# Coimisiún na Scrúduithe Stáit
# State Examinations Commission

## LEAVING CERTIFICATE EXAMINATION, 2016

## PHYSICS AND CHEMISTRY – HIGHER LEVEL

### MONDAY, 20 JUNE – MORNING, 9:30 to 12:30

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**Six** questions to be answered.

Answer any **three** questions from **Section I** and any **three** questions from **Section II**.

All questions carry equal marks.

However, in each section, one additional mark will be given to each of the first two questions for which the highest marks are obtained.

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**N.B.** Relevant data are listed in the *Formulae and Tables* booklet, which is available from the superintendent. Take $g = 9.8$ m s$^{-2}$ as the acceleration due to gravity at the surface of the Earth.

## SECTION I – PHYSICS (200 marks)

**1.** Answer **eleven** of the following items (*a*), (*b*), (*c*), etc. All the items carry equal marks.
*Keep your answers short*.

(*a*) Distinguish between speed and velocity.

(*b*) State the property of a body of mass $m$ moving with velocity $v$ defined by (*i*) $mv$, (*ii*) $\frac{1}{2}mv^2$.

(*c*) Mass **A** moving at 20 m $s^{-1}$ collided with a stationary 3 kg mass **B**. After the collision both objects moved together with a velocity of 8 m $s^{-1}$. What was the mass of **A**?

(*d*) Define the unit of energy, i.e. the joule.

(*e*) A pin is placed 15 cm from a concave mirror of focal length 10 cm.
How far from the mirror is the image formed?

(*f*) Select from the list that follows the type of electromagnetic radiation that has
(*i*) the longest wavelength, (*ii*) photons of the greatest energy.

**gamma rays** **microwaves** **ultraviolet rays** **x-rays**

(*g*) Name a phenomenon of light that can be explained *only* in terms of its wave nature.

(*h*) What thermometric property is used in
(*i*) a liquid-in-glass thermometer,
(*ii*) a constant-volume gas thermometer?

(*i*) What are the two fixed points (reference temperatures) on the Kelvin scale of temperature?

(*j*) State Coulomb's law of force between electric charges.

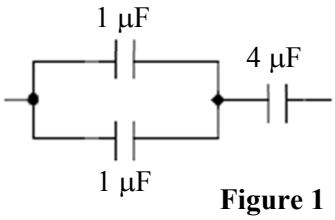


**Figure 1**

(*k*) Calculate the effective capacitance of the arrangement of capacitors shown in **Figure 1**.

(*l*) Fleming's left hand rule for the force on a current-carrying conductor in a magnetic field is shown in **Figure 2**.
If the forefinger indicates the direction of the magnetic field, what quantity is represented by arrow
(*i*) **X**,
(*ii*) **Y**?

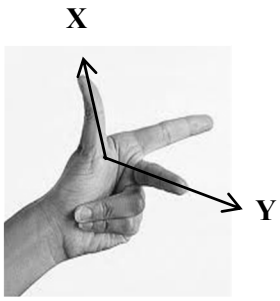


**Figure 2**

(*m*) Explain why the core of a transformer, like that shown in **Figure 3**, conserves energy
(*i*) when it is made of *soft* iron,
(*ii*) when it is laminated.

(*n*) When projected from the same starting point, at the same velocity, into the same magnetic field, an alpha-particle and a beta-particle are both deflected onto circular paths.
State two ways their deflections differ.

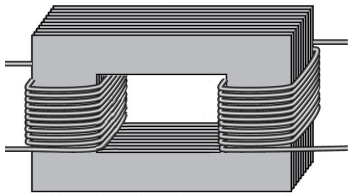


**Figure 3**

(*o*) The mass loss in a nuclear reaction is $1.6 \times 10^{-29}$ kg.
How much energy is released in the reaction?

(11 × 6)

**2.** (*a*) Define (*i*) mass, (*ii*) weight.
Classify each of these quantities as a vector or as a scalar. (12)

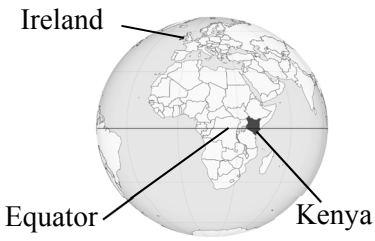


**Figure 4**

(*b*) A student in Ireland carried out experiments to measure *g*, the acceleration due to gravity at the surface of the Earth.

(*i*) Draw a labelled diagram of a suitable apparatus.

(*ii*) What two sets of measurements should have been taken by the student using this apparatus?

Using the data obtained, the student drew a suitable straight line graph through the origin.

(*iii*) Sketch this graph labelling the axes correctly.

(*iv*) Describe how *g* was calculated using the graph.

(*v*) A student in Kenya also measured *g*. See **Figure 4**. Note that the radius of the Earth at any point on the Equator is greater than its radius at Ireland.

Explain how you would expect the average value for *g* measured in Kenya to differ from that measured in Ireland.

(33)

(*c*) **Figure 5**, not drawn to scale, shows a car at point *P* travelling horizontally at 5 m $s^{-1}$. At *P* it accelerates at 2.5 m $s^{-2}$ for 8 s and reaches a velocity *v* at *Q* and then continues at this constant velocity for 20 s. The car is brought to rest at *R* by uniform braking over a further 30 s.

**Figure 5**

(*i*) Calculate the velocity *v* of the car after the first 8 s.

(*ii*) Draw, on graph paper, a velocity-time graph to represent the motion of the car from *P* to *R*.

(*iii*) Find the distance travelled by the car at constant velocity. (21)

**3.** (*a*) State Snell's law of refraction. (6)

(*b*) Define (*i*) refractive index, (*ii*) critical angle. (12)

(*c*) Using a block of glass, a beam of white light and a protractor, a student obtained data to verify Snell's law.

The graph shown in **Figure 6** was obtained using the angles of incidence *i* measured in air and the corresponding angles of refraction *r*.

(*i*) Explain how the graph verifies Snell's law.

(*ii*) Use the graph to find the refractive index of this glass.

(*iii*) Find the angle of refraction corresponding to an angle of incidence (in air) of 35º.

(*iv*) Calculate the critical angle for this glass.

(*v*) Name the phenomenon that occurs when a ray of light strikes the glass/air boundary at an angle of incidence of 40º. (33)

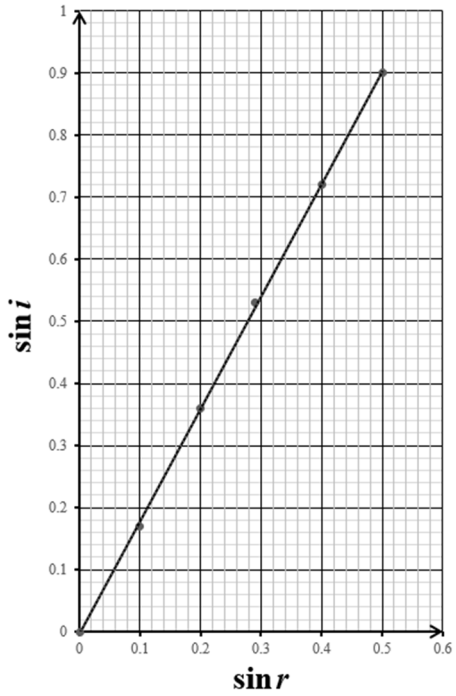



**Figure 6**

(*d*) An astronomical telescope in *normal adjustment* has two convex lenses, **A** and **B**, arranged as in **Figure 7**.

Lens **A** has a focal length of 180 cm.

The distance between the centres of **A** and **B** is 195 cm.

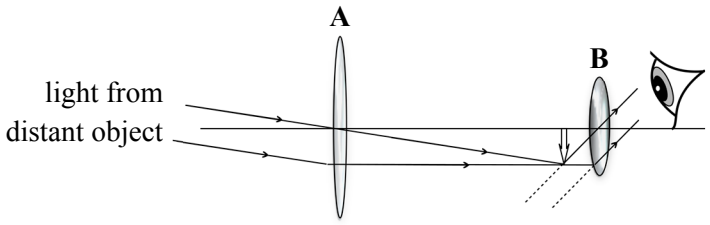



**Figure 7**

(*i*) Name lenses **A** and **B**.

(*ii*) How far from lens **A** is the first image formed?

(*iii*) When the telescope is in normal adjustment, where is the final image formed?

(*iv*) Why is it an advantage to have the telescope in normal adjustment? (15)

**4.** (*a*) Consider a fixed mass of gas at constant temperature.

Name and state the law (**A**) governing the changes in the pressure of this gas as its volume changes.

Copy **Figure 8** into your answerbook and label the axes so that it represents a graph verifying law **A**. (15)

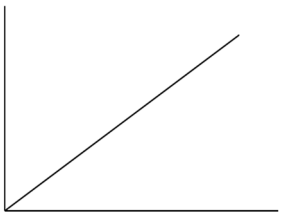


**Figure 8**

(*b*) Consider a fixed mass of gas at constant pressure.

Name and state the law (**B**) governing the changes that take place in its volume as the gas is heated.

Make another copy of **Figure 8** in your answerbook and label the axes so that it now represents a graph verifying law **B**. (15)

(*c*) Distinguish between a real gas and the ideal gas.

State two assumptions of the kinetic theory that hold true for the ideal gas but not for a real gas.

Under what conditions of pressure does a real gas most resemble the ideal gas? (15)

(*d*) Airplane tyres must perform through a broader temperature range and withstand different types of stresses compared to the tyres on road vehicles, e.g. the sudden increase in pressure on landing, as in **Figure 9**.

For safety reasons airplane tyres are often filled with nitrogen gas instead of air.

(*i*) Calculate the number of moles of nitrogen gas occupying a volume of 0.380 $m^3$ at a pressure of $1.60 \times 10^6$ Pa inside an airplane tyre on the ground where the temperature is 295 K.

(*ii*) Calculate the pressure of the gas inside this tyre at high altitude where the temperature of the gas in the tyre has decreased by 40 ºC and the volume occupied has decreased to 0.350 $m^3$.

(*iii*) How does the velocity of the molecules within the airplane tyre change as a result of the change in conditions from (*i*) to (*ii*) above? Explain. (21)

**Figure 9**

**5.** (*a*) Define electrical potential difference (*V*) between two points.

What is the SI unit of potential difference? (9)

(*b*) In an experiment the potential difference *V* across a 0.5 m length of nichrome wire of uniform diameter, kept at constant temperature, was measured for different values of current *I* flowing in the wire. The following data were obtained.

| ***I* (A)** | 0.5 | 1.0 | 2.0 | 2.5 | 3.0 | 3.5 | 4.5 |
|---|---|---|---|---|---|---|---|
| ***V* (units)** | 0.71 | 1.43 | 2.86 | 3.57 | 4.29 | 5.01 | 6.43 |

(*i*) Draw a labelled diagram of a suitable electric circuit to obtain these measurements.

(*ii*) Plot a graph of potential difference *V* (*y*-axis) against current *I*.

(*iii*) State and name the law verified by your graph.

(*iv*) Use your graph to find the potential difference that allows a current of 1.8 A to flow.

(*v*) Find the slope *m* of your graph.

What property of the wire is given by *m*?

(*vi*) How would you expect the value of *m* to change if a 1.0 m length of the same nichrome wire was used instead of the 0.5 m?

Justify your answer.

Explain why high voltage is used to transmit electricity over long distances.

(57)

**6.** Answer any **two** of the following parts (*a*), (*b*), (*c*), (*d*). Each part carries 33 marks.

(*a*) Define (*i*) potential energy, (*ii*) work. (6)

**Figure 10**

High-diving made its debut at the World Aquatic Championships in Barcelona in 2013. Men dive from a 27 m high platform and women from a 20 m platform, as shown in **Figure 10**.
Calculate

(*iii*) the change in potential energy of a diver of mass 65 kg from the instant he stepped off the 27 m high platform until he entered the water, having dropped straight down,

(*iv*) the vertical velocity of the diver just before he entered the water,

(*v*) the time taken to fall 27 m.

Does the mass of the diver affect his final velocity before entering the water? Explain. (27)

(*b*) What phenomenon is defined as *the spreading of waves into the geometrical shadow of an obstacle*? (3)

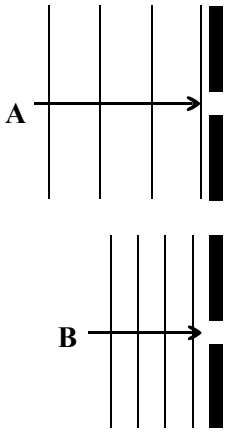



**Figure 11**

**Figure 11** represents waves **A** and **B** approaching gaps of equal width. Copy and complete the diagram in your answerbook to show the waves having passed through the gaps. (9)

Monochromatic light fell on a pair of Young's slits 0.02 mm apart and produced an interference pattern on a screen.
The second bright fringe made an angle of 3.7º with the normal.
Calculate

(*i*) the wavelength of the light,

(*ii*) the frequency of the light,

(*iii*) the energy of a photon of light of this frequency. (21)

(*c*) State three effects of an electric current.

**Figure 12**

Which of these effects

(*i*) is used to define the unit of current, i.e. the ampere,

(*ii*) causes a filament bulb to produce incandescent light? (15)

A 100 W filament bulb can be replaced by a 25 W CFL (compact fluorescent lamp), like that shown in **Figure 12**, without any reduction in the brightness of the light emitted. Assuming a 230 V mains supply, calculate the current flowing through

(*iii*) a 100 W filament bulb,

(*iv*) a 25 W CFL.

Calculate the cost saving in a week when a 100 W bulb in use for 5 hours a day is replaced by a 25 W bulb. Take the cost of a unit of electricity (1 kW h) as 20 cent.

Suggest a benefit to the environment of switching to CFLs. (18)

(*d*) (*i*) Define the half-life of a radioisotope. (6)

The table below shows the mass of a sample of sodium–24 at 10-hour intervals over a 70-hour period.

| **time (hours)** | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|---|
| **mass (mg)** | 400 | 260 | 160 | 100 | 65 | 40 | 25 | 13 |

(*ii*) Draw a graph to represent these data.

(*iii*) Use the graph to determine the half-life of sodium–24.

(*iv*) Write an equation to represent the beta-decay of a sodium–24 nucleus.

(*v*) Because of its short half-life, sodium–24 is sometimes injected into patients as a tracer to help diagnose circulatory dysfunction. State one precaution that should be observed by the medical personnel administering the injection to minimize their own exposure to radiation. (27)

## SECTION II – CHEMISTRY (200 marks)

**7.** Answer **eleven** of the following items (*a*), (*b*), (*c*), etc. All the items carry equal marks.
*Keep your answers short.*

(*a*) How many (*i*) electrons, (*ii*) protons, are there in an $\mathbf{Al^{3+}}$ ion?

(*b*) Define relative atomic mass.

(*c*) The 2010 Nobel Prize in Physics was awarded for pioneering work on graphene, a form of the element carbon shown in **Figure 13**. Name two other physical forms of the element carbon.

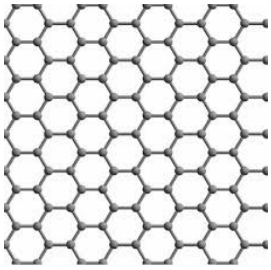


**Figure 13**

(*d*) The relationship $E_1 - E_2 = hf$ applies when a sodium street light glows. What do the terms $E_1$ and $f$ represent?

(*e*) What is the maximum number of electrons that can be accommodated in (*i*) a *p* orbital, (*ii*) a *d* subshell?

(*f*) Select two molecular crystals from the following list of solids.
**gold** **dry ice** **sodium chloride** **iodine**

(*g*) Taking the valency of gallium (**Ga**) as three, write the formula for the simplest compound formed from (*i*) gallium and nitrogen, (*ii*) gallium and oxygen.

(*h*) Write a balanced equation for the reaction that occurs when a small piece of sodium is dropped into water as shown in **Figure 14**.

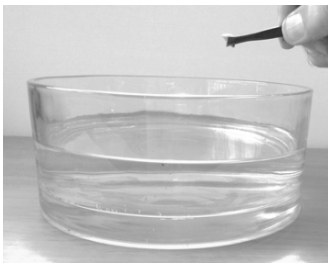


**Figure 14**

(*i*) Why does a $\mathbf{H_2O}$ molecule have a dipole moment but a $\mathbf{BeF_2}$ molecule does not?

(*j*) Define *heat of combustion.*

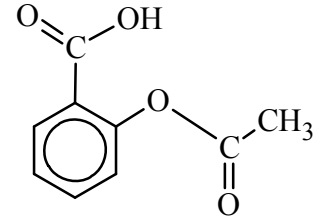
(*k*) Under what circumstances can sodium chloride conduct electricity?

(*l*) Calculate the percentage by mass of oxygen in cubic zirconia ($\mathbf{ZrO_2}$) used to make the dental implants shown in **Figure 15**.
[O = 16; Zr = 91]

**Figure 15**

(*m*) Identify the reagent required and the necessary condition for the conversion of $\mathbf{CH_4}$ to $\mathbf{CH_3Cl}$.

(*n*) The molecular formula for methylbenzene, shown on the left in **Figure 16**, is $\mathbf{C_7H_8}$. What is the molecular formula for aspirin shown on the right?



| methylbenzene = $\mathbf{C_7H_8}$ | aspirin = ? |
|---|---|

**Figure 16**

(*o*) Name a reagent used to distinguish an aldehyde from a ketone.

(11 × 6)

**8.** (*a*) Define (*i*) atomic number, (*ii*) the first ionisation energy of an element. (12)

(*b*) Plot a graph of first ionisation energy *versus* atomic number, for the elements with atomic numbers 3 to 12 inclusive, using the values on page 80 of the *Formulae and Tables* booklet.

(*i*) Referring to your graph, explain the general increase in first ionisation energy values across the second period of the periodic table.

(*ii*) Which element on your graph requires the most energy to form a mole of its monopositive ions?

(*iii*) Explain the peaks on your graph for the elements with atomic numbers 4 and 7. (27)

(*c*) Plasma screen television sets like the one shown in **Figure 17** emit light when a mixture of noble gases such as neon (**Ne**) and xenon (**Xe**) is ionised using high voltages. The resulting mixture of free electrons and positive ions is known as a plasma.

(*i*) Write the *s*, *p* electron configuration of a neon atom.

(*ii*) Why is a lot of energy required to ionise a neon atom?

(*iii*) Explain why the first ionisation energy of xenon is less than that of neon. (15)

**Figure 17**

(*d*) What is an atomic orbital?

How do the 2*p* atomic orbitals in neon differ from one another?

State one difference between the 2*s* and a 2*p* atomic orbital of a neon atom. (12)

**9.** Students were asked to prepare 250 $cm^3$ of a 0.08 M sodium carbonate solution from anhydrous sodium carbonate (**$Na_2CO_3$**), a primary standard.

(*a*) (*i*) Explain the underlined term.

(*ii*) State two properties of a compound that would enable it to be used as a primary standard.

(*iii*) What mass of anhydrous sodium carbonate was required to prepare 250 $cm^3$ of the 0.08 M solution? (15)

(*b*) Group **A** suggested making up the solution in container **A** and Group **B** selected container **B** as shown in **Figure 18**.

(*i*) Name containers **A** and **B**.

(*ii*) Explain why the use of container **B** would give a more accurate result. (9)

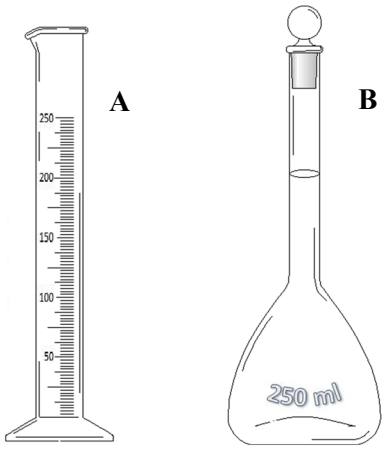



**Figure 18**

(*c*) Describe the procedure the students of Group **B** followed in preparing their solution. (15)

(*d*) A number of 25.0 $cm^3$ portions of the sodium carbonate solution were titrated against a 0.20 M solution of nitric acid (**$HNO_3$**) according to the equation:

$$\mathbf{2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + H_2O + CO_2}$$

(*i*) Explain why methyl orange would be suitable whereas phenolphthalein would be unsuitable as an indicator for this titration.

(*ii*) Using methyl orange, what colour change occurred at the end point?

(*iii*) Calculate the volume of nitric acid required to neutralise 25.0 $cm^3$ of the 0.08 M sodium carbonate solution.

(*iv*) Calculate the pH of a 0.20 M nitric acid solution. (27)

**10.** (*a*) Define (*i*) reduction, (*ii*) reducing agent, in terms of electron transfer.
Identify (*iii*) the substance reduced, (*iv*) the reducing agent, in the following balanced equation. (12)

$$\mathbf{PbO + H_2 \rightarrow Pb + H_2O}$$

(*b*) Arrange the elements **Fe**, **Pb**, **Mg** and **Cu** in the order in which they occur in the electrochemical series.
Explain in terms of *the electrochemical series* why

(*i*) a plumber should not connect a copper pipe directly to an iron pipe but could use a plastic connector between them,

(*ii*) pieces of magnesium are sometimes attached to underground iron pipes,

(*iii*) it is unlikely that lead pipes would have to be replaced because of corrosion. (15)

(*c*) State *Faraday's first law of electrolysis*. (6)

(*d*) **Figure 19** shows an apparatus used in the electrolysis of acidified water using inert electrodes.

(*i*) Name an acid suitable for acidifying the water.

(*ii*) Why is it necessary to acidify the water?

(*iii*) Which electrode, **X** or **Y**, is the anode?

(*iv*) Name a material suitable for use as the inert electrodes.

(*v*) At which electrode, **X** or **Y**, is oxygen gas formed according to the following reaction?

$$\mathbf{2H_2O \rightarrow O_2 + 4H^+ + electrons}$$

(*vi*) How many electrons are produced for every oxygen molecule formed in the reaction above?

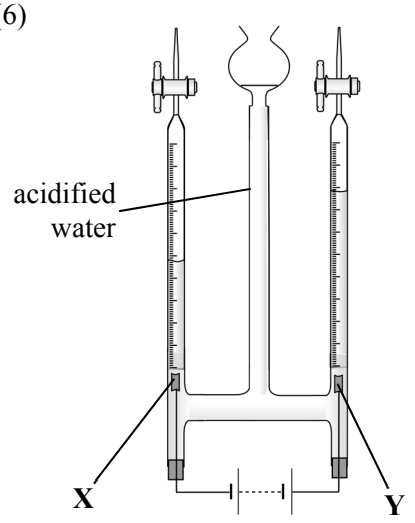


**Figure 19**

If a current *I* was passed through acidified water for 15 minutes and a charge of 135 C was transferred, calculate

(*vii*) the current *I*,

(*viii*) the mass of oxygen gas released. (33)

**11.** (*a*) Bananas, harvested in the tropics and shipped green, are 'ripened' just before being placed on supermarket shelves by exposure to the gaseous hydrocarbon ethene ($\mathbf{C_2H_4}$).
Ethene molecules are unsaturated.

(*i*) Explain the underlined terms.

(*ii*) Draw the structure of the ethene molecule.

(*iii*) Name the homologous series to which ethene belongs.

(*iv*) Ethene gas was prepared in the laboratory using the apparatus shown in **Figure 20**.
Identify the liquid held at **X** and solid **Y**.

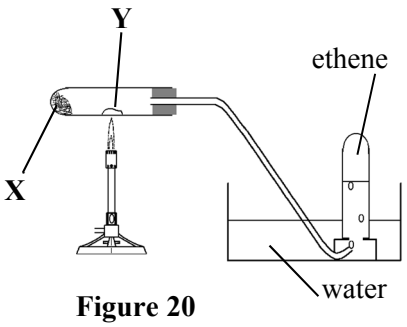


**Figure 20**

(*v*) Give one safety precaution observed during the experiment.

(*vi*) Describe how a sample of ethene gas could be tested for unsaturation. (45)

(*b*) (*i*) Draw the structures of an ethanol molecule and of an ethanoic acid molecule.

(*ii*) Draw a circle around the functional group in **each** structure.

(*iii*) Classify, as a *dehydration*, an *oxidation* or a *reduction*, the conversion of wine to vinegar on exposure to air. In the process ethanol molecules are converted to ethanoic acid molecules. (15)

(*c*) The smell associated with ripening strawberries is caused by a complex mixture of compounds including the ester shown. in **Figure 21**. Give the name of this ester. (6)

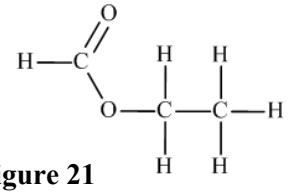


**Figure 21**

**12.** Answer any **three** of the following parts (*a*), (*b*), (*c*), (*d*). Each part carries 22 marks.

(*a*) What term is used to describe the type of reaction in which heat is absorbed?

$$\mathbf{C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}} \qquad \mathbf{\Delta H = -393.5\ kJ\ mol^{-1}}$$
$$\mathbf{H_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow H_2O_{(l)}} \qquad \mathbf{\Delta H = -285.8\ kJ\ mol^{-1}}$$
$$\mathbf{6C_{(s)} + 6H_{2\,(g)} + 3O_{2\,(g)} \rightarrow C_6H_{12}O_{6\,(s)}} \qquad \mathbf{\Delta H = -1271.0\ kJ\ mol^{-1}}$$

Use the information above to calculate the energy change when one mole (180 g) of glucose ($\mathbf{C_6H_{12}O_6}$) is made by plant photosynthesis according to the following balanced equation.

$$\mathbf{6CO_{2\,(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6\,(s)} + 6O_{2\,(g)}}$$

What mass of glucose is produced when 561 kJ of light energy is absorbed in this process?

(*b*) In terms of Brønsted-Lowry theory

(*i*) define an acid,

(*ii*) distinguish between a strong acid and a weak acid,

(*iii*) explain a *conjugate acid-base pair*.

Identify a species acting as an acid in the following reaction.

$$\mathbf{H_2O + HF \rightleftharpoons H_3O^+ + F^-}$$

What is the conjugate base of this acid?

Water may be described as <u>amphoteric</u>. Explain the underlined term.

**Figure 22**

(*c*) The breathing equipment used by the rescue worker shown in **Figure 22** contains potassium dioxide ($\mathbf{KO_2}$) that acts as a source of oxygen and absorbs carbon dioxide as follows:

$$\mathbf{4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2}$$

(*i*) What volume of carbon dioxide at s.t.p. reacts with 0.8 moles of potassium dioxide?

How many molecules of carbon dioxide are there in this volume?

(*ii*) How many moles of oxygen are produced in the reaction of 0.8 moles of potassium dioxide?

What mass of $\mathbf{K_2CO_3}$ is produced?

(*d*) The shape of a molecule is determined by the number of bonding pairs and the number of lone pairs of electrons in the valence shell of the central atom. These electron pairs take up positions to minimise repulsions between them.

(*i*) Why do electron pairs repel each other?

(*ii*) Compare the magnitude of the repulsion between two lone pairs and the repulsion between two bonding pairs of electrons.

Account for this difference in the magnitude of the repulsions.

(*iii*) Supply the pieces of information **A** to **E** omitted from the columns of the table below.

| Arrangement | Shape | No. lone pairs | No. bonding pairs | Bond angle | Example |
|---|---|---|---|---|---|
|  | **A** | 2 | 2 | 104.5° | $\mathbf{H_2O}$ |
|  | pyramidal | **B** | 3 | **C** | $\mathbf{NH_3}$ |
|  | **D** | 0 | **E** | 109.5° | $\mathbf{CH_4}$ |

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