Level 3 Certificate and Extended Certificate in Applied Science

KEY CONCEPTS IN SCIENCE

Unit Number: J/507/6497

Monday 23 January 2017 Morning Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
• a calculator.

Instructions
• Use black ink or black ball-point pen.
• Answer all questions.
• You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
• Do all rough work in this book. Cross through any work you do not want to be marked.

Information
• You will be provided with a copy of the Periodic Table and formula sheet.
• There are three sections in this paper:
  Section A – Biology
  Section B – Chemistry
  Section C – Physics.
• You should answer all questions in each section.
• You should spend approximately 30 minutes on each section.
• The marks for questions are shown in brackets.
• The maximum mark for this paper is 60.

Advice
• Read each question carefully.
Sports scientists study breathing and respiration. Breathing and respiration are different processes.

(a) Select the correct feature of breathing.

Breathing is:

A physical and external.  
B chemical and external.  
C physical and internal.  
D chemical and internal.
(b) Respiration occurs in cells. Respiration has different stages. Glycolysis is one of the stages of respiration.

Where in a cell does glycolysis occur? [1 mark]

A  Cytoplasm
B  Lysosomes
C  Mitochondria
D  Nucleus

(c) The Krebs cycle occurs in mitochondria. Figure 1 shows a mitochondrion.

Figure 1 shows a mitochondrion that has been magnified 5000 times. In Figure 1 the distance between point A and point B is 4.6 cm

Calculate the length of the mitochondrion, in micrometres (μm), before magnification. [2 marks]

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

Length = ______________________________ μm

(d) Describe the role of NADH in respiration? [1 mark]

_____________________________________________________________________________________
_____________________________________________________________________________________

Turn over
(e) A sports scientist is measuring the basal metabolic rate (BMR) of different people. BMR is the minimum amount of energy required to maintain essential body processes. The sports scientist uses direct calorimetry to determine the BMR of the different people.

Describe how BMR is measured using direct calorimetry.

[4 marks]

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

(f) Another sports scientist measured the BMR of men and women using indirect calorimetry. The men and women in the study had different body masses. Table 1 shows the mean BMR values for different body masses.

<table>
<thead>
<tr>
<th>Body mass in kg</th>
<th>BMR Men</th>
<th>BMR Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>85</td>
<td>1855</td>
<td>1550</td>
</tr>
<tr>
<td>95</td>
<td>1970</td>
<td>1620</td>
</tr>
<tr>
<td>105</td>
<td>2075</td>
<td>1700</td>
</tr>
<tr>
<td>115</td>
<td>2187</td>
<td>1775</td>
</tr>
<tr>
<td>125</td>
<td>2300</td>
<td>1855</td>
</tr>
</tbody>
</table>
Complete the bar chart in Figure 2 to show the data for the women. The results for the men have been done for you.

Figure 2

(g) Table 1 shows that BMR for men is higher than BMR for women of the same body mass.

Give one reason for this pattern.

[1 mark]
The global human population is rapidly increasing. The production of sufficient food for the increasing number of people is a major global concern. Food poverty is when people do not have enough food for a healthy diet. Scientists try to increase the efficiency of food chains and ecosystems to help reduce food poverty. The efficiency of different ecosystems can be assessed by comparing primary production.

(a) What is meant by gross primary production (GPP)?

_____________________________________________________________________________________
_____________________________________________________________________________________

(b) The GPP of a tropical rainforest is estimated to be 160 000kJ m\(^{-2}\) per year. The net primary production (NPP) of the tropical rainforest is 40 000 kJm\(^{-2}\) per year.

Explain why the NPP is lower than the GPP.

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

(c) The NPP in a temperate rainforest in the UK is estimated to be 26 000 kJm\(^{-2}\) per year.

Suggest three reasons why the NPP in a temperate forest is lower than in a tropical rainforest.

Reason 1  __________________________________________________________________________
_____________________________________________________________________________________
Reason 2  __________________________________________________________________________
_____________________________________________________________________________________
Reason 3  __________________________________________________________________________
_____________________________________________________________________________________
(d) Some dieticians promote a meat-free diet. This would improve the efficiency of food chains.

Give **two** reasons why the efficiency of a food chain would increase if more people ate a meat-free diet.

[2 marks]

Reason 1 __________________________________________________________________________
_____________________________________________________________________________________

Reason 2 __________________________________________________________________________
_____________________________________________________________________________________

Turn over for Section B
Section B – Chemistry

Answer all questions in this section

Material scientists consider the properties of a substance carefully before choosing it for a particular function. The properties of a substance depend upon the type of bonding and the forces between the particles.

A material scientist requires a substance to conduct electricity at 900°C, but be an insulator in temperatures below 900°C. The material scientist selects an ionic substance.

(a) Draw a labelled diagram to show the ionic structure of solid sodium chloride. Your diagram should be a 3-dimensional representation.

[2 marks]

(b) Explain why sodium chloride will only conduct electricity at high temperatures.

[2 marks]
(c) Magnesium oxide (MgO) is used as an insulator in electrical heating elements. Explain why magnesium oxide has a higher melting point than sodium chloride. [2 marks]
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

(d) Metal hydroxides are ionic substances.
   (i) Give the formula for calcium hydroxide. [1 mark]
_____________________________________________________________________________________

   (ii) Barium hydroxide will react in a similar way to calcium hydroxide. State why. [1 mark]
_____________________________________________________________________________________
_____________________________________________________________________________________

   (iii) Write the balanced symbol equation for the neutralisation of barium hydroxide by hydrochloric acid (HCl). [2 marks]
_____________________________________________________________________________________
_____________________________________________________________________________________

Turn over for the next question
Copper is widely used as an electrical conductor.

(a) State in which block of the Periodic Table copper is located. [1 mark]

_____________________________________________________________________________________
_____________________________________________________________________________________

(b) Copper is extracted from copper ore. High-grade copper ore consists mostly of copper carbonate (CuCO₃).

(i) 10 tonnes of copper ore contains 54% CuCO₃.

Calculate the mass of copper carbonate in the ore. Give the correct unit in your answer. [2 marks]

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

Mass = ______________________________

(ii) During processing, the copper carbonate is reacted with sulfuric acid to make copper sulfate.

\[
\text{CuCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{H}_2\text{O} + \text{CO}_2
\]

The relative molecular mass (Mᵣ) of copper carbonate is 123.5.

Calculate the relative molecular mass (Mᵣ) of copper sulfate (CuSO₄). [1 mark]

_____________________________________________________________________________________
_____________________________________________________________________________________

Relative molecular mass (Mᵣ) = ______________________________
(iii) Calculate the mass of copper carbonate required to give 3 tonnes of copper sulfate. Assume 100% yield.

[3 marks]

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

Mass = ______________________________

(c) Aqueous copper ions (Cu^{2+}) are a blue colour.

(i) Give the electron arrangement of a Cu^{2+} ion.

[1 mark]

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

(ii) Explain why aqueous copper ions are blue. Use the idea of electron transitions in your explanation.

[2 marks]

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

Turn over for Section C
A technician thinks the efficiency of an electric motor depends on the mass being lifted. She wants to design an experiment to calculate the efficiency of an electric motor as it lifts different masses from the floor onto a laboratory bench. She has a joulemeter to measure the energy transferred by the motor as the mass is lifted.

Figure 3 shows some of the equipment she plans to use.

**Figure 3**

To low voltage supply

Joulemeter

Switch

Electric motor

Object

(a) Describe how she would do this experiment. In your description you should state:
- the measurements she would take
- how she should ensure that her results are valid
- how she should present her results.

[5 marks]
(b) (i) A 400 g mass is lifted 0.85 m from the floor to the bench.

Calculate the change in gravitational potential energy of the mass as it is lifted. Assume \( g = 9.8 \text{ ms}^{-2} \).  

\[ \text{[1 mark]} \]

\[ \text{Change in gravitational potential energy} = \boxed{} \text{ J} \]

(ii) The joulemeter reading is 8.1 J

Calculate the efficiency of the electric motor.

\[ \text{[2 marks]} \]

\[ \text{Efficiency} = \boxed{} \]

(c) Give one reason why the efficiency of the electric motor is not 100%.

\[ \text{[1 mark]} \]

\[ \text{} \]
An apprentice engineer investigates the properties of a thermistor as its temperature changes. He uses a water bath to change the temperature of the thermistor.

**Figure 4** shows the apparatus used.

Figure 4

![Apparatus diagram]

(a) (i) Which graph shows the change in current as the thermistor is heated?

Circle the correct letter.

[1 mark]

[A] [B] [C] [D]
(ii) Explain why you have chosen the graph in question (a) (i).

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

[2 marks]

(b) The apprentice engineer uses the thermistor to make a potential divider circuit.

Figure 5 shows the potential divider circuit.

Figure 5

9 V power supply

A

V

Fixed resistor

The voltage across the thermistor decreases as the thermistor is heated.

State what happens to the voltage across the fixed resistor.
Give one reason for your answer.

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

[2 marks]

(c) Give one use for a potential divider circuit which includes a thermistor.

_____________________________________________________________________________________
_____________________________________________________________________________________
_____________________________________________________________________________________

[1 mark]
Figure 6 shows a sprinter at the start of a race.

(a) Explain why the sprinter accelerates forwards when using the starting blocks.

Use Newton's Laws of Motion in your explanation.

[3 marks]
(b) At the start of the race the sprinter accelerates uniformly at 1.3 m s$^{-2}$.

He reaches a maximum speed of 10.4 m s$^{-1}$.

Calculate the distance he has run when he has reached his maximum speed.

[2 marks]

Distance = ________________________________ m
There are no questions printed on this page