IJSO

14th INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

THE NETHERLANDS 2017

Water and sustainability

Multiple Choice Test

December, 5th 2017

Carefully read the "EXAMINATION RULES" and "EXAM INSTRUCTIONS"

QUADRAAM

Radboud Universiteit

Hogeschool van Arnhem en Nijmegen

slo

EXAMINATION RULES

1. You are NOT allowed to bring any personal items into the examination room, except for the water bottle, personal medicine or approved personal medical equipment.
2. You must sit at your designated desk.
3. Check the stationery items (pen, calculator, and scrap paper) provided by the organizers.
4. Do NOT start answering the questions before the **"START"** signal.
5. You are NOT allowed to leave the examination room during the examination except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. If you need to visit the bathroom, please raise your hand.
7. Do NOT disturb other competitors. If you need any assistance, raise your hand and wait for a supervisor to come.
8. Do NOT discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.
9. At the end of the examination time you will hear the **"STOP"** signal. Do NOT write anything more on the answer sheet after this stop signal. Arrange the exam, answer sheets, and the stationary items (pen, calculator, and scrap paper) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

EXAM INSTRUCTIONS

1. After the "START" signal, you will have 3 hours to complete the exam.
2. ONLY use the pen and pencil provided by the organizers.
3. Check that your name, code and country are on your answer sheet and sign your answer sheet. Raise your hand, if you do not have the answer sheet.
4. Read each problem carefully and indicate your answer on the answer sheet using a cross (as shown below). There is only one correct answer for each question.

   Example: (A) is your answer.

1	X	B	C	D

5. If you want to change your answer, circle your first answer and then indicate your new answer using a cross (as shown below). You can only make ONE correction per question.

   Example: (A) is your first answer and (D) is your final answer.

1	(X)	B	C	X

6. Only the answer sheet will be evaluated. Before writing your answers on the answer sheet, use the scrap paper provided.
7. Point rules

Correct answer	: + 1 point
Wrong answer	: – 0.25 point
No answer	: no point

8. The total number of questions is 30. Check that you have a complete set of the test questions (15 pages, page 5 - page 19) after the "START" signal is given. Raise your hand, if you find any missing sheets.
9. Useful information for answering the questions (atomic masses, constants and formulas) is provided on page 4.

GENERAL INFORMATION

The first twenty elements of the Periodic System with their standard atomic weights							
H 1.008							He 4.003
Li 6.941	Be 9.012	B 10.81	C 12.01	N 14.01	O 16.00	F 19.00	Ne 20.18
Na 22.99	Mg 24.31	Al 26.98	Si 28.09	P 30.97	S 32.06	Cl 35.45	Ar 39.95
K 39.10	Ca 40.08						

Constants

acceleration due to gravity: $g = 9.81\ \text{m/s}^2$

gas constant $R = 8.3145\ \text{J/(mol K)}$

Formulas

area of a circle: $A = \pi r^2$

circumference of a circle: $C = 2\pi r$

volume: $V = Ah$

density: $\rho = \frac{m}{V}$

pressure: $p = \frac{F}{A}$

heat: $Q = mc\Delta T$

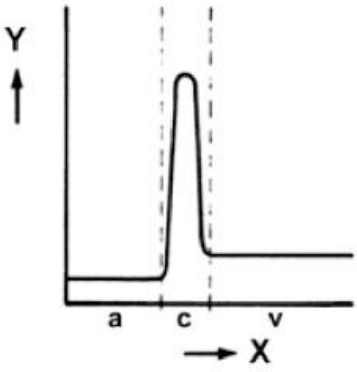
power: $P = \frac{E}{t}$

gravitational potential energy: $E_p = mgh$

Ohm's law: $V = IR$

Biology questions – Corrected version

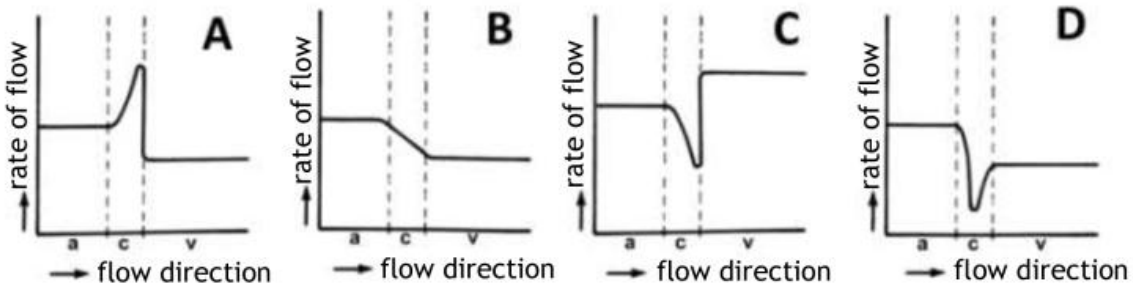
Rate of flow of blood



In a muscle in the upper arm of a human, blood runs through arteries, capillary vessels and veins. The picture shows the total area of a cross section of one of these arteries (a), the subsequent capillary vessels (c) and the corresponding returning veins (v).

X = direction of the blood flow
Y = total area of cross section

1. Which of the following pictures correctly shows the rate of flow (velocity) of the blood through an artery, a capillary vessel and a vein concerned?



Fermentation and Respiratory Quotient RQ

Floris investigates the conversion of glucose by yeast. The glucose is converted anaerobically as well as aerobically. Consider the reaction equations:

Aerobic: $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$
Anaerobic: $C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$

Floris starts off with a solution containing 0.50 mol of glucose and some yeast. By measuring the loss of mass he is able to determine the amount of CO_2 generated.

When all the glucose is converted, the total loss in mass due to the generation of CO_2 is 79.2 g (= 1.8 mol CO_2). Floris assumes that no carbon dioxide remains in the solution. Now Floris is able to calculate the Respiratory Quotient of the process.

The Respiratory Quotient is defined as:

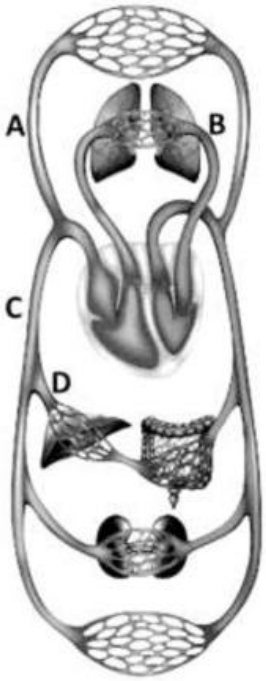
$$RQ = \frac{\text{moles of } CO_2 \text{ (produced)}}{\text{moles of } O_2 \text{ (used)}}$$

2. What is the correct Respiratory Quotient?

A $RQ = 0.67$
B $RQ = 1.2$
C $RQ = 1.5$
D $RQ = 1.8$

Glucose concentration in blood

The picture shows blood circulation in a mammal.
Four locations are indicated by A, B, C and D.

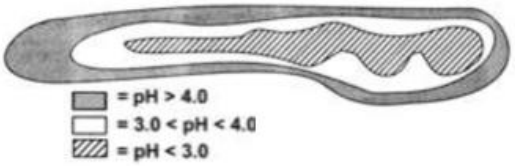


3. Which location has the lowest glucose concentration?

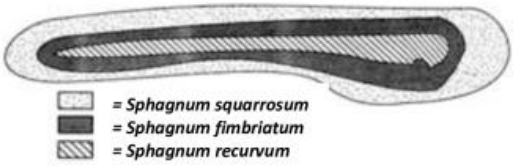
Sphagnum

The distribution of *Sphagnum* (moss) species is influenced by pH, but not by other abiotic factors.
After a long period of stable weather conditions Tom investigates the distribution of three different *Sphagnum* species on a small island surrounded by brackish water. The results are shown below.

pH distribution



moss distribution



Three conclusions are:

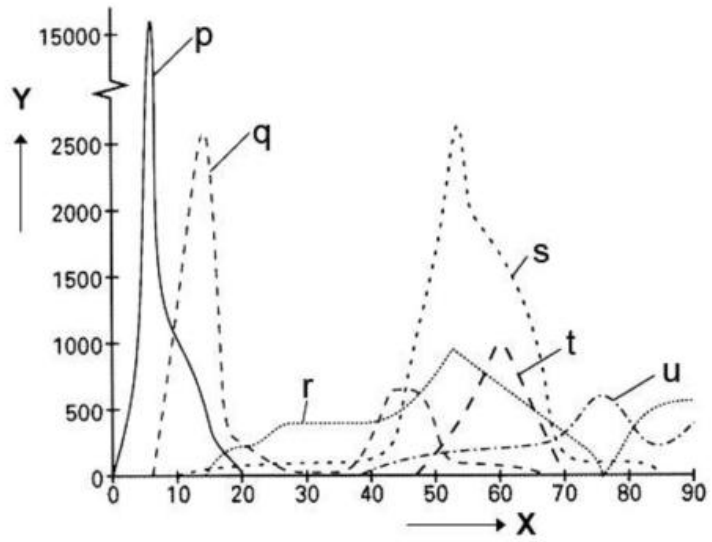
I *Sphagnum squarrosum* can only survive if pH > 4.0.
II Competition occurs between *Sphagnum recurvum* and *Sphagnum fimbriatum*.
III *Sphagnum recurvum* and *Sphagnum squarrosum* have overlapping habitats.

4. Which conclusion(s) are correct?

A only II
B only I and III
C only II and III
D I, II and III

Hay water

Mary boiled water and dried grass in a beaker for some time, and left it uncovered for several days. During that period only heterotrophic bacteria were found in the beaker. After ten days, she added a few drops of water from a ditch and covered it with a lid. The water from the ditch only contained heterotrophic unicellular organisms, but no bacteria or fungi. Mary regularly determined the population size of the different species present in the beaker over three months. Alltogether six different species (p - u) were found. The diagram shows the number of individuals per mL in the beaker.



X = Time (days); Y = number of individuals per mL

Looking at the results Mary considers two conclusions.

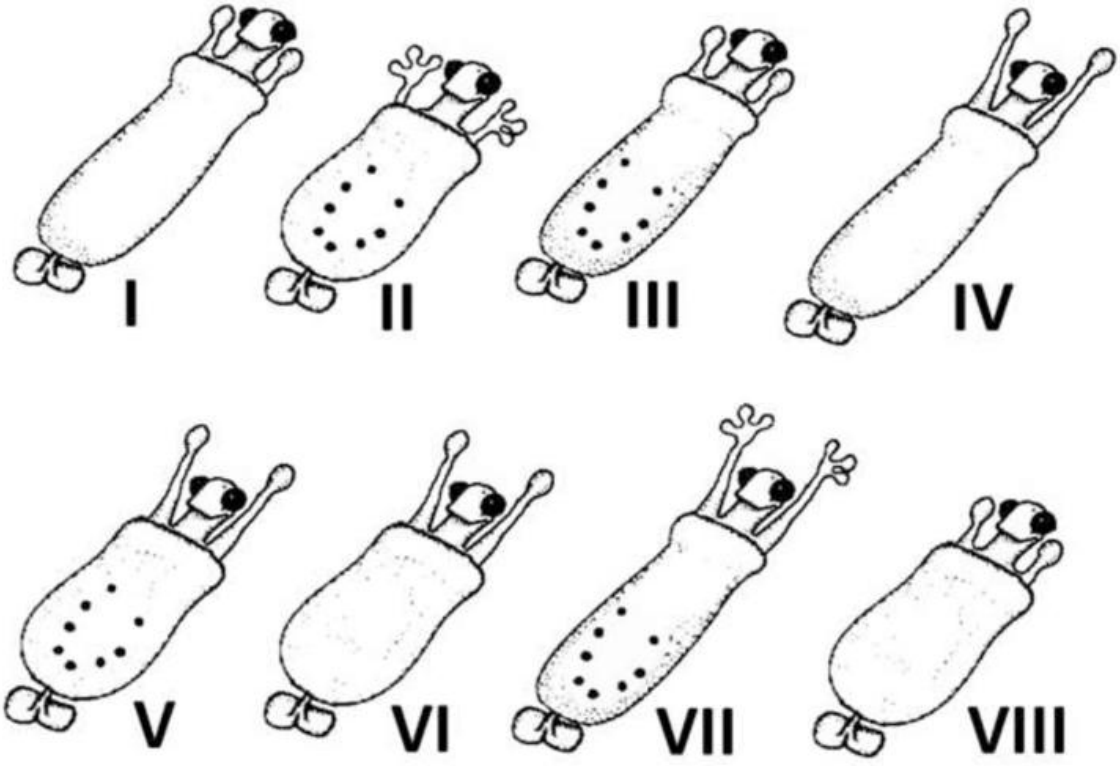
I Eventually the number of dividing bacteria will decrease to zero.
II Eventually a climax stage will develop, comprising bacteria and other heterotrophic unicellular organisms, in a stable natural equilibrium.

5. Which conclusion(s) is/are correct?

A only I
B only II
C both I and II
D neither I nor II

Identification of Caminalcules

In modern biology DNA plays an important role in distinguishing different species. In the past this was done primarily by considering external characteristics. The picture below shows *Caminalcules*: non-existent creatures invented by Joseph Camin to demonstrate to his students how to distinguish species and set up evolutionary trees.



The eight *Caminalcules* shown can be distinguised with just three of the following four features:
Long arms, long body, presence of belly spots, and presence of fingers.

6. Which of the following four features is **NOT** needed?

   A long arms
   B long body
   C presence of belly spots
   D presence of fingers

Water loss

In a pilot study the daily water loss of a group of subjects is monitored under different conditions. Three processes are monitored: diffusion (not sweating) of water through skin, lung ventilation, and urine production.
The table shows the results in a random order.

	Average daily loss of water in mL/day		
	mild exercise at 20 °C	mild exercise at 30 °C	strenuous exercise at 20 °C
Process I	350	250	650
Process II	50	50	50
Process III	1400	1300	600

7. Which processes correspond to lung ventilation and urine production?

	lung ventilation	urine production
A	process I	process II
B	process I	process III
C	process II	process III
D	process III	process I

Temperature-sensitive alleles

Some fly species have alleles that are temperature sensitive. Fertilized eggs only develop below a specific temperature, see the table below.

Genotype	Temperature necessary for development
EE	< 18 °C
Ee	< 20 °C
ee	< 28 °C

Two flies, both with genotype Ee, mate. Their fertilized eggs (F1) are allowed to develop at 19 °C. The F1 flies mate randomly and the eggs produced are again allowed to develop at 19 °C.

8. What fraction of eggs produced in the F1 crossing will **not** develop?

A 1/9
B 2/9
C 4/9
D 6/9

DNA and evolutionary relation

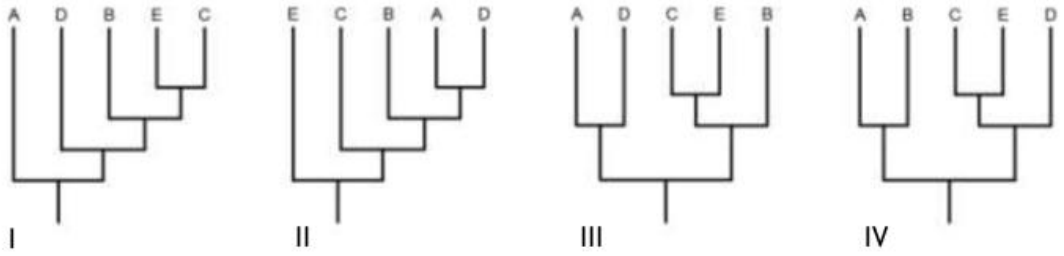
Several people (A - E) in the same city contract Legionnaires' disease. It is important to identify how many sources are causing this outbreak, and what those sources are, to prevent the disease from spreading. The pathogens' DNA is extracted, and the alleles of seven of its genes are determined to identify the number of sources. Then, for each pair of patients, we count how often the alleles for those seven genes are different, known as the 'distance' between the patient's pathogens. If the two pathogens of two patients are identical on all seven genes, then the distance is 0, whereas if the pathogens have different alleles for all seven genes, the distance is 7. The distances for all pairs of patients A - E are given below in the 'Distance matrix'.

Distance matrix

Patient A	Patient B	Patient C	Patient D	Patient E	
	5	5	1	4	Patient A
		2	5	2	Patient B
			6	1	Patient C
				6	Patient D
					Patient E

The data in the table can be used to depict the relation of the pathogens in patients A - E as a dendrogram (tree structure).

9. Which of the dendrograms below corresponds to the distance matrix?



A I
B II
C III
D IV

Legionella

Strains of *Legionella* (the bacterium responsible for Legionnaires' disease) can be identified by means of the allele for the gene *flaA*. This gene codes for a protein that is part of the bacterium's flagellum.

The bases 670 to 700 of the coding strand (the complement of the template strand) of the DNA of an allele of *Legionella*'s *flaA* gene are represented below. Bases 197 to 199 make up the start codon.

	670----------700	
5'	T T T C A G T A T C G G C A G C A C A A A A G C T T C T T C T	3'

10. What is the correct order of the amino acids in the part of the protein that is coded for by the DNA fragment above? Use the table below, in which the genetic code is depicted.

standard genetic code									
1st base (5'-end)	2nd base								3rd base (3'-end)
	U		C		A		G		
U	UUU	Phe (F)	UCU	Ser (S)	UAU	Tyr (Y)	UGU	Cys (C)	U
	UUC		UCC		UAC		UGC		C
	UUA	Leu (L)	UCA		UAA	Stop	UGA	Stop	A
	UUG		UCG		UAG	Stop	UGG	Trp (W)	G
C	CUU		CCU	Pro (P)	CAU	His (H)	CGU	Arg (R)	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Gln (Q)	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Ile (I)	ACU	Thr (T)	AAU	Asn (N)	AGU	Ser (S)	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lys (K)	AGA	Arg (R)	A
	AUG	Met (M)	ACG		AAG		AGG		G
G	GUU	Val (V)	GCU	Ala (A)	GAU	Asp (D)	GGU	Gly (G)	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glu (E)	GGA		A
	GUG		GCG		GAG		GGG		G

A Phe - Ser - Ile - Gly - Ser - Thr - Lys - Ala - Ser - Ser
B Phe - Gln - Tyr - Trp - Gln - His - Lys - Ser - Phe - Phe
C Ser - Val - Ser - Ala - Ala - Gln - Lys - Leu - Leu
D Lys - Ser - *Stop*

Chemistry questions

Photosynthesis by algae

Surface water can contain organic and inorganic matter. In many surface water most of the organic matter is formed by photosynthesis. Phytoplankton, such as algae, are one of the major producers of organic matter. In this organic matter carbon atoms, nitrogen atoms and phosphorous atoms often occur in the following ratio: C : N : P = 106 : 16 : 1. Organic matter produced during photosynthesis by algae can be described by the formula $C_{106}H_{263}O_{110}N_{16}P$.

The following incomplete equation summarizes phytoplankton photosynthesis:

$$\_\ NO_3^- + \_\ HPO_4^{2-} + \_\ H^+ + \ldots \rightarrow C_{106}H_{263}O_{110}N_{16}P + \ldots \qquad \text{(equation 1)}$$

In this equation some coefficients are missing as well as the formulas of some molecules.

11. Which molecules are missing in this incomplete equation?

	on the left	on the right
A	CO_2	H_2O and O_2
B	CO_2 and H_2O	O_2
C	CO_2 and O_2	H_2O
D	O_2	CO_2 and H_2O

12. What should the coefficient of H^+ be when equation 1 is balanced?

A 3
B 16
C 17
D 18

Green chemistry

Green chemistry is an area of chemistry and chemical engineering that deals with the development of sustainable production processes.
Two important concepts in green chemistry are atom economy and the *E* – factor. The formulas for these concepts are:

$$\text{atom economy} = \frac{\text{mass of the desired product}}{\text{mass of the starting materials}} \times 100\%$$

and

$$E - \text{factor} = \frac{\text{mass of the starting materials} - \text{mass of the obtained product}}{\text{mass of the obtained product}}$$

13. Which words have to be filled in for I and for II in the sentence below?

A green process has a ..I.. atom economy and a ..II.. *E* – factor.

	I	II
A	high	high
B	high	low
C	low	high
D	low	low

Determination of oxygen

Dissolved oxygen (O_2) is important for underwater life. The concentration of oxygen in polluted surface water can decrease dangerously. Therefore this concentration is determined regularly.
The concentration of dissolved oxygen can be determined with a titration. A sample of 10.00 mL is taken from the surface water. The sample is treated with an acidic solution of potassium iodide after which the following reaction takes place:

$$O_2 + 4\,H^+ + 4\,I^- \rightarrow 2\,I_2 + 2\,H_2O$$

An excess of an acidic solution of potassium iodide is added to make sure that all oxygen reacts.
Next the iodine is titrated with a 0.0100 M solution of sodium thiosulfate ($Na_2S_2O_3$). The following reaction takes place:

$$I_2 + 2\,S_2O_3^{2-} \rightarrow 2\,I^- + S_4O_6^{2-}$$

Starch is used to indicate the endpoint of the titration.

A student performed the determination. At the end of the titration the solution turned colorless when the last drop of the solution of sodium thiosulfate was added, as it should. Nevertheless it turned out that the calculated concentration of dissolved oxygen higher than expected.

14. Which of the following errors could be responsible for this result?

I After rinsing the burette with distilled water the burette was immediately filled with the solution of sodium thiosulfate.
II At the start of the titration the nozzle through which the titrant should leave the burette was filled with air, not with the solution of sodium thiosulfate.

A only I
B only II
C both I and II
D neither I nor II

The numerical value of the concentration of dissolved oxygen in mg per liter is given by the relation $K \times V_{thio}$.

In which V_{thio} is the volume, in mL, of the sodium thiosulfate solution that was used in the titration.

15. What is the value of K?

A 4.00
B 8.00
C 16.0
D 32.0

Fertilizer from urine

In some open air rock festivals in The Netherlands, the urine that those attending produce is collected. This urine is first treated in such a way that the urea in it is converted into ammonium salts. Then the pH of the solution is adjusted and a solution of magnesium chloride is added, to give an insoluble compound called struvite. The formula of struvite is $MgNH_4PO_4.6H_2O$. In this way phosphate is recovered, which contributes to slowing the depletion of natural sources of phosphorous. Also a useful fertilizer is obtained.

The pH of the solution is important, as both phosphate and ammonium are involved in pH dependent equilibria. In Figure 1 the percentage occurrence of H_3PO_4, $H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-} as a function of pH is given. In Figure 2 the percentage occurrence of NH_4^+ and NH_3 as a function of pH is given.

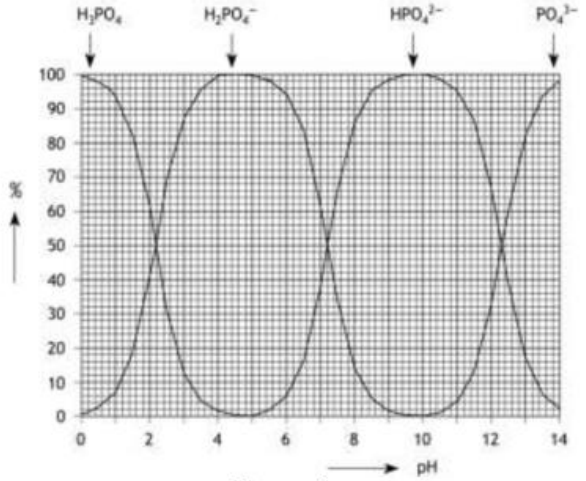


Figure 1

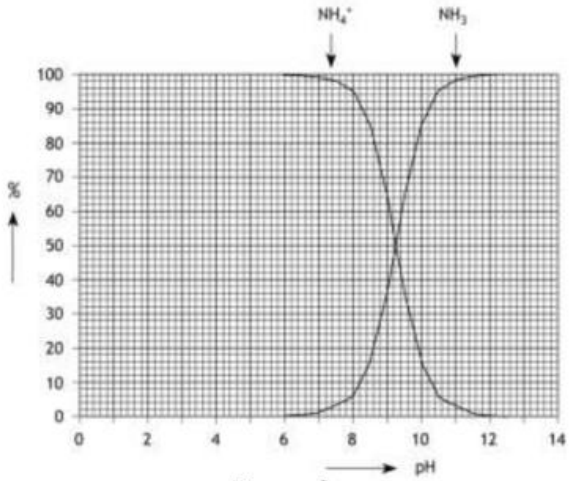


Figure 2

The reaction wherein struvite is formed, is carried out at a pH of about 8.
The reaction equation shows the main species that are present in the solution.

16. Which equation describes the formation of struvite at pH = 8?

A $Mg^{2+} + NH_3 + 7\,H_2O + PO_4^{3-} \rightarrow MgNH_4PO_4.6H_2O + OH^-$
B $Mg^{2+} + NH_4^+ + PO_4^{3-} + 6\,H_2O \rightarrow MgNH_4PO_4.6H_2O$
C $Mg^{2+} + NH_3 + HPO_4^{2-} + 6\,H_2O \rightarrow MgNH_4PO_4.6H_2O$
D $Mg^{2+} + NH_4^+ + HPO_4^{2-} + 5\,H_2O + OH^- \rightarrow MgNH_4PO_4.6H_2O$

Hydrogen fuel cell

Hydrogen is regarded as a fuel of the future, because there is no emission of CO_2.
Hydrogen can be used in fuel cells.

17. Which reaction takes place at which electrode in a hydrogen powered fuel cell during use?

	positive electrode	negative electrode
A	$H_2 \rightarrow 2\,H^+ + 2\,e^-$	$O_2 + 4\,H^+ + 4\,e^- \rightarrow 2\,H_2O$
B	$H_2 + 2\,e^- \rightarrow 2\,H^+$	$O_2 + 4\,H^+ \rightarrow 2\,H_2O + 4\,e^-$
C	$O_2 + 4\,H^+ + 4\,e^- \rightarrow 2\,H_2O$	$H_2 \rightarrow 2\,H^+ + 2\,e^-$
D	$O_2 + 4\,H^+ \rightarrow 2\,H_2O + 4\,e^-$	$H_2 + 2\,e^- \rightarrow 2\,H^+$

Elimination of CO_2

Carbon dioxide is a greenhouse gas. During the combustion of fossil fuels, large amounts of carbon dioxide are formed. To prevent this from entering the atmosphere, one might consider to remove it using the so called water-gas shift reaction. In this reaction carbon dioxide reacts with hydrogen to form carbon monoxide and water:

$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$

The enthalpy of formation of CO_2, CO, and H_2O are as follows:
$CO_2(g)$: – 394 kJ/mol, CO(g): – 111 kJ/mol and $H_2O(g)$: – 242 kJ/mol.

18. What is the reaction enthalpy ($\Delta_r H$) of the forward reaction; is this reaction endothermic or exothermic?

	$\Delta_r H$	endothermic/exothermic
A	– 41 kJ/mol	endothermic
B	– 41 kJ/mol	exothermic
C	+ 41 kJ/mol	endothermic
D	+ 41 kJ/mol	exothermic

Using the water-gas shift reaction to prevent carbon dioxide from entering the atmosphere has the drawback that the highly toxic gas carbon monoxide is formed. Carbon monoxide can be converted into methanol by adding extra hydrogen gas. The formation of methanol from carbon monoxide and hydrogen is an equilibrium reaction:

$CO(g) + 2\ H_2(g) \rightleftharpoons CH_3OH(g)$

The forward reaction is exothermic.

19. Which of the following conditions favors the formation of methanol in this equilibrium reaction?

I high pressure
II high temperature

A only I
B only II
C both I and II
D neither I nor II

Fertilizers

The quality of surface water in the Netherlands is influenced by the use of fertilizers in agriculture. Many fertilizers contain nitrogen (N). It is important to reduce the use of nitrogen in fertilizer to minimize the nitrogen load of surface water.
Three nitrogen containing fertilizers are:
$(NH_4)_2SO_4$ (ammonium sulfate), $CaCN_2$ (calcium cyanamide), and $CO(NH_2)_2$ (urea).

20. Which of these fertilizers has the highest mass percentage of nitrogen?

A ammonium sulfate
B calcium cyanamide
C urea
D all three have the same mass percentage of nitrogen

Physics questions

Solar shower

You can use solar power to have a warm shower while camping. The Solar Camp Shower bag (see Figure 1), contains 15 kg of water with a temperature of 18 °C. On a sunny day, the water absorbs 200 W of solar power.

Figure 1: Solar Camp Shower.

21. How long does it take for the water to reach a temperature of 35 °C? (The specific heat of water is $c = 4.2 \times 10^3$ J/(kg K).)

A 0.4 h
B 0.8 h
C 1.5 h
D 3.0 h

Liquid and vapor

Boiling transforms 1 liter of liquid into 1000 liters of vapor at a certain pressure.

Consider the following statements.

I The density of the vapor is 1/1000th times the density of the liquid.
II The average distance between the molecules in the vapor phase is 10 times the average distance between the molecules in the liquid phase.

22. Which of these statements is true?

A only I
B only II
C both I and II
D neither I nor II

Hydro pneumatic suspension

The hydro pneumatic suspension of some cars is equipped with spring bulbs. Such a metal bulb is filled with nitrogen gas. The purpose of the gas is to lift about ¼ of the weight of the car that rests on the suspensions, via a piston, oil and a rubber membrane (see Figure 2). The area of the rubber membrane is 200 cm^2. The weight of the car that rests on the suspensions is 16 000 N. Neglect the weight of the oil and the piston. The whole system is in rest. The pressure of the outer air is $1.0 \cdot 10^5$ Pa.

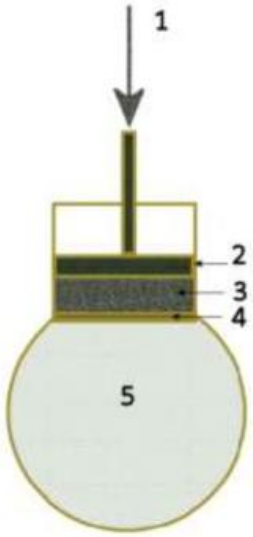


Figure 2: Spring bulb.
1 = ¼ weight of the car
2 = piston
3 = oil
4 = rubber membrane
5 = nitrogen gas

23. What is the pressure of the enclosed nitrogen gas?

A $2.0 \cdot 10^5$ Pa
B $3.0 \cdot 10^5$ Pa
C $8.0 \cdot 10^5$ Pa
D $12 \cdot 10^5$ Pa

Heating paraffin

A constant amount of heat is added per second to a certain amount of solid paraffin (see Figure 3).

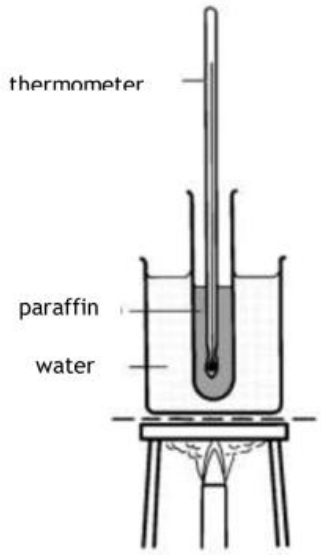


Figure 3: Experimental setup

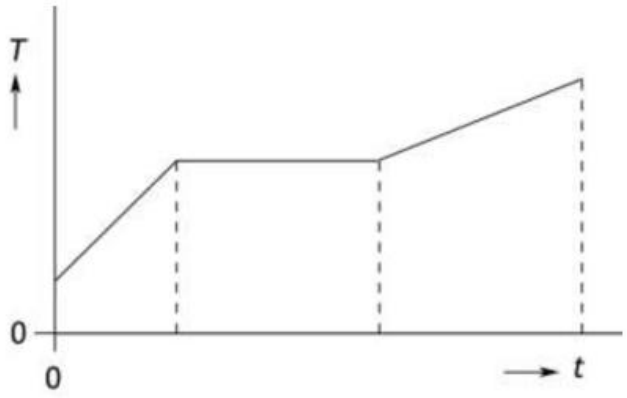


Figure 4: *T* - *t* diagram

The graph in Figure 4 displays the temperature (T) of the paraffin as a function of time (t).

Consider the following two statements regarding the change in the temperature of the paraffin.

I The specific heat capacity of liquid paraffin is smaller than that of solid paraffin.
II During melting, the potential energy of the molecules increases.

24. Which of these statement(s) is true?

A only I
B only II
C both I and II
D neither I nor II

A little boat and a bottle in a river

On a windless day, someone throws an empty sealed bottle in the river Waal, and the bottle floats downstream. At the same time, and at the same place, a powerboat sails upstream. After 10 minutes, the boat turns quickly around and travels downstream with the same power as before. After a while, the boat overtakes the bottle. At that time, the bottle and the boat are 3 km downstream from the initial starting point.

25. How fast does the river Waal flow on a windless day?

A 3 km/h
B 9 km/h
C 12 km/h
D 15 km/h

Electric circuit

In the circuit depicted in Figure 5, slide S is displaced along variable resistor R towards point X.

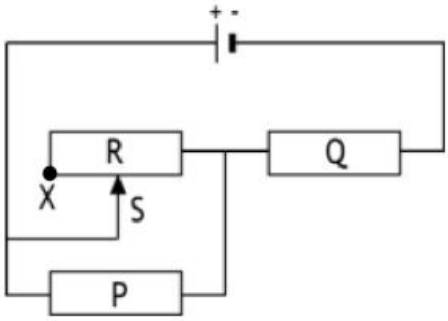


Figure 5: Electric circuit

26. How does the current passing resistors P and Q change?

	in P	in Q
A	increases	increases
B	increases	decreases
C	decreases	increases
D	decreases	decreases

Supertanker

A supertanker sails from the North Sea, via a river, to the port of Rotterdam.


Figure 6: Supertanker

27. Which statement about the draft (i.e. how deep a ship lies in the water) is true when the ship sails from the sea into the river?

A The tanker will have a deeper draft in the river.
B The tanker will have a shallower draft in the river.
C The draft will remain the same.
D The draft depends on the air pressure.

Electricity storage

In California, storage systems will be installed to improve regulation of the production of electricity by wind turbines. When there is an energy surplus, the wind turbine drives a flywheel. The cylindrical flywheel has a diameter of 0.90 m, a length of 1.5 m and a mass of 1 350 kg. The maximum frequency of the flywheel is 20 000 revolutions per minute. When the storage system has to supply electricity, the flywheel drives the generator. The rotational energy of a spinning object equals $E_{rot} = \frac{1}{2} I\omega^2$, with the moment of inertia $I = \frac{1}{2} mR^2$ for a cylinder with mass m and radius R that turns with angular velocity ω (in rad/s).

28. Taking these data into account, how much energy can maximally be stored by the flywheel?

A $7.6 \cdot 10^6$ J
B $1.5 \cdot 10^8$ J
C $3.0 \cdot 10^8$ J
D $1.2 \cdot 10^9$ J

Sky crane

A sky crane was used for the landing of the Mars explorer 'Curiosity'.
The four exhausts expel combustion gases that hold the crane at a constant height before landing. The four exhausts are arranged in an oblique arrangement. In Figure 7 you can see the thrust exerted on the crane by the gas from exhaust A. The thrust of the gas ejected from the other exhausts have the same magnitude and operate at the same angle.

Compare the thrust (F_{thrust}) at A to the gravitational force (F_g) on the whole system.

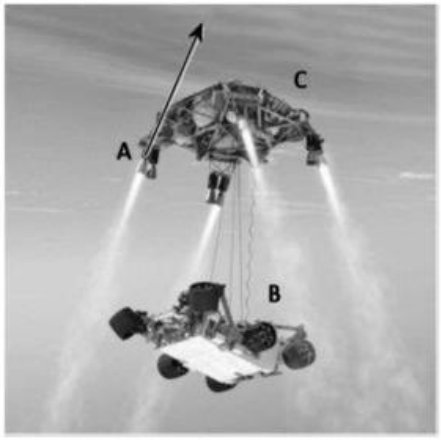


Figure 7: The landing system
A = One of the four exhausts
B = Mars explorer 'Curiosity'
C = Flying crane

29. Which statement is true?

A $F_{thrust} = F_g$
B $F_{thrust} = \frac{1}{4} F_g$
C $F_{thrust} < \frac{1}{4} F_g$
D $F_{thrust} > \frac{1}{4} F_g$

Properties of water

Two specific properties of water are highlighted below.

Property 1
The heat capacity of water is large compared to other common substances.

Property 2
The density of water behaves differently between 0 °C and 4 °C compared to other substances (see Figure 8).

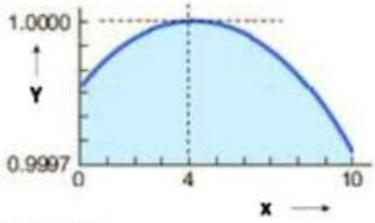


Figure 8:
Y = density of water in kg/dm^3
X = temperature in °C

Consider the following statements:

I Property 1 has a stabilizing effect on the average temperature on earth.
II Property 2 causes that liquid water with a temperature of + 4 °C will be located on the bottom of a ditch, when there is a thin layer of ice on top of the water.

30. Which of these statements is true?

A only I
B only II
C both I and II
D neither I nor II

IJSO

14th INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

THE NETHERLANDS 2017

Water and sustainability

Multiple Choice Test

Answer key

December, 5th 2017

QUADRAAM

Radboud Universiteit

Hogeschool van Arnhem en Nijmegen

slo

Answer key

Biology questions

Rate of flow of blood

1. **D**

On average the total amount of blood running should stay the same (in fact slightly less in capillary vessels and vein due to run off of lymph through lymph vessels, but this influence can be neglected). So roughly the rate of flow will be a flipped version of the cross section area ⇒ D is correct.

Fermentation and Respiratory Quotient RQ

2. **C**

Assume *a* mol is converted aerobically, so (0.5 – *a*) mol glucose is converted anaerobically.
This means that 6*a* mol CO_2 (aerobically) plus 2×(0.5 - *a*) mol CO_2 (anaerobically) is generated while 6*a* mol O_2 is used.
Total amount generated mol CO_2 = 6*a* + 2×(0.5 - *a*) = 4*a* + 1 and this equals 1.8, so *a* = 0.2.
In other words: 1.8 mol CO_2 is generated and 6×0.2=1.2 mol O_2 is used.

$$RQ = \frac{\text{moles of CO2 (produced)}}{\text{moles of O2 (used)}} = \frac{1.8}{1.2} = 1.5$$

Glucose concentration in blood

3. **A**

Liver is essential as it releases glucose. So D is highest.
From liver vein the blood flows into posterior (inferior) vena cava (C). There it is mixed with lower glucose containing blood stream coming from lower body parts. After right atrium and ventricle of the heart blood flows to lungs where some glucose is consumed. After that it flows back through pulmonary artery (B) to the heart. Next blood leaves the heart by aorta and flows partly to the brains (again some glucose consumption) and other body parts. From upper body finally blood returns to the heart by anterior (superior) vena cava (A).

Sphagnum

4. **C**

At some places (especially East part) *Sphagnum squarrosum* exist while pH<4.0, so conclusion I is wrong. *Sphagnum recurvum* and *Sphagnum fibriatum* are neighbors and do not mix. The boundary is sharp, but does not overlap with the pH boundaries. So competition must exist. Conclusion II is correct.
The picture shows that *S. squarrosum* and *S. recurvum* exist in different pH ranges: *S. squarrosum* doesn't occur where pH<3, while *S. recurvum* doesn't exist where pH>4. So III is correct.

Hay water

5. **A**

I The beaker only contains heterotrophic organisms which are dissimilating and consuming organic materials. No organic compounds are produced by something like photosynthesis. So mass must decrease.

II The heterotrophic organisms are continuously using organic compounds, which will run out. Their number will gradually decrease to zero. A climax stadium will not be established.

Determination of Caminalcules

6. **D**

See table. Features present are indicated with √ for I up to VIII.
With focusing only on long arms, long body and belly spots it is possible to identify all eight creatures. Fingers, only present in II and VII, are not needed.

Feature	I	II	III	IV	V	VI	VII	VIII
Long arms				√	√	√	√	
Long body	√		√	√			√	
Belly spots		√	√		√		√	
Fingers		√					√	

Water loss

7. **B**

Diffusion of water through skin (do not mix up with sweating) is not influenced by body activity and must be constant. So this is II → A and C are incorrect. Strenuous activity will result in extra air inhalation (breathing), causing extra water loss by lung ventilation. This must be process I. Meanwhile this extra water loss will result in reduction of urine production (process III).

Temperature-sensitive alleles

8. **A**

Genotype F1 is: ¼ EE + ½ Ee + ¼ ee, but EE will not develop at 19 °C, so F1 offspring is ⅔ Ee and ⅓ ee.
The combination EE again will not develop. The fraction of genotype EE in F2 will be: ½ × ⅔ (Ee) × ½ × ⅔ (Ee) = 1/9.

DNA and evolutionary relationship

9. **C**

A & D and C & E are most related (short distance) and must be close together in the dendogram.
D & E and D & C must be far from each other in the dendogram as they are least related (i.e. largest distance). The only dendogram matching with these statements is C.

Legionella

10. **A**

(670 – 199)/3 = 157, an integer result, so the T at position 671 is the first base of a new codon. This codon is T T C on the coding strand, which is transcribed into RNA as U U C, which is translated into Phe. The next codon is A G T, which is transcribed into A G U and translated into Ser, so answer A is correct.

Chemistry questions

Photosynthesis by algae

11. **B**

In photosynthesis carbon dioxide and water are converted and oxygen is formed.

12. **D**

On the right side only neutral molecules are written.
1 HPO_4^{2-} and 16 NO_3^- are needed to supply the P and N atoms in $C_{106}H_{263}O_{110}N_{16}P$.
1 HPO_4^{2-} and 16 NO_3^- have 18 negative charges, so 18 positive charges at the left side are needed to obtain neutrality.

Green chemistry

13. **B**

The atom economy represents how much of the starting materials gets into the products. The higher the better.
The *E*-factor represents how much waste is obtained. The lower the better.

Determination of oxygen

14. **C**

If the burette is not rinsed with the solution of sodium thiosulfate, this solution is diluted with the water from the inside of the burette. Because of this V_{thio} will be too high and consequently the result.
If there is air in the tap aperture of the burette, in the beginning of the titration the level of the solution in the burette goes down while no solution leaves the burette. Because of this V_{thio} will be too high and consequently the result.

15. **B**

V_{thio} mL 0,0100 M sodium thiosulphate solution contains $V_{thio} \times 0.0100$ mmol $S_2O_3^{2-}$; this has reacted with $\frac{1}{2} \times V_{thio} \times 0.0100$ mmol I_2 and to form this amount of I_2, in the first reaction $\frac{1}{2} \times \frac{1}{2} \times V_{thio} \times 0.0100$ mmol O_2 has reacted with iodide.
$\frac{1}{2} \times \frac{1}{2} \times V_{thio} \times 0.0100$ mmol O_2 is $\frac{1}{2} \times \frac{1}{2} \times V_{thio} \times 0.0100 \times 32.00$ mg.
This was dissolved in 10.00 mL surface water. So the O_2 concentration in the surface water is $\frac{1}{2} \times \frac{1}{2} \times V_{thio} \times 0.0100 \times 32.00 \times \frac{10^3}{10.00} = 8.00 \times V_{thio}$ mg/L.

Fertilizer from urine

16. **D**

From figure 1 it can be seen that at pH = 8 the predominant phosphate species is HPO_4^{2-} and from figure 2 it can be seen that at pH = 8 the predominant ammonium species is NH_4^+.

Hydrogen fuel cell

17. **C**

In an electrochemical cell, the electrode where the oxidator, in this case oxygen, reacts is the positive electrode . The other electrode is the negative electrode.

No CO_2

18. **C**

$\Delta_r H = -\Delta_f H_{CO_2} + \Delta_f H_{CO} + \Delta_f H_{H_2O}$ = –(–394) + (–111) + (–242) = +41 kJ/mol.

The reaction enthalpy is positive, so the reaction is endothermic.

19. **A**

According to Le Chatelier's principle an increase in pressure leads to a decrease in the number of gas molecules.
And an increase in temperature favors the endothermic reaction.

Fertilizers

20. **C**

All three fertilizers have the same amount of N atoms per mol. So the one with the least molar mass has the highest mass percentage of N.
The molar masses are:

$(NH_4)_2SO_4$:	132.14 g/mol
$CaCN_2$:	66.02 g/mol
$CO(NH_2)_2$:	60.06 g/mol.

Physics

Solar Shower

21. **C**

The amount of heat the water takes up is:
$Q = mc\Delta T = 15 \times 4.2 \cdot 10^3 \times (35 - 18) = 1.07 \cdot 10^6$ J.

The heating time can be calculated as: $t = \frac{Q}{P} = \frac{1.07 \cdot 10^6}{200} = 5.33 \cdot 10^3$ s and that is $\frac{5.33 \cdot 10^3}{3600} = 1.5$ h.

Liquid and vapor

22. **C**

Because $\rho = m/V$, the density of the vapor becomes 1000 times lower than the density of the liquid. It is easy to see that statement II is also correct.

Hydro pneumatic suspension

23. **B**

$p = 1.0 \cdot 10^5 + \frac{4000}{200 \cdot 10^{-4}} = 3.0 \cdot 10^5$ Pa

Heating paraffin

24. **B**

The specific heat capacity of the solid and liquid paraffin is indicated by the *slopes* of the first and the last part of the graph, respectively. If the slope is steeper, the heat capacity is lower, so the heat capacity of liquid paraffin is higher than the heat capacity of solid paraffin, so statement I is false.
During melting, the temperature is constant, so the kinetic energy of the molecules is constant, so only the potential energy of the molecules increases. N.B. The work done on the environment is neglected here.

A little boat and a bottle in the river

25. **B**

Because we are considering relative motions here, we can omit the motion of the river for the time being. In that case, the boat travels for 10 minutes in one direction followed by 10 minutes in the opposite direction after which it overtakes the bottle. In truth, the bottle has covered a distance of 3 km in 20 minutes, so the speed of the river is 3 km per 1/3 hour, so 9 km/h.

Electric circuit

26. **B**

When the slide is displaced towards X, the total resistance in the circuit increases. As a result, both the current in, and the voltage over Q decrease. The voltage across P must increase, because the sum of the voltages is equal to the voltage of the source. This means that the current in P will also increase.

Super tanker

27. **A**

The density of salt water is higher than the density of fresh water, so the buoyancy of a volume of salt water is higher than the buoyancy of the same volume of fresh water. Hence, the tanker will displace a larger volume of fresh water and will have a deeper draft in the river, which contains fresh water.

Electricity storage

28. **C**

$E_{rot} = \frac{1}{2} I\omega^2$, with $I = \frac{1}{2} mR^2$

Thus $E = \frac{1}{4} mR^2\omega^2 = \frac{1}{4} \times 1\,350 \times 0.45^2 \times \left(\frac{20\,000 \times 2\pi}{60}\right)^2 = 3.0 \cdot 10^8$ J.

Sky crane

29. **D**

The thrust force is pointed diagonally upwards and is larger than its vertical component. Together, the vertical components must equal the gravitational force F_g. So $F_{thrust} > \frac{1}{4} F_g$

Properties of water

30. **C**

Because of its high heat capacity, a lot of heat is needed to increase the temperature of a volume of water and, the other way round, a lot of heat is emitted when it cools down. Thus, water limits temperature changes in its surroundings: statement I is correct.

Because the density of water of + 4 ^{0}C is greater than the density of water between 0 ^{0}C and 4 ^{0}C, the bottom of the ditch will contain water of + 4 ^{0}C: statement 2 is also correct.