Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2026

PHYSICS AND CHEMISTRY – HIGHER LEVEL

WEDNESDAY, 17TH JUNE – MORNING, 9:30 TO 12:30

Six questions to be answered.

Answer at least **two** questions from Section I, at least **two** questions from Section II and **any two other** questions.

All the 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 the Earth.

Do not hand this up.

This document will not be returned to the State Examinations Commission.

SECTION I – PHYSICS

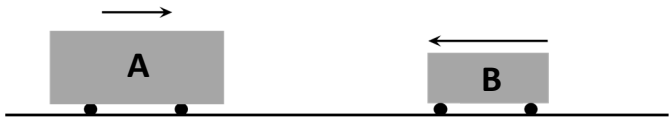
1. Answer **eleven** of the following items (*a*), (*b*), (*c*), etc. All the items carry equal marks.
Keep your answers short.

(*a*) Distinguish between a vector and a scalar quantity.

(*b*) Two speed cameras, located 9 km apart, record a motorist's average speed as 108 km per hour. Calculate the time taken, in seconds, for the motorist to travel between the two cameras.

(*c*) Define the SI unit of energy, the Joule.

(*d*) Cart **A** of mass 500 g is travelling horizontally with a speed of 4 m s^{-1}. It collides with cart **B** of mass 250 g travelling in the opposite direction with a speed of 6 m s^{-1}. Cart **A** comes to rest as a result of the collision. Calculate the new velocity of cart **B**.



(*e*) Draw a ray diagram to show the formation of an upright, magnified, virtual image in a concave mirror.

(*f*) An object is placed 3 cm from a convex (converging) lens. A virtual image is formed 4 cm from the lens. Calculate the focal length of the lens.

(*g*) What is meant by dispersion of light?

(*h*) Distinguish between longitudinal and transverse waves.

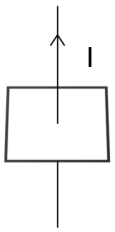
(*i*) Calculate the frequency of an electromagnetic wave of wavelength 1.5 mm travelling through a vacuum.

(*j*) State the name given to the temperature at which water, ice and steam exist in equilibrium. What is the value of this temperature on the Kelvin scale?

(*k*) Explain how two identical beakers of the same liquid could have the same temperature but contain different quantities of heat.

(*l*) State two assumptions of the kinetic theory of gases.

(*m*) Copy and complete the diagram on the right to show the shape and direction of the magnetic field lines around the wire carrying current *I*.



(*n*) The primary coil of a transformer in a phone charger has 1200 turns. It is connected to a 230 V mains supply. Calculate the number of turns required in the secondary coil to generate an output of 4.6 V.

(*o*) State the principle on which the operation of the moving-coil galvanometer is based.

(*p*) Compare the ionising abilities of beta particles and gamma rays.

(*q*) Explain why nuclear fusion reactions require such high temperatures.

(*r*) Identify particle **X** which is formed by the fusion of two helium–3 nuclei as shown by the equation:

$$\mathbf{{}^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + 2X}$$

(11 × 6)

2. (*a*) A student completed an experiment to calculate a value for the acceleration due to gravity, *g*.

(*i*) Draw a labelled diagram of the arrangement of the apparatus used in this experiment.

(*ii*) What measurements were taken to calculate *g*?

(*iii*) Describe how these measurements were taken.

(*iv*) How were these measurements used to calculate *g*? (27)

(*b*) A ball with a mass of 6.0 kg and a feather with a mass of 1.5×10^{-3} kg at the same height are dropped vertically from rest in a near perfect vacuum. 2.04 s later they both strike the ground.

(*i*) Explain why the ball and feather strike the ground at the same time.

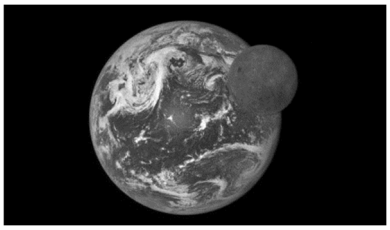
(*ii*) Calculate the velocity of the objects at the moment they strike the ground.

(*iii*) Calculate the initial height of the objects above the ground.

(*iv*) Calculate the kinetic energy of the ball as it strikes the ground.

(*v*) By what factor does the kinetic energy of the ball differ from the kinetic energy of the feather at the instant they strike the ground? (21)

(*c*) (*i*) State Newton's universal law of gravitation.



(*ii*) Using this law, derive the relationship between *g*, the acceleration due to the Earth's gravity and *G*, the gravitational constant.

The Moon is Earth's only natural satellite.

(*iii*) Calculate the attractive force between the Earth and the Moon.

(*mass of Earth* $= 5.9 \times 10^{24}$ *kg; mass of the Moon* $= 7.3 \times 10^{22}$ *kg;*

distance from the centre of the Earth to the centre of the Moon $= 3.8 \times 10^{8}$ *m*)

(18)

3. (*a*) (*i*) What is meant by refraction of light?

(*ii*) What is meant by the term critical angle? (12)

(*b*) In an experiment to verify Snell's law, the angle of incidence *i* and the angle of refraction *r* for a ray of light as it passes from air into glass was measured and the following data collected.

i (degrees)	30	40	50	60	70	80
r (degrees)	20	26	33	38	42	44

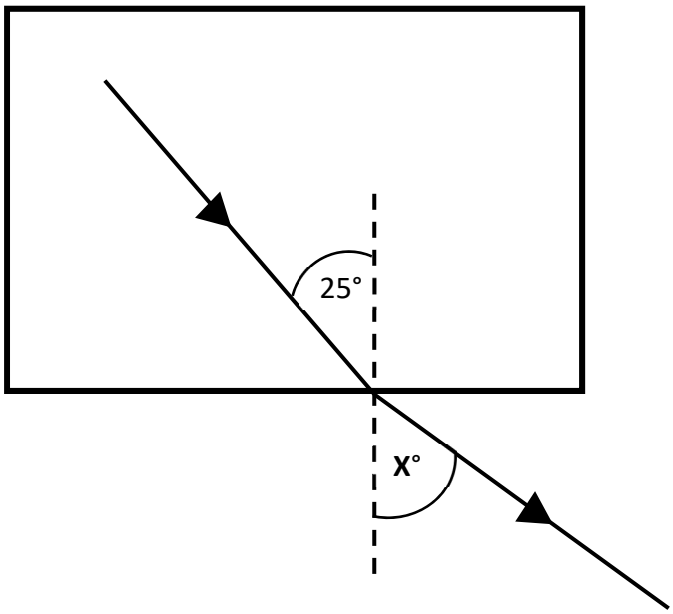
(*i*) Draw a labelled diagram of the arrangement of the apparatus used in this experiment.

(*ii*) Draw a suitable graph to verify Snell's law.

(*iii*) Explain how your graph verifies Snell's law.

(*iv*) Use your graph to determine the refractive index of the material. (33)

(*c*) A ray of light is incident on the internal boundary of a rectangular acrylic block in air, as shown. The refractive index of acrylic is 1.49.



(*i*) State the change that occurs, if any, in the speed of the ray of light as it travels from the acrylic into air.

(*ii*) Calculate the angle of refraction **X**.

(*iii*) Determine the critical angle of acrylic.

(*iv*) Sketch a diagram to predict the path of the ray of light when the angle of incidence exceeds the critical angle of acrylic. (21)

4. (*a*) Brownian motion, which was first observed in 1877, provided evidence for the kinetic theory of gases.

(*i*) What is meant by the term Brownian motion?

(*ii*) Describe how Brownian motion can be demonstrated in a school laboratory.

(*iii*) State two ways Brownian motion provides evidence for the kinetic theory of gases.

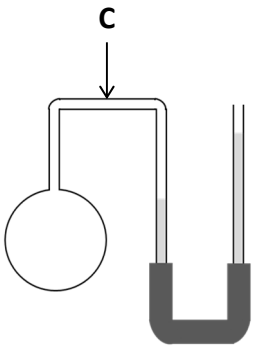
(*iv*) State one contribution to atomic theory resulting from the observation above. (18)

(*b*) The growing understanding of the properties of matter led to the development of a wide range of measuring instruments, including the thermometer.

(*i*) What are the two reference temperatures used to establish the Celsius scale?

(*ii*) Describe how each of these reference temperatures can be measured in the laboratory.

A constant volume gas thermometer, as shown, can be used as a standard thermometer.



(*iii*) State two features of a gas thermometer which make it suitable for use as a standard thermometer.

(*iv*) Explain why the tube labelled **C** should be kept as short and narrow as possible.

(*v*) Identify a gas suitable for use in the gas thermometer at very low temperatures. Justify your answer. (30)

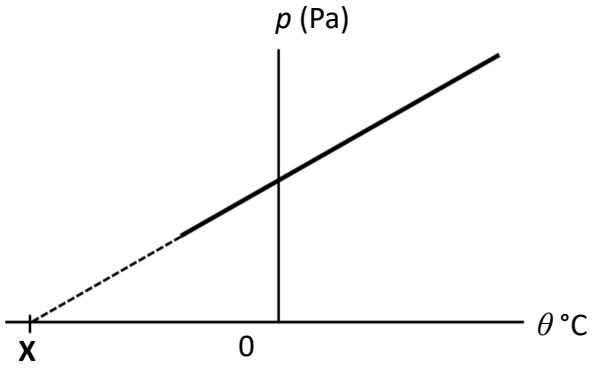
(*c*) The graph shows how the pressure p of a gas varies with temperature θ, on the Celsius scale, at constant volume V.

(*i*) State the precise fixed value of the temperature **X**.

(*ii*) State the average kinetic energy of the gas particles at temperature **X**?

(*iii*) Show the relationship between the equation of state for the ideal gas and the slope of the graph shown.

(*iv*) Copy the graph shown into your answerbook. On your graph sketch a line showing how the slope changes when the volume is doubled.



(18)

5. (*a*) (*i*) What is meant by electrical resistance?

(*ii*) Define the unit of electrical resistance, the ohm.

(*iii*) Explain why the resistance of a metallic conductor increases with temperature.

(*iv*) State two other factors that affect the resistance of a metallic conductor. (21)

(*b*) A constant current was passed through a fixed mass of water, at room temperature, for varying lengths of time *t*. The temperature of the water θ was recorded after each time interval as shown in the table below.

t (s)	0	10	20	40	60	80	100
θ (°C)	15.9	17.2	18.4	20.5	23.2	25.6	28.0

(*i*) Draw a graph, on graph paper, to show the relationship between *t* and θ.

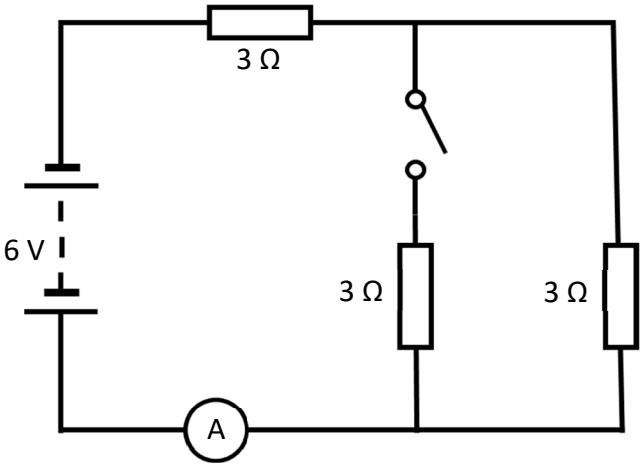
(*ii*) State the relationship between *t* and θ.

(*iii*) Use your graph to estimate the temperature of the room before the current begins to flow. Justify your answer.

(*iv*) Use your graph to estimate the temperature of the water after 67 s.

(*v*) Use your graph to determine the time taken to increase the temperature of the water by 11 °C. (24)

(*c*) Use the circuit diagram below to answer the following questions.



(*i*) Calculate the reading on the ammeter when the switch is *open.*

(*ii*) Calculate the reading on the ammeter when the switch is *closed.*

(*iii*) Sketch a circuit diagram to show how the three resistors shown could be arranged to give a reading of 6 A on the ammeter (21)

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

(*a*) Electric fields exist around charged objects.

(*i*) What is an electric field?

(*ii*) Name an instrument which can be used to detect the presence of an electrical field.

(*iii*) What is the unit of electric charge?

(*iv*) Draw a labelled diagram to show how an electric field pattern can be demonstrated in the laboratory.

(*v*) Describe how an insulated spherical conductor can be charged negatively by induction.

(*vi*) Draw the electric field pattern around the negatively charged sphere.

The charged sphere is then earthed.

(*vii*) Draw a diagram to show the type and distribution of charge on the sphere after earthing. (33)

(*b*) (*i*) What is meant by the half-life of a radioactive isotope?

The table shows the radioactive decay of a sample of Thallium–201 measured over a 240-hour period.

time (hours)	0	40	80	120	160	200	240
mass (mg)	2	1.37	0.94	0.64	0.44	0.25	0.21

(*ii*) Draw a graph, on graph paper, to represent this data.

(*iii*) Use your graph to estimate the half-life of **Tl**–201.

The nuclear equation below represents the beta decay of another isotope of thallium, **Tl**–208.

$$^{208}_{81}\mathrm{Tl} \rightarrow {}^{X}_{Y}\mathrm{Z} + {}^{0}_{-1}\mathrm{e}$$

(*iv*) Identify the number **X**.

(*v*) Identify the number **Y**.

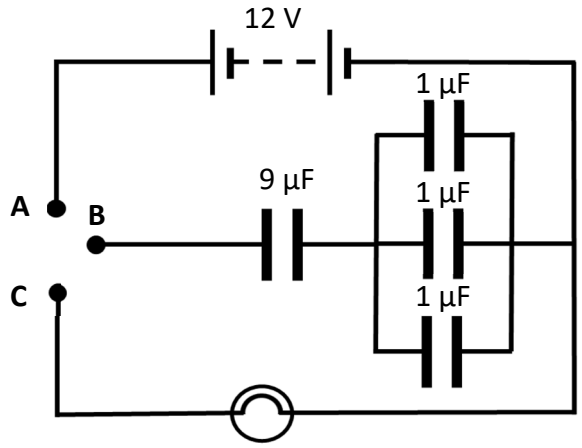
(*vi*) Identify the element represented by **Z**.

(*vii*) Identify the element whose alpha decay results in the formation of the element gold, **Au**–197. (33)

(*c*) (*i*) What is meant by capacitance?

(*ii*) State three factors on which the capacitance of a parallel plate capacitor depends.

A 12 V battery is connected to four capacitors arranged as shown.



(*iii*) Calculate the effective capacitance of the circuit.

(*iv*) Calculate the charge stored in the circuit when **B** is connected to **A**.

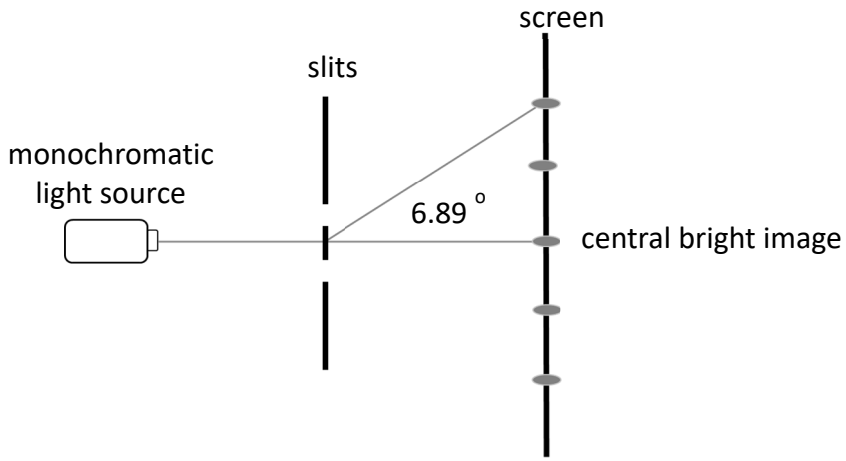
(*v*) What would be observed if **B** is then connected to **C**? Justify your answer. (33)

(*d*) (*i*) Explain what is meant by a monochromatic light source.

(*ii*) Explain what is meant by the term interference.

(*iii*) Distinguish between constructive and destructive interference.

Monochromatic light falls on a pair of Young's slits 0.015 mm apart producing an interference pattern on a screen as shown in the diagram below.



(*iv*) Calculate the wavelength of the light.

(*v*) Calculate the energy of a photon of this wavelength.

(*vi*) What other phenomenon occurs as the light passes through the slits? (33)

SECTION II – CHEMISTRY

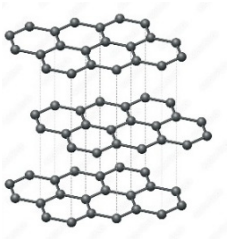
7. Answer **eleven** of the following items (*a*), (*b*), (*c*), etc. All the items carry equal marks.
Keep your answers short.

(*a*) How many (*i*) protons and (*ii*) electrons are there in a $^{40}_{20}\mathbf{Ca}^{2+}$ ion?

(*b*) State two reasons why the electronegativity value of potassium is less than that of sodium.

(*c*) Calculate a value for the relative atomic mass of a sample of boron (**B**) composed of 19.9% boron–10 and 80.1% boron–11.

(*d*) Write the chemical formulae for:
(*i*) copper(I) oxide,
(*ii*) iron(III) oxide.



(*e*) Graphite is an allotrope of carbon. Explain why graphite is
(*i*) a good electrical conductor,
(*ii*) a good lubricant.

(*f*) State two possible shapes for covalent molecules of general formula $\mathbf{AB_3}$.

(*g*) Calculate the percentage by mass of chromium (**Cr**) in $\mathbf{K_2Cr_2O_7}$.

(*h*) State two properties of transition metals.

(*i*) Identify from the following list (*i*) a basic oxide and (*ii*) a covalent hydride.

$\mathbf{Al_2O_3}$ $\mathbf{MgH_2}$ $\mathbf{PH_3}$ $\mathbf{Na_2O}$

(*j*) Identify, in methane ($\mathbf{CH_4}$), the type of:
(*i*) *intramolecular* bonding present,
(*ii*) *intermolecular* forces present.

(*k*) Identify two metals from the list shown that will not liberate hydrogen from dilute hydrochloric acid:

Al Ag Zn Mg Cu

(*l*) What is meant by the heat of reaction?

(*m*) Copy, complete and balance the following chemical equation:

$$\mathbf{HCl + Mg(OH)_2 \rightarrow}$$

(*n*) Under what circumstances can ionic compounds conduct electricity?

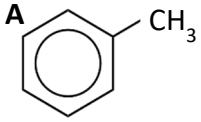
(*o*) For a crystal of potassium chloride (**KCl**) identify
(*i*) the types of particles that occupy the lattice points,
(*ii*) the forces that bind these particles together.

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

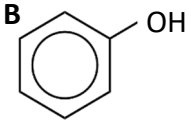
(*q*) Draw the structures of the two compounds that have the molecular formula $\mathbf{C_4H_{10}}$, showing all atoms and all bonds.

(*r*) Name the aromatic compounds **A** and **B** shown.

A

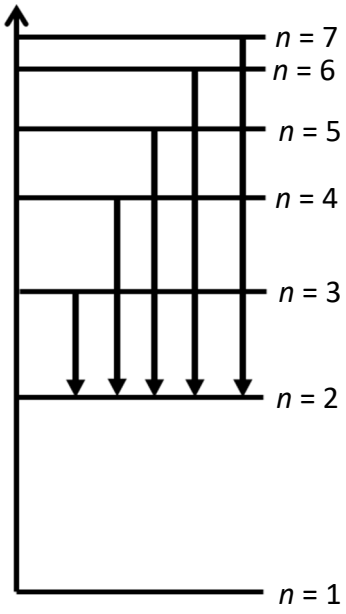


B



(11 × 6)

8. (*a*) Neils Bohr used the emission spectrum of hydrogen to describe the arrangement of the electrons in energy levels.



(*i*) What is meant by the term energy level?

(*ii*) Describe the arrangement of electrons in the energy levels n = 1 to n = 3 according to Bohr's theory.

(*iii*) Name the series of visible lines in the hydrogen emission spectrum.

(*iv*) Explain the origin of the series of visible lines in the emission spectrum of hydrogen.

(*v*) Describe the relationship between the frequency of a line in the hydrogen emission spectrum and two of the main energy levels in a hydrogen atom.

(27)

(*b*) The emission spectrum of various metals such as sodium and potassium can be viewed by allowing the light from a flame test on the metal salt to pass through a spectroscope.

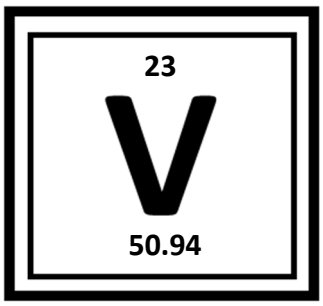
(*i*) Describe how you would conduct a flame test on metal salts of sodium and potassium.

(*ii*) State the colour observed in a flame test on a salt of sodium.

(*iii*) State the colour observed in a flame test on a salt of potassium.

(*iv*) Explain why the emission spectra of sodium and potassium are different. (18)

(*c*) (*i*) Write the full s, p, d electron configuration for an atom of vanadium (**V**) in its ground state, including the number of electrons in each atomic sublevel.



(*ii*) State the total number of orbitals occupied by the electrons in an atom of vanadium.

(*iii*) Describe the arrangement of electrons in a full p sublevel.

(*iv*) How do the atomic orbitals in a p sublevel differ from each other?

(*v*) One of the electrons in a vanadium atom is described by the set of quantum numbers $\{3, 1, -1, +\frac{1}{2}\}$. Specify the orbital occupied by this electron. (21)

9. Propanoic acid (**C_2H_5COOH**) is a weak acid found in many everyday products, primarily as a preservative to prevent mould. A student carried out an investigation in a school laboratory to determine the concentration of propanoic acid in a solution of preservative by titration against a 0.2 M solution of sodium hydroxide (**NaOH**).

(*a*) (*i*) Describe how a 200 cm^3 sample of **C_2H_5COOH** solution, in a beaker, could be diluted to exactly 1000 cm^3.

(*ii*) Name a piece of apparatus that could be used to accurately measure and transfer 25.0 cm^3 portions of the diluted **C_2H_5COOH** solution into a conical flask.

(*iii*) Describe how this piece of apparatus was rinsed before use. (21)

(*b*) The table below shows three indicators A, B and C with their pH range .

Indicator	pH range
A	3.8 – 5.4
B	6.0 – 7.6
C	8.0 – 9.8

(*i*) Which indicator from the table would be suitable for the above titration? Justify your choice.

(*ii*) Name a suitable indicator for this titration.

(*iii*) State the colour change observed at the end point for the indicator in (*ii*). (15)

(*c*) 25.0 cm^3 of the diluted **C_2H_5COOH** solution was titrated against the 0.2 M **NaOH** solution. The titration reaction is described by the following balanced chemical equation:

$$\mathbf{C_2H_5COOH + NaOH \rightarrow C_2H_5COONa + H_2O}$$

One approximate and two accurate titrations were carried out. The results are shown in the table below.

Approximate titration	First accurate titration	Second accurate titration
16.9 cm^3	16.7 cm^3	16.6 cm^3

(*i*) Calculate the average volume (titre) of **NaOH** needed to neutralise the **C_2H_5COOH**.

(*ii*) Calculate the number of moles of **NaOH** in the average titre.

(*iii*) Calculate the concentration of the *dilute* **C_2H_5COOH** solution in moles per litre.

(*iv*) Calculate the concentration of the *dilute* **C_2H_5COOH** solution in grams per litre.

(*v*) Calculate the concentration of the *original* **C_2H_5COOH** solution in grams per litre. (30)

10. (*a*) (*i*) Explain what is meant by reduction in terms of electron transfer.

(*ii*) Identify the substance *reduced* in the following reaction.

$$\mathbf{CuO + H_2 \rightarrow Cu + H_2O}$$

(*iii*) Identify the substance *oxidised* in the following reaction.

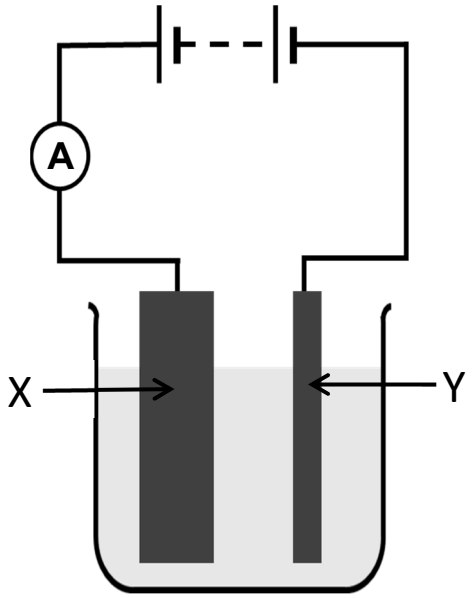
$$\mathbf{Zn + I_2 \rightarrow ZnI_2}$$

(*iv*) Why is reduction always accompanied by oxidation?

(*v*) Explain how **Cu_2O** acts as both an oxidising reagent and a reducing agent in the following reaction:

$$\mathbf{Cu_2O + 2H^+ \rightarrow Cu + Cu^{2+} + H_2O}$$ (18)

(*b*) The arrangement on the right can be used to purify 'blister' copper by electrolysis. This is a type of partially purified copper characterised by its blistered or bubbly surface due to the release of **SO_2** gas.



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

(*ii*) What energy conversion occurs during electrolysis?

(*iii*) Identify the two ions formed when copper(II) sulfate dissociates in solution.

(*iv*) Which electrode **X** or **Y** is acting as the cathode? Justify your answer.

(*v*) Write a balanced chemical equation for the reaction occurring at the cathode.

'Blister copper' can contain impurities such as silver (**Ag**) and gold (**Au**).

(*vi*) What happens to these impurities during electrolysis.

It was observed during electrolysis that the blue colour of the copper(II) sulfate solution remained.

(*vii*) Explain this observation. (39)

(*c*) 3.6×10^4 C of charge flows through the above electrolytic cell in one hour.

(*i*) Calculate the current passing through the ammeter.

(*ii*) Calculate the number of moles of electrons flowing in the circuit. (9)

11. (*a*) (*i*) What is meant by the term homologous series?

(*ii*) Name the homologous series to which compounds **A** to **D** belong.

A	C_2H_2
B	C_2H_5OH
C	HCOOH
D	C_6H_6

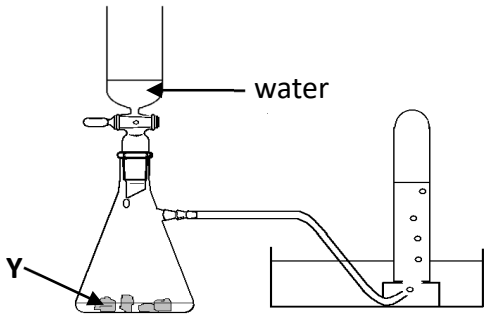
(15)

(*b*) (*i*) Draw the structure of the main organic product of the reaction between compound **D** (C_6H_6) and Br_2.

(*ii*) Classify this reaction as addition or substitution.

(*iii*) Identify the catalyst involved in this reaction. (9)

(*c*) C_2H_2 is a gaseous unsaturated hydrocarbon that can be prepared in a school laboratory using the apparatus shown.



(*i*) Identify solid **Y**.

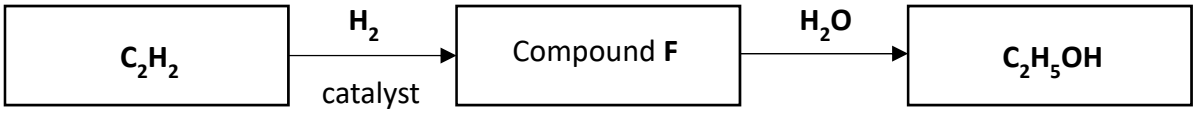
(*ii*) Write a balanced chemical equation for the preparation of C_2H_2.

(*iii*) What is meant by the term unsaturated hydrocarbon?

(*iv*) Describe how acidified potassium permanganate can be used to show C_2H_2 is unsaturated.

(*v*) Draw the structure of the product of the addition of bromine to C_2H_2 showing all atoms and bonds. (24)

(*d*) Compound **A** can be converted to compound **B** via the following scheme.



(*i*) Identify a suitable catalyst for the synthesis of compound **F** from C_2H_2.

(*ii*) Identify compound **F**.

(*iii*) Classify the type of reaction occurring in the synthesis of C_2H_5OH from compound **F**.

Compounds **B** and **C** react together in the presence of sulfuric acid to form the ester **G**.

(*iv*) State the IUPAC name of ester **G**.

(*v*) Draw the structure of ester **G**, showing all atoms and all bonds. (18)

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

(*a*) (*i*) What is meant by the first ionisation energy of an element?

The table shows the first eight ionisation energies of an atom of sulfur (**S**).

ionisation number	1	2	3	4	5	6	7	8
ionisation energy (kJ mol^{-1})	1000	2260	3390	4540	6990	8490	27100	31700

(*ii*) Explain how the 6th and 7th ionisation energy values of sulfur provide evidence supporting the existence of energy levels.

(*iii*) Write an equation to represent the second ionisation of sulfur.

(*iv*) Explain why the second ionisation energy of an element is always greater than the first. (22)

(*b*) The following reaction shows the production of zinc nitrate $\mathbf{Zn(NO_3)_2}$ which is used as a catalyst in many chemical reactions.

$$\mathbf{3Zn + 8HNO_3 \rightarrow 3Zn(NO_3)_2 + 2NO + 4H_2O}$$

If 13 kg of zinc **Zn** granules are used in the reaction

(*i*) Calculate the number of moles of **Zn** used.

(*ii*) Calculate the number of moles of nitric acid $\mathbf{HNO_3}$ required.

(*iii*) Calculate the volume of nitrogen monoxide **NO** produced at s.t.p.

(*iv*) What mass of $\mathbf{Zn(NO_3)_2}$ is produced? (22)

(*c*) (*i*) What is meant by the term strong acid according to Brønsted-Lowry theory?

(*ii*) Copy and complete the following equation, assuming that $\mathbf{H_2SO_4}$ acts as an acid.

$$\mathbf{H_2SO_4 + HNO_3 \rightarrow}$$

(*iii*) Identify a conjugate pair in your equation.

(*iv*) State the relationship between pH and hydrogen ion concentration.

(*v*) Calculate the concentration of a solution of nitric acid $\mathbf{HNO_3}$ with a pH of 1.2. (22)

This question continues on the next page.

(*d*) (*i*) What is meant by heat of combustion?

$$\mathbf{C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}} \qquad \Delta H = -393.5 \text{ kJ mol}^{-1}$$

$$\mathbf{H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}} \qquad \Delta H = -285.8 \text{ kJ mol}^{-1}$$

$$\mathbf{8H_{2(g)} + 7C_{(s)} \rightarrow C_7H_{16(l)}} \qquad \Delta H = -223.9 \text{ kJ mol}^{-1}$$

(*ii*) Use the data above to calculate the heat of combustion of heptane ($\mathbf{C_7H_{16}}$) according to the following balanced chemical equation:

$$\mathbf{C_7H_{16(l)} + 11O_{2(g)} \rightarrow 7CO_{2(g)} + 8H_2O_{(l)}}$$

(*iii*) Is this an exothermic or an endothermic reaction? Justify your answer. (22)

Acknowledgements

Images

Page 3	youtube.com
Page 3	nasa.gov
Page 9	adobe stock
Page 9	chemix.org

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Leaving Certificate – Higher Level

Physics and Chemistry

Wednesday, 17th June

Morning, 9:30 – 12:30