results must be written in the designated boxes on the answer sheets. Data written elsewhere will not be graded.

6. While you are in the examination venue, you should wear safety spectacles at all times.

7. Eating of any kind of food is strictly prohibited during the examination. If necessary, you may ask the laboratory assistant and take a snack break nearby outside the venue.

8. Participants are expected to work safely, to behave socially and to keep equipment and work environment clean. When carrying out discussions with your team mates, keep your voice low.

9. Do not leave the examination room until you have permission to do so. Ask the laboratory assistant if you need to use the bathroom and you will be escorted.

10. Work may only begin when the start signal is given.

11. You have 3 hours to complete the experimental tasks, and record your results on the answer sheets. There will be a pre-warning 30 minutes before the end of your time. You must stop your work immediately after the stop command is given. A delay in doing this by 5 minutes will lead to zero points for the task.

12. After completing the task, put all the equipment back in its original place.

13. After the stop command is given, put ONLY the final answer sheets (one copy) on top of the envelope on the desk. Wait for the laboratory assistant to check and collect it. You can take the other papers with you.

CHEMISTRY EXPERIMENT

Energy Content of Fuels

Introduction

Ethanol is an important chemical that is widely used in various industrial sectors. It is a crucial feedstock in the production of various commodities. Examples include pharmaceuticals, paints, inks, detergents, cosmetics, toiletries, speciality chemicals, and beverages to name a few. Ethanol can also be used as an alternative fuel for transport applications. Biodiesel is a mixture of various long chain hydrocarbon molecules, typically methyl, propyl, or ethyl esters. Biodiesel can be used in standard diesel engines, or as a low carbon alternative to heating oil. In some countries, ethanol is used as a gasoline additive (gasohol) or as a petrol (gasoline) substitute, and biodiesel is used with various diesel powered vehicles or engines. Both of these chemicals can be produced from renewable sources. For example, ethanol can be produced from sugar cane, and bio-diesel from high yielding seed oils such as castor, jatropha or palm fruit seeds. The use of renewable resources is one of many proposed strategies to help reduce the effects of climate change and contribute towards sustainable growth and development on a national level.

In this experiment, you will compare the energy content of ethanol and bio-diesel by measuring their heats of combustion in kJ g^{-1} of fuel. In order to find the heat of combustion, you will first use the energy from burning ethanol or bio-diesel to heat a known quantity of water. By monitoring the temperature of the water, you can find the amount of heat transferred to it, using the formula

$$q = C_p \bullet m \bullet \Delta t$$

where q is the heat transferred, C_p is the specific heat capacity of water, m is the mass of water and Δt is the change in temperature of the water. Finally, the amount of fuel burned will be taken into account by calculating the heat per gram of fuel consumed in the combustion.

Objectives

In this experiment, you will

- Compare the heat of combustion for biodiesel and ethanol.
- Calculate the heat of combustion and per cent efficiency for both fuels.

Materials

Small oil lamp

Glass stirring rods

Digital thermometer

100 mL graduated cylinder

Small stainless steel cup

An iron tripod

Utility clamps

Lighter

Ethanol

Biodiesel

Procedure

1. Ensure you and your partners are wearing a laboratory coat and safety glasses.
2. Check that your work station has a digital thermometer, lighter, an oil lamp and supports as in the image.

Part 1: Ethanol

3. Weigh the empty oil lamp on the mass balance provided, and record the value on your data sheet.
4. Using a firm grip, turn the top half of the oil lamp and separate it from the base chamber. See Figure 1.

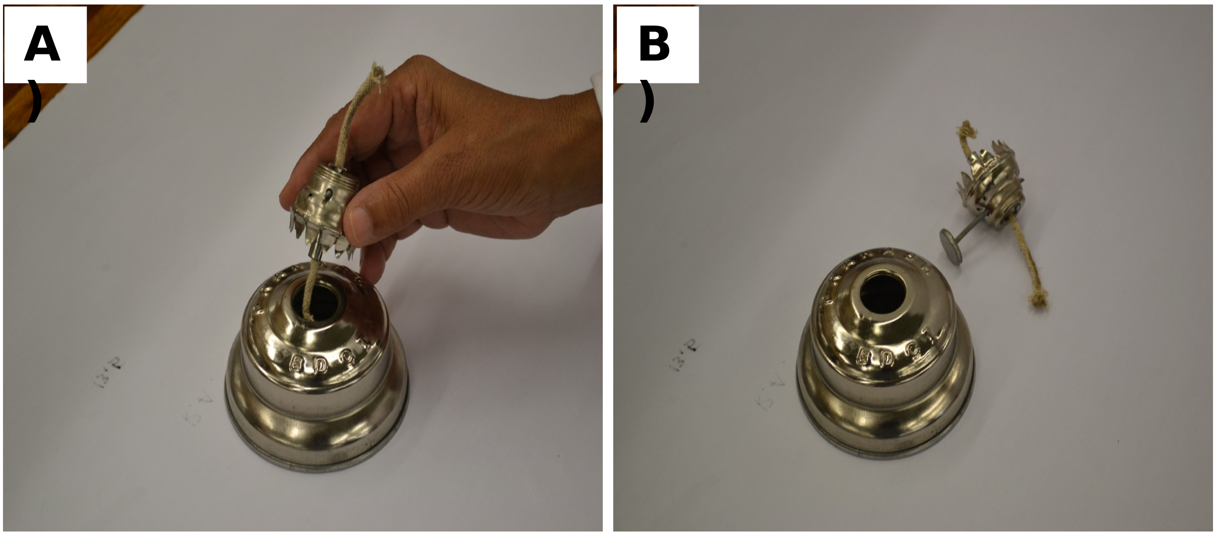

Figure 1

5. Use the measuring cylinder provided to add approximately 100 mL of ethanol into the open chamber of the oil lamp.
6. Place the top half of the oil lamp back onto the open chamber of the lamp and re-weigh (do not close the lamp tightly).
7. Record the mass of the oil lamp fully assembled and with ethanol.
8. Weigh the empty stainless steel cup on the mass balance provided, and record the value on your data sheet.
9. Use a measuring cylinder to add approximately 200 mL of chilled (icy) water to the empty stainless steel cup.
10. Weigh the stainless steel cup + water, and record the value.
11. Condition the top half of the wick with the ethanol, by simply removing the top half of the lamp, invert, dip the wick into the ethanol for 15 – 25 seconds, and then return to its original position and firmly rotate closed.

12. Set up the apparatus as shown in Figure 2. Ensure the stainless steel cup is 5 cm above the oil lamp. Use a utility clamp to suspend the digital thermometer in the water. The digital thermometer should not touch the bottom of the cup.

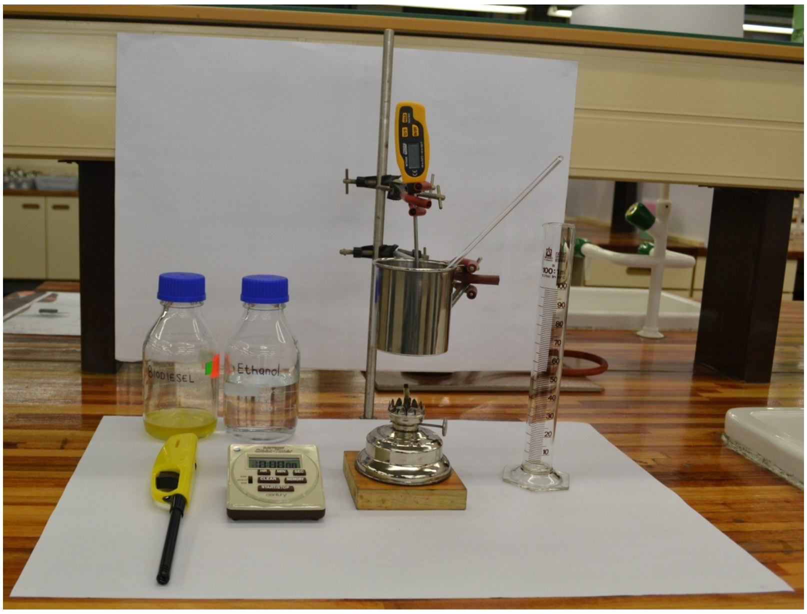

Figure 2

13. Start data collection. Record the initial temperature of the water, t_1, in your data table. Then light the oil lamp. Heat the water in the stainless steel cup until the temperature reaches approximately 30 °C, and then extinguish the flame using a beaker/dowser provided. CAUTION: Keep hair and clothing away from an open flame.
14. Continue stirring the water and record the temperature every 30 seconds until the temperature stops rising. Record the maximum temperature, t_2.
15. Wait 5 – 10 minutes, and then determine and record the final mass of the cooled oil lamp and contents.

Part 2: Biodiesel

1. Repeat Steps 3-15 this time with biodiesel.

Processing the data

1. Find the mass of water heated.
2. Find the change in temperature of the water, Δt.

3. Calculate the heat absorbed by the water, q, using the formula in the introduction of this experiment. For water, C_p is 4.18 J g^{-1} °C^{-1}. Change your final answer to kJ.
4. Find the mass of fuel (ethanol or biodiesel) burned.
5. Calculate the heat of combustion for ethanol and biodiesel, in kJ g^{-1}.
6. Calculate the % efficiency in both trials of the experiment. Divide your experimental value (in kJ g^{-1}) by the accepted value, and multiply the answer by 100. The accepted value for the heat of combustion of ethanol is 30.0 kJ g^{-1}, and for biodiesel it is 41.2 kJ g^{-1}.

Physics Experiment: Solar photovoltaic cells

Introduction

One method of converting energy from the sun (solar energy) is to use a solar cell also known as a photovoltaic cell. A solar cell uses the photovoltaic effect to convert solar radiation directly to DC electrical energy. The rate of energy generation or power from the solar cell depends on the amount of solar radiation falling on the active area of the cell. This power output () can be calculated from the product of the solar cell current (I) and voltage (V) expressed mathematically as.

The current and voltage of a solar cell vary depending on the load (resistance) connected across the cell as well as the amount of solar radiation that is incident on the cell. This variation is normally shown as a graph of current versus voltage and is referred to as the current-voltage (*IV*) characteristic curve. A typical curve is shown in figure 1 (all variables and parmeters are defined below).

Figure 1: Typical *IV* characteristic curves for a solar cell.

The current from the solar cell when the load resistance is zero (an open circuit) is called the short circuit current (I_{sc}). The voltage measured across the cell in this open circuit is called the open circuit voltage (V_{oc}).

The incident solar radiation is normally specified in terms of radiation flux density (referred to as irradiance, G). Irradiance is measured in W m^{-2}. It is evident from Figure 1 that I_{sc} for a solar cell increases with the increase in the amount of solar radiation incident on the active area of the cell.

In this experiment you will investigate the variation of I_{sc} with G for 2 small solar panels connected in series. Each solar panel consists of 12 individual solar cells connected in series. The short circuit current I_{sc} as a function of G can be expressed as

(1)

where I_{sco} is a known reference short circuit current measured at a known quantity of solar irradiance G_o and α is a constant that accounts for the non-linear variation of I_{sc} with G. The incident irradiance G is proportional to the angle of incidence (θ) between the radiation beam and the normal to the solar panels. Equation 1 can then be written as

(2)

where G_{s0} is the irradiance from the radiation source at normal incidence ($\theta = 0°$) to the solar cells.

Objective

The objective of the experiment is to determine the constant α using equation (2).

Apparatus

The experimental set up is shown in figure 2. It consists of a halogen lamp directed to shine its light onto a small PV module. The PV module is connected in series to a digital ammeter. The inclination of the PV module can be varied from 0° to 90° and a mounted protractor is used to measure the angle of inclination.

Procedure

1. Familiarise yourself with the experimental set-up but do not disconnect any cabling and remove any fixed components of the apparatus.

   a. Make sure that the digital ammeter dial is set to an appropriate position to measure a maximum current of 100 mA.

   b. Switch the halogen lamp on and check whether you get a reading from the ammeter.

   c. Adjust the inclination of the PV module by raising the white board that the PV module is attached to and check whether the ammeter reading decreases.

   d. Switch off the lamp and lay the PV module to its original horizontal position.

2. With the lamp switched on, record the following data in the data table on the answer sheet:

   a. the current (I_1) generated by the PV cells when *increasing* the inclination (θ) of the cells from 0° to 80° in equal intervals of 10°.

   b. the current (I_2) generated by the PV cells when *decreasing* the inclination (θ) of the cells from 80° to 0° in equal intervals of 10°.

3. Switch off the lamp and ammeter.

4. Determine the average of I_1 and I_2 and record it as I_{sc} in the table.

5. Use your results to calculate log (cos θ) and log (I_{sc}) and record them in the appropriate columns in the data table.

Questions

1.1 Record in the measured values θ, I_1, I_2 and the calculated I_{sc}. **(2 marks)**

1.2 Fill in the calculated log (cos θ) and log (I_{sc}). **(1.5 marks)**

2. Plot the graph of log (I_{sc}) versus log (cos θ). **(2 marks)**

3. Determine α from your graph. **(2 marks)**

4. Given that I_{sco} = and G_0 = 1000 W m^{-2} use your graph determine the value of G_{s0}.
(2 marks)

5. In which direction would you face a photovoltaic panel being installed on a home in Durban? Place a cross on your choice on the answer sheet. **(0.5 marks)**