Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2024

PHYSICS AND CHEMISTRY – HIGHER LEVEL

WEDNESDAY, 19TH 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.

The 2024 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.

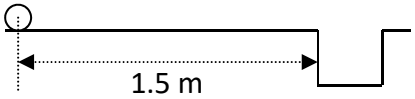
SECTION I – PHYSICS

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 law of gravitation.

(*b*) Velocity and mass are both physical quantities.
Explain how the addition of velocities is different to the addition of masses.

(*c*) The diagram on the right shows a golf ball at rest on a horizontal surface 1.5 m from a hole. A golfer hits the ball so that it moves horizontally with an initial velocity of 1.2 m s^{-1}. The ball decelerates at 0.4 m s^{-2} as it travels to the hole.



Calculate the velocity of the ball when it reaches the edge of the hole.

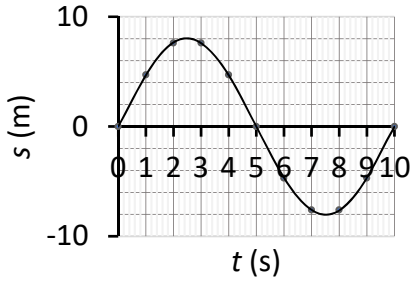
(*d*) Calculate how much work is done when a mass of 60 kg is raised vertically to a height of 8 m.

(*e*) One property of electromagnetic waves is that they are transverse waves.
State **two** other properties.

(*f*) A beam of electrons can undergo interference.
What information about electrons can be deduced from this fact?

(*g*) In order to probe muscle tissue in the human body ultrasound waves with a wavelength of 0.4 mm and a speed of 1580 m s^{-1} are used.
Calculate the frequency of this ultrasound wave.

(*h*) The graph on the right shows the displacement *s* of a wave over time *t*.
What is (i) the amplitude, (ii) the frequency of this wave?

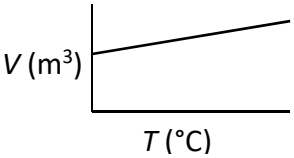


(*i*) What thermometric property is used when calibrating (i) a constant volume gas thermometer, (ii) a mercury thermometer?

(*j*) Explain what is meant by Brownian motion.

(*k*) What are the **two** reference temperatures used to set up the Kelvin scale of temperature?

(*l*) Explain how the graph shown on the right can be used to estimate a value for absolute zero on the Celsius scale.



(*m*) Three resistors 2 Ω, 3 Ω and 4 Ω are arranged in parallel.
Calculate the total resistance.

(*n*) State **two** properties of a parallel-plate capacitor which determine the amount of charge it can store.

(*o*) State Faraday's law of electromagnetic induction.

(*p*) Draw the magnetic field around a current-carrying solenoid.

(*q*) A deuterium nucleus and a tritium nucleus fuse together to form a helium nucleus and particle **X** as shown by the equation: $^{2}_{1}\mathbf{H} + {}^{3}_{1}\mathbf{H} \rightarrow {}^{4}_{2}\mathbf{He} + \mathbf{X}$. Identify **X**.

(*r*) State the principle of mass-energy conservation. (11 × 6)

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

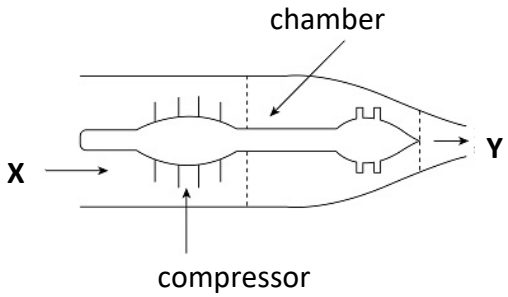
(*a*) mass,

(*b*) acceleration?

(ii) State Newton's second law of motion.

(iii) Use Newton's second law of motion to derive an equation which shows the relationship between force, mass and acceleration.

The diagram on the right shows a jet engine. Air of mass 195 kg enters at **X**, is heated and then exits at **Y**. The speed of the air mass increases by 460 m s^{-1} in 0.75 s as it passes through the engine.



(iv) Calculate

(*a*) the acceleration of the air mass,

(*b*) the force the air mass exerts on the engine. (30)

(*b*) An experiment to demonstrate the relationship between the acceleration *a* of a trolley when a force *F* is applied to it was carried out. The following data were collected. Each force *F* was applied to the trolley, which was initially at rest and the final velocity was measured.

F (N)	0.50	0.75	1.00	1.25	1.50	2.00
a (ms^{-2})	3.0	4.6	6.0	7.4	8.9	11.9

(i) Draw a graph, on graph paper, of acceleration against force.

(ii) Use your graph to calculate the mass that had been accelerated.

(iii) The acceleration of the trolley was 3 m s^{-2} for a time of 1.9 s. Calculate the final velocity of the trolley.

(iv) Draw a labelled diagram of the apparatus you could use to carry out this experiment.

(v) State one precaution that should be taken to ensure an accurate result. (36)

3. (*a*) (i) State the laws of reflection of light.

(ii) Describe, with the aid of a labelled diagram, an experiment to measure the focal length of a concave mirror.

(iii) How can the radius of curvature of the mirror be determined from the result of the experiment? (18)

(*b*) An object is placed 30 cm in front of a concave mirror with a focal length of 40 cm.

(i) Calculate

(*a*) the image distance from the mirror,

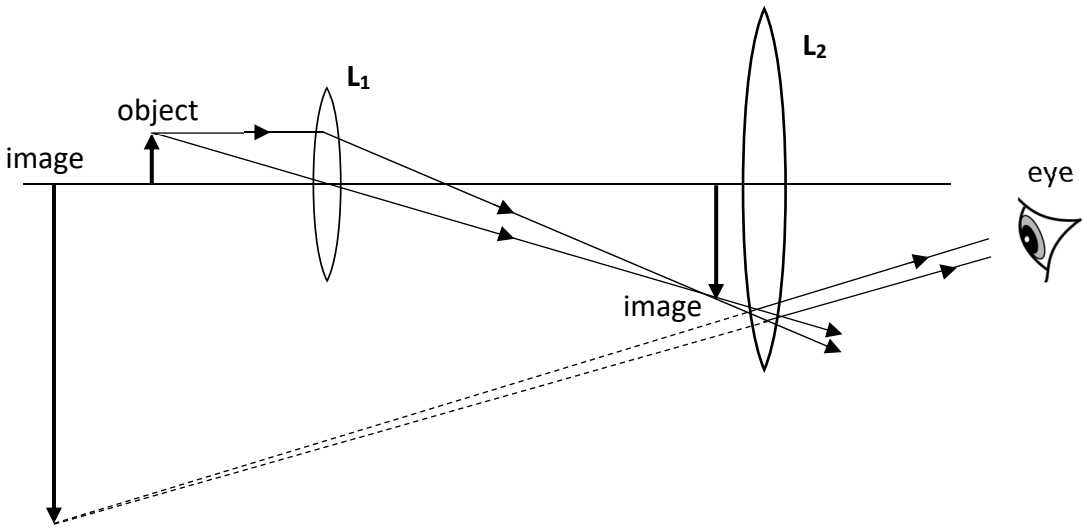
(*b*) the object height, if the image produced is 18 cm high.

(ii) State three properties of the image produced.

A different concave mirror produces a real image with a magnification of 3 when the object is placed 30 cm in front of it.

(iii) Calculate the focal length of this mirror. (33)

(*c*) The diagram below shows the formation of images by the lens arrangement in a compound microscope.



(i) Explain why this microscope is **not** in normal adjustment.

(ii) Name the lenses $\mathbf{L_1}$ and $\mathbf{L_2}$.

(iii) How do the focal lengths of the two lenses compare?

(iv) If the focal lengths of both lenses are reduced, how is the magnification of the final image affected? (15)

4. (*a*) The kinetic theory attempts to explain the temperature, the pressure and other characteristics of a gas in terms of the motion of the particles of the gas.

(i) State **two** assumptions of the kinetic theory that are obeyed

(a) by all gases,

(b) by only some gases.

(ii) What term is used to describe the gas that

(a) **does** obey all of the assumptions of this theory,

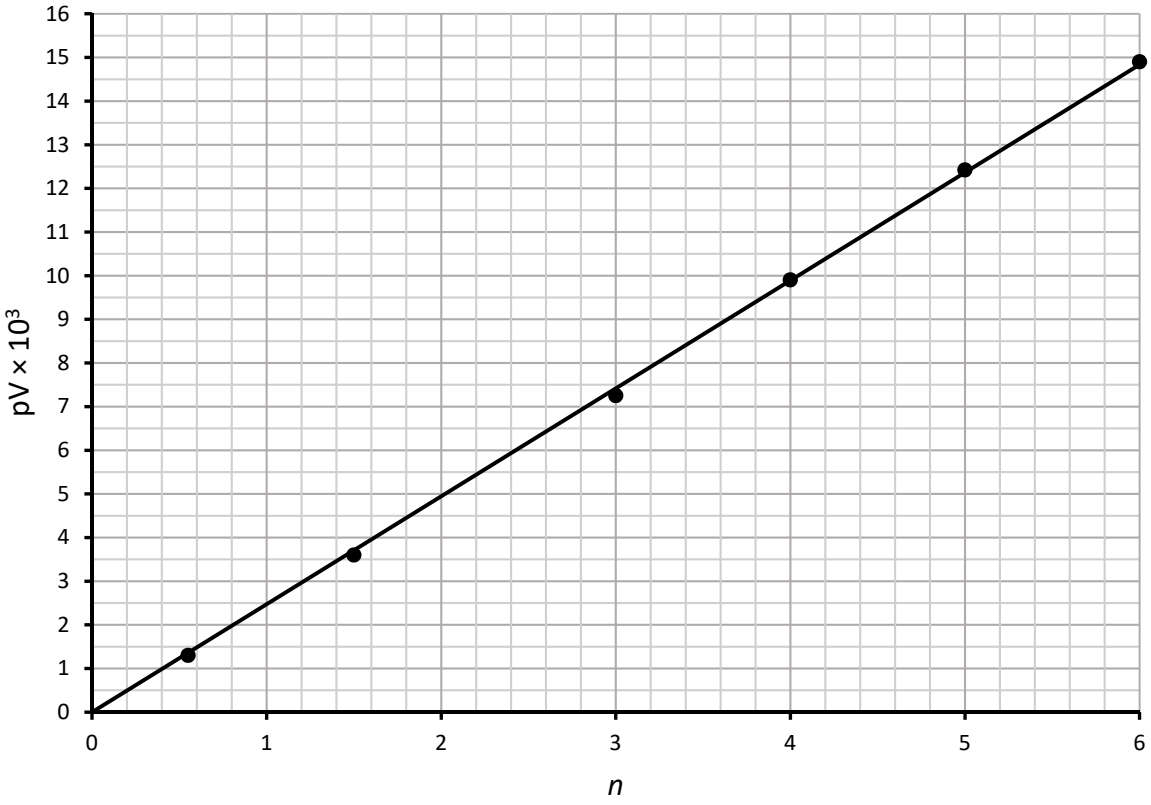
(b) **does not** obey all of the assumptions of this theory?

(iii) How does the kinetic theory explain the pressure exerted by gases?

(iv) How does the pressure of a gas change when the speed of the particles of the gas increases? Justify your answer.

(v) How does the temperature of a gas change when the speed of the particles of the gas increases? Justify your answer. (36)

(*b*) The graph below shows *pV* against the number of moles of a gas *n* at constant temperature *T*, where *p* is the pressure and *V* is the volume of the gas in a container.



(i) Use the slope of the graph to find this constant temperature *T*.

(ii) How many moles of the gas would be present if the pressure was 7×10^3 Pa and the volume 0.2 m^3 at constant temperature *T*?

(iii) What is the unit of measurement of *pV*?

(iv) How will the temperature of the gas change if *pV* is kept constant and the number of moles of gas in the container is increased? Justify your answer. (30)

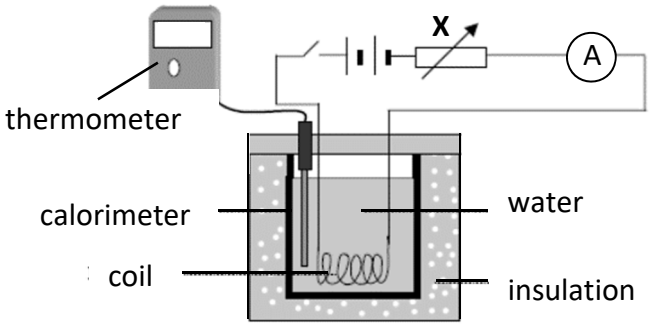
5. (*a*) (i) Define

(*a*) electrical resistance,

(*b*) the unit of electrical resistance *i.e.* the ohm.

(ii) Suggest **two** properties of a wire coil which would determine the size of its resistance. (15)

(*b*) The diagram shows an apparatus used to investigate the heating effect of a current.
A current I was allowed to flow through the coil for a fixed length of time and the rise in temperature of the water $\Delta\theta$ was recorded. This was repeated for different values of the current I.



The following data were recorded:

I (A)	1.0	2.0	2.5	3.0	3.5	4.0
$\Delta\theta$ (°C)	1.2	4.8	7.5	10.8	14.7	19.2

(i) Draw a graph, on graph paper, that shows the relationship between I^2 and $\Delta\theta$.

(ii) Hence, or otherwise, describe the relationship between the change in temperature and the current.

(iii) Why was a fixed mass of water used for each value of the current?

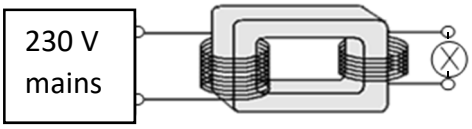
(iv) Suggest a material which might be used for insulation.

(v) Apart from insulation, state one other way of reducing heat loss.

(vi) What is the function of **X**?

(vii) Use your graph to determine the size of the current flowing when the rise in temperature is 6 °C. (36)

(*c*) The diagram shows a transformer with 9200 turns in its primary coil.
The primary coil is connected to a 230 V mains supply. A 6.0 V lamp connected to the secondary coil operates at full brightness.



(i) State one characteristic of the core of the transformer which helps to improve its efficiency.

Assume the transformer operates with 100% efficiency.

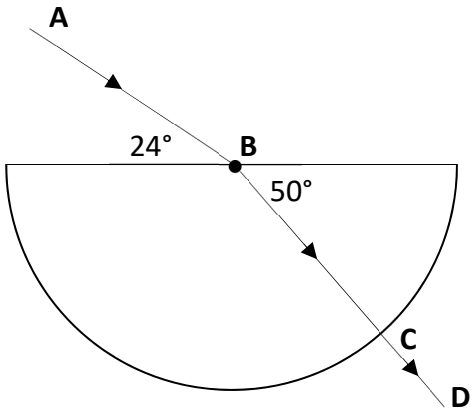
(ii) Calculate

(*a*) the number of turns in the secondary coil,

(*b*) the current in the primary circuit, if the current in the lamp is 0.23 A. (15)

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

(*a*) A transparent semicircular block has a ray of light **AB** directed at the centre of the flat edge of the block. The diagram below shows the path of the ray through the block and the emerging ray **CD**.



(i) State why the emerging ray **CD** does not change direction as it leaves the block.

(ii) As the ray enters the block, find

(*a*) the angle of incidence,

(*b*) the angle of refraction.

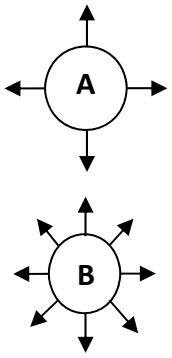
(iii) Name and state the law which indicates the relationship between the two angles.

(iv) Calculate the refractive index of the block.

(v) The angle between **AB** and the block is increased. How is the size of the angle of refraction affected? Justify your answer.

(vi) Determine the critical angle of the block. (33)

(*b*) The diagram shows the electric field around two identical spheres **A** and **B** which are given different quantities of charge.



(i) What type of charge is on sphere **A**?

(ii) Which sphere has the greater charge? Justify your answer. (9)

A plastic rod is rubbed with a cloth and becomes negatively charged. The rod is then held close to a neutral metallic ball suspended from a nylon thread.

(iii) The metallic ball is attracted to the rod. Explain why this happens.

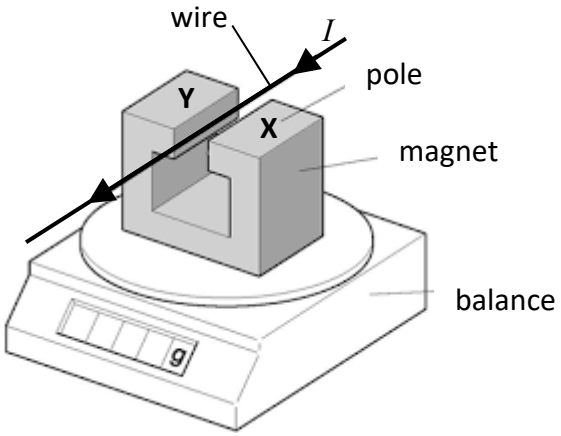
(iv) The rod is then positively charged. Explain why the neutral ball is still attracted towards the rod.

(v) The ball is earthed when the positively charged rod is held close. What charge is left on the ball when the earth is removed? Justify your answer.

(vi) Draw a diagram to show the distribution of the charge on the ball when the rod is removed.

(vii) State the SI unit of electric charge. (24)

(*c*) The diagram on the right shows a magnet with poles **X** and **Y** supported by a frame placed on an electronic mass balance which shows a reading of 7.980 g. When the current I flows in the wire the balance reads 8.620 g.



(i) Explain the change in the reading on the balance when the current I flows in the wire.

(ii) Explain, with the aid of a labelled diagram, the direction of the force acting on a current-carrying conductor that is in a magnetic field.

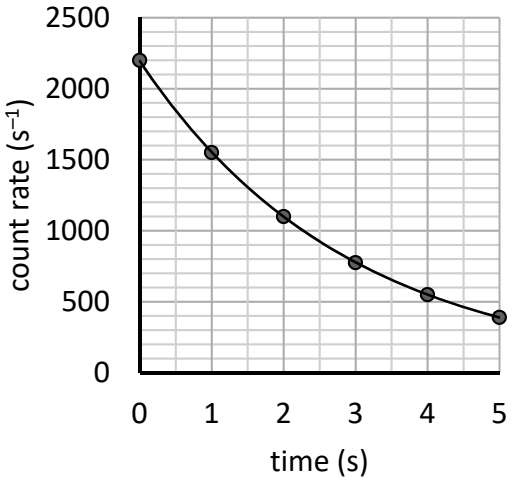
(iii) Is **X** a north pole or a south pole? Justify your answer. (21)

A moving-coil galvanometer operates on the principle demonstrated above.

(iv) What does a moving-coil galvanometer measure?

(v) Show, with the aid of a diagram, how a galvanometer can be adapted to operate as a moving-coil voltmeter. (12)

(*d*) The graph on the right shows the decay curve for a particular radioactive substance.



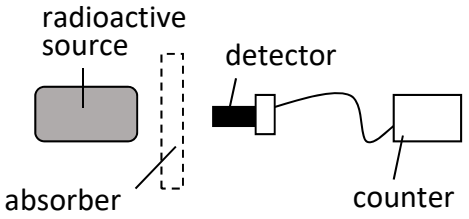
(i) What term is used to describe the time taken for the activity (count rate) of a radioactive isotope to reduce by 50%?

(ii) Use the graph to determine this time.

(iii) Predict the value of the count rate 1.5 s from the start of the measurements.

(iv) How long will it take the count rate to decrease by 75%? (21)

A student measures the level of radiation emitted by a radioactive source. He places a detector close to the source and puts different absorbers between the source and the detector. The source is found to emit only two types of radiation.



The results are in the table below.

Absorber	none	0.1 mm paper	3 mm aluminium	100 mm lead
Counts per minute	125	73	73	10

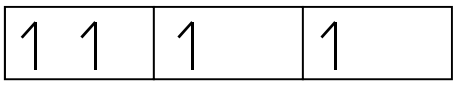
(v) Which two types of radiation are being emitted by the source? Justify your answer. (12)

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 molecules are in 6g of $\mathbf{N_2}$ gas?

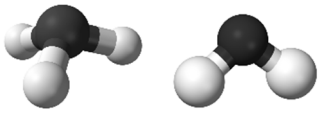
(*b*) The diagram on the right incorrectly represents the outer 4 electrons in the 2p sublevel of a neutral atom.
(i) Why is the representation incorrect?
(ii) Copy and write the correct representation.



(*c*) The set of quantum numbers $\{3, 1, 0, \frac{1}{2}\}$ describes one of the electrons in an atom.
Which quantum number describes
(i) the shape of the orbital containing the electron,
(ii) the energy of the electron in that orbital?

(*d*) The ions $\mathbf{F^-}$ and $\mathbf{Mg^{2+}}$ both have the same number of electrons.
Which has the larger radius? Justify your answer.

(*e*) Explain why the size of the bond angle in water is less than the size of the bond angle in ammonia.


ammonia water

(*f*) Define electronegativity.

(*g*) What is a cation?

(*h*) Balance the following equation: $\mathbf{FeSO_4 \rightarrow Fe_2O_3 + SO_2 + SO_3}$

(*i*) State Hess's law.

(*j*) An atom has 2 more protons and 3 more neutrons than an atom of $^{56}_{26}\mathbf{Fe}$.
(i) identify the atom, (ii) state its atomic and mass numbers.

(*k*) How many grams of aluminium (**Al**) are there in 50 g of $\mathbf{Al_2O_3}$?

(*l*) Consider the compounds in the following list: $\mathbf{CaO \quad Al_2O_3 \quad SO_2 \quad HCl \quad NH_3 \quad CH_4}$
Identify from the list
(i) an acidic oxide, (ii) a hydride with low solubility in water, (iii) a basic hydride.

(*m*) Rusting of iron is a familiar corrosion process. What two substances must be present to react with iron during the rusting process?

(*n*) Write (i) the formula of the acid which has the conjugate base $\mathbf{H_2PO_4^-}$, (ii) the formula of the base which has the conjugate acid $\mathbf{H_2O}$.

(*o*) Benzene is a stable molecule due to the presence of delocalised electrons.
What is meant by delocalised electrons?

(*p*) Distinguish between saturated and unsaturated hydrocarbons.

(*q*) Esters are formed when alcohols react with carboxylic acids.
What (i) alcohol, (ii) carboxylic acid reacts to form the ester $\mathbf{HCOOCH_3}$?

(*r*) Draw the structural formula of 3-methyl-but-1-ene. (11 × 6)

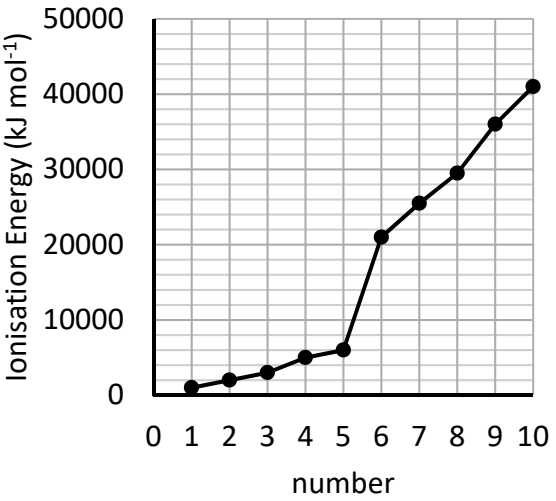
8. (*a*) (*i*) Define the first ionisation energy of an element.

The following equation describes the process occurring when the first ionisation energy of sodium is measured:

$$Na_{(g)} \rightarrow Na^{+}_{(g)} + e^{-}$$

(*ii*) Write an equation to describe the process occurring when the second ionisation energy of sodium is measured. (18)

The first 10 successive ionisation energies of element **X** are shown on the right.



(iii) Explain why there is such a large increase in energy from the fifth to the sixth ionisation energies.

(iv) Use the graph to estimate this increase in energy.

(v) Identify element **X** if it occurs in period 3 of the periodic table. Justify your answer.

(vi) How many ionisation energies in total will this element **X** have?

(vii) Write the s,p electronic configuration of element **X**.

(viii) What is the lowest ionisation energy that will remove an electron from a full sublevel? Explain your answer. (27)

(*b*) (i) What are isotopes?

(ii) Define relative atomic mass.

A sample of chromium contains **four** isotopes and has a relative atomic mass of 52.09. The mass numbers and % abundance of three of the isotopes are given in the following table.

mass number	52	53	54
% abundance	82.8	10.9	2.7

(iii) Determine

(*a*) the % abundance of the fourth isotope,

(*b*) the mass number of the fourth isotope. (21)

9. (*a*) (i) What is a molar solution?

(ii) How could you change the molarity of a given solution?

A solution of H_2SO_4 contains 1.96 g of H_2SO_4 in one litre of solution.

(iii) Calculate the molarity of the solution.

(iv) Calculate the pH of a solution of H_2SO_4 containing 1.96 g in one litre of solution. (18)

(*b*) To determine the ammonia concentration in a household cleaning product a chemist diluted 20 cm^3 of the product to 500 cm^3 using deionised water.
25 cm^3 portions of the diluted solution were titrated against 0.15 M H_2SO_4.
In solution ammonia (NH_3) exists as ammonium hydroxide (NH_4OH), a weak base.
The following reaction occurs during this titration:

$$2NH_4OH + H_2SO_4 \rightarrow (NH_4)_2SO_4 + 2H_2O$$

(i) Name a piece of apparatus that was used to carry out the dilution accurately.

(ii) State an advantage of diluting the cleaning product before titration.

The H_2SO_4 was placed in the burette using a funnel.

(iii) Why was a funnel used?

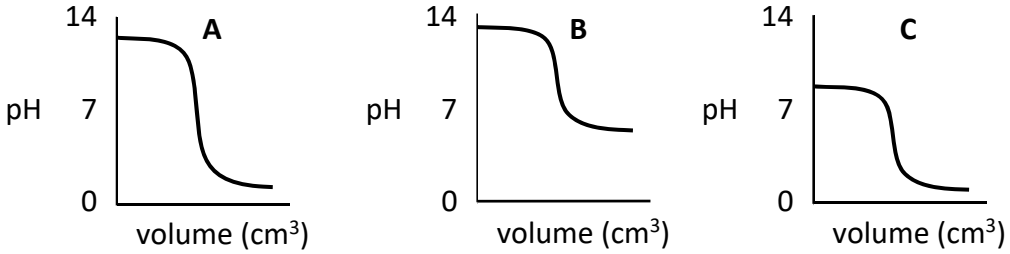
(iv) Why should the funnel be removed before taking readings?

(v) State an advantage of using a conical flask rather than a beaker during the titration.

During the titration the inside of the flask was washed down with deionised water.

(vi) Explain why this does not result in an inaccurate result. (15)

Three titration curves **A**, **B** and **C** are shown below.



(vii) Which curve could represent the above titration? Justify your answer.

(viii) Name a suitable indicator for the titration.

(ix) What colour change occurs at the endpoint?

(x) Use your choice of curve to explain why this indicator is the most suitable for this titration. (18)

On average, 13.2 cm^3 of 0.15 M H_2SO_4 were required to neutralise the 25 cm^3 portions of the diluted NH_4OH solution.

(xi) Calculate

(*a*) the concentration of the diluted NH_4OH solution in moles per litre,

(*b*) the molarity of the original solution,

(*c*) the mass of ammonia (NH_3) per 100 cm^3 of the cleaning product solution. (15)

10. (*a*) (i) What is the electrochemical series?

The following is a list of metals arranged in order of their increasing ability to act as oxidising agents: **K** **Mg** **Zn** **Fe** **Ni** **Pb**

(ii) What is an oxidising agent in terms of electron transfer?

(iii) Explain why potassium (**K**) is such a poor oxidising agent.

(iv) Which of the metals will form the least stable oxide? Explain your answer. (21)

(*b*) Cadmium metal tends to form Cd^{2+} ions. When a zinc metal strip is placed in a solution of $CdCl_2$ cadmium metal is deposited on the strip. When a strip of cadmium metal is placed in a solution of $Ni(NO_3)_2$ nickel metal is deposited on the strip.

(i) Write an equation to represent

(*a*) the reaction of $CdCl_2$ with zinc,

(*b*) the reaction of cadmium with $Ni(NO_3)_2$.

(ii) What can you conclude about the position of cadmium in the above list of metals? Justify your answer. (21)

(*c*) In 2022, Bus Éireann introduced electric buses powered by hydrogen fuel cells.

Hydrogen gas (H_2) is introduced at electrode **X** and oxygen gas (O_2) from the air at electrode **Y** as shown.

The electrodes are inert and separated by an electrolyte membrane which allows H^+ ions to pass through, but blocks electrons.

The electrons pass through an external circuit producing a current.

The chemical reactions involved are the reverse of those occurring in the electrolysis of water.

At electrode **Y** the following reaction occurs:

$$O_{2(g)} + H^+ + e^- \rightarrow H_2O_{(l)}$$

(i) Copy and balance this equation.

(ii) Write an equation for the reaction occurring at electrode **X**.

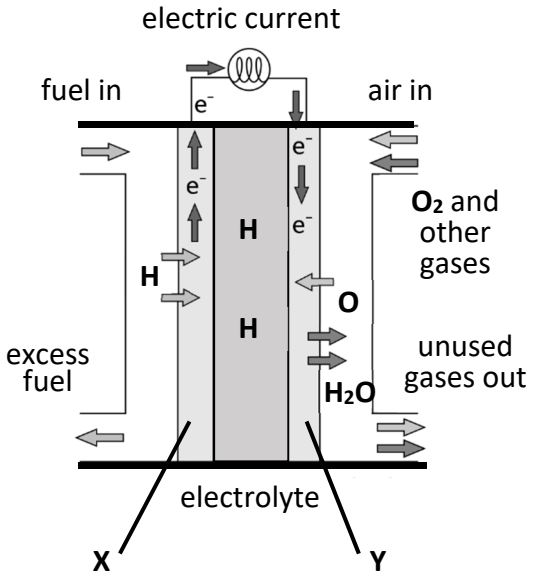
(iii) Which electrode is the anode? Justify your answer.

0.2 moles of water are formed by a fuel cell.

(iv) Calculate how many

(*a*) Faradays of electricity are transferred,

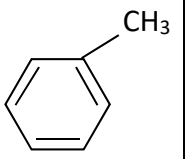
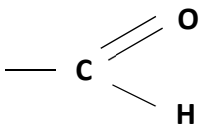
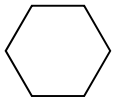
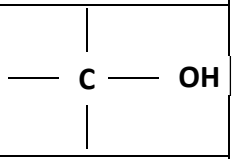
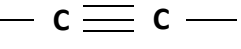
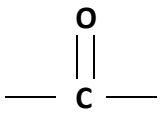
(*b*) coulombs of charge pass. (24)



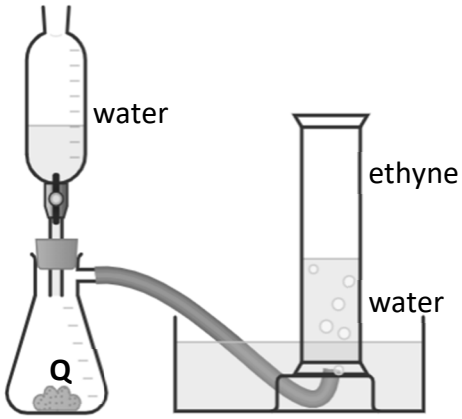
11. (*a*) (i) Identify the compounds **A**, **B**, **C & D** as being aliphatic or aromatic compounds.

(ii) Write a molecular formula for compound **B**.

(iii) Name the homologous series of each of the compounds which have the functional groups **E**, **F, G & H**. (30)

A		**E**	
B		**F**	
C	**butane**	**G**	
D	**benzoic acid**	**H**	

(*b*) The diagram shows an apparatus used to prepare ethyne gas by dropping water onto a solid **Q**.



(i) Identify solid **Q**.

(ii) Write a balanced equation for the reaction occurring.

(iii) Describe the colour change observed when ethyne gas is passed through a test tube of bromine solution.

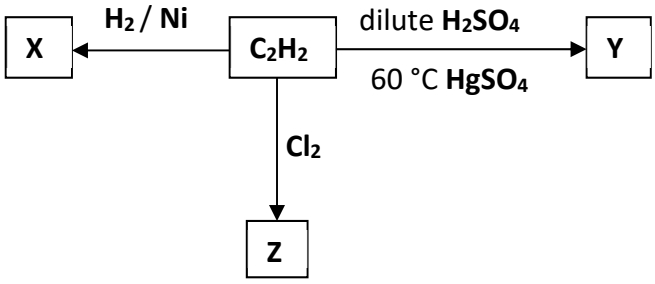
(iv) What does this colour change indicate about ethyne? (18)

Ethyne undergoes the three reactions shown in the diagram below.

(v) Name the main products **X**, **Y** and **Z** of each reaction.

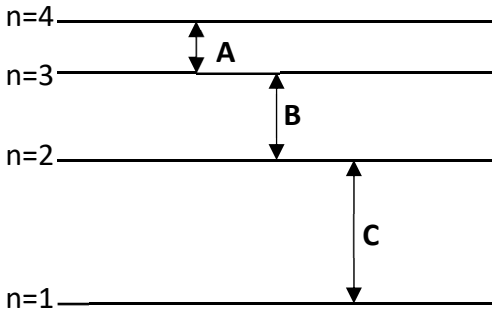
(vi) Classify the reactions resulting in the products **X** and **Y** as being either an oxidation, reduction, hydrogenation or a substitution reaction.

(vii) If compound **X** undergoes a hydration reaction, what will the product of the reaction be? (18)



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

(*a*) Some of the energy levels in an atom of hydrogen are shown.



An energised hydrogen atom can emit photons with certain discrete frequencies.

Three possible transitions **A**, **B** & **C** of the electrons in an atom of hydrogen are shown.

(i) State **two** ways in which hydrogen atoms can be energised.

(ii) A photon in the visible region of the electromagnetic spectrum is emitted. Identify the transition involved.

(iii) What colour is this line in the emission spectrum of hydrogen?

(iv) What name is given to this series of lines in the visible region of the spectrum?

(v) Write an equation to show the relationship between the energy lost by the electron during the transition and the frequency of the emitted photon of radiation.

(vi) The energy lost by an electron is 3.028×10^{-19} J during a transition. Calculate the frequency of the light emitted.

(*b*) A mixture of magnesium oxide **MgO** and magnesium hydroxide **$Mg(OH)_2$** has a mass of 4.8 g. The mixture is reacted with **CO_2** to form **$MgCO_3$** according to the following equations:

$$\mathbf{MgO} + \mathbf{CO_2} \rightarrow \mathbf{MgCO_3}$$
$$\mathbf{Mg(OH)_2} + \mathbf{CO_2} \rightarrow \mathbf{MgCO_3} + \mathbf{H_2O}$$

The mass of water produced is 0.315 g.

(i) How many moles of water are produced?

(ii) How many grams of **$Mg(OH)_2$** is present in the mixture?

(iii) What mass of **MgO** is in the mixture?

(iv) How many moles of **CO_2** are required for each of the reactions above?

(v) What is the total volume of **CO_2** at STP that is required?

(vi) What mass of **$MgCO_3$** in total is produced?

(*c*) (i) Define heat of combustion.

The following balanced equation represents the complete combustion of methanol:

$$2CH_3OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 4H_2O_{(l)}$$

(ii) How many moles of oxygen are required for the complete combustion of 1 mole of methanol?

(iii) Are combustion reactions exothermic or endothermic?

The combustion of nitrogen can be represented by $2N_{2(g)} + 5O_{2(g)} \rightarrow 2N_2O_{5(g)}$

(iv) Calculate the heat of combustion of N_2 from the following data:

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

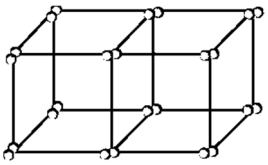
$$N_2O_{5(g)} + H_2O_{(l)} \rightarrow 2HNO_{3(l)} \qquad \Delta H = -76.6 \text{ kJ mol}^{-1}$$

$$N_{2(g)} + 3O_{2(g)} + H_{2(g)} \rightarrow 2HNO_{3(l)} \qquad \Delta H = -348.2 \text{ kJ mol}^{-1}$$

(*d*) In crystalline solids, particles are arranged in a regular repeating pattern.

(i) What is this regular repeating pattern called?

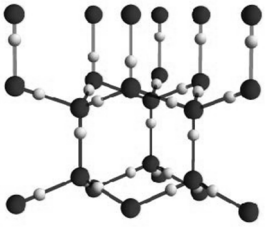
The structure of iodine, a molecular crystal is shown in the diagram on the right.



(ii) What are the attractive forces holding the iodine molecules together in the crystal?

Ice is another example of a molecular crystal, shown in the diagram below.

(iii) What type of intermolecular attraction holds the water molecules together in an ice crystal?



(iv) Name **two** other types of crystal and give an example of each type.

(v) For any one of the crystal types you have stated in **part (iv)**, describe how the particles are held in position.

Acknowledgements

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Leaving Certificate – Higher Level

Physics and Chemistry

Wednesday, 19th June

Morning, 9:30 – 12:30