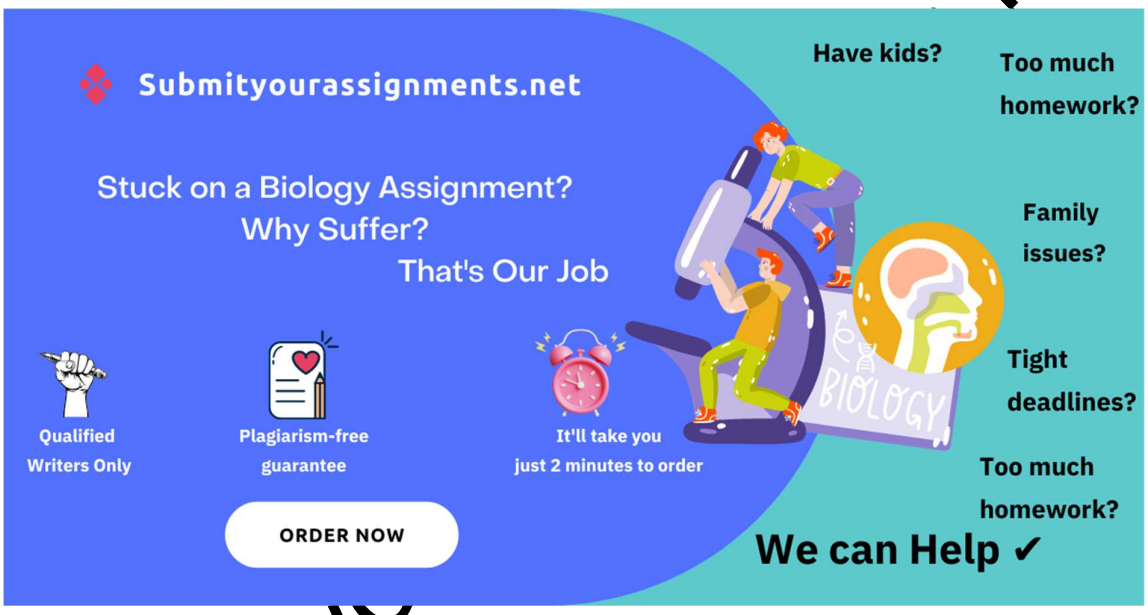
Module IML3526: Biochemistry and Further Chemistry

Portfolio Task 2- Biochemistry



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Instructions to Candidates

Write your name in the space below:

Name……

Information for Candidates

Answer **ALL** questions.

Full marks will be obtained for correct answers to ALL questions.

There are **six** questions in this question paper.

The total mark for this task is **75.**

Write your answers in the spaces provided.

Show all working in your answers.

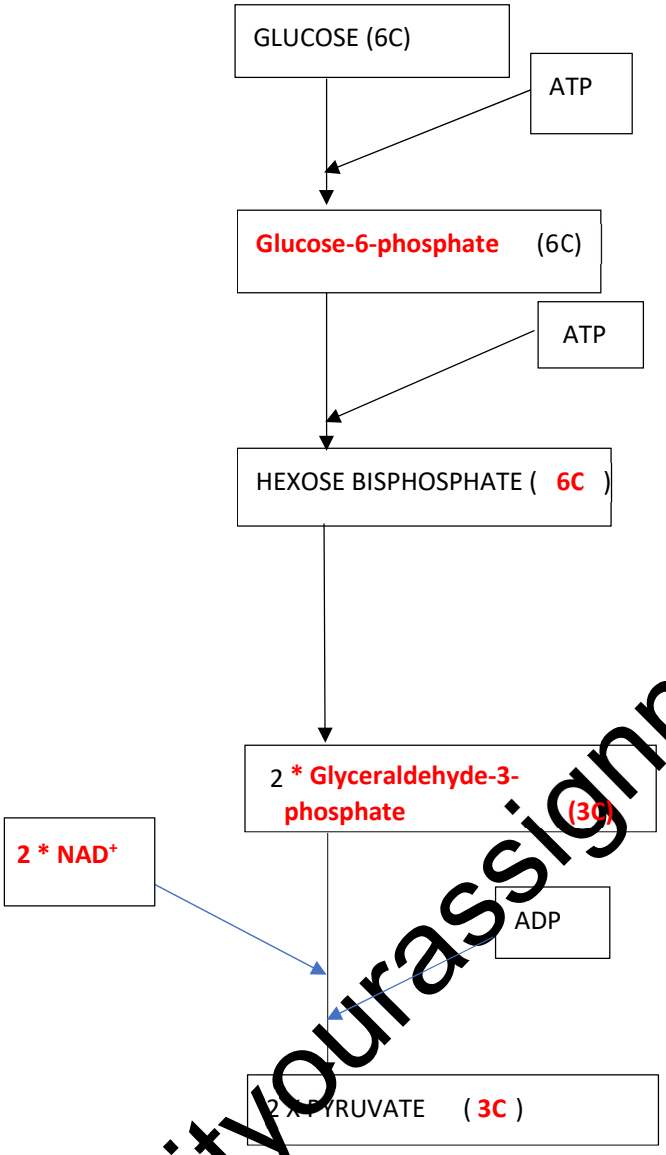
1. Glycolysis is a biochemical pathway that occurs in all living organisms that respire. It takes place during both aerobic and anaerobic respiration.

(a) Complete the flow diagram below summarising the process of glycolysis by writing in:

- The names of the organic compounds are in the empty boxes.
- The number of carbon atoms present in the compounds in the empty brackets.

(7 marks)

ORGANIC COMPOUNDS



(b) Give the name of **two** different types of reactions that take place during glycolysis.

1. **Investment reactions**

2. **Harvesting reactions**

(2 marks)

(c) Where **precisely**, in a eukaryotic cell, does glycolysis take place?

Cytoplasm

(1 mark)

(d) Pyruvate, the product of glycolysis, can be used in both aerobic and anaerobic respiration in humans.

When aerobic respiration occurs in cells, the product pyruvate is oxidised to acetyl CoA in the link reaction (pyruvate oxidation).

(i) Give the name of the enzyme that catalyses the conversion of pyruvate to acetyl-Coenzyme A.

Pyruvate Dehydrogenase (PDH)

(1 mark)

(ii) How many ATP molecules are produced in the link reaction during the aerobic respiration of one molecule of glucose?

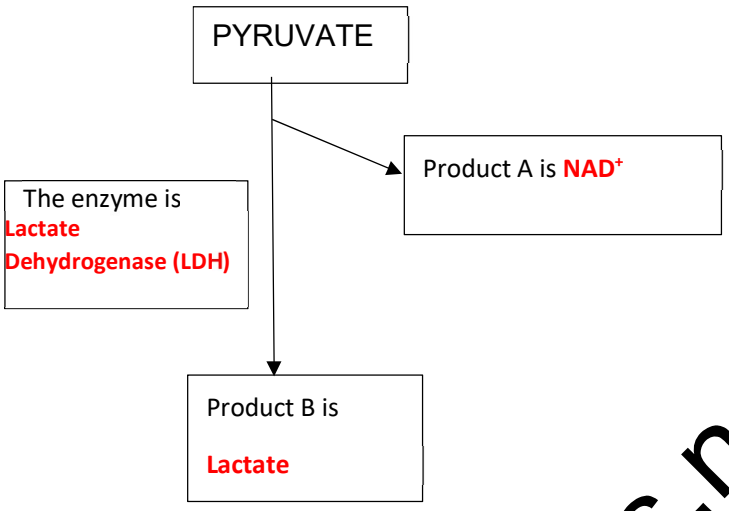
None

(1 mark)

Anaerobic respiration takes place in the skeletal muscles during vigorous exercise.

(iii) Complete the following flow diagram for this process by filling in the answers in the boxes

(3 marks)



(iv) How many molecules of ATP are formed from one molecule of glucose during anaerobic respiration?

2 ATP molecules

(1 mark)

(v) Give **two** differences between anaerobic respiration in humans and anaerobic respiration in yeast.

1. **Anaerobic respiration in human cells produces lactic acid, whereas, in yeast cells, anaerobic respiration produces alcohol (ethanol).**

2. **In yeast cells, anaerobic respiration releases carbon dioxide with the three-carbon pyruvate converting to two-carbon ethanol. In contrast, pyruvate is reduced to lactate, a three-carbon molecule.**

(2 marks)

TOTAL MARKS = 18

2. The letters below shows the sequence of bases in a short length of mRNA.

AUGAACCGGUAAGGCCACCGGCCAUAC

(a) What is the maximum number of amino acids in the polypeptide chain for which this piece of mRNA could code?

Nine amino acids

(1 mark)

(b) How many different types of tRNA molecules would be required to produce a polypeptide from this piece of mRNA?

Nine

(1 mark)

(c) What would be the DNA sequence that codes for the mRNA sequence shown above?

TACTTGGCCATTCCGGTGGCCGGTATG

(1 mark)

(d) What would be the anticodon present in the tRNA molecule that transfers the amino acid to the ribosome for the codon GAC in mRNA?

CUG

(1 mark)

(e) Give three ways in which the structure of a tRNA molecule differs from that of a mRNA molecule.

1. **tRNA is L-shaped in 3-dimensional conformation, whereas mRNA is linear.**

2. **mRNAs carry codon sequences complementary to the template strand of DNA, whereas tRNAs carry anticodon complementary to the codon in mRNA.**

3. **tRNAs are approximately 70-90 nucleotides long, whereas the size of an mRNA depends upon the length of the protein-coding sequences.**

(3 marks)

(f) One feature of the genetic code is that it is universal. Give **three** other features of the genetic code.

1. **The genetic code is redundant because one amino acid is coded by more than one codon**

2. **The genetic code is unambiguous because one codon only codes for one amino acid.**

3. **The genetic code is read in triplets, that is, three sequential nucleotides.**

(3 marks)

(g) Describe **one** possible post-translational modification that can occur to the protein.

Glycosylation is a post-translational modification that can be done on a protein. It involves the addition of carbohydrate moieties to a protein by covalently bonding them to side groups of specific amino acids. In most cases, glycosylation imparts extracellular signaling properties to a protein.

(1 mark)

(h) Describe how DNA is replicated in eukaryotic cells. Your description should include details of the various steps that take place and the enzymes involved.

DNA replication proceeds through three main phases: initiation, elongation, and termination.

- **Initiation**
  The initiation of DNA replication begins with the recruitment of the Origin Replication Complex (ORC) to the origin of replication (ORI) on DNA. ORC has ATPase activity and recruits the necessary proteins necessary for DNA replication. These include CDKs, helicase, SSB proteins, RFC, PCNA, and DNA polymerase III. The initiation proceeds with the activation of the helicase that begins to unwind the DNA as the cell transits from the G1 phase to the S phase under the influence of regulatory proteins such as CDK, DD4, CDC45, and GINS.
- **Elongation**
  The elongation of DNA replication proceeds in both strands, given that DNA replication, is semi-conservative and bidirectional. The process involves the action of helicase that unwinds the DNA double strands by breaking the hydrogen bond. Subsequently, single strand binding (SSB) protein stabilizes the single strand and prevents them from reannealing. DNA gyrase (topoisomerase II) acts on the DNA to release the positive

supercoils created by DNA unwinding. DNA elongation proceeds in the 5' to 3' direction under the action of primase that adds primers complementary to the DNA strand to induce replication. The unwound DNA creates a replication fork with a leading and lagging strand. The leading strand is that which follows the direction of the replication fork and has continuous replication, whereas the lagging strand is replicated in the opposite direction to the replication form in a discontinuous manner, forming the Okazaki fragment. In the leading strand, a single RNA primer is added by primase that recruits DNA polymerase III that adds nucleotides to the growing chain in the 5' to 3' direction. It requires a single primer.

In contrast, primase adds multiple primers to the lagging strand, recruiting DNA polymerase III, which then recruits DNA polymerase I to replicate the strand in short sequences called Okazaki fragments. DNA ligase then joins the Okazaki fragment to form a new and complete strand in the lagging strand. DNA ligase has 3' to 5' exonuclease activity that allows for proofreading to prevent DNA replication. DNA polymerase I also have 5' to 3' exonuclease activity that allows it to perform DNA repair.

- **Termination**

  DNA replication is terminated when the helicase reaches the end of the DNA strands or two replication forks meet and ligate under the influence of the SCF E3 ubiquitin ligase complex.

(See figure 1 below)

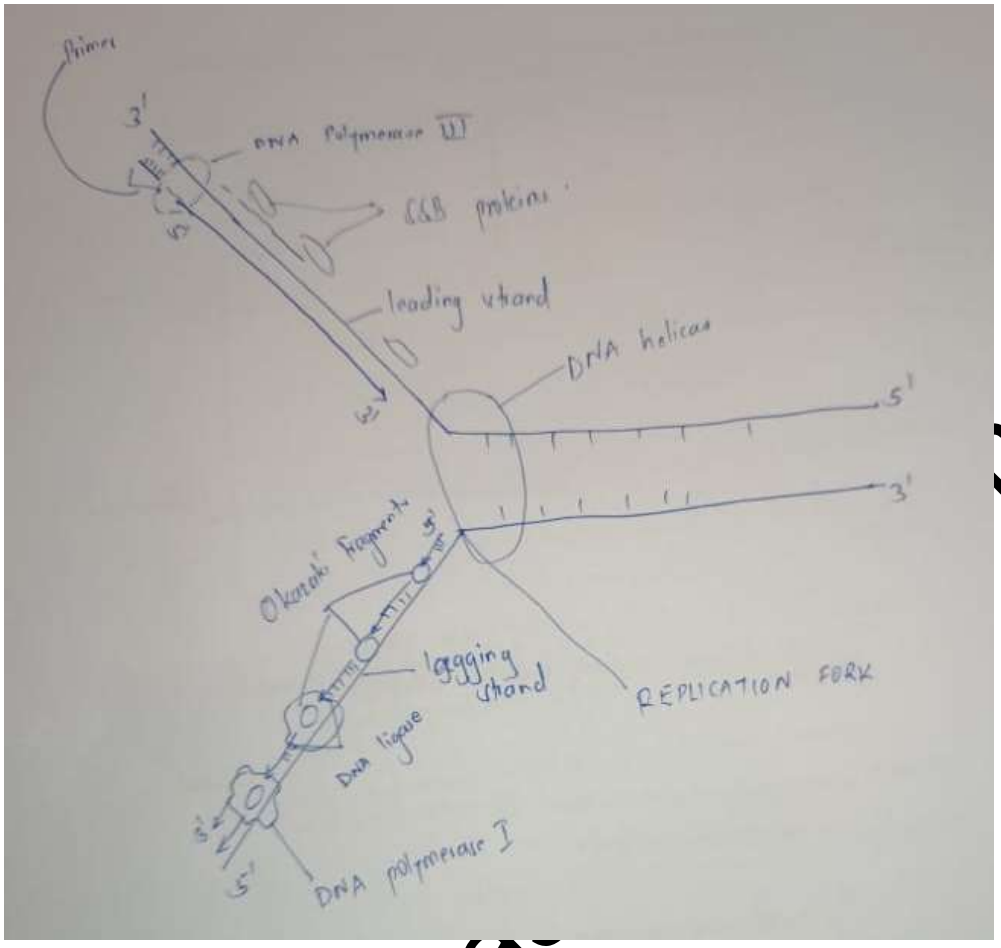
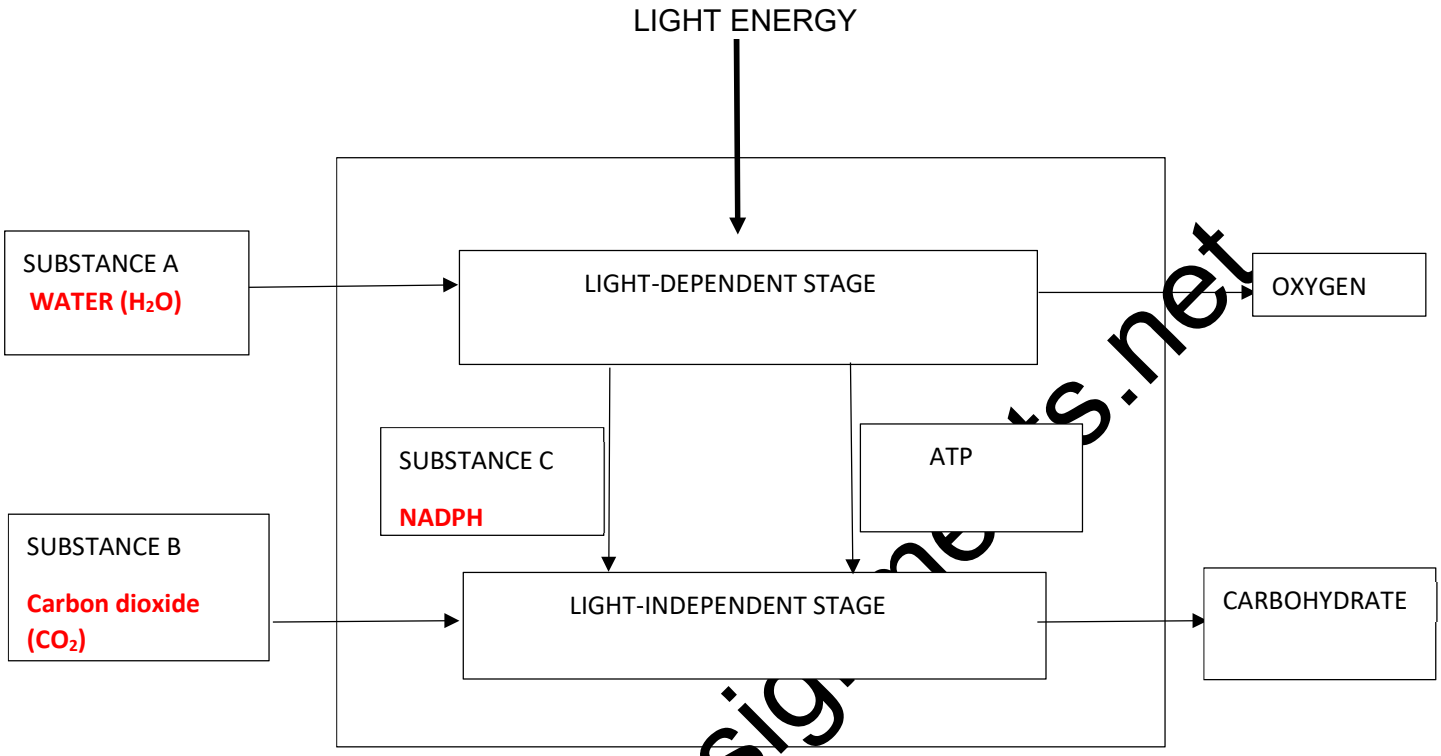


Figure 1: Replication fork activities in DNA replication

(5 marks)

TOTAL MARKS = 16

3. The diagram below summarises the biochemical pathways that take place during photosynthesis in mesophyll leaf cells.



(a) Write the names of the substances **A** to **C** in the boxes in the above diagram.

(3 marks)

(b) Where precisely is the location of:

1. The light-dependent stage?

   Thylakoid

2. The light-independent stage?

   Stroma

(2 marks)

(c) What is the reaction called in which oxygen is formed from compound A?

Oxidation reaction. Because water loses its electrons to form diatomic oxygen.

(1 mark)

(d) Give the equation for the reaction in part (c).

$$H_2O_{(l)} \longrightarrow \tfrac{1}{2}H^+_{(aq)} + O_{2(g)}$$

(1 mark)

(e) What is the process called by which ATP is formed during the light-dependent stage?

Chemiosmosis

(1 mark)

(f) Describe how ATP is formed during the light-dependent reaction.

The movement of electrons through the photosystems results in the diffusion of hydrogen ions to the stroma. This creates an ion gradient because the accumulation of hydrogen ions in the stroma cannot stay in such a state for a long time. As a result, the hydrogen ions move down the concentration gradient from the stroma to the thylakoid, driving ATP synthase, which has a pump-like action that drives the phosphorylation of ADP with inorganic phosphate to form ATP.

(4 marks)

(g) What is the name of the reaction by which substance **C** is formed?

Reduction. Because $NADP^+$ is reduced by the electrons flowing down the photosystems to NADPH.

(1 mark)

(h) State the role played by substance **C** in the light-independent stage.

Substance C, NADPH, is a high-energy molecule that captures energy and electrons that helps fuel reactions in the light-independent stage of photosynthesis. However, in the light stage, it mainly functions as an electron acceptor.

(2 marks)

TOTAL MARKS = 15

4. This question is about the structure of DNA.

(a) What type of polymer is DNA?

Polynucleotide

(1 mark)

(b) Give **three** differences between DNA and RNA.

1. DNA's structure comprises deoxyribose as the sugar component of its backbone, whereas RNA comprises ribose as the sugar component of its backbone.

2. RNA is single-stranded, whereas DNA exists as a double strand.

3. In DNA, the purine-pyrimidine hydrogen bonds form between Guanine and Cytosine and Adenine and Thymine. In contrast, hydrogen bonds form between Guanine and Cytosine and Adenine and Uracil in RNA.

(3 marks)

(c) A piece of a DNA strand contained 21% of adenine. Calculate the percentages of the other bases in this strand by completing the table below.

Base	Percentage
Adenine	21
Cytosine	**29**
Guanine	**29**
Thymine	**21**

(3 marks)

(d) Discuss the different types of ways in which the DNA sequence might be altered through point mutations and the possible effects on the proteins that could result from these mutations.

DNA is the genetic material in living organisms and encodes proteins that confer functionality and traits that conger life. DNA is made of four nucleotides, which associate in double strands to form the genomic material. Point mutation occurs due to alteration of one of the four nucleotides in the DNA sequence, resulting in changes in the information (protein) it codes. The various types of point mutations include;

- **Substitution. This occurs when a single nucleotide in a DNA sequence is changed. It may be harmless to the final protein expressed or deleterious, such as in the substitution of the beta-chain of globin may result in the creation of a faulty beta-globin chain, causing sickle cell anaemia.**
- **Insertion. This occurs when an extra nucleotide is added to the DNA sequence. It causes frameshift mutation that may be deleterious because of altered codon reading.**
- **Deletion. This occurs when a nucleotide within a DNA sequence is lost. It causes frameshift mutation that may be deleterious because of altered codon reading.**

(3 marks)

TOTAL MARKS = 10

5. The Krebs cycle is the third stage in aerobic respiration. It is discovered by Hans Krebs in 1937.

(a) Give the names of **three** types of reactions that take place in the cycle.

(3 marks)

1. **Phosphorylation reaction.**

2. **Redox reactions.**

3. **Hydration reaction**.

(b) Give the names of **three** products of this cycle.

1. **Adenosine triphosphate (ATP)**
2. **Reduced Nicotinamide adenine dinucleotide (NADH)**
3. **Reduced flavin adenine dinucleotide ($FADH_2$)**

(3 marks)

(c) Where precisely does the Krebs cycle take place?
Mitochondrion

(1 mark)

(d) Complete this equation by writing in the number of carbon atoms in the brackets.

Acetyl-CoA + Oxaloacetate → Citrate

(**2** C atoms) (**4** C atoms) (**6** C atoms)

(3 marks)

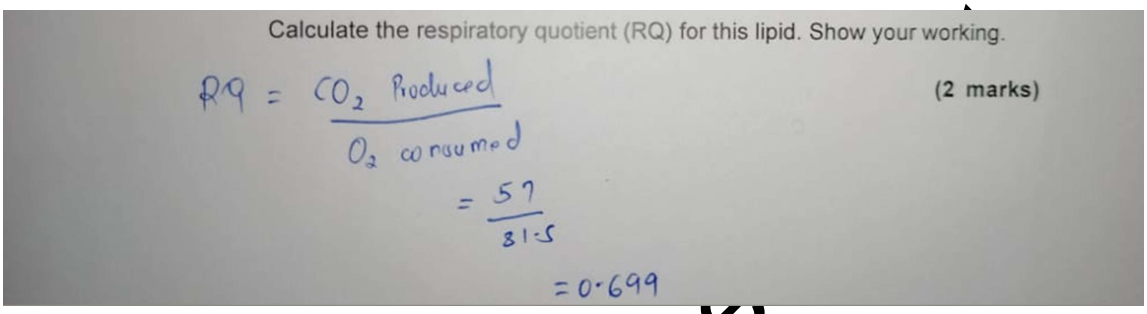
TOTAL MARKS = 10

6. (a) The lipid tristearin has the molecular formula of $C_{57}H_{110}O_6$. When it is respired aerobically, the equation for the reaction is:

$$C_{57}H_{110}O_6 + 81.5O_2 \rightarrow 57CO_2 + 55H_2O$$

Calculate the respiratory quotient (RQ) for this lipid. Show your work.

(2 marks)



(b) Explain why the respiratory quotient for a typical sugar such as glucose, $C_6H_{12}O_6$ is 1.0.

Because it indicates that sugars, such as glucose, are the suitable nutrients from which the body draws energy, highlighting their preference for energy-giving foods.

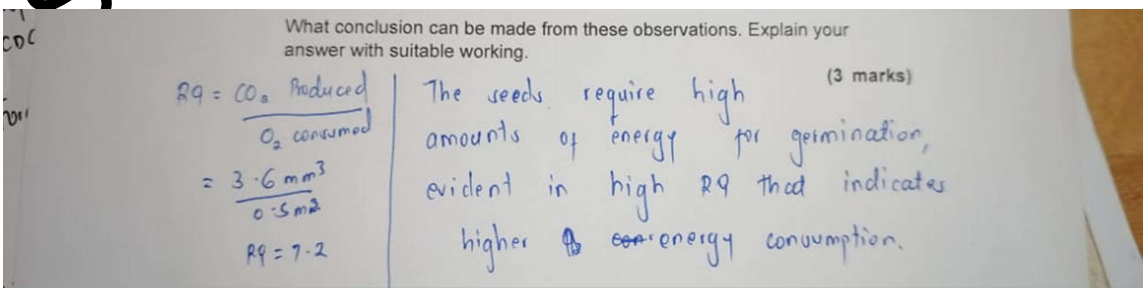
(1 mark)

(c) A respirometer was used to measure the respiratory quotient in germinating seeds. For these germinating seeds that had been soaked in water, the volume of oxygen taken in was $0.5mm^3$, and the volume of carbon dioxide given out by the seeds in the same time period was $3.6mm^3$.

What conclusion can be made from these observations? Explain your answer with suitable work.

(3 marks)

The seeds require high amounts of energy to germinate, evidenced in the high RQ of 7.2, which indicates high energy consumption.



TOTAL MARKS = 6

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