A Journey to Europa 🚀

IJSO Theory Mock Test

Answer sheet

Problem 1—Gaseous Planets (5.25 points)

Part A: Diamond Formation

A1. Find the enthalpy change of reaction.

(0.25 points)

Calculation:

$\Delta H =$

A2. Find the activation energy E_{a_1} of reaction (1)

(1.00 points)

Calculation:

$E_{a_1} =$

A3. Find the activation energy E_{a_2} of the inverse reaction.

(0.25 points)

Calculation:

E_{a_2} =

Part B: Decomposition of methane

B1. Calculate the enthalpy change of reaction (2)

(0.25 points)

Calculation:

ΔH =

B2. Which of the following will increase the rate of the forward reaction? *Tick the appropriate boxes.*

(0.50 points)

- ☐ Increase the temperature.
- ☐ Decrease the temperature.
- ☐ Increasing the pressure.
- ☐ Decreasing the pressure.
- ☐ Adding more methane.
- ☐ Adding a catalyst.

B3. Find the equilibrium concentration of hydrogen gas $[H_2]$ in mol/L.

(0.75 points)

Calculation:

$[H_2]$ =

Part C: Reaction in the Planets

Calculate the enthalpy change of reaction (3)

(0.25 points)

Calculation:

$\Delta H\ =$

Part D: Methane combustion

D1. Write the balanced equation for this reaction.

(0.30 points)

D2. Find the values of constants a and b.

(0.30 points)

Calculation:

a =

b =

D3. What is the total mass of the gases inside the reactor?

(0.50 points)

Calculation:

Mass =

D4. What is the value K_0 of the equilibrium constant?

(0.60 points)

Calculation:

K_0 =

D5. Compare each of the values of constants K_A, K_B and K_C with the initial K_0 value. Put > or = or <

(0.30 points)

K_A		K_0
K_B		K_0
K_C		K_0

Problem 2—Before the Journey in Europa (3.85 points)

Part A: Preparing the Fuel Supply

A1. How many grams of hydrogen gas do we need?

(0.60 points)

Calculation:

Mass =

A2. What is the minimum tank volume (in liters) needed to store all the hydrogen?

(0.65 points)

Calculation:

V_{min} =

A3. Calculate the extra tank volume (in liters) needed to store the oxygen needed for the entire trip if the trip lasts for 2 weeks.

(0.60 points)

Calculation:

V_{extra} =

Part B: Thermal Shielding & Material Selection

B1. What is the heat flux (W/m²) through the aluminum if one side is at 25°C and the other at –160°C?

(0.50 points)

Calculation:

Heat Flux =

B2. Calculate the new total heat flux through the combined system (aluminum + foam), treating the layers as resistors in series.

(1.00 points)

Calculation:

Heat Flux =

B3. Calculate the total energy absorbed (in joules) by the solar panel due to sunlight throughout the whole trip.

(0.50 points)

Calculation:

Energy =

Extra space for problem 2:

Problem 3—Discovery during the Journey (4.25 points)

Part A: Chemical Analysis of the Reddish Sample

A1. If 1.80 g of $Fe(OH)_2$ precipitate is formed, calculate the mass of $FeSO_4$ originally present.

(0.50 points)

Calculation:

Mass =

A2. If 0.875 g of $Mg(OH)_2$ is obtained, calculate the mass of $MgCl_2$ in the original sample.

(0.50 points)

Calculation:

Mass =

A3. Based on your answers to A1 and A2, calculate the mass percent composition of $FeSO_4$ and $MgCl_2$ in the original 10.0 g sample.

(0.25 points)

Calculation:

Mass percent of $FeSO_4$ =

Mass percent of $MgCl_2$ =

Part B: The depth of the crater

B1. What is the gravitational acceleration on Europa?

(0.50 points)

Calculation:

g =

B2. What is the speed of sound?

(0.75 points)

v =

B3. What is the depth of the crater?

(1.50 points)

Calculation:

Depth =

B4. What is the wavelength of that sound wave?

(0.25 points)

Calculation:

Wavelength =

Extra space for problem 3:

Problem 4—Life in Europa (9.40 points)

Part A: Interpreting Signs of Life

A1. Identify two of these gases. Put a cross in the appropriate boxes.

(0.50 points)

Oxygen	
Water Vapor	
Methane	
Carbon Dioxide	

A2. *Tick the appropriate box.*

- ☐ Proteins with specific chirality (e.g., L-amino acids)
- ☐ Nucleic acids (like DNA or RNA)
- ☐ Polysaccharides (e.g., storage or structural polymers)
- ☐ Hydrocarbons or amino acids

(0.30 points)

A3. *Tick the appropriate box.*

- ☐ Greater than
- ☐ Equal to
- ☐ Less than
- ☐ Has no effect

(0.30 points)

Part B: Life in the Europan Ocean Depths

B1. a) Calculate the concentration of these structures in terms of structures per mL.
(0.40 points)

Calculation:

Structures per milliliter =

B1. b) Calculate the approximate volume of a single average rod-shaped structure in cubic micrometers (μm^3).
(0.50 points)

Calculation:

Volume =

B1. c) What is the volume of a single structure in liters?
(0.30 points)

Volume =

B2. *Tick the appropriate boxes (continuation on next page):*

- ☐ Cell membranes with specialized lipids to maintain fluidity under high pressure and low ambient temperatures (away from direct vent heat).
- ☐ Enzymes that function optimally at near-freezing temperatures (psychrophilic) for life further from vent openings.
- ☐ Efficient mechanisms to repair DNA damage, considering Jupiter's radiation environment and potential residual radiation.

☐ Strict dependence on sunlight for energy production.

☐ Ability to utilize inorganic chemical compounds as an energy source.

☐ Thick cell walls primarily composed of cellulose for structural support.

(0.60 points)

B3. (Fill-in-the-blank)

To maintain cell membrane fluidity in the generally cold deep ocean of Europa (away from the immediate vent plume), the fatty acid chains in their phospholipid bilayer membrane would likely need a ___________ (higher / lower) proportion of chemical bonds that introduce kinks into the fatty acid chains, such as ________ (double / triple / single) bonds.

(0.40 points)

Part C: Metabolism and the Chemistry of Alien Life

C1. a) What is the general metabolic term for organisms that obtain energy by oxidizing inorganic substances, like the Europan microbes utilizing H_2S?

(0.30 points)

Term =

C1. b) In the given reaction, is H_2S acting as an oxidizing agent or a reducing agent? Put a cross in the appropriate box.

(0.20 points)

Oxidizing Agent	
Reducing Agent	

C2. How much energy (in kJ) does this colony generate per hour from this reaction? (0.40 points)

Calculation:

Energy =

C3. a)

- ✓ **(Tick):** If the statement is scientifically correct AND directly relevant to the context.
- **0 (Zero):** If the statement is scientifically correct BUT its direct relevance to the context is minor or indirect, or it pertains to a different aspect not central to the discussion.
- ✗ **(Cross):** If the statement is scientifically incorrect.

Statements	Evaluation
A. The tendency of Group 14 elements to form extended chains by bonding with themselves (catenation) is a key factor in their ability to create the framework of macromolecules.	
B. Due to possessing four valence electrons, elements in Group 14 typically engage in forming up to four covalent bonds with other atoms.	
C. Certain microorganisms, like diatoms, incorporate silicon into their cell walls in the form of silica, creating intricate protective structures.	

D. When forming the structural basis of large molecules, Group 14 elements achieve stability primarily through the formation of ionic bonds.	
E. The energy and stability of the bonds formed between identical atoms of a Group 14 element (e.g., C-C vs. Si-Si) are virtually the same, making them equally suitable for chain formation under all conditions.	

(0.50 points)

C3. b) *Tick the appropriate box.*

- ☐ Liquid methane (a non-polar solvent abundant in the outer solar system)
- ☐ Highly purified water (as it is a universal solvent)
- ☐ Molten sulfur (found in volcanic regions) could dissolve some silicon compounds.
- ☐ Gaseous hydrogen (as a lightweight atmospheric component)

(0.40 points)

c)

Biological catalysts and many cellular structures on Earth are primarily made of macromolecules called proteins. These are polymers of __________ __________. For any molecule to effectively serve as the primary hereditary material (e.g., DNA on Earth), it must primarily be capable of accurate self-__________ and the stable __________ of genetic information. A major challenge for hypothetical silicon-based life (compared to carbon-based life that produces gaseous CO_2 as a waste product) is that the primary oxide of silicon (silicon dioxide, SiO_2) is typically a __________ (physical state) at common planetary surface temperatures, making its metabolic cycling and disposal difficult.

(0.60 points)

Part D: Dynamics of Europan Microbial Life

D1. a) Assuming continuous exponential growth, calculate the number of microbial cells expected after 40 Earth hours.

(0.70 points)

Calculation:

Number of Microbial Cells =

D1. b) How many generations would have occurred during these 40 Earth hours?

(0.30 points)

Calculation:

No. of Generations =

D2. a) Calculate the frequency of the T_S allele in this sampled population.

(0.60 points)

Calculation:

Frequency of the T_S allele =

D2. b) Calculate the frequency of the T_F allele in this sampled population.

(0.60 points)

Calculation:

Frequency of the T_F allele =

D2. c) what would be the expected frequency of the $T_F T_s$ (heterozygous) genotype? Show your calculation.

(0.60 points)

$T_F T_s$ frequency =

D2. d) *Tick the appropriate boxes.*

- ☐ Heterozygous genotypes are more suited since they have both characters.
- ☐ Lacking distinct specializations reduces an organism's fitness in environments that specifically favor any one of those specializations.
- ☐ The TS and TF alleles are codominant, and codominance inherently causes a disruption in the expected Hardy-Weinberg equilibrium for heterozygotes.
- ☐ The population at Vent Prime is small and relatively isolated, leading to a higher incidence of inbreeding.
- ☐ Vent Prime may consist of distinct micro-habitats with differing selective pressures.

(0.60 points)

D3. e) what term describes the status of this allele in the population?
(0.30 points)

Term =

Extra space for problem 4:

Problem 5—Life-Sustaining Chemicals (2.25 points)

A. If in the sample carbon is only found as one isotope and oxygen as two isotopes, find the mass numbers of the isotopes.

(0.50 points)

Calculation:

Mass number of the 1st oxygen isotope:
Mass number of the 2nd oxygen isotope:
Mass number of the carbon isotope:

B. Find the number of neutrons in each isotope.

(0.25 points)

Calculation:

Number of neutrons in the 1st oxygen isotope:
Number of neutrons in the 2nd oxygen isotope:
Number of neutrons in the carbon isotope:

C. Find the relative abundances of the three isotopologues.

(0.25 points)

Calculation:

Relative abundance of 44u isotopologue = **0**

Relative abundance of 46u isotopologue =

Relative abundance of 48u isotopologue =

D1. Attribute each abundance to its isotopologue.

(0.50 points)

Isotopologue	**Abundance**
44u isotopologue	
46u isotopologue	
48u isotopologue	

D2. Calculate the abundances of the two isotopes in the sample from Europa.

(0.75 points)

Calculation:

Isotope	Abundance
1st isotope	
2nd isotope	

Extra space for problem 5:

Problem 6—Jicu and His Rover (5.00 points)

Part A: Uncontrolled Descent

A1. Assume that Jicu weighs 70 kg and that the rover weighs 500 kg. Find how much force is pulling the rover downhill with Jicu onboard.

(0.25 points)

Calculation:

Force =

A2. Assuming no brakes and no slipping, calculate the acceleration of the rover.

(0.25 points)

Calculation:

Acceleration =

A3. How much braking torque per wheel is needed to maintain constant speed?

(0.50 points)

Calculation:

Torque =

A4. Calculate the thermal energy generated by friction over 4 m (along the slope) of uncontrolled slide in the rough patch.

(0.50 points)

Calculation:

Energy generated =

A5. Estimate the energy dissipated during the impact (in kJ).

(0.50 points)

Calculation:

Energy =

A6. Calculate the rotational kinetic energy lost.

(0.50 points)

Calculation:

Kinetic Energy Lost =

Part B: Aftermath of the Crash

B1. Calculate whether the frame would have deformed plastically or remained intact.

(1.00 points)

Calculation:

B2. Calculate the spring constant of the rover's suspension system based on the observed vibrations.

(0.50 points)

Calculation:

Spring constant =

B3. How much force is required to overcome this static friction if Jicu attempts to move the rover uphill at a constant speed?

(0.75 points)

Calculation:

Force required =

B4. How much time (in minutes) will they have before the battery runs out?
(0.25 points)

Calculation:

Time =

-- End of answer sheet --