IJSO

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THE NETHERLANDS 2017

# Water and sustainability

**Theoretical Test**

**Marking scheme**

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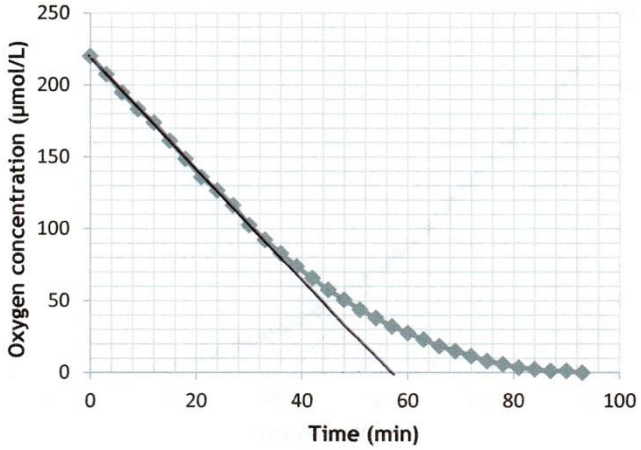
# Biology questions

## Plants in floodplains

1. Maximum score 1.2
   An example of a correct calculation is:
   The slope of the initial decline of the curve describes the maximum respiration rate per liter per minute. This slope is $\frac{220}{56}$ µmol/(L min) (see figure).



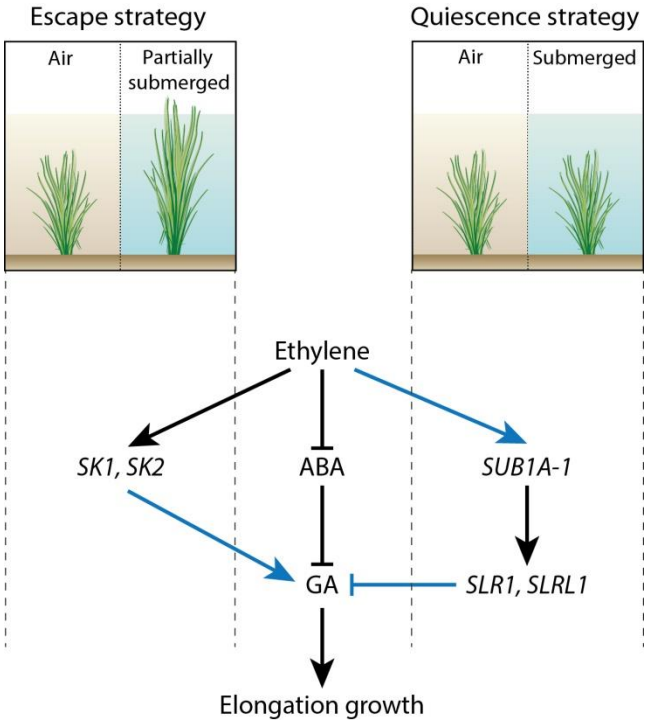

   The volume of the box is 1.2 L, so the maximum respiration rate of the submerged plant is $\frac{220}{56} \times 1.2 = 4.7$ µmol/min (range: ± 0.2 µmol/min).

   · notion that the slope of the initial decline of the curve describes the maximum respiration rate per liter per minute 0.4
   · calculation of the slope 0.4
   · multiplying the slope by 1.2 (L) 0.4

2. Maximum score 0.4
   4.7 µmol/min

   *Remark*
   *The answer should be the same as the result of the calculation of question 1.*

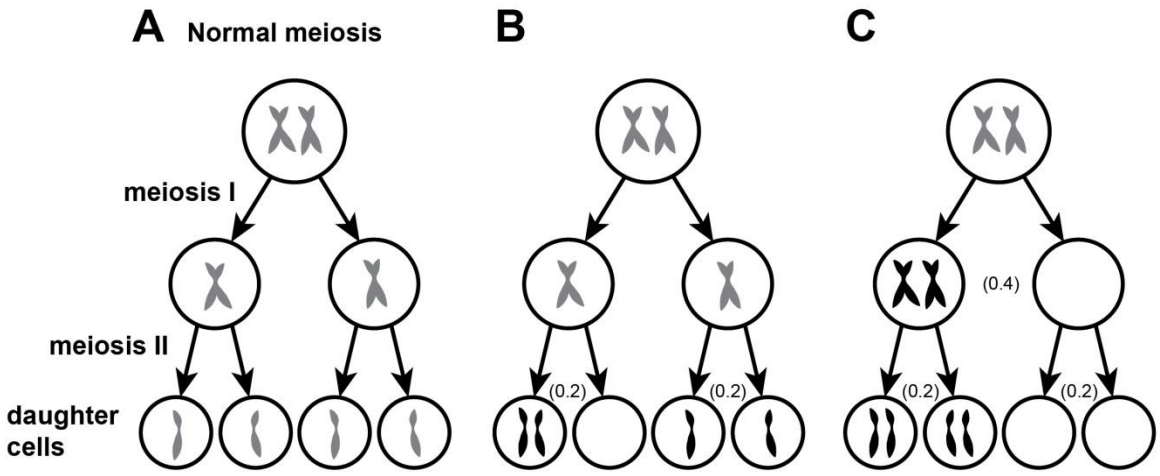
3. Maximum score 1.2




per correct interaction 0.4

## Oysters

4. Maximum score 1.2
   A correct answer may look as follows:




correct meiosis I step (from first to second row of C) 0.4
per correct meiosis II step (second to third row of B and C) 0.2
scores are also indicated in the figure above (in brackets).

*Remark*
*Cells derived from the same cell can be permuted.*
*If in B the student gives a faulty meiosis II for all four daughter cells, he/she also receives full points.*
*If nothing is filled in on the second row of C, the student does not receive points for the empty cells on the third row.*

5. Maximum score 0.8

| Species | *O. edulis* (oyster) | *B. ostreae* (protist) |
|---|---|---|
| Role | III | IV |

per correct answer 0.4

6. Maximum score 0.8

| Parameter | *p* | *q* |
|---|---|---|
| Description | IV | VI |

per correct answer 0.4

7. Maximum score 1.2

| Parameter | $a$ | $b$ | $c$ |
|---|---|---|---|
| Triploid vs. diploid | + | o | − |

Explanation:
$a$: birth/growth rate of oyster: '[triploid oysters] grow and mature faster'.
$b$: death rate of oyster: no info provided
$c$: infection parameter: '[triploid oysters] are more resistant to infections'.

per correct cell 0.4

*Remark*
*No points for empty cells.*

## Osmosis in fish

8. Maximum score 1.2

at location 1: → (arrow to the right)
at location 2: ← (arrow to the left)
at location 3: H (low % $O_2$)
at location 4: L (high % $O_2$)

- directions of both arrows at locations 1 and 2 are opposite 0.4
- if arrows are opposite and direction at locations 1 and 2 correct 0.4
- both indications at locations 3 and 4 correct 0.4

9. Maximum score 0.8

I swell up
II very little
III large
IV diluted

per correct answer 0.2

## Anammox

10. Maximum score 1.2

| Hypothesis | Experiment | | | Prediction | | |
|---|---|---|---|---|---|---|
| I | A | (B) | C | (1) | 2 | |
| II | (A) | B | C | (1) | 2 | |
| III | A | B | (C) | (1) | OR | (2) |

- all pairings of I – III with A – C are correct 0.8
  if two pairing of I – III with A – C are correct 0.4
  if two pairing of I – III with A – C are correct 0.2
- all predictions correct 0.4
  if one or two pairing(s) of I – III with A – C is/are correct and the corresponding prediction correct 0.4
  if all pairings correct, but one prediction incorrect 0.2
  if no pairing is correct or no prediction is correct 0

# Chemistry questions

## Water and the fight against *Legionella*

11. Maximum score 1.2

An example of a correct answer is:
After $x$ D-values the concentration is decreased to $0.10^x \times 1\,200$ cfu/L. So to reach a level of 100 cfu/L: $0.10^x \times 1\,200 = 100$. This gives $x = 1.08$.
So after heating during $1.08 \times 5 = 5.4$ min the concentration of *Legionella* in the water is below the level that is regarded as safe.

- after $x$ D-values the concentration is decreased to $0.10^x \times 1\,200$ cfu/L 0.4
- calculation of $x$ 0.4
- rest of the calculation 0.4

12. Maximum score 1.6

An example of a correct answer is:
The equilibrium is: $HClO + H_2O \rightleftharpoons H_3O^+ + ClO^-$

$$K_a = \frac{[H_3O^+][ClO^-]}{[HClO]} \text{ or } [H_3O^+] = K_a \frac{[HClO]}{[ClO^-]}$$

So when $[H_3O^+] > K_a$ then $[HClO] > [ClO^-]$ or $pH < pK_a$. $pK_a = -\log 4.0 \cdot 10^{-8} = 7.40$.
In the pH region below 7.40 $[HClO] > [ClO^-]$.

- correct expression for $K_a$ 0.4
- when $[H_3O^+] > K_a$ then $[HClO] > [ClO^-]$ 0.4
- calculation of the pH value 0.4
- this is a maximum pH 0.4

*Remark*
*If the student gives the wrong number of significant figures, no points will be subtracted.*

13. Maximum score 1.2

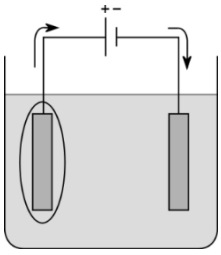
- half-reaction of the reducing agent: $Cu(s) \rightarrow Cu^{2+}(aq) + 2\,e^-$ 0.4
- half-reaction of the oxidizing agent: $2\,HClO + 2\,H^+(aq) + 2\,e^- \rightarrow Cl_2(aq) + 2\,H_2O$ 0.4
- overall reaction equation: $Cu(s) + 2\,HClO(aq) + 2\,H^+(aq) \rightarrow Cu^{2+}(aq) + 2\,H_2O(l) + Cl_2(aq)$ 0.4

If the following answer is given: 0.8
half-reaction of the reducing agent: $2\,HClO + 2\,H^+(aq) + 2\,e^- \rightarrow Cl_2(aq) + 2\,H_2O$
half-reaction of the oxidizing agent: $Cu(s) \rightarrow Cu^{2+}(aq) + 2\,e^-$
overall reaction equation: $Cu(s) + 2\,HClO(aq) + 2\,H^+(aq) \rightarrow Cu^{2+}(aq) + 2\,H_2O(l) + Cl_2(aq)$

*Remarks:*
- *When the student gives an equation like*
  *$Cu(s) - 2\,e^- \rightarrow Cu^{2+}(aq)$*
  *no points will be subtracted.*
- *No points will be subtracted for missing or incorrect state indications.*

14. Maximum score 0.8

A correct answer may look as follows:




· correct electrode indicated 0.4
· flow of the electrons correct in relation to indicated electrode 0.4

15. Maximum score 0.8

$2 \sim S-H + 2\ Ag^+ \rightarrow \sim S-S \sim + 2\ Ag + 2\ H^+$

· $2 \sim S-H$ left and $2\ H^+$ right 0.4
· $2\ Ag^+$ left and $2\ Ag$ right 0.4

16. Maximum score 0.4

The reaction of silver ions with $\sim S-H$ groups in one protein chain results in a change of the tertiary structure of the protein.

## Wastewater treatment

17. Maximum score 1.2

An example of a correct answer is:

$0.632 \times 2 \times 32.00 \times 10^{-3} \times 175\,000 \times 365 \times 3 \times 0.19 = 1.5 \cdot 10^{6}$ euros

- calculating the number of moles of oxygen needed per inhabitant per day: multiplying 0.632 (moles) by 2 — 0.4
- converting the number of moles of oxygen needed into kg oxygen needed per inhabitant per day: multiplying by the molar mass of oxygen (= 32.00 g/mol) and by $10^{-3}$ (kg/g) — 0.4
- converting the amount of kg oxygen needed per inhabitant per day into kg oxygen per year for the population of Nijmegen: multiplying by 175 000 (inhabitants) and by 365 (days per year) — 0.2
- converting the amount of kg oxygen per year for the population of Nijmegen into the costs per year: multiplying by 3 (kWh per kg oxygen) and by 0.19 (€ per kWh) and the answer lies in between $1.47 \cdot 10^{6}$ euros and $1.5 \cdot 10^{6}$ euros — 0.2

*Remark*

*If the answer is given as 1 470 000 euros or 1 500 000 euros no points are subtracted.*

18. Maximum score 1.6

An example of a correct answer is:

$\frac{2-0.75}{2} \times 100\% = 63\%$.

- oxidizing one mole of $NH_4^+$ to $NO_3^-$ in the conventional process requires 2 moles of oxygen — 0.4
- oxidizing one mole of $NH_4^+$ to $NO_2^-$ in the anammox process requires 1.5 moles of oxygen — 0.4
- only half of the amount of $NH_4^+$ has to be oxidized — 0.4
- calculation of the percentage reduction — 0.4

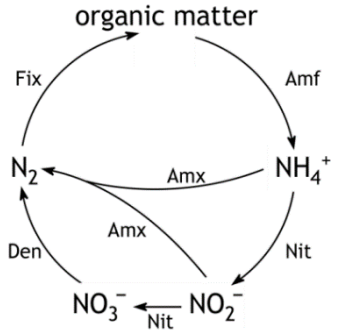
If the answer $\frac{2-1.5}{2} \times 100\% = 25\%$ is given: — 1.2

If the answer $\frac{3-1}{3} \times 100\% = 67\%$ is given — 0.8

If the answer $\frac{3-2}{3} \times 100\% = 33\%$ is given — 0.4

19. Maximum score 1.2

A correct answer may look as follows:




- $NH_4^+$ connected with $N_2$ via $NO_2^-$ and $NO_3^-$ — 0.4
- 'Nit' and 'Den' in the right place — 0.4
- shortcut 'Amx' from $NH_4^+$ to $N_2$ and shortcut 'Amx' from $NO_2^-$ to $N_2$ — 0.4

# Physics questions

## Wind energy

20. Maximum score 0.4

$P = 8P_0$ (W)

21. Maximum score 1.6

An example of a correct answer is:

$P = ½ \times \pi \times \left(\frac{80}{2}\right)^2 \times 1.2 \times \left(\frac{36\times10^3}{3600}\right)^3 \times 0.70 \times 0.59 = 1.2\cdot10^6$ W

- · calculation of the area that is covered by the sails: $\pi \times \left(\frac{80}{2}\right)^2$ 0.4
- · calculation of the wind speed in m/s: multiplying 36 (km/h) by $10^3$ (m/km) and dividing by 3600 (s/h) 0.4
- · applying the factor 0.70 × 0.59 0.4
- · completion of the calculation 0.2
- · answer in 2 or 3 significant figures 0.2

22. Maximum score 1.2

An example of a correct answer is:

The volume of water that has to be pumped is $V = \frac{m}{\rho} = \frac{3.3\cdot10^{11}}{1.03\cdot10^3} = 3.2\cdot10^8$ m$^3$.

The height difference is $h = 40.0 - 32.0 = 8.0$ m.

So the area of the reservoir is $A = \frac{V}{h} = \frac{3.2\cdot10^8}{8.0} = 4.0\cdot10^7$ m$^2$.

- · use of $A = \frac{V}{h}$ 0.4
- · use of $V = \frac{m}{\rho}$ 0.4
- · completion of the calculation 0.2
- · answer in 2 or 3 significant figures 0.2

23. Maximum score 2.0

An example of a correct answer is:

The increase in potential energy is: $\Delta E_p = mg\Delta h = 3.3\cdot10^{11} \times 9.81 \times ½ \times (40.0 + 32.0) = 1.17\cdot10^{14}$ J.

The total average power of the wind turbines is $75 \times 5.0\cdot10^6 = 375\cdot10^6$ W.

Since $E = Pt$, and $E = \Delta E_p$, it follows that $t = \frac{\Delta E_p}{P} = \frac{1.17\cdot10^{14}}{375\cdot10^6} = 3.11\cdot10^5$ s or $\frac{3.11\cdot10^5}{3600} = 86$ h.

- · insight that $\Delta E_p = mg\Delta h$ 0.4
- · insight that $\Delta h = ½ \times (40.0 + 32.0)$ m 0.4
- · calculation of $\Delta E_p$ 0.4
- · use of $E = Pt$ 0.4
- · completion of the calculation 0.2
- · answer in 2 or 3 significant figures 0.2

24. Maximum score 1.2

| Yes | No | Question |
|---|---|---|
| | √ | Because of its location at sea, nobody is annoyed by this plant. |
| √ | | In this plant, energy can be stored and subsequently be used in the absence of wind. |
| √ | | In this plant, energy can be stored and subsequently be used whenever necessary. |
| | √ | This plant is a cheap way of generating electricity. |
| √ | | This plant can supply a constant power. |
| √ | | The power supply of this plant can be adapted to the demand. |
| | √ | This plant can replace a number of coal-fired power stations. |
| | √ | This plant does not expel $CO_2$. |

Per correct answer 0.15

*Remark:*
*For every wrong argument 0.15 points deduction. The total score for this question cannot be less than 0 points.*

## Room for the river

25. Maximum score 0.8

An example of a correct derivation is:

For $n$ holds: $n = \frac{A}{Q} D^{2/3} S^{1/2}$

So the unit of $n$ is: $\frac{\mathrm{m}^2}{\mathrm{m}^3/\mathrm{s}} \mathrm{m}^{2/3}$ or $\mathrm{s/m}^{1/3}$.

- all units correctly used 0.4
- rest of the derivation 0.4

26. Maximum score 1.2

An example of a correct calculation is:

$D = \left(\frac{0.10 \times 1.4 \cdot 10^4 \times 0.018}{200 \times (5.0 \cdot 10^{-4})^{1/2}}\right)^{3/5} = 2.8$ m.

- multiplying $1.4 \cdot 10^4$ ($m^3/s$) by 0.10 0.4
- use of the correct values of $D$, $W$ and $S$ 0.4
- completion of the calculation 0.2
- answer in 2 or 3 significant figures 0.2

27. Maximum score 1.6

An example of a correct calculation is:

$0.99 \times 0.99^{2/3} \times \frac{0.018}{0.022} \times 10\% = 8.0\%$.

- insight that $A$ decreases by 1% 0.4
- insight that because of the decrease in $D$ of 1%, the drain decreases by a factor $0.99 \times 0.99^{2/3}$ 0.4
- insight that when $n$ increases by a factor $\frac{0.022}{0.018}$, the drain decreases by a factor $\frac{0.018}{0.022}$ 0.4
- completion of the calculation 0.2
- answer in 2 or 3 significant figures 0.2

*Remark*
*If D of previous question is used, correct calculation gives the same answer and same amount of marks.*