Theoretical Test

December 7th, 2019

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 4 hours to complete the exam.
2. ONLY use the pen and pencil provided by the organizers.
3. Check if your name, code and country name are filled in your answer sheets and sign every page of the answer sheets. Raise your hand, if you do not have the answer sheets.
4. You have 30 pages of exam sheet – including the front page. Raise your hand, if you find any sheets missing.
5. Read the problems carefully and write the correct answers in the corresponding boxes of the answer sheets.
6. Only the answer sheets will be evaluated. Before writing your answers on the answer sheets you may use the scrap paper provided to avoid errors on your answer sheets.
7. The number of points that can be obtained is indicated for each question.
8. The total number of questions is 5 questions and every question consist of 3 parts. Check if you have a complete set of the test questions sheets. Raise your hand, if you find any sheets missing.
9. Useful information for answering the questions is provided on pages 4 and 5.
10. Always show your calculations. If you do not show your calculations, no points are awarded for the question.
11. You should write your final answers down in the appropriate number of digits.

GENERAL INFORMATION

Constant	
Acceleration due to gravity	$g = 9.81\ m/s^2$
Universal gas constant	$R = 8.314\ \frac{J}{mol \cdot K}$
	$R = 0.08206\ L \cdot atm/mol \cdot K$
Refractive index of air	$n = 1$
Avogadro's constant	$N_A = 6.022 \times 10^{23}\ mol^{-1}$
Speed of light	$c = 2.998 \times 10^8\ m/s$
Planck's constant	$h = 6.626 \times 10^{-34}\ J \cdot s$
Specific heat capacity of water	$c_w = 4.18\ J/g \cdot °C$
Pressure	$1\ atm = 101{,}325\ Pa$
Density of water	$1\ g/mL$

IUPAC Periodic Table of the Elements

1																	18
1 H hydrogen 1.008 [1.0078, 1.0082]	2		Key: atomic number **Symbol** name conventional atomic weight standard atomic weight									13	14	15	16	17	2 He helium 4.0026
3 Li lithium 6.94 [6.938, 6.997]	4 Be beryllium 9.0122											5 B boron 10.81 [10.806, 10.821]	6 C carbon 12.011 [12.009, 12.012]	7 N nitrogen 14.007 [14.006, 14.008]	8 O oxygen 15.999 [15.999, 16.000]	9 F fluorine 18.998	10 Ne neon 20.180
11 Na sodium 22.990	12 Mg magnesium 24.305 [24.304, 24.307]	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 26.982	14 Si silicon 28.085 [28.084, 28.086]	15 P phosphorus 30.974	16 S sulfur 32.06 [32.059, 32.076]	17 Cl chlorine 35.45 [35.446, 35.457]	18 Ar argon 39.948
19 K potassium 39.098	20 Ca calcium 40.078(4)	21 Sc scandium 44.956	22 Ti titanium 47.867	23 V vanadium 50.942	24 Cr chromium 51.996	25 Mn manganese 54.938	26 Fe iron 55.845(2)	27 Co cobalt 58.933	28 Ni nickel 58.693	29 Cu copper 63.546(3)	30 Zn zinc 65.38(2)	31 Ga gallium 69.723	32 Ge germanium 72.630(8)	33 As arsenic 74.922	34 Se selenium 78.971(8)	35 Br bromine 79.904 [79.901, 79.907]	36 Kr krypton 83.798(2)
37 Rb rubidium 85.468	38 Sr strontium 87.62	39 Y yttrium 88.906	40 Zr zirconium 91.224(2)	41 Nb niobium 92.906	42 Mo molybdenum 95.95	43 Tc technetium	44 Ru ruthenium 101.07(2)	45 Rh rhodium 102.91	46 Pd palladium 106.42	47 Ag silver 107.87	48 Cd cadmium 112.41	49 In indium 114.82	50 Sn tin 118.71	51 Sb antimony 121.76	52 Te tellurium 127.60(3)	53 I iodine 126.90	54 Xe xenon 131.29
55 Cs caesium 132.91	56 Ba barium 137.33	57-71 lanthanoids	72 Hf hafnium 178.49(2)	73 Ta tantalum 180.95	74 W tungsten 183.84	75 Re rhenium 186.21	76 Os osmium 190.23(3)	77 Ir iridium 192.22	78 Pt platinum 195.08	79 Au gold 196.97	80 Hg mercury 200.59	81 Tl thallium 204.38 [204.38, 204.39]	82 Pb lead 207.2	83 Bi bismuth 208.98	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium	89-103 actinoids	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds damstadtium	111 Rg roentgenium	112 Cn copernicium	113 Nh nihonium	114 Fl flerovium	115 Mc moscovium	116 Lv livermorium	117 Ts tennessine	118 Og oganesson

57 La lanthanum 138.91	58 Ce cerium 140.12	59 Pr praseodymium 140.91	60 Nd neodymium 144.24	61 Pm promethium	62 Sm samarium 150.36(2)	63 Eu europium 151.96	64 Gd gadolinium 157.25(3)	65 Tb terbium 158.93	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.05	71 Lu lutetium 174.97
89 Ac actinium	90 Th thorium 232.04	91 Pa protactinium 231.04	92 U uranium 238.03	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

DO NOT turn to next page

before the "**START SIGNAL**"

QUESTION 1

Part 1:

Qatar state is one of the most important countries that produce Natural gas, it is formed from marine organisms that died, sank to the bottom of the ocean, and got covered with sediments. Most of the dead organisms decayed before becoming covered with sediments. Some of them, however, are buried along with the rest of the sediment. As more and more sediments are deposited over time, the temperature slowly increased. If the pattern of the temperature increase is just right, some of the dead organisms are changed into natural gas and oil.

Qatar Gas LNG Tanker

http://www.qatargas.com/english/operations/qatargas-chartered-fleet

i. Write a balanced equation for the complete combustion of the natural gas (CH_4), where the standard enthalpy of combustion is -802.3 kJ/mol for gas phase products? (0.25)

ii. How much energy is released from combustion of methane to raise 60.0 mL of water from 25.0 °C to 40.0 °C? (0.5)

iii. By looking at the table below; calculate the C-H bond enthalpy: (0. 5)

	O=O	O-O	H-O	C-O	C=O
Bond enthalpy(kJ/mol)	498	142	464	358	841

Part 2:

Qatargas company is a unique global energy operator in terms of size, service and reliability. The Company operates 14 Liquefied Natural Gas (LNG) trains with a total annual production capacity of 77 million tonnes. This makes Qatargas the largest LNG producer in the world.

The Liquified Natural Gas (LNG) Process:

The first step of liquefaction is the separation of condensate from gas. The separated condensate is sent to storage awaiting export. The natural gas then flows to the liquefaction trains for processing into LNG. During the first phase of this process, sulphur compounds, carbon dioxide, and water are removed in stages. The gas is then chilled using propane, C_3H_8.

The heavy hydrocarbons are separated out and fractionated into liquefied petroleum gas (LPG) and plant condensate. The cryogenic main heat exchanger in each train then cools the gas to approximately (-150. °C) , liquefying it in the process. Finally, as the pressure is reduced to almost zero, the temperature decreases to (-162 °C) , nitrogen is removed, and LNG is transferred to one of the storage tanks prior to being loaded into a LNG vessel.

The main purpose of gas liquefaction is to decrease the volume it occupies as well as making the process of transfer all over the world easy and efficient.

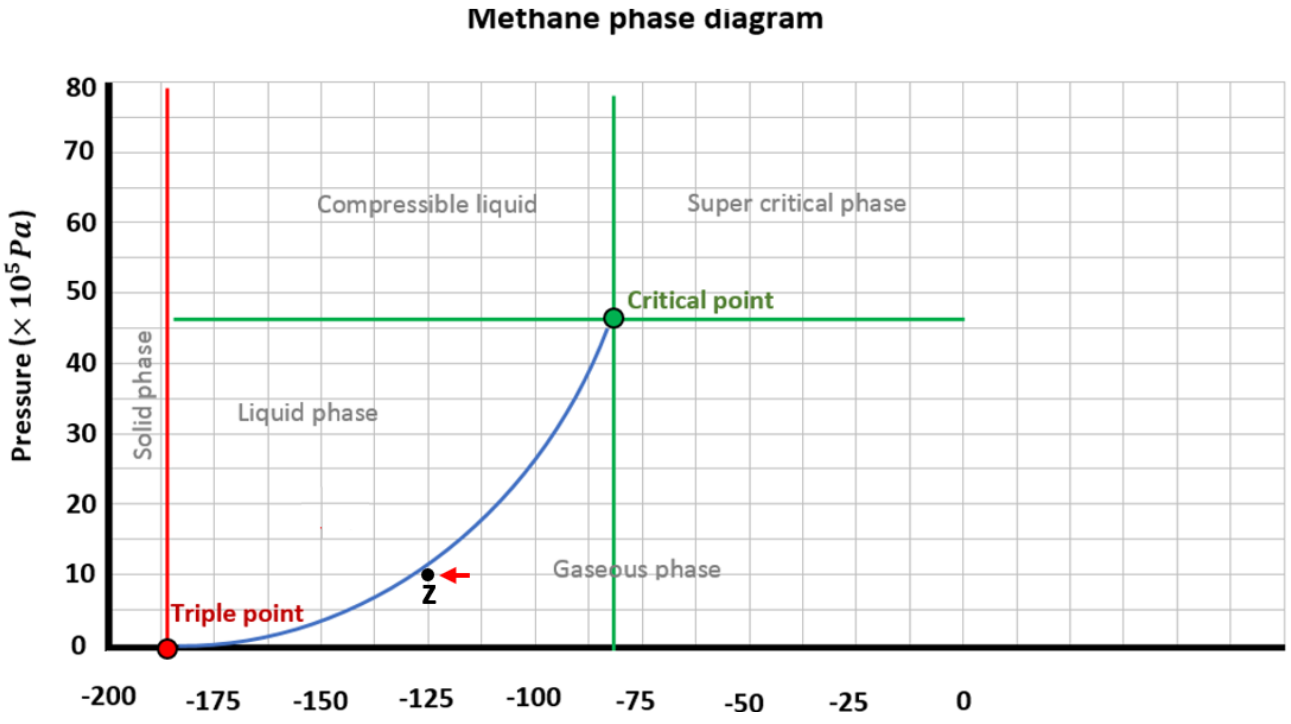
The question here is to examine to what extent the gas volume can be reduced after the liquefaction process.

A container contains a gas at a temperature of 3.10×10^2 K and a pressure of 101 kPa.

i. Find the volume in m^3 occupied by 1.25 mol of the gas in the container, assuming it is an ideal gas. (0.25)

ii. Assuming the gas molecules, in point (i), can be approximated as small spheres of diameter of 2.50×10^{-10} m, determine the fraction of the volume occupied by the gas molecules. (0.5)

iii. Assuming the gas in the container, in point (i), is natural gas which consists mainly from methane, use the phase change graph below to calculate the percentage volume change (with reference to point i above) just before liquefaction at point Z on the graph (indicated by an arrow). (0.5)



Part 3:

Decomposition or decay is a biological process that occurs naturally and is an essential process that helps to recycle materials. The rate of this process depends on three major factors: soil organisms, physical environment and the quality of the organic matter. Decomposers break down the dead organisms into their simple compounds. The following questions are related to the process of decay.

i. The following products are released during the decomposition process except: (0.25)

a. Carbon dioxide (CO_2).
b. Plant nutrients.
c. Resynthesized organic compounds.
d. Oxygen (O_2).

ii. Extreme high temperature might reduce the decay process due to...(0.25)

a. changing the conformation of enzymes.
b. changing the amino acid sequence of enzymes.
c. increasing the activation energy of enzymes.
d. increasing the ability of the enzyme to bind to the substrate.

iii. Which of the following factors are directly affecting decay? Choose three and indicate on the answer sheet, if the factor is (+) or is not (0) an important factor in affecting decay. (0.25 for all three choices being correct)

a. temperature
b. nitrogen
c. water
d. phosphate
e. oxygen
f. carbon dioxide
g. light

Factor	a	b	c	d	e	f	g
+/0							

iv. In ecosystems, rate of energy flow and nutrient cycling can determine ecosystem productivity and biodiversity. Which of the following organisms is considered to be effective in both processes: (0.25)

a. Mushroom.
b. Camel.
c. Date palm.
d. Insects.

v. Biomagnification is the process by which some toxic chemicals build up across an entire food chain and affects all of the animals higher up in the chain. Biomagnification usually happens for chemicals that (0.25)

a. Are not readily degraded and they dissolve in fat.
b. Are not readily degraded and they dissolve in water.
c. Are readily degraded and do not dissolve in water.
d. Are readily degraded and do not dissolve in fat.

vi. A student left two apples; one of them in an empty glass cup and the other in a glass cup filled with honey. Both cups were left open to the air and subjected to decay. After one month, the student observed that the apple left in the empty glass had several lesions, while the other apple immersed in honey still looked intact and firm.

The expected reason for the observed result is…. (0.25)

a. High concentrations of sugar cause chemical destruction to the bacterial cell wall.

b. There was a low concentration of nutrients for microbial growth.

c. The concentration of oxygen is decreased to zero percent.

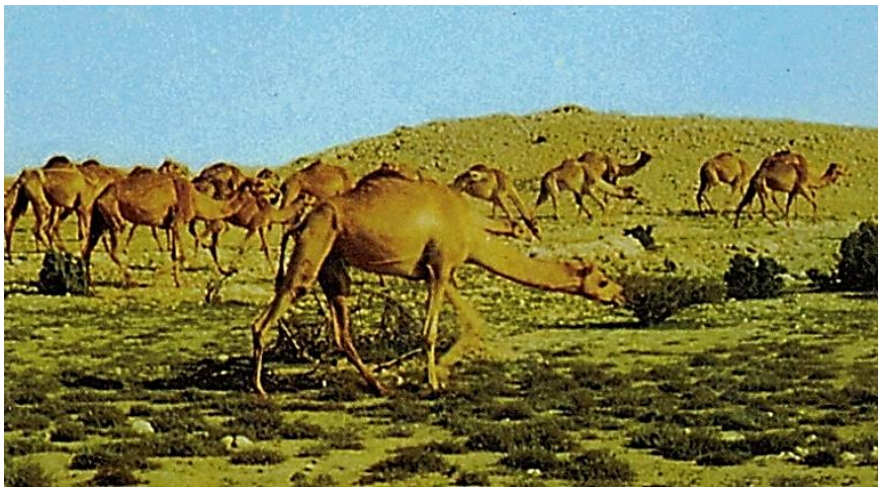
d. Microorganisms were not able to grow due to high osmotic pressure caused by high sugar content in honey.

QUESTION 2

Part 1:

Camels make up a large part of Qatar's heritage and are a part of the country's desert tradition. They were the only mode of transport in the Qatar area long before cars and other modes of transport came into the limelight and took over. A very interesting fact is that the word 'camel' is derived from the Arabic word 'Jamal'. Camels can survive in very harsh climates and environments and are biologically adapted for desert life.

Arabian camels have just one hump in comparison to Asian camels which have two humps. The hump stores fat tristearin (molecular weight = 890 g/mol), and if food is scarce, nourishment is provided by the hump as oxidation of the fat produces water and energy.



Arabian Camels Grazing in Qatar Desert

(Copyright Hala Al-Easa)

Tristearin is a typical animal fat and on combusting of 4.45 g tristearin, 12.51 g of carbon dioxide and 4.98 g of water were produced. However, a new undiscovered organic compound (QI) containing only carbon and hydrogen, was isolated from a mixture of Tristearin and QI and analyzed. When a 4.67 g gaseous sample of isolated, pure QI was prepared and a small amount is burned in excess oxygen and it yielded 151.2 mg of CO_2 and 69.62 mg H_2O. The density of QI in its vapor form is 4.668 g/ L at 25.0 °C and 1.00 atm. Before any testing can be done as to how QI interacts with tristearin, we need to determine the molecular formula for the isolated QI compound.

i. Determine the molecular formula for QI? (2.0)

ii. If the camel combusts hump stored fat tristearin during metabolism, as shown in the equation below, identify the missing coefficients (a, b) in the reaction. (0.5)

$$a\ C_{57}H_{110}O_6 + 163\ O_2 \longrightarrow 114\ CO_2 + b\ H_2O$$

iii. Camels have many adaptations to handle the hot and arid desert conditions. Among them is the ability to go a long time without drinking water and the ability to drink large quantities of water very quickly. A typical camel can drink 200 liters (53 gallons) of water in three minutes. Suppose that at an instant on a peak summer day a camel was able to generate 3.8 L of water using the stored fat in its hump, by the oxidation of tristearin. Calculate the mass of tristearin and the number of ATP molecules produced, if one mole of tristearin produces 458 moles of ATP. (1.0)

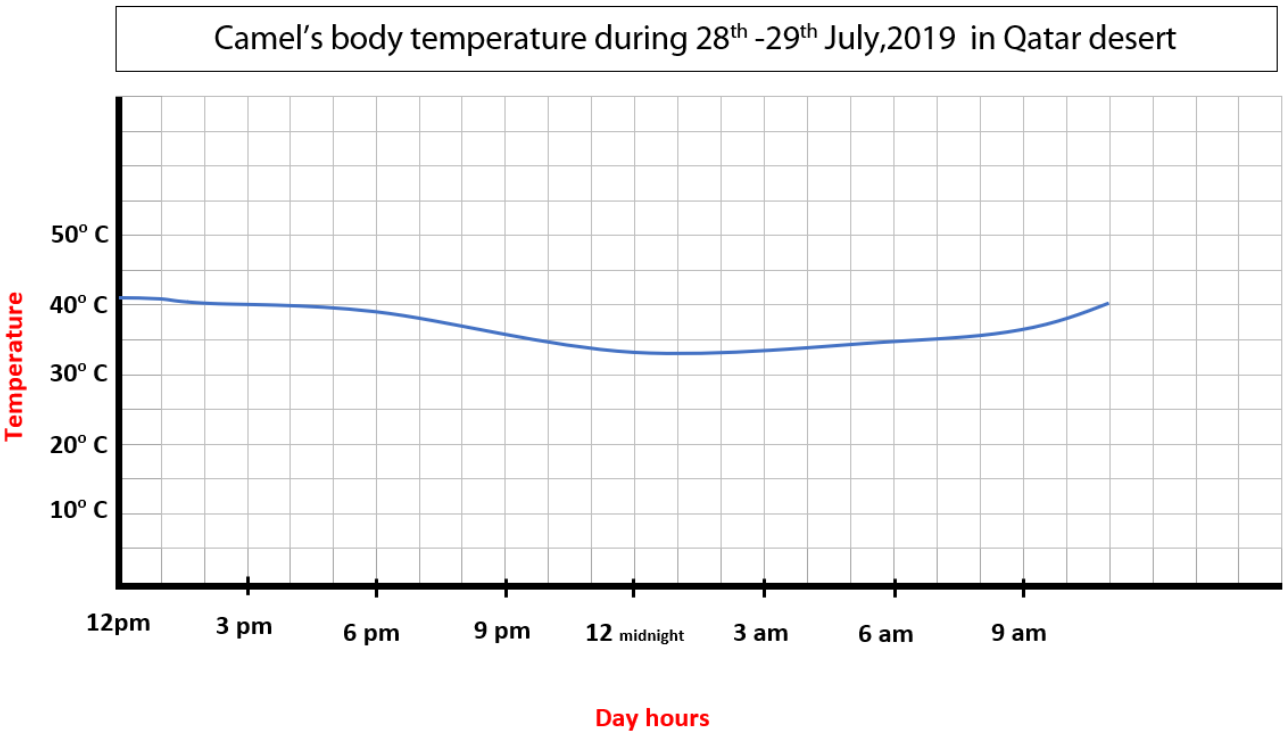
Part 2:

Camels are able to tolerate relatively large changes in their body temperature. This allows camels to conserve water by not sweating as the environmental temperature rises. This characteristic is important for camels to survive with very little water.

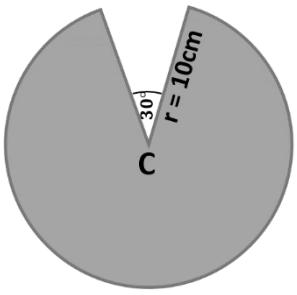
The following graph shows average changes in camel body temperature during a typical day in Qatari desert.

i. If camels, like human, use sweating as one of the mechanisms to keep their body temperature almost constant, calculate the maximum amount of water (in liters) a 5.50×10^2 kg Camel would have to sweat at 12 pm to reduce its body temperature to the lowest value during that day. Assuming that the only way to maintain the temperature is the evaporation of sweat. (0.5)

(Note: specific heat capacity of mammal is about $3.48 \times 10^3\ \mathrm{J/kg.K}$ and the latent heat of vaporization of water at the lowest temperature is $2.42 \times 10^6\ \mathrm{J/kg}$.

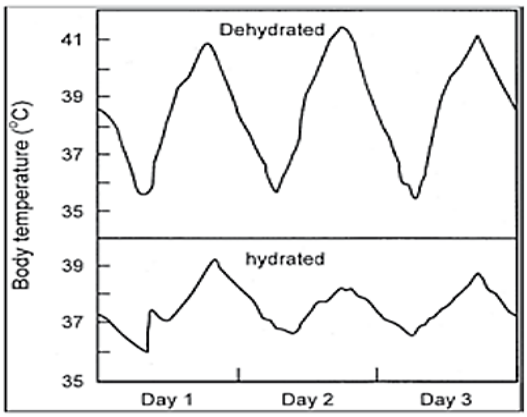


ii. The structure of the camel's foot is well-adapted to survive in deserts. The wide spreading feet keeps the camel from sinking into loose and shifting sands. Furthermore, the wide surface of each foot resists sinking by decreasing the pressure on the sand. If we model the camel's foot as shown in the figure below, calculate the pressure due to the camel weight on the sand. Use the camel's mass mentioned in point (i).(0.5)



Part 3:

The daily body temperature of a hydrated and a dehydrated camel fluctuates by some degrees Celsius to prevent water loss through evaporation as shown in the graph below. The mechanism allows the camel to gain approximately 2,900 kcal of heat, which corresponds to 5 litres of water being saved. The heat stored during the day (which causes drastic body temperature fluctuations) is dissipated at night (Schmidt-Nielsen, 1997).



Fluctuations of body temperature dehydrated and the hydrated camel (Schmidt-Nielsen, 1997).

i. According to the above graph, which condition results in more fluctuation of body temperature? (0.25)

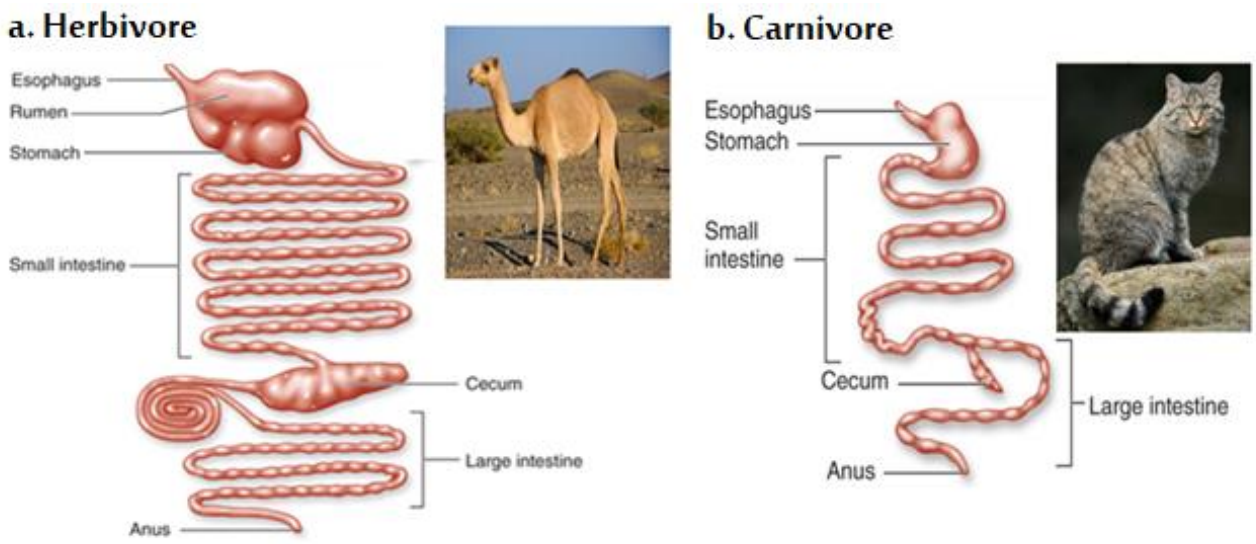
a. **Hydration**
b. **Dehydration**

ii. What are the product(s) of the saturated fat breakdown that takes place in the camel's hump? (0.5)

a. Fatty acids, and glycerol.
b. Water, fatty acids, and glucose.
c. Fatty acids, amino acids, and carbon dioxide.
d. Water only.

iii. A Camel has light coloured coat during the summer and it possess relatively long and slender legs which might be helpful in … (0.25)

a. Insulating its body from the intense heat radiated from desert sand.
b. Helping it to walk a long in sandy desert.
c. Providing an adaptive method for cooling during day.
d. All of the above.



The above figures show the general structure of digestive systems for herbivores and carnivores, such as Arabian camel and Arabian wildcat live in Qatar desert. Arabian camel is a herbivore, has the ability to feed on grass and thorny plants. Wildcat is a carnivore which feeds on rodents and other small mammals and is considered as an endangered species due to overhunting.

iv. Which organ in the digestive system helps to store and digest harsh and sharp food? (0.25)

a. Esophagus.

b. Rumen.

c. Large intestine.

d. Cecum.

v. The cecum of herbivores is larger than the cecum of carnivores because it helps to... (0.25)

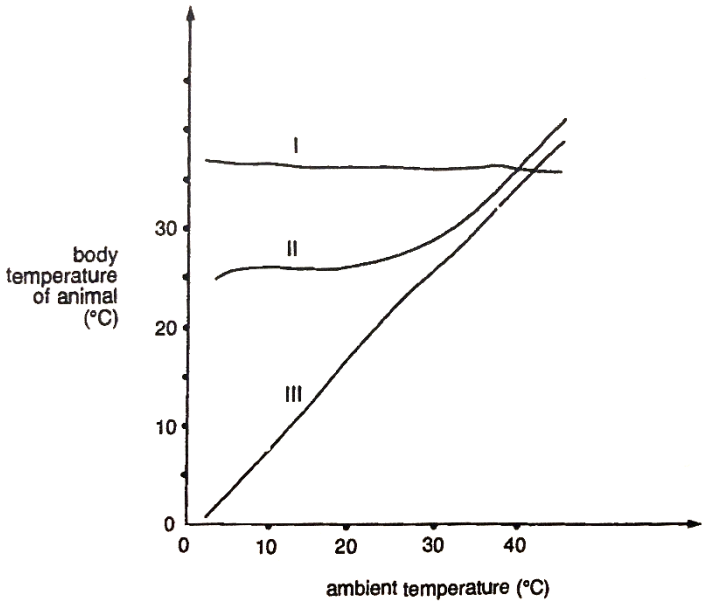
a. Digest proteins.

b. Store faeces.

c. Break down cellulose.

d. Break down lipids.

vi. The graph below shows the results of an experiment in which the internal temperature of three different organisms were monitored as the external temperature (ambient temperature) changes.



According to the above graph and based on your knowledge of temperature regulation, which of the following statements is <u>not</u> correct? (0.5)

a. Organism I could be a bird
b. Organism II may pant and/or sweat when the external temperature ranged 20°C to 25°C
c. Organism II was poikilothermic when the external temperature ranged between 5°C and 20°C
d. Organism III could be a snake.

QUESTION 3

Part 1:

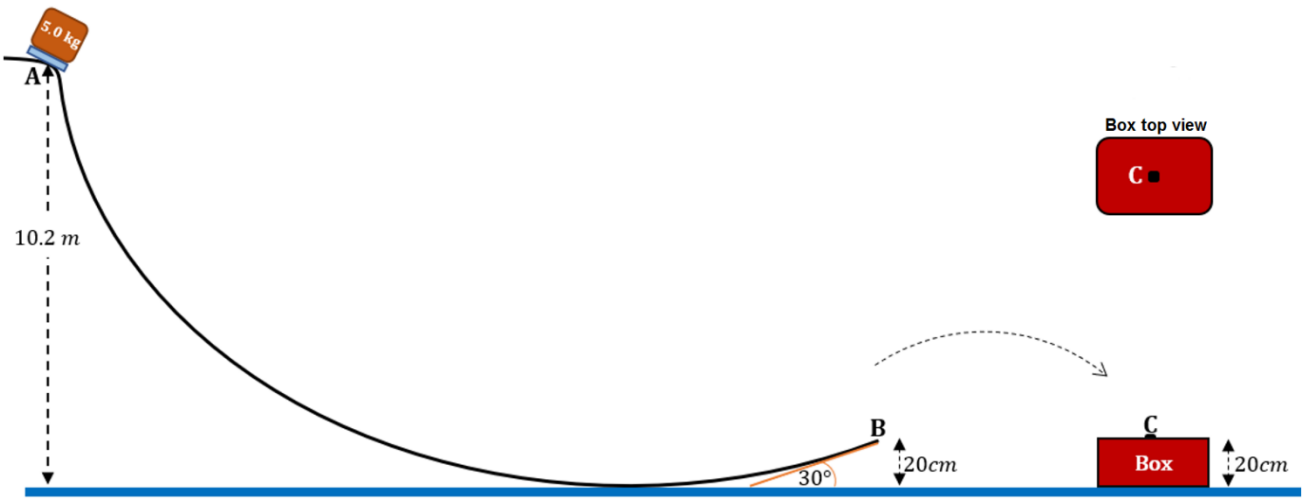
A ($5.00\ kg$) cubic shaped wooden block is released from rest to slide on a rough track from point (A) to point (B). To decrease the frictional force between the block and the track, a very thin sheet of ice of mass ($0.500\ g$) and temperature of ($-5.00\ ^\circ C$) was attached to the bottom of the block as shown in figure. At point (B) the wooden block will travel in air, after the attached ice sheet has totally melted. A box is placed so that the wooden block travels in the air from (B) to land on this box at point (C) as shown in the figure. Assume that the ice sheet doesn't exchange any heat neither with air nor with the wooden block and there is no air resistance with the block, calculate the following:

i. The time that the wooden block takes to travel from point (B) to Point (C). (1.0)

ii. The distance should the point (C) on the box be placed away from point (B).(0.5)

iii. The maximum height from the ground that the wooden block will reach during its journey from point (B) to point (C). (0.5)

Note: Specific heat capacity of ice is 2090 J/kg · °C. Latent heat of water at 0 °C is 3.33×10^5 J/kg.



Part 2:

Consider a dry ice block (solid CO_2) of mass 0.10 kg and temperature -255 °C.

i. The freezing point of dry ice is lower than that of solid water, -78.5 °C compared to 0 °C. Which of the following statements best rationalizes this fact? (0.25)

a. Dry ice has no net dipole moment and exhibits dipole-dipole interactions

b. Both dry ice and solid water have London dispersion forces, but stronger in dry ice resulting in a lower freezing point.

c. Solid water is polar and has only dipole-dipole interactions.

d. Both dry ice and solid water have polar bonds and London dispersion (van der Waals) forces. However, only solid water has hydrogen-bonding.

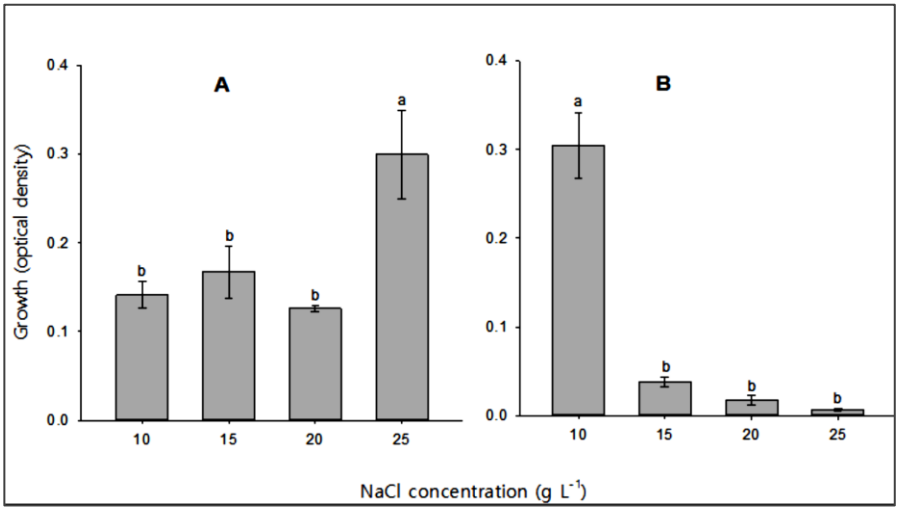
ii. Assuming that an ice block of 0.500 g at temperature – 5.00 °C was heated to 150 °C so that it gained heat energy of 1559 J, find the ratio between the given value for specific heat capacity of ice and that of water vapor. (1.0)

Consider the latent heat of water evaporation at 100 °C to be 2.256×10^6 J/kg.

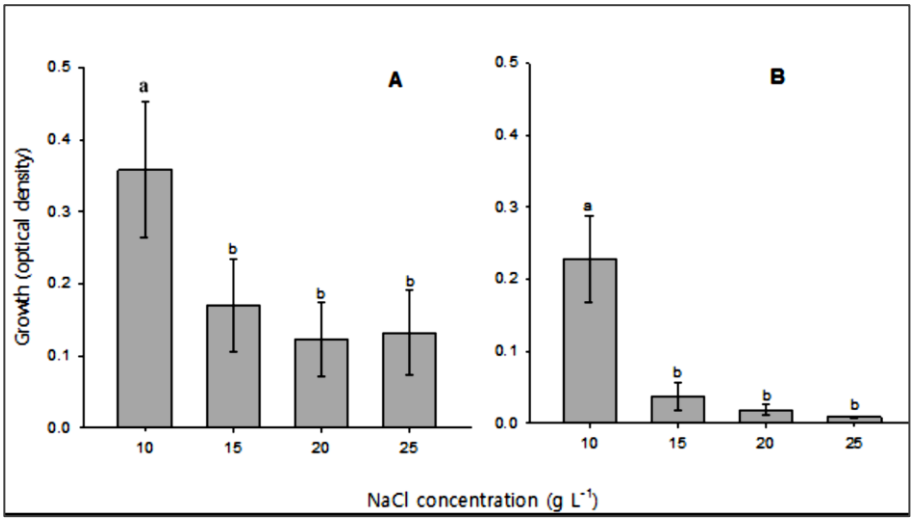
Note: Specific heat capacity of ice is 2.09×10^3 J/kg.°C. Latent heat of fusion of water at 0 °C is 3.33×10^5 J/kg.

Part 3:

A recent research was conducted at Qatar University by Abu-Dieyeh *et al* (2019) to simulate bioremediation under natural desert conditions. The authors isolated mercury tolerant strains of bacteria from the Qatari coastal area and investigated the growth of potential bacteria in the presence of salt ingredients. Part of the results are presented in the figure below.



Acinetobacter schindleri



Bacillus infantis

Effect of salinity (NaCl concentration) on the growth of two bacterial strains isolated from Qatari coastal area and grown in nutrient broth medium, in the absence (A) and in the presence of 10 ppm $HgCl_2$ (B). Within each graph, mean values with common letters are not significantly different at $P \leq 0.05$. Error bars represents the standard error of the means (N = 5).

i. What is the dependent variable in the experiment? (0.5)

a. NaCl concentration.

b. Bacterial species.

c. Bacterial Growth (Optical Density).

d. Fixed experimental conditions.

ii. According to the results in the above figure, in the absence of mercury, *Acinetobacter schindleri* is more tolerant to high salinity ($\geq$ 25 g L^{-1})? (0.25)

a. True.

b. False.

iii. Which of the following is incorrect regarding the significance of the results in the above figures (1.0)

a. In the presence of mercury, the growth of *A. schindleri* was similarly inhibited as influenced by 15, 20 or 25 g L^{-1} NaCl.

b. In the absence of mercury, the growth of *A. schindleri was* significantly greater as influenced by 25 g L^{-1} than lower concentrations of NaCl.

c. Overall, better growth was obtained for both bacteria in the absence of mercury.

d. Bacteria *B. infantis* is better recommended as a potential bio-remediating agent for arid land soil polluted with mercury.

iv. Which one of the following is the most appropriate answer as to why the authors investigated the salinity factor in Qatari environment? (0.5)

i	**The authors were interested in studying heat resistant bacteria.**
ii	**The authors were looking for saline tolerant bacteria.**
iii	**The authors were looking for saline non tolerant bacteria.**
iv	**The authors were interested in bioremediation of mercury in desert environment.**

a. i and iii.

b. iii and iv.

c. ii and iv.

d. ii and iii.

v. The authors conducted their experiments to find out an endogenous potential bacterium that can bio-uptake mercury from contaminated desert soil contaminated with mercury from spent fluorescent lamps. If authors decided to do further research to ensure the potentiality and survival of the isolated bacteria in Qatari soil (high salinity), what should they do? (0.5)

a. Conduct laboratory experiments to study the survival of bacteria under different temperatures.

b. Conduct laboratory experiments to study the survival of bacteria under different moisture conditions.

c. Conduct laboratory experiments to study the survival of bacteria under combinations of the two factors (temperature and moisture).

d. Conduct short and long-term field experiments to study the survival and potentiality of bacteria in Qatari soil.

vi. If one of the above-mentioned bacteria is reported to be adapted for mercury tolerance and a scientist wants to grow the bacteria on a new plate that has enriched culture media. Deduce the most likely correct statement: (0.25)

a. The newly grown bacteria will lose the adaptation and no longer can tolerate mercury.

b. The bacteria will maintain the adaptation and will continue to tolerate mercury.

c. The newly grown bacteria might lose adaptation but continue to tolerate mercury.

d. It is difficult to predict if the newly grown bacteria will be able to tolerate mercury.

vii. Suppose that mercury (Hg) is present as a pollutant in an aquatic lake and the following food chain is found:

Phytoplankton → zooplankton → small fish (species X) → larger fish (species Y) → largest fish (species Z) → Aquatic Bird.

Your friend wants to purchase one kg of fresh fish and requests your advice about the least toxic one, which species you will recommend to your friend? (1.0)

a. Species Y.

b. Species Z.

c. Species X.

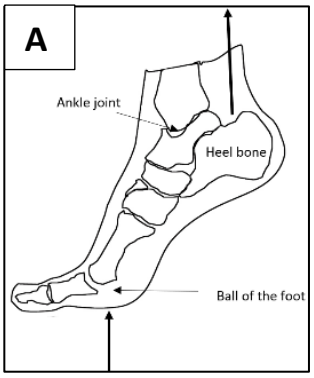
d. All have similar toxicity.

QUESTION 4

Part 1:

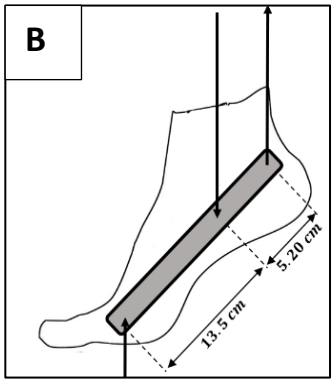
Preparing for the football world cup - Qatar 2022, some Qatari sport clubs make a case study to calculate the specific tension (*maximum tension force per unit area*) of the calf muscles for one of their best players. First, they recorded some anatomical data as follows:

- Body mass $= 72.0$ kg
- Calf cross sectional area (avg.) $= 23.0\ \text{cm}^2$
- Distance from the ball of the foot to the ankle joint $= 13.5$ cm
- Distance from heel bone to ankle joint $= 5.20$ cm



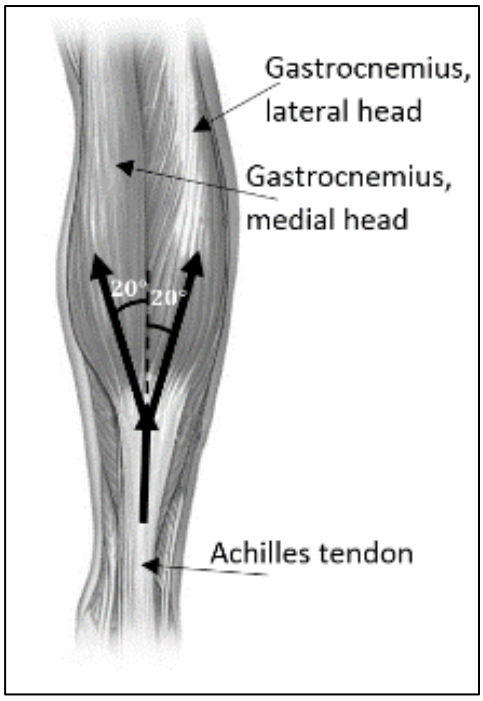
i. Specific tension: the player is asked to raise his body, as high as possible, to be balanced on the ball of one foot as shown in the figure (A).

a. What is the force in the Achilles tendon if the player stands on one foot only? Consider all foot bones as one rigid body as shown in figure (B). Neglect the weight of foot bones. (1.0)



b. Calculate the specific tension of the calf muscles. (0.5)

c. If two gastrocnemius muscles (lateral and medial head) contribute equally to a total of 60% of the force exerted on the Achilles tendon(. Calculate the force contributed by each of these two muscles on the tendon. (0.5)



ii. Bone strength:

For a healthy football player, the tibia bone can endure a maximum force about 36.0 N per 4.90×10^2 mm^2 before fracture. The figure shows player (A) tried to kick the ball but unfortunately, he hit player (B) instead. As a result, player (B) received the full kick in his tibia (assume that his tibia was stationary before collision). After collision the leg of player (B) moved back with velocity of 4.25 m/s. The mass of his leg is 3.20 kg and the impact time 55.0 ms and impact area is 6.20×10^2 mm^2.

Do you think that the tibia of the player (B) will bear this shock without fracturing? (0.25)

Select in the answer sheet: ( ) Yes OR ( ) No

Show your calculations in details in the answer sheet. (1.0)

Consider that no other external forces affect the leg of player (B).

iii. Developing a football shin guard.

https://www.elpasochiropractorblog.com/2017/07/soccer-shin-

Many sport companies develop shin pads to absorb impact that can cause injury upon severe collisions during football matches. In an experiment to compare the performances of different shin pad brands, a simulated human tibia is covered by each shin pad. A kicking device (impactor) is used to mimic the foot of the attacking player. A force meter is placed beneath the pad to measure the impact on the tibia. The following table represents the results.

Shin pad	Impact duration (ms.)	Kicking Force (N)	Sensor force (N)
Brand (1)	15	1066	11.5
Brand (2)	15	867	11.2
Brand (3)	17	846	17.8
Brand (4)	20	778	8.8
Brand (5)	13	622	9.0
Brand (6)	13	1096	6.6
Brand (7)	17	550	32.5

In order to help Player (B) to choose the best shin pad, sort the brands in descending order starting with the one which absorbs highest amount of force per unit time . (1.0)

Part 2:

Doping in sports is the administration of *prohibited performance-boosting drugs* by athletes and competitors. The list of banned drugs is huge, including but not limited to stimulants, anabolic steroids, amino acids, etc. Tests for doping materials can be made on both blood and urine samples. Several technologies could be used to detect doping.

i. One of the techniques used to detect doping is usage of ion-selective electrodes (ISE). As their name implies, these electrodes are selective for certain ions. Methamphetamine (MA) is a central nervous system (CNS) stimulant and the most abused drug in the world. An MA ion-selective electrode obeys the equation E (V) = constant + 0.059 log[MA^+]. The potential was -0.430 V when the electrode was immersed in 0.100 M MA^+ solution.

What is [MA^+] if E (V) = -0.300 V? (0.5)

Part 3:

During sport activities, players used to encounter muscle fatigue, which is the weakening in ability of a muscle to generate force. There are two main causes of muscle fatigue: (1) Neural due to the limitations of a nerve's ability to generate a sustained signal and (2) Metabolic which is more common and due to the reduced ability of the muscle fiber to contract.

i. What is (are) the most significant cause(s) of metabolic fatigue? Choose one option. (0.25)

a. Due to extensive contractions, the muscle runs out of oxygen, so it shifts to anaerobic respiration.

b. The blood circulation (flow) decreased in the muscle.

c. The extreme weather conditions.

d. a and b are correct.

ii. Histological examinations of skeletal muscle biopsy can tell if the person is a long distance runner or not. The most diagnostic feature used is (0.25)

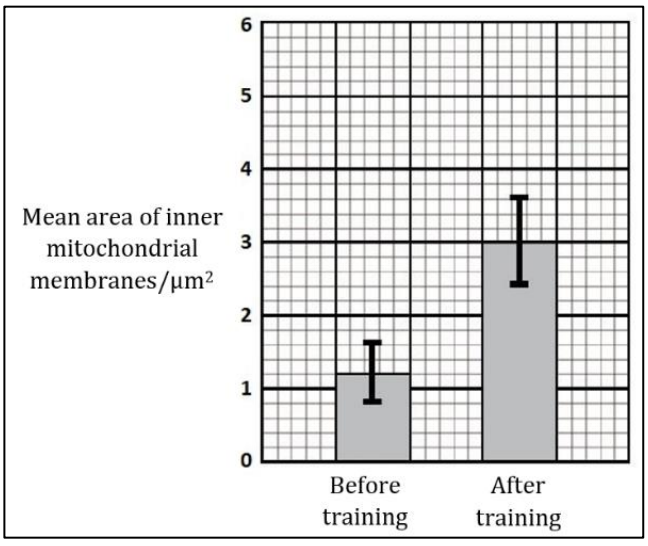
a. The colour of the muscle fiber cell

b. The number of mitochondria per muscle fiber cell

c. The number of rough endoplasmic reticulum per muscle fiber cell

d. The size of the muscle fiber cell

iii. The graph below shows the results of an experiment to measure the mean area of inner mitochondrial membranes taken from different samples of muscular cells for a number of football players before and after a training program. Study the figure carefully and then answer the following question:



Which of the following best explain the after-training conditions? (0.5)

a. ATP produced will increase as the area of the inner mitochondrial membrane increases.

b. ATP produced will decrease as the area of the inner mitochondrial membrane increases.

c. ATP produced will stay the same and no correlation with the mean area of inner mitochondrial membrane.

d. ATP produced has no significance relation with the results shown above.

QUESTION 5

Part 1:

One of the most spectacular artefacts in the National Museum of Qatar (NMoQ), a true testament to the pearl-trade, is the Pearl Carpet of Baroda. It was commissioned by the Maharaja of Baroda in 1865. The carpet has long been considered a remarkable work of art. The Baroda carpet was made with more than 1.5 million Arabian Gulf pearls, as well as rubies, emeralds, sapphires and diamonds.

The Baroda Carpet.

i. During the restoration of the Baroda Carpet, a peculiar mineral not seen mixed with the composition of pearls before known as *smithsonite* ($ZnCO_3$) was found in the elemental analysis in the lab during the restoration process. When a solid mixture of *smithsonite* and pearls containing only $CaCO_3$ is heated strongly, carbon dioxide gas is given off and a solid mixture of ZnO and CaO is obtained. If a 30.00 g sample of a mixture of $ZnCO_3$ and $CaCO_3$ produces 12.00 g of CO_2, then to the correct significant figures, what is the percentage by mass of *smithsonite* in the original mixture and ensure to include the balanced chemical equation ? (2.0)

ii. In very close proximity to the National Museum of Qatar, is the Doha corniche. A beautiful seafront extending for seven kilometers. Pollution of the seawater has increased with many pollutants such as heavy metal on the rise which can be harmful to the marine life and its habitats. Pollution of the Gulf waters increased after human development with many dangerous pollutants, including heavy metals, such as chromium. Naturally occurring chromium (Cr) is composed of four stable isotopes; ^{50}Cr, ^{52}Cr, ^{53}Cr, and ^{54}Cr with ^{52}Cr being the most abundant (83.789% natural abundance).

Main isotopes of chromium (Cr)		
Isotope	**Fractional molar abundance**	**half-life** ($t_{1/2}$)
^{50}Cr	4.345%	stable
^{51}Cr	artificial radioisotope	27.7025 d
^{52}Cr	83.789%	stable
^{53}Cr	9.501%	stable
^{54}Cr	2.365%	stable

a. Calculate relative atomic mass for Chromium using the abundance of the stable isotopes. (0.25)

b. How many grams of (^{53}Cr) are there in 250 kg $FeCr_2O_4$? (0. 25)

iii. Iron(II) can be directly calibrated by dichromate in a sulfuric acid-containing medium using an appropriate indicator according to the equation:

$$6\ FeCl_2 + K_2Cr_2O_7 + 13H_2SO_4 \longrightarrow Cr_2(SO_4)_3 + 3\ Fe_2(SO_4)_3 + K_2SO_4 + 12\ HCl + 7H_2O$$

a. Write the half equation for the oxidation reaction. (0.25)

b. Write the half equation for the reduction reaction. (0.25)

iv. Chromium is also used for the formation of alloys with zinc and copper which has an important medical and industrial use. Knowing that the reduction potential for $Cr^{+3/0} = -0.74V$, which of the following elements can be used for the formation of a galvanic cell in which chromium is the anode. Calculate E_{cell} for both reactions. (0.5)

a. Copper (reduction potential = +0.34 V)

b. Zinc (reduction potential = -0.76 V)

Part 2:

Qatar is a peninsula located in the eastern shore of the Arabian Peninsula, and in the middle of the west coast of the Arabian Gulf, Qataris used to extract pearls from the Arabian Gulf for trading. Pearls formed by saltwater or freshwater mollusks—a diverse group of animals that includes oysters, mussels, clams, conchs, and gastropods. If a tiny soil particle or a shell fragment enters inside a shell of mollusk, it will be coated with layer upon layer to finally form a pearl at the end of this process.

i. Why do you think these animals produce pearls? (0.25)

a. To repel predators.

b. To protect themselves when an irritant becomes entrapped.

c. To make animals look beautiful.

d. To give light reflections that enable the animal to move at night.

ii. The process of pearl formation in clams and other bivalves might refer to the feeding habit of these animals, which is: (0.25)

a. Bulk feeding.

b. Filter feeding.

c. Fluid feeding.

d. Nectar feeding.

iii. The process of pearl formation can be described as an interaction between... (0.25)

a. Biotic and abiotic factors.

b. A fragment of shell and a soil particle.

c. Abiotic factors and soil particles.

d. Abiotic factors and shell of mollusks.

iv. As aquatic invertebrates, clam and other bivalves do gas exchange using... (0.25)

a. Lungs.

b. Skin.

c. Gills.

d. Mouth.

v. Consider the following food chain: (0.25)

phytoplanktons→Bivalves →Sea stars →Sea otters→Dolphins

Dolphins used to eat large fishes but because of extensive fishing, Dolphins converted their feeding to sea otter. If exploiting of large fishes continues to occur, what is the correct scenario about Bivalves:

a. Bivalves population will increase in density.

b. Bivalves population will decrease in density.

c. No clear effect on bivalve's density.

d. Dolphins will turn to eat bivalves.

vi. Many species of mollusks are considered as food for many vertebrates, such as, fish, birds and seagulls. What is the relationship between mollusks and seagulls? (0.25)

a. Mutualism.

b. Predation.

c. Commensalism.

d. Parasitism.

Part 3:

A chromium alloy steel is used to make suspension cables and wires that are used in many fields such as construction cranes, elevators and sports .

i. Calculate the weight hanged in a string whichcauses an increase in a chromium steel wire of length 2.0 m and cross-section area of 2.0 $\mathbf{mm}^2$ by 0.50 mm, knowing that the Young modulus is 220 GPa. (0.5)

ii. Two cables of the chromium steel alloy have lengths ratio 1:3, and diameters ratio 3:1, if they are stretched by the same force, what is the ratio of their increase in length? (0.5)

iii. A chromium steel alloy rod of Young modulus Y and coefficient of linear expansion α was clamped between two rigid supports, separated by a distance L. If the rod has length L, cross sectional area A and its temperature increased by ΔT, express the force exerted by the rod on the supports in terms of ($Y, A, L, \alpha, and\ \Delta T$). Ignore change in cross sectional area due to heat. (0.5)

END