Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2025

PHYSICS AND CHEMISTRY - HIGHER LEVEL

WEDNESDAY, 18 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 $g = 9.8$ m s^{-2} as the acceleration due to gravity at the surface of the Earth.

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The 2025 examination papers were adjusted to compensate for disruptions to learning due to COVID-19. This examination paper does not necessarily reflect the same structure and format as the examination papers of past or subsequent years.

SECTION I – PHYSICS

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

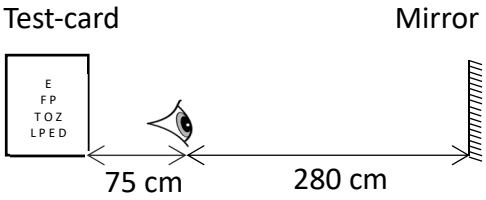
(*a*) State Newton's first law of motion.

(*b*) Calculate the work done by a mass of 50 kg when its velocity changes from 15 m s^{-1} to 25 m s^{-1}.

(*c*) Define the SI unit of force, the Newton (N).

(*d*) Calculate the gravitational force exerted by the Sun on the Earth.
(mass of Sun = 1.989×10^{30} kg, mass of Earth = 5.972×10^{24} kg,
distance between Sun and Earth = 1.496×10^{11} m)

(*e*) An optician places a test card 75 cm behind a patient who is 280 cm from a plane mirror, as shown. Calculate the distance from the patient to the image of the card.



(*f*) Images formed by mirrors show <u>lateral inversion</u>. Explain the underlined term.

(*g*) State a property of gas particles affected by a change in temperature.

(*h*) State the conditions of pressure and temperature under which the behaviour of a real gas approximates to that of the ideal gas.

(*i*) Write an expression for the relationship between temperature on the Kelvin scale, *T*, and temperature on the Celsius scale, θ.

(*j*) State two ways in which light can be dispersed.

(*k*) An interference pattern can be observed using Young's slits. Describe how the pattern observed on the screen changes when the distance between the slits is decreased.

(*l*) Explain why metals are good conductors of electricity.

(*m*) State one advantage of using (*i*) high voltages (*ii*) alternating current in the long-distance transmission of electrical energy.

(*n*) State the principle on which the moving coil galvanometer is based.

(*o*) The force between two identical point charges 5 cm apart is 2.5×10^{-4} N. What would the effect on the force be when the distance between the charges is increased to 10 cm?

(*p*) Explain why neutrons are the most effective subatomic particle for bombarding nuclei.

(*q*) What is meant by the term radioactivity?

(*r*) Calculate the energy released when 0.0075 % of the mass of 1 kg of natural uranium is converted into energy. (11 × 6)

2. (*a*) (*i*) What is meant by momentum?

(*ii*) State the principle of conservation of momentum. (9)

(*b*) An experiment was carried out to verify the principle of conservation of momentum. Body **A** of mass 310 g travelled 41 cm in 0.5 s before colliding with body **B** of mass 230 g, which was at rest. After collision the two masses moved on together with a common constant velocity of 0.471 m s^{-1}.

(*i*) Draw a labelled diagram of an arrangement of apparatus that can be used to verify the principle of conservation of momentum.

The effects of the external forces, gravity and friction, are minimised in this experiment.

(*ii*) State how the effects of both gravity and friction can be minimised.

(*iii*) Calculate the initial velocity of body **A**.

(*iv*) Calculate the total momentum before the collision.

(*v*) Calculate the total momentum after the collision.

(*vi*) Use the data to show that this experiment verifies the principle of conservation of momentum. (42)

(*c*) (*i*) What is meant by the kinetic energy of an object?

(*ii*) Calculate the kinetic energy lost during the collision.

(*iii*) Account for the loss in kinetic energy during the collision. (15)

3. (*a*) (*i*) State Snell's law.

Diamonds are cut so as to 'sparkle'. This is due to the phenomenon of total internal reflection within the gemstone. The critical angle for diamond is 24.4°.

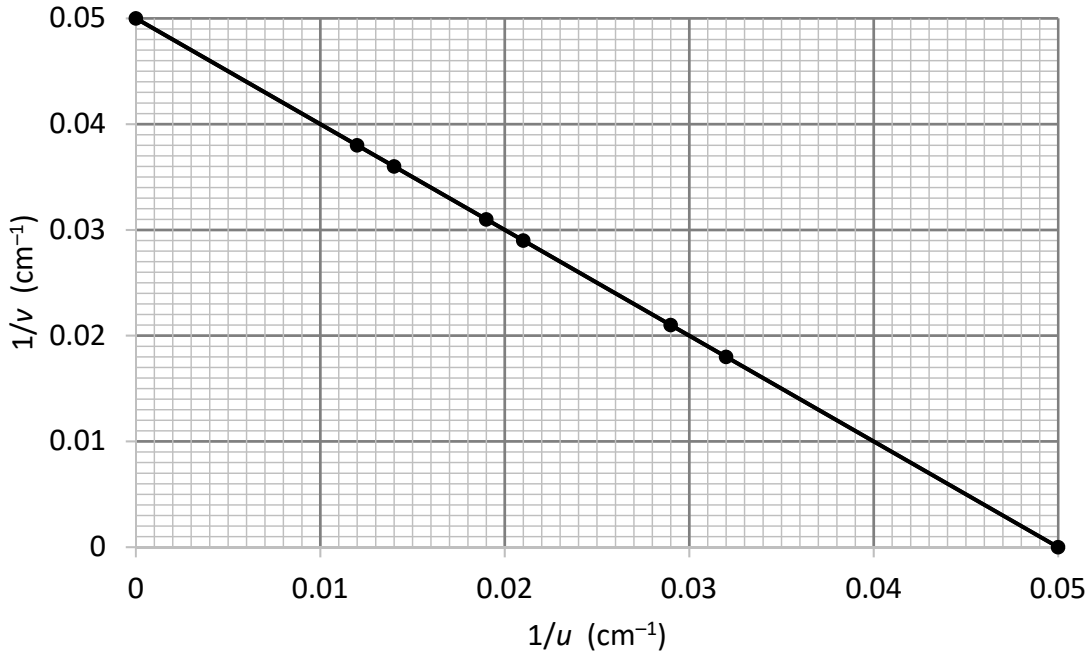
(*ii*) What is meant by the critical angle of a material?

(*iii*) State the two conditions necessary for total internal reflection of light to occur.

(*iv*) Calculate the refractive index of diamond.

(*v*) Draw a labelled diagram to show how a light beam can travel along an optic fibre by means of total internal reflection. (30)

(*b*) In an experiment to determine the focal length of a convex lens, object distance (*u*) and image distance (*v*) are measured and the results are displayed on a graph.



(*i*) Use the graph above to determine the focal length of the lens.
Note: only work written in your answerbook can be awarded marks.

(*ii*) Calculate the magnification of the image when the object is placed 25 cm from the lens.

(*iii*) Does the radius of curvature of a convex lens increase or decrease with increasing focal length? Justify your answer. (21)

(*c*) An object is placed 20 cm from a concave lens of focal length 5 cm.

(*i*) Calculate the image distance, *v*.

(*ii*) Draw a ray diagram to show the formation of a virtual image by a concave lens. (15)

4. (*a*) (*i*) State Boyle's law.

(*ii*) Draw a labelled diagram of an apparatus which can be used to verify Boyle's law.

An experiment to verify Boyle's law was carried out using 0.15 moles of a gas at a temperature, *T* and the following data obtained.

V ($\times 10^{-3}$ m^3)	1.81	2.01	2.58	3.61	4.48	5.16
P ($\times 10^6$ Pa)	0.20	0.18	0.14	0.10	0.08	0.07

(*iii*) Using the recorded data, draw a suitable graph on graph paper showing the relationship between the pressure and volume of a gas.

(*iv*) Explain how your graph verifies Boyle's law.

(*v*) Use the slope of the graph to find temperature, *T*. (42)

(*b*) (*i*) Distinguish between heat and temperature.

(*ii*) Define the term absolute zero.

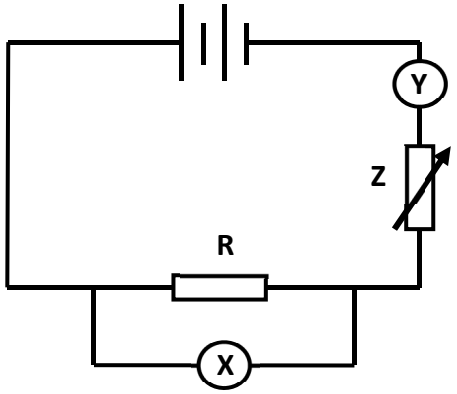
(*iii*) State the exact value of absolute zero on the Celsius scale.

(*iv*) What is meant by the triple point of water?

The pressure recorded using a constant volume gas thermometer at the freezing point of water is 9.5 kPa. The pressure at the boiling point of water is 13 kPa. The pressure at room temperature is 10.2 kPa.

(*v*) Calculate the temperature of the room. (24)

5. (*a*) Using the circuit shown below, a constant current, I, was passed through different resistors with resistance *R*.



(*i*) State Ohm's law.

(*ii*) Identify the meters labelled **X** and **Y.**

Z is a variable resistor.

(*iii*) State the function of **Z** in the circuit.

The potential difference, *V*, across each resistor was measured and the data recorded.

R (Ω)	0	3	5	6.5	8	10	12
V (Volts)	0	1.2	2.2	2.6	3.2	4.0	4.8

(*iv*) Plot a graph, on graph paper, of *R* versus *V*.

(*v*) Explain how your graph verifies Ohm's law.

(*vi*) Use your graph to find the constant current, I, flowing in each resistor.

One of the data points is inconsistent with the other data points.

(*vii*) Identify the point.

(*viii*) Suggest, with reference to Ohm's law, a reason for the inconsistency. (42)

(*b*) (*i*) Define electrical power.

(*ii*) Define the unit of electrical power, the watt.

A 2000 W electric kettle is connected to a 230 V supply.

(*iii*) Calculate the current flowing.

(*iv*) Calculate the resistance of the kettle's element.

(*v*) Calculate the energy, in kilojoules, consumed by the kettle in 15 minutes. (24)

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

(*a*) Thulium–170 (**Tm**—170) is a radioisotope commonly used in portable X–ray equipment. It has a half-life of 128.6 days. It decays by beta emission.

(*i*) What is a radioisotope?

(*ii*) Write a nuclear equation to show the decay of **Tm**—170 by beta emission.

A sample of **Tm**—170 initially contains 1.6×10^{20} radioactive atoms.

(*iii*) Calculate the number of atoms remaining after 643 days.

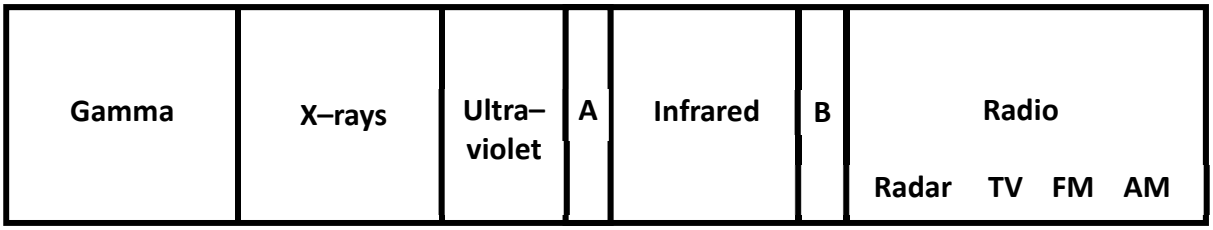
(*iv*) Compare the penetrating ability of alpha and beta particles.

Cu—62 is a radioisotope used for medical imaging. It is injected into the bloodstream and a scan is carried out to detect the gamma rays emitted.

(*v*) State the effect of gamma ray emission on the atomic number of **Cu**—62.

(*vi*) State one precaution medical personnel should take when using radioisotopes. (33)

(*b*) The image below shows a series of different types of radiation arranged in order of increasing wavelength.



(*i*) State the name of the series shown above.

(*ii*) State the speed of X–rays in a vacuum.

(*iii*) Name the radiation types labelled **A** and **B**.

(*iv*) Compare the frequencies of gamma rays and radio waves.

Under certain conditions photons cause electrons to be released from the surface of a metal.

(*v*) Explain the underlined term.

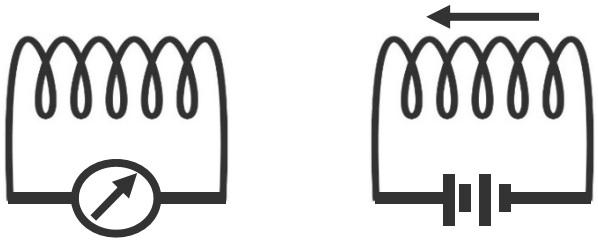
(*vi*) Identify this phenomenon.

(*vii*) Calculate the frequency of a UV photon with a wavelength of 2.54×10^{-9} m.

(*viii*) Calculate the energy of the UV photon in (*vii*). (33)

This question continues on the next page.

(*c*) The diagram shows a coil **A**, at rest and attached to a galvanometer. Coil **B** attached to a d.c. supply, moves towards **A.** The galvanometer deflects.



coil **A** coil **B**

(*i*) What is meant by electromagnetic induction?

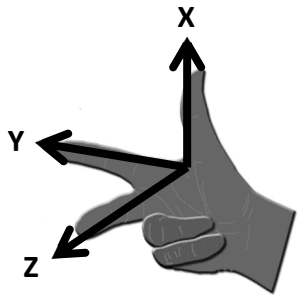
(*ii*) State two factors which will determine the size of the deflection of the galvanometer.

(*iii*) What change in the deflection will occur if coil **B** is wrapped around a soft iron core? Justify your answer.

(*iv*) What change in the deflection will occur if coil **B** is moved away from coil **A**? Justify your answer.

(*v*) Under what circumstances might the galvanometer deflect if both coils are stationary?

The Right-Hand Rule can be used to determine the direction of the current in a conductor as shown.



(*vi*) Which letter shows the direction of the current?

(*vii*) Which letter shows the direction of the magnetic field?

(33)

(*d*) An object starting from rest moves a distance of 90 m from **A** to **B** with constant acceleration of 20 m s^{-2}.

For the next 7 seconds it then travels from **B** to **C** with constant velocity.

It comes to rest at **D** with constant deceleration of 12 m s^{-2}.

(*i*) What quantity is defined as the rate of change of velocity?

(*ii*) Calculate the velocity at **B**.

(*iii*) Calculate the time taken to reach **B**.

(*iv*) Calculate the time taken to travel from **C** to **D**.

(*v*) Draw, on graph paper, a velocity-time graph to represent the motion of this object.

(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*) electrons, (*ii*) neutrons, has the ion $^{56}_{26}\mathbf{Fe}^{3+}$?

(*b*) What is an atomic orbital?

(*c*) Explain what is meant by the term isotope.

(*d*) Write the chemical formula for manganese(IV) oxide.

(*e*) Calculate the percentage of carbon by mass in $\mathbf{(NH_4)_2CO_3}$.

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

(*g*) State two differences between Mendeleev's periodic table and the modern periodic table of the elements.

(*h*) Explain what is meant by the first ionisation energy of an element.

(*i*) Metals are good conductors of electricity. State two other physical properties of metals.

(*j*) Identify two oxides that react with water to form acid rain.

(*k*) Name the process by which the application of an electric current to a substance results in a chemical change.

(*l*) Identify the type of reaction involved in (*i*) the removal of oxygen (*ii*) the loss of electrons, from a compound.

(*m*) The heat of solution of calcium chloride $\mathbf{CaCl_2}$ is –82.8 kJ mol^{-1}. Calculate the heat released when 55.5 g of calcium chloride is dissolved in water.

(*n*) Draw a diagram showing how hydrogen bonding arises between two water molecules.

(*o*) Calculate the $\mathbf{H^+}$ ion concentration in a monoprotic acid with a pH of 1.92.

(*p*) Name a homologous series of organic compounds that contain (*i*) a hydroxyl group (*ii*) a carbonyl group.

(*q*) Write a balanced chemical equation for the monochlorination of methane in the presence of uv light.

(*r*) Explain why benzene usually undergoes substitution rather than addition reactions.

(11 × 6)

8. (*a*) (*i*) What is meant by electronegativity?

(*ii*) State and explain the trend in electronegativity values across the second period of the periodic table. (12)

(*b*) The following covalent hydrides are formed by elements in the second period of the periodic table.

NH_3 **BeH_2** **H_2O** **CH_4**

(*i*) Using electronegativity values, arrange the molecules in the above list in order of increasing bond polarity.

(*ii*) Describe how electronegativity values can be used to predict the type of bond that occurs between a pair of atoms.

(*iii*) Identify one compound from the list above containing a non-polar covalent bond.

(*iv*) Identify one compound from the list above containing a polar covalent bond.

(*v*) Explain whether you would expect **H_2O** or **H_2S** to have the stronger bond. (24)

(*c*) (*i*) Draw a dot and cross diagram to show the arrangement of the valence electrons in **CH_4** and **NH_3**.

(*ii*) Use electron pair repulsion theory to predict and explain the shapes of the **CH_4** and **NH_3** molecules.

(*iii*) Which of these two compounds, **CH_4** or **NH_3**, would you expect to be the more soluble in the non-polar solvent cyclohexane? Justify your answer.

(*iv*) Explain why the molecule **H_2O** has a dipole moment while **BeH_2** does not. (30)

9. (*a*) A white solid **$MHCO_3$**, where **M** represents a metallic element, is a weak base that dissolves in water. This solution undergoes neutralisation when titrated against a standardised solution of hydrochloric acid (**HCl**).

(*i*) Explain the underlined terms.

(*ii*) Suggest a primary standard that could be used to standardise the hydrochloric acid.

(*iii*) State two precautions that should be taken to avoid error when preparing the burette for a titration.

(*iv*) State two precautions that should be taken while using the conical flask to ensure an accurate end point. (27)

(*b*) (*i*) Name a suitable indicator for the titration. Justify your choice.

(*ii*) State the colour change that occurs at the endpoint.

(*iii*) What was observed during the titration to indicate that a gas was produced? (15)

(*c*) The **$MHCO_3$** solution was prepared by dissolving 2.0 g of **$MHCO_3$** in deionised water and making the solution up to 250 cm^3. On average 19.2 cm^3 of 0.104 M **HCl** solution was required to neutralise 25.0 cm^3 portions of the **$MHCO_3$** solution according to the following balanced equation:

$$\mathbf{MHCO_3 + HCl \rightarrow MCl + H_2O + CO_2}$$

(*i*) Calculate the concentration of the **$MHCO_3$** solution in moles per litre.

(*ii*) Calculate the number of moles of **$MHCO_3$** in the 250 cm^3 of solution.

(*iii*) Calculate the mass of 1 mole of **$MHCO_3$**.

(*iv*) Identify the element **M**. (24)

10. (*a*) (*i*) What is meant by the term oxidising agent?

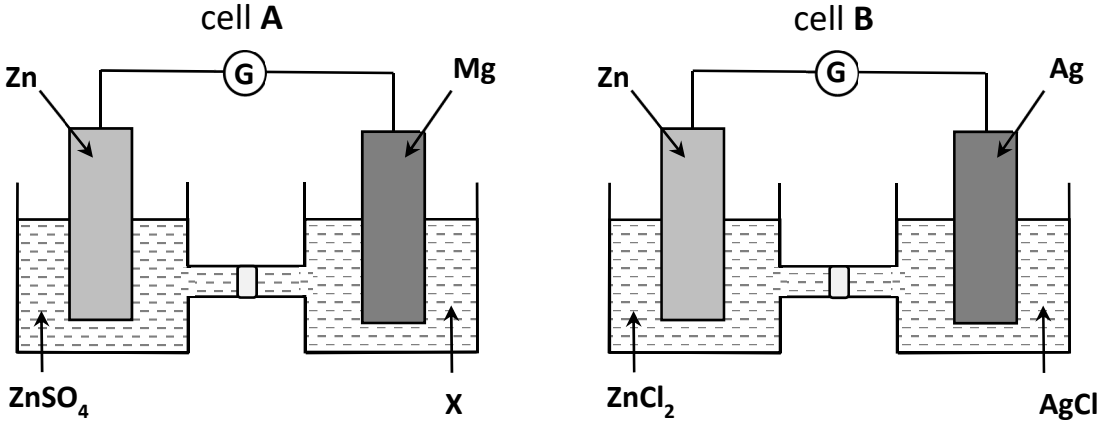
(*ii*) Arrange the following list of metals in order of their increasing ability to act as oxidising agents.

Al **Ag** **Cu** **Mg** **Zn** **Na**

(*iii*) Select a metal from the list in part (*ii*) which reacts easily with dilute hydrochloric acid.

(*iv*) Write a balanced chemical equation for the reaction with the chosen metal. (18)

(*b*) The image below shows two cells, **A** and **B** each having a porous glass disc separating two solutions. The deflection of the galvanometer**, G,** indicates the flow of electrons in both cell **A** and cell **B**.



(*i*) State the direction of the flow of electrons in cell **B** above.
Justify your answer.

(*ii*) In which cell does the galvanometer show the greatest deflection?
Explain your answer.

(*iii*) Identify the solution **X** in cell **A**.

(*iv*) Which metal acts as the cathode in cell **A**? (24)

(*c*) Magnesium (**Mg**) can be produced commercially by electrolysis of a molten electrolyte using <u>inert electrodes</u>.

(*i*) Explain the underlined term.

(*ii*) Identify a suitable salt that can be used as the molten electrolyte.

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

A current of 5 A flows through the molten electrolyte for 20 minutes.

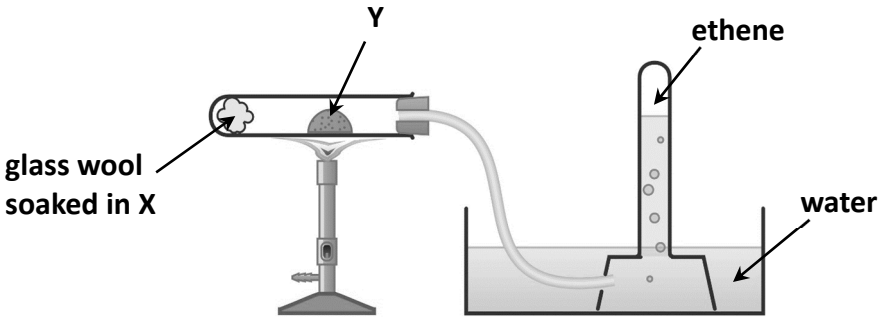
(*iv*) Calculate the charge transferred.

(*v*) Calculate the number of moles of electrons produced.

(*vi*) Calculate the number of moles of **Mg** produced.

(*vii*) Calculate the mass of **Mg** produced. (24)

11. (*a*) Ethene is used as a starting material for a large number of industrial compounds. Ethene can be prepared in a school laboratory using the apparatus shown.



(*i*) Identify **X** and **Y**.

(*ii*) What is the purpose of the glass wool?

(*iii*) Explain why it is possible to collect ethene over water.

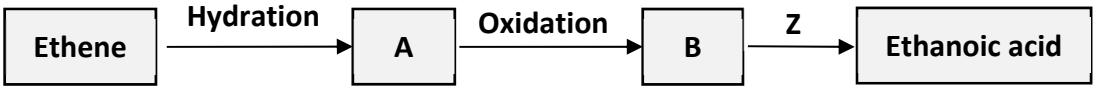
The ethene collected is passed through a solution of acidified **$KMnO_4$**.

(*iv*) State the colour change that occurs.

(*v*) Identify the property of ethene responsible for the colour change.

(*vi*) Write a balanced chemical equation for the combustion of ethene. (27)

(*b*) The reaction scheme shows how ethene can be converted to ethanoic acid.



(*i*) Identify the compounds **A** and **B**.

(*ii*) Draw the structures of molecules **A** and **B**, showing all the atoms and bonds.

(*iii*) Clearly label the functional group in each molecule from (*ii*).

(*iv*) Identify the reaction type **Z**. (21)

(*c*) (*i*) Identify the homologous series to which ethanoic acid belongs.

(*ii*) Write a balanced chemical equation for the reaction of ethanoic acid with sodium hydroxide.

(*iii*) Identify the ester produced when ethanoic acid reacts with methanol in the presence of sulfuric acid (**H_2SO_4**).

(*iv*) Explain why the reaction between ethanoic acid and methanol can be classified as a condensation reaction. (18)

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

(*a*) (*i*) Write the *s*, *p*, *d* configuration of a neutral bromine atom.

(*ii*) State and explain the trend in atomic radii down Group 17 in the periodic table.

(*iii*) Arrange the following in order of decreasing atomic radii: $\mathbf{F^-}$, $\mathbf{Br^-}$, **F**, **Br**. Justify your answer. (22)

(*b*) Hydrofluoric acid (**HF**) cannot be stored in glass bottles because compounds called silicates in the glass react with **HF**. Sodium silicate ($\mathbf{Na_2SiO_3}$), for example, reacts as follows:

$$\mathbf{Na_2SiO_{3(s)} + 8HF_{(aq)} \rightarrow H_2SiF_{6(aq)} + 2NaF_{(aq)} + 3H_2O_{(l)}}$$

(*i*) How many moles of **HF** are required to react with 3.66 g of $\mathbf{Na_2SiO_3}$?

(*ii*) How many oxygen atoms are present in 3.66 g of $\mathbf{Na_2SiO_3}$?

(*iii*) What mass of **NaF** is produced?

(*iv*) How many molecules of water are formed? (22)

(*c*) $\mathbf{PCl_3}$ is one of the chlorides of phosphorous. $\mathbf{PCl_3}$ reacts with water according to the equation:

$$\mathbf{PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3X}$$

(*i*) Identify compound **X**?

(*ii*) What term is used to describe a substance such as $\mathbf{H_3PO_3}$ which acts as both an acid or a base?

(*iii*) Write a balanced chemical equation for the reaction where $\mathbf{H_3PO_3}$ reacts as an acid with water.

(*iv*) Write a balanced chemical equation for the reaction where $\mathbf{H_3PO_3}$ reacts as a base with water.

(*v*) Write the chemical formula for another chloride of phosphorous. (22)

(*d*) (*i*) Define heat of formation.

(*ii*) Write a balanced chemical equation to represent the formation of one mole of methane ($\mathbf{CH_4}$).

(*iii*) Calculate the heat change for the reaction: $\mathbf{3C_{(s)} + 4H_{2(g)} \rightarrow C_3H_{8(g)}}$ from the following data:

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

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

$$\mathbf{C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}} \qquad \Delta H = -2220.1 \text{ kJ mol}^{-1}$$

(22)

Acknowledgements

Images

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Leaving Certificate – Higher Level

Physics and Chemistry

Wednesday, 18 June

Morning, 9:30 – 12:30