Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2011

PHYSICS AND CHEMISTRY – HIGHER LEVEL

MONDAY, 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.

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

(*a*) What energy conversion takes place as a child rises up through the air from the surface of a trampoline as shown in **Figure 1**?

Figure 1

(*b*) What is the relationship between G, the gravitational constant and g, the acceleration due to gravity?

(*c*) Define the unit of power, i.e. the *watt*.

(*d*) Give one use for a convex mirror.

(*e*) Give two properties of the final image formed in a compound microscope.

(*f*) Why is sound classified as a longitudinal wave?

(*g*) State *Boyle's law*.

(*h*) A gas has a volume of 330 cm^3 at 300 K. What is the volume of the gas at 450 K, if the pressure remains constant?

(*i*) Copy the diagram in **Figure 2** into your answerbook and draw the magnetic field around the current-carrying conductor.

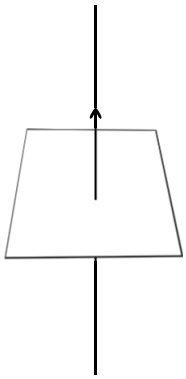


Figure 2

(*j*) Why is high voltage used to transmit electricity over long distances?

(*k*) What is electromagnetic induction?

(*l*) Give two ways of reducing energy losses in a tranformer.

(*m*) What is radioactivity?

(*n*) Give two properties of beta-particles.

(*o*) What is the main source of energy in the sun?

(11 × 6)

2. Define (i) velocity, (ii) momentum.

What is *kinetic energy*?

State *the principle of conservation of momentum*. (18)

Figure 3 shows an arrangement of two trolleys on a sloped track that you used to investigate the principle of conservation of momentum. Trolley **A** was set in motion at constant velocity and collided with trolley **B** that was stationary. Both trolleys then moved together at a new constant velocity.

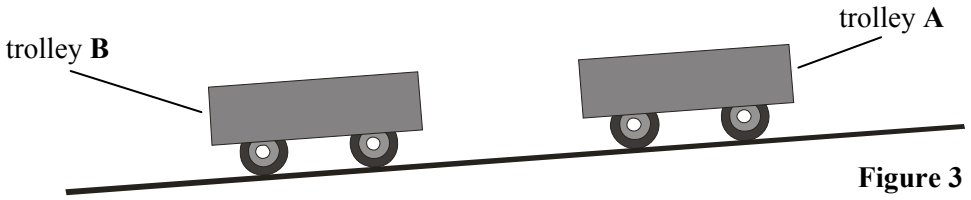


Figure 3

Explain why the track was sloped.

How did you ensure that the two trolleys moved together after collision?

Describe how the initial velocity of trolley **A** was measured.

How do you know that trolley **A**, before the collision, did not accelerate down the track? (21)

The mass of trolley **B** was increased and the process was repeated. The following data were obtained:

	mass **A**/kg	mass **B**/kg	initial velocity of **A**/m s^{-1}	final velocity of **A**/m s^{-1}
Process 1	0.200	0.300	0.160	0.063
Process 2	0.200	0.600	0.160	0.041

Show that the data in the table are consistent with the principle of conservation of momentum. (15)

Calculate the kinetic energy lost in the collision between the trolleys during process 1.

What happened to this lost energy? (12)

3. (*a*) Refraction occurs when light changes direction as it passes from one medium into another.

State Snell's law of refraction. (6)

When does a ray of light **not** change direction when it passes from one medium into another?

Explain the term *total internal reflection*.

Draw a diagram to show how the direction of a ray of light can be changed by 90º using a 45º glass prism. (21)

(*b*) To verify Snell's law, a student measured the angle of incidence *i* and the corresponding angle of refraction *r*, for a ray of light passing through a rectangular block of glass. The procedure was repeated for different angles of incidence *i*. The following results were obtained:

i/degrees	10.0	20.0	30.0	40.0	50.0	60.0	70.0
r/degrees	7.0	13.0	19.5	25.0	31.0	35.0	39.0

(*c*) Draw a diagram to show

(i) a ray of light striking the side of the glass block at an angle of incidence of 30º

(ii) the path of the light through the glass

(iii) the ray emerging from the block.

Label the refracted ray and the angle of refraction on your diagram. (12)

(*d*) Using the above data, draw a suitable graph and explain how your graph verifies Snell's law. (18)

(*e*) Use your graph to find the refractive index of the glass. (9)

4. (*a*) Give two assumptions of the *kinetic theory of gases*.

Brownian movement provides evidence to support the kinetic theory of gases.
Describe how to demonstrate Brownian movement. What is observed? (18)

What is an *ideal gas*? (6)

A sample of helium gas is stored in a container of fixed volume.
How does the pressure on the walls of the container depend on the motion of the helium atoms inside?
Describe how the motion of the helium atoms changes as the gas is cooled.
At very low temperatures, how does helium differ in its behaviour from an ideal gas? (12)

(*b*) A mercury thermometer and a constant volume gas thermometer containing helium are both immersed in a container of warm water as shown in **Figure 4**.

What is the thermometric property of
(i) the mercury thermometer
(ii) the constant volume gas thermometer? (6)

Why is there a need for a standard thermometer?
Why is the constant volume gas thermometer chosen as the standard?

Give one disadvantage of the constant volume gas thermometer. (12)

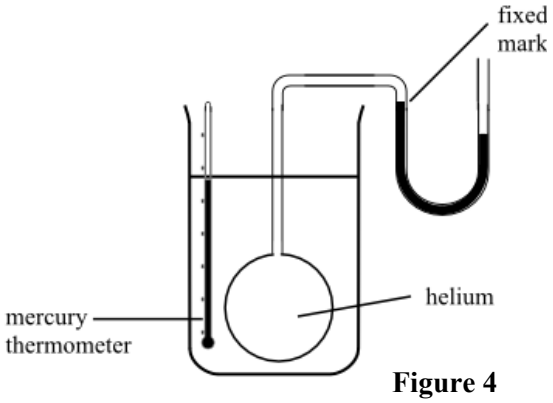


Figure 4

The temperature of the warm water was calculated to be 330 K using measurements taken with the constant volume gas thermometer. The helium gas in the thermometer had a pressure of 130 kPa and a volume of 500 cm^3 at this temperature.

Calculate the number of moles of helium gas in the constant volume gas thermometer. (12)

5. (*a*) Explain, in terms of electron transfer, what happens when an object becomes positively charged.

State Coulomb's law of force between two point charges.

When two point charges are separated by distance of 2 cm, the force between them is 2250 N. What is the size of the force between the two charges when the distance between them is changed to 4 cm? (15)

Make a copy in your answerbook of **Figure 5**, a pear-shaped conductor on an insulated stand. Show on your diagram how the charge is distributed over the conductor when it is charged positively.

What is an *electric field*?

Describe how to demonstrate the presence of an electric field pattern. (18)

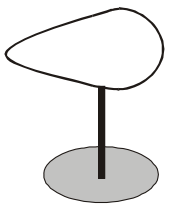


Figure 5

(*b*) Define *capacitance*.

Give one use for a capacitor. (12)

A charged parallel plate capacitor and an electroscope were arranged as shown in **Figure 6**.

As the plates were moved farther apart
(i) what was observed
(ii) how did the potential difference between the plates of the capacitor change
(iii) how did the capacitance of the parallel plate capacitor change? (9)

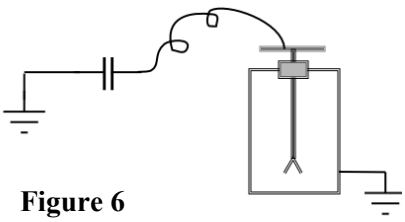


Figure 6

The capacitance of a parallel plate capacitor is 3.6 μF.

What charge is stored in this capacitor when it is connected to a 9.0 V battery?

What is the capacitance of the capacitor if the common area of the plates is doubled, without changing the distance between the plates? (12)

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

(*a*) Define (i) acceleration, (ii) force. (9)

State *Newton's second law of motion*. (6)

Draw a labelled diagram of an arrangement of apparatus used to show that the acceleration of a moving body is proportional to the applied force. (9)

Calculate the force required to accelerate an object of mass 50 kg from rest to a velocity of 20 m s^{-1} in a distance of 80 m across a smooth horizontal surface. (9)

(*b*) The photoelectric effect provides evidence for the particle behaviour of electromagnetic radiation and for the existence of photons.

What is a photon?

Calculate the energy of a photon of infrared radiation that has a wavelength of 1.4×10^{-5} m. (15)

Electrons are released by the photoelectric effect when ultraviolet light shines on a freshly cleaned zinc plate, but electrons are **not** released when infrared radiation shines on the zinc plate.

Explain why electrons are released from zinc by ultraviolet radiation but not by infrared radiation. (6)

Name a phenomenon that provides evidence for the wave nature of light.

Describe how you could demonstrate the phenomenon you have named. (12)

(*c*) What is an electric current?

State Ohm's law. (9)

Figures 7 and **8** show two circuits, each containing two filament lamps, each of which has a resistance of 4 Ω. Each circuit is connected to a 12 V battery.

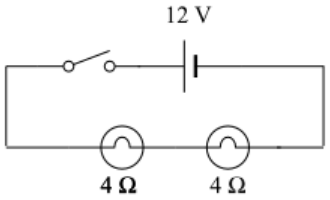


Figure 7

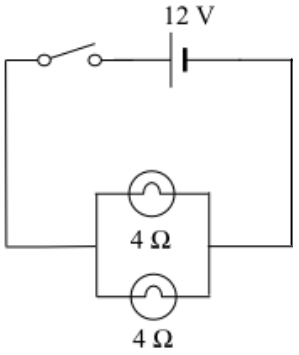


Figure 8

Calculate the effective resistance of each circuit. (9)

Calculate the current flowing through each lamp

(i) in the series circuit

(ii) in the parallel circuit. (12)

In which circuit do the lamps light brightest? (3)

(*d*) **Figure 9** illustrates the nuclear fission of a uranium-235 nucleus when it was struck by a neutron and disintegrated according to the following nuclear equation:

$$^{235}_{X}\mathbf{U} + {}^{1}_{0}\mathbf{n} \rightarrow {}^{93}_{Y}\mathbf{Rb} + {}^{Z}_{55}\mathbf{Cs} + 3\,{}^{1}_{0}\mathbf{n} + \mathbf{energy}.$$

What are the values of *X*, *Y* and *Z*? (9)

Explain how the fission of a uranium-235 nucleus could lead to a chain reaction in a uranium sample. (6)

What is meant by mass-energy conservation in a nuclear reaction?

Calculate the mass lost when a uranium-235 nucleus undergoes fission to release 1.08×10^{-12} J of energy. (12)

Give an application of nuclear fission. (6)

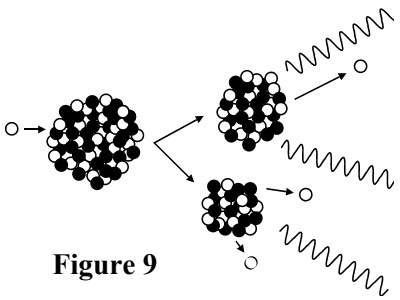


Figure 9

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*) What is (i) the atomic number, (ii) the mass number, of an atom of $^{56}_{26}$**Fe**?

(*b*) Suggest a suitable term to use as a heading for column **A** and a suitable term for column **B** in the table on the right.

CARBON	
A	**B**
Diamond Graphite	Carbon-12 Carbon-13 Carbon-14

(*c*) Define *relative atomic mass* of an element.

(*d*) A platinum rod was cleaned in hydrochloric acid, dipped into a salt of a metal and held in the flame of a Bunsen burner as shown in **Figure 10**. What colour flame was observed when the salt used was (i) potassium chloride, (ii) sodium chloride?

(*e*) Why is a metal a good conductor of electricity?

(*f*) What is meant by the *valency* of an element?

(*g*) What is (i) the conjugate acid of $\mathbf{H_2O}$, (ii) the conjugate base of $\mathbf{NH_4^+}$?

(*h*) What two types of acid-base titrations use phenolphthalein as a suitable indicator?

(*i*) Sodium metal reacts vigorously in cold water. What are the products of this reaction?

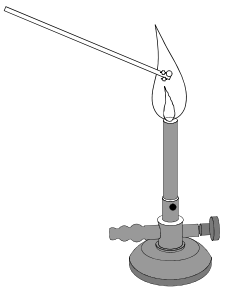


Figure 10

(*j*) Calculate the percentage of oxygen in silicon dioxide ($\mathbf{SiO_2}$).
[Si = 28; O = 16]

(*k*) From the following list of hydrides, select (i) an acidic substance, (ii) a substance that is gaseous at room temperature.

H_2S **NH_3** **MgH_2** **NaH**

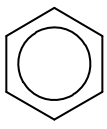
(*l*) Define *heat of solution*.

(*m*) Name the two substances always formed when an organic compound is burned in excess oxygen.

(*n*) Draw the molecular structure of the compound 1-bromopropane, a solvent used in some liquid correction fluids like that shown in **Figure 11**.

Figure 11

(*o*) Name the two aromatic compounds (i) and (ii), shown in **Figure 12**, that occur in small amounts in petrol.

(i) 

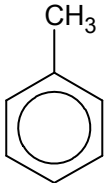
(ii) 

Figure 12

(11 × 6)

8. (*a*) What is an *atomic orbital*?

Draw the structure of a *p-orbital*.

Write the electron configuration (*s*, *p*) of a chlorine atom in its ground state.

The four quantum numbers of an electron in a chlorine atom are 3, 1, 1, ½. What information about the electron is given by (i) the first quantum number, (ii) the fourth quantum number? (21)

(*b*) Define *electronegativity*.

Give the name or formula of a compound made from two different elements of the first eighteen elements that has pure covalent bonding.

What type of bonding occurs in the compound BeH_2?

What is the shape of a BeH_2 molecule?

What type of bond is formed when magnesium and oxygen combine? Use diagrams to show the formation of the bond in magnesium oxide. (27)

(*c*) Define the *first ionisation energy* of an element.

Figure 13 represents the first ionisation energy values of the elements in the third period of the periodic table.

Explain the general increase across the period.

Why are the values for magnesium and for phosphorus higher than expected? (18)

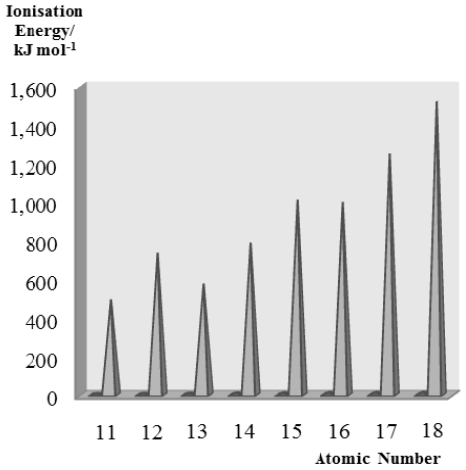


Figure 13

9. A student determined the concentration of a hydrochloric acid solution by titration with 25.0 cm^3 portions of a primary standard solution of anhydrous sodium carbonate.

(*a*) Explain the underlined term.

Describe how the student prepared 500 cm^3 of a 0.05 M primary standard solution from 2.65 g of pure anhydrous powdered sodium carbonate, supplied on a clockglass. (21)

(*b*) (i) How was a burette rinsed before filling it with the hydrochloric acid solution?

(ii) Why was a small funnel used when filling the burette?

(iii) Why was the funnel removed before adjusting the liquid to the zero mark?

(iv) Describe how the liquid level in the burette was adjusted to the zero mark.

(v) Why was a pipette filler used to fill the pipette with 25.0 cm^3 sodium carbonate solution? (18)

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

State the colour change observed in the conical flask at the end-point of this titration. (9)

(*d*) Write a balanced equation for this titration reaction. (6)

(*e*) On average 21.2 cm^3 of hydrochloric acid was required to neutralise 25.0 cm^3 portions of the 0.05 M sodium carbonate solution.

Calculate the concentration of the hydrochloric acid solution in

(i) moles per litre

(ii) grams per litre. (12)

[H = 1; Cl = 35.5]

10. (*a*) Define *oxidation*.

What is the electrochemical series?

In what order do the common metals **copper**, **aluminium** and **iron** occur in the electrochemical series? (12)

A freshly sanded piece of aluminium is placed in a solution of copper sulfate in a beaker. The following reaction occurs:

$$\mathbf{2Al + 3CuSO_4 \rightarrow Al_2(SO_4)_3 + 3Cu}$$

What changes are observed as the reaction proceeds?

Identify (i) the substance oxidised, (ii) the oxidising reagent.

Why must the aluminium be first cleaned with sandpaper? (15)

Would a chemical reaction occur if a piece of freshly sanded iron were placed in a solution of aluminium sulfate? Justify your answer. (6)

(*b*) Aluminium oxide $\mathbf{Al_2O_3}$ is purified in Ireland and exported to Russia for electrolysis to produce pure aluminium metal and oxygen gas as a co-product. The electrolysis of the molten aluminium oxide is carried out using inert electrodes in a cell like that shown in **Figure 14**.

Explain the underlined terms.

How does molten aluminium oxide conduct electricity? (15)

The cathode reaction is $\mathbf{Al^{3+} + 3e^- \rightarrow Al}$.

Write the corresponding anode reaction where oxygen is produced. (6)

A current of 220 000 A is passed through the molten aluminium oxide in a cell.

Calculate

(i) the charge that flows in ten minutes

(ii) the mass of aluminium metal produced in ten minutes. (12)

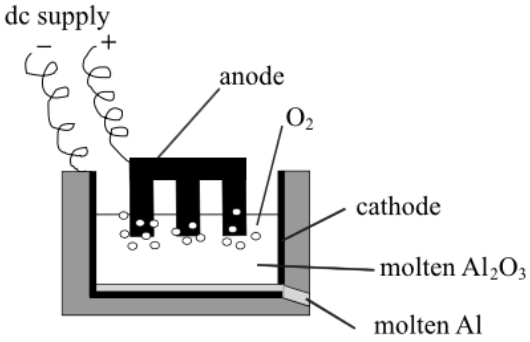


Figure 14

11. The hydrocarbons methane and ethene are important gaseous organic chemicals. Methane is the first member of the alkane homologous series and is a saturated compound. Ethene, an alkene, is unsaturated.

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

(*b*) Give a major use for **either** methane **or** ethene. (3)

(*c*) Draw the molecular structure of (i) methane, (ii) ethene. (9)

(*d*) What is the difference between a saturated and an unsaturated organic compound?

Name a reagent used in a test to show that ethene is unsaturated.
What colour change confirms that ethene is unsaturated? (15)

(*e*) What are the products when one mole of chlorine and one mole of methane react at room temperature?

What is the essential condition for this reaction to occur?

Is this a substitution reaction or an addition reaction? Justify your answer. (15)

(*f*) Describe, with the aid of a labelled diagram, how to convert ethanol to ethene. (12)

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

(*a*) **Figure 15** shows four of the energy levels of the electron in a hydrogen atom.
E_1 is the ground state and E_2, E_3, E_4 are the excited states.

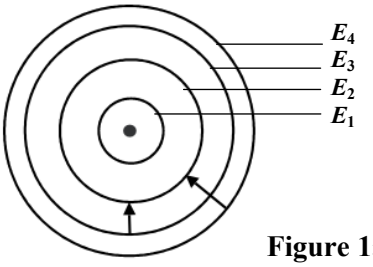


Figure 15

Define *energy level*.

Explain

(i) how the electron can be promoted from a lower energy level to a higher one, e.g. E_1 to E_3

(ii) why the electron does not remain in any of the excited states E_2, E_3 or E_4

(iii) why the electron cannot occupy the spaces between the energy levels

(iv) what happens when the electron falls from a higher energy level to a lower level

(v) the difference observed when an electron falls from E_4 to E_2 instead of from E_3 to E_2.

(*b*) Distinguish between a strong acid and a weak acid according to the Brønsted-Lowry theory.

Write an expression to define pH.

What is the relationship between pH and pOH?

Calculate the pH of

(i) a 0.2 M solution of $\mathbf{H_2SO_4}$

(ii) a 0.2 M solution of **KOH**.

(*c*) When alcohol in the form of ethanol ($\mathbf{C_2H_5OH}$) is consumed by a person, it is converted to ethanal ($\mathbf{CH_3CHO}$) and then to ethanoic acid ($\mathbf{CH_3COOH}$) and finally to carbon dioxide and water, which are expelled by the body.

The reactions that occur are:

$$\mathbf{C_2H_5OH \rightarrow CH_3CHO + H_2}$$

$$\mathbf{H_2 + \tfrac{1}{2}O_2 \rightarrow H_2O}$$

$$\mathbf{CH_3CHO + \tfrac{1}{2}O_2 \rightarrow CH_3COOH}$$

$$\mathbf{CH_3COOH + 2O_2 \rightarrow 2H_2O + 2CO_2}$$

If the person consumed a bottle of wine, containing 92 g of ethanol, calculate

(i) the number of moles of ethanol in the bottle of wine

(ii) the number of moles of carbon dioxide produced when the alcohol is processed in the body

(iii) the volume of carbon dioxide exhaled when measured at standard temperature and pressure

(iv) the total mass of water produced in the body in the processing of the alcohol

(v) the number of molecules of oxygen required for the last reaction in the process.

(*d*) State *Hess's law.*

Consider the following reactions:

$$\mathbf{Fe_2O_{3\,(s)} + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2\,(g)}} \qquad \mathbf{\Delta H = -26.3\ kJ\ mol^{-1}}$$

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

$$\mathbf{CO_{(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow CO_{2\,(g)}} \qquad \mathbf{\Delta H = -283.5\ kJ\ mol^{-1}}$$

Use Hess's law and the heats of reaction listed above to calculate the heat of reaction for the extraction of iron metal from one of its ores using coke, according to the following reaction:

$$\mathbf{2Fe_2O_{3\,(s)} + 3C_{(s)} \rightarrow 4Fe_{(s)} + 3CO_{2\,(g)}}$$

Is energy absorbed or released as this reaction proceeds? Justify your answer.

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