14th INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

THE NETHERLANDS 2017

Water and sustainability

Practical Test

Answer sheets

December, 9th 2017

Radboud Universiteit

Quadraam Gelderse Onderwijs Groep

Hogeschool van Arnhem en Nijmegen

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The contractile vacuole of *Paramecium*

1. **(1 point)** Below, five possible statements about the experiment are given. (Note that the statements are not necessarily correct!). Indicate in **Table A1** which statements represent hypotheses and which statements represent predictions, while making sure to match corresponding hypotheses and their predictions if the hypotheses were true. You have to use one statement twice.
   a. The contraction frequency of the anterior vacuole is the same for both salt concentrations.
   b. *Paramecium* regulates water outflow by changing the contraction frequency of the vacuole when the osmotic value of the surroundings changes.
   c. Salt concentration does not affect *Paramecium*.
   d. Paramecium counterbalances water inflow in different environments by changing only the volume that is pumped out per contraction of the vacuole.
   e. The anterior vacuole contracts more often for the lower salt concentration than for the higher salt concentration.

***Table A1** – Hypothesis and prediction*

	Hypothesis	Prediction
1		
2		
3		

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2. **(2.1 points)** One of your supervisors will note down the scores you obtained for your microscopy sample on his/her own sheet. He/she will tick one of the boxes below when he/she has scored your work. DO NOT fill anything in these boxes.

3. **(0.7 points)** Compare the *Paramecia* in the samples with and without the methylcellulose gel. What is the **most appropriate** reason to use a gel to make the samples? Tick the correct answer.

- ☐ A The gel provides a constant 'base level' osmotic value, so the difference in salt concentrations between the two cultures is better defined.
- ☐ B The gel inhibits the movements of the *Paramecia*, so it is easier to observe them, and their contractile vacuoles, under the microscope.
- ☐ C The gel prevents the water in the sample from evaporating, so the salt concentration stays constant over time.
- ☐ D The gel provides an abundant food source for the *Paramecia*, so they do not have to move around anymore to collect food. As a result, it is easier to observe them, and their contractile vacuoles, under the microscope.
- ☐ E The gel prevents the cover slip from crushing the *Paramecia*.

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4. **(3.9 points)** Observe six consecutive contractions of the anterior vacuole of a *Paramecium*. Note down the total time between contraction 1 and contraction 6 in the correct column of **Table A2** below.

Table A2.–*The total time between six consecutive contractions of the anterior contractile vacuoles of nine* Paramecia *at two different salt concentrations.*

	$t_{\text{6 contractions}}$ (s)	
Culture → / ***Paramecium* no. ↓**	**'P–'**	**'P+'**
1		
2		
3		
4		
5		
6		
7		
8		
9		

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5. **(0.9 points)** From the measured times in **Table A2**, calculate the corresponding contraction frequencies $f_{\text{contraction}}$, and write these in **Table A3**. Write down the calculation for the first *Paramecium* in culture **P—** (*i.e.* corresponding to the bold cell in **Table A3**) in the box below. Fill out the correct unit between the brackets in the top cell of **Table A3**.

calculation

$f_{\text{contraction}}$ =

Table A3*–The contraction frequencies of the anterior contractile vacuoles of nine* Paramecia *at two different salt concentrations.*

	$f_{\text{contraction}}$ (… … … … …)	
Culture -> / ***Paramecium* no. ↓**	**'P—'**	**'P+'**
1		
2		
3		
4		
5		
6		
7		
8		
9		

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6. **(0.8 points)** From the numbers in **Table A3**, calculate the average contraction frequencies of the anterior contractile vacuoles for each culture and write them in **Table A4**. Write down your calculation for the '**P—**' culture (*i.e.* corresponding to the bold cell in **Table A4**) in the box below.

calculation

$f_{\text{contraction, average, 'P—'}} =$

***Table A4** – The average contraction frequencies of the anterior contractile vacuoles of nine* Paramecia *at two different salt concentrations.*

Culture →	'P—'	'P+'
$f_{\text{contraction, average}}$ (...)		

Instead of the average, scientists sometimes determine the so-called 'median' of a number of data points. The median can be found by arranging the data points from small to large (or the other way round); the median then is the middle number. If the number of data points is even, there is no middle number and the median is calculated as the average of the two middle numbers.

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7. **(0.2 points)** *Per culture*, copy the contraction frequencies from **Table A3** to **Table A5**, but order them from small to large.

Table A5–*The contraction frequencies of the anterior contractile vacuoles of nine* Paramecia *at two different salt concentrations, ordered from small to large.*

	$f_{\text{contraction}}$ (...)	
Culture → / ***Paramecium* no. ↓**	**'P–'**	**'P+'**
1		
2		
3		
4		
5		
6		
7		
8		
9		

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8. **(0.4 points)** For each culture, determine the median of the contraction frequencies of the anterior contractile vacuoles of nine *Paramecia* and write them in **Table A6**.

Table A6*–The median contraction frequencies of the anterior contractile vacuoles of nine* Paramecia *at two different salt concentrations.*

Culture →	**'P–'**	**'P+'**
$f_{\text{contraction, median}}$ (…)		

9. **(0.8 points)** What, in general, is the advantage of the using the median over the average? And what is the disadvantage? (N.B. 'extreme values' are either very large or very small values). Tick one correct advantage and one correct disadvantage.

Advantage:

☐ A The median is less sensitive to extreme values than the average.

☐ B If there are no extreme values, the median is a more accurate description of the data than the average.

☐ C The median is easier to calculate, since it is only based on one (for an odd number of values) or two (for an even number of values) values, whereas the average uses all values.

Disadvantage:

☐ A Since the median is based on only one or two values, it is a less accurate description of the data than the mean.

☐ B The median is more sensitive to extreme values.

☐ C If there are no extreme values, the median is a less accurate description of the data than the average.

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10. **(0.8 points)** Can each of the following conclusions be drawn based on this experiment?

		YES	NO
I	The volume of water displaced by one contraction of the contractile vacuoles is constant across salt concentrations.	☐	☐
II	The iso-osmotic value of *Paramecium* is higher than the osmotic value of both '**P—**' and '**P+**'.	☐	☐
III	The contraction frequency of the contractile vacuoles is constant over time.	☐	☐
IV	A change in salt concentration of the environment does not affect *Paramecium*.	☐	☐

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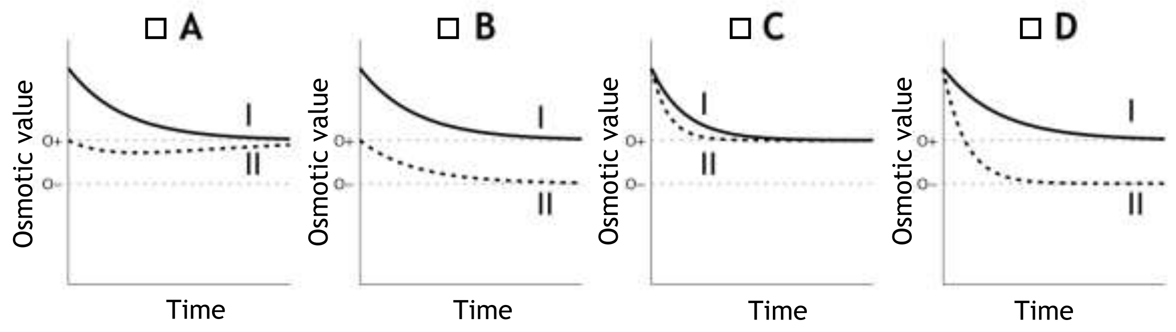
11. (0.7 points) *Paramecium* has the ability to adjust its internal osmotic value (**O**) to its surroundings over the course of several hours. Of course there is a limit to this ability. Assume that the minimum osmotic value *Paramecium* can achieve is equal to that of the surroundings in the '**P+**' culture. Call this osmotic value **O+.**

Four graphs are shown. Tick the graph that correctly depicts:

Case I: the osmotic value of a *Paramecium* cell over time when it is transferred from an iso-osmotic environment (where *Paramecium* had the same osmotic value as its environment) equal to 1.5×**O+** into an environment with an osmotic value of **O+**.

Case II: the osmotic value of a *Paramecium* cell over time when it is transferred from an iso-osmotic environment equal to 1.5×**O+** into an environment with an osmotic value **O—** equal to that of the '**P—**' culture.



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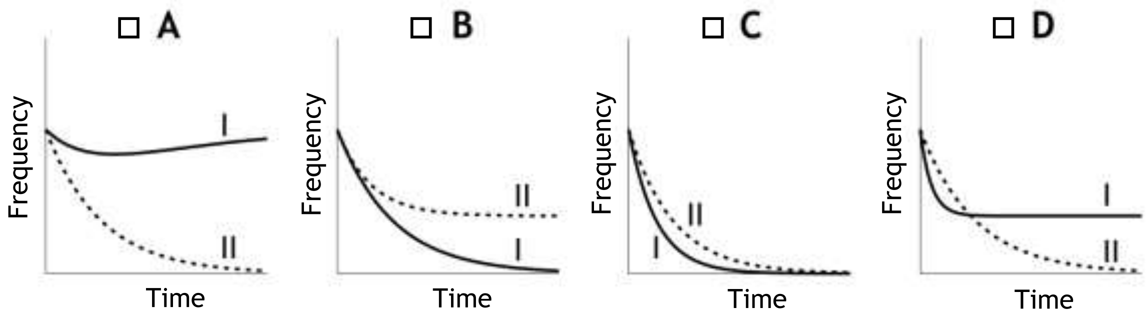
12. **(0.7 points)** Similarly, tick the graph below that correctly depicts the contraction frequencies of the contractile vacuoles of the *Paramecia* in cases I and II over time.



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Determining the chloride concentration of a sodium chloride solution using the Fajans titration

A. Determining the densities of the solutions

1. **(1.9 points – 0.6 points for the calculation and 1.3 points for accuracy of the result)**
   Calculate the density of the sodium chloride solution in g/mL. Only if you are unable to get a result, use the arbitrary value of 1.12 g/mL for subsequent questions.

measurements   calculation   answer: $\rho_{\text{NaCl sln}} =$ g/mL

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2. **(1.9 points – 0.6 points for the calculation and 1.3 points for accuracy of the result)**
Calculate the density of the silver nitrate solution in g/mL. Only if you are unable to get a result, use the arbitrary value of 1.05 g/mL for subsequent questions.

measurements

calculation

answer: $\rho_{AgNO_3\ sln} =$ g/mL

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B. Trial titration

Write the results of the trial titration in this box (you will get no marks for this).

C. Accurate titrations

3. **(0.4 points)** For every accurate titration, write down the initial (i) and final (f) masses of the syringes containing the sodium chloride solution and the silver nitrate solution.

	$m_{\text{NaCl syringe, i}}$ (g)	$m_{\text{NaCl syringe, f}}$ (g)	$m_{\text{AgNO}_3\text{ syringe, i}}$ (g)	$m_{\text{AgNO}_3\text{ syringe, f}}$ (g)
Titration 1				
Titration 2				
Titration 3				

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4. **(0.85 points)** Calculate the volumes of sodium chloride solution that you titrated. Show the calculation for titration 1 only. Complete the table.

calculation

	$V_{\text{NaCl solution}}$
Titration 1	
Titration 2	
Titration 3	

5. **(0.85 points)** Calculate the volumes of silver nitrate solution that you used to titrate the sodium chloride solution. Show the calculation for titration 1 only. Complete the table.

calculation

	$V_{\text{AgNO}_3\text{ solution}}$
Titration 1	
Titration 2	
Titration 3	

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6. **(0.4 points)** Calculate the molarity (*i.e.* the concentration in mol/L) of silver nitrate in the solution. Only if you are unable to calculate the molarity, use the arbitrary value of 0.440 mol/L for subsequent calculations.

calculation
molarity: mol/L

7. **(2.9 points – 0.9 points for calculation and 2.0 points for consistency of practical work)** Calculate the molarities of chloride in mol/L that follow from the three accurate titrations. Show the calculation for titration 1 only.

calculation

	C_{Cl^-} (mol/L)
Titration 1	
Titration 2	
Titration 3	

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8. **(3.2 points - 0.2 points for calculation and 3.0 points for accuracy of practical work)** Calculate the average $\overline{C}_{\mathrm{Cl}^-}$ in mol/L of the three chloride concentrations that you calculated in question 7.

calculation
answer: $\overline{C}_{\mathrm{Cl}^-} =$ mol/L

9. **(0.6 points)** Calculate the sodium chloride concentration of the solution in g/L.

calculation
answer: $C_{\text{mass, NaCl sln}} =$ g/L

Do not write in the box below

Penalty for using extra materials	Signature of lab assistant

Signature:	

Blue energy

A. Measuring potential differences using the concentration cell

1. **(1.2 points)** Fill out the remaining columns of Table A1.

Table A1 *– Measurement results of the voltage for solutions **X0** to **X4**.*

Solution	C_{NaCl} (g/L)	$\log(C_{NaCl})$	V (mV)
X0			
X1			
X2			
X3			
X4			

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2. **(1.4 points)** Plot the values of V against $\log(C)$. Draw the data points as clear dots. Draw the straight line of best fit through the data points using the set square.

Figure A1 – *Graph of the measurements: voltage as function of* $\log(C)$.

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3. **(1.0 points)** The relationship between V and $\log(C)$ is linear and can be written as $V = a + b \cdot \log(C)$. Determine from Figure A1 the values of a and b, without uncertainties.

calculation
$a =$ mV
$b =$ mV

4. **(0.5 points)** Indicate in Figure A1 clearly which point corresponds to the unknown solution **X0** and write down the coordinates below (without units).

coordinates corresponding to solution **X0**:
horizontal:
vertical:

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5. **(0.9 points)** Determine the concentration C_0 of solution **X0**.

calculation   answer: $C_0 =$ g/L

B. Measuring the electrical conductance of the solutions

6. **(0.4 points).** Let the lab assistant check your electrical circuit.
You may not write in the next box.

Correct circuit: ☐ yes ☐ no Signature lab assistant:	Remarks:

Signature:	

Use table B1 in questions 7 to 12 and use the information in your procedure sheets to complete this table.

Table B1 *– Measurement results for salt solutions **X1** to **X4** and **X0**. Also write down the missing units in the column headings.*

Solution	C_{NaCl} (g/L)	V_1(______)	V_2(______)	I (______)	G (______)	σ (______)
X0						
X1						
X2						
X3						
X4						

7. **(1.0 points)** Write the readings of the multimeters in Table B1, and complete the symbols of the measuring quantities with the correct units in the top row.

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8. **(0.8 points)** Calculate from your measurements the current I which went through the setup, and calculate for each known salt concentration the conductance G. Enter your results in Table B1. Show in the box below the calculations for **X1** only.
The conductance is the reverse of the resistance and has as unit S (which stands for Siemens). See the equation sheet for more information, and enter the results in Table B1 .

calculation of the current I for **X1**
calculation of the conductance G for **X1**

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9. **(1.4 points)** Plot the conductance G against concentration C in a graph (Figure B1). Clearly indicate your measurement data as dots on the graph. Based on your data points draw a smooth curve (best fit).

Figure B1 *– Graph of the measurements: conductance as function of concentration.*

10. **(0.8 points)** Determine from your graph the concentration of the solution labeled **X0**. Show clearly how you obtained your result.

answer: $C_0 =$ g/L

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11. **(0.8 points)** Determine values for l and A of the pair of electrodes. Use SI units, so l in m and A in m^2.

calculation   answers: $l =$ m $A =$ m^2

12. **(0.4 points)** Calculate the specific conductivities of solutions **X0** and **X1** to **X4** and write down the results in Table B1. Show in the box below the calculation for **X0** only.

calculation   answer for X**0**: $\sigma =$ S/m

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C. Calculating the theoretical maximum electrical power

13. Consider your graph in Figure A1 and answer the following questions.
    a) **(0.2 points)** If you want to obtain the maximum voltage from the RED cell, which of the solutions **X0** to **X4** should you use for the salt water?
    b) **(0.2 points)** Which of the solutions **X0** to **X4** should you use for the fresh water?
    c) **(0.5 points)** Read from Figure A1 how large the potential difference ΔV is across the cell when using the solutions you chose in questions 13a and 13b.

solution to be used for the salt water: solution to be used for the fresh water: $\Delta V =$ mV

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14. **(0.5 points)** Calculate the conductance G_{fresh} of the fresh water side and G_{salt} of the salt water side of the RED cell. Use the specific conductivities from Table B1 on the answer sheet.
Note: if you don't have data for σ, use $\sigma_{\mathrm{fresh}} = 0.99\ \mathrm{S/m}$ and $\sigma_{\mathrm{salt}} = 11.6\ \mathrm{S/m}$ for your calculations.

calculations
answers: $G_{\mathrm{fresh}} =$
$G_{\mathrm{salt}} =$

15. **(0.5 points)** Calculate the internal resistance of the RED cell.

calculation
$R_{\mathrm{int}} =$

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16. (0.8 points) Calculate the current I through the external resistor. Use the potential difference ΔV you found in question 13.
Note: if you don't have a value for ΔV, use $\Delta V = 55.0$ mV as a value for your calculation.

calculation $I =$ A

17. (0.4 points) Calculate the power P this RED cell delivers to the external resistor.

calculation $P =$ W

18. (0.3 points) How many of these RED cells you need for a power plant to generate 1.0 MW?

answer: