Ocean exploration and studies of water

IJSO MCQ mock test

This is an IJSO mock test, a paper made to mimic the style and difficulty of IJSO questions. Its aim is to help students in preparing for the IJSO and IJSO like competitions.

The questions in this paper were made by the following past IJSO participants (in alphabetical order):

- Alex Jicu (Romania) – Mock Test no. 1 Coordinator
- Filip Kilibarda (Serbia)
- Fillios Memtsoudis (Cyprus)
- Jathurshan Myuran (Sri Lanka)
- Parthipan Kasiban (Sri Lanka)
- Thenura Wickramaratna (Sri Lanka)

In solving the questions, you might need to use the following constants:

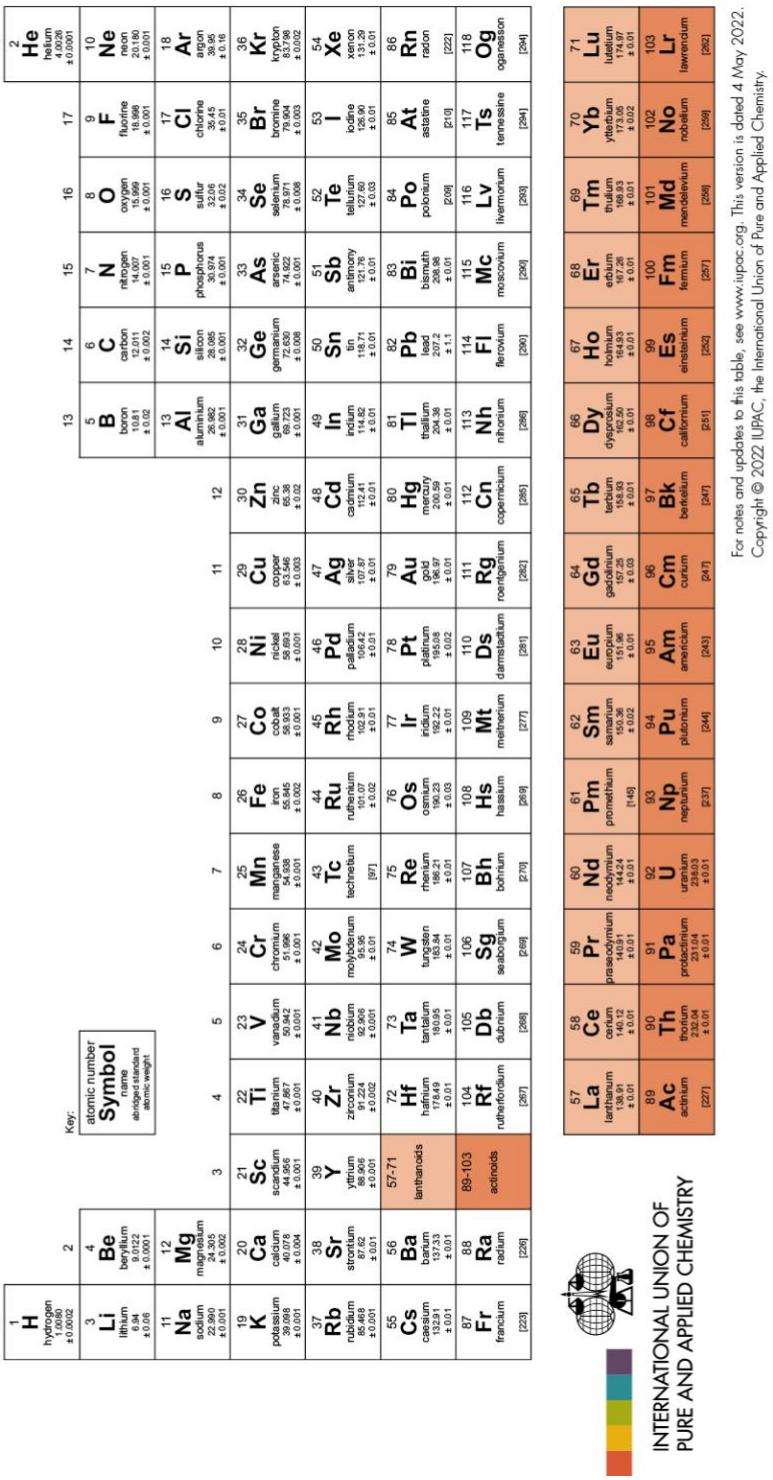
Number	Constant	Notation	Value
1	Acceleration due to gravity	g	9.8
2	Gravitational constant	G	$6.67 \cdot 10^{-11}$
3	Planck's constant	h	$6.62 \cdot 10^{-34}$
4	Elementary charge	e	$1.6 \cdot 10^{-19}$
5	Speed of light in vacuum	c	$3 \cdot 10^{8}$
6	Density of water	ρ	1000
7	Stefan-Boltzmann constant	σ	$5.67 \cdot 10^{-8}$
8	Universal gas constant	R	8.314
9	Avogadro's number	N_A	$6.022 \cdot 10^{23}$
10	Faraday's constant	F	96 500
11	Pi	π	3.14
12	Electrical permittivity of free space	ε_0	$8.85 \cdot 10^{-12}$
13	Magnetic permeability of free space	μ_0	$4\pi \cdot 10^{-7}$
14	Mass of Earth		$5.97 \cdot 10^{24}$
15	Mass of Moon		$7.35 \cdot 10^{22}$
16	Mass of Sun		$1.99 \cdot 10^{30}$
17	Radius of Earth		$6.4 \cdot 10^{6}$
18	Radius of Moon		$1.7 \cdot 10^{6}$
19	Radius of Sun		$6.96 \cdot 10^{8}$
20	Specific heat capacity of water	c_w	4200
21	Average molar mass of air	M	28.9

All constants are given in their respective SI units. If any other value is provided in the problem, use the value provided, not the one in the table.

You can also use the following conversion formulas:

$T(K) = t(°C) + 273$	$t(°F) = \frac{9}{5}t(°C) + 32$
$1bar = 1atm = 101\,000Pa = 760mmHg$	$1u = 1Da = 1.66 \cdot 10^{-27}kg$
$1L = 10^{-3}m^3$	$1\ day = 24h$

If needed, you can use the periodic table given bellow:



Use atomic masses rounded to two decimal places.

Question 1 – Little Timmy in the waters

Humans have been spear fishing for food for thousands of years. Little Timmy is stranded on an island and has to get some food. He sees a fish in the water in front of him. Where should little Timmy aim the spear relative to where you see the fish, in order to hit it.

A. Closer to him

B. Further away from him

C. Above the fish

D. Depends on the depth of the water

Problem proposed by Filip Kilibarda

Question 2 – Little Timmy's carps

While fishing, little Timmy noticed two very different scale patterns on carps which had no other difference. Some of the carps were normal, while the others had scales only on the dorsal and ventral margins (they are called line carps).

He later found out that scale patterns are influenced by the two alleles of one gene - S and s, and the two alleles of another gene - N and n.

In the following analysis we'll consider all carps are SS so the S gene doesn't influence the analysis.

All of the ova from a female individual were fertilized with spermatozoa from one male individual. The table below gives the phenotypes of the parents and of the descendants:

Female phenotype	Male phenotype	Descendants phenotype
Common	Common	Common
Line	Line	1 common : 2 line
Common	Line	1 common : 1 line
Line	Common	1 common : 1 line

From the data given, what can you say about the N-n alleles?

A. The transmission of the genes is X-linked

B. The transmission of the genes is Y-linked

C. There exists a genotype which makes individuals not viable

D. The transmission of the genes is extranuclear (probably mitochondrial)

Problem proposed by Alex Jicu

Question 3 – Little Timmy on the island

Since Little Timmy was stranded on an island he decided to go around the beach to find some organisms so he could familiarize him with the environment. When exploring the beach he saw some seagrass full submerged in shallow waters. So he decided to take them with him so he could see the structure of the sea grass stem. After he returned he observed the cross section under a light microscope

What would be the difference between the cross section of this plant and the cross section of a typical monocot plant?

A. Phloem
B. Xylem
C. Cambium
D. No difference

Problem proposed by Jathurshan

For questions 4 and 5 read the following information:

Thinking about a way to escape the island, little Timmy remembered he has a Holmes signal.

The Holmes signal refers to a rescue package with a perforated bottom and a hole that contains $Ca_3P_{2(s)}$ and $CaC_{2(s)}$. In case of danger, it is thrown into the sea, where the two compounds react with water (H_2O) according to reactions (1) and (2), producing phosphine (PH_3) and acetylene ($CH \equiv CH$):

(1) $Ca_3P_{2(s)} + H_2O_{(\ell)} \rightarrow PH_{3(g)} + Ca(OH)_{2(aq)}$

(2) $CaC_{2(s)} + H_2O_{(\ell)} \rightarrow CH \equiv CH_{(g)} + Ca(OH)_{2(aq)}$

Phosphine ignites spontaneously when it comes into contact with water, and this causes the combustion of acetylene according to the reaction:

(3) $CH \equiv CH_{(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(\ell)}$

This produces an intense flame and a huge smoke cloud visible from far away.

Question 4 – Heat in the Holmes signal

Given the enthalpies of formation:

- $CH \equiv CH$: $+230\ \text{kJ} \cdot \text{mol}^{-1}$
- $CO_{2(aq)}$: $-395\ \text{kJ} \cdot \text{mol}^{-1}$
- $H_2O_{(\ell)}$: $-285\ \text{kJ} \cdot \text{mol}^{-1}$

The enthalpy change (ΔH) of reaction (3) per mole of acetylene is:

A. $-1305\ \text{kJ} \cdot \text{mol}^{-1}$
B. $-2610\ \text{kJ} \cdot \text{mol}^{-1}$
C. $-5220\ \text{kJ} \cdot \text{mol}^{-1}$
D. $+2610\ \text{kJ} \cdot \text{mol}^{-1}$

Problem proposed by Fillios Memtsoudis

Question 5 – Phosphine and its analogue ammonia

The molecules of ammonia (NH_3) and phosphine (PH_3) both have a trigonal pyramidal. Select the correct statement regarding their polarity and solubility in water:

A. NH_3 is more polar than PH_3 because nitrogen is more electronegative, so NH_3 is more soluble in water.
B. NH_3 and PH_3 have the same polarity because they have the same molecular shape, so their solubility in water is equal.
C. PH_3 is more polar than NH_3 because phosphorus forms stronger bonds with hydrogen.
D. PH_3 is more soluble in water than NH_3 because it has larger atoms and more electrons

Problem proposed by Fillios Memtsoudis

Question 6 – Limits of the human body

When diving, divers have to face very harsh conditions, testing the limits of the human body. From a cardiological point of view, the most important factor is the heart rate. Roughly, the maximum heart rate one's heart can resist to is given by the formula:

$$\text{Maximum BPM} = C - \text{Age} \quad (*)$$

where C is a constant.

After a difficult swimming training session, a 25 year old healthy diver goes to his cardiologist for a checkup. After performing an EKG, the cardiologist finds the diver's atrial systole duration to be 0.047s, while the duration of the ventricular diastole is found to be 0.239s.

Knowing that the diver's heart rate is 80% of the maximum possible value for his heart and that the total diastole's duration is equal to half the cardiac cycle, find the value of the constant C in equation (*):

(Suppose that systoles do not overlap)

A. 181

B. 195

C. 220

D. 227

Problem proposed by Alex Jicu

Question 7 – More about divers

A team of deep-sea divers is exploring a coral reef at a depth of 30 meters. While diving, they breathe compressed air through their scuba tanks. During their dive, nitrogen gas (N_2) from the air slowly dissolves into their blood plasma due to the high ambient pressure.

After spending 30 minutes at this depth, one of the divers saw a shark, panicked and made a rapid, uncontrolled ascent to the surface without any decompression stops. Soon after, the diver experienced joint pain, dizziness, and difficulty breathing.

Which of the following best explains the biological mechanism causing the diver's symptoms?

A. Rapid pressure decrease causes nitrogen to bind irreversibly to haemoglobin, displacing oxygen and causing hypoxia.

B. Sudden decompression leads to nitrogen gas forming bubbles in the bloodstream and tissues, disrupting blood flow and damaging cells.

C. The cold temperature at depth caused oxygen to precipitate out of plasma, leading to oxidative stress upon surfacing.

D. Prolonged exposure to high pressure denatures respiratory enzymes, leading to failure of oxygen transport.

Problem proposed by Thenura Dilruk

Question 8 – Deep-sea exploration in a submarine

A team of oceanographers are exploring the ocean depth inside a small submarine. Assume the density of seawater to be $\rho = 1025\frac{kg}{m^3}$, and atmospheric pressure to be $P_0 = 1.0 \cdot 10^5 Pa$

Inside the submarine, a spherical bubble with radius r = 2.0mm is released from a nozzle.

Neglecting surface tension, which of the following is closest to the net force acting outward on the inside of the surface of the bubble just as it forms at 500m depth?

A. 16.4 N

B. 63.1 N

C. 252.5 N

D. 257.0 N

Problem proposed by Thenura Dilruk

Question 9 – Experiment in the submarine

A team of scientists is conducting an experiment in a submarine to investigate the behavior of combustion. Instead of open flames, they're studying solid fuel decomposition of hydrazine-based compounds used in spacecraft thrusters. In the sealed chamber, a sample of unsymmetrical dimethylhydrazine (UDMH), $H_2NN(CH_3)_2$, is thermally decomposed in the presence of a catalyst to generate nitrogen gas and smaller hydrocarbon fragments.

The unbalanced reaction is:

$$H_2NN(CH_3)_2 \rightarrow N_2 + CH_4$$

As part of the experiment, a 5.00 g sample of UDMH is decomposed inside a sealed 2.00 L chamber at 298 K. Assume complete decomposition and ideal gas behavior.

Which of the following is closest to the final pressure inside the chamber due to the gaseous products?

A. 1.57 atm

B. 2.04 atm

C. 3.00 atm

D. 3.64 atm

Problem proposed by Thenura Dilruk

Question 10 – Titan submersible accident

In June 2023, the Titan submersible imploded on its way down to the Titanic wreckage, sadly killing all five people on board. After the incident, many experts reasoned that the difference in the mechanical properties of the carbon fiber and titanium materials used for the submersible could have led to a breaking apart of the submersible at its joints, where the two materials met.

The Young's modulus of carbon fiber is 500 MPa and that of titanium is 380 Mpa.

If a piece of carbon fiber and a piece of titanium, with lengths of 50 cm and of identical dimensions, are subjected to the same tensile stress of 200 Mpa, what will be the difference in the lengths of both materials?

A. 0.10cm

B. 6.3cm

C. 14cm

D. 19cm

Problem proposed by Filip Kilibarda

Question 11 – Breathing in the submarine

When going underwater, in a submarine, having enough oxygen to breathe is essential. For this, oxygen generators are used. Oxygen generators are devices based on oxygen generating reactions.

The average quantity of oxygen needed by a human is 15L/hour.

Consider all the oxygen needed by two humans going on a 2 hour mission comes from an oxygen generator based on the ignition of a mixture containing 95% (w/w) sodium chlorate and the rest barium peroxide. Upon ignition, the sodium chlorate decomposes to sodium chloride, while the barium peroxide turns into barium oxide.

What mass of this mixture can ensure the quantity of oxygen required by the two men plus a 20% safety margin?

(It is known that, in the submarine conditions, one mole of gas occupies 22.4 liters)

A. 99g

B. 119g

C. 198g

D. 237g

Problem proposed by Alex Jicu

Question 12 – Algae also breathe

A student group studying eutrophication measured the oxygen levels in a pond and found it to be 8 mg/l. They filled one opaque bottle and one transparent bottle with a liter of pond water samples and left them in direct sunlight near the pond. After an hour they returned and, the oxygen concentration was 5 mg/l in the opaque bottle and 12 mg/l in the transparent bottle

If the gross primary production(GPP) is defined as the total amount of O2 synthesized and net primary production(NPP) is the amount of excess oxygen produced by photosynthesis which is released to the environment, find the GPP, respiration rate and NPP respectively of this algae species assuming there is no other organisms in this sample.

	GPP	Resp. rate	NPP
A.	7 mg/l/h	3 mg/l/h	4 mg/l/h
B.	4 mg/l/h	3 mg/l/h	7 mg/l/h
C.	17 mg/l/h	3 mg/l/h	4 mg/l/h
D.	7 mg/l/h	4 mg/l/h	3 mg/l/h

Problem proposed by Parthipan Kasiban

Question 13 – And marine animals also breathe

A team of researchers are studying the mitochondrias of marine animals to see possible evolutive differences between them and those of land species.

In an experiment they are studying mitochondrial function using isolated, active mitochondria placed in a buffered solution containing ADP, inorganic phosphate (Pi), and oxygen. They measure oxygen consumption and ATP synthesis under different conditions. They observe standard rates of both processes (Baseline). Then, they add Compound Z to the buffer and observe that oxygen consumption continues at the baseline rate, but ATP synthesis dramatically decreases. However, if they subsequently add DNP (2,4-dinitrophenol), a known protonophore that makes the inner mitochondrial membrane permeable to protons (H+), oxygen consumption significantly increases above the baseline rate, while ATP synthesis remains negligible.

Based on these results, what is the most likely mechanism of action for Compound Z?

A. It directly inhibits the electron transport chain (ETC) complexes, preventing proton pumping.
B. It acts as a protonophore, similar to DNP, dissipating the proton gradient across the inner mitochondrial membrane.
C. It blocks the flow of protons (H+) through the ATP synthase enzyme complex.
D. It inhibits the transport of ADP into the mitochondrial matrix or ATP out of the matrix.

Problem proposed by Parthipan Kasiban

Question 14 – Sphere on the ocean surface

A sphere of density $\rho_0 = \frac{\rho}{2}$, where ρ is the density of water, floats in an ocean. Let y be the distance from the surface of the water to the bottom of the sphere and R be the radius of the sphere. For some values of y, a vertical downward force F needs to act on the sphere to submerge it in the water. Which of the graphs accurately shows the dependence of F against the value of the ratio y/R?

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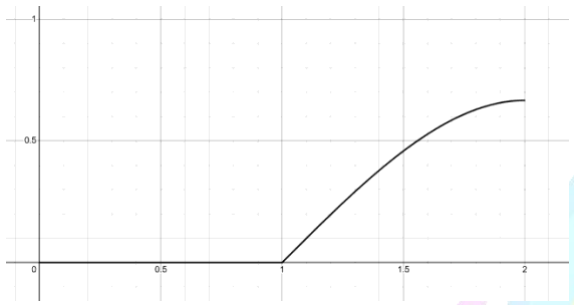
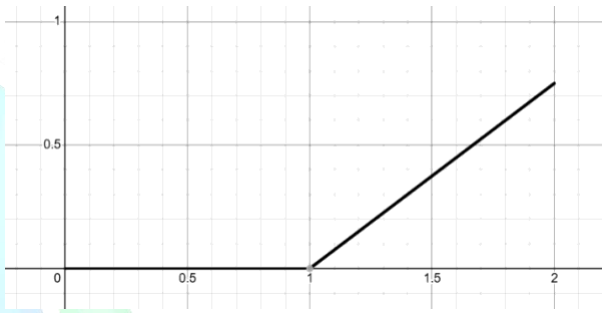
<tr><td>  </td><td>  </td></tr>
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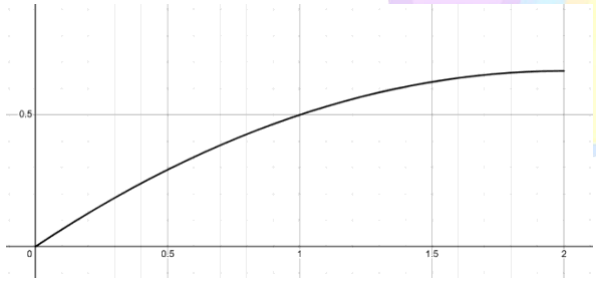
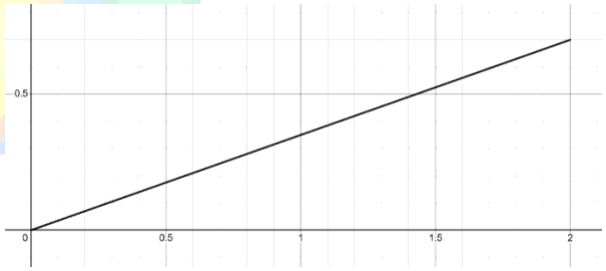
<tr><td>  </td><td>  </td></tr>
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Problem proposed by Alex Jicu

Question 15 – Carbon dioxide in the ocean

One important chemical reaction in the ocean helps buffer changes in pH and involves the formation of carbonic acid:

$$CO_{2(aq)} + H_2O_{(\ell)} \rightleftharpoons H_2CO_{3(aq)}$$

This reaction is reversible and slow in the absence of a catalyst, but in marine organisms, an enzyme called carbonic anhydrase speeds it up dramatically.

Suppose you conduct an experiment where the rate of formation of carbonic acid is measured in two setups:

- Setup A – Pure seawater
- Setup B – Seawater with added carbonic anhydrase

Which of the following observations best indicates that the enzyme increased the rate of the forward reaction?

A. The pH of Setup A drops faster than that of Setup B.

B. The concentration of CO_2 increases more quickly in Setup B.

C. The concentration of H_2CO_3 increases more quickly in Setup B.

D. The equilibrium position shifts more to the right in Setup B.

Problem proposed by Thenura Dilruk

Question 16 – More on carbon dioxide

As oceanographers study the chemistry of seawater, they find that carbon dioxide from the atmosphere dissolves into the ocean, reacting with water to form carbonic acid. This weak ($pK_{a1} = 6.3$ and $pK_{a2} = 10.3$) acid plays a key role in maintaining the pH balance of ocean water and in the formation of shells by marine organisms.

The solvation equilibrium of CO_2 is:

$$CO_{2(g)} \rightleftharpoons CO_{2(aq)}$$

and is described quantitatively by Henry's Law $[CO_{2(aq)}] = K_H \cdot p_{CO_2}$.

At 5°C, the partial pressure of carbon dioxide just above the seawater is equal to around 0.005 atm.

Aqueous carbon dioxide is equivalent to carbonic acid ($[CO_{2(aq)}] = [H_2CO_3]$).

If the concentration of the HCO_3^- ion in seawater is $[HCO_3^-] = 8 \cdot 10^{-4}$M and Henry's constant for carbon dioxide is $K_H = 0.05\ \text{mol}\ L^{-1}\text{atm}^{-1}$, find the pH of the seawater:

A. 6.6

B. 6.8

C. 7.2

D. 7.4

Problem proposed by Alex Jicu and Thenura Dilruk

Question 17 – Oceanic temperature gradient

In a particular region of the ocean, the temperature decreases rapidly with depth in a layer called the thermocline. This results in a change in water density and, consequently, the speed of sound in water. A submarine sends a sonar pulse vertically downward from just above the thermocline. Above the thermocline, the temperature is uniform at 25°C. Within the thermocline, the temperature drops linearly from 25°C to 5°C over a depth of 100 m. Below the thermocline, temperature is constant at 5°C.

The speed of sound v in seawater is approximately given by

$$v(T) \approx 1449 + 4.6T$$

where T is in °C and v is in m/s.

Which of the following statements is most accurate regarding the sonar pulse's behavior as it travels downward through the ocean?

A. The sonar pulse travels in a straight line, but its speed decreases gradually in the thermocline.

B. The sonar pulse bends downward in the thermocline due to increasing speed with depth.

C. The sonar pulse bends upward in the thermocline due to decreasing speed with depth.

D. The sonar pulse stops at the boundary between warm and cold water due to total internal reflection.

Problem proposed by Thenura Dilruk

Question 18 – Using the temperature gradient

Sunlight warms the surface of the ocean, causing a temperature difference between the surface water (at 30℃) and deeper water (at 5℃). An experimental ocean thermal energy conversion (OTEC) system is being tested to extract useful energy from this temperature difference using a heat engine.

Assume the system works as an ideal Carnot engine. The efficiency of a Carnot engine is given in the equation below:

$$\text{Efficiency} = 1 - \frac{T_C}{T_H}$$

where T_C represents the absolute temperature of the colder reservoir and T_H represents the absolute temperature of the hotter reservoir.

If 90000J of energy was extracted from the hotter reservoir and that energy was used to run a turbine of efficiency 45% to use to supply energy to an oil rig in the middle of the ocean. A scientist is doing an experiment by using this energy to boil seawater taken from the surface of the sea for an experiment. How much seawater can she boil using the energy obtained from running the turbine?

The specific latent heat of vaporization of water is $L = 2.3 \cdot 10^6 \frac{J}{kg}$ and the specific heat capacity of water is $4200 \frac{J}{kg \cdot K}$

A. 1.29 g

B. 1.45 g

C. 2.86 g

D. 13.0 g

Problem proposed by Thenura Dilruk

Question 19 – Water in the oceans

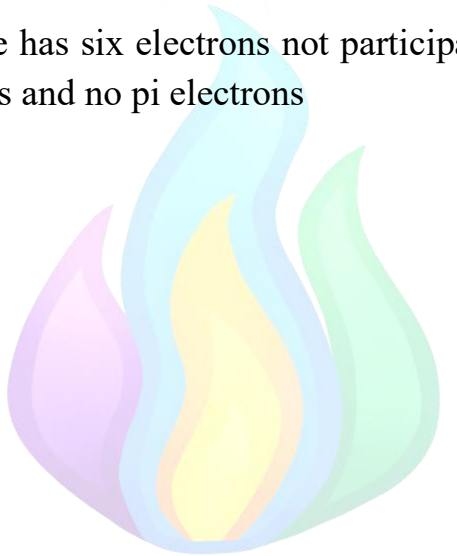
The most common molecule in oceans is (unsurprisingly) the water molecule – H_2O. Choose the right option about properties of the water molecule:

A. The O-H bonds in water are polar, but due to water's linear structure, the net dipole moment is zero

B. Water is a very common solvent, being able to dissolve a huge number of compounds such as NaCl, $FeSO_4$, $Al(NO_3)_3$, NH_3, I_2, $CuCl_2$ and $FeCl_2$

C. Water is an acid-base ampholyte, its conjugate acid being the hydroxide ion, while the conjugate base is the hydronium (hydroxonium) ion

D. The water molecule has six electrons not participating in chemical bonding, four sigma electrons and no pi electrons



Problem proposed by Alex Jicu

Question 20 – Sodium in oceanic waters

The first ionization energy is given in the table below for the first five alkali metals (not knowing which belongs to which):

IE_1(kJ/mol)	376	408	419	496	520

For sodium, the heat of sublimation is H_{sub} = 108 kJ/mol and the solvation enthalpy of sodium cations is H_{hyd} = -406kJ/mol.

A very commonly known experiment involving water is the explosive reaction of sodium and water. In this process, sodium is being oxidized from Na to Na^+ cations.

The energy absorbed by the oxidation of one sodium atom is:

A. 1.10eV

B. 1.14eV

C. 2.05eV

D. 3.29eV

Problem proposed by Alex Jicu

Question 21 – Sodium and magnesium in oceanic waters

Seawater contains a variety of dissolved ions. Two of the most abundant are sodium (Na^+) and magnesium (Mg^{2+}), both essential for marine life and involved in oceanic chemical processes. Despite both being in the same period, magnesium ions are more strongly hydrated (surrounded by water molecules) than sodium ions.

Which of the following best explains why Mg^{2+} ions are more strongly hydrated than Na^+ ions?

A. Mg^{2+} has a larger ionic radius than Na^+, so it attracts more water molecules.

B. $Mg^{2+}$is more electronegative than Na^+ and thus pulls water molecules more strongly.

C. Mg^{2+}has a higher charge density than Na^+, resulting in a stronger electrostatic attraction to water.

D. Na^+ is a metal, while $Mg^{2+}$is a non-metal in solution.

Problem proposed by Thenura Dilruk

Question 22 – More about sodium and magnesium

In a region of seawater a homogeneous electric field of intensity E causes the movement of ions leading to an electric current. The average speed of ions due to the influence of the electric field is given by $v = \mu \cdot E$, where μ is a constant called ionic mobility.

The mobility of sodium ions is $\mu_{Na} = 5.20 \cdot 10^{-8}\ m^2 s^{-1} V^{-1}$, while that of magnesium ions is $\mu_{Mg} = 5.50 \cdot 10^{-8}\ m^2 s^{-1} V^{-1}$.

If the concentration (number of ions per unit volume) of sodium ions is three times that of the magnesium ions, the ratio between the current due to magnesium and the current due to sodium (I_{Mg}/I_{Na}) is:

A. 0.35

B. 0.71

C. 1.06

D. 2.12

Problem proposed by Alex Jicu

Question 23 – Coral reefs

Ocean acidification and increasing ocean temperatures had a disastrous effect on marine coral populations across the globe. Due to the action of various marine biological organizations local coral populations have increased within the last 2 years. One of such organizations found out that some coral communities have adapted and became more resistant to changes in their surroundings. The organization collected samples of this coral and allowed them to reproduce and introduced them to increasingly harsher conditions.

After a few generations this coral community adapted to survive in conditions way worse than the conditions found in the site where the samples were originally collected. This can be stated as an example of which mechanism of genetic change?

A. Natural selection
B. Artificial selection
C. Genetic engineering
D. Gene technology

Problem proposed by Parthipan Kasiban

Question 24 – More species in coral reefs

The Coral Triangle, spanning across Philippines, Malaysia, Indonesia and Papua New Guinea has the highest coral diversity among all others. In a marine environment biomass pyramid is used to show the amount of living organic matter in an ecosystem. The unit used to measure this is grams per square meter. Out of the given biomass pyramids which is the correct one.

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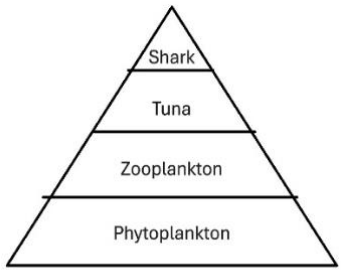
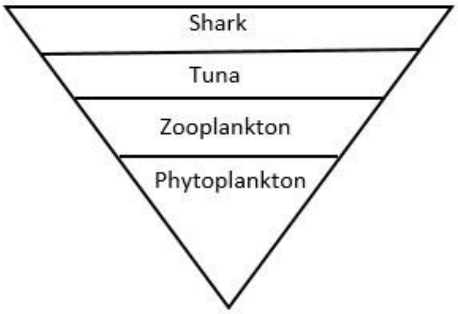
<tr><td> 
</td><td> 
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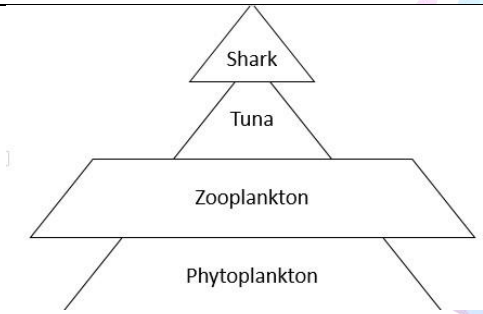
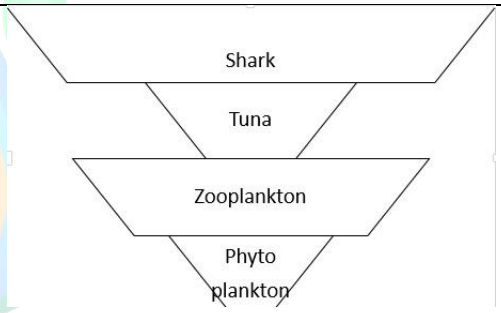
<tr><td> 
</td><td> 
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Problem proposed by Jathurshan

Question 25 – One more marine ecosystem

A research team investigating a tropical marine ecosystem near Brazil found that the gross primary productivity (GPP) of the area is 20 000 kJ per month. Producers use 25% of this energy for respiration. Energy is transferred through the food chain at 10% efficiency between trophic level.

How much energy (in kJ/month) is ultimately stored in the biomass of the tertiary consumers?

A. 0.15 kJ/month
B. 1.5 kJ/month
C. 2 kJ/month
D. 15 kJ/month

Problem proposed by Parthipan Kasiban

Question 26 – The swimmer

John was a swimmer and he usually goes out on Saturdays to swim. One day he came back with ear pain, itching and mild hearing loss. Later he was diagnosed with Otitis Externa (aka Swimmer's Ear). It is caused by bacterial or fungal growth in moist ear canal after swimming. So in the following answers what may have increased the risk of this disease?

A. Cleaning ears once a month
B. Wearing earplugs while swimming
C. Frequent use of cotton swabs to remove the moisture
D. Use of alcohol-based ear drops regularly after swimming

Problem proposed by Jathurshan

Question 27 – Oceanic measurements

A country's tsunami alert system was activated by an incoming large wave.

The alert system consists of two buoys 100 metres apart. The time elapsed between the first buoy being hit by the wavefront and the second buoy being hit by the wavefront is 20 seconds.

Satellite images also showed that the distance between two successive wavefronts is 12 metres.

What is the frequency of the tsunami wave?

A. 0.42 Hz

B. 2.4 Hz

C. 5.0 Hz

D. 60 Hz

Problem proposed by Filip Kilibarda

Question 28 – Another oceanic measurement

Scientists deploy an underwater magnetometer in the ocean to map subtle variations in the Earth's magnetic field. They notice that when crossing a boundary between two water masses – one warm and less salty, the other cold and saltier – the detected magnetic field shows a tiny but measurable fluctuation.

Which of the following best explains the situation?

A. The colder, saltier water has high density, which bends magnetic field lines.

B. Variations in temperature cause changes in the permeability of water, altering the magnetic field.

C. Moving saline water in the presence of Earth's magnetic field induces small electric currents that generate secondary magnetic fields.

D. The magnetometer reacts to pressure differences caused by the different densities due to different salinities

Problem proposed by Thenura Dilruk

Question 29 – Optic measurements

Consider a glass vessel (the index of refraction of glass is $n_g = 1.5$) in which some oceanic water ($n_w = 1.3$) is poured (see the figure).

The radius of curvature of the curved surface is equal to $R = 50\text{cm}$.

It is known that for a lens with index of refraction n and radii of curvature R_1 and R_2, one can calculate the convergence using the lens maker's formula:

$$C = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where the radii are positive or negative depending on their orientations. The curvature radius of plane surfaces is infinite.

If light is shined from below the vessel onto the plane glass surface, what is the equivalent convergence of the system?

A. -0.4 m^{-1}

B. +0.4 m^{-1}

C. -5.6 m^{-1}

D. +5.6 m^{-1}

Problem proposed by Alex Jicu

Question 30 – Ship hulls corrosion

The corrosion of ship hulls in seawater is an important issue in marine environments. Seawater acts as an electrolyte, facilitating redox reactions between the metal hull (iron) and dissolved oxygen. A steel ship hull (assumed to be pure iron) is corroding in seawater due to the following redox reactions:

- Anode (oxidation): iron is oxidized to iron (ii) ($E° = +0.44$ V)
- Cathode (reduction): $O_{2(g)} + 2H_2O_{(\ell)} + 4e^- \longrightarrow 4HO^-$ ($E° = +0.40$ V)

Assume the total charge transferred during corrosion over a day is 96 500 C.

Select the correct statement

A. The cell potential is –0.84 V and 1 mole of Fe is oxidized.
B. The cell potential is +0.84 V and 0.5 moles of Fe are oxidized.
C. The cell potential is +0.84 V and 1 mole of Fe is oxidized, corresponding to 55.8 g of Fe lost.
D. The cell potential is +0.40 V and 2 moles of Fe are oxidized

Problem proposed by Fillios Memtsoudis