Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2018

PHYSICS AND CHEMISTRY – HIGHER LEVEL

WEDNESDAY, 20 JUNE – MORNING, 9:30 to 12:30

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.

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

(*b*) Distinguish between mass and weight.

(*c*) **Figure 1** is a velocity time graph for an object.

(*i*) What is the acceleration between **B** and **C**?

(*ii*) What is the distance travelled between **C** and **D**?

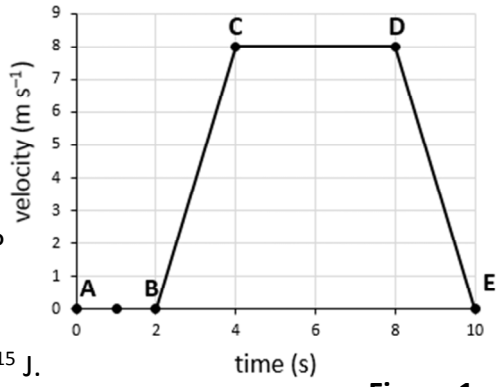

Figure 1

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

(*e*) The energy of a photon in a beam of *x*-rays is 1.5×10^{-15} J. Calculate the frequency of the associated *x*-rays.

(*f*) Arrange the following forms of electromagnetic radiation in order of *increasing* wavelength.

radio waves **infrared radiation** **gamma rays** **blue light**

(*g*) State an energy conversion that takes place during the photoelectric effect.

(*h*) State Boyle's law.

(*i*) A constant volume gas thermometer, like that shown in **Figure 2**, is used as a standard thermometer. Why is a standard thermometer necessary?

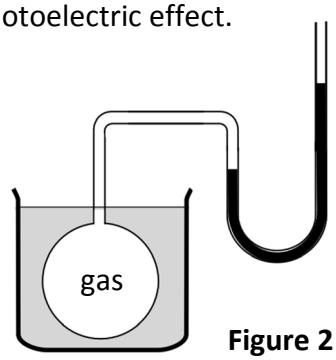

Figure 2

(*j*) According to kinetic theory, how is the behaviour of the molecules of a gas affected by

(*i*) an increase in the pressure of the gas,

(*ii*) a decrease in the temperature of the gas?

(*k*) **Figure 3** shows a positively-charged, insulated, metal sphere **A** placed near an uncharged, insulated, metal sphere **B**. Draw a diagram to show how charge became distributed on **B**.

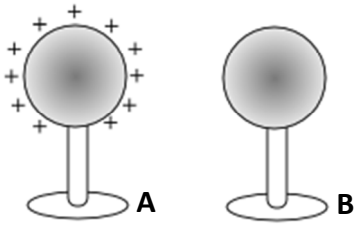

Figure 3

(*l*) Name a device based on the principle that a current carrying conductor in a magnetic field experiences a force.

(*m*) What is the effect on the capacitance of a parallel-plate capacitor of increasing (*i*) the distance between the plates, (*ii*) the common area of the plates?

(*n*) What name is given to the following type of nuclear reaction?

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{92}_{36}\mathrm{Kr} + {}^{141}_{56}\mathrm{Ba} + 3{}^{1}_{0}n + \text{energy}$$

Give an application of this type of reaction.

(*o*) What type of electromagnetic radiation can be emitted from a radioactive nucleus?

(11 × 6)

2. (*a*) (*i*) Define momentum.

(*ii*) What is the S.I. unit of momentum?

(*iii*) What quantity is proportional to the rate of change of momentum? (12)

(*b*) When two moving objects have the same momentum

(*i*) do they necessarily have the same speed,

(*ii*) do their velocities necessarily have the same direction?

Explain your answers. (12)

(*c*) State the *principle of conservation of momentum*.

As part of an experiment to verify the principle of conservation of momentum, trolley **A** of mass 314 g was set in motion with constant velocity on a runway. It travelled 11.2 cm in 0.20 s. It collided with trolley **B** of mass 326 g that was initially at rest. Both trolleys then moved together with constant velocity and travelled 5.5 cm in 0.20 s.

State one precaution that should be taken to ensure that the trolleys run at constant velocity.

Calculate

(*i*) the initial velocity of **A**,

(*ii*) the velocity of **A** and **B** combined after the collision,

(*iii*) the total momentum before the collision,

(*iv*) the total momentum after the collision.

Do these results verify the principle of conservation of momentum? Justify your answer. (33)

(*d*) Juno, shown in **Figure 4**, is a space probe that was launched in August 2011 and approached the planet Jupiter in July 2016 at a velocity of 210,000 km per hour. Its total mass at that time was 2,825 kg. To reduce its speed in the same direction to 208,050 km per hour for successful entry into an orbit around Jupiter, it burned some fuel and expelled 447 kg of hot combustion gases into space.
Calculate the velocity, in km per hour, with which the gases were expelled. (9)

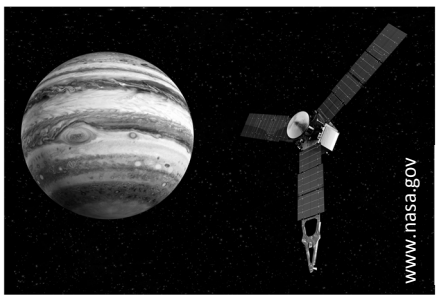

Figure 4

3. (*a*) **Figure 5** shows a ray of light from a ray box passing through a transparent, semi-circular plastic block and back into air at **O**.

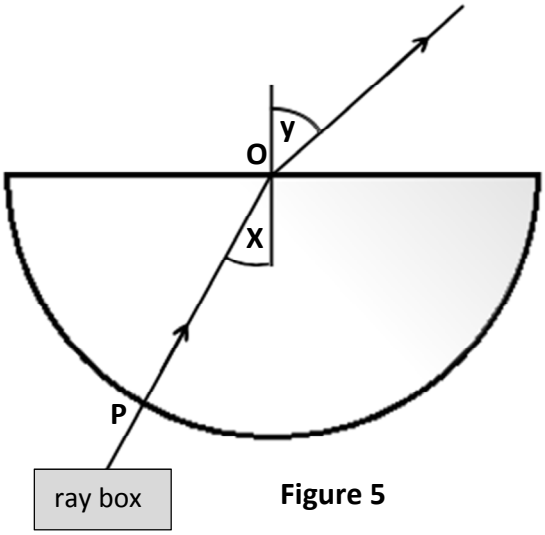

Figure 5

(*i*) Name and state the law that describes the relationship between the angle **X** and the angle **Y**. (9)

(*ii*) Explain why the incident ray is *not* refracted at **P**. (3)

(*iii*) Calculate the refractive index of the plastic if **X** = 30° when **Y** = 48°. (6)

(*iv*) Explain how this apparatus could be used to find the critical angle for this plastic. (6)

(*v*) Calculate the critical angle for the plastic. (6)

(*vi*) What happens at **O** when the critical angle is exceeded? (6)

(*b*) Distinguish, in terms of light rays, between a real and a virtual image. (6)

(*c*) An object was placed at the same fixed distance (*u*) from a number of convex lenses of different focal lengths (*f*). The image distance (*v*) for each lens was found. Values for $1/f$ and $1/v$ are given in the table.

$1/f$ (cm^{-1})	0.20	0.15	0.10	0.025	0.010
$1/v$ (cm^{-1})	0.15	0.10	0.05	–0.025	–0.040

(*i*) What is the significance of the negative $1/v$ values?

(*ii*) Draw a graph of $1/v$ *versus* $1/f$ (*x*-axis).

(*iii*) Hence or otherwise find *u*. (24)

4. (*a*) Define temperature. (6)

(*b*) State Charles' law. (6)

(*c*) What is meant by the absolute scale of temperature? (6)

(*d*) A syringe containing a fixed mass of air was immersed in a number of water baths at different temperatures. The pressure was kept constant at 1.1×10^5 Pa. The data below were obtained for the volume of the air at each of these temperatures.

Volume (cm^3)	19.5	20.5	21.4	22.8	23.6	24.9	25.9
Temperature (°C)	0.0	15	30	45	60	75	90

(*i*) Plot a graph of volume (*y*-axis) *versus* temperature in °C. (12)

(*ii*) Explain how your graph could be used to find the value for absolute zero on the Celsius scale. (6)

(*iii*) Sketch the graph you would expect to obtain if the volume of air in the syringe is plotted against *absolute* temperature.
How would this graph verify Charles' law? (9)

(*iv*) Give a reason why it is not possible to measure the actual volume of air in the syringe at absolute zero. (6)

(*v*) Calculate the number of moles of oxygen gas in the syringe if the air contained 21% oxygen by volume. (15)

5. (*a*) Define (*i*) electric current, (*ii*) the unit of current, i.e. the ampere. (12)

(*b*) Heat is produced when electric current flows through a metallic conductor. The heat produced in a given time is proportional to the square of the current flowing when the resistance of the conductor is kept constant.
Using a labelled diagram of the apparatus, describe an experiment to verify this relationship. (18)

(*c*) What is electromagnetic induction? (6)

(*d*) Transformers are used in the supply of electricity from a generating station to your home.
Explain how a transformer like that shown in **Figure 6** works. (9)

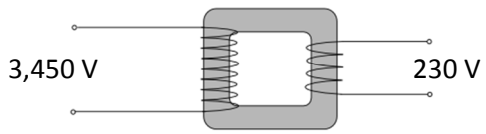

Figure 6

(*i*) State two ways of reducing energy losses in a transformer.

(*ii*) What is the ratio of turns in the primary coil compared with the secondary coil when the input voltage is 3,450 V and the output voltage is 230 V? (12)

(*e*) Explain, in terms of heat produced in the cables, why electricity is transmitted at high voltage from a power station to a transformer near your home. (9)

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

(*a*) State the principle of conservation of energy. (6)

In a curling match a competitor released a stone of mass 18.0 kg, like that shown in **Figure 7**, with kinetic energy of 20.25 J and it travelled 12.5 m across ice in a straight line before coming to rest. Calculate

(*i*) the initial velocity of the stone,

(*ii*) the deceleration of the stone,

(*iii*) the force that brought the stone to rest,

(*iv*) the time taken for the stone to come to rest. (21)

Name the horizontal force that brought the stone to rest.

What happened to the 20.25 J of kinetic energy? (6)

Figure 7

(*b*) Three identical 4 Ω bulbs **A**, **B** and **C** are connected to a 12 V power supply as shown in the circuit in **Figure 8**. Calculate

(*i*) the total resistance of this arrangement of bulbs,

(*ii*) the current flowing through **A**,

(*iii*) the potential difference across **A**,

(*iv*) the current flowing through **B**. (24)

If switch **S** is opened, how is the brightness of **A** affected?

Explain your answer. (9)

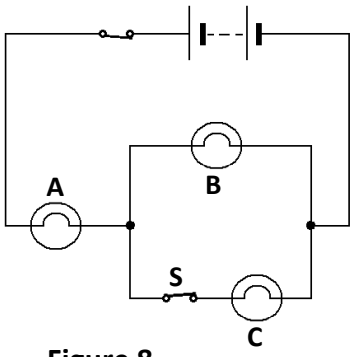

Figure 8

(*c*) Both diffraction and interference occur when a narrow beam of monochromatic light passes through a pair of narrow slits forming a pattern of bright and dark images on a screen. Explain the underlined terms. (15)

How does the formation of these images contribute to our understanding of the nature of light? (6)

Calculate the wavelength of the light used if the separation between the centres of the slits was 0.4 mm, the screen was placed 2.3 m from the slits and the distance from the central bright image to the 9th bright image was 3.5 cm. (12)

(*d*) What changes take place in the structure of a nucleus when (*i*) alpha decay occurs, (*ii*) beta decay occurs?

Compare the ionising abilities of alpha and beta particles.

Account for the difference in their ionising abilities. (21)

Gold–198 is a beta particle emitter. It can be used by environmental scientists to trace the movement of sand in cases of coastal erosion. The graph in **Figure 9** shows how the activity of a sample of **Au**–198 changes with time.

Write a nuclear equation to represent the beta-decay of **Au**–198.

Use **Figure 9** to find the half-life of **Au**–198. (12)

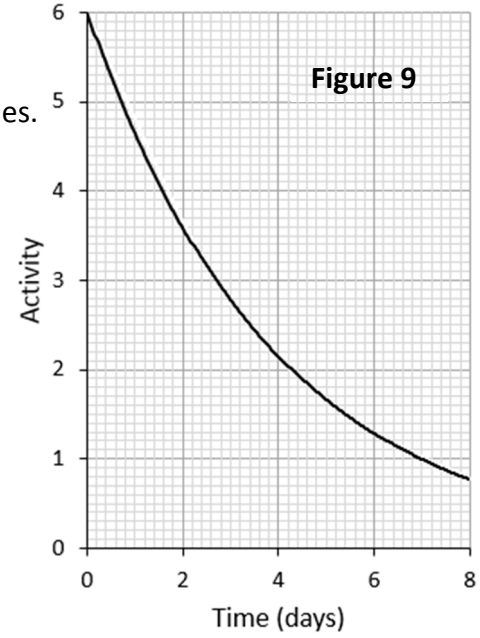

Figure 9

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*) neutrons, has the aluminium ion, $^{27}_{13}\mathbf{Al^{3+}}$?

(*b*) Define relative atomic mass.

(*c*) **Figure 10** shows buckminsterfullerene ($\mathbf{C_{60}}$), an allotrope of carbon.
What are allotropes?
Name an allotrope of carbon that can conduct electricity.

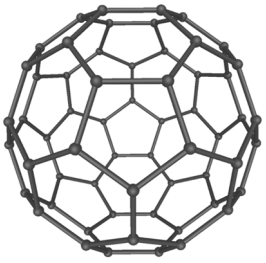

Figure 10

(*d*) Write the chemical formula for zinc chloride.

(*e*) Define electronegativity.

(*f*) Hydrides are <u>binary compounds</u> of hydrogen. Explain the underlined term.
Classify the hydride $\mathbf{H_2S}$ as ionic or covalent.

(*g*) $\mathbf{Na_2PO_xF}$, an additive in the toothpaste in **Figure 11**, contains 33⅓%, by mass, of oxygen. What is the value of ***x*** in the formula?
(**O** = 16, **F** = 19, **Na** = 23, **P** = 31)

Figure 11

(*h*) Under what circumstances does sodium chloride conduct electricity?

(*i*) Classify sulfur dioxide as an amphoteric, an acidic, a basic or a neutral oxide.
What environmental problem is caused by the presence of $\mathbf{SO_2}$ in the atmosphere?

(*j*) Flask **A** contains helium gas and an identical flask **B** contains argon gas at the same temperature and pressure. Which flask, **A** or **B** or neither, contains
(*i*) the greater mass of gas,
(*ii*) the greater number of atoms?

(*k*) Balance the equation: $\mathbf{Ga_2O_3 + HCl \rightarrow GaCl_3 + H_2O}$

(*l*) The heat of solution (ΔH) of sodium nitrate ($\mathbf{NaNO_3}$) is 20.5 kJ mol^{-1}.
How much heat is absorbed when 17 g of sodium nitrate is dissolved in water?
Does the temperature of the solution increase or decrease as the crystals dissolve?
(Take the M_r of $\mathbf{NaNO_3}$ as 85.)

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

(*n*) Copy **Figure 12** of the structure of alanine, an amino acid used by living organisms to synthesise protein.
(*i*) Circle the methyl group in your structure.
(*ii*) What is the group inside the box called?

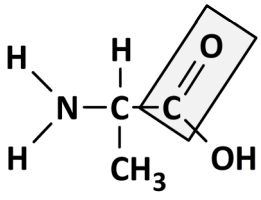

Figure 12

(*o*) Name a compound that has the molecular formula $\mathbf{C_4H_8}$ *and* draw its structure.

(11 × 6)

8. **Figure 13** represents the first six main energy levels of an atom as proposed by Neils Bohr about 1913. Sublevels and orbitals were introduced later to account for certain experimental observations.

(*a*) (*i*) What is the maximum number of electrons that can be accommodated in the $n = 2$ level?

(*ii*) How many sublevels are associated with the $n = 2$ energy level?

(*iii*) What is an atomic orbital?

(*iv*) How many orbitals are associated with the $n = 2$ energy level? (15)

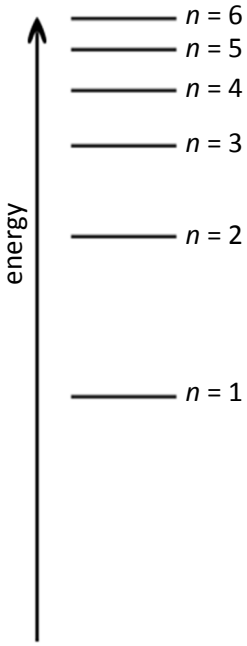

Figure 13

(*b*) Copy the diagram and use it to help you account for the visible lines in the hydrogen emission spectrum. (9)

(*c*) Flame tests provide evidence for energy levels in atoms.

(*i*) Describe how to carry out a flame test on an unknown salt.

(*ii*) What metallic element when present in a salt produces a lilac flame? (12)

(*d*) One of the electrons in an atom is described by the set of quantum numbers {3, 1, –1, –½}.

(*i*) What main energy level is occupied by this electron?

(*ii*) Draw the shape of the orbital occupied by this electron. (9)

(*e*) **Figure 14** shows the successive ionisation energies for all the electrons of element **X**.

(*i*) Define *first ionisation energy*.

(*ii*) Identify element **X** and write its *s*, *p* electron configuration.

(*iii*) Why is there a sharp increase from the 11th to the 12th ionisation energy? (21)

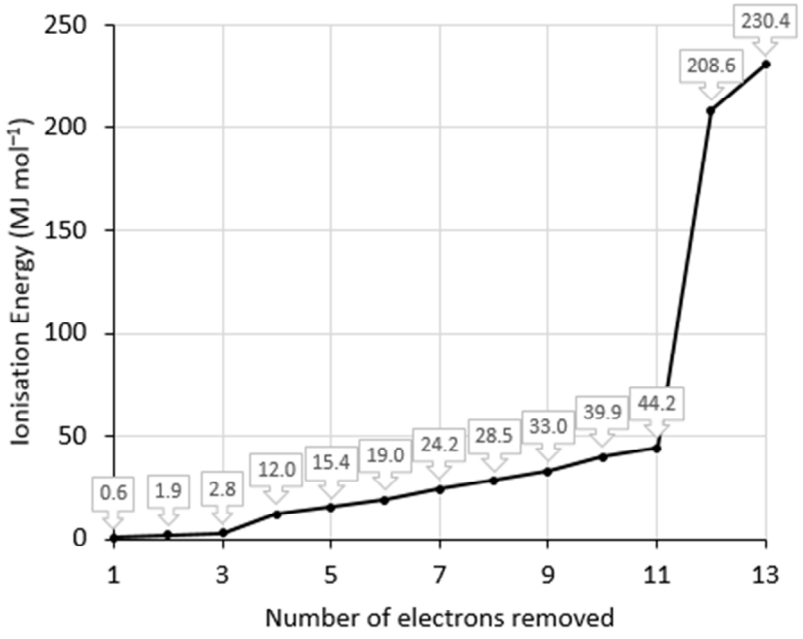

Figure 14

9. Limewater is a <u>saturated solution</u> of calcium hydroxide (**$Ca(OH)_2$**) in water. The concentration of a freshly prepared, filtered limewater solution was found by titration with a <u>standard solution</u> of hydrochloric acid. A 0.045 M solution of hydrochloric acid was titrated against three 20.0 cm^3 portions of the limewater using methyl orange indicator.
The balanced equation for the reaction is:

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

(*a*) Explain the underlined terms. (12)

(*b*) Give a common use for limewater in the laboratory.
Why is it necessary to keep limewater solutions stoppered whenever possible? (9)

(*c*) The piece of apparatus **X** in **Figure 15** was used to add the **HCl** solution to the limewater in a titration flask. **X** was filled to the zero mark before commencing each titration.

(*i*) Name **X**.

(*ii*) Describe how **X** was rinsed before use.

(*iii*) Use the end point readings **A**, **B** and **C**, shown in **Figure 15**, for the three titrations to determine the correct average volume of **HCl** needed to neutralise 20.0 cm^3 of the limewater.

(*iv*) How could the presence of an air bubble in the nozzle of **X** have affected the result obtained in a titration reading? (18)

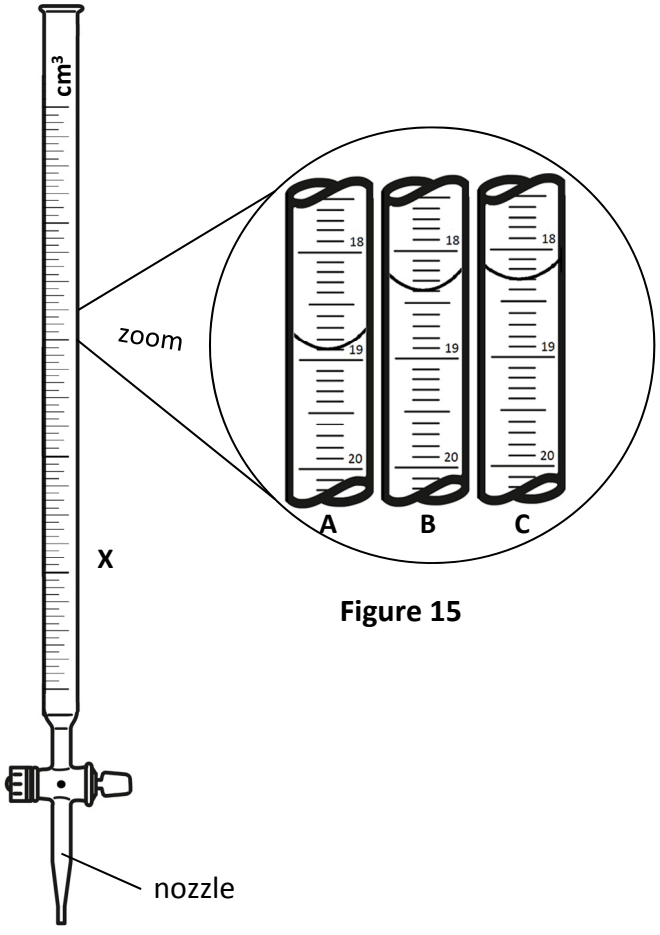

Figure 15

(*d*) State the colour change observed at the end point in the titration flask. (6)

(*e*) Calculate the concentration of the limewater in
(*i*) moles per litre,
(*ii*) grams per litre. (12)

(*f*) Define pH.
Calculate the pH of the limewater solution. (9)

10. Six metals are listed below in order of their *decreasing* ease of oxidation.

magnesium aluminium zinc iron copper platinum

(*a*) Define, in terms of electron transfer, (*i*) oxidation, (*ii*) oxidising reagent. (9)

(*b*) From the list above, select (*i*) the strongest reducing agent, (*ii*) the metal whose ions are most difficult to reduce, (*iii*) the metal that reacts most vigorously with steam. (9)

(*c*) What reaction, if any, would you expect to occur if a wire made of iron was placed (*i*) in a copper(II) sulfate solution, (*ii*) in a zinc sulfate solution? (9)

(*d*) An aluminium object resists corrosion by means of a layer of metal oxide that forms on its surface. Why can an iron object not resist corrosion in the same way? (6)

(*e*) **Figure 16** shows water, acidified by the addition of a few drops of sulfuric acid, undergoing <u>electrolysis</u> using platinum electrodes. Oxygen gas was liberated at one of the electrodes according to the following equation.

$$2H_2O \rightarrow 4H^+ + O_2 + 4e^-$$

(*i*) Explain the underlined term.

(*ii*) Write a balanced equation for the reaction that occurs at the other electrode.

(*iii*) At which electrode did oxidation occur? Justify your answer.

(*iv*) How many moles of electrons were transferred to liberate one mole of O_2 in the reaction above?

(*v*) What charge, in coulombs, liberates 0.0056 moles of O_2?

(*vi*) Calculate the current if 0.0056 moles of O_2 was liberated in 30 minutes. (33)

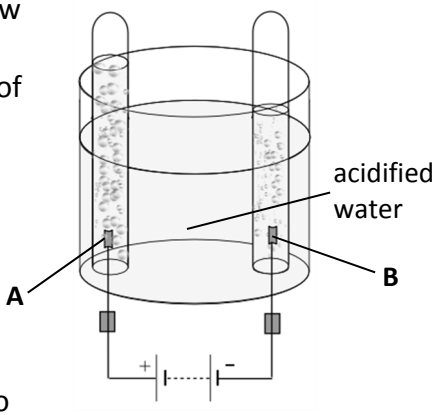

Figure 16

11. Study the reaction scheme in **Figure 17** and answer the questions that follow.

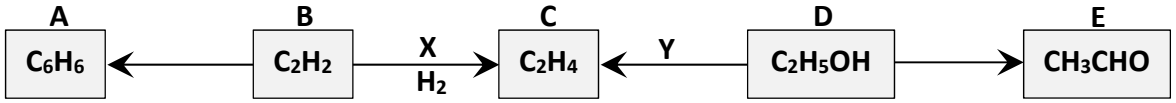

Figure 17

(*a*) (*i*) What is a functional group?

(*ii*) What is a homologous series? (9)

(*b*) Name

(*i*) compounds **A**, **B**, **C**, **D** and **E**,

(*ii*) catalysts **X** and **Y**,

(*iii*) the homologous series to which **E** belongs,

(*iv*) the type of reaction involved in the conversion of **D** to **E**. (27)

(*c*) (*i*) Draw the structural formula for **A**.

(*ii*) Describe the bonding in **A**. (12)

(*d*) (*i*) What is observed when **B** is bubbled into bromine solution as shown in **Figure 18**?
Account for this observation. (9)

(*ii*) Write a balanced equation for the combustion of **B** in oxygen.
Give a common application of this reaction. (9)

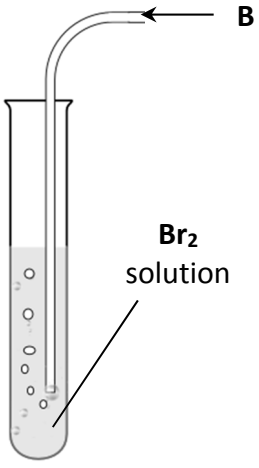

Figure 18

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

(*a*) Car airbags are inflated by the nitrogen gas generated by the rapid decomposition of sodium azide (**NaN_3**) according to the equation:

$$2NaN_3\,(s) \rightarrow 2Na\,(s) + 3N_2\,(g)$$

The sodium produced reacts with potassium nitrate as follows:

$$10Na\,(s) + 2KNO_3\,(s) \rightarrow 5Na_2O\,(s) + K_2O\,(s) + N_2\,(g)$$

Calculate

(*i*) the number of moles of sodium azide in an airbag containing 78 g **NaN_3**,

(*ii*) the mass of sodium produced in the first reaction,

(*iii*) the total volume, at s.t.p., of the nitrogen gas produced in both reactions.

Does this nitrogen cause air pollution when it is released into the atmosphere? Explain.

(*b*) Refer to the Brønsted-Lowry theory to

(*i*) define an acid,

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

Copy and complete the following equation, assuming that **$H_2PO_4^-$** acts as a base.

$$HCl\,(aq) + H_2PO_4^-\,(aq) \rightarrow$$

Identify a conjugate pair in your equation.

Figure 19

The venom of an ant, like that shown in **Figure 19**, contains methanoic acid, a weak acid. The venom had the same pH as a solution of nitric acid, a strong acid. Explain why this is possible.

(*c*) Define heat of formation.

$$C\,(s) + O_2\,(g) \rightarrow CO_2\,(g) \qquad \Delta H = -393.5 \text{ kJ mol}^{-1}$$

$$H_2\,(g) + \tfrac{1}{2}O_2\,(g) \rightarrow H_2O\,(l) \qquad \Delta H = -285.8 \text{ kJ mol}^{-1}$$

$$CH_3COOH\,(l) + 2O_2\,(g) \rightarrow 2CO_2\,(g) + 2H_2O\,(l) \qquad \Delta H = -875.2 \text{ kJ mol}^{-1}$$

Use the heats of reaction above to calculate the heat of formation of ethanoic acid according to the following equation.

$$2C\,(s) + 2H_2\,(g) + O_2\,(g) \rightarrow CH_3COOH\,(l)$$

Is this an exothermic or an endothermic reaction?

Give a common use for ethanoic acid solutions.

(*d*) *Intra*molecular bonds exist between the atoms *in* a molecule.

Draw a dot and cross diagram to show the intramolecular bonding in a molecule of ammonia (**NH_3**).

State and explain the shape of the ammonia molecule.

Define *inter*molecular forces.

Name the type of intermolecular force that occurs in (*i*) ammonia gas, (*ii*) water, (*iii*) methane gas.

Explain, in terms of intermolecular forces, why **NH_3** is very soluble in water.

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