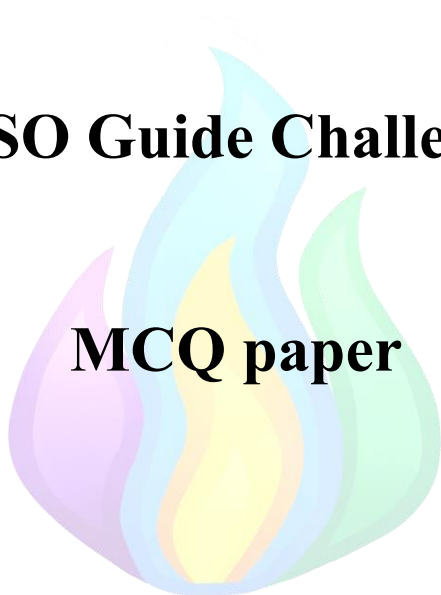


IJSO Guide Challenge

MCQ paper



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

Constant	Notation	Value
Acceleration due to gravity	g	9.8 ms^{-2}
Gravitational constant	G	$6.67 \cdot 10^{-11} \text{ m}^3 / \text{kg} \cdot \text{s}^2$
Planck's constant	h	$6.62 \cdot 10^{-34} \text{ J} \cdot \text{s}$
Elementary charge	e	$1.6 \cdot 10^{-19} \text{ C}$
Speed of light in vacuum	c	$3 \cdot 10^8 \text{ ms}^{-1}$
Density of water	ρ	1000 kg m^{-3}
Stefan-Boltzmann constant	σ	$5.67 \cdot 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4}$
Universal gas constant	R	$8.314 \text{ J mol}^{-1} \text{ K}^{-1}$ $0.0821 \text{ atm L mol}^{-1} \text{ K}^{-1}$
Avogadro's number	N_A	$6.022 \cdot 10^{23} \text{ mol}^{-1}$
Faraday's constant	F	$96\,500 \text{ C/mol}$
Pi	π	3.14
Electrical permittivity of free space	ϵ_0	$8.85 \cdot 10^{-12} \text{ F} \cdot \text{m}^{-1}$
Magnetic permeability of free space	μ_0	$4\pi \cdot 10^{-7} \text{ H/m}$
Mass of Earth		$5.97 \cdot 10^{24} \text{ kg}$
Mass of Moon		$7.35 \cdot 10^{22} \text{ kg}$
Mass of Sun		$1.99 \cdot 10^{30} \text{ kg}$
Radius of Earth		$6.4 \cdot 10^6 \text{ m}$
Radius of Moon		$1.7 \cdot 10^6 \text{ m}$
Radius of Sun		$6.96 \cdot 10^8 \text{ m}$
Specific heat capacity of water	c_w	$4200 \text{ J/kg} \cdot ^\circ\text{C}$
Average molar mass of air	M	28.9 g/mol

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:

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

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

(Use atomic masses rounded to two decimal places.)

IUPAC Periodic Table of the Elements

1	2	Key:										13	14	15	16	17	18	
1 H hydrogen 1.008 ±0.0002	2 He helium 4.0026 ±0.0001											5 B boron 10.81 ±0.002	6 C carbon 12.011 ±0.001	7 N nitrogen 14.007 ±0.001	8 O oxygen 15.999 ±0.001	9 F fluorine 18.998 ±0.001	10 Ne neon 20.180 ±0.001	
3 Li lithium 6.94 ±0.001	4 Be beryllium 9.0122 ±0.0001											13 Al aluminum 26.982 ±0.001	14 Si silicon 28.086 ±0.001	15 P phosphorus 30.974 ±0.001	16 S sulfur 32.06 ±0.02	17 Cl chlorine 35.45 ±0.01	18 Ar argon 39.948 ±0.001	
11 Na sodium 22.990 ±0.001	12 Mg magnesium 24.305 ±0.002											31 Ga gallium 69.723 ±0.001	32 Ge germanium 72.630 ±0.008	33 As arsenic 74.922 ±0.001	34 Se selenium 78.971 ±0.008	35 Br bromine 79.904 ±0.003	36 Kr krypton 83.798 ±0.002	
19 K potassium 39.098 ±0.001	20 Ca calcium 40.078 ±0.004	21 Sc scandium 44.956 ±0.001	22 Ti titanium 47.867 ±0.001	23 V vanadium 50.942 ±0.001	24 Cr chromium 51.996 ±0.001	25 Mn manganese 54.938 ±0.001	26 Fe iron 55.845 ±0.002	27 Co cobalt 58.933 ±0.001	28 Ni nickel 58.693 ±0.001	29 Cu copper 63.546 ±0.003	30 Zn zinc 65.38 ±0.02	49 In indium 114.82 ±0.01	50 Sn tin 118.71 ±0.01	51 Sb antimony 121.76 ±0.01	52 Te tellurium 127.60 ±0.03	53 I iodine 126.90 ±0.01	54 Xe xenon 131.29 ±0.01	
37 Rb rubidium 85.468 ±0.001	38 Sr strontium 87.62 ±0.01	39 Y yttrium 88.906 ±0.001	40 Zr zirconium 91.224 ±0.002	41 Nb niobium 92.906 ±0.001	42 Mo molybdenum 95.94 ±0.01	43 Tc technetium [97]	44 Ru ruthenium 101.07 ±0.02	45 Rh rhodium 102.91 ±0.01	46 Pd palladium 106.42 ±0.01	47 Ag silver 107.87 ±0.01	48 Cd cadmium 112.41 ±0.01	81 Tl thallium 204.38 ±0.01	82 Pb lead 207.2 ±0.1	83 Bi bismuth 208.98 ±0.01	84 Po polonium [209]	85 At astatine [210]	86 Rn radon [222]	
55 Cs caesium 132.91 ±0.01	56 Ba barium 137.33 ±0.01	57-71 lanthanoids	72 Hf hafnium 178.49 ±0.01	73 Ta tantalum 180.948 ±0.01	74 W tungsten 183.84 ±0.01	75 Re rhenium 186.207 ±0.01	76 Os osmium 190.23 ±0.01	77 Ir iridium 192.22 ±0.01	78 Pt platinum 195.084 ±0.02	79 Au gold 196.967 ±0.01	80 Hg mercury 200.59 ±0.01	113 Nh nihonium [286]	114 Fl flerovium [289]	115 Mc moscovium [290]	116 Lv livermorium [293]	117 Ts tennessine [294]	118 Og oganeson [294]	
87 Fr francium [223]	88 Ra radium [226]	89-103 actinoids	104 Rf rutherfordium [261]	105 Db dubnium [262]	106 Sg seaborgium [266]	107 Bh bohrium [264]	108 Hs hassium [277]	109 Mt meitnerium [268]	110 Ds darmstadtium [271]	111 Rg rogersium [282]	112 Cn copernicium [285]							

Introduction

Welcome to the first paper of the IJSO Guide Challenge 2026. This year, the papers are following Dan. Dan is a geologist who loves our Earth and studying it, but he needs your help with some physics, biology and chemistry.

To help him, you will be given some situations and you will have to answer 15 multiple choice questions, with four given answer options, out of which only one is correct. For every correct answer you will receive 10 points, for every wrong answer you will lose 3 points and if you don't know the answer there will be no penalty.

You will submit your answer to <https://forms.gle/UZaUMx6adFfRR4dc6>.

In order to avoid you accidentally forgetting to answer a question, you are required to answer every question in the Google Forms, with "I don't know" being added as an option.

Special thanks to the following people (in alphabetical order) for their involvement in the creation of the MCQ paper:

- Alex Jicu (Romania)
- Dilina Weragama (Sri Lanka)
- Fillios Memtsoudis (Cyprus)
- Josephine Ankomah (Canada)
- Marie Lautenschlager (Germany)
- Thenura Wickramaratna (Sri Lanka)
- Yasir Habib (Pakistan)

The IJSO Guide team wishes you and Dan the best of luck in your explorations!

(P) Question 1 – Green energy

Being a geologist, Dan knows all about our wonderful planet and what needs to be done to save it. To do this, he tries to use energy as green as possible.

Charging a battery by riding a bicycle and converting mechanical energy into electrical energy and then potential chemical energy inside the battery is not at all a new idea. Let's explore the feasibility of such a process in a real context.

As Dan cycles, he needs to put in mechanical work. The total torque he needs to apply is equal to $\tau = 30\text{N} \cdot \text{m}$. It is known that the mechanical power is given by $P_{\text{mech}} = \tau \cdot \omega$, where ω is the angular velocity of the wheels (which roll without slipping). It is known that the radius of a wheel is $R = 30\text{cm}$. Then, the following mechanisms are employed:

- The rolling makes an alternating voltage appear via a magnet system
- The alternating voltage is turned into a direct voltage (with energy losses)
- The direct voltage creates a voltage across the battery (with energy losses)
- The battery is charged electrochemically (with energy losses)

All these energy losses lead to an overall efficiency of the process $\eta = 50\%$.

To calculate the maximum energy capacity of the battery, you may use the following data:

- The maximum charge that can be transferred by the battery, $Q = 720\,000\text{C}$
- The voltage of the battery is around $U = 5\text{V}$

At what percentage would a ride from Apahida to Cluj-Napoca ($D = 12\text{km}$) charge the battery?

- A. 16.7%
- B. 33.3%
- C. 66.7%
- D. 83.3%

Problem proposed by Alex Jicu

Next, Dan goes to a paleontological site and starts exploring it.

(B) Question 2 – Fish fossils

Studying the old isolated paleontological site with many fish fossils, Dan discovered an isolated ecosystem, with few species and not a very complex food chain, where he made a breakthrough discovery - a new chemical compound called thenurium that was present in small amounts in the marine environment. Thenurium remained in the fish bodies and was resistant to the passing of time (because of its structure and because of the unique environment in that site), making it possible to analyze the amount of thenurium in different species and find out some information about these species.

He also discovered two new fish species - *Internationales juniorus* (IJ) and *Scientius olimpiadus* (SO). He found that, on average SO contained significantly more thenurium than IJ.

Which of the following is a reasonable conclusion for Dan to draw about the ecological properties of that environment?

- A. Thenurium couldn't have been a protein, because proteins are readily directly excreted in urine and don't accumulate
- B. SO is not a phytophagous (plant eating) species
- C. In the relevant food chain, SO must be the link that comes immediately after IJ
- D. IJ is a primary consumer in the food chain

Problem proposed by Alex Jicu

(B) Question 3 – More fish

While studying the fish from the previous question, Dan and his colleagues decide to go diving themselves. As they descend deeper into the water, they notice that their bodies begin to respond to the changing conditions. Some of them try to impress the others with their knowledge and make the following statements:

I. When ascending from a deep dive, you should do so slowly because, in the worst case, a rapid ascent can lead to symptoms such as severe joint pain, dizziness, or difficulty breathing.

II. During a deep-dive, the curvature of the eardrum significantly increases, towards the inside.

III. During a prolonged dive, anaerobic glycolysis causes the pH in the muscle tissue to increase.

IV. During a prolonged dive, the heart rate increases. This reduces the oxygen consumption of the heart and helps conserve the limited oxygen reserves of the body.

Which of the following is correct?

- A. Only statements I and II are correct.
- B. Only statements II and IV are correct.
- C. Only statements I, II and IV are correct.
- D. All four statements are correct.

Problem proposed by Marie Lautenschlager

(C) Question 4 – A new mineral!

Hanksite is a rare water-soluble mineral, with the formula $\text{Na}_{22}\text{K}(\text{SO}_4)_9(\text{CO}_3)_2\text{Cl}$. During his exploration of the site, Dan finds a mineral which contains the same ions as hanksite, but in a different proportion, along with some more inert impurities. To find its composition, Dan does some tests on it.

Firstly, he mixes 10 g of the chemical with 50 mL of 0.5M sulfuric acid (H_2SO_4). After the test ended, Dan titrated the remaining acid with 0.5 M sodium hydroxide (NaOH) and saw that 44 mL was needed.

Then, for the second part of Dan's tests, he dissolves 10g of the mineral in water and adds barium chloride (BaCl_2). Later, he filters, dry and weighs the precipitate obtained and finds its mass to be 5.78 g.

Find the mass percentages of carbonate and sulfate respectively in the chemical.

	Percentage of Carbonate (CO_3^{2-})	Percentage of Sulfate (SO_4^{2-})
A	8.4%	12.4%
B	8.4%	23.8%
C	16.8%	12.4%
D	16.8%	23.8%

Problem proposed by Thenura Wickramaratna

(P) Question 5 – Rolling cylinder

Dan noticed an approximately cylindrical block, which can be considered uniform, rolling down from the top of an incline leading right into the paleontological site. He observed the cylinder to roll without slipping

The cylinder had a mass of 215 kg and a radius of 2.76 m, while the angle of the incline was 35°.

The surface was rough enough to provide static friction, with a coefficient of static friction of value 0.35.

Which option correctly gives the value and orientation of the friction force?

Note: When a regular block (a cube) slides down a frictionless incline, its acceleration has an easily derivable value, equal to a . When a cylinder rolls without slipping, its acceleration is $a' = \frac{a}{1+k}$, where k is called the gyration factor and, for a cylinder, it's equal to 0.5.

	Value (N)	Orientation
A	402.84	Down the inclined plane
B	402.84	Up the inclined plane
C	604.08	Down the inclined plane
D	604.08	Up the inclined plane

(P) Question 6 – Bringing the rocks up

Dan is extracting rocks from an ancient paleontological site, hoping he will be able to find fossils within them. The mass of the rocks is 5000 kg while the mass of the bucket is 100 kg. The rocks need to be raised from a crate of 50 m depth. The efficiency of the machine used to lift is 40%. It is said that the bucket can only raise 200 kg of payloads in one go. It is also mentioned that when the bucket is lowered, it is lowered with constant velocity (not dropped). Find how much energy needs to be spent to raise all of the rocks.

- A. 3.68 MJ
- B. 4.90 MJ
- C. 9.19 MJ
- D. 12.25 MJ



Problem proposed by Thenura Wickramaratna

(C) Question 7 - Analyzing the rocks

To analyze the alkalinity of the extracted rocks, Dan prepared a solution of ethanoic acid (CH_3COOH). He knows that ethanoic acid is a weak acid and only partially ionizes in water:



To see how the equilibrium responds to a change in concentration, Dan adds a small amount of sodium ethanoate (CH_3COONa) to the solution. Since sodium ethanoate dissolves readily, it increases the concentration of CH_3COO^- ions in the solution.

What happened to the equilibrium when Dan adds CH_3COO^- ?

- A) The added CH_3COO^- shifts the equilibrium to the left, reducing the ionization of CH_3COOH and therefore decreasing the H^+ concentration.
- B) The added CH_3COO^- shifts the equilibrium to the right, increasing the ionization of CH_3COOH and increasing the H^+ concentration.
- C) Adding CH_3COONa increases the K_a of CH_3COOH , which causes the H^+ concentration to increase.
- D) Adding CH_3COO^- makes the equilibrium constant smaller, causing the concentration of H^+ to decrease.

Problem proposed by Yasir Habib

(B) Question 8 – Joseph

Dan's friend, Joseph, is accompanying him at the paleontology site. Joseph underwent surgery before the trip and is experiencing severe skin irritation at the surgical site. The doctors at the paleontology site diagnose him with *Staphylococcus*, a bacterial skin infection. He is prescribed Cephalexin, a broad-spectrum antibiotic that interferes with bacterial cell-wall synthesis. Three days later, Joseph returns without improvement. Testing identifies HA-MRSA, Hospital Associated Methicillin-resistant *Staphylococcus aureus*. These bacteria are now resistant to the antibiotic and a different antibiotic, intravenous vancomycin, is prescribed.

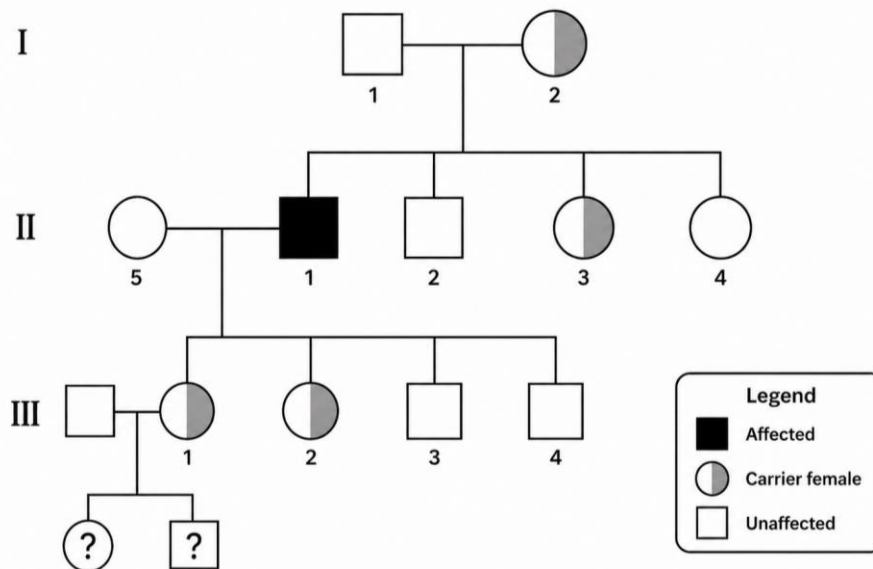
Which explanation best explains why the bacterial population changed?

- A. The antibiotic altered gene transcription processes, causing the bacteria to develop cephalixin-resistant mutations so they could survive treatment. This acquired resistance was passed onto their offspring.
- B. Several bacteria were killed off, and a smaller bottleneck led to genetic drift, randomly increasing resistant bacteria mutation frequency.
- C. Conjugation, the transfer of genetic material, occurred between cephalixin-resistant bacteria and susceptible bacteria, allowing the resistance to spread quickly.
- D. The resistant mutation was already present in a small amount of the bacterial population. The susceptible ones were eliminated by cephalixin, and the select few resistant bacteria were able to reproduce and lead to repopulation.

Problem proposed by Josephine Ankomah

(B) Question 9 – More visitors

A family came to visit the paleontology site. Many of them have a genetic enzymatic deficiency, leading to symptoms such as fatigue or jaundice. The following pedigree shows their family history:



Help the Dan determine the type of inheritance pattern this condition exhibits and the outcomes of individual III 1's offspring:

- A. X-linked dominant, the boy has a 50% chance of being affected and a 50% chance of being unaffected while the girl has a 50% chance of being unaffected and 50% chance of being a carrier.
- B. X-linked recessive, the boy has a 50% chance of being affected and a 50% chance of being unaffected while the girl has a 50% chance of being unaffected and 50% chance of being a carrier.
- C. Autosomal dominant, the boy has a 100% chance of being affected while the girl has a 50% chance of being unaffected and 50% chance of being affected.
- D. X-linked recessive, the boy has a 50% chance of being affected and a 50% chance of being unaffected while the girl has a 100% chance of being unaffected non-carrier.

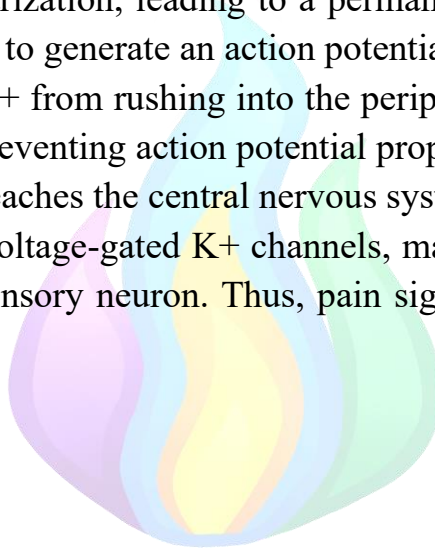
Problem proposed by Josephine Ankomah

(B) Question 10 – Dan gets hurt as well

Dan trips over a boulder at the site, and ends up with a deep laceration to the leg requiring several sutures. Repair would be painful, thus the physician administers lidocaine, a local anesthetic, around the injured area. Within minutes, Dan no longer experiences sharp pain and the physician can carry on with the procedure.

Which of the following correctly explains how lidocaine might work?

- A. Lidocaine blocks the Na/K pump, effectively reducing the polarization of the cell (by reducing the partial positive charge on the inside face of the cellular membrane)
- B. Lidocaine inhibits the sodium-potassium pump, causing immediate intracellular depolarization, leading to a permanent rest potential, inhibiting the neuron's ability to generate an action potential
- C. Lidocaine stops Na⁺ from rushing into the peripheral sensory neuron during a depolarization, preventing action potential propagation along the axon. The pain signal never reaches the central nervous system.
- D. Lidocaine blocks voltage-gated K⁺ channels, making it impossible for them to repolarize the sensory neuron. Thus, pain signals never reach the central nervous system



Problem proposed by Josephine Ankomah

(C) Question 11 – Cave collapse

Dan was exploring a cave system, when suddenly the floor collapsed and trapped him. Until the rescuers arrived, he had to generate an electrical current. The following list gives his electronics and the voltage required to turn them on:

- A light bulb, which needs a voltage of 0.50V
- A walkie talkie, which needs a voltage of 0.80V
- A GPS device, which needs a voltage of 1.00V
- A phone, which needs a voltage of 1.50V

He creates a battery by inserting a copper nail and a zinc nail in a potato. The inside of the potato acts as an electrolyte, which can be considered to contain a mixture of some organic and inorganic acids, which are not active from a redox point of view. One half-reaction takes place at each electrode (Cu cathode and Zn anode), creating a potential across them. Below are given some potentials, some of which you will use to solve the problem:

Half-reaction	Potential
$\text{Zn}^{2+} + 2\text{e}^{-} \rightarrow \text{Zn}$	-0.76V
$\text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu}$	+0.34V
$2\text{H}^{+} + 2\text{e}^{-} \rightarrow \text{H}_2$	0.00V
$\text{O}_2 + 4\text{H}^{+} + 4\text{e}^{-} \rightarrow 2\text{H}_2\text{O}$	+1.23V

Which of the electronics can Dan turn on, using only one battery?

- A. Only the light bulb
- B. The light bulb and the walkie talkie
- C. The light bulb, the walkie talkie and the GPS
- D. All 4 devices

Problem proposed by Alex Jicu

(C) Question 12 – Emergency fuel

In the cave, Dan urgently needs to get warm so he won't suffer from hypothermia. He was prepared for this. Previously, he asked a chemistry student, Yashab, to compare two fuels to see how efficiently they release energy. He burned a small amount of fuel beneath a beaker containing water and notices that the water temperature rises.

He repeated the experiment under the same conditions but used a different fuel. Although both fuels released heat when burned, the temperature increase is different.

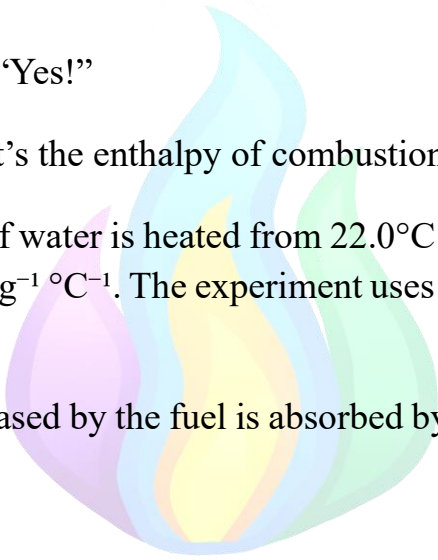
Dan asks: "Can we determine the energy released by the fuel just by looking at the temperature change?"

Yashab's answer is clear: "Yes!"

Dan then says: "So...what's the enthalpy of combustion for this fuel?"

In the experiment, 159 g of water is heated from 22.0°C to 47.0°C. The specific heat capacity of water is $4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$. The experiment uses 1.13 g of a fuel with a molar mass of 76.7 g mol^{-1} .

Assuming all the heat released by the fuel is absorbed by the water, what is Yashab's answer?

- 
- A) $-5.65 \times 10^3 \text{ kJ mol}^{-1}$
 - B) $-4.52 \times 10^3 \text{ kJ mol}^{-1}$
 - C) $-2.26 \times 10^3 \text{ kJ mol}^{-1}$
 - D) $-1.13 \times 10^3 \text{ kJ mol}^{-1}$

Problem proposed by Yasir Habib

(C) Question 13 – Electrolysis

For future, accidents, Dan decides to always have a backup DC power supply with him. Before going in another cave, he decides to check the efficiency of the power supply in an electrolysis experiment.

A current of 2.0 A is passed through a solution of copper (ii) sulfate (CuSO_4) for 40 minutes 15 seconds.

During the experiment:

- Copper is deposited at one electrode.
- A gas is released at the other electrode.

What is the gas that forms and what volume of gas forms (molar volume at STP is 22.4L/mol and the efficiency can be taken to be 100%)?

	Gas	Volume
A	Hydrogen	0.48 L
B	Hydrogen	0.96 L
C	Oxygen	0.28 L
D	Oxygen	0.48 L

Problem proposed by Yasir Habib

In his free time, Dan likes to visit different places which give him opportunities to learn more about our Universe.

(P) Question 14 – The astronomy camp

During an astronomy camp, Dan is studying the motion of a small satellite orbiting the Earth. Initially, the satellite moves in a circular orbit of radius r with an orbital speed v and an orbital period T .

Dan then transfers the satellite to a new circular orbit whose radius is $6r$. During this process, the mass of the satellite becomes twice its original value.

Assume that:

- Earth is the only significant source of gravitational force
- The satellite's mass remains constant once it reaches the new orbit
- Air resistance is negligible
- Both the initial and final orbits are circular.

Dan now wants to know:

If the satellite initially has orbital speed v and period T , what will its new orbital speed v' and orbital period T' be?

	v'	T'
A	$\frac{v}{\sqrt{6}}$	$6\sqrt{6}T$
B	$\frac{v}{6}$	$6T$
C	$\frac{v}{\sqrt{6}}$	$6T$
D	$\sqrt{6}v$	$6\sqrt{6}T$

Problem proposed by Yasir Habib

(P) Question 15 – The basalt columns

Dan visited a site famous for its basalt columns, similar to those below:



Basalt is a volcanic rock that forms when liquid magma cools down. When basalt forms, it's massive and has no holes in it. After that, it cools down, which makes it want to contract - mechanical stress appears which eventually leads to the famous hexagonal fractures, with the volume that “disappeared” being filled by air. The porosity of a basalt sample (percentage of volume occupied by air) is around 2.36%. If the coefficient of thermal expansion is equal to $\gamma = \frac{1}{V_0} \frac{\Delta V}{\Delta T} = 2.4 \cdot 10^{-5} \text{K}^{-1}$ and the temperature of the basalt is $T \approx 15^\circ\text{C}$, what is the approximate temperature at which the massive pore-less basalt formed?

- A. 800°C
- B. 900°C
- C. 1000°C
- D. 1100°C

Problem proposed by Alex Jicu